EXPERIMENT 1
DC MOTOR SPEED CONTROL SYSTEM

OBJECTIVES

In order to understand how dc motor speed control system works, in this experiment we will study the closed loop system of speed control, the effect of gain and disturbances for speed control, and two directional speed control.

REFERENCE

Ogata K. Modern Control Engineering. 2010
Anonymous. User's Manual Modular Feedback Servo System

EQUIPMENT REQUIRED

1 *Operational unit*	OA150A
1 *Attenuator unit*	AU150B
1 *Pre-Amp unit*	PA150C
1 *Servo Amplifier*	SA150D
1 *Power Supply*	PS150E
1 *Load unit*	LU150L
1 *Voltmeter*	

PRE-EXPERIMENT TASK

Explain DC motor speed control system and it's all components!

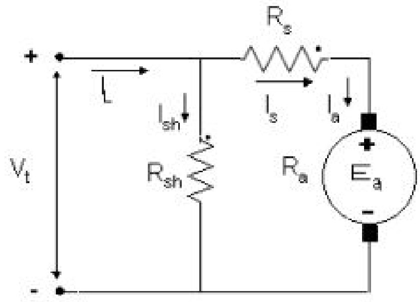
INTRODUCTION

Electric motor is an electromagnetic device which convert electrical force into mechanical forces. This mechanical force is used to operate pump, fan, blower, etc. DC motor needs direct current voltage supply on field coil to be converted into mechanical force. Field coil in DC motor is called stator (static component) and armature coil is called rotor (rotating component).
Electric current in magnetic field will give mechanical force. If the wires that bring current is shaped into circle/loop, then both side loops, will get force effect in different direction. Those forces produce torque to rotate motor.
Basic methods of DC motor control are as followed:

1. Field control.
2. Voltage control.
3. Armature resistance control.

1. Field Control

This method can be done by controlling shunt field current with reducing and increasing through resistance variable that is connected to field coil in series as



shown in Figure 1

Figure 1. Field Control Circuit in DC Motor

2. Voltage Control

This control is done by adjusting the voltage supplied to the motor as shown in Figure 2.

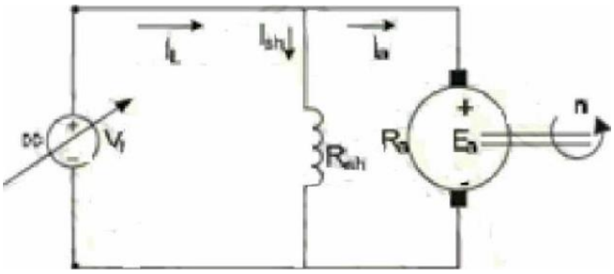


Figure 2. Voltage Control Circuit in DC Motor

3. Armature Resistance Control

This control can be done by adjusting the armature resistance by connecting series with resistance variables as shown in Figure 3.

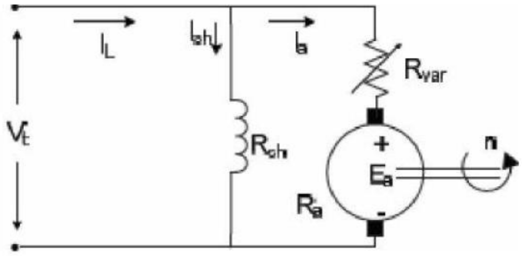


Figure 3. Armature Resistance Control Circuit in DC Motor

Devices Used:

Modular Servo System MS 150

Modular servo system MS 150 is an electronic circuit block used to control the speed and position of a DC servo motor. Modular servo system MS 150 consist of power supply, servo amplifier, two units of the DC motor, reduction gear tachogenerator unit, transducers and modules.

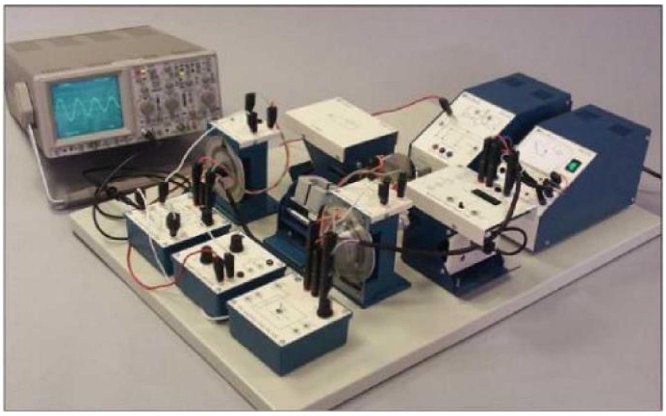


Figure 4. Modular Servo System MS 150

Parts of Modular Servo System MS 150

Parts of modular servo system MS 150 used to identify a DC motor, namely:

a. Power Supply
   Input that provided is 115V and 230V, 50/60 Hz, 40VA. With the resulting output is 24V DC, 2A that used to supply DC motor.
b. DC Motor
   DC motor used are permanent magnet motor that have extended shaft. The motor shaft extended for pads directly from the inertia that used in magnetic braking.
c. Reduction Gear Tachogenerator Unit
   Modular feedback tachogenerator GT150X is used to convert mechanical quantities into electrical quantities.
d. Servo Amplifier
   Modular feedback servo amplifier SA150D consists of a series SA150D transistor which can drive a DC motor with bidirectional rotation.
e. Op Amp Unit
   Op Amp unit is used to amplify in feedback control system. Its use includes the addition operation to correct error for closed-loop control system and can also be used as the addition of extra time constant to show unstable condition.
f. Attenuator Unit
   Attenuator unit provide a reference voltage when connected to DC source and can be used to control the gain.

The speed control can be done by controlling the input signal (voltage) to the DC motor, because speed of DC motor is affected by the magnitude of input voltage.

Such control system commonly called the open-loop speed control system. In state of constant load or in a state of no-load, open-loop control system may still be used. However, in a state load change, the open-loop system is not able to be accounted for more reliability.

Open-loop speed control system can be modified to the system closed-loop. This system compares the actual speed with speed desired. The comparison will generate an error signal (error signal) which will then be used to drive the motor through servo amplifier. Thus, the motor can maintain a constant speed value.

In the first experiment, the feedback signal in this case is voltage generated by the tachogenerator compared with a reference signal in opposite polarity. Comparison of the sum of the reference signal with feedback signal that is used for provide input to the servo amplifier to drive the motor. As comparators, operational amplifiers used. While DC motors used assembled using armature control.

In a second experiment, the magnetic brakes to be used as a load by installing the aluminum disc at high speed shaft. On this experiment was intended to show that to gain higher, reduced speed will cause more error. Thus, raising the gain will reduce speed on variety of load reduction as indicated in Figure 5.

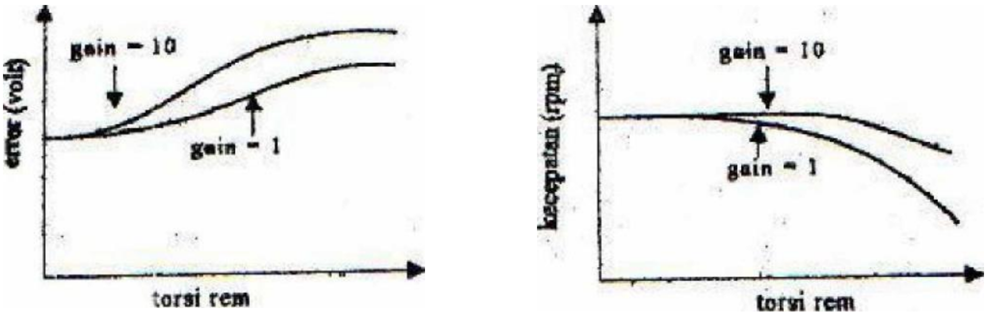


Figure 5. Brake Torque Vs Error and Brake Torque Vs Speed Graph.

In the last part of this experiment will be created speed control system with two-way rotation, namely in the forward direction (forward) and direction backward (reversed). The system uses a high gain, so the component Op-Amp replaced with Pre-Amp because these tools can make the motor rotates forward or backward, and have a gain about 25.

EXPERIMENT

Experiment 1. Simple Close Loop Velocity Control System

Servo amplifiers require positive input voltage, so the op - amp should produce a positive output voltage. In this experiment, the op-amp functioned as an inverter so as to produce a positive output then input op - amp should be negative.

Cautions:

1. Read the work steps in advance and understand.
2. Make sure the polarity of the reference voltage (input) negative voltage and voltage of the tachogenerator is positive.

3. Stop the measurement and turn off the power supply if the current exceeds power supply indicator show 2A.

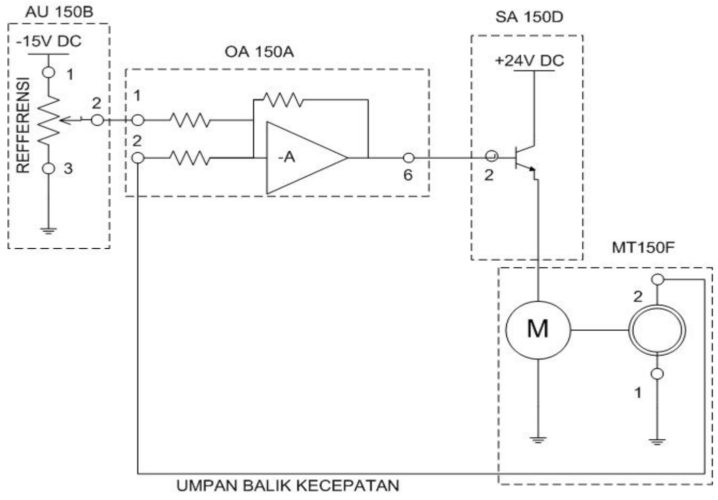


Figure 6. Simple closed-loop speed control system circuit

A. Operational Procedure:

1. Create the circuit as shown in figure 2.6. Do not connect first tachogenerator voltage at input OA150 A (Check +/- of the connector)
2. Check again the connectors are connected before turn on the power supply.
3. Using voltmeter, adjust potentiometer 1 to the minimum position (0 volt).
4. If the motor rotates, calibrate set zero offset in OU150A so the motor should not rotate.
5. Set potentiometer 1 at a voltage of -2 volt, and determine the positive voltage of the tachogenerator using voltmeter.
6. Enter positive tachogenerator output voltage to the input OU150A according figure 2.6.
7. Reset potentiometer 1 at the minimum position (0 volt).
8. Set the reference voltage on the potentiometer 1 as shown in table 1 and record the measured data at each setting the reference voltage.
9. After completion of the measurement make sure the power supply is turned off first before packing tools.

B. Experimental Data

Reference Voltage (Volt)	*Tachogenerator* Voltage (Volt)	Error Voltage (Volt)	Motor Speed (rpm)
-1			
-2			
-3			
-4			

Reference Voltage (Volt)	*Tachogenerator* Voltage (Volt)	Error Voltage (Volt)	Motor Speed (rpm)
-5			
-6			
-7			

C. Analysis and Experiment Task

1. Explain why *tachogenerator* voltage is smaller than reference input voltage?
2. Compare the result on third row (error voltage) and also the sum of first row (reference voltage) and second row (*tachogenerator* voltage)?
3. What kind of feedback which is used from that experiment? What happened if the polarity of *tachogenerator* is reversed*? (*connect the negative output to the op-amp's input)
4. Make a speed versus error voltage graph, and speed versus *tachogenerator* voltage graph?
5. What is *conclusion* from the mathematical equation from regression analysis?

Experiment 2: Gain Impact for Velocity Because of Load's Diversity

Caution:

1. Read the steps first.
2. Make sure that gain is always in position 1 for angular velocity value below 2000 rpm.
3. Make sure the polarity for reference voltage is negative and tachogenerator voltage is positive.
4. Stop the experiment if the current on power supply is more than 2 ampere

A. Operational Procedure:

1. Make the circuit like Figure 7. Don't connect the tachogenerator voltage on OA150A (warn the polarity of the connector).
2. Check again the connector which ic connect before activated power supply.
3. Set potentiometer (2) in gain position 1, and set the reference voltage on potentiometer (1) until motor have angular velocity about 2000rpm.
4. Give load according to the table 2-2 and record the measurement data.
5. Repeat for gain 10, and set the reference voltage on potentiometer (1) until motor have angular velocity about 2000 rpm.
6. After the experiment, make sure that power supply is off first before pack the tools and component.

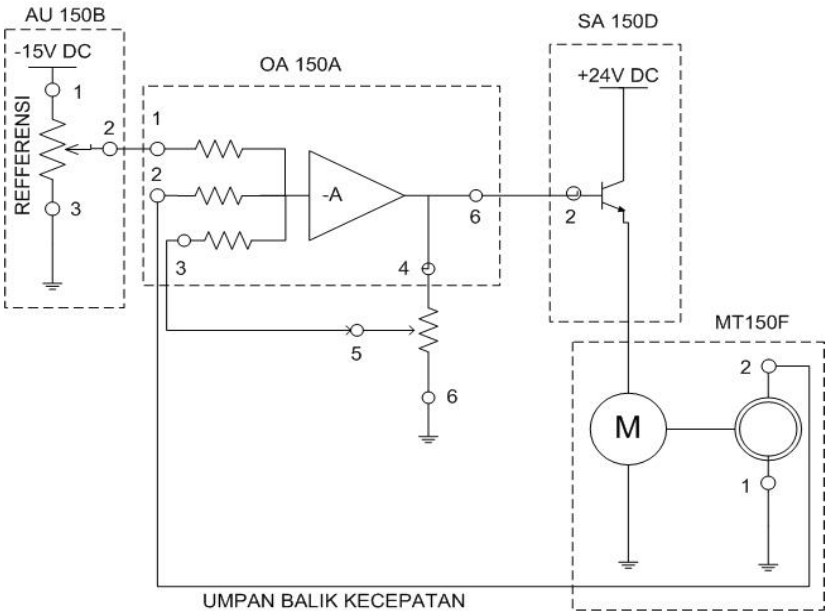


Figure 7. Speed control system circuit with gain

B. Experimental Data

Load	Reference Voltage (Volt)		Tachogenerator Voltage (Volt)		Error Voltage (Volt)		Motor Speed (rpm)	
	Gain 1	Gain 10	Gain 1	Gain 10	Gain 1	Gain 10	Gain 1	Gain 10
0								
2								
4								
6								
8								
10								

C. Analysis and Experiment Task

1. Make the error vs break torque graph for gain 1 and 10 in single coordinate, and also make speed vs break torque for gain 1 and 10 in single coordinate!
2. Make a conclusion from your graph!

Experiment 3: Two Directions Rotation Speed Control System

Caution:

1. Read the step
2. Make sure that the polarity of reference input voltage is always reverse from tachogenerator voltage.
3. Stop the activity and shut down the power supply if current is more than 2 ampere.

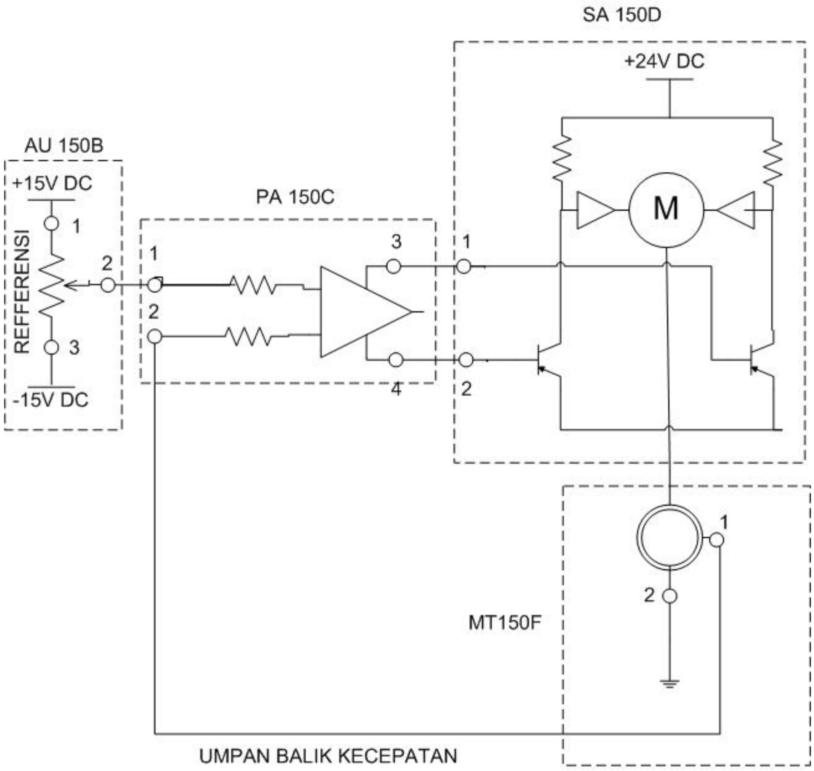


Figure 8 Rangkaian Sistem pengaturan dua arah

A. Operational Procedure:

1. Make the circuit as shown in Figure 2.8. Do not connected the reference voltage first (on potentiometer 1) and *tachogenerator* voltage on terminal input PA150C (attention on polarity of the connector which is connected).
2. Check the connector which is connected before activated power supply.
3. Using voltmeter, set potentiometer (1) on 0 volt. After that connect to the input terminal op-amp.
4. Rotate the knop of potentiometer 1 gently until the motor rotate slowly.
5. Connect the either output tachogenerator voltage to the op-amp input.
6. Observe if the motor rotates faster, disconnect the connector and change

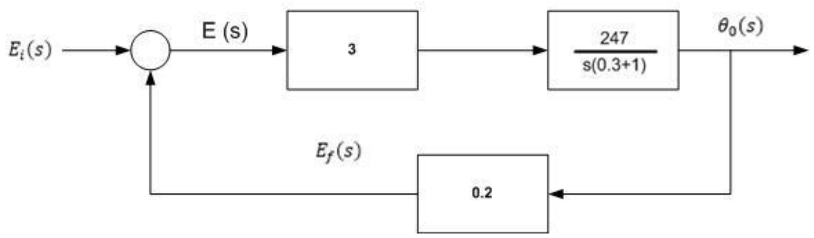
with another tachogenerator output. Set the potentiometer 1 voltage value according to reference value on table 2.3 and complete the table. After all, before packing the tools, make sure that power supply is off.

B. Experimental Data

Direction: Forward					Direction: Backward				
Ref. Volt. (volt)	Tacho Volt. (volt)	Error Voltage (volt)		Speed (rpm)	Tacho Volt. (volt)	Teg. Tacho (volt)	Error Voltage (volt)		Speed (rpm)
		Socket 3	Socket 4				Socket 3	Socket 4	

C. Analysis and Experiment Task:

1. Make an error voltage vs break graph and speed vs break graph for two different way rotation? (forward and reverse in single graph).
2. Speed control system's block diagram:



For input 5 volt, determine the error steady state for speed $\theta(s)$.