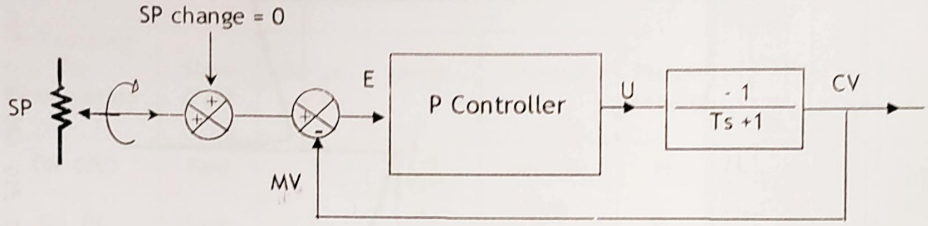
B) CLOSE LOOP CONTROL

B1)Close loop control with set point change

1) Proportional control with manual change in set point

$$Gp(s) = \frac{1}{(Ts+1)}$$

No of		System	
Lags	Integrators	Type	Order
1	0	0	1



Observations on CRO

Wiring seq. +12V-1, GND-2, -12V-3, A1-4, 6-A10, CRO (I/P CHI)-A11, CRO(I/P CHII)-6, CRO(GND)-49

OR

Observations on CIA.

Wiring seq: +12V-1, GND-2, -12V-3, A1-4, 6-A10, A11-A13, A14-CIA CH0, 6-A15, A16-CIA CH1, CIA GND - 49.

Manually change the set point & observe the SP & MV on voltmeter as shown in the table below. Calculate the error (SP-MV) at various PB conditions.

PB=200%			PB=100%			PB=5%		
SP	MV	Error (SP-MV)	SP	MV	Error (SP-MV)	SP	MV	Error (SP-MV)
8	2.8	5.2	8	4.8	3.2	8	8	0
4	1.4	2.6	4	2.4	1.6	4	4	0
0	0	0	0	0	0	0	0	0
-4	-1.4	-2.6	-4	-2.4	-1.6	-4	-4	0
-8	-2.8	-5.2	-8	-4.8	-3.2	-8	-8	0

Theoretically

$$\text{Error} = \frac{SP}{Kc + 1}$$

$$\text{Where } Kc = \frac{100}{\% PB}$$

Calculate the error using above formula & compare with the measured as shown in the table below.

PB=200%			PB=100%			PB=5%		
SP	Error (SP-MV)	Error (calculated)	SP	Error (SP-MV)	Error (calculated)	SP	Error (SP-MV)	Error (calculated)
8	5.2	5.3	8	3.2	4	8	0	0.38
4	2.6	2.66	4	1.6	2	4	0	0.19
0	0	0	0	0	0	0	0	0
-4	-2.6	-2.66	-4	-1.6	-2	-4	0	-0.19
-8	-5.2	-5.3	-8	-3.2	-4	-8	0	-0.38

☞ **Conclusion**

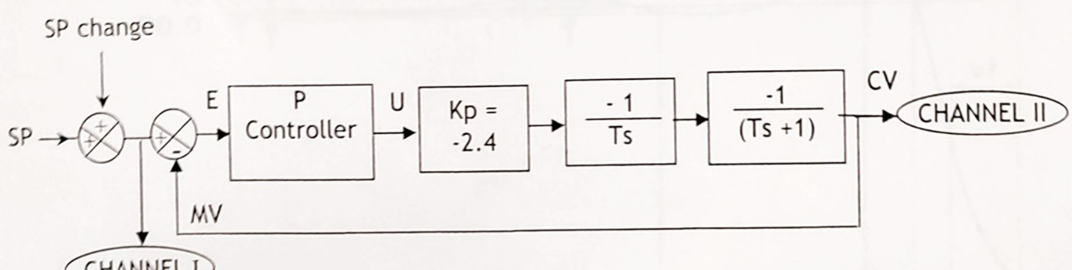
From the table above you can observe that the error between i/p & o/p varies as per the proportional gain varies. For the above process error reduces as proportional band decreases. The error measured & calculated are approximately equal.

B1-2) Proportional control with step change in set point PSB1_2iii) first order lag with integrator

$$Gp(S) = \frac{2.4}{(Ts)(Ts+1)}$$

No of		System	
Lags	Integrators	Type	Order
1	1	1	2

FG setting for observation	Slow /Fast	Range I/II	Amp.	Period	Process settings	Samples/ div on graph	Level shifter
On CRO	Slow	II	7.2 (Vpp)	200mSec	Fast	NA	NA
On PC	Slow	I	40 (%pp)	240 Samples	Slow	30	±9V to 2.5V



Observations on CRO
Wiring seq. +12V-1, GND-2, -12V-3, A1-4, 6-12, 14-38,39-A10, FG(square o/p)-A9, FG (GND)-49, CH0-A11, CHI-39,GND-48

OR

Observations on CIA
Wiring seq. +12V-1,GND-2,-12V-3,A1-4,6-12,14-38,39-A10, FG(square o/p)-A9, A11-A13, A14-CIA CH1, 39-A15, A16-CIA CH0, CIA GND - 48.

process response at various PB settings. Also calculate the transient response specifications.

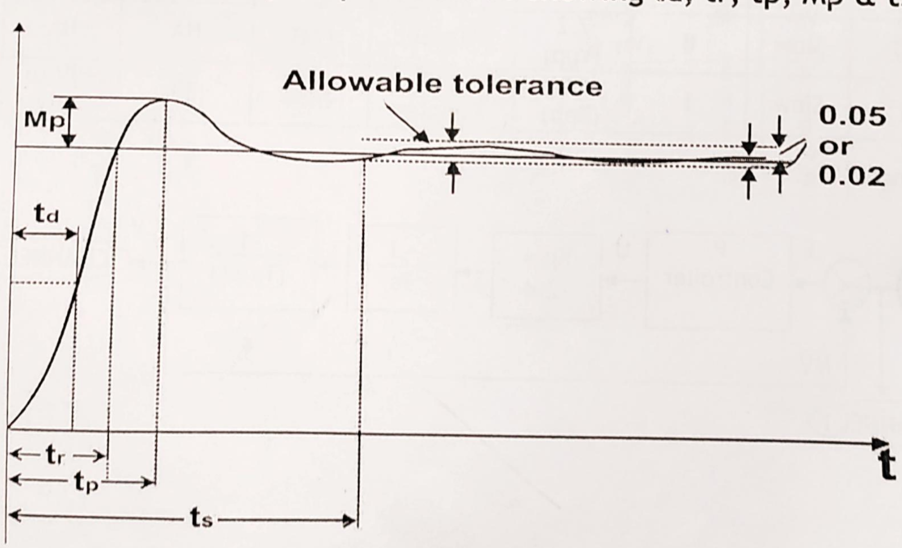
Determination of transient response specifications on PC

1) Delay time, *td*: The delay time is the required for the response to reach half the final value the very first some.
2) Rise time *tr* : The rise time is the time required for the response to rise from 10% to 90%, 5% to 95%, or 0% to 100% of its final value.
3) Peak time *tp* : The peak time is the time required for the response to reach the first peak of the overshoot
4) Maximum (percent) overshoot, *Mp* : The maximum overshoot is the maximum peak value of the response curve measured from unity. If the final steady-state value of the response differs from unity, then it is common to use the maximum percent overshoot. It is defined by

$$\text{Maximum percent overshoot} = \frac{c(t_p) - c(\infty)}{c(\infty)} \text{X } 100\%$$

The amount of the maximum (percent) overshoot directly indicates the relative stability of the system.

Fig.3.21 Unit-Step response curve showing td, tr, tp, Mp & ts



5) Setting time *ts* : The settling time is the time requited for the response curve to reach and stay within a range about the final value of size specified by absolute percentage of the final value (usually 2% or 5%). The settling time is related to the largest time constant of the control system.

1) Set PB = 100% & observe the system response.

Calculate the trasient response specifications from the graph as per the procedure writtn in the previous experiment.

1) Max. Overshoot (Mp)

C(tp) = 0.987 V, C(infinite) = 1.27V

Therefore Mp = (1.27- 0.987 / 0.987) X100 = 28.67

2) Peak Time (Tp) = 17 samples X 0.12 = 2.04 Sec

3) Settling Time (Ts) = 61 samples X 0.12 = 7.32 Sec

4)Delay time (Td) = 6 samples X 0.12 = 0.72 Sec

☞ **Conclusion** :- from the graph it can be observed that 100% PB reduces the error in the o/p to zero & system become stabe with overshoot & undershoot as above trasient response parameters calculated.

Observations & Calculations on CRO for determination of transient response parameters.

1) Do not connect step (squre wave) signal to SP change (A9). Rotate SP pot and ensure that O/P of SP at All = 0V
2) Connect step I/P to SP change (square wave) and SP O/P (A11) to CHI (trigger CHI), MV (response of process to CHII.
3) Put readings in formula given above.
   a) C (tp) = 6V

      $C(\infty) = 3.6V$

      $$\therefore \text{Maximum \% overshoot} = \frac{6-3.6}{3.6} \text{X } 100$$

      $$= \frac{2.4}{3.6} \text{ X } 100$$

      $$= 66.67\%$$

   b) Peak Time (Tp) = 1.2div x 20msec/div = 24ms.
   c) Settling Time (Ts) = 4 x 20msec/div = 80ms.
   d) Delay Time (Td) = 0.8 x 20msec. = 16ms

Fig.3.22 PSB1_2iii(pb100)) Proportional control with step change in set point-First order lag with integrator (PB100%)

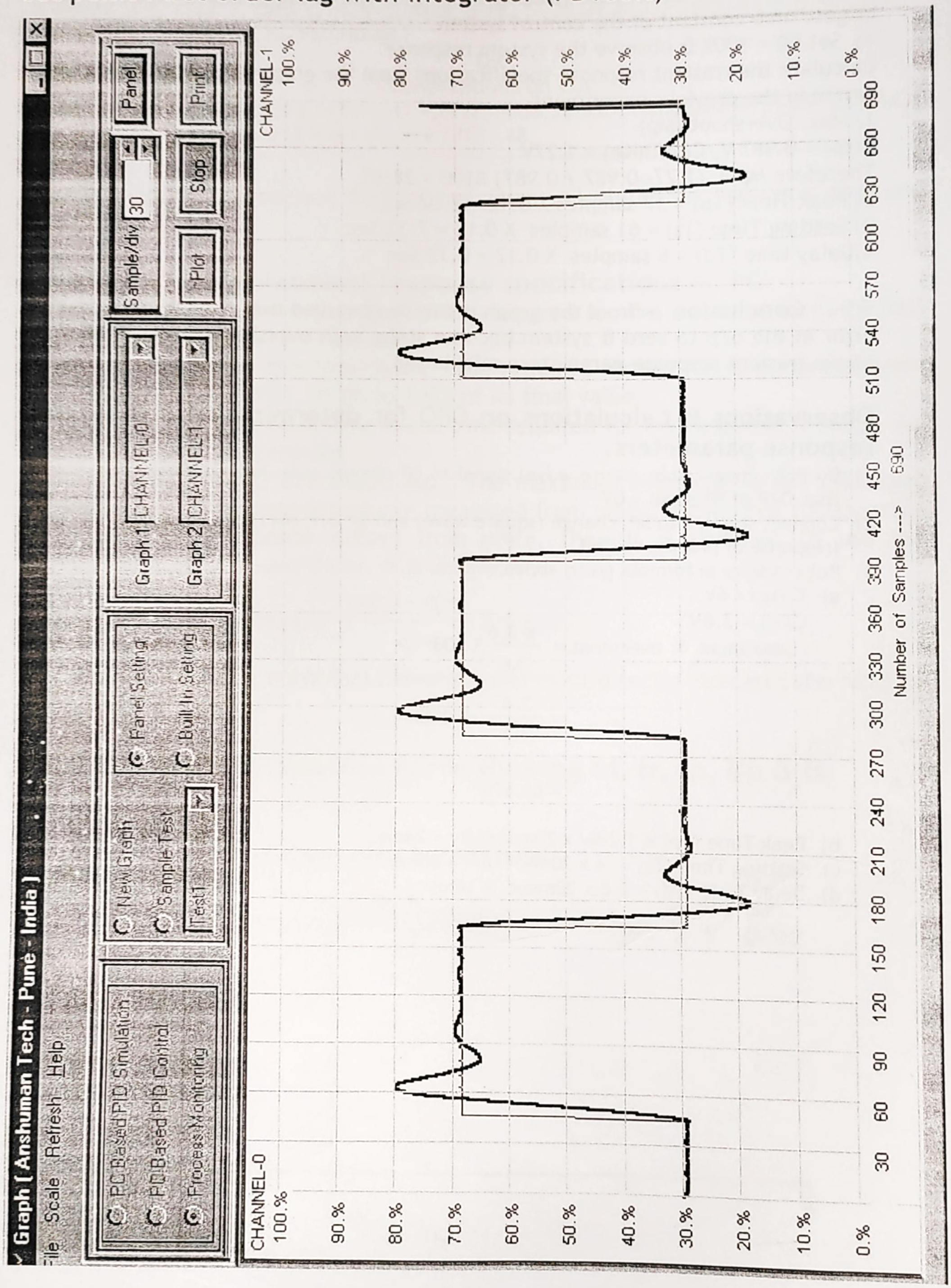
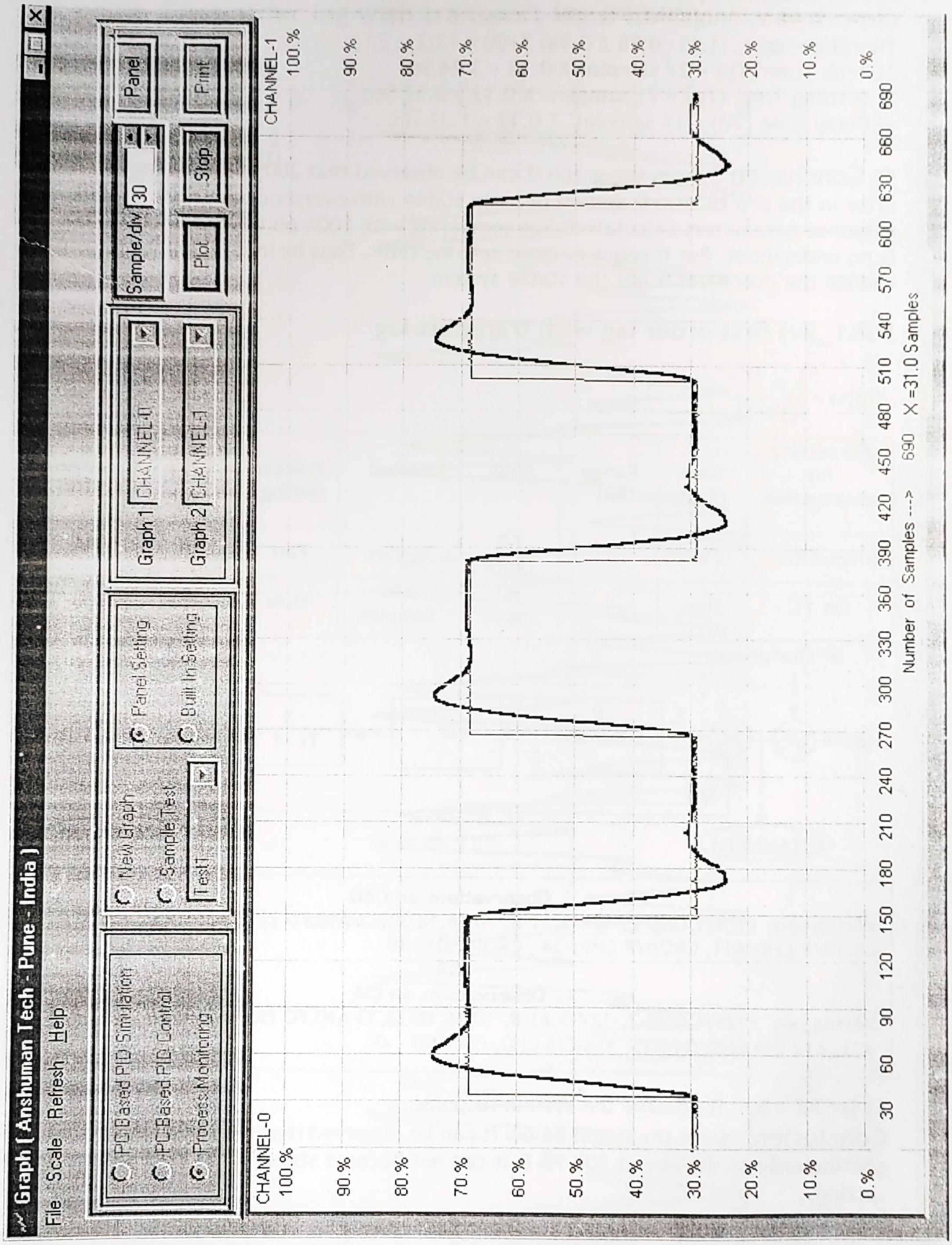


Fig.3.23 PSB1_2iii(pb200)) Proportional control with step change in set point-First order lag with integrator (PB200%)



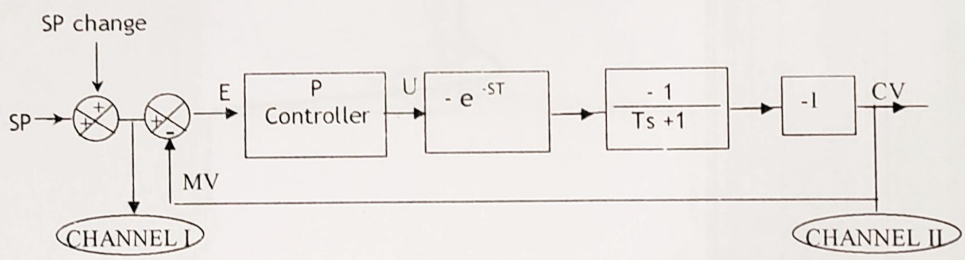
2) Set PB = 200% & observe the system response.
Calculate the trasient response specifications from the graph.
1) Max. Overshoot (Mp)
C(tp) = 0.98 V, C(infinite) = 1.11V
Therefore Mp = (1.11- 0.98 / 0.98) X100 = 13.2
2) Peak Time (Tp) = 27 samples X 0.12 = 3.24 Sec
3) Settling Time (Tp) = 71 samples X 0.12 = 8.52 Sec
4) Delay time (Td) = 11 samples X 0.12 = 1.32 Sec

☞ **Conclusion** :- from the graph it can be observed that 200% PB reduces the error in the o/p to zero & system become stable with overshoot as above trasient response parameters calculated. But comparing with 100% pb the overshoot is less & no undershoot. But it requires more settling time. Thus by increasing pb we reduce the overshoot & get the stable system.

PSB1_2v) first order lag with transport lag

$$Gp(s) = \frac{e^{-ST}}{(Ts+1)}$$

FG setting for observation	Slow /Fast	Range I/II	Amp.	Period	Process settings	Samples/ div on graph	Level shifter
On CRO	Fast	I	7.2 (Vpp)	36mSec	Fast	NA	NA
On PC	Slow	I	40 (%pp)	240 Samples	Slow	30	±9V to 2.5V



Observations on CRO

Wiring seq. +12V-1,GND-2,-12V-3,A1-8, 10-16,18-32,33-A10,FG (Square wave I/P)-A9, CRO(I/P CHI)-A11, CRO(I/P CHII)-34 , CRO(GND) - 49.

OR

Observations on CIA

Wiring seq. +12V-1,GND-2,-12V-3,A1-8, 10-16,18-32,33-A10,FG (Square wave I/P)-A9 A11-A13, A14-CIA CH1, 34-A15, A16-CIA CH0, CIA GND - 49.

1) Set PB = 50% & observe the system response.

Conclusion - from the graph below it can be observed that the system is continuously oscillatory at 50% PB & it can not become stable at this set point settings.

Fig.3.24 PSB1_2v(pb50)) Proportional control with step change in set point- First order lag with transport lag (PB50%)

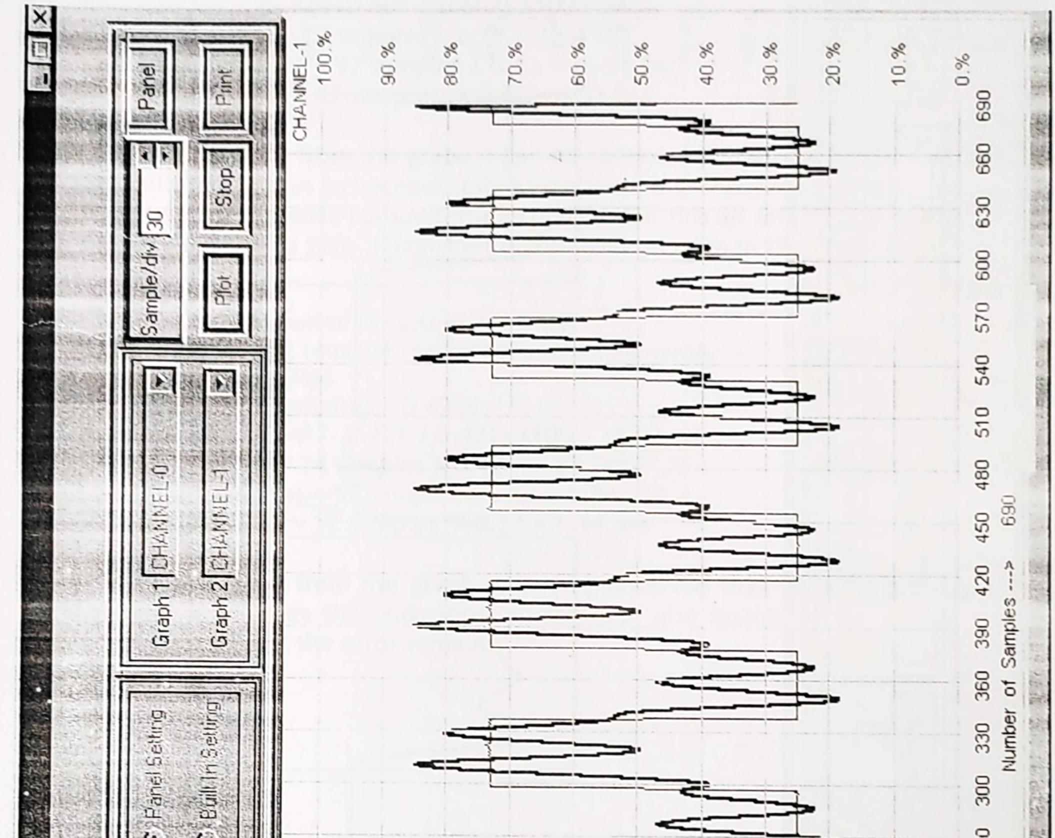
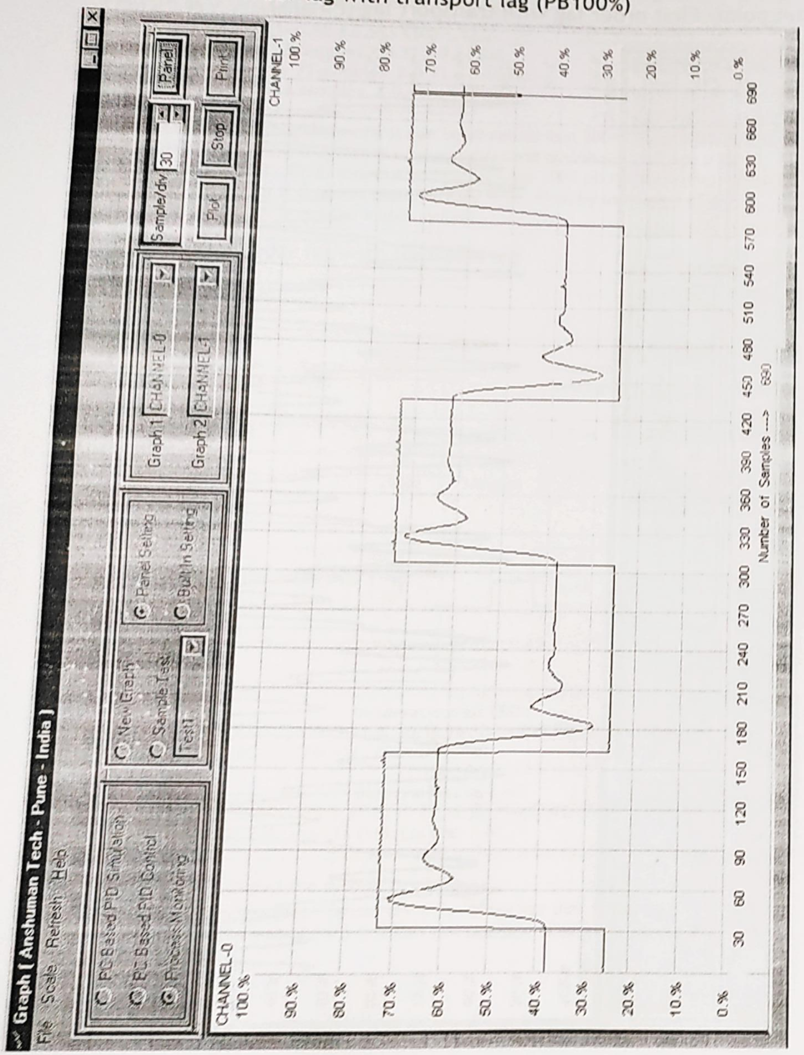


Fig. 3.25 PSB1_2v(pb100)) Proportional control with step change in set point-First order lag with transport lag (PB100%)



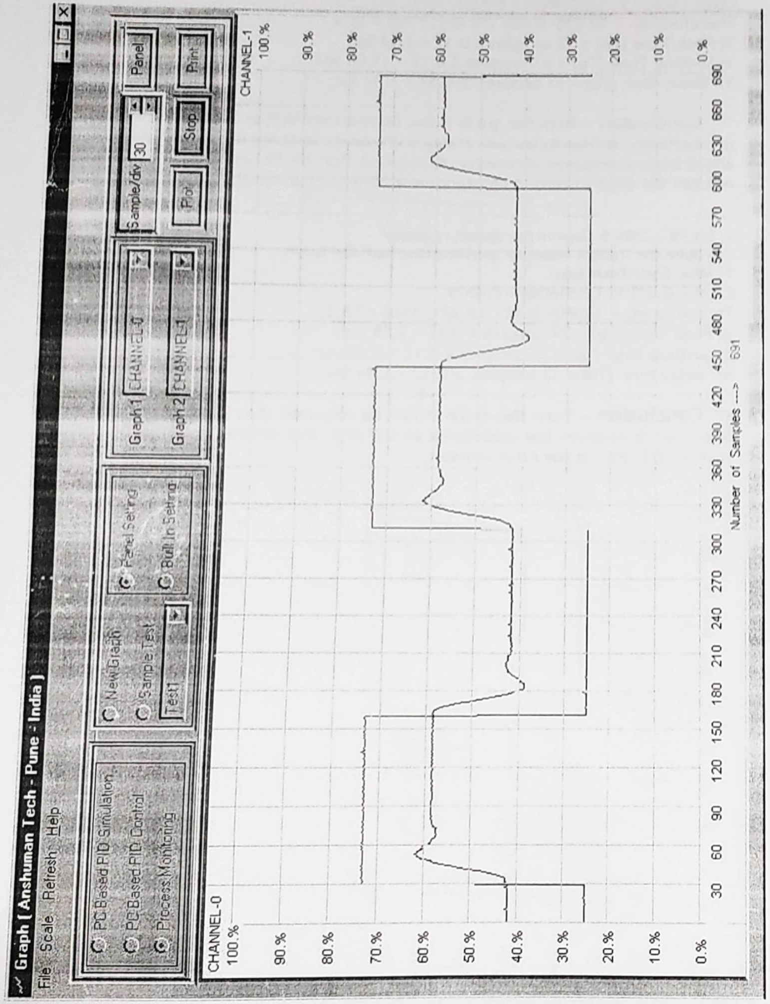
2)Set PB = 100% & observe the system response.
Calculate the trasient response specifications from the graph.
1) Max. Overshoot (Mp)
C(tp) = 0.607 V, C(infinite) = 0.828V
Therefore Mp = (0.828- 0.607 / 0.607) X100 = 36.4
2) Peak Time (Tp) = 22 samples X 0.12 = 2.64 Sec
3) Settling Time (Tp) = 92 samples X 0.12 = 11.04 Sec
5) Delay time (Td) = 11 samples X 0.12 = 1.32 Sec

☞ **Conclusion** :- from the graph it can be observed that at 100% PB system does not oscillates. It tries to become stable with some overshoot & undershoot as above trasient response parameters calculated. But this PB settings can not reduces the error to zero. A constant error always remain in the system o/p.

3) Set PB = 200% & observe the system response.
Calculate the trasient response specifications from the graph.
1) Max. Overshoot (Mp)
C(tp) = 0.421 V, C(infinite) = 0.497V
Therefore Mp = (0.497- 0.421 / 0.421) X100 = 18.02
2) Peak Time (Tp) = 24 samples X 0.12 = 2.88 Sec
3) Settling Time (Tp) = 57 samples X 0.12 = 6.84 Sec
6) Delay time (Td) = 12 samples X 0.12 = 1.44 Sec

☞ **Conclusion** :- from the graph it can be observed that 200% PB reduces the overshoot & removes the undershoot in the o/p. also system settle earlier than that of 100% PB but the error remains.

Fig.3.26 PSB1_2v(pb200)) Proportional control with step change in set point-First order lag with transport lag (PB200%)

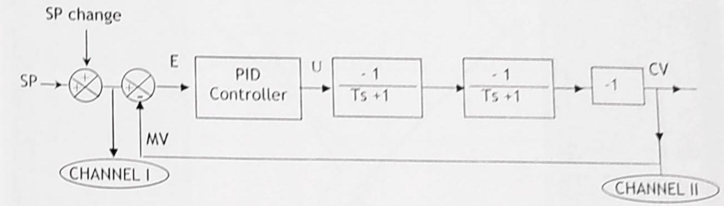


B1-3) Proportional control with ramp change in set point
PSB1_3ii) Two first order lags

$$Gp(s) = \frac{1}{(Ts+1)(Ts+1)}$$

No of		System	
Lags	Integrators	Type	Order
2	0	0	2

FG setting for observation	Slow /Fast	Range I/II	Amp.	Period	Process settings	Samples/ div on graph	Level shifter
On CRO	Fast	I	7.2 (Vpp)	36mSec	Fast	NA	NA
On PC	Slow	I	40 (%pp)	240 Samples	Slow	30	±9V to 2.5V



Observations on CRO
Wiring seq. +12V-1,GND-2,-12V-3,A1-4,6-12,14-32,33-A10, FG(Trg. o/p)-A9, CH0-A11, CHI-24,GND-49

OR

Observations on CIA
Wiring seq. +12V-1,GND-2,-12V-3,A1-4,6-12,14-32,33-A10, FG(Trg. o/p)-A9, A11-A13, A14-CIA CH1, 34-A15, A16-CIA CH0, CIA GND - 49.

Connect the test setup as per the above wiring sequence & observe the process response at various PB settings
1) Set PB=100

From the graph it is observed that the o/p follows the i/p ramp change with error. This means that 100% PB can not reduces the system o/p error to zero. The error is not a constant steady state error.

☞ **Conclusion** - from the graph it can be observed that 100% PB is not efficient to reduce the system error.

Fig.3.27 PSB1_3ii(pb100)) Proportional control with ramp change in set point- Two first order lags with PB=100%

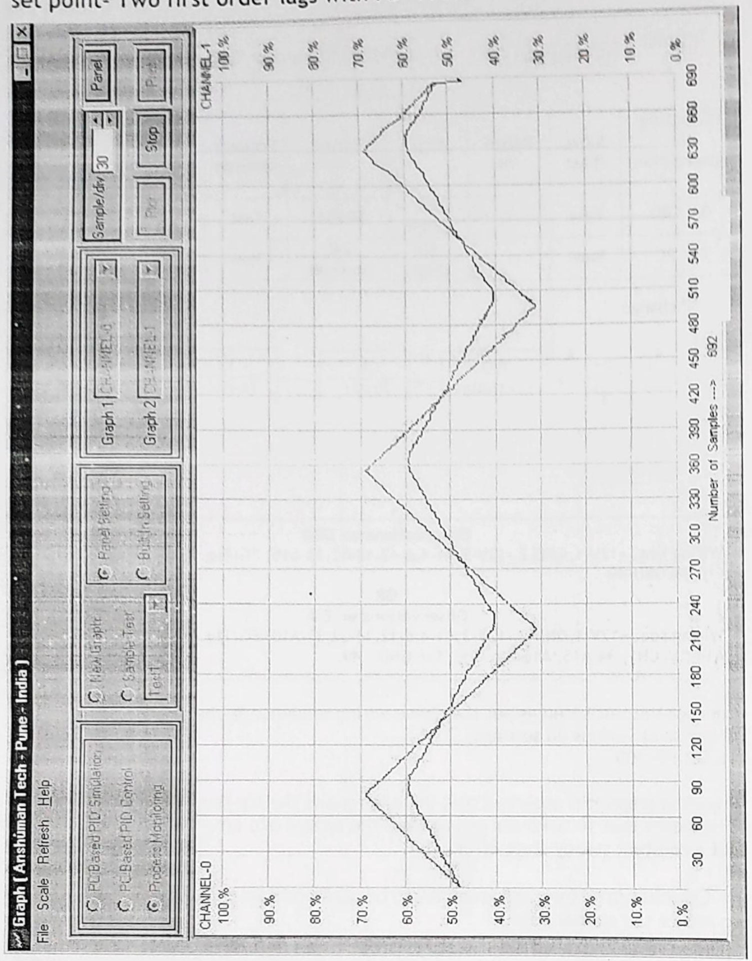
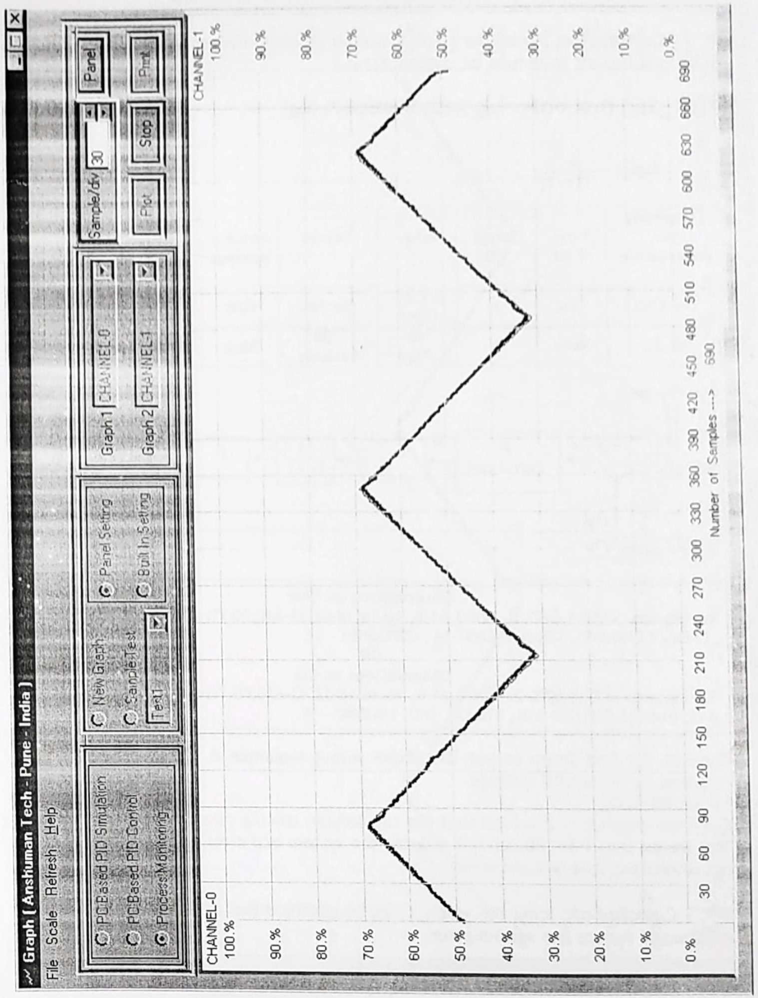


Fig.3.28 PSB1_3ii(pb5)) Proportional control with ramp change in set point- Two first order lags with PB=5%



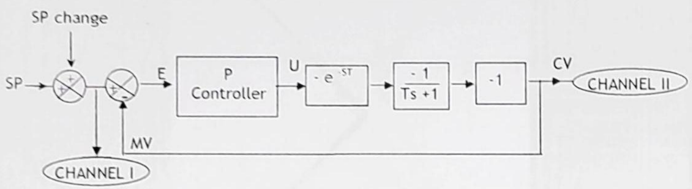
2) Set PB= 5%
From the graph it is observed that the o/p follows the i/p ramp change without error. This means that 5% PB reduces the system o/p error to zero.

☞ **Conclusion :** from the graph it can be observed that only reducing the PB to 5% is sufficient to reduce the system error.

PSB1_3iv) first order lag with transport lag

$$Gp(s) = \frac{e^{-ST}}{(Ts+1)}$$

FG setting for observation	Slow /Fast	Range I/II	Amp.	Period	Process settings	Samples/ div on graph	Level shifter
On CRO	Fast	I	7.2 (Vpp)	36mSec	Fast	NA	NA
On PC	Slow	I	40 (%pp)	300 Samples	Slow	30	±9V to 2.5V



Observations on CRO
Wiring seq. +12V-1,GND-2,-12V-3,A1-8, 10-16,18-32,33-A10,FG (Trg. wave I/P)-A9, ,CRO(I/P CHI)-A11, CRO(I/P CHII)-34 , CRO(GND) - 49.
OR
Observations on CIA
Wiring seq. +12V-1,GND-2,-12V-3,A1-8, 10-16,18-32,33-A10,FG (Trg. wave I/P)-A9, A11-A13, A14-CIA CH1, 34-A15, A16-CIA CH0, CIA GND - 49.

Connect the test setup as per the above wiring sequence & observe the process response at various PB settings
1) Set PB=100
From the graph it is observed that the o/p follows the i/p ramp change with error. This means that 100% PB can not reduces the system o/p error to zero. The error is not a constant steady state error.

☞ **Conclusion:** from the graph it can be observed that 100% PB is not efficient to reduce the system error.

Fig 3.29. PSB1_3iv(pb100)) Proportional control with ramp change in set point-First order lag with transport lag (PB100%)

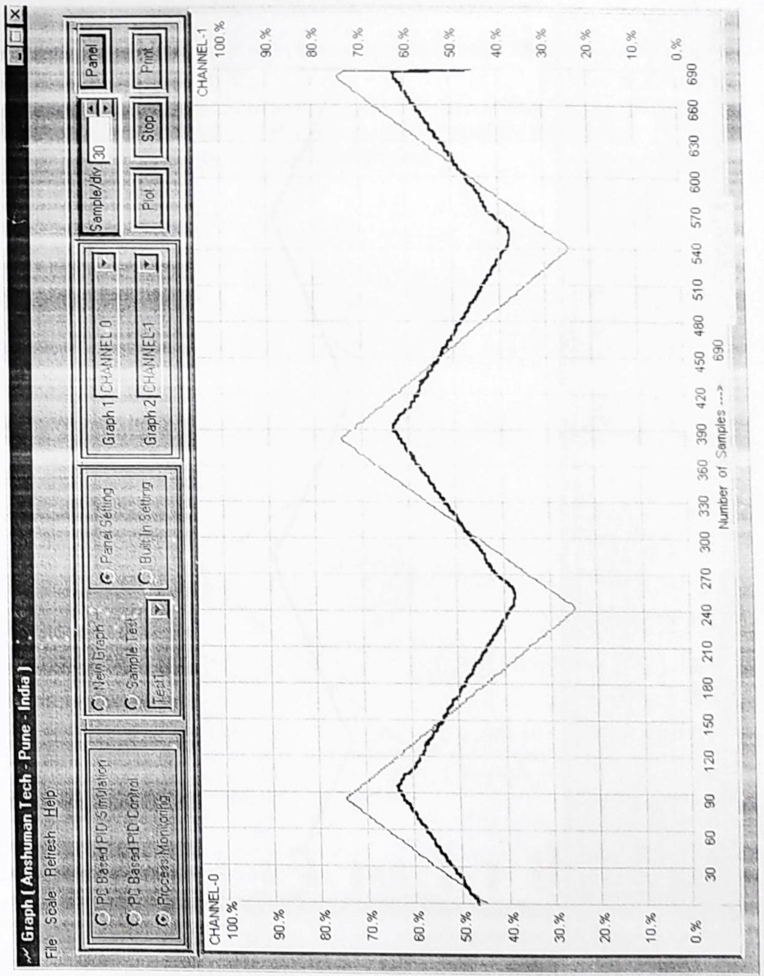
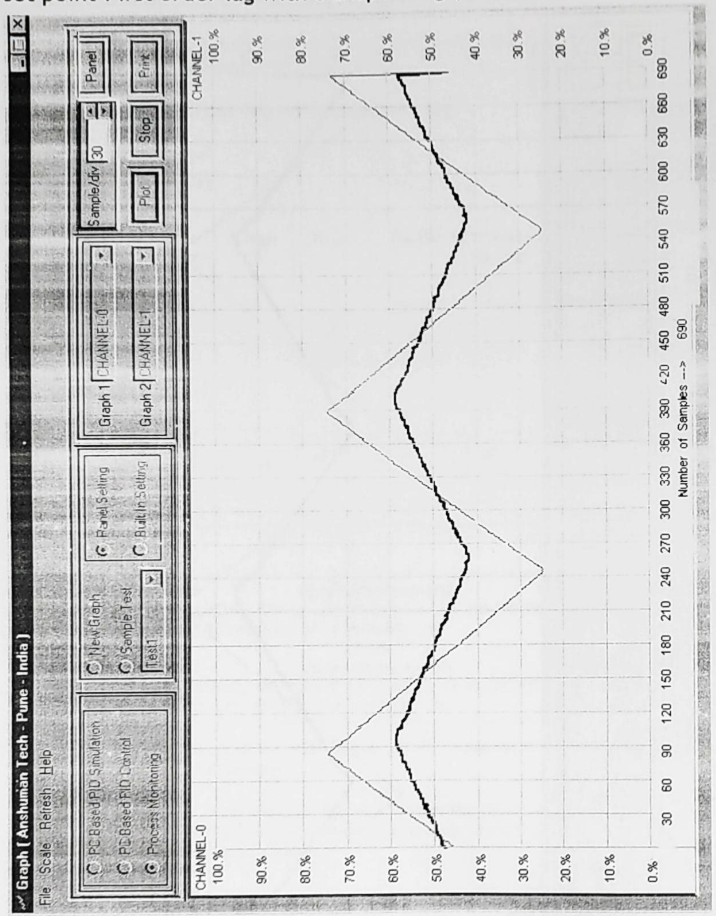


Fig.3.30 PSB1_3iv(pb200)) Proportional control with ramp change in set point-First order lag with transport lag (PB200%)



2) Set PB=200

From the graph it is observed that the o/p follows the i/p ramp change with error. This means that 200% PB can not reduces the system o/p error to zero. The error is not a constant steady state error. The error will always remain in the o/p for any PB settings.

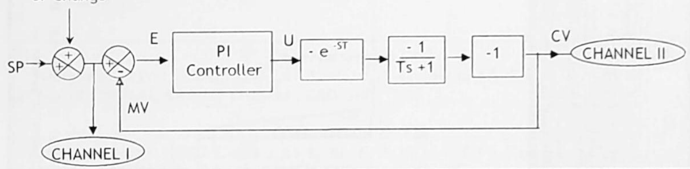
☞ **Conclusion :** from the graph it can be observed that 200% PB is not efficient to reduce the system error.

B1-4) Proportional + Integral control with step change in set point & determination of transient & steady state response specifications.

PSB1_4iii) first order lag with transport lag

$$Gp(s) = \frac{e^{-ST}}{(Ts+1)}$$

FG setting for observation	Slow /Fast	Range I/II	Amp.	Period	Process settings	Samples/ div on graph	Level shifter
On CRO	Fast	I	7.2 (Vpp)	36mSec	Fast	NA	NA
On PC	Slow	I	40 (%pp)	330 Samples	Slow	30	±9V to 2.5V



Observations on CRO

Wiring seq. +12V-1,GND-2,-12V-3,A1-8, 10-16,18-32,33-A10,FG (Square wave I/P)-A9, CRO(I/P CHI)-A11, CRO(I/P CHII)-34 , CRO(GND) - 49.

OR

Observations on CIA

Wiring seq. +12V-1,GND-2,-12V-3,A1-8, 10-16,18-32,33-A10,FG (Square wave I/P)-A9, A11-A13, A14-CIA CH0, 34-A15, A16-CIA CH1, CIA GND - 49.

Set PB 200% & Ti 0.6 Sec

from the graph of expt PSB1_2v it can be observed that 200% PB reduces the overshoot & removes the undershoot in the o/p but the error remains. To remove this error we add 0.6 Sec I action in the system. This addition improves the system response by reducing the error with following trasient response parameters.

1) Max. Overshoot (Mp)

C(tp) = 1V, C(infinite) = 1.18V

Therefore Mp = (1.18- 1 / 1) X100 = 18

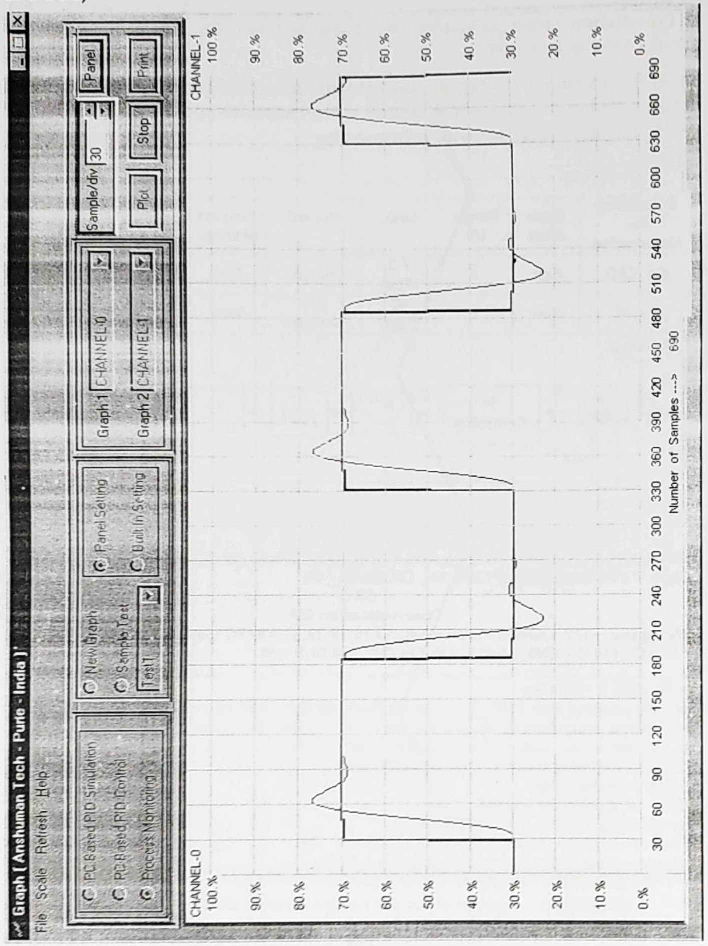
2) Peak Time (Tp) = 34 samples X 0.12 = 4.08 Sec

3) Settling Time (Tp) = 71 samples X 0.12 = 8.52 Sec

2) Delay time (Td) = 17 samples X 0.12 =2.04 Sec

☞ **Conclusion** - addition of 0.6 Sec I action removes the error remain due to only P action in the system. Hence addition of I action improves the system response.

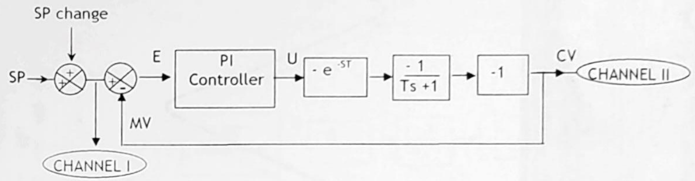
Fig.3.31 PSB1_4iii(pb200)) Proportional + Integral control with step change in set point-First order lag with transport lag(PB200% & Ti 0.6 Sec)



B1-5) Proportional + Integral control with ramp change in set point. PSB1_5iii) first order lag with transport lag

$$Gp(s) = \frac{e^{-ST}}{(Ts+1)}$$

FG setting for observation	Slow /Fast	Range I/II	Amp.	Period	Process setting s	Samples / div on graph	Level shifter
On CRO	Fast	I	7.2 (Vpp)	36mSec	Fast	NA	NA
On PC	Slow	I	40 (%pp)	170 Samples	Slow	30	±9V to 2.5V



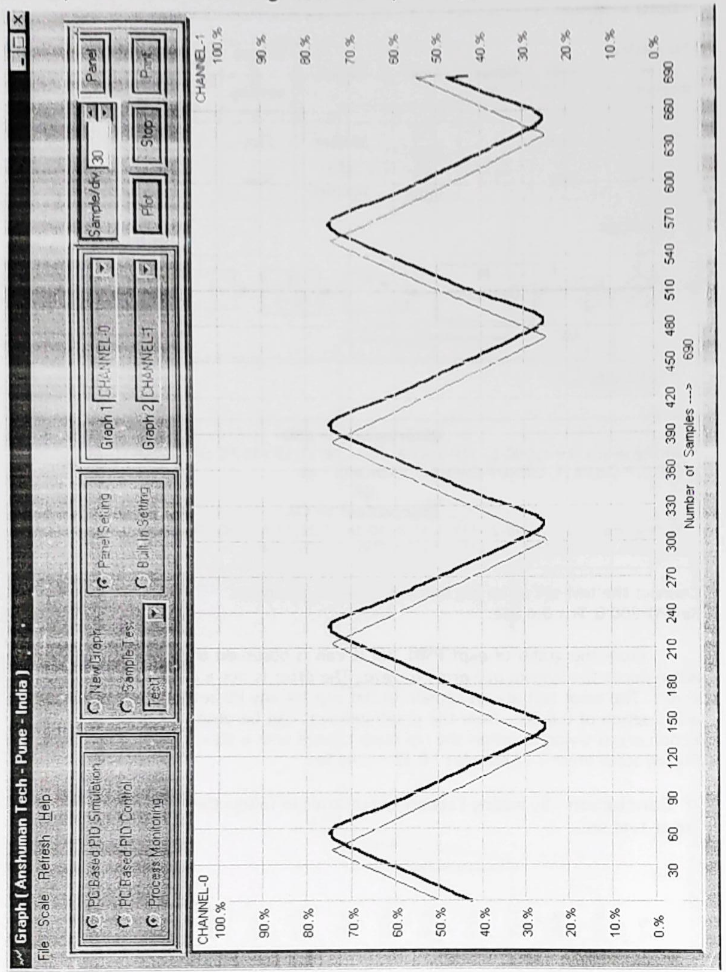
Observations on CRO Wiring seq. +12V-1,GND-2,-12V-3,A1-8, 10-16,18-32,33-A10,FG (Trg. wave I/P)-A9, CRO(I/P CHI)-A11, CRO(I/P CHII)-34 , CRO(GND) - 49. OR Observations on CIA Wiring seq. +12V-1,GND-2,-12V-3,A1-8, 10-16,18-32,33-A10,FG (Trg. wave I/P)-A9, A11-A13, A14-CIA CH1, 34-A15, A16-CIA CH0, CIA GND - 49.

Connect the test set up as per the wiring sequence above.
Set PB=200 & Ti = 0.6 Sec.

From the graph of expt PSB1_3iii it can is observed that only 200% PB can not reduces the system o/p error to zero. The error is not a constant steady state error. The error will always remain in the o/p for any PB settings. To reduce this add I action of 0.6 Sec. from the graph below it can be observed that by adding I action o/p is trying to follow the i/p ramp change with a steady state error.
Steady state error = 12 samples * 0.12 = 1.44 Sec.

☞ **Conclusion** - By adding I action system tries to follow the i/p with a constant lag of 1.44 sec.

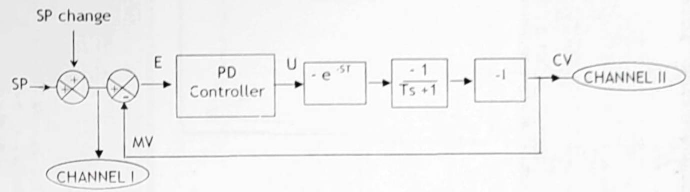
Fig.3.32 PSB1_5iii) Proportional + Integral control with ramp change in set point-First order lag with transport lag(PB 200% & Ti 0.6 Sec)



B1-6) Proportional + Derivative control with step change in set point - Steady & transient response verification.
PSB1_6iv) first order lag with transport lag

$$Gp(s) = \frac{e^{-sT}}{(Ts+1)}$$

FG setting for observation	Slow /Fast	Range I/II	Amp.	Period	Process settings	Samples/ div on graph	Level shifter
On CRO	Fast	I	7.2 (Vpp)	36mSec	Fast	NA	NA
On PC	Slow	I	40 (%pp)	320 Samples	Slow	30	±9V to 2.5V



Observations on CRO

Wiring seq. +12V-1,GND-2,-12V-3,A1-8, 10-16,18-32,33-A10,FG (Square wave I/P)-A9, CRO(I/P CHI)-A11, CRO(I/P CHII)-34 , CRO(GND) - 49.

OR

Observations on CIA

Wiring seq. +12V-1,GND-2, -12V-3, A1-8, 10-16,18-32, 33-A10, FG (Square wave I/P)-A9, A11-A13, A14-CIA CH0, 34-A15, A16-CIA CH1, CIA GND - 49.

1) Set PB = 100% & Td = 1Sec.
From graph of PSB1_2v we had already observed that only P action of 100% settles the system with overshoot & undershoot. To improve the performance D action of 1 Sec is added in the system. This reduces the overshoot & settles the system with following transient response parameters.
1) Max. Overshoot (Mp)
C(tp) = 0.628 V, C(infinite) = 0.531V
Therefore Mp = (0.628- 0.531 / 0.531) X100 = 18.26
2) Peak Time (Tp) = 17 samples X 0.12 = 2.04 Sec
3) Settling Time (Tp) = 71 samples X 0.12 = 8.52 Sec
7) Delay time (Td) = 10 samples X 0.12 = 1.2 Sec

☞ **Conclusion** - Addition of D action reduces the overshoot & undershoot. Thus improves the system performance.

Fig.3.33 PSB1_6iv) Proportional + Derivative control with step change in set point- First order lag with transport lag (PB 100%,Td 1 Sec)

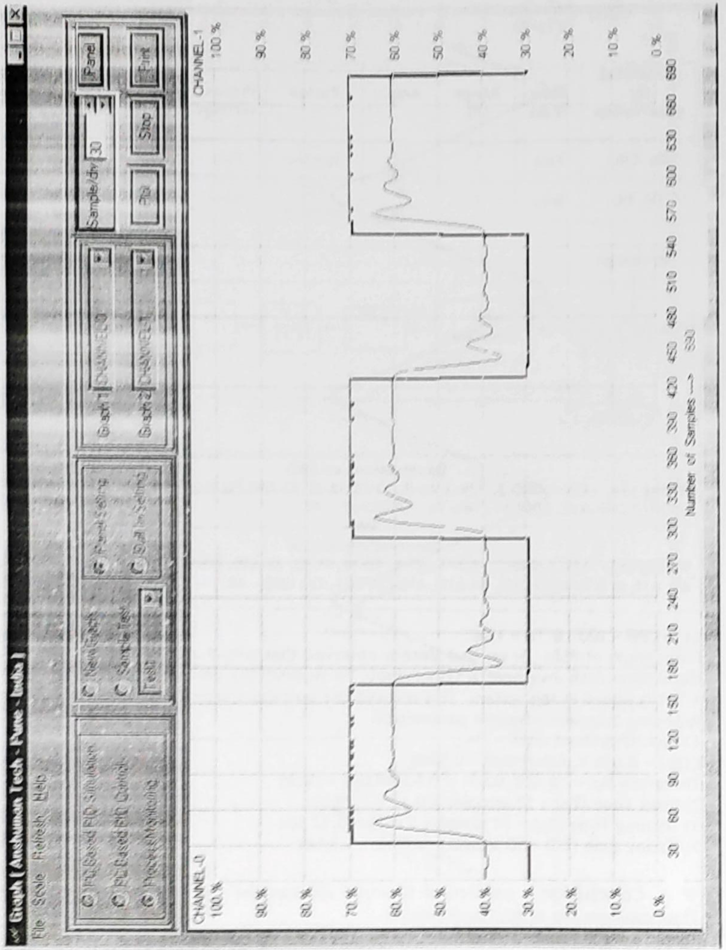
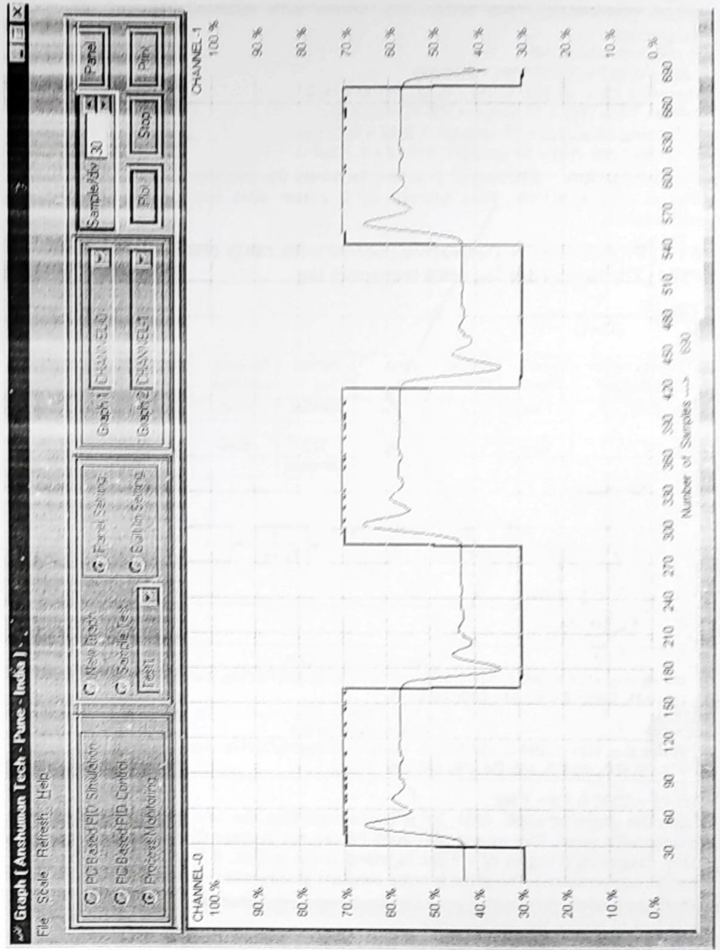


Fig.3.34 PSB1_6iv) Proportional + Derivative control with step change in set point- First order lag with transport lag (PB 200%,Td 2 Sec)



2) Set PB = 200% & Td = 2 Sec.
From graph of PSB1_2v we had already observed that only P action of 200% settles the system with few overshoot. D action of 2 Sec is added in the system. But it settles the system with large overshoot & undershoot. Hence here D action does not improve the system performance. This settles the system with following transient response parameters.

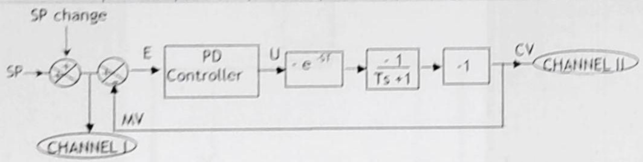
1) Max. Overshoot (Mp)
C(tp) = 0.552 V, C(infinite) = 0.352V
Therefore Mp = (0.552- 0.352 / 0.352) X100 = 56.8
2) Peak Time (Tp) = 17 samples X 0.12 = 2.04 Sec
3) Settling Time (Tp) = 77 samples X 0.12 = 9.24 Sec
8) Delay time (Td) = 10 samples X 0.12 = 1.2 Sec

☞ **Conclusion** - Addition of D action increases the overshoot & undershoot than that of only P action. Thus addition of D action does not improve the system performance.

B1-7) Proportional + Derivative control with ramp change in set point PSB1_7ii) first order lag with transport lag

$$Gp(s) = \frac{e^{-ST}}{(Ts+1)}$$

FG setting for observation	Slow /Fast	Range I/II	Amp.	Period	Process settings	Samples/ div on graph	Level shifter
On CRO	Fast	I	7.2 (Vpp)	36mSec	Fast	NA	NA
On PC	Slow	I	40 (%pp)	320 Samples	Slow	30	±9V to 2.5V

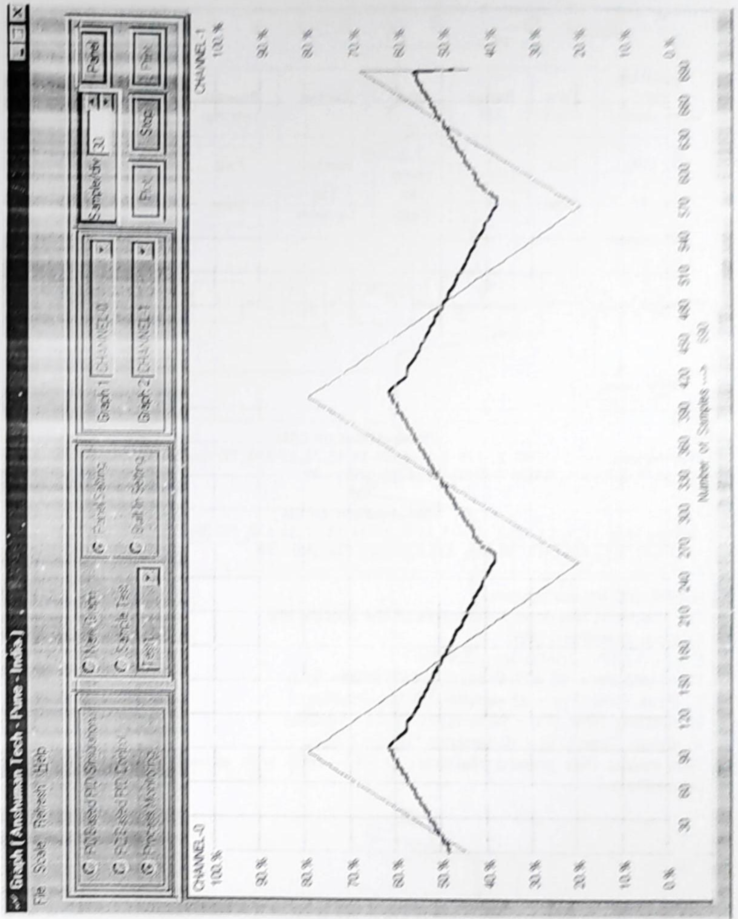


Observations on CRO
Wiring seq. +12V-1,GND-2,-12V-3,A1-8, 10-16,18-32,33-A10,FG (Trg. wave I/P)-A9, CRO(I/P CHI)-A11, CRO(I/P CHII)-34 , CRO(GND) - 49.
OR
Observations on CIA
Wiring seq. +12V-1,GND-2,-12V-3,A1-8, 10-16,18-32,33-A10,FG (Trg. wave I/P)-A9, A11-A13, A14-CIA CH1, 34-A15, A16-CIA CH0, CIA GND - 49.

Set PB = 200% & Td = 1 Sec.
From the graph or expt. PSB1_3iv it is observed that the o/p follows the i/p ramp change with error. This means that 200% PB can not reduces the system o/p error to zero. Therefore D action of 1.9 Sec is added in the system. But it does not affect the system performance. The error is not a constant steady state error.

☞ **Conclusion :** from the graph it can be observed that only PD controller is not efficient to reduce the system error.

Fig.3.35 PSB1_7ii) Proportional + Derivative control with ramp change in set point - First order lags with transport lag (PB 200%,Td 1 Sec)

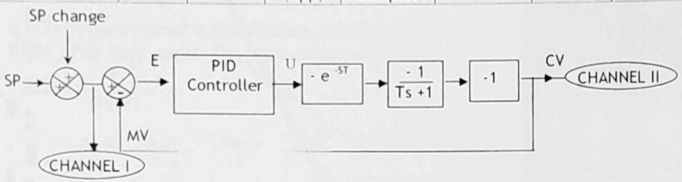


B1-8) Proportional + Integral + Derivative control with step change in set point- steady & transient response specification.

PSB1_8i) First order lag with transport lag

$$G_p(s) = \frac{e^{-ST}}{(Ts+1)}$$

FG setting for observation	Slow /Fast	Range I/II	Amp.	Period	Process settings	Samples / div on graph	Level shifter
On CRO	Fast	I	7.2 (Vpp)	36mSec	Fast	NA	NA
On PC	Slow	I	40 (%pp)	310 Samples	Slow	30	±9V to 2.5V



Observations on CRO

Wiring seq. +12V-1,GND-2,-12V-3,A1-8, 10-16,18-32,33-A10, FG (Square wave I/P)-A9, CRO(I/P CHI)-A11, CRO(I/P CHII)-34 , CRO(GND) - 49.

OR

Observations on CIA

Wiring seq. +12V-1,GND-2,-12V-3,A1-8, 10-16,18-32,33-A10, FG (Square wave I/P)-A9, A11-A13, A14-CIA CH1, 34-A15, A16-CIA CH0, CIA GND - 49.

Set PB=100 for our system.

The transient response parameters of the process are

1) Max. Overshoot (Mp)

C(tp)= 0.607V, C(infinite) = 0.441V

Therefore Mp = (0.607- 0.441 / 0.441) X100 = 37.6

2) Peak Time (Tp) = 22 samples * 0.12 = 2.62Sec

3) Settling Time (Ts) = 90 samples * 0.12 = 10.8Sec

4) Delay Time (Td) = 10 samples * 0.12 = 1.2Sec

This means that process stabilizes at PB = 100% with above transient response parameters.

Fig.3.36 PSB1_8i) Proportional control with step change in set point-First order lag with transport lag(PB 100%)