Laboratory Tutorial#1

1.1. Objective: To become familiar with the modules and how they operate.

1.2. Equipment Required: Following equipment is required to perform above task.

Quantity	Apparatus	
1	OU150A	Operation Amplifier Unit
1	AU150B	Attenuator Unit
1	PA150C	Pre-amplifier Unit
1	SA150D	Servo Amplifier
1	PS150E	Power Supply
1	MT150F	Motor-Tacho Unit
1	IP150H	Input potentiometer Unit
1	OP150K	Output Potentiometer Unit
1	LU150L	Load Unit

1.3. Approximate Time Required: One to two Hours

1.4. Prerequisites: Elementary knowledge of electronics.

1.5. Preliminary Procedure

Attach Operational Amplifier Unit, Attenuator Unit, Pre-amplifier unit, Servo Amplifier unit, Power Supply unit, Motor unit and Input and Output potentiometer units to the baseplate by means of their magnetic feet.

1.6 Discussion

A **servomechanism** or **servo** is an automatic device that uses error-sensing feedback to correct the performance of a mechanism. The term correctly applies only to systems where the feedback or error-correction signals help control mechanical position or other parameters.

Modern servomechanisms use solid state power amplifiers, usually built from MOSFET or thyristor devices. Small servos may use power transistors. The origin of the word is believed to come from the French “Le Servomoteur” or the slavemotor, first used by J. J. L. Farcot in 1868 to describe hydraulic and steam engines for use in ship steering. In the strictest sense, the term servomechanism is restricted to a feedback loop in which the controlled quantity or output is mechanical position or one of its derivatives (velocity and acceleration).

Servomechanisms were first used in military fire-control and marine navigation equipment, speed governing of engines, automatic steering of ships, automatic control of guns and electromechanical analog computers. Today, servomechanisms are employed in almost every industrial field. Among the applications are cutting tools for discrete parts manufacturing, rollers in sheet and web processes, elevators, automobile machine tools and aircraft engines, robots, remote manipulators and teleoperators, telescopes, antennas, space vehicles, satellite tracking antennas ,remote control airplanes, anti -aircraft gun control systems, mechanical knee and arm prostheses, and tape, disk, and film drives.

The Feedback MS150 Modular Servo system is particularly intended for experimental use by students who are starting on studies of closed-loop systems. Each of the units of this equipment is fitted with magnetic feet and can be attached to the base-board in any desired position. The main power supplies for the Servo Amplifier unit and the Motor Tacho unit are fed through the cables terminating in octal plugs fitted to both Motor-Tacho and Servo Amplifier unit. The lead from the motor should be plugged into the Servo Amplifier and that from the Amplifier into the Power Supply. Both Power Supply unit and Servo Amplifier unit are fitted with 4mm sockets from which ±15 d.c supplies can be drawn to operate all other units of the system. For each experiment a patch diagram is included to show all the necessary connections to be made with patch leads provided. It is assumed however, that the students will automatically plug the main power supply octal plugs, so these are left off the diagrams to simplify them. The components of the MS150 System are abbreviated in the text for convenience. These components are:

OU150A	Operation Amplifier Unit
AU150B	Attenuator Unit
PA150C	Pre-amplifier Unit
SA150D	Servo Amplifier
PS150E	Power Supply
MT150F	Motor-Tacho Unit
IP150H	Input potentiometer Unit
OP150K	Output Potentiometer Unit
LU150L	Load Unit

So that you can become familiar with the kit before you start the assignments, examine each unit as it is described.

1.6.1 Power supply Unit (PS150E)

This unit supplies a 24v d.c 2A unregulated supply to the motor through an 8-way connector to the Servo Amplifier, as it is this unit that controls the motor.

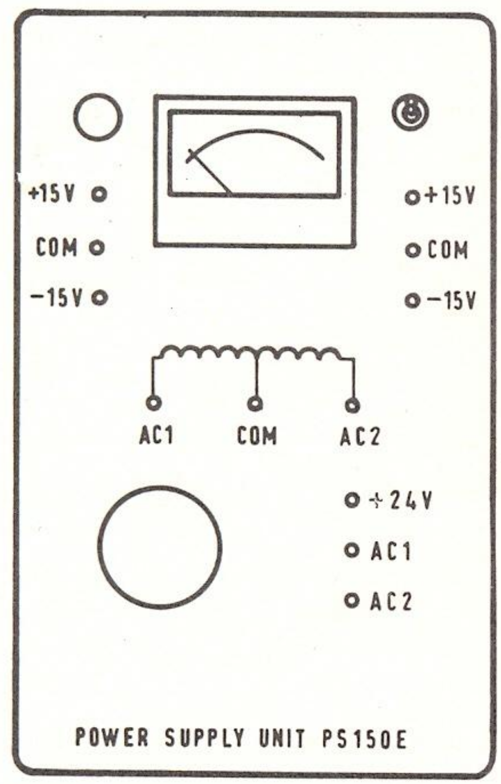


Figure-1.1: Power Supply Unit (PS150E)

On the front panel there are two sets of 4mm sockets to provide ±15v stabilized d.c supplies to operate the smaller amplifiers and provide reference voltage. The power supply unit in laboratory tutorials is represented as in figure-1.1.

1.6.2 Motor-Tacho Unit (MT150F)

This Unit is made up of three parts

1. A d.c series-wound split-field motor which has an extended shaft, and onto which can be fixed the magnetic brake or inertia disc.
2. A d.c tacho-generator with output on the top of the unit
3. For control experiments, there is a low-speed shaft driven by a 30:1 reduction gearbox.

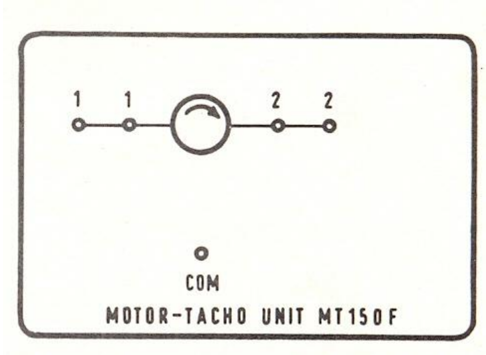


Figure-1.2: Motor- Tacho Unit (MT150F)

Figure-1.2 gives the diagram used for this unit in laboratory handouts.

1.6.3 Servo Amplifier unit (SA150D)

This unit contains the transistors which drive the motor in either direction. On the front panel connection are provided for patching the armature for different modes of control (e.g. Field controlled or armature controlled). The Servo Amplifier is shown in following figure.

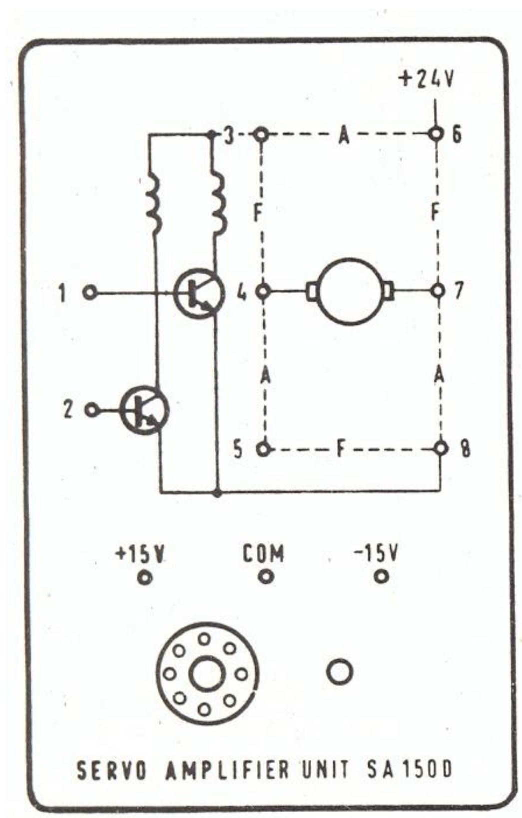


Figure-1.3: Servo Amplifier Unit (SA150D)

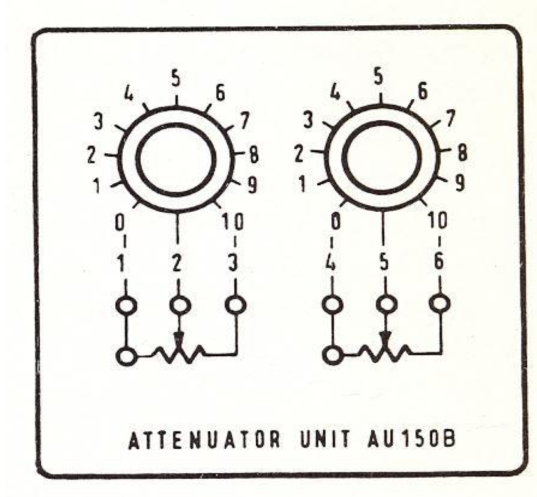


Figure-1.4: Attenuator Unit (AT150B)

1.6.4 Attenuator Unit (AT150B)

This unit contains two variable 10KΩ potentiometers as shown in figure-1.4. The proportion of the resistance being selected is indicated by a dial graduated from 0 to 10. This unit can either provide a reference voltage when connected to a d.c source or be used as a gain control when connected to the output of an amplifier.

1.6.5 Input and Output Potentiometer Units (IP150H & OP150K)

These are rotary potentiometers, used in experiments on position control. The input potentiometer is used to set up a reference voltage and the output potentiometer is connected to the low speed shaft of the motor by using the push-on couplings. Figure-1.5 gives the circuit diagram for these units.

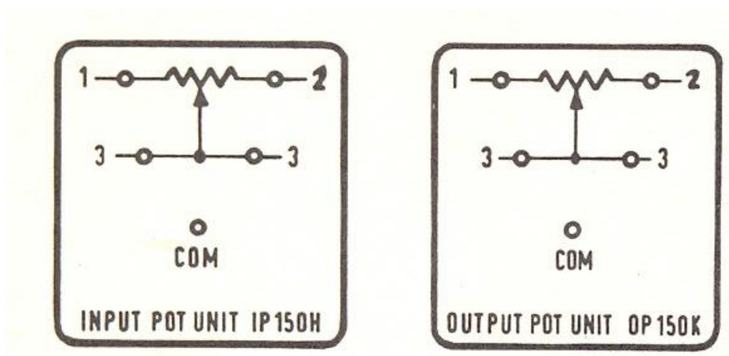


Figure-1.5: Input and Output Potentiometer Units (IP150H & OP150K)

1.6.6 Pre-Amplifier Unit (PA150C)

This provides the correct signals to drive the Servo Amplifiers in SA150D. The two inputs are effectively summed, allowing two signals to be applied (e.g. reference voltage and the tacho-generator voltage).

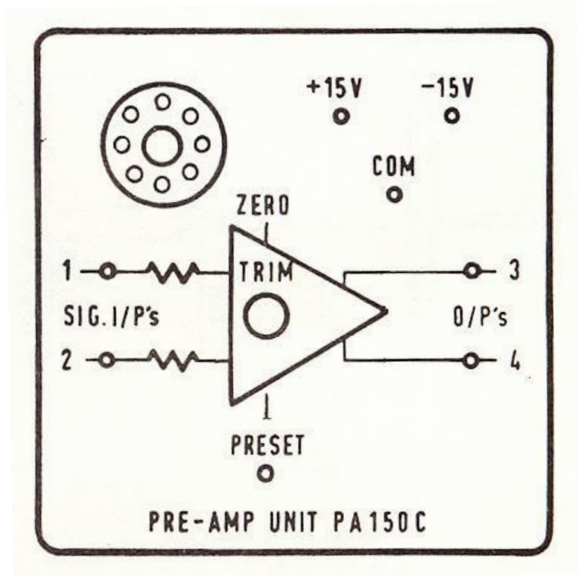


Figure-1.6: Pre-Amplifier Unit (PA150C)

A positive signal applied to either input causes the upper output (3) to go positive, the other output (4) staying near zero. A negative input causes the lower output (4) to go positive, the upper one staying near zero. The bidirectional motor drive is obtained when these outputs are linked to the Servo Amplifier inputs.

1.6.7 Operational Amplifier Unit (OU150A)

This provides inverting voltage gain and means of summing two or more signals, as well as facilities for introducing compensation networks. Figure-1.7 gives the layout of this unit.

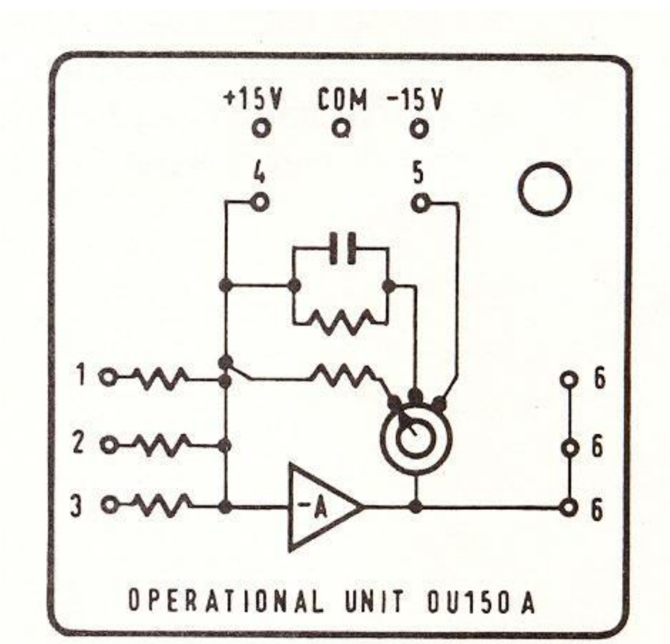


Figure-1.7: Operational Amplifier Unit (OU150A)

1.6.7 Load Unit (LU150L)

An Aluminum disc can be mounted on the motor shaft and when rotated between the poles o the magnet of the load unit, the eddy currents generated have the effect of a brake. The strength of the magnetic brake can be controlled by the position of the magnet.

1.7 Lab Tasks

1.7.1 Task#1: To connect up the motor

You are now acquainted with sufficient units to be able to connect up the motor. The motor direction depends upon which of the two field coils is energized, and the speed upon the amount of drive voltage applied to the inputs of Servo Amplifier. In this practical we shall use one direction only, and vary the drive voltage using one of the attenuators. Set up the circuit of figure-1.8, in which the armature links are patched for armature control mode.

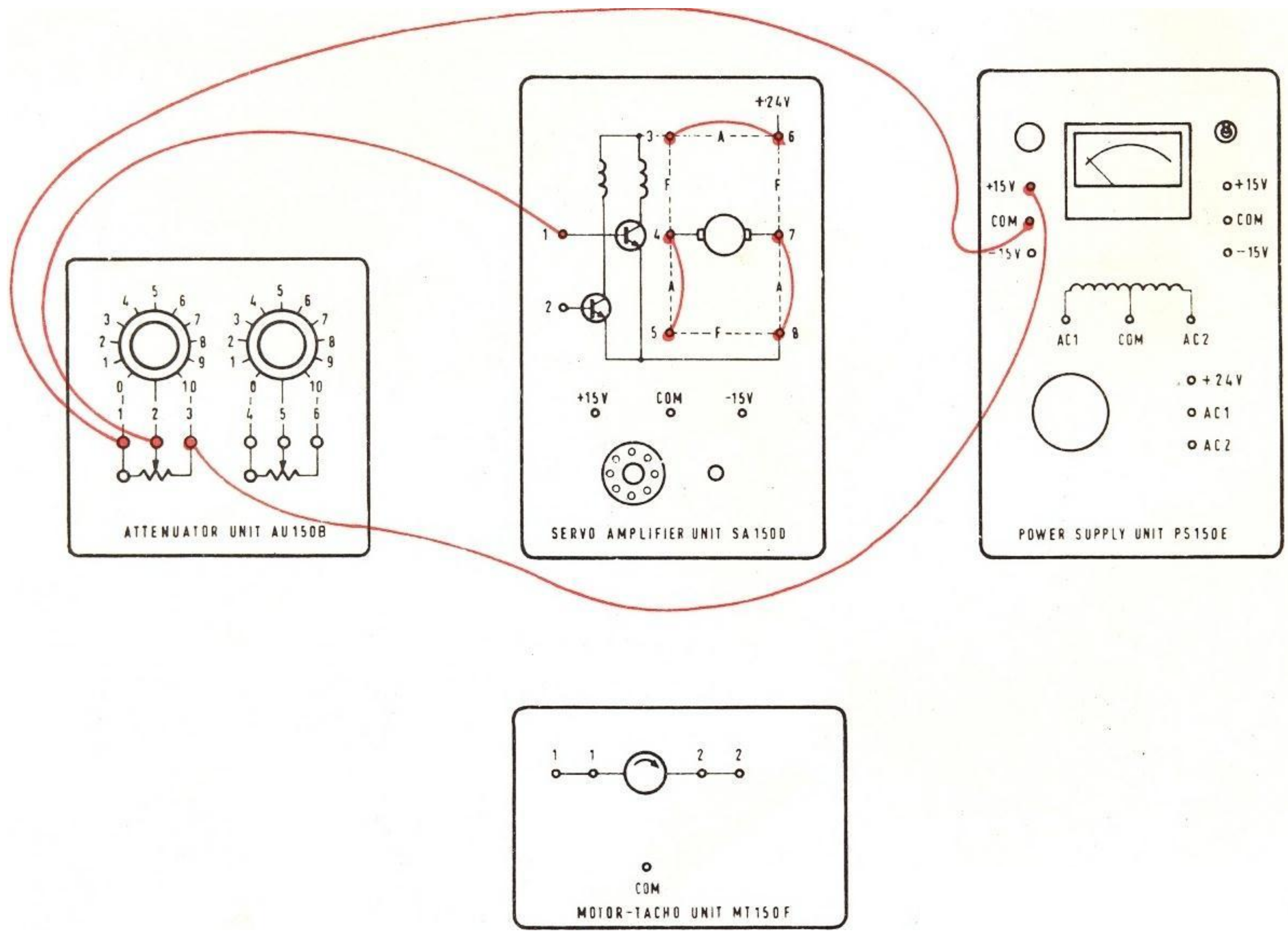


Figure-1.8: Connecting up the motor in armature control mode

1.7.2 Task#2: To drive the motor in field control mode

Patch the F links together in order to drive the motor in field control mold.

1.8: Lab Assignments

1.8.1 Assignment#1: Drive the armature controlled d.c motor in either direction.

1.8.2 Assignment#2: Drive the filed controlled d.c motor in either direction.

Conclusion/ Comments:

Laboratory Tutorial#2

2.1. Objective: To illustrate the performance of a motor being controlled by a servo amplifier.

2.2. Equipment Required: Following equipment is required to perform above task.

Quantity	Apparatus	
1	AU150B	Attenuator Unit
1	SA150D	Servo Amplifier
1	PS150E	Power Supply
1	MT150F	Motor-Tacho Unit
1	LU150L	Load Unit
1	Stop Clock	
1	Multimeter	

2.3. Approximate Time Required: One to two Hours

2.4. Prerequisites: Laboratory Tutorial#1.

2.5 Discussion

In later laboratory assignments we are going to show how an electric motor can be used in position and speed control systems. This assignment will illustrate the characteristics of the motor used in this kit and show how it can be controlled by the Servo Amplifier.

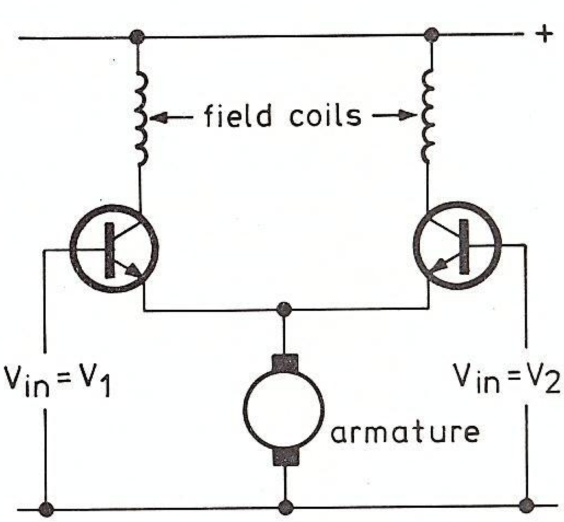
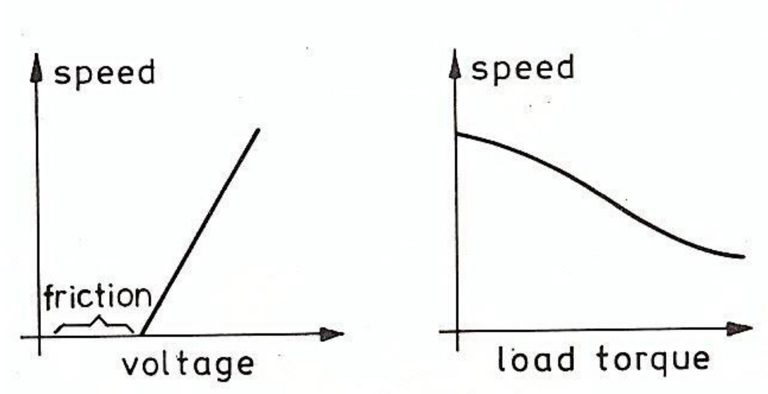


Figure-2.1: Armature control Arrangement

The motor has a split field winding, with current flow in each part of the coil being controlled by a transistor. This mean the direction of rotation can be reversed, with input 1 on the Servo Amplifier making the motor rotate in one direction and the input 2 in other direction, as in figure-2.1. As the motor accelerates the armature generates an increasing 'back-emf' V_b tending to oppose the applied voltage V_{in}. The armature current is thus roughly proportional to (V_{in}-V_b). If the speed drops (due to loading) V_b reduces, the current increases and thus so does the motor torque. This tends to oppose the speed drop. This mode of control is called 'armature-control' and gives a speed proportional to V_{in}, as in figure-2.2 (a).



(a) Speed vs input voltage (V_{in}) **(b)** Speed vs Torque

Figure-2.2: Motor Characteristics (Armature control Mode)

Due to brush friction, a certain minimum input signal is needed to start the motor rotation. Figure-2.2 (b) shows how the speed varies with torque.

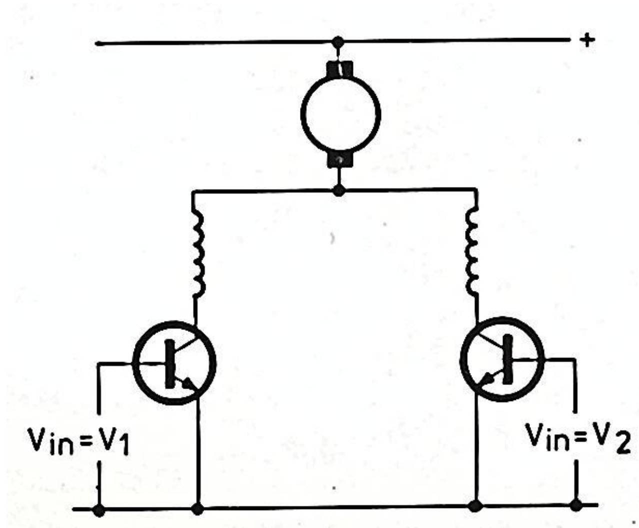


Figure-2.3: Field Control Arrangement

The connections on the Servo Amplifier also allow the armature to be connected in the collector circuits of the transistors, as in figure-2.3, and this configuration will be referred to as 'field control'. In this case back emf will have much less effect on the motor current. This means that the transistor current and therefore the motor current largely determined by the input signal V_{in}.

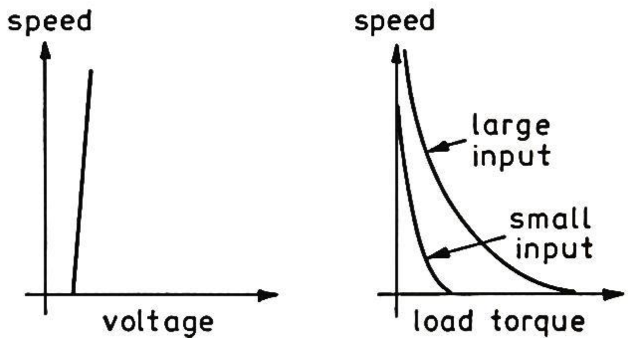


Figure-2.4: Motor Characteristics (Field control Mode)

Figure-2.4 (a) shows how with the motor unloaded, any small increase in input (above the minimum value) will cause a large increase in speed. This makes the motor difficult to control. Under load there is a very sharp fall in speed, as shown in figure-2.4 (b).

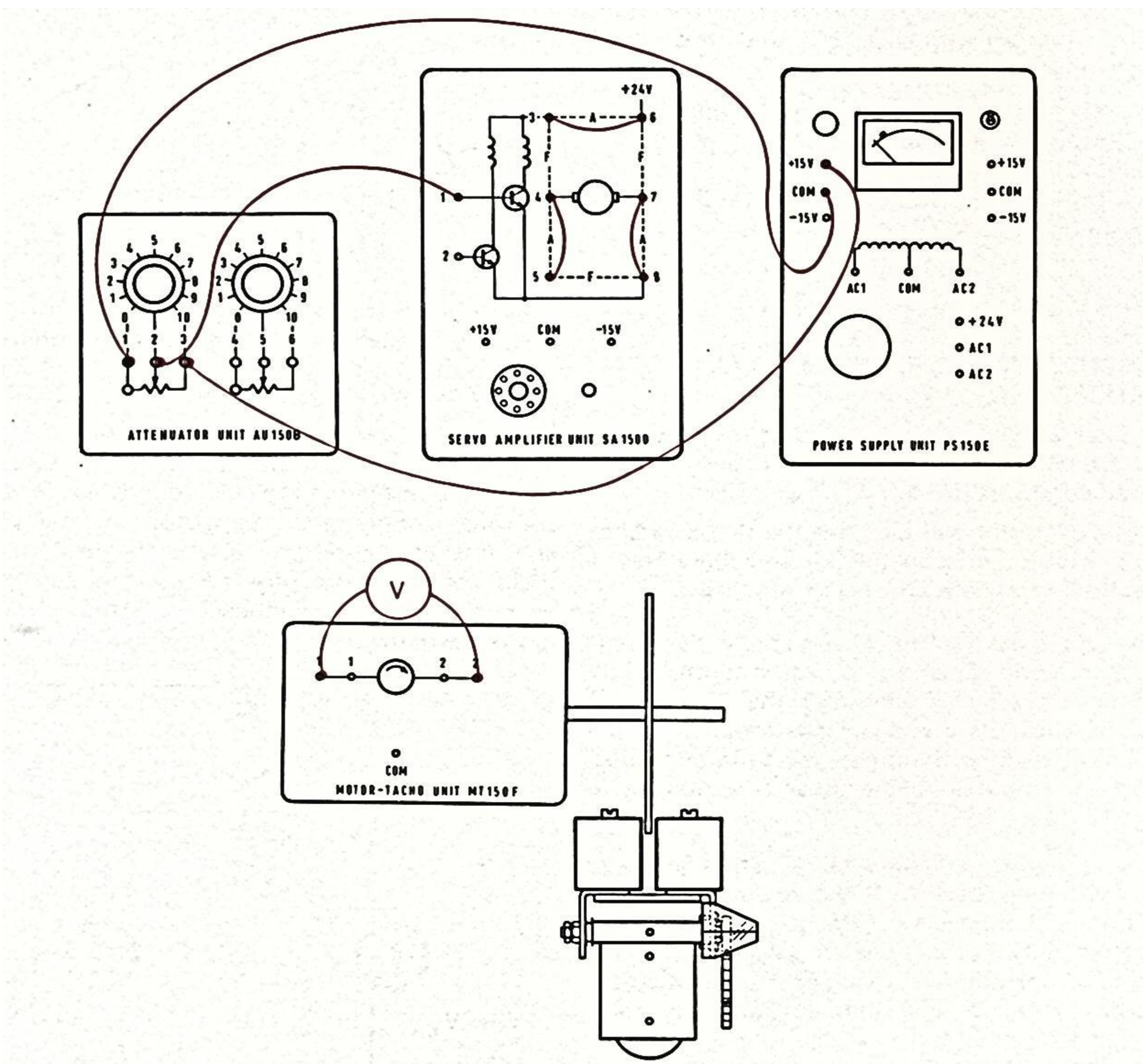


Figure-2.5: Experimental set up (Armature Control Mode)

2.6 Experimental Set Up

The first experiment will be to obtain the characteristic of the motor connected for armature control, as in figure-2.5. By using one of the potentiometers on the Attenuator unit, it is possible to obtain a variable input signal V_{in}. The kit provides a tacho-generator coupled to the motor. To obtain values of speed, it will be necessary to calibrate this generator by finding the factor K_g, which is the volts generated per thousand rev/min.

Connect the voltmeter across the tacho outputs and switch on the power. Turn the slider on the potentiometer till there is a reading of 1V on the voltmeter. Count the turns of the geared 30:1 low speed shaft in one minute. Tabulate your result as in table-2.1.

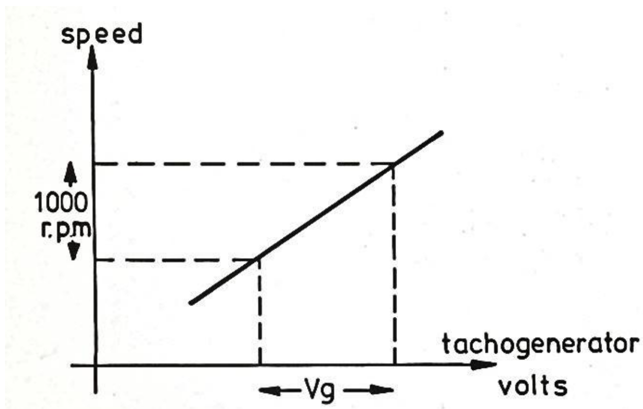


Figure-2.6: Tachogenerator volts vs speed

Repeat this reading with a 2V generator output. Then repeat for 3V, 4V, 5V, 7V and 10V and plot the graph of your results, as in figure-2.6, of speed against Tachogenerator volts. The calibration factor $K_g = \frac{V_g}{N}$ should be about 2.5V to 3V per 1000 rev/min.

S.No	Tachogenerator volts (V_g)	V_{in}	No. of rotations of low Speed Shaft (a)	Speed in rev/min N=30×a

Table-2.1: Armature control d.c Motor Speed characteristics

To measure the torque/speed characteristics, fix the brake so that it passes over the disc smoothly while the motor is running. Then set the brake at position 10 with the ammeter on the power supply unit not exceeding 2 amp. Note the value of the input voltage. Take the Tachogenerator readings over the range of the brake down to zero position and tabulate your results as in table-2.2.

V_{in}=				
S.No	**Brake Position**	**Tachogenerator volts (V_g)**	**No. of rotations of low Speed Shaft (a)**	**Speed in rev/min N=30×a**
V_{in}=				
S.No	**Brake Position**	**Tachogenerator volts (V_g)**	**No. of rotations of low Speed Shaft (a)**	**Speed in rev/min N=30×a**

Table-2.2: Armature control d.c Motor Torque Characteristic

Now reset the brake back to maximum position and reduce the input voltage so that the motor is slowly rotating. Take readings over the brake range tabulating the further results. Plot the two sets of results, as in figure-2.2 (b), of speed against torque for the two input voltage values.

Conclusion/Comments:

Laboratory Tutorial#3

3.1. Objective: To show how rotary potentiometers mounted on the output and input of a positional control system can generate an error signal.

3.2. Equipment Required: Following equipment is required to perform above task.

Quantity	Apparatus	
1	OU150A	Operation Amplifier Unit
1	PS150E	Power Supply
1	IP150H	Input potentiometer Unit
1	OP150K	Output Potentiometer Unit
1	Multimeter	

3.3. Approximate Time Required: One to two Hours

3.4. Prerequisites: Laboratory Tutorialt#1.

3.5. Discussion

In any closed loop system error is calculated by taking the difference of input and output of the system. In this assignment we will use summing amplifier to produce error signal. In setting up the experiment, care has to be taken initially to set the amplifier output to as near zero as possible. If as in figure-3.1 we make V_2 the opposite polarity to V_1 on connecting these voltages to the amplifier the output voltage would be:

$$V_o = -A(V_1 - V_2)$$

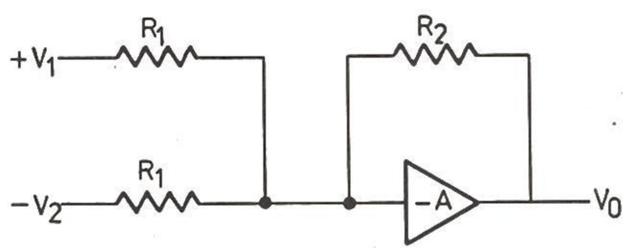


Figure-3.1: Summing Amplifier

We now have a device that can compare two voltages and unless one voltage is exactly the opposite potential of the other, the amplifier will have an output proportional to the difference.

If the inputs V_1 and V_2 are supplied from circular potentiometers with their sliders coupled to a cursor traversing a dial marked in degrees, we can add together the input voltages to form a simple 'error channel' to represent the difference in angular position of the two cursors.

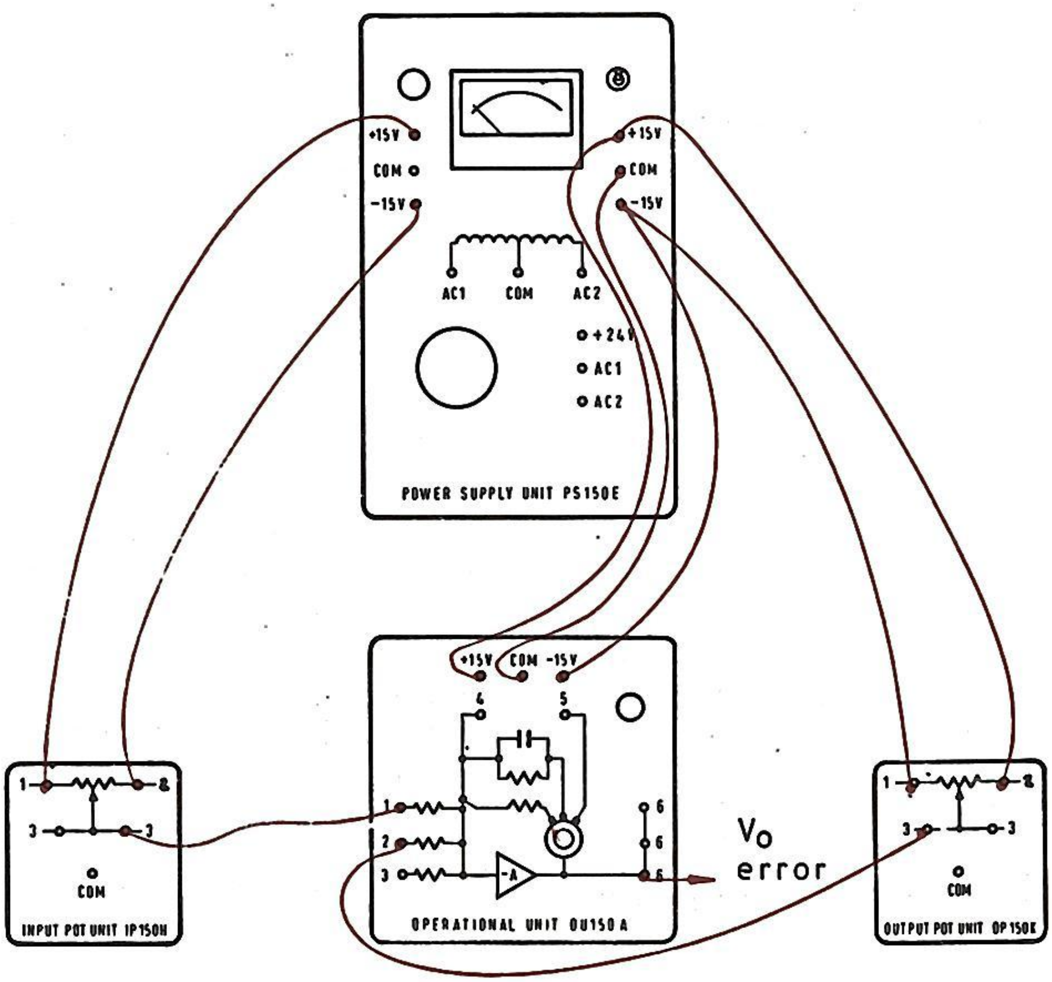


Figure-3.2: Error Channel Set Up

Set up the units as in figure-3.2 but do not yet connect the two amplifier input leads.

1.6 Experimental Set Up

Set the feedback selector switch to 100KΩ resistor. Connect the voltmeter to the output of the Operational amplifier, adjust the zero set so that the output of the amplifier becomes as near to zero as possible.

Before connecting the two sliders into the operational amplifier inputs make certain that

- The resistance between slider (3) and the input terminal (1) is same on both input and output potentiometers for all angular positions. If not, then loosen the dial and make an adjustment.

- As in figure-3.2, connect the rotary potentiometer with opposite polarities. This is very important otherwise the signals when summed will not cancel.

S.No	Input potentiometer		Output potentiometer		$V_1 - V_2$	V_o
	θ_i	V_1	θ_o	V_2		

Table-3.1: Error Channel Analysis

Now set the angular position of input and output potentiometers to zero and tabulate the readings, as in table-3.1. Rotate the two cursors to 30˚ and note the reading again. Repeat the same procedure for some arbitrary angular positions and tabulate the readings.

An important constant in an error channel is the 'error factor' K_e which gives the volts/degrees of misalignment. In a position control system the misalignment would be between input and output shafts, represented in this experiment by the positions of the cursors.

Conclusion/ Comments:

Laboratory Tutorial#4

4.1. Objective: To show how an automatic position control system works.

4.2. Equipment Required: Following equipment is required to perform above task.

Quantity	Apparatus	
1	OU150A	Operation Amplifier Unit
1	AU150B	Attenuator Unit
1	PA150C	Pre-amplifier Unit
1	SA150D	Servo Amplifier
1	PS150E	Power Supply
1	MT150F	Motor-Tacho Unit
1	IP150H	Input potentiometer Unit
1	OP150K	Output Potentiometer Unit
1	Multimeter	

4.3. Approximate Time Required: Two Hours

4.4. Prerequisites: Laboratory Tutorialt#1 and Laboratory Tutorial#3.

4.5. Discussion

In laboratory tutorial#3 we saw how rotary potentiometers could generate an error signal to show the misalignment of the output cursor with that of the input cursor. Now if the output potentiometer is mounted on the shaft of the geared motor, we would have the basis of an automatic position control system. That is, we use the error signal to drive the motor in a direction such as to reduce the misalignment to zero, as shown in figure-4.2. In previous laboratory tutorial we found that the error signal could vary from positive to negative. On examining the field windings we found that one transistor would energise one winding for drive in one direction and other would cause reverse rotation. Now the pre-amplifier is able to provide this type of control because if there is a positive voltage on either of its inputs, then one of its outputs becomes positive, whilst if one of its inputs becomes negative, then the other output becomes positive.

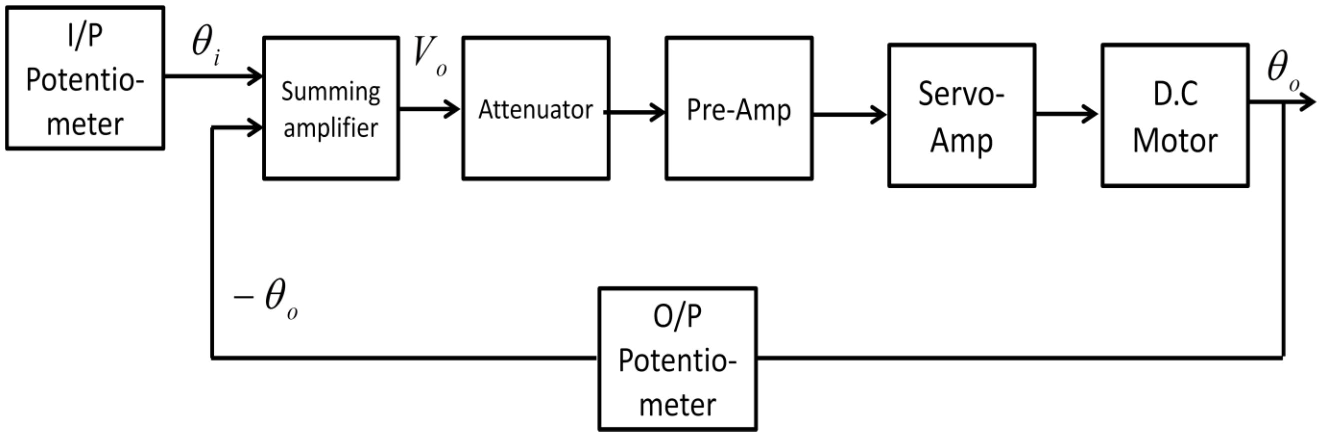


Figure-4.1: Block Diagram of Position Control System

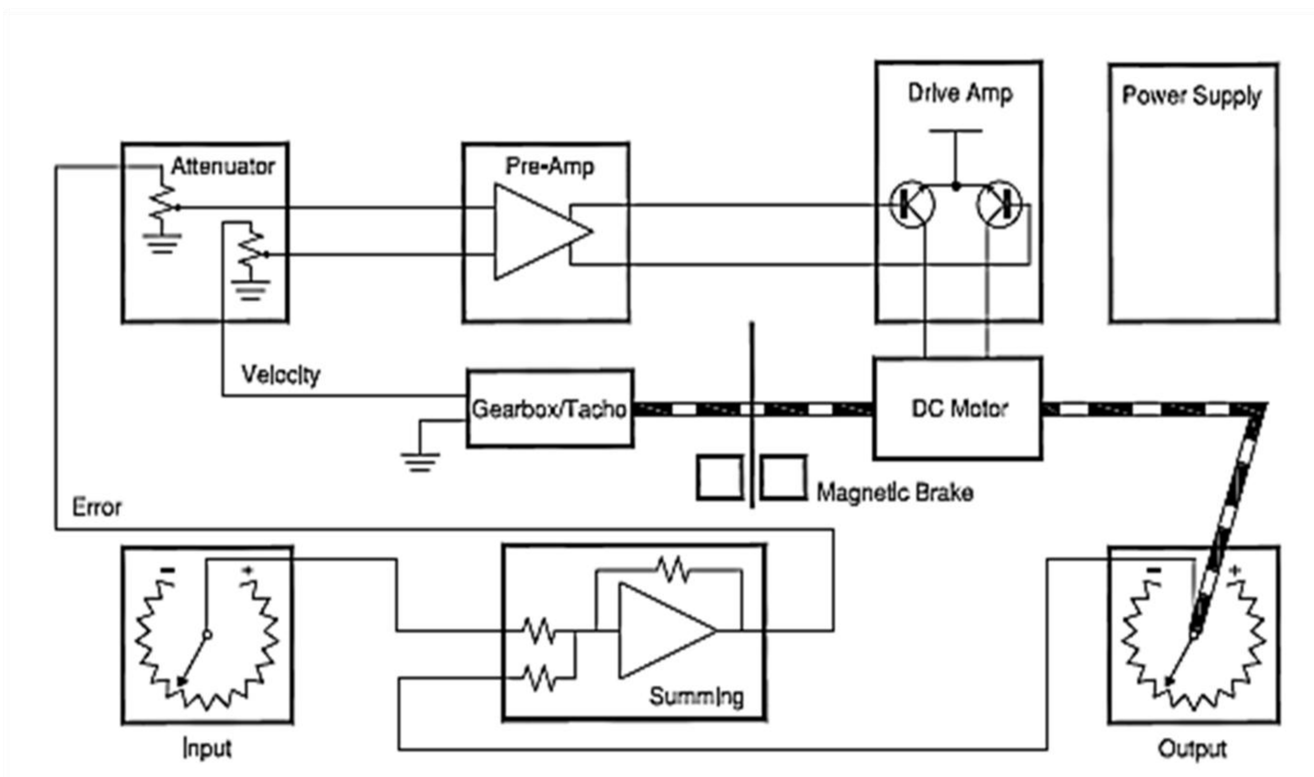


Figure-4.2: Position Control System

4.5. Experimental Set Up

We shall utilize the error signal (output V_o of the operational amplifier) to drive the output potentiometer via the pre-amplifier and the d.c motor, as shown in figure-4.3. The potentiometer on the Attenuator unit can now be used as a gain control and should initially be set to zero before switching on the power. The slider should be connected to the input of the pre-amplifier. With the gain set to zero adjust the pre-amplifier zero so that motor does not rotate.

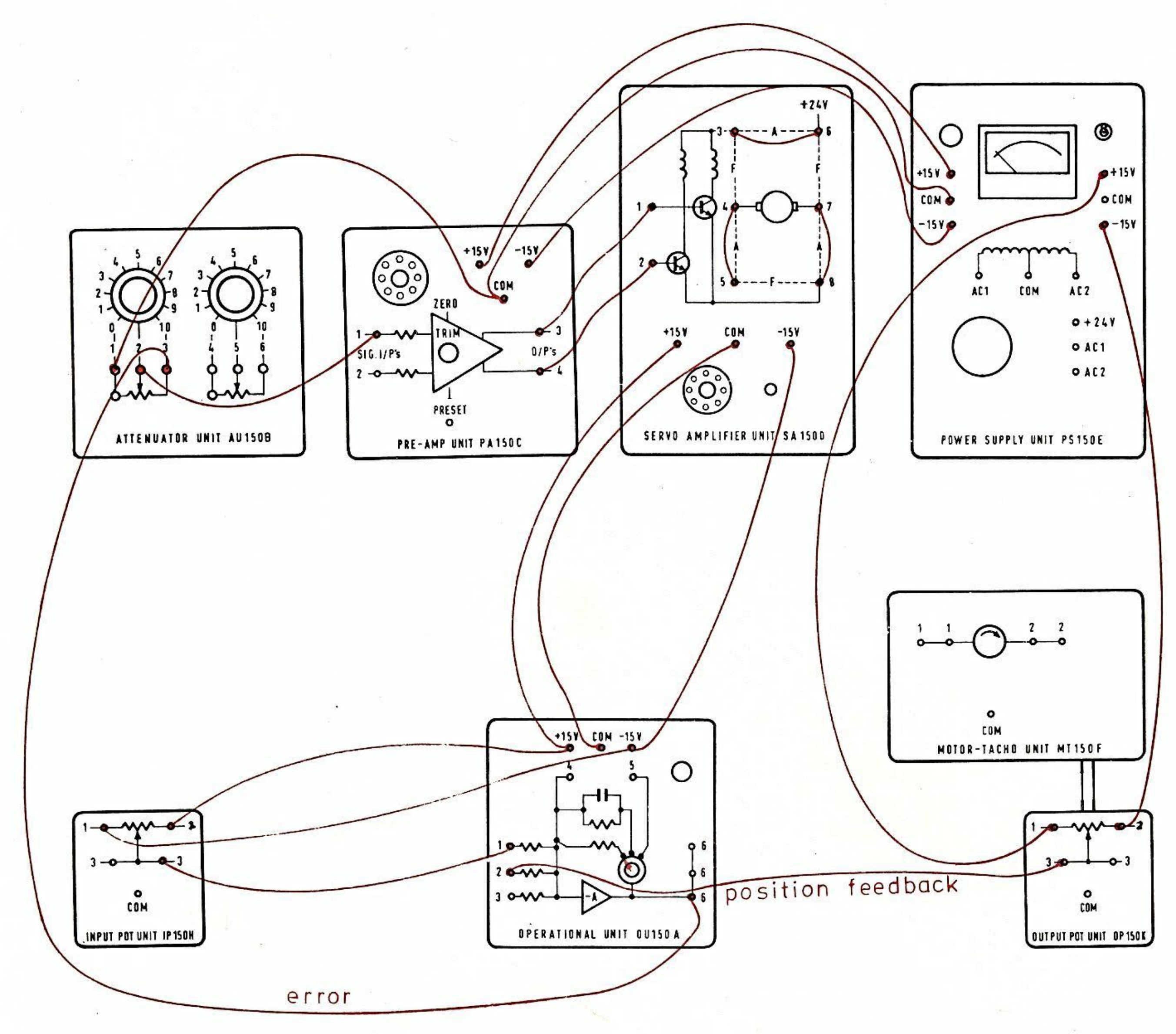


Figure-4.3: Closed loop position control system set up

Now set the input potentiometer to some arbitrary angle and increase the attenuator setting. The output shaft should rotate to an angle nearly equal to that of the input shaft. If the output cursor stops before arriving at the set position (i.e. system has steady state error) adjust the gain using attenuator unit so that the difference between input position and the output position is minimized. This could introduce overshoots in the system's response or can even make the system unstable. Change the input position to several arbitrary angles and tabulate the results in following table.

S.No	Input potentiometer θ_i		Output potentiometer θ_o		***Misalignment*** **(**$\theta_o - \theta_i$**)**

Table-4.1: Position control System

Conclusion/ Comments: