

18.3 Practical Exercise

Characteristics of a Positional Control System - 1

Proportional Control

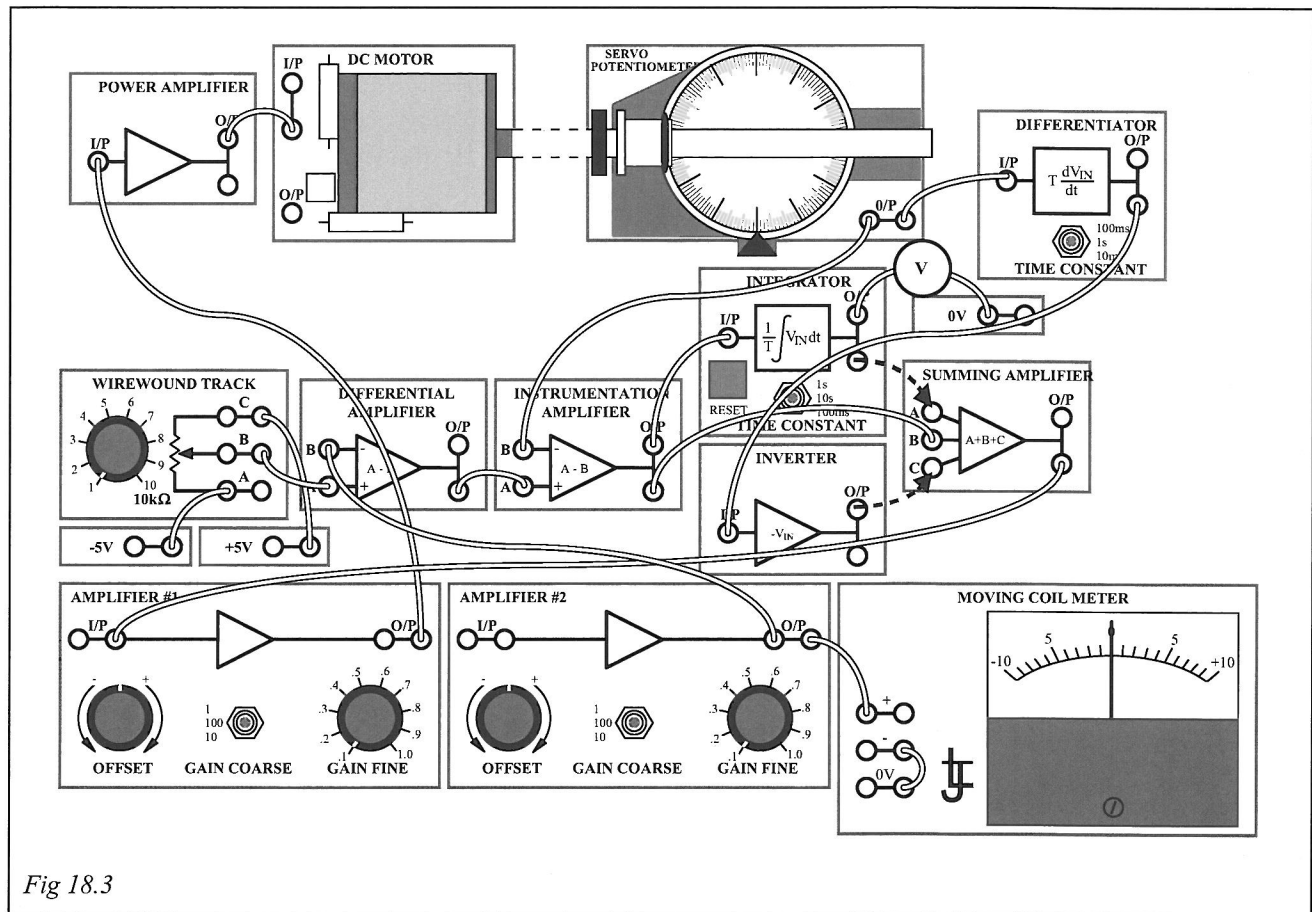


Fig 18.3

Study the diagram.

The **proportional** control section runs across the middle of the diagram. The 10kΩ wirewound resistor is the command input. The function of the Differential Amplifier is to inject a step input voltage later in the investigation. The step voltage is generated by Amplifier #2 offset voltage, which is the only purpose for including this amplifier. You will see that it does not need an input for this purpose.

Integral control will be added later by connecting the Integrator in between the Error Detector (the Instrumentation Amplifier) and the Summing Amplifier.

Derivative control will also be added later via the Summing Amplifier. The Inverter in between the Differentiator and the Summing Amplifier is to provide *negative* feedback.

The Summing Amplifier combines all of the control systems as required.

- Connect the circuit as shown in Fig 18.3. This circuit is arranged for **proportional** control only.
- Press the left hand side of the mounting plate of the Servo Potentiometer and then release it to engage with the drive shaft.
- Set Amplifier #1 GAIN COARSE control to 10 and GAIN FINE to 0.1 to give an overall gain of 1.0.
- Remove the power connection to the Motor. Switch ON the power supply.
- Set Amplifier #2 GAIN COARSE control to 100 and GAIN FINE to 1.0 and adjust the OFFSET control for an output of +3V. Return the GAIN COARSE control to 1. The output voltage should fall to near zero volts. Note that since this +3V step is fed into the system via the inverting input of the Differential Amplifier the actual step injected will be -3V.
- Transfer the Moving Coil Meter to terminal B of the 10k Ω wirewound resistor. Adjust the setting of the 10k Ω resistor control to its central position to give 0V output.
- Zero the setting of the Servo Potentiometer dial against the pointer.
- Transfer the Moving Coil Meter to the output of the Power Amplifier and adjust Amplifier #1 OFFSET to give 0V. Restore the Motor power connection.
- Rotate the 10k Ω wirewound resistor control slowly over its full travel. The Motor drive shaft and the Servo Potentiometer dial should rotate and follow the movement of the command input, although the system may be sluggish and there will be a lag before the Servo Potentiometer starts to follow the input setting. This is because the system gain is low, Amplifier #1 gain being set to 1.0.

Amplifier #1 Gain = 1.0	Positive	Negative
Maximum Dial Reading (degrees)		

Table 18.3



18.3a Enter your maximum Servo Potentiometer dial reading with positive input voltage in degrees when Amplifier #1 gain is 1.0.

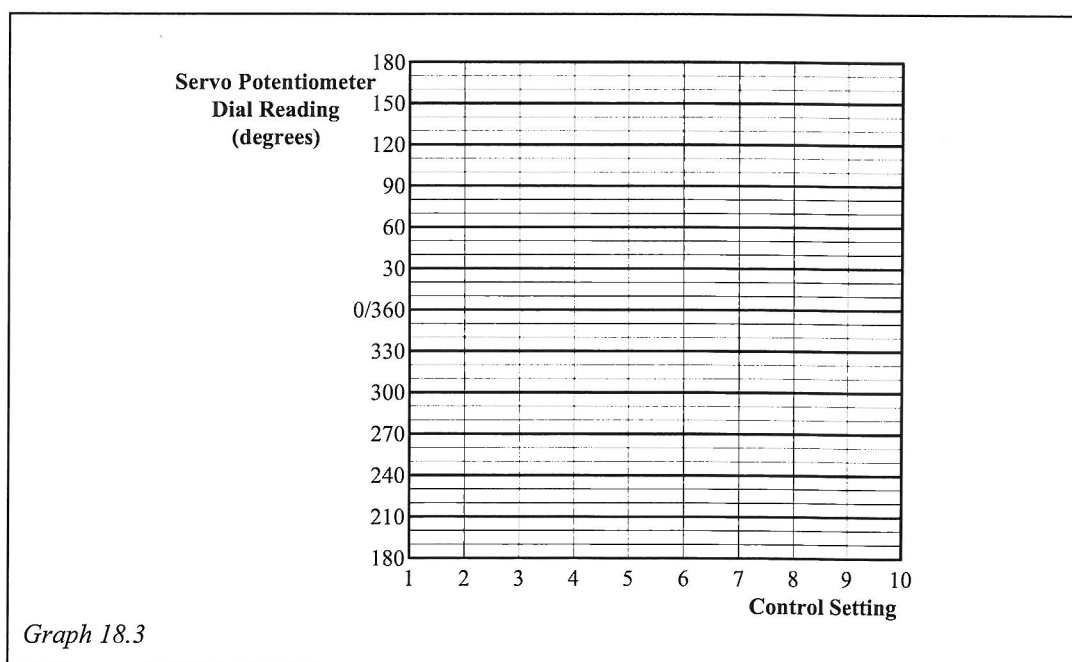
- Return the 10k Ω resistor to its central position. Set Amplifier #1 GAIN FINE to 0.5 (overall gain 5) and repeat the procedure. With this higher setting of the gain control the Servo Potentiometer should follow the input closely for no load on the drive shaft and it should be possible to obtain the full travel of the wirewound track resistor in both directions.

Rotate the input control slowly when nearing the end of the travel or the Servo Potentiometer contact may overshoot and pass the end of the track, causing the drive shaft to rotate continuously. If this occurs, return the 10k Ω resistor quickly to its central position.

- Note the full range of travel of the Servo Potentiometer against the setting of the 10k Ω wirewound resistor command input. Record the results in Table 18.4.

Control Setting	1	2	3	4	5	0V	6	7	8	9	10
Servo-Potentiometer Dial Reading (deg.)						0/ 360					

Table 18.4



- Plot the graph of Dial Reading against Control Setting on the axes provided on the previous page (Graph 18.3).
- Repeat the readings in the reverse direction and compare the dial readings obtained with the previous readings recorded in Table 18.4.



18.3b Read from your graph and enter the approximate Control Setting for a Servo Potentiometer dial reading of 90°.

- Set Amplifier #1 GAIN FINE to 1.0 and use the input command control to return the Servo Potentiometer dial reading to 0°.
- Move the Servo Potentiometer dial by rotating the Hall effect disc by hand and note the total range (for example +20° to -10° = 30°, it may not be symmetrical) over which the dial can be moved without the system responding and moving the dial back. This value represents a **deadband** over which the system does not respond. Record the result in Table 18.5.

Amplifier #1 Gain	10 x 1.0 = 10	10 x 0.5 = 5	10 x 0.1 = 1
Deadband (deg.)			

Table 18.5

- Repeat the procedure for Amplifier #1 GAIN FINE settings of 0.5 and 0.1, adding the results to Table 18.5.



18.3c The effect of system gain on the deadband is:

- ☐ a high gain gives a small deadband
- ☐ b high gain gives a large deadband
- ☐ c gain makes no difference to deadband
- ☐ d there is no change in deadband below a gain of 5



18.3d Enter your value of deadband in degrees when the gain of Amplifier #1 is 5.

- Set Amplifier #1 GAIN FINE to 0.1.
- Switch the GAIN COARSE control of Amplifier #2 from 1 to 100 and note the effect on the output shaft position. Return the control to 1 and again note the effect. Repeat the procedure several times.
Take care not to touch the OFFSET control when you are doing this as the setting is very critical.
- Repeat the procedure with the Amplifier #1 GAIN FINE set 0.5 and then 1.0.



18.3e The effect of gain on the response to a step input was that the *speed of response* was:

- | | |
|---|--|
| ☐ a greatest with high gain | ☐ b slowest with high gain |
| ☐ c the same for any value of gain | ☐ d no response with gain less than 2.5 |



18.3f The effect of gain on the response to a step input was that *overshoot* was:

- | | |
|---|--|
| ☐ a greatest with high gain | ☐ b least with high gain |
| ☐ c the same for any value of gain | ☐ d no response with gain less than 2.5 |



18.3g A proportional control system which has low gain in the feedback loop will have:

- | |
|--|
| ☐ a large deadband and underdamped response to a step input |
| ☐ b small deadband and overdamped response to a step input |
| ☐ c large deadband and overdamped response to a step input |
| ☐ d small deadband and underdamped response to a step input |

- Switch OFF the power supply, but:

Keep the circuit connected if possible for the following Exercises.

18.4 Practical Exercise

Characteristics of a Positional Control System - 2

Proportional + Integral Control

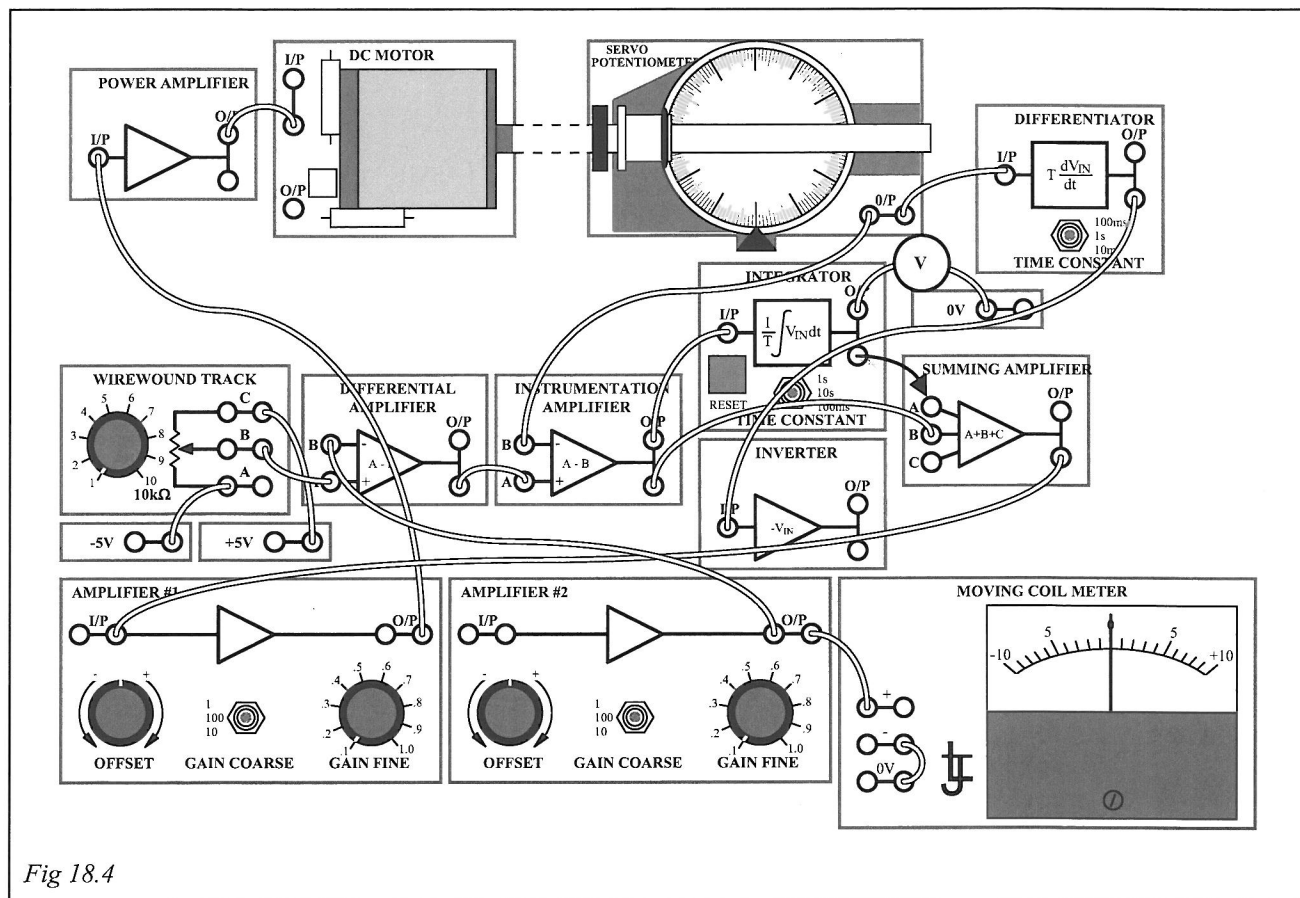


Fig 18.4

- If necessary, re-connect the circuit as shown in Fig 18.4 (without the Integrator output connected initially). Re-check the settings as follows:
- Remove the power connection to the Motor. Zero the setting of the Servo Potentiometer dial against the pointer. Ensure that the potentiometer is engaged with the drive shaft.
- Set Amplifier #1 GAIN COARSE control to 10 and GAIN FINE to 0.1 to give an overall gain of 1.0.
- Switch ON the power supply.
- Connect the Moving Coil Meter temporarily to terminal B of the 10kΩ resistor and check the setting to its central position to give 0V output.

- Transfer the Moving Coil Meter back to the output of the Power Amplifier and check the adjustment of Amplifier #1 OFFSET to give 0V.
- Transfer the Moving Coil Meter to the output of Amplifier #2, set the GAIN COARSE control to 100 and GAIN FINE to 1.0 and check the adjustment of the OFFSET control for an output of +3V. Return the GAIN COARSE control to 1. This control will again be used to introduce a step input.
- Restore the power connection to the Motor. With the Integrator time constant set to 1s, press and hold the RESET button, connect the Integrator output lead to the Summing Amplifier input as shown by the arrow in Fig 18.4 and then release the RESET button.
- **In the event of continuous rotation of the Motor shaft in the following tests, immediately return the Amplifier #2 GAIN COARSE switch to 1 and then hold the Integrator RESET button until the shaft becomes stationary.**
- Note the effect on the output Servo Potentiometer dial reading when a step input is applied by switching Amplifier #2 GAIN COARSE to 100 and then back to 1. Watch the long term effect on the Integrator output voltage (on the digital voltmeter) and on the dial setting.



18.4a

The Integrator output voltage:

- ☐ a goes negative and then quickly returns to zero volts
- ☐ b goes positive and then quickly returns to zero volts
- ☐ c goes quickly to a positive voltage and then remains constant
- ☐ d is still varying after two minutes



18.4b

The Servo Potentiometer Dial Setting:

- ☐ a moves slowly and smoothly towards a target
 - ☐ b moves rapidly towards a target, overshoots and stays there
 - ☐ c moves rapidly towards a target, overshoots and then returns
 - ☐ d moves slowly towards a target in jerking steps
- Repeat the procedure with the Amplifier #1 GAIN FINE set 0.5 (overall gain of 5) and then 1.0 (overall gain of 10) and respond to the following questions:



18.4c With Amplifier #1 gain set to 5 compared to the gain at 1, the effect on speed of response was:

- ☐ a faster ☐ b slower ☐ c the same ☐ d no rotation



18.4d With Amplifier #1 gain set to 5 compared to the gain at 1, the effect was:

- ☐ a more overshoot ☐ b less overshoot
☐ c no overshoot ☐ d continuous oscillation



18.4e With Amplifier #1 gain set to 10 compared to the gain at 5, the effect on speed of response was:

- ☐ a faster ☐ b slower ☐ c the same ☐ d no rotation



18.4f With Amplifier #1 gain set to 10 compared to the gain at 5, the effect was:

- ☐ a more overshoot ☐ b less overshoot
☐ c no overshoot ☐ d continuous oscillation

- With Amplifier #1 GAIN COARSE set to 10 and GAIN FINE to 1.0, repeat the procedure with the time constant set to 10s and then 100ms and note the effect.
- Count the number of overshoots for each of the time constant settings (if possible).



18.4g The time constant which gave the smallest number of overshoots was:

- ☐ a 1s ☐ b 10s ☐ c 100ms ☐ d all the same

- With the time constant switched to 100ms and Amplifier #1 GAIN FINE set to 0.5, note the effect of displacing the output from its stable position manually by moving the Hall effect disc about 10° on the dial and then releasing it.



18.4h A very short time constant may result in:

- ☐ a no overshoot on return ☐ b some overshoot on return
☐ c build up to continuous running ☐ d slow response

- Switch OFF the power supply but **keep the circuit connected if you can.**

18.5 Practical Exercise

Characteristics of a Positional Control System - 3

Proportional + Derivative Control

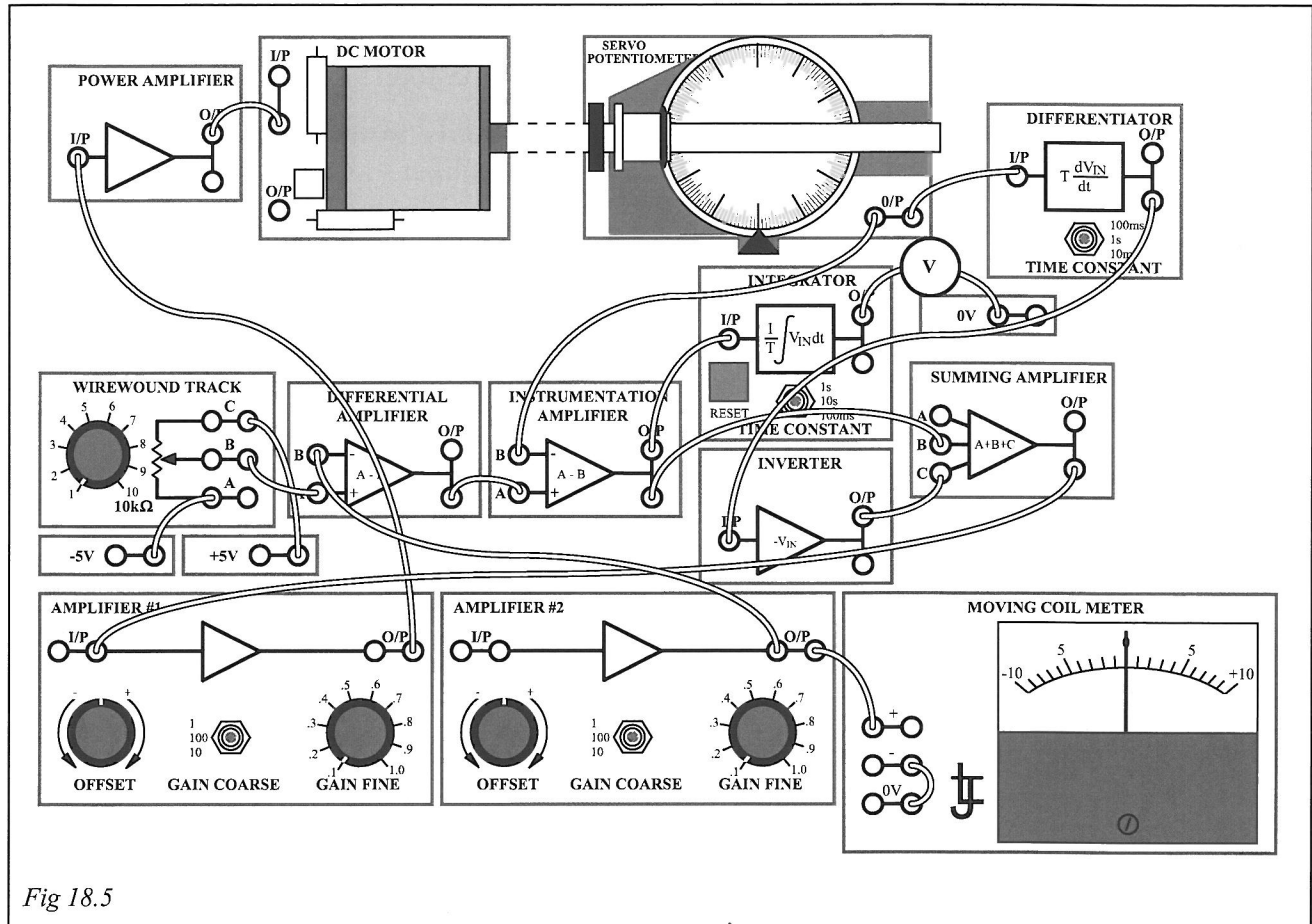


Fig 18.5

- If you still have the circuit connected then remove the lead from the Integrator output to the Summing Amplifier and connect the output from the Inverter to the Summing Amplifier as shown in Fig 18.5. Otherwise connect the circuit as shown.

Re-check the settings as follows:

- Remove the power connection to the Motor. Zero the setting of the Servo Potentiometer dial against the pointer. Ensure that the potentiometer is engaged with the drive shaft.

- Set Amplifier #1 GAIN COARSE control to 10 and GAIN FINE to 0.1 to give an overall gain of 1.0.
- Switch ON the power supply.
- Transfer the Moving Coil Meter temporarily to terminal B of the 10k Ω resistor and check the setting to its central position to give 0V output.
- Transfer the Moving Coil Meter temporarily to the output of the Power Amplifier and check the adjustment of Amplifier #1 OFFSET to give 0V.
- Transfer the Moving Coil Meter back to the output of Amplifier #2, set the GAIN COARSE control to 100 and GAIN FINE to 1.0 and check the adjustment of the OFFSET control for an output of +3V. Return the GAIN COARSE control to 1.
- Restore the power connection to the Motor.
- Set the Differentiator time constant to 1s and note the output Servo Potentiometer response to a step input of +3V applied by changing Amplifier #2 gain control from 1 to 100 and then back to 1.
- Repeat the procedure and note the response for Differentiator time constant settings of 100ms and 10ms.



18.5a After the step input has been applied in both directions the Servo Potentiometer dial reading:

- ☐ a returns accurately to zero setting
 - ☐ b may not return to zero setting
 - ☐ c returns nearest to zero setting with a time constant of 1s
 - ☐ d overshoots when the time constant is long
- With the Differentiator time constant set to 10ms, note the effect of manually moving the output from its stable position by about quarter of a turn with the Hall effect disc.



18.5b Is there any tendency to re-adjust and correct the error?

☐ Yes or ☐ No



18.5c

Derivative control affects the response:

- ☐ a when the output is in the steady state
- ☐ b during change of output only
- ☐ c when there is no error signal
- ☐ d only when the command input is steady



18.5d

Increasing the time constant of the differentiator:

- ☐ a causes the output to change more quickly
- ☐ b increases the damping effect
- ☐ c corrects any steady state error
- ☐ d results in faster response

- Switch OFF the power supply, but

Keep the circuit connected if possible for the next exercise.

The diagram illustrates a control system for a DC motor. The main components and their interconnections are as follows:

- POWER AMPLIFIER:** Receives the input signal (I/P) and drives the DC motor (O/P).
- DC MOTOR:** The actuator that converts electrical energy into mechanical motion.
- SERVO POTENTIOMETER:** A feedback device that provides a position signal (O/P) to the DIFFERENTIATOR and the SUMMING AMPLIFIER.
- DIFFERENTIATOR:** Processes the servo potentiometer output with a transfer function $T \frac{dV_{IN}}{dt}$. It includes a TIME CONSTANT selector (100ms, 1s, 10ms) and a voltage meter (V).
- INTEGRATOR:** Processes the servo potentiometer output with a transfer function $\frac{1}{T} \int V_{IN} dt$. It includes a TIME CONSTANT selector (100ms, 1s, 10ms) and a RESET switch.
- INVERTER:** Provides a signal with a transfer function $-V_{IN}$.
- SUMMING AMPLIFIER:** Combines the outputs of the DIFFERENTIATOR, INTEGRATOR, and INVERTER (A + B + C) to produce the final control signal (O/P).
- DIFFERENTIAL AMPLIFIER:** Provides a signal with a transfer function $A - B$.
- INSTRUMENTATION AMPLIFIER:** Provides a signal with a transfer function $A - B$.
- WIREWOUND TRACK:** A 10kΩ potentiometer used for manual control or calibration.
- AMPLIFIER #1 and #2:** Two identical amplifier blocks, each with an OFFSET knob, a GAIN COARSE knob (1, 100, 10), and a GAIN FINE knob (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0).
- MOVING COIL METER:** A meter with a scale from -10 to +10, used for monitoring the system output.

The system is powered by a -5V and +5V supply. The connections between the blocks are shown by lines, indicating the flow of signals and feedback loops.

- Re-check the settings as follows:

- 320

- Set Amplifier #1 GAIN COARSE control to 10 and GAIN FINE to 0.1 to give an overall gain of 1.0.
- Switch ON the power supply.
- Connect the Moving Coil Meter temporarily to terminal B of the 10k Ω resistor and check the setting to its central position to give 0V output.
- Transfer the Moving Coil Meter back to the output of the Power Amplifier and check the adjustment of Amplifier #1 OFFSET to give 0V.
- Transfer the Moving Coil Meter to the output of Amplifier #2, set the GAIN COARSE control to 100 and GAIN FINE to 1.0 and check the adjustment of the OFFSET control for an output of +3V. Return the GAIN COARSE control to 1. This control will again be used to introduce a step input.
- Restore the power connection to the Motor.
- Press the Integrator RESET button and then connect the Integrator output to the Summing Amplifier input. Set Amplifier #1 GAIN COARSE to 10 and GAIN FINE to 1.0.
- Note and record in Table 18.6 the effect of applying a 3V step input to the system with all the possible combinations of Integrator and Differentiator time constants to note their effect and determine the combination giving optimum response, possibly with one small overshoot.

Test	Integrator time constant	Differentiator time constant	Continuous running YES/NO	Response time SLOW/MEDIUM/FAST	Number of Oscillations
1	10s	1s			
2		100ms			
3		10ms			
4	1s	1s			
5		100ms			
6		10ms			
7	100ms	1s			
8		100ms			
9		10ms			

Table 18.6

- Check your best results against each other, referring to the question below.



18.6a

Which of the following is the most desirable characteristic for a positional control system?

- ☐ a Continuous running
- ☐ b Slow response time, no oscillations
- ☐ c Fast response time, no oscillations
- ☐ d Fast response time, two or more oscillations

- Switch OFF the power supply, but

Keep the circuit connected if possible for the next exercise.