# EXPERIMENT 1
# DC MOTOR POSITION CONTROL

## OBJECTIVE
Doing experiment of control system is essential to knowing the comparison between control theory and the practical. DC motor position control can show the response of first order system and also second order system. Adjusting the gain controller will change the behavior of the system.

## REFERENCE
Ogata, K. Modern Control Engineering. 2010.
Anonym. Modular Servo System – DC, Synchro & AC Basic Assignments

## EXPERIMENT EQUIPMENT
In this experiment will used some servos as shown Table 1.

Table 1 Equipment of DC Motor Position Control Experiment

| Quantity | Designation | Description |
|---|---|---|
| 1 | OA150A | Op Amp Unit |
| 1 | PS150E | Power Supply |
| 1 | IP150H | Input Potentiometer |
| 1 | OP150K | Output Potentiometer |
| 1 | - | Reduction Gear Tacho Unit |
| 1 | AU150B | Attenuator Unit |
| 1 | PA150C | Pre Amplifier |
| 1 | SA150D | Servo Amplifier |
| 1 | DCM150F | DC Motor |
| 1 | GT150X | Reduction Gear Tacho Unit |
| 13 | | Jumper Cable |
| 5 | | Power Cable |

## PRE-EXPERIMENT TASK
1. Explain open loop and closed loop of control system!
2. How position control of DC motor works?

## INTRODUCTION
The purpose of this laboratory experience is to provide an introduction to control systems and give explanation application of control system. In this experiment will give explanation about position control of DC motor. First experiment will do error investigating, the second is simple position control system the last is closed loop control system.

### The Components of the Control System
The basic goal of a control system is to produce an output as a response to an input signal or command and keep it this way in the presence of external interference, disturbances, etc. Control systems can be basically classified as open-loop systems or closed-loop systems depending on how they are built. This introductory lab experience will explore both types of

systems.

**Voltage Regulation**

For permanent magnet dc motors, the magnetic field value is constant. Then you only need to set the magnitude of the voltage at the motor terminals. Current passing through the armature will cut the magnetic field of permanent magnet. According to the Lorentz law, if there is a current-carrying conductor in a magnetic field then, there will be a force that moves the conductor. The magnitude of the force is proportional to the current through conductors. The amount of current is affected by the voltage received by conductor. A force that emerged later converted into a rotation force by mechanical rings.

The equivalent circuit of the motor can be seen in Figure 1. While armature resistance is constant, by regulating the voltage at the terminals, it will regulate the speed of the motor. Then by doing closed-loop analysis, will be obtained Equation 1.

$$\frac{Es - Eo}{Ro} = Io \qquad (1)$$

Where $Es$ is voltage terminal, $Eo$ is induction voltage, is $Ro$ armature resistance, and $Io$ is armature current.

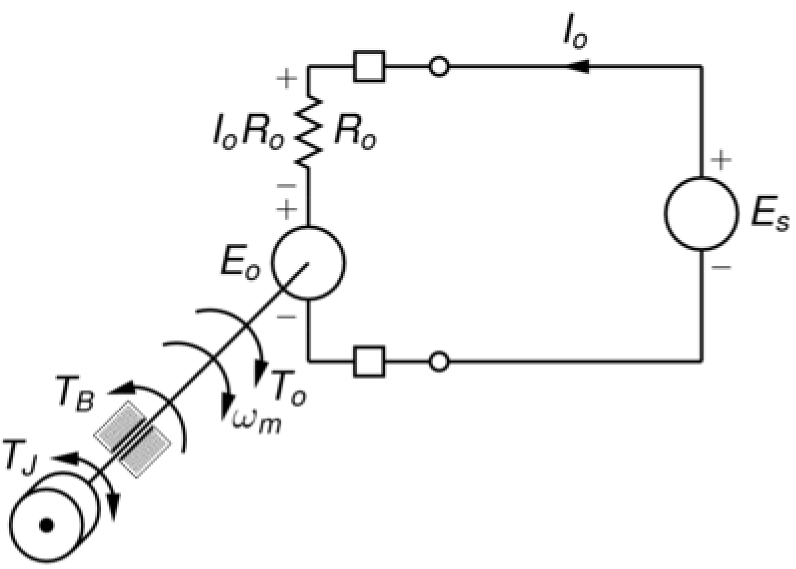



Figure 1 Equivalent Circuit of Permanent Magnet DC Motor

Increasing the value $Eo$ will increase the speed of DC motor. If the rotor of the DC motor attached to output potentiometer is increased the value of $Eo$ and suddenly decrease it to the zero value will bring the shaft of motor in the certain position.

**Equipment: Modular Servo MS-150**

Modular servo MS-150 is a lab instrument to practice speed and position control on dc motor. Parts of modular servo system MS-150 is consist of the op-amp unit, attenuator, pre-amplifier, servo amplifier, power supply, dc motor, input and output rotary potentiometer, magnetic brakes, and tachogenerator.

**Power supply PS150E**
Supplying power to the modular servo with AC input voltage 115V and 230V, 50/60 Hz, 40VA. The resulting output DC 24V, + 15V DC and -15V DC, with current must not exceed 2A.

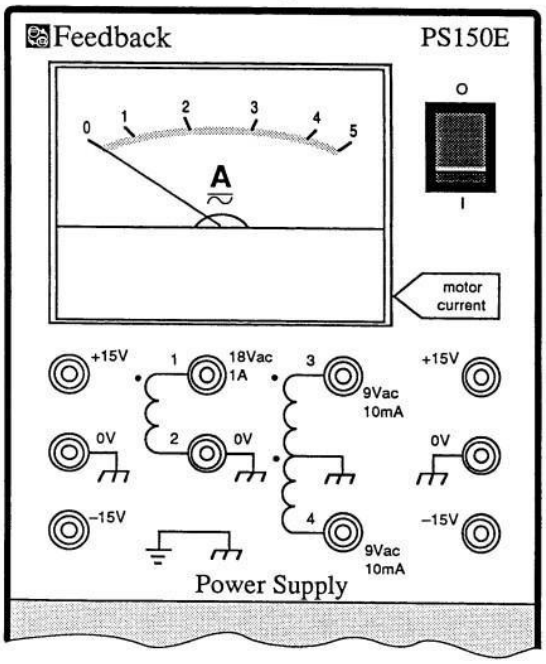



Figure 2 Power Supply PS150E

**DC Motor DCM150F**
DC motor that used is a separate excited dc motor, more precisely using permanent magnets to generate magnetic field. There are shafts that coupled with tachogenerator.

**Tachogenerator**
With the induced voltage generated by a dc motor, used as a dc motor rotation speed reader. The magnitude of the voltage generated is proportional to the reading of the motor rotation.

**Servo Amplifier SA150D**
Consists of two transistors that form long-tailed pair connection, to drive the motor in two different directions. If the voltage difference between terminals one and two are zero, then the motor will stop. When the terminal one is greater than the terminal two, then the motor will rotate at the speed depends on the magnitude of the voltage difference between terminals one and two. In contrast, when the terminal two is greater than the terminal one, the motor will rotate in the opposite direction.

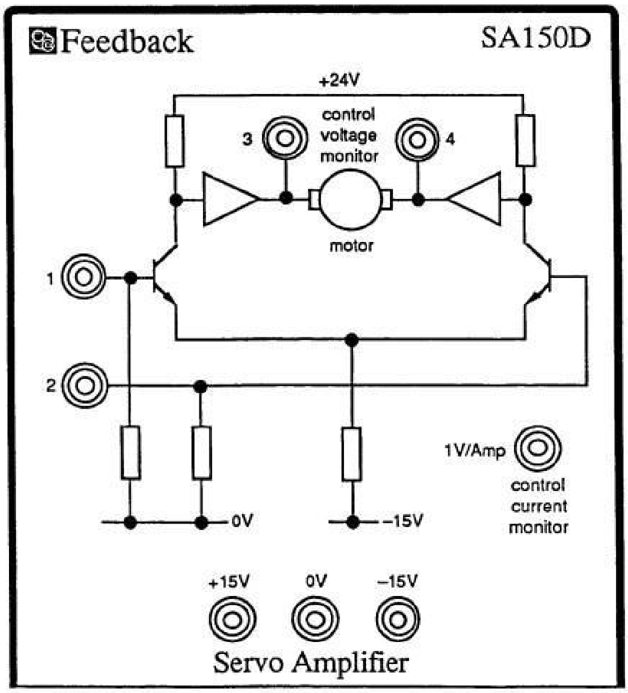


Figure 3 Servo Amplifier SA150D

**Op Amp OA150E**

In the op amp circuit, there is summing amplifier circuit. The output is the sum of the input signal and multiplied with the gains. In OA150E device there are three setting options for feedback resistance, thus the amount of amplifier can be arranged.

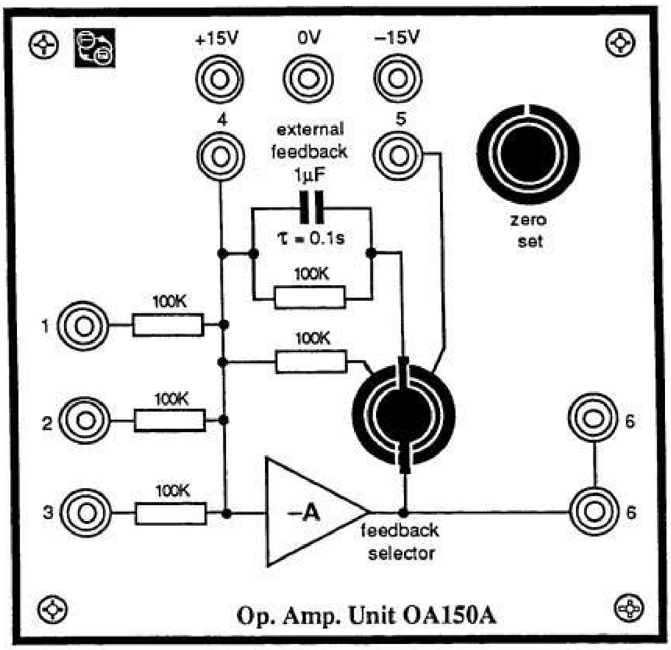


Figure 4 Op-Amp OA150

**Attenuator AU150B**

Potentiometer circuit which aims to reduce the signal or the voltage passing through. When rotated clockwise terminal one and two have a small resistance, on the contrary when rotated counter-clockwise. Maximum resistance owned by AU150B is 10kOhm.

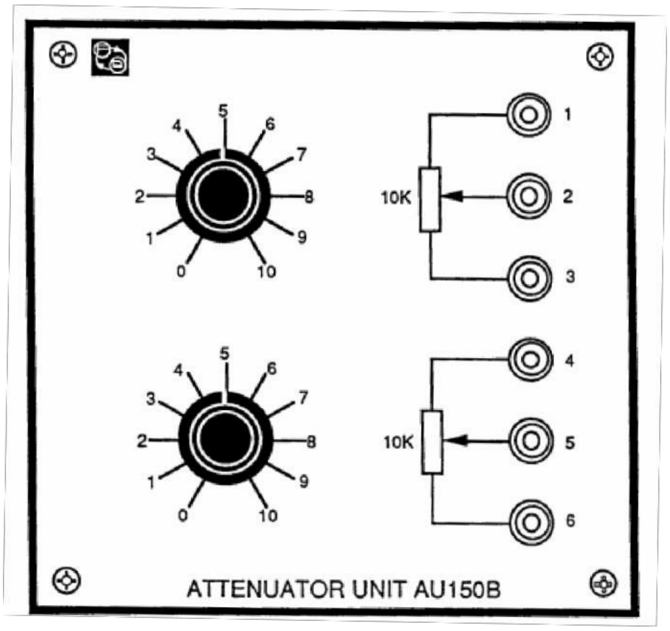



Figure 5 Attenuator AU150B

## EXPERIMENT

### Error Channel Investigation

It is possible to use an amplifier of high gain to produce an output Vo that is the (minus) sum of the input voltages (V1+V2). This can be done by connecting across the amplifier a feedback resistor R2, which then multiplies the output voltage by a factor, where R1 was the input resistance.

### A. Operational Procedure

1. Adjust zero offset of OA150A so the output Op-Amp became zero volt if the input summing is zero volt.
2. Connect the voltmeter to the output (Terminal 6) of the OA150A, switch on and adjust the zero set to as near zero as possible.
3. After setting zero set, set the MS150 equipment like in the Figure 6a without coupling arrangement.
4. Set the value of output potentiometer as shown in Table 2.
5. Set the input potentiometer (IP150) as the Table 2.
6. Take note the error voltage to the Table 2 in error voltage column.
7. Repeat step 5 and 6 for all potentiometer input degree.

### B. Experimental Data

The value that get from step number six in operational procedure of error channel investigation write in Error Voltage column as shown in Table 2

Table 2 Experiment of Error Channel Investigation

| No | Input Potentiometer (Degree) | Output Potentiometer (Degree) | Error Voltage (Volt) |
|---|---|---|---|
| 1 | 0 | 120 | |
| 2 | 20 | | |
| 3 | 40 | | |
| 4 | 60 | | |
| 5 | 80 | | |
| 6 | 100 | | |
| 7 | 120 | | |

**C. Analysis and Experimental Task**

1. In the closed loop position control, what is the function of input potentiometer (IP150) and output potentiometer (OP150)?
2. Find the misalignment value of the input potentiometer and output potentiometer? How can be misalignment occur? Give explanation!

**Open Loop Position Control**

Two rotary potentiometer can be used to generate an error signal to show the misalignment of the output cursor with that the input cursor. If the output potentiometer is mounted on the shaft of a geared motor, can make the basis of an automatic control system. The error signal can be used to drive the motor in a direction such as to reduce the miss alignment to zero.

**A. Operational Procedure**

1. Set the component of MS150F to be like Figure 6.
2. Use the push-on coupling to link a low speed shaft of the GT150X to the output potentiometer shaft.
3. Starting AU150B the potentiometer knob at the fully counter clockwise position so the output voltage of potentiometer become zero. Gradually turn it till the motor just rotates and record to Table 3.
4. Set the input potentiometer as the value shown in Table 4.
5. Watch the error voltage, turn the potentiometer until the error voltage became almost zero.
6. Take note the error voltage and the value of output potentiometer.

**B. Experimental Data**

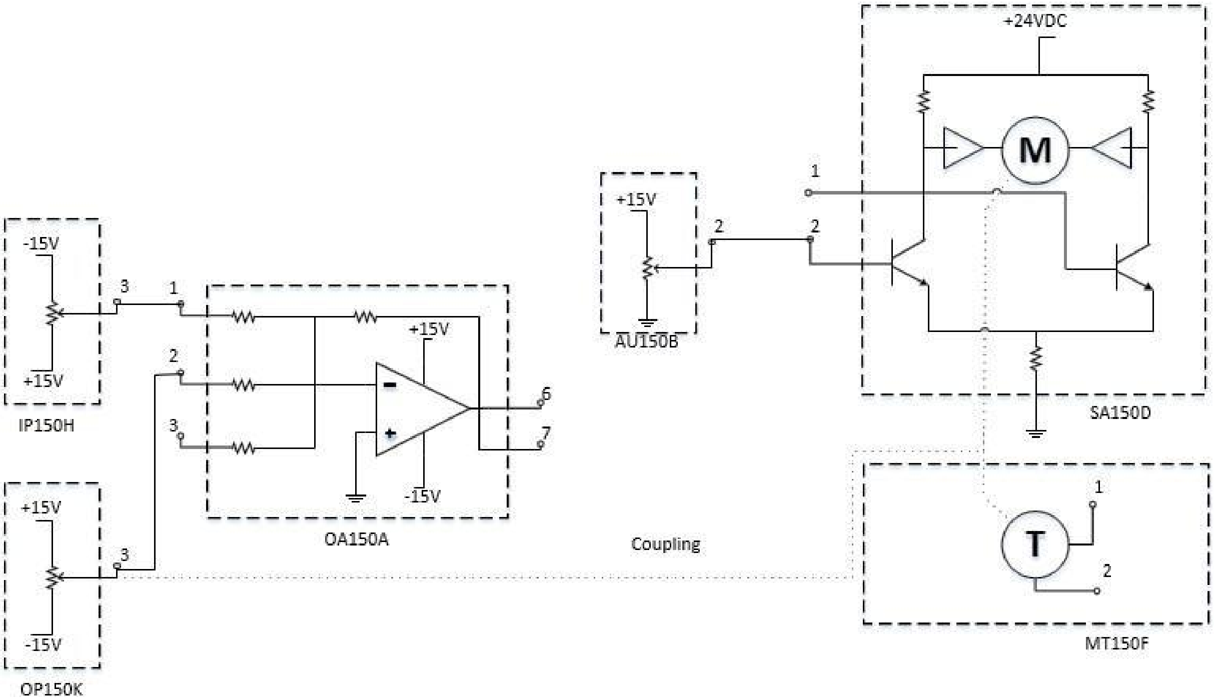
The value that get from step number four and number six in operational procedure of open loop position control, write in Table 3 and Table 4.

Table 3 Minimum Gain of DC Motor Rotation

| | |
|---|---|
| **Minimum voltage of attenuator at which the motor just rotates (Volt)** | |
| **Direction in which the output rotary potentiometer moves (CW/CCW)** | |

Table 4 Open Loop Miss alignment

| **Input Potentiometer (Degree)** | **Output Potentiometer (Degree)** | **Error Voltage (Volt)** | **Miss alignment (Degree)** |
|---|---|---|---|
| **20** | | | |
| **40** | | | |
| **10** | | | |
| **84** | | | |
| **80** | | | |
| **100** | | | |




(6a) Summing Error (6b) Direct Control DC Motor
Figure 6 Open Loop Position Control Scheme

## C. Analysis and Experimental Task

1. Explain how the system works !
2. Draw a functional block diagram. You can consider the pre-amplifier and the servo amplifier as "black boxes" without having to explain how they work !
3. Is this an open-loop or a closed-loop system? Why?

**PA150C Characteristic**

Pre-amplifier PA150C have two input and two output. The two output have unique value that will be explored by this experiment.

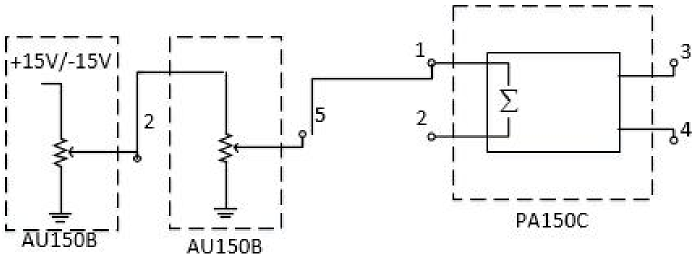



Figure 7 PA150C Characteristic Arrangement

**A. Operational Procedure**

1. Arrange the equipment like in the Figure 7 with +15V reference.
2. Verify the zero offset by connecting the input to the ground and measure the output voltage with volt meter.
3. In the upper attenuator, adjust the output to +1V (Terminal 2).
4. Adjust lower attenuator to scale 1, and take note the value of terminal 3 and 4 in PA150C as Table 5, repeat until scale value is nine.
5. Repeat step number 1 with -15V reference.

**B. Experimental Data**

The value that get from step number four from operational procedure of PA150C Characteristic, write in Table 5.

Table 5 PA150C Characteristic Voltage

| Reference (+15V) | | PA150C Output | | |
|---|---|---|---|---|
| Scale | Vi | Vo(3) | Vo(4) | Vo(4-3) |
| 1 | | | | |
| 3 | | | | |
| 5 | | | | |
| 7 | | | | |
| 9 | | | | |
| Reference (-15V) | | PA150C Output | | |
| Scale | Vi | Vo(3) | Vo(4) | Vo(4-3) |
| 1 | | | | |
| 3 | | | | |
| 5 | | | | |
| 7 | | | | |
| 9 | | | | |

**C. Analysis and Experiment Task**

1. Draw the characteristic of PA150C by making curve of PA150C as vertical axis and Vi as the horizontal axis! Give conclusion!

**Closed Loop Position Control System**

The difference between set point and feedback generate error value. Generated value than became input to the controller which will give correction value to the actuator.

## A. Operational Procedure

1. Set the equipment of MS150 F to be like Figure 8.
2. Set the upper potentiometer (terminal 2) of AU150B become to zero.
3. Set the gain of the attenuator as the Table 6.
4. Now set the IP150H to some arbitrary angle and increase the gain control setting and take a note Table 6, repeat for the next value of input potentiometer.

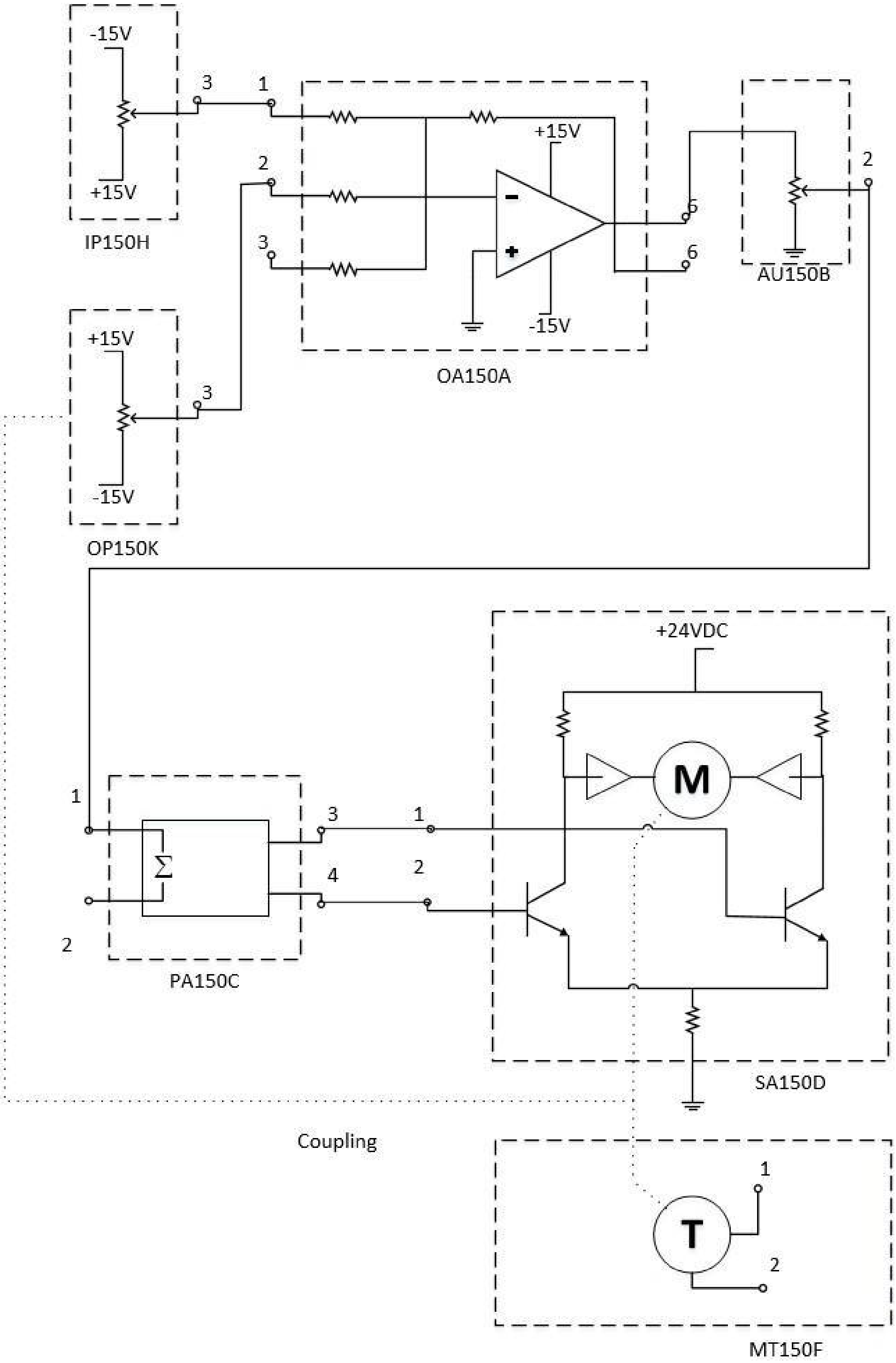



Figure 8 Closed Loop Position Control

## B. Experimental Data

The value that get from step number four from operational procedure of Closed Loop Position Control System, write in Table 6.

Table 6 Data Experiment of Closed Loop Position Control

| **Output Cursor position in Degrees** | | |
|---|---|---|
| **Gain = 1.5/15** | | |
| **Required (Degree)** | **Actual (Degree)** | **Misalignment (Degree)** |
| **10** | | |
| **20** | | |
| **30** | | |
| **40** | | |
| **50** | | |
| **60** | | |
| **70** | | |
| **Gain = 2.5/15** | | |
| **Required (Degree)** | **Actual (Degree)** | **Misalignment (Degree)** |
| **10** | | |
| **20** | | |
| **30** | | |
| **40** | | |
| **50** | | |
| **60** | | |
| **70** | | |

## C. Analysis and Experiment Task

1. Explain how this new system works! Explain the signal path!
2. Draw a functional block diagram. You can consider the pre-amplifier and the servo amplifier as “black boxes” without having to explain how they work.
3. Is this an open-loop or a closed-loop system? Why?