PRACTICAL WORK BOOK
For The Course
EE-372 Linear Control Systems

For

Third Year

(Computer & Information Systems & Telecommunication Engineering)

Name of Student: ______________________________

Class: ____________________ Batch :____________

Discipline: ______________________________

Class Roll No.: __________ Examination Seat No.__________

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EXPERIMENT # 1 (a)

OBJECT : Study of Servo and Servo-Mechanism.

INTRODUCTION :

Servomechanism has consist of two words ***SERVO*** (sounds like servant) means slave and ***MECHANISM*** gives the impression of mechanical gearing and linkages

WHERE ARE SERVO USED ?

In aircraft system these servos used in the radar, the ailerons, the engines, and are designed into some of the complex radio and, radar instruments used for navigation. Marine engineers know about high power servos , using hydraulic , or pneumatic pressures, to control ships stabilizers, steering gear, or floating platforms on oil and gas rigs

For handling radio-active isotopes, remotely placed in a screened chamber we may use servo-controlled mechanical fingers to position these hazardous materials Satellite tracking aerials, radio telescopes , rocket guidance systems use position control servos.

SERVO SYSTEM :

The most common servo system arc:

1.) Velocity control of the motor .
2.) Position control of the motor shaft.
3.) Torque control of the motor
4.) Hybrid control (combination of 1 & 2).

In Industry hydraulic, pneumatic and electro-mechanical servo system are mostly used.

OPEN LOOP CONTROL SYSTEM :

If we want to operate motor on desire speed (say 500 rpm). We can control speed by using different methods. lf operator sees that the speed is 400 rpm this means 100 rpm low he increase speed to adjust desired value . This will make the speed change , the operator will see the change and make the further adjustment if necessary (as in Fig 1.4) This System is an example of open loop control system. When a human operator has observe the error and correct the output accordingly the system is called "Open loop control system".

CLOSED LOOP SYSTEM :

Closed loop system is also a feedback system . The feedback signal comes from output into input of the controller .

FEATURES :

- For measuring the value of the output .
- For comparing that value with the desired value, to produce an error signal
- A controller which alters the output in a way that depends on the error signal. The controller therefore must be able to control enough power to produce the desired output.

EXPERIMENT # 1 (b)

OBJECT : Study of Servo Demonstrator

INTRODUCTION :

Servo Demonstrator is designed for instruction on the basic principles of servo mechanisms. The equipment comprises in two parts

(1) A Circuit board (Electronic unit)ESP 721
(2) A Mechanical unit ESP 722

The two units combine to form a complete servo system, whose characteristics can be modified by various plug-in resistors. In this way oscillatory under damped, critically damped and over damped behaviors can be established and recorded

ELECTRONIC UNIT (ESP 721) :

The circuit board contains all the electronic components and amplifiers necessary to drive servo motor and to derive position , velocity and torque feedback signals .

The ESP 721 requires a supplies of 15V at 500 mA, regulated . Five resistors on plug-in mounts are supplied with the ESP 721 For setting its gain and Feedback. The layout of ESP 721 servo mechanism is shown in Fig 2.1.a In the layout , the manual input potentiometer controls the servo pan position and micro switch provides step function inputs.

The amplifier AA is an operational summing amplifier to generate a position error voltage set by the potentiometer and the Feedback position voltage from the potentiometer in the ESP 722 mechanism. But this potentiometer is also shown on upper right of the layout.

The amplifier AC is an op-amp to generate a voltage proportional to motor speed. The comparator compares the desired and measured value.

Plug in resistor fitting in mounted pillars, to combine position, speed and torque signals in adjustable ratio. These signals are fed to amplifier AB. This is the power amplifier to drive the motor from the combined signal Protective diodes are used to avoid damage through incorrect power connections. You can understand by all this information by seeing actual circuit diagram as Fig 2.1.b.

MECHANICAL UNIT (ESP 722) :

The mechanical unit contains tile servo motor and gear box, position feedback potentiometer and recording mechanism. In this unit permanent magnet dc motor is used as servo motor. Feedback potentiometer is attached to the motor has resistance of 1500 ohm.

Paper drive motor is a synchronous of 120V / 240V & 50 / 60 Hz with angle 100m A Cam is attached to the shaft of the servo motor who moves with the movement occur in the shaft and drive the cam follower .Who moves the pen attached in pen
holder on paper . The paper speed is 10 mm/s . Due to the movement of pen according lo the servo motor movement plots the gain or oscillation etc.

HOW TO START ?

The following setting up procedure should be followed before starting any of the experiments.

DO NOT switch on any power until indicated in your workbook .

The servomechanisms ESP722 has a cable ending on fine flying-leads .These should be connected to the pins in the area of the servo - amplifier ESP 721 indicated by the broken line rectangle.

In order from top to bottom (as shown in layout) , The red lead goes on the pin marked R , the yellow lead goes on the pin marked Y , the green lead goes on the pin marked GN.Black to BK, Blue to B.

The Electronic circuit board ESP 721 has a cable ending in flying leads which should be connected as, red to +15V, blue to -15V and green to the common on 0V terminal of the supplies, check that switch at back of servo-mechanism is off and then connect the power cable to suitable A.C supply.

The pen holder is shown in fig 2.1.c Put the suitable pen , ball - point or pencil in it , and adjust the pencil in the holder so that when it rests on the paper „ the cam follower extends horizontally , engage with the cam and clear of the sides of the unit.

PRECAUTIONS :

(1) EXTREME care must be taken when raising or lowering the pen carriage and pen.

(2) CARE should be taken that the color coding of the fine leads is observed while connecting the ESP 722 servomechanism to the ESP 72 I servo amplifier.

(3) PLUG in the resistor carefully so as not to deform the legs of the resistors , otherwise there will be improper connections .

(4) WHEN the paper drive is switched on, it should be ensured that the paper is feeding smoothly

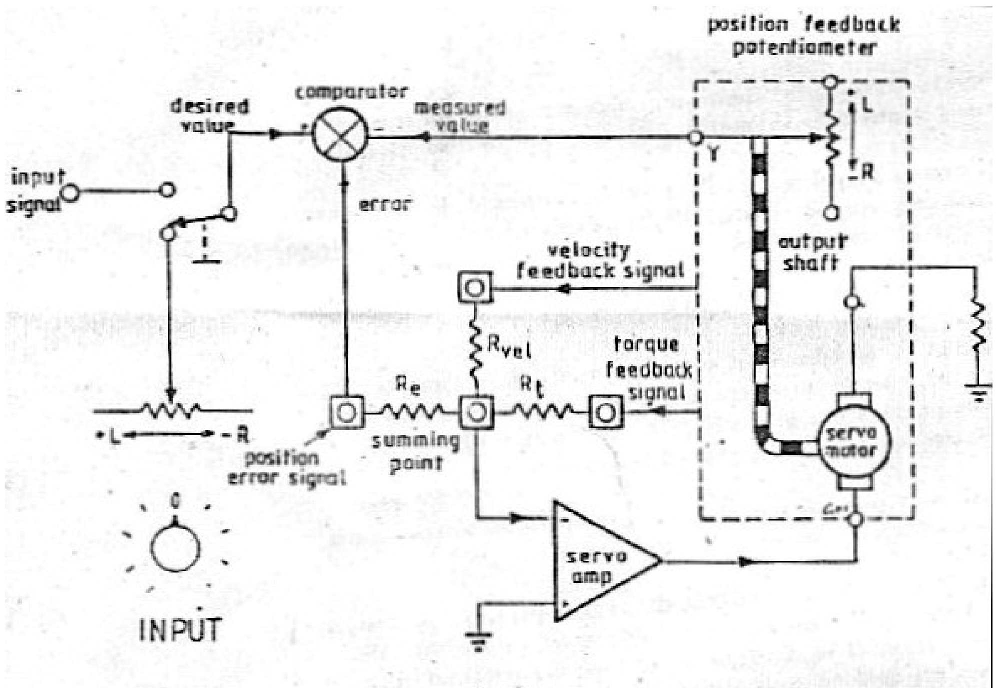
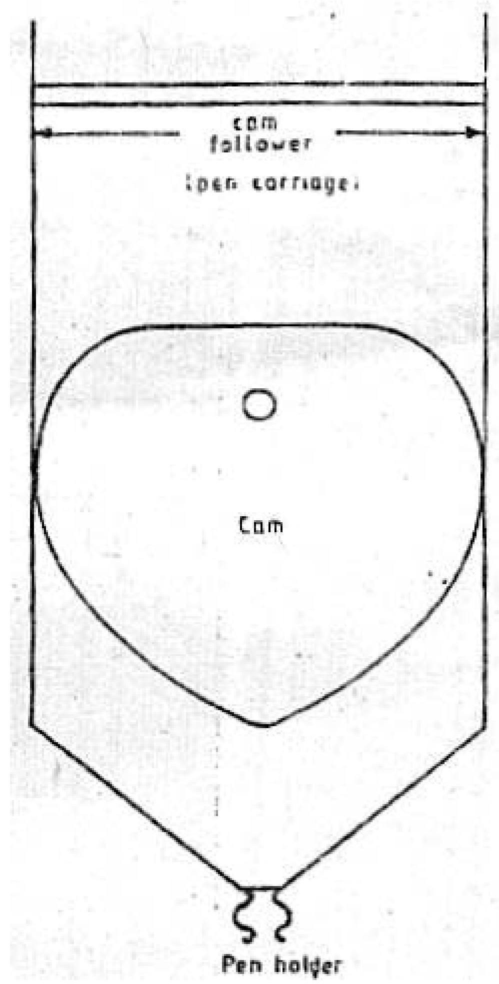
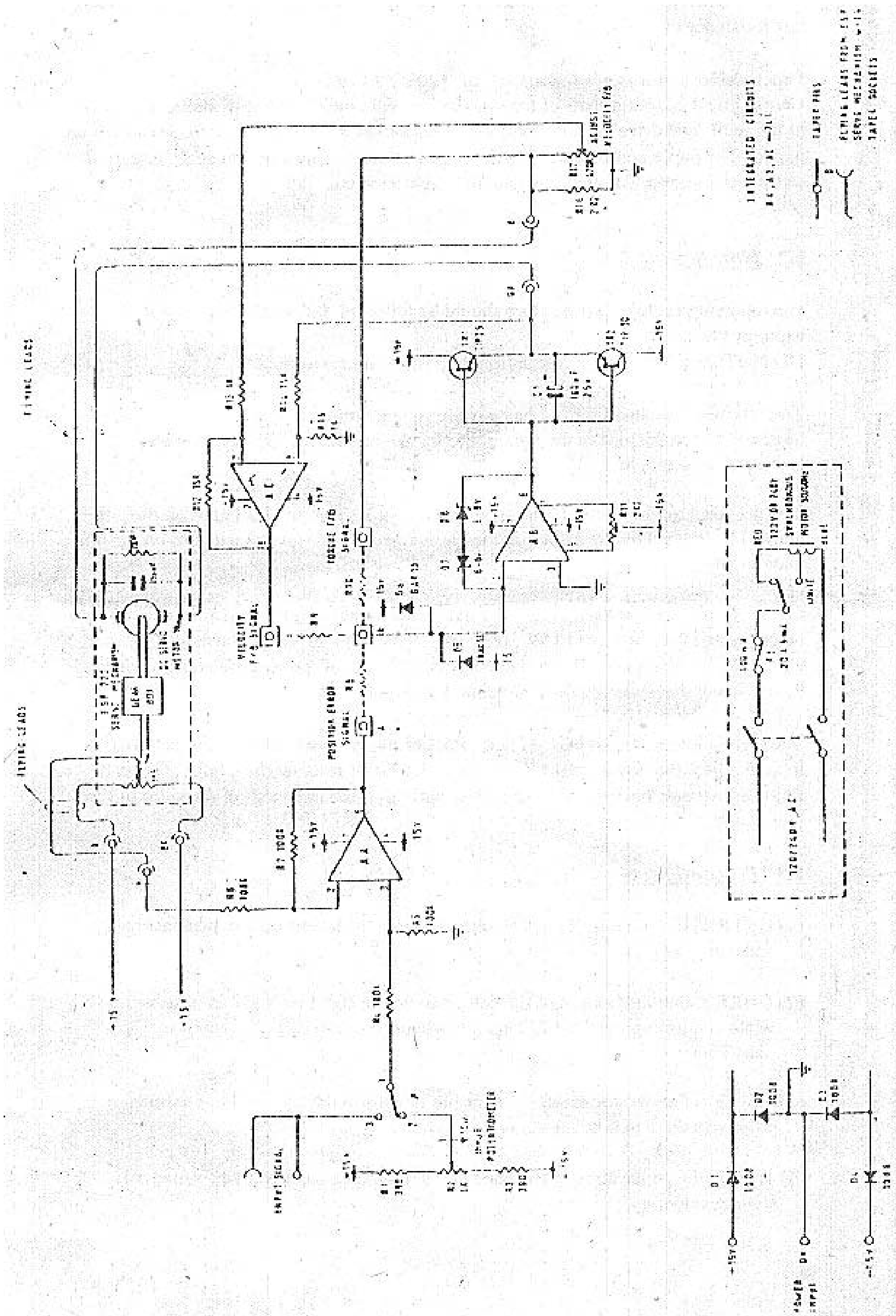

position feedback
potentiometer
desired
value
comparator
measured
value
input
signal
error
Y
L
R
output
shaft
velocity
feedback signal
Rvel
torque
feedback
signal
Re
Rt
+L
-R
summing
point
position
error signal
servo
motor
servo
amp
INPUT

Fig 2.1.a


cam
follower
(pen carriage)
Cam
Pen holder



EXPERIMENT # 2

OBJECT : Speed control of servo machine by OPEN LOOP system.

APPARATUS :

Servo Amplifier (ESP721)
Servo mechanism (ESP722)
Voltmeter (0-10V) DC
Resistance's (10k, 5.6k & 1k)
Pencil or ball-point
Power Supply ±15V

We consider open loop and closed loop systems separately and then we compare the result of these.

(a) OPEN LOOP SPEED CONTROL :

THEORY :

Open-loop speed control of a motor means that there is no automatic connection for unwanted speed variations. For examples when a load is applied to the motor shaft , this can result in a reduction of speed. Unless the load is removed , the speed would have to be manually corrected by adjusting the input setting .

The OPEN-LOOP experiments requires the pen carriage, and pen to be raised , and lowered to show how this applied load affects the motor speed .

PROCEDURE :

(1) Complete experimental SET - UP

(2) Disconnect the YELLOW lead (y) and BLACK lead from the position feedback potentiometer .

(3) Plug-in Re=10 kohm, RT=5.8 kohm, RVEL=10 kohm.

(4) Raise the pen carriage and pen , and lower to the rear of the servomechanism (load removed).

(5) Connect a d.c voltmeter (10 V range) across the velocity Feedback Signal socket. and ground.

(6) Switch on 15V supplies, and turn the INPUT potentiometer, until the motor stops.

(7) Slowly turn the INPUT potentiometer RIGHT, until the voltmeter reading is varying about 2 volts .

(8) Switch off 15 V supplies .

(9) Return the carriage and pen to the normal position (this is the load applied) , and check that the pen projects sufficiently from the holder to allow the carriage clearance of the servo side cheeks when it moves across the paper

(10) Switch on 15V supplies

(11) Make a note of the velocity signal on the voltmeter (load on) .

(12) Switch POWER On for paper drive, and record two complete revolutions of the cam ; switch off paper drive (Rear switch) .

(13) Slowly turn the INPUT (manual correction) potentiometer until the velocity signal is varying about 2 volts again (this was the no load speed) .

(14) Switch POWER ON for paper drive, and record two complete revolutions of the cam, switch off paper drive.

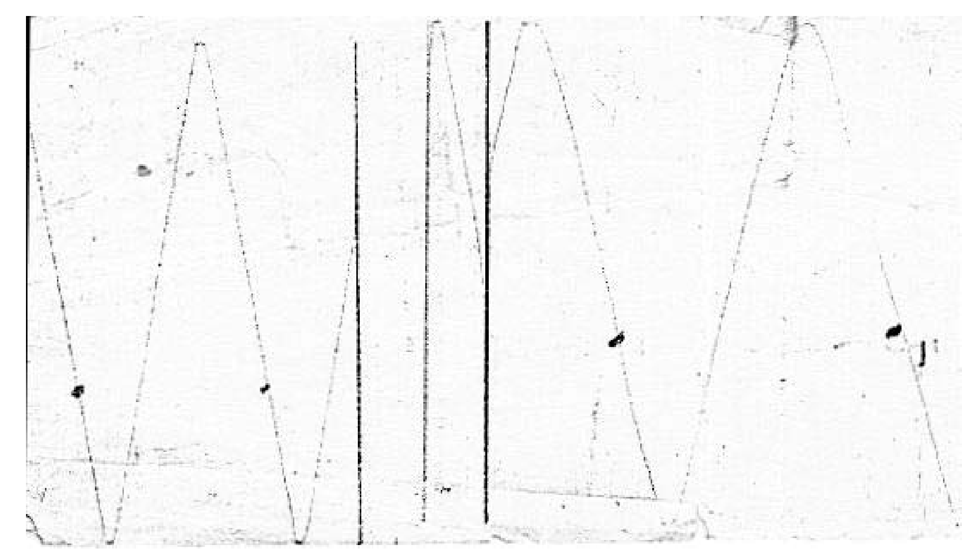
(15) Switch off 15V supplies.

(16) Raise the pen carriage (no load) .

(17) Switch on 15V supplies, and note that the velocity signal exceeds 2. volts, manual correction is again- required .

(18) Switch off 15V supplies, and carefully return the pen carriage to the normal position.

OBSERVATION :



	BEFORE	AFTER
(1) Velocity Feedback Signal		
(2) Distance for 1 revolution		
(3) Speed of Paper		
(4) Time to complete 1 revolution		

(5) Speed of Servo Motor = $\frac{\text{Number of Seconds in a minute}}{\text{Time to complete 1 revolution}}$

= ____________________________ =

(6) Error at NO Load = Measured voltage - Desired Voltage =

=

RESULT :

We have derived that speed regulation of Servo Motor is very poor for OPEN LOOP system.

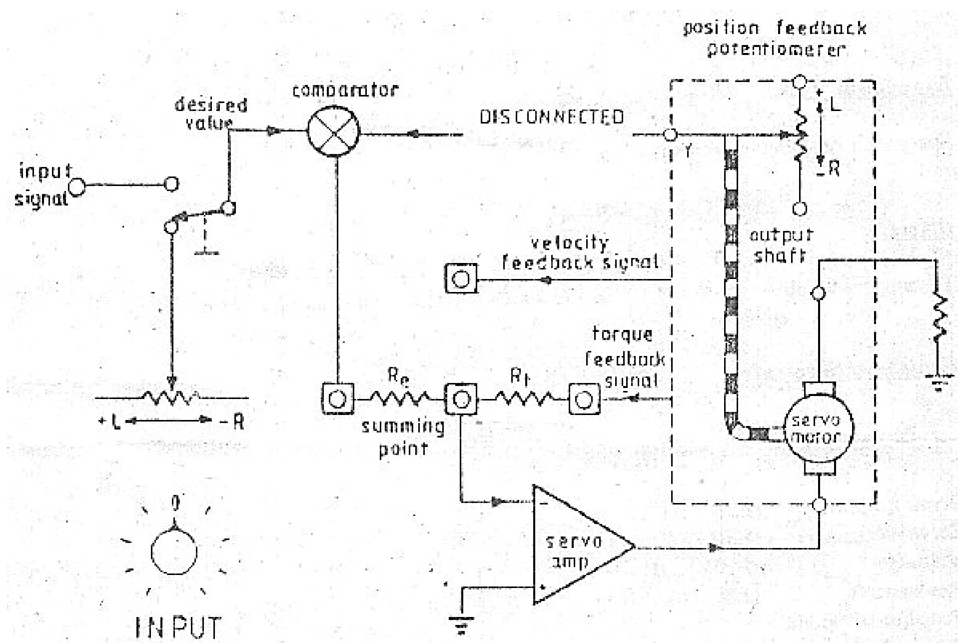

position feedback
potentiomerer
comparator
desired
value
DISCONNECTED
input
signal
+L
-R
Y
output
shaft
velocity
feedback signal
torque
feedback
signal
R_e
R_f
summing
point
servo
motor
servo
amp
+L
-R
0
INPUT

Fig 1.a

EXPERIMENT # 3

OBJECT : Speed control of servo machine by CLOSE LOOP system

APPARATUS:

Power supply 15V
DC Voltmeter (0-10V)
Re=10 kohm , Rt=5.6 kohm, Rvel= 10kohms.
ESP 721
ESP 722

THEORY:

In closed loop speed control system, the output signal is feed back (velocity feed back) and compared with the input speed demand at the summing point the error signal produced causes the servo amplifier to regulate the motor speed load changes on the motor shaft or internal disturbances in the system are automatically compensated fro if within the range of control of the system.

PROCEDURE :

(1) Complete experimental SET - UP

(2) Disconnect the YELLOW lead (y) lead from the position feedback potentiometer .

(3) Plug-in Re=10 kohm, RT=5.6 kohm, RVEL=10 kohm.

(4) Raise the pen carriage and pen , and lower to the rear of the servomechanism (load removed).

(5) Connect a d.c voltmeter (10 V range) across the velocity Feedback Signal socket. and ground.

(6) Switch on 15V supplies, and turn the INPUT potentiometer, until the motor stops.

(7) Slowly turn the INPUT potentiometer RIGHT, until the voltmeter reading is varying about 2 volts .

(8) Switch off 15 V supplies .

(9) Return the carriage and pen to the normal position (this is the load applied) , and check that the pen projects sufficiently from the holder to allow the carriage clearance of the servo side cheeks when it moves across the paper

(10) Switch on 15V supplies

(11) Make a note of the velocity signal on the voltmeter (load on) .

(12) Switch POWER On for paper drive, and record two complete revolutions of the cam ; switch off paper drive (Rear switch) .

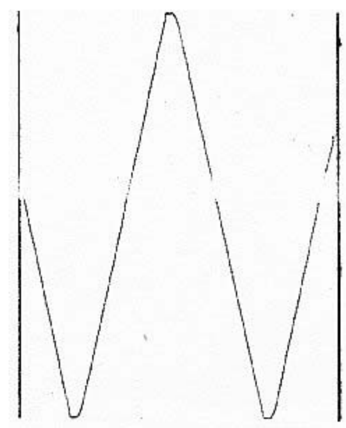
(13) Switch off 15V supplies.

(14) Raise the pen carriage (no load) .

(15) Switch on 15V supplies, and note that the velocity signal does not exceeds 2. volts, manual correction is not required again .

(16) Switch off 15V supplies, and carefully return the pen carriage to the normal position.

OBSERVATION :



	BEFORE	AFTER
(6) Velocity Feedback Signal		
(7) Distance for 1 revolution		
(8) Speed of Paper		
(9) Time to complete 1 revolution		

(10) Speed of Servo Motor $= \dfrac{\text{Number of Seconds in a minute}}{\text{Time to complete 1 revolution}}$

= __________________________ =

(6) Error = Measured voltage at NO Load - Desired Voltage =

=

RESULT :

We have derived that speed regulation of Servo Motor is very good for CLOSE LOOP system.

EXPERIMENT # 4

OBJECT : Position control of Servo motor by OPEN LOOP system.

APPARATUS :

Servo Amp (ESP 721)
Servo Mechanism (ESP 722)
Resistances (10 KΩ, 5.6 KΩ, 1 KΩ)
Pencil or Ball point
Power Supply ±15 V

THEORY :

The rotation of the cam moves the pin LEFT and RIGHT across the paper. The pen can be stopped in a desired position by adjusting the INPUT potentiometer to start and stop the cam.

In the OPEN-LOOP system, the angular position of the INPUT does not indicate the OUTPUT position and unless you look at the pen there is no way of knowing its actual position.

PROCEDURE :

(1) Complete the experimental SET-UP.

(2) Disconnect the YELLOW and BLACK leads from the position feedback potentiometer.

(3) Plug in Re =10 KΩ, Rvel =5.6 KΩ, Rt = 1 KΩ

(4) Switch on 15 V supplies and adjust the INPUT potentiometer until the OUTPUT (pen) stops in the middle of the paper.

(5) Pull the paper forward approximately 10mm, to produce a reference line (position 0). Note the INPUT position.

(6) Adjust the INPUT until the OUTPUT moves 5mm LEFT (position 1) . Note the INPUT position.

(7) Pull the paper forward 10 mm.

(8) Adjust the INPUT until the OUTPUT moves 5 mm LEFT (position 2)

(9) Pull the paper forward 10 mm.

(10) Adjust the INPUT, until the OUTPUT moves 5 mm LEFT (position 1). Note the INPUT position.

(11) Pull the paper 10 mm. Continue the experiment but the pen now moves right.

(12) Adjust the INPUT until the OUTPUT moves 5 mm RIGHT (position 2). Note the INPUT position.

(13) Pull the paper 10 mm.

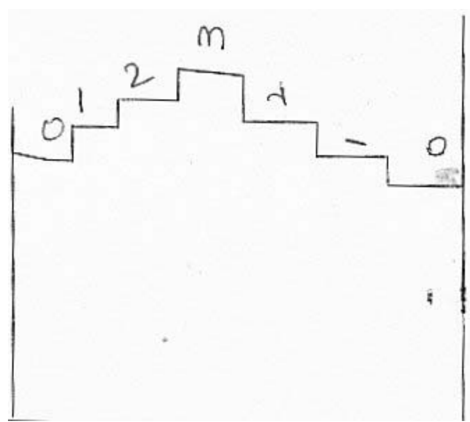
(14) Adjust the INPUT until the OUTPUT moves 5 mm RIGHT (position 1).

(15) Pull the paper forward 10 mm.

(16) Adjust the INPUT until the OUTPUT moves 5 mm RIGHT (position 1). Note the INPUT position.

(17) Pull the paper forward and tear off the record.

OBSERVATION :



RESULT :

The INPUT position is not directly related to the OUTPUT position in OPEN-LOOP system.

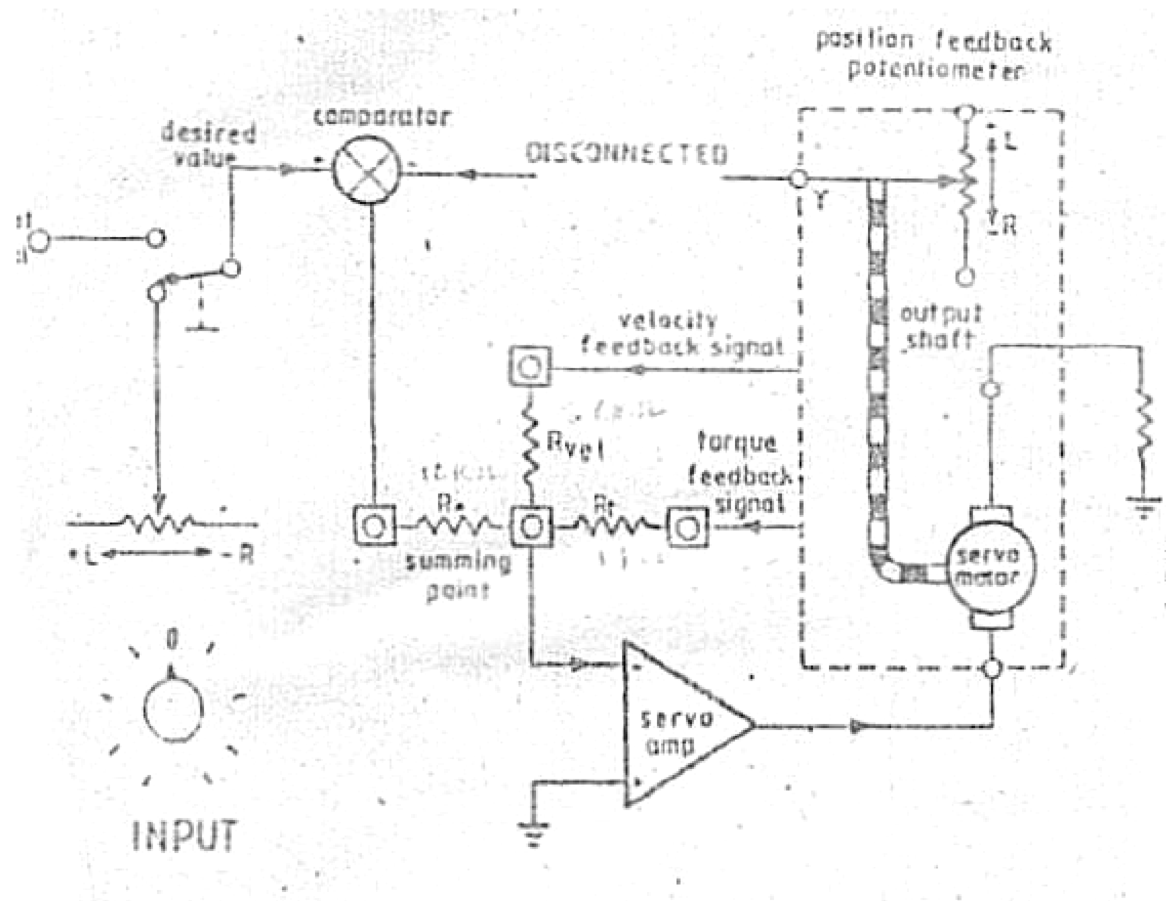

position feedback
potentiometer
comparator
desired
value
DISCONNECTED
Y
L
R
output
shaft
velocity
feedback signal
R_{vel}
torque
feedback
signal
R_e
R_t
summing
point
servo
motor
servo
amp
+L
-R
0
INPUT

Fig.2.a

EXPERIMENT # 5

OBJECT : Position control of Servo motor by CLOSE LOOP system.

APPARATUS :

Servo Amp (ESP 721)
Servo Mechanism (ESP 722)
Resistances (10 KΩ, 5.6 KΩ, 1 KΩ)
Pencil or Ball point
Power Supply ±15 V

THEORY :

The INPUT position is represented by the D.C voltage on the slides of the INPUT potentiometer. Similarly the OUTPUT position is the D.C voltage on the slider of the position feedback potentiometer (connected to the motor shaft).

The loop is closed by feeding the OUTPUT (position) voltage back and comparing it to the INPUT (position) voltage. The difference (error or deviation) is then applied as a correcting signal to the servo amplifier, which causes the motor to drive the slider of the Position Feedback Potentiometer to a position where OUTPUT equals INPUT.

PROCEDURE :

(2) Complete the experimental SET-UP.

(3) Connect the YELLOW and BLACK leads to the position feedback potentiometer.

(4) Plug in Re =10 KΩ, Rvel =5.6 KΩ, Rt = 1 KΩ

(4) Switch on 15 V supplies and adjust the INPUT potentiometer until the OUTPUT (pen) stops in the middle of the paper.

(5) Pull the paper forward approximately 10mm, to produce a reference line (position 0). Note the INPUT position.

(6) Set the INPUT to position 1 LEFT

(7) Pull the paper forward 10 mm.

(8) Set the INPUT to position 2 LEFT

(9) Pull the paper forward 10 mm.

(10) Set the INPUT to position 3 LEFT

(11) Pull the paper 10 mm. Continue the experiment but the pen now moves right.

(12) Set the INPUT to position 2 RIGHT.

(13) Pull the paper 10 mm.

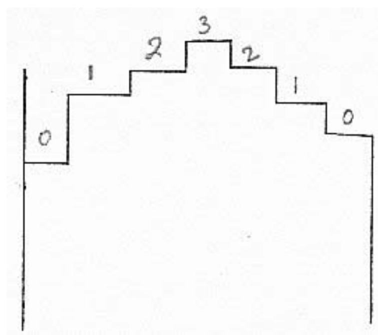
(14) Set the INPUT to position 1 RIGHT.

(15) Pull the paper forward 10 mm.

(16) Set the INPUT to position 0.

(17) Pull the paper forward and tear off the record.

OBSERVATION :



RESULT :

In CLOSE-LOOP system, the setting of the INPUT position gives an indication of the OUTPUT position.

COMPARISION :

Due to position feedback from sliding potentiometer in closed loop system angular position of input potentiometer shows the output position of the motor shaft. While in open loop system angular position of Input potentiometer does not indicate the output position of the motor shaft.

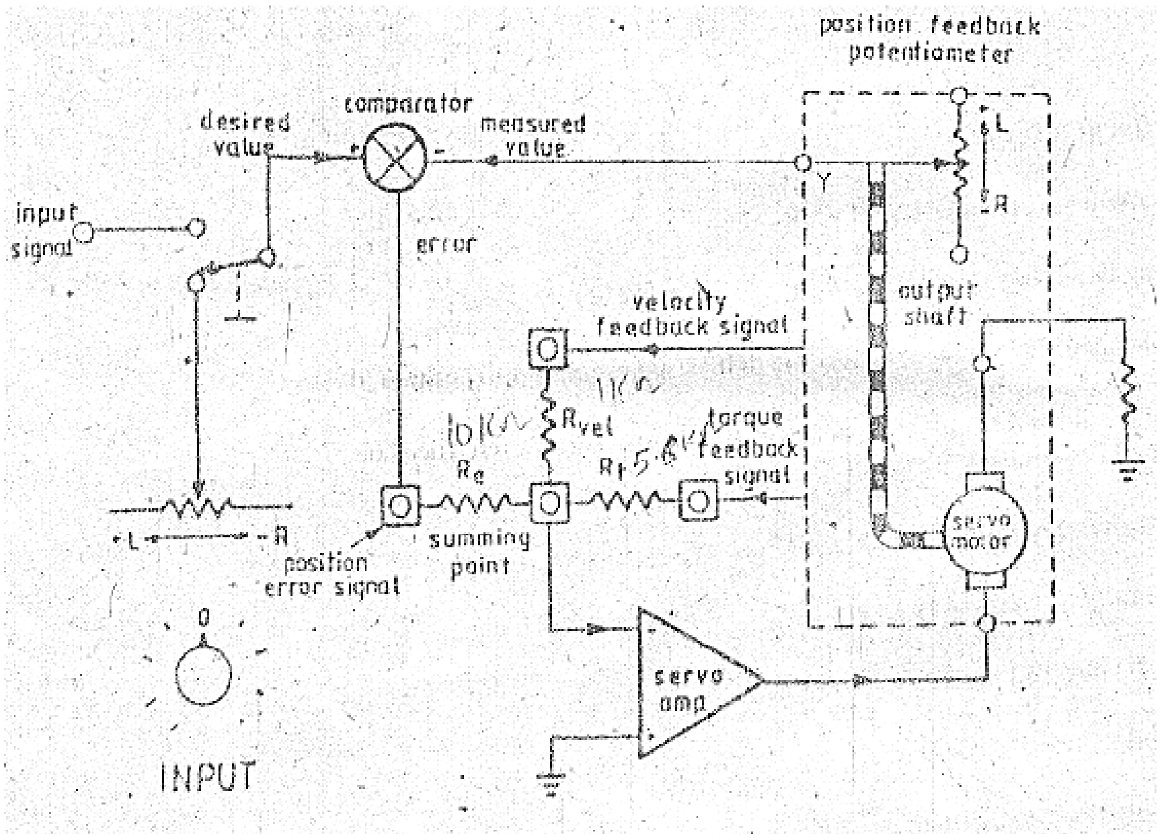

position feedback
potentiometer
comparator
desired
value
measured
value
input
signal
error
Y
L
R
output
shaft
velocity
feedback signal
R$_{vel}$
torque
feedback
signal
R$_e$
R$_t$
summing
point
position
error signal
+L
R
servo
motor
servo
amp
0
INPUT

Fig 2.6

Experiment # 6

Object:

To study the Close loop Automatic Control of level and the effect caused by the variation in the conditions.

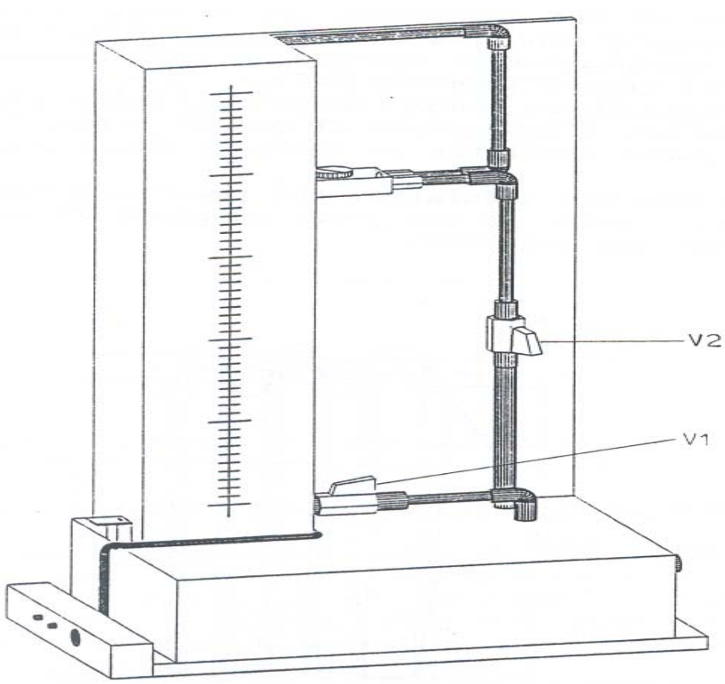
Equipment:

1. Measurement Unit mod. IU9/EV.
2. Power Supply module PS1-PSU/EV.
3. Module holder.
4. Level, Pressure and Flow rate transducer kit G30A.
5. Level and Flow Control kit G30B.
6. Attachment unit TY30A/EV.
7. DIN cable.
8. Connecting wires.

Theory:

MEASUREMENT OF LEVEL AND PRESSURE

With pressure and level measurements, the pressure sensor set at the bottom of the vertical column of unit TY30A/EV is used see the figure bellow:



Definition of an Analog Variable:

An analog measurement ring permits the generation of a D.C. voltage which behavior follows the water level in the column; this means that each value of the column corresponds to only one value of the output voltage. So there is analogy between the level and the variable representing it (output voltage of the measurement system). We can say that a variable or information is analog when it varies in continuous, or when, it can not be discontinuous by its own nature. This means that an analog variable (in our case, the water level of the column) can take infinite values.

The Pressure Sensor:

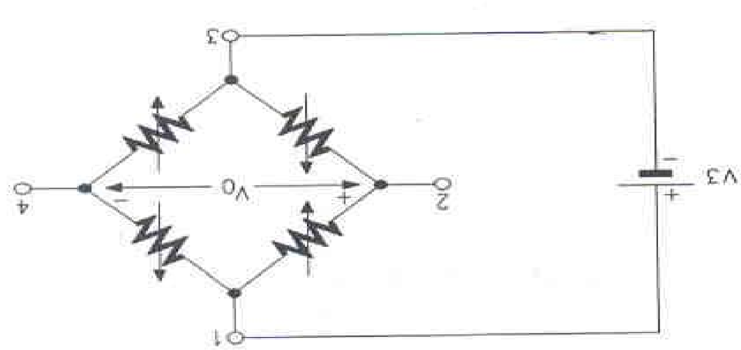
Under static condition, the level of a liquid is linked to pressure, according to a law of proportionality. If "1" represents the level, which is the height, of a liquid in a tank, the pressure at the bottom will be given by:

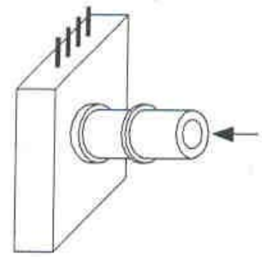
$$p = 1.g.Ms$$

where:

p = pressure (in Pa = Pascal = $N.m^2 = 10^{-5}$ bar)
L = level (in m)
g = acceleration of gravity ($g = 9.81\ m.s^{-2}$)
Ms = specific mass of the liquid ($kg.m^{-3}$).

Consequently, it is sufficient to measure the a pressure to obtain the level. Among the different available pressure transducers, the STRAIN GAUGE ones have become the mostly used.
The operating principle of these transducers is the piezoresistivity (property of the materials which change their resistance as function of the deformation to which they are subjected). The four resistors connected at Wheatstone's bridge are taken from a silicon diaphragm (fig. bellow).





The diaphragm is then welded on a glass ring which supports it. The bridge is powered on a diagonal by a constant voltage generator and a voltage variable with pressure which acts on the diaphragm is taken from the opposite diagonal.
In this system, the sensor uses the pressure of the water on the column to generate an elementary deformation on the in-built strain gauges. The strain gauges are resistors, whose resistive value depends on the deformations they are subjected. In the sensor used, the resistors are connected with a Wheatstone's bridge, so the output voltage Vo varies proportionally with pressure. The sensor used in our system has an operation range ("pressure range") which varies from 0 to 0.07 bar. The dynamic of the output voltage of the last circuit is of 42 mV (which represents the Full Scale Output), when there is a power voltage of 10V. This device is available as differential sensor or, in this case, as absolute pressure sensor. In module G30A, the connection between level sensor and its signal conditioner is carried out via a cable to be inserted on the 8-pin DIN sockets marked as "TRANSDUCERS".

GENERAL NOTIONS:

Before dealing with the control of level and flow, we will briefly survey the main concepts of automatic control which are necessary to understand the same process. This is not a treatment on the Theory of Automatic Controls, we just take the concepts of this theory which are necessary to explain the process controls.
A "PHYSICAL PROCESS" or simply a "PROCESS" is a complex set of physical transformations and/or matter and/or energy transmissions. Examples of industrial processes can be: petrol refinery, metal lamination, vapour production, etc. These complex processes consist of more elementary processes.
The Theory of Automatic Controls, in fact, demonstrates that the knowledge of the single parts of the system gives the knowledge of the whole system. A "CONTROL" is the set of actions to be performed to condition a process until it takes the wished behavior. An "AUTOMATIC CONTROL" is the set of control actions made without the intervention of man. These actions can be made by the devices composing the "CONTROL SYSTEM. In a manual control, the action developed by man varies continuously according to the result coming from the comparison between the information related to the value of the controlled variable and the information related to the value prescribed for this variable. In automatic control, instead, the system alone can control the variables of the control action in order to

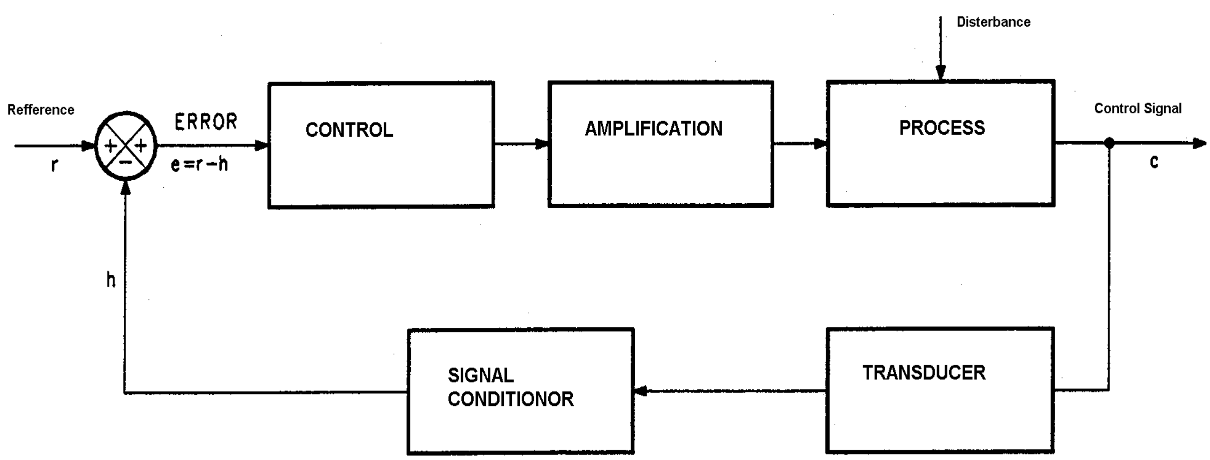
zero the difference between the value taken by the controlled variable and the one prescribed for it.
An "INPUT" or "SET-POINT" is the stimulus (or excitation) applied to the control system. It represents the ideal behavior of the output of the process. The "OUTPUT" of the process is the variable of the process which is wished to be controlled. A "SYSTEM" is the set composed by the process and by the control system.

Division of the Control Systems

The control systems are classified into two general categories, precisely:

* Open-loop systems.
* Feedback or Closed-loop Systems.

An open-loop system is characterized by the fact that the control action is independent from the output. In closed-loop systems, instead, the control action depends in some way from the output.
It is just the shift between the controlled action and the value of the reference variables which starts an action which last purpose is to zero this shift.
The block diagram of a generic control system with negative feedback is given bellow:



The meaning of the blocks and the signals is the following:

Controller:

It consists by the set of devices required to generate a proper control signal to be applied to the amplifier and then to the process.

Transducer and Signal Conditioner:

These are devices which convert the physical variable of the controlled output, into a variable homogeneous with the Set-Point.

Error Signal:

It is the signal obtained by the difference between the Set-Point and the feedback signal supplied by the Signal Conditioner.

Disturbance:

It is an unwished (input) signal which changes the value of the output.

The main advantages of the closed-loop control systems in respect to the open-loop ones and which justify the use of the closed-loop control can be synthesized in this way:

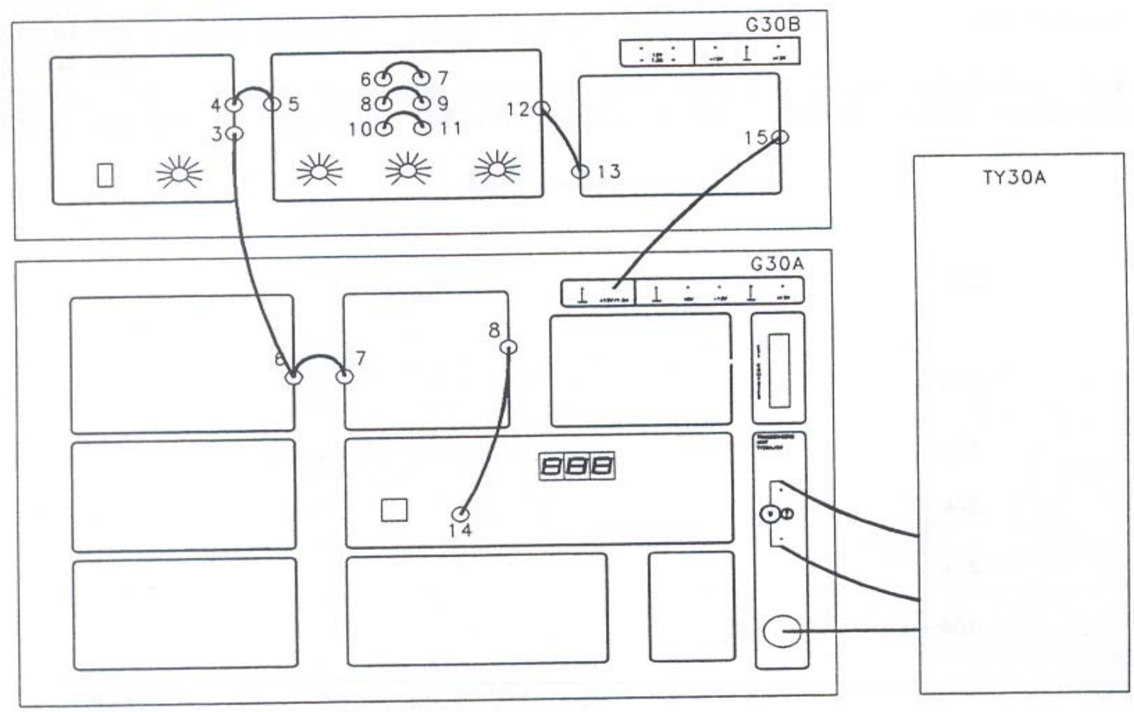
- Less sensitivity to parametric variations.
- Less effects on the disturbing actions.

The importance of these two advantages can be better explained by the fact that parametric variations and disturbances are generally aleatory, i.e. unpredictable if not in their statistic characteristics.

Procedure:

1. Connections between G30A and G30B:
   - Connect jack 15 of G30B to input +12V DC/1.5A of G30A.
   - Connect jack 3 of G30B to jack 6 of G30A.

2. Connection between G30A and TY30A:
   - Connect "+" and "-" present on G30A to corresponding terminals of TY30A.
   - With DIN cable connect G30A to TY30A.
3. **Power supply for module G- 30A:** connect power supplies ± 12 VDC/2A and 5VDC/1.5A
4. **Power supply for module G- 30B:** connect ± 12 VDC/2A & +12VDC/2A.
5. Inside module G30A, connect terminals 6 to 7,8 to 14 this will enable display to show level of liquid.
6. Make connections as per figure given bellow.
7. Put level switch to ON position on G30A.
8. Open valve V1 of Unit TY30A to half position and turn valve V2 ON.
9. Turn switch I1 to position LEVEL.
10. Set PID controller to half way position with the knobs PROPORTIONAL, INTEGRATIVE and DERIVATIVE.
11. From Set-point and Error Block of G30B apply a voltage of 0V at terminal 2 and note the display of G30A.
12. Fill the observation table taking corresponding readings.
13. Also note the effect of changing the flow of fluid by varying valve V1.
14. Draw graph taking Set-point values on x-axis and level in mm on y-axis.



Observation:

S/No	Set-point value (Volts)	Level in mm
1		
2		
3		
4		
5		
6		
7		
8		
9		

Effect of increasing decreasing flow by valve V1:

Result:

The Automatic Close Loop System of Level Control is studied and the effect of variations are observed.

Experiment # 7

Object:

The effect of PROPORTIONAL, INTEGRETIVE and DERIVATIVE Components of PID Controller on Closed Loop Automatic Control of level.

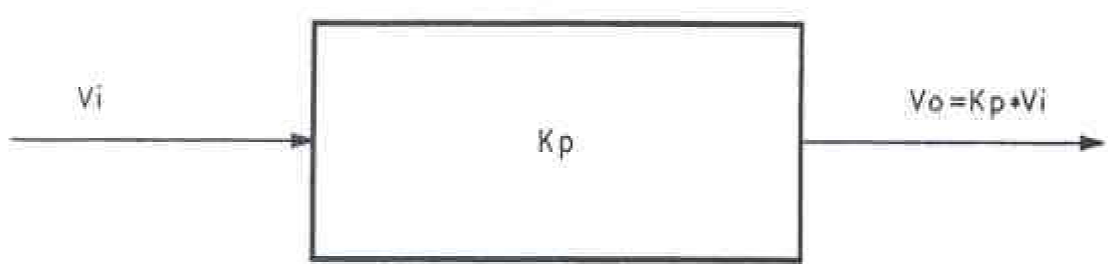
Equipment:

9. Measurement Unit mod. IU9/EV.
10. Power Supply module PS1-PSU/EV.
11. Module holder.
12. Level, Pressure and Flow rate transducer kit G30A.
13. Level and Flow Control kit G30B.
14. Attachment unit TY30A/EV.
15. DIN cable.
16. Connecting wires.

Theory:

Proportional Action (P):

It is the action introduced by the amplifier attenuator. The output, apart from the multiplicative coefficient, is a perfect copy of the input. The figure shows an amplifier attenuator which transfer function is equal to KP.

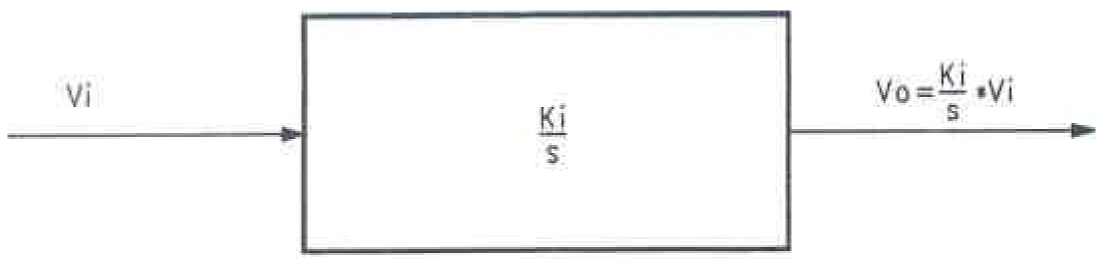


Integrative Action (I):

This action is introduced by a pure integrator. The transfer function of the block bellow which carries out the integrative action is equal to:

$$\mathbf{W(s) = KI/s = 1/(\tau I.s)}$$

where “τI” is called “Time constant of the Integrative Action". The output, related to a step input, has a delay of linear kind. After a time equal to the constant of the Integrative action, the output reaches the value of the input. Once the input value is reached, the output keeps on rising with the same slope, until the input is null.

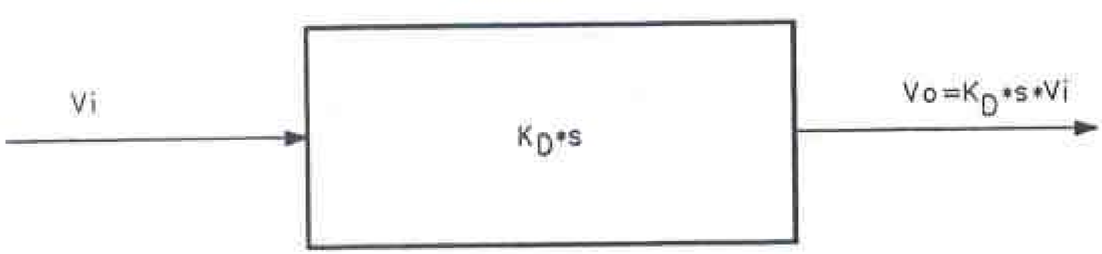


Derivative Action (D):

It is the action introduced by a pure derivator. The output, relative to a linear ramp input, has a value equal to the one the input will take after a time equal to the constant of the derivative action.
The transfer function is equal to:

W(s) = s.KD = s.Td

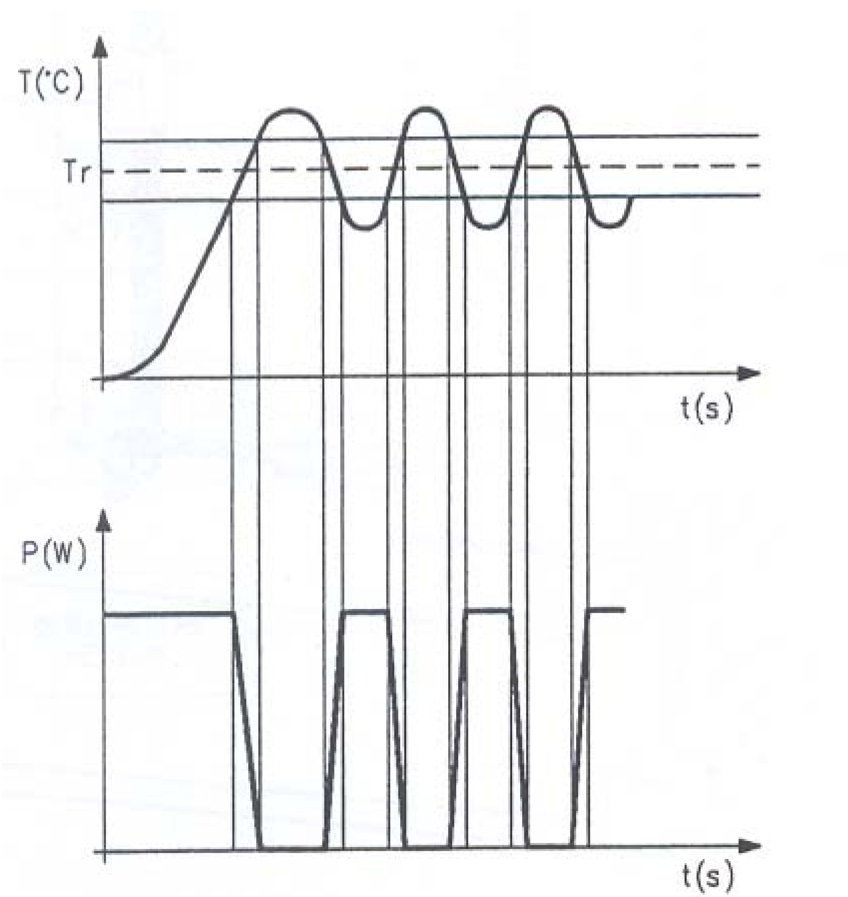
where **τD** is called "Time Constant of the Derivative Action" and which physical meaning is shown in fig. bellow.



The value of the output, equal to the value the input will take after a time τD, is kept until the input changes slope.

Regulation with (P) Controller:

With this kind of regulator the output signal of the controller is proportional to its input signal: the variable which can be varied in this case is the constant of proportionality, i.e. the ratio between
output and input. There is a value of the output signal for each value of the input signal, this value is determined by the constant of proportionality. The above said is true only if the controller is ideal; with a real controller, if the constant of proportionality is too big or if the constant of proportionality is too high, there is saturation and consequently a non linear behavior. It is obvious that the behavior is linear only for a limited band of input values (proportional band).
Refer to fig. to see this fact better.ASASA



The error signal, obtained by the comparison between the reference signal (wished value for the output) and the signal supplied by the signal conditioner of the transducer (value effectively obtained across the output), normally constitutes the input signal of the controller; this signal, on passing across the proportional controller, is amplified by the constant of proportionality (KP).
Outside the proportional band (where the behavior is linear) the controller determines a production of ON/OFF power, i.e the actuator is applied all the power available or nothing, while inside it the power is modulated.

Once the transistors are modulated, the power supplied by the amplifier of the actuator, depends on the power supplied by the load and by the efficiency of the same actuator.
The main characteristic of this controller is to have an error always different from zero; we can affirm that the error is proportional to the gain of the regulator and depends on the coefficient KP and by the value of the proportional band. We can also say that the error different from zero is necessary to obtain an output voltage different from zero. You must also note that, when the KP increases, if the error diminishes, the system gets toward unstable condition. According to the proportional band set there are different behaviors of the controlled variable (in this case level) as function of time.

Fig. shows different behaviours of automatic control of level with:

a) Too large Bp
b) Correct Bp
c) Too narrow Bp

<u>Regulation with (P I) and (P I D) Controller:</u>

In the integrative controller, the output voltage is the integral of the input voltage. The main disadvantage of the controller with proportional action is that it always needs an input voltage different from zero (and consequently an error different from zero in closed-loop control systems) to have an output voltage different from zero. With the integrative action, there can be an output different from zero with null output and then the error with at steady state can be reduced to zero.
Then, the great advantage of the integrative controller is to reach a steady state with null error. Anyway, if the inertia of the system is high or if the time constant of. the integrative action is high, it may happen that the system is taken to unstable conditions (oscillations). To solve these problems, we can put together the proportional and the integrative actions, in order to exploit the advantages of both regulations and reduce the introduced problems.

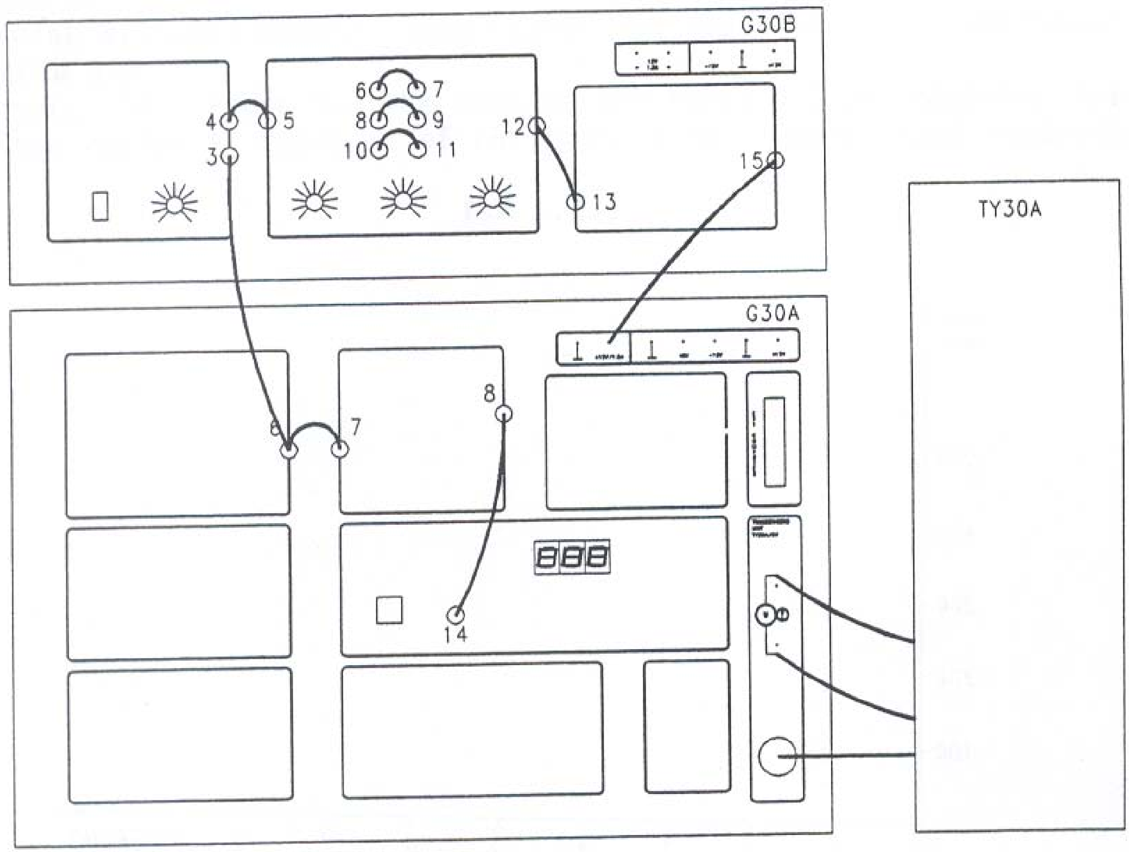
If the oscillations remain, you can add the derivative action, together with the proportional-integrative one: the effectiveness of the derivative

action depends largely on the controlled variable. In the derivative controller the output is the derivate of the input function and so it has a high influence on the signals which rapidly vary. As limit case with constant input voltage, its output is null. While the process evolves, the derivative action decades and the integrative one takes its .place to reduce the regulations error to zero
in respect to the steady state value. We will see, that in case of level and position regulation, the
Influence of the derivative action is very poor due to the fact that the variables under test vary very slowly.

Procedure:

15. Connections between G30A and G30B:
    - Connect jack 15 of G30B to input +12V DC/1.5A of G30A.
    - Connect jack 3 of G30B to jack 6 of G30A.

16. Connection between G30A and TY30A:
    - Connect "+" and "-" present on G30A to corresponding terminals of TY30A.
    - With DIN cable connect G30A to TY30A.
17. **Power supply for module G- 30A:** connect power supplies ± 12 VDC/2A and 5VDC/1.5A
18. **Power supply for module G- 30B:** connect ± 12 VDC/2A & +12VDC/2A.
19. Inside module G30A, connect terminals 6 to 7,8 to 14 this will enable display to show level of liquid.
20. Make connections as per figure given bellow.
21. Put level switch to ON position on G30A.
22. Open valve V1 of Unit TY30A to half position and turn valve V2 ON.
23. Turn switch I1 to position LEVEL.
24. Insert only PROPROTIONAL action of controller by connecting only the P knob and setting it to minimum value.
25. From Set-point and Error Block of G30B apply a voltage of 0V at terminal 2 and note the voltage level at terminal 4 of Set-point Block which is the Error signal.
26. Fill the observation table taking corresponding readings.
27. Measure for all values indicated in the observation column.
28. Now change the value of KP by P knob to maximum and repeat the same.
29. Draw the two graphs on single graph paper taking Set-point values on x-axis and Error output on y-axis and also give your conclusion on the space provided.
30. Now insert Integrative and Derivative control on PID and put them on half way positions and measure the Error signal.
31. Note how the Integrative action tends to zero the Error.
32. Turn I & P knobs to minimum and check the error again.
33. Give your observation stating why system is not stable at high P values.



Observation:

S/No	Set-point value (Volts)	Error at min P (V)	Error at max P (V)	Error when PID(V)
1				
2				
3				
4				
5				
6				
7				
8				
9				

Effect of increasing decreasing P value:

Result:

The effect of different components of PID on Automatic Close Loop System of Level Control are studied and the effect of variations in Proportional Band are observed.

Experiment # 8

Object:

To study the Closed-loop Automatic Control of flow and the effect caused by the variation in the conditions.

Equipment:

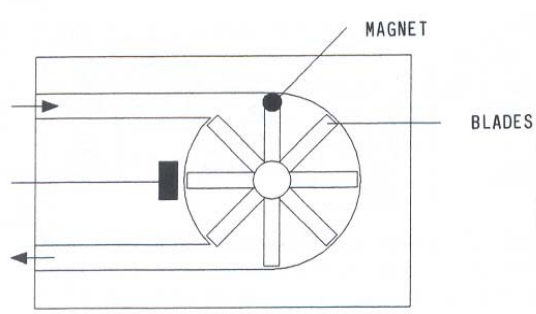
17. Measurement Unit mod. IU9/EV.
18. Power Supply module PS1-PSU/EV.
19. Module holder.
20. Level, Pressure and Flow rate transducer kit G30A.
21. Level and Flow Control kit G30B.
22. Attachment unit TY30A/EV.
23. DIN cable.
24. Connecting wires.

Theory:

FLOW DIGITAL MEASUREMENT:

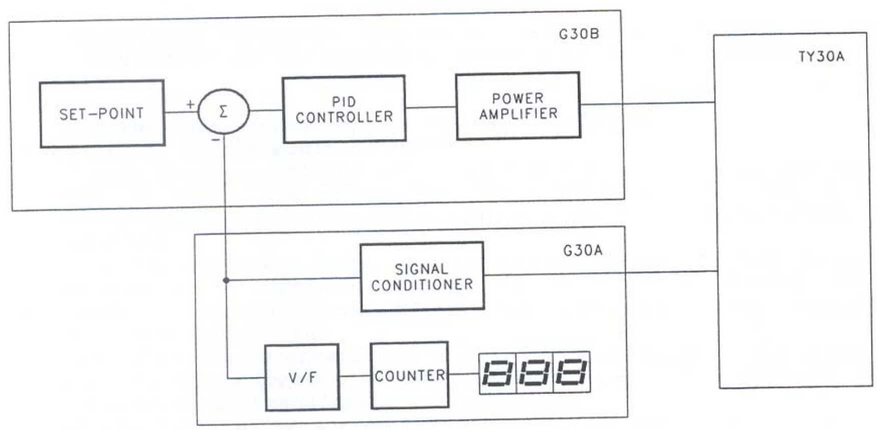
The Flow Transducer:

The proper name of this sensor is "blade or turbine flowmeter"; this chapter demonstrates how this sensor can give meaningful information on the flow. The sensor consists in a turbine on which blades the magnets are mounted (see figure).

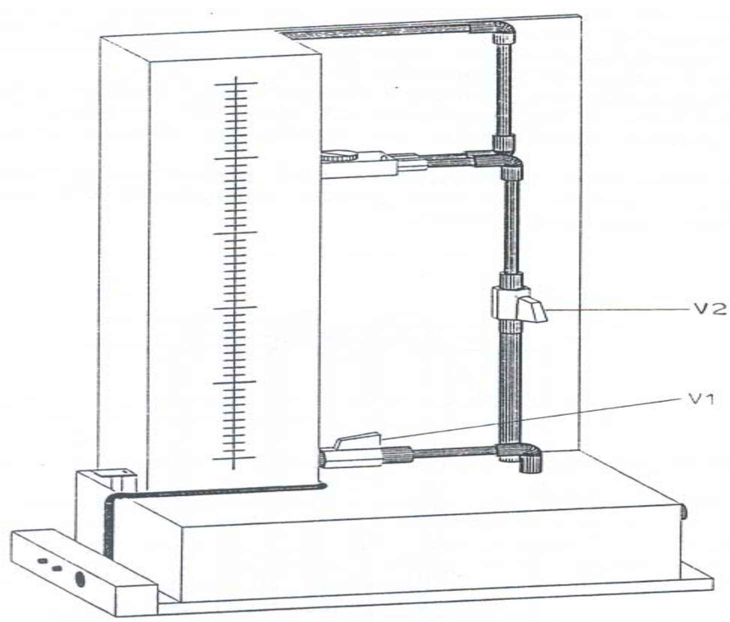


The rotation of these magnets, caused by the water flow, is detected by the magnetic field sensor (Hall Effect probe), which permits to transform the magnetic field variations into electrical variations (voltage variations). Once filtered and squared by the signal conditioner, the voltage variations generate a rectangular pulse corresponding to the passage of the blades in front of the Hall Effect probe.

As the rotation angle of the turbine is proportional to the volume of the liquid flowing across the blades, the sensor produces a number of pulses carried out via the modules G30A and G30B and via the external unit TY30A, appears as shown in the block diagram of fig. bellow.



As concerns the different actions developed by the PID controller you can refer to the same considerations made in the previous experiment.



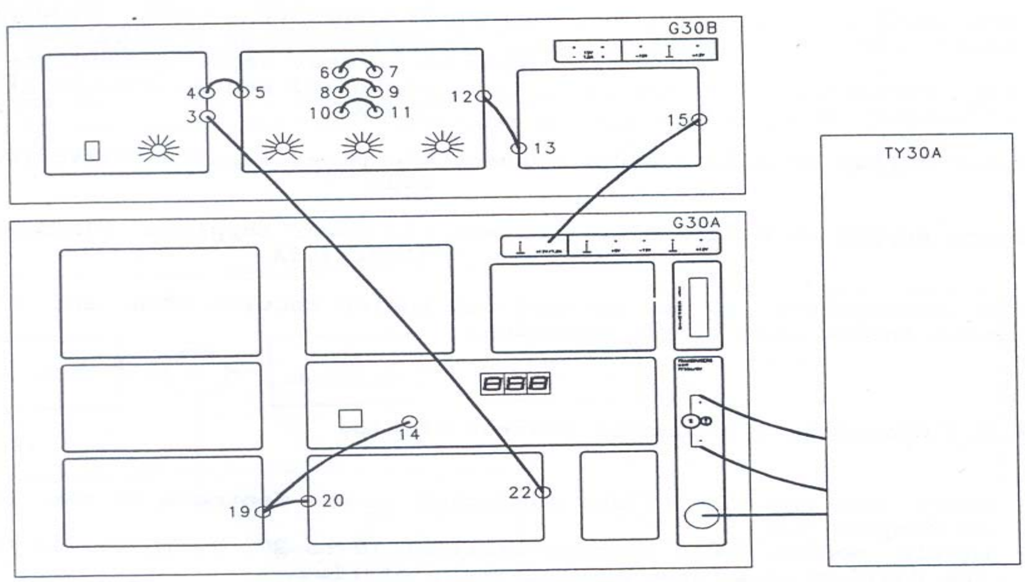
Procedure

34. Connections between G30A and G30B:
    - Connect jack 15 of G30B to input +12V DC/1.5A of G30A.
    - Connect jack 3 of G30B to jack 6 of G30A.

35. Connection between G30A and TY30A:

- Connect "+" and "-" present on G30A to corresponding terminals of TY30A.
- With DIN cable connect G30A to TY30A.

36. **Power supply for module G- 30A:** connect power supplies ± 12 VDC/2A and 5VDC/1.5A
37. **Power supply for module G- 30B:** connect ± 12 VDC/2A & +12VDC/2A.
38. Inside module G30A, connect terminals 19 to 20, 19 to 14 this will enable display to show flow of liquid.
39. Inside module G30B, connect terminals 4 to 5, 6 to 7, 8 to 9, 10 to 11 and 12 to 13.
40. Turn switch I1 to the position FLOWRATE.
41. Make connections as per figure given bellow.
42. Open valve V1 and V2 of Unit TY30A to the position ON.
43. Set PID controller to half way position with the knobs PROPORTIONAL, INTEGRATIVE and DERIVATIVE.
44. From Set-point and Error Block of G30B apply a voltage of 0V at terminal 2 and note the display of G30A.
45. Fill the observation table taking corresponding readings.
46. Slightly close valve V2 so that the operating conditions of the controller are varied. pay attention not to close the valve too much in this way the pump will not reach the set flow rate value.
47. Repeat the measurements and note new reading in column flow rate 2.
48. Draw graph of both on a single graph paper taking Set-point values on x-axis and flow rate in lit/min on y-axis.



Observation:

S/No	Set-point value (Volts)	Flowrate (1)	Flowrate (2)
1	6		
2	5		
3	4		
4	3		
5	2		
6	1		
7	0		

Effect of increasing decreasing flow by valve V1 & V2:

Result:

The Automatic Close Loop System of Flow Control is studied and the effect of variations are observed.

Experiment # 9

Object: The effect of PROPORTIONAL, INTEGRETIVE and DERIVATIVE Components of PID Controller on Closed Loop Automatic Control of Flow.

Equipment:

25. Measurement Unit mod. IU9/EV.
26. Power Supply module PS1-PSU/EV.
27. Module holder.
28. Level, Pressure and Flow rate transducer kit G30A.
29. Level and Flow Control kit G30B.
30. Attachment unit TY30A/EV.
31. DIN cable.
32. Connecting wires.

Theory:

Proportional Action (P):

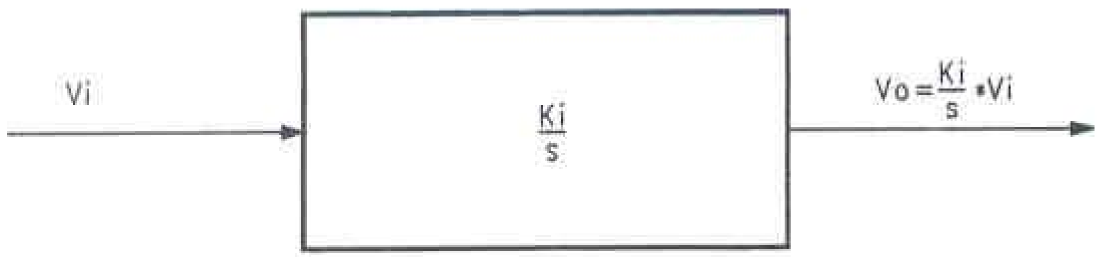
It is the action introduced by the amplifier attenuator. The output, apart from the multiplicative coefficient, is a perfect copy of the input. The figure shows an amplifier attenuator which transfer function is equal to KP.

Integrative Action (I):

This action is introduced by a pure integrator. The transfer function of the block bellow which carries out the integrative action is equal to:

$$W(s) = KI/s = 1/(\tau I.s)$$

where "**τ**I" is called "Time constant of the Integrative Action". The output, related to a step input, has a delay of linear kind. After a time equal to the constant of the Integrative action, the output
reaches the value of the input. Once the input value is reached, the output keeps on rising with the same slope, until the input is null.

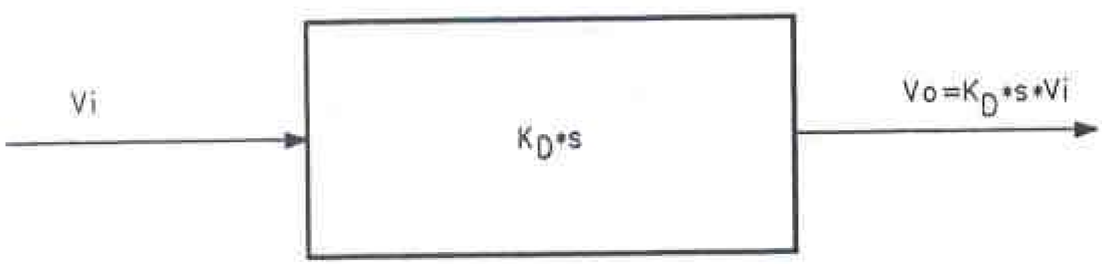


Derivative Action (D):

It is the action introduced by a pure derivator. The output, relative to a linear ramp input, has a value equal to the one the input will take after a time equal to the constant of the derivative action.
The transfer function is equal to:

$$\mathbf{W(s) = s.KD = s.\tau D}$$

where **τD** is called "Time Constant of the Derivative Action" and which physical meaning is shown in fig. bellow.

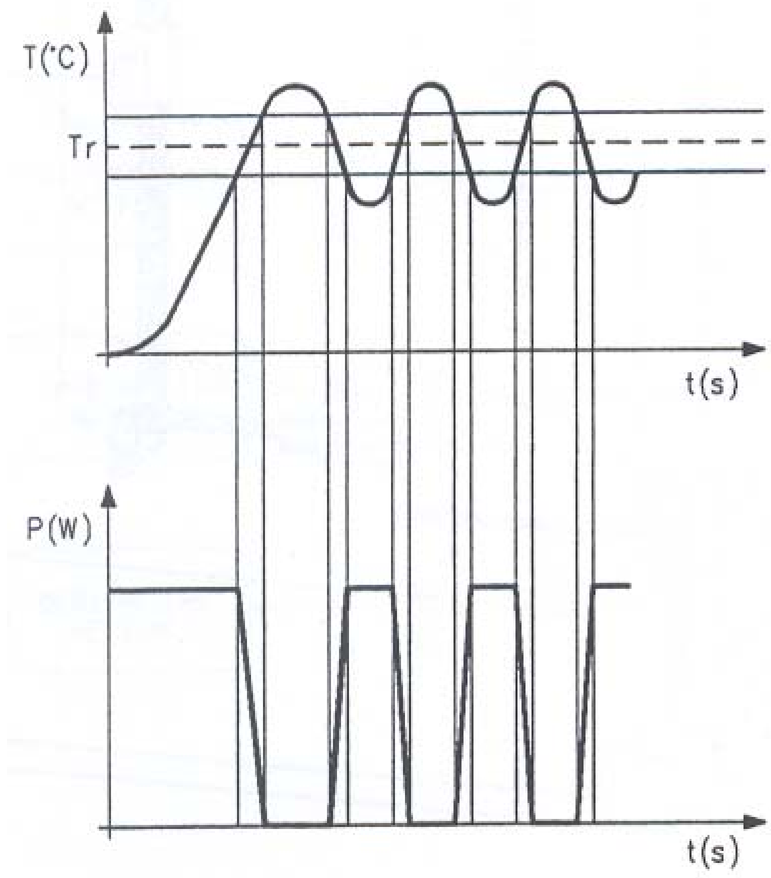


The value of the output, equal to the value the input will take after a time τD, is kept until the input changes slope.

Regulation with (P) Controller:

With this kind of regulator the output signal of the controller is proportional to its input signal: the variable which can be varied in this case is the constant of proportionality, i.e. the ratio between
output and input. There is a value of the output signal for each value of the input signal, this value is determined by the constant of proportionality. The above said is true only if the controller is ideal; with a real controller, if the constant of proportionality is too big or if the constant of proportionality is too high, there is saturation and consequently a non linear behavior. It is obvious that the behavior is linear only for a limited band of input values (proportional band).

Refer to fig. to see this fact better.



The error signal, obtained by the comparison between the reference signal (wished value for the output) and the signal supplied by the signal conditioner of the transducer (value effectively obtained across the output), normally constitutes the input signal of the controller; this signal, on passing across the proportional controller, is amplified by the constant of proportionality (KP).
Outside the proportional band (where the behavior is linear) the controller determines a production of ON/OFF power, i.e the actuator is applied all the power available or nothing, while inside it the power is modulated.
Once the transistors are modulated, the power supplied by the amplifier of the actuator, depends on the power supplied by the load and by the efficiency of the same actuator.
The main characteristic of this controller is to have an error always different from zero; we can affirm that the error is proportional to the gain of the regulator and depends on the coefficient KP and by the value of the proportional band. We can also say that the error different from zero is necessary to obtain an output voltage different from zero. You must also note that, when the KP increases, if the error diminishes, the system gets toward unstable condition. According to the proportional band set there are different behaviors of the controlled variable (in this case level) as function of time.
Fig. shows different behaviours of automatic control of level with:
a) too large Bp
b) correct Bp
c) too narrow Bp

Regulation with (P I) and (P I D) Controller:

In the integrative controller, the output voltage is the integral of the input voltage. The main disadvantage of the controller with proportional action is that it always needs an input voltage different from zero (and consequently an error different from zero in closed-loop control systems) to have an output voltage different from zero. With the integrative action, there can be an output different from zero with null output and then the error with at steady state can be reduced to zero.

Then, the great advantage of the integrative controller is to reach a steady state with null error. Anyway, if the inertia of the system is high or if the time constant of. the integrative action is high, it may happen that the system is taken to unstable conditions (oscillations). To solve these problems, we can put together the proportional and the integrative actions, in order to exploit the advantages of both regulations and reduce the introduced problems. If the oscillations remain, you can add the derivative action, together with the proportional-integrative one: the effectiveness of the derivative action depends largely on the controlled variable. In the derivative controller the output is the derivate of the input function and so it has a high influence on the signals which rapidly vary. As limit case with constant input voltage, its output is null. While the process evolves, the derivative action decades and the integrative one takes its .place to reduce the regulations error to zero

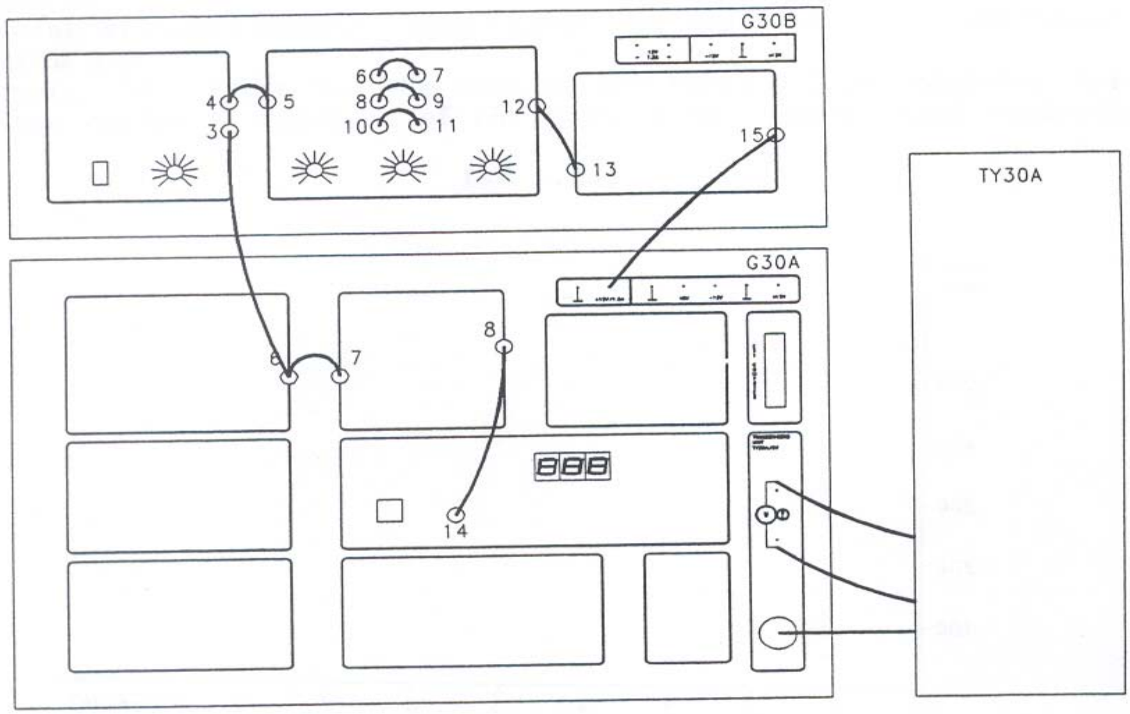
in respect to the steady state value. We will see, that in case of level and position regulation, the

influence of the derivative action is very poor due to the fact that the variables under test vary very slowly.

Procedure:

49. Connections between G30A and G30B:
    - Connect jack 15 of G30B to input +12V DC/1.5A of G30A.
    - Connect jack 3 of G30B to jack 6 of G30A.

50. Connection between G30A and TY30A:
    - Connect "+" and "-" present on G30A to corresponding terminals of TY30A.
    - With DIN cable connect G30A to TY30A.
51. **Power supply for module G- 30A:** connect power supplies ± 12 VDC/2A and 5VDC/1.5A
52. **Power supply for module G- 30B:** connect ± 12 VDC/2A & +12VDC/2A.
53. Inside module G30A, connect terminals 19 to 20, 19 to 14 this will enable display to show flow of liquid.
54. Inside module G30B, connect terminals 4 to 5, 6 to 7, 8 to 9, 10 to 11 and 12 to 13.
55. Turn switch I1 to the position FLOWRATE.
56. Make connections as per figure given bellow.
57. Turn switch I1 to position FLOWRATE.
58. Insert only PROPROTIONAL action of controller by connecting only the P knob and setting it to halfway position.
59. From Set-point and Error Block of G30B apply a voltage of 3.2V at terminal 2 which corresponds to the flow value of 2 lit/min and note the voltage level at terminal 4 of Set-point Block which will be the Error signal.
60. Fill the observation table taking corresponding readings.
61. Observe how the system regulated only with the Proportional component is unstable.
62. Give an explanation of this fact in the space provided in the observation column.
63. Now change the value of KP by P knob to minimum and observe if the system stabilizes and measure the Error voltage at this value and give reason.
64. Now insert Proportional, Integrative and Derivative control on PID and put them on half way positions and measure the Error signal.
65. From Set-point and Error Block of G30B apply a voltage of 3.2V at terminal 2 which corresponds to the flow value of 2 lit/min and note the voltage level at terminal 4 of Set-point Block which will be the Error signal.
66. The variation of this voltage indicates the system is not stable.
67. Now turn Integrative knob to half way position and observe the Error.
68. Note how the Integrative action tends to 0 the Error.
69. Turn the knob I to minimum value and again note the error.
70. Also note that the Derivative action does not have a significant importance by varying the knob of Derivative action.



Observation:

S/No	Set-point value (Volts)	Error at half way P (V)	Error at minimum P (V)	Error at half way I(V)	Error at minimum I(V)
1	3.2				

Effect of increasing decreasing P value:

Result:

The effects of different components of PID on Automatic Close Loop System of Level Control are studied and the effects of variations in Proportional Band are observed.