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Experiment - 1

• **Aim**: To study the speed of DC motor.

• **Apparatus**: DC motor speed control system.

• **Theory**

i) **Motor Unit**: Comprises of a small permanent magnet DC motor of V = 12V, 0.4A at full load. An overcurrent protection circuit is incorporated if current exceeds.

ii) **Control Unit**: It has speed measurement system, electronic tachogenerator, error detector & forward gain amplifier, digital voltmeter for measurement.

iii) **Speed Measurement System**: Disc attached with motor shaft with interrupt light falling apart a photodiode thus generates 10 pulses for every resolution. These pulses are fed to a single conditioner. The output indicates revolutions per minute.

iv) **Tachogenerator**: A proportional DC voltage is generated by a frequency to voltage converter. This voltage can be applied to motor amplifier by switch nearby tacho out socket.

Observations

Specifications :– K_A = Error Gain

K_A = 3, 4, 5, 6, 7, 8, 9

V_R = 0.7 V

Open Loop

On Load (with break)

~~Error~~ KA Gain	V_T	Speed
3	0.25	255
4	0.71	1161
5	0.88	1171
6	1.63	1628
7	2.09	2084
8	2.54	2547
9	3.00	2988

No Load (without brake)

Error	V_T	Speed
3	0.47	426
4	0.89	895
5	1.36	1365
6	1.84	1837
7	2.32	2312
8	2.78	2776
9	3.24	3233

Closed Loop

On Load (with brake)

Error	V_T	Speed
3	0.12	118
4	0.28	397
5	0.4	567
6	0.5	706
7	0.58	820
8	0.65	913
9	0.4	994
10	0.75	1062

No Load (Without brake)

Error	V_T	Speed
3	0.20	284
4	0.35	492
5	0.46	655
6	0.55	785
7	0.63	893
8	0.7	983
9	0.75	1062
10	0.80	1128

(v). Error detector & forward gain amplifier : In open loop the error signals are fed to an amplifier, the gain of which can be altred.

(vi) Motor driver amplifier : It's a unity gain amplifier designed to deliever necessary current to motor.

(vii) Digital Voltmeter : A common input of voltmeter is connected with system ground internally.

(viii) Signal Source : A DC reference voltage potentiometer provided for set point V & rectangular wave of big.

(ix). Break Control : Two position switch applied regulated DC voltage to an electromagnet fitted in motor for breaking purpose.

Procedure

Open Loop System

- Set V_R = 0.7 V. Adjust K_A = 41.7V. Keep switch towards left hand side thus motor runs in open loop.
- ~~Have~~ Note the RPM. Apply disturbances by mean of break.
- Switch OFF break.
- Set K_A = 6. Note RPM. Apply break.
- Do it for 2 readings with on load & no load.

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Closed Loop System

Set $K_A = 4$. Put switch towards V_1 at $V_R = 0.7V$ thus to make close loop circuit.
Repeat steps as ~~p~~ before taken for open loop.

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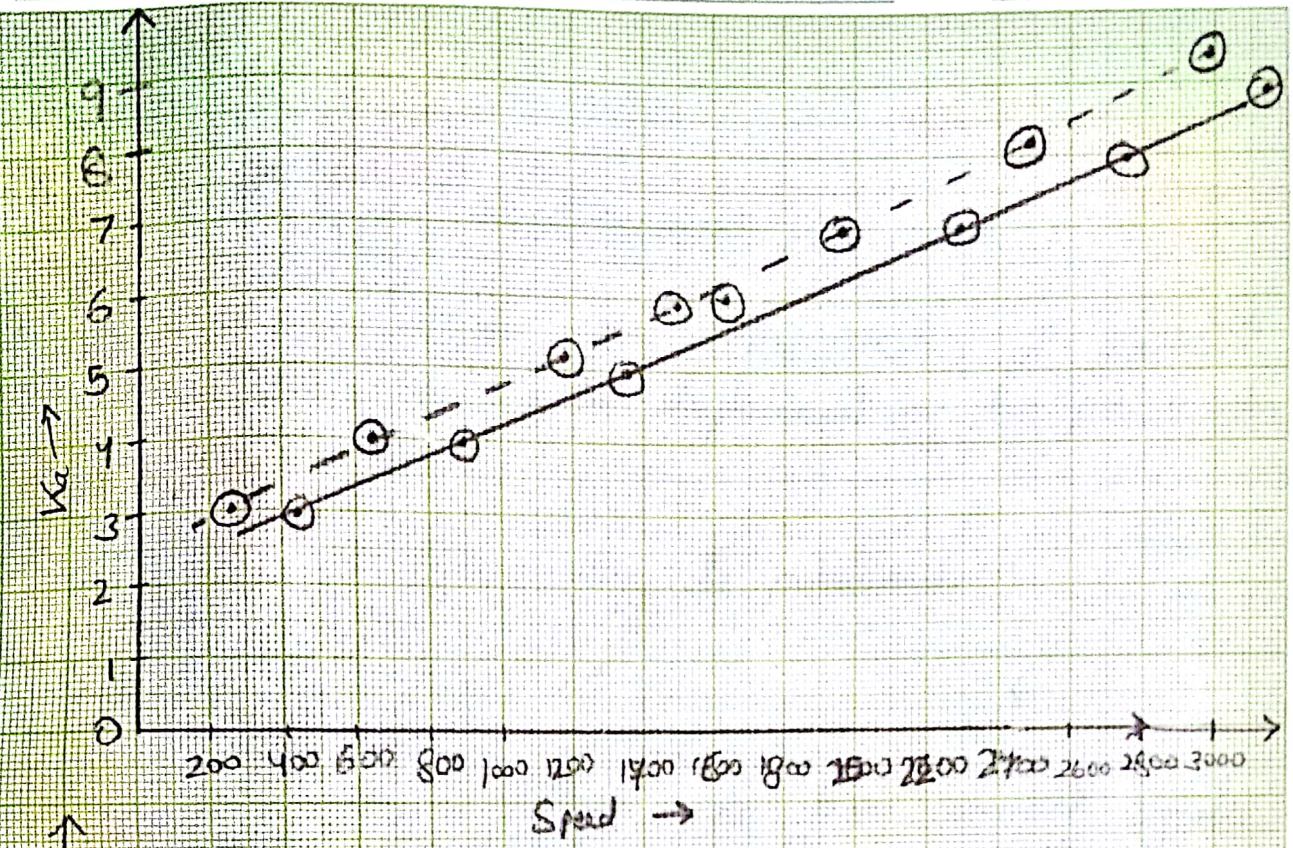
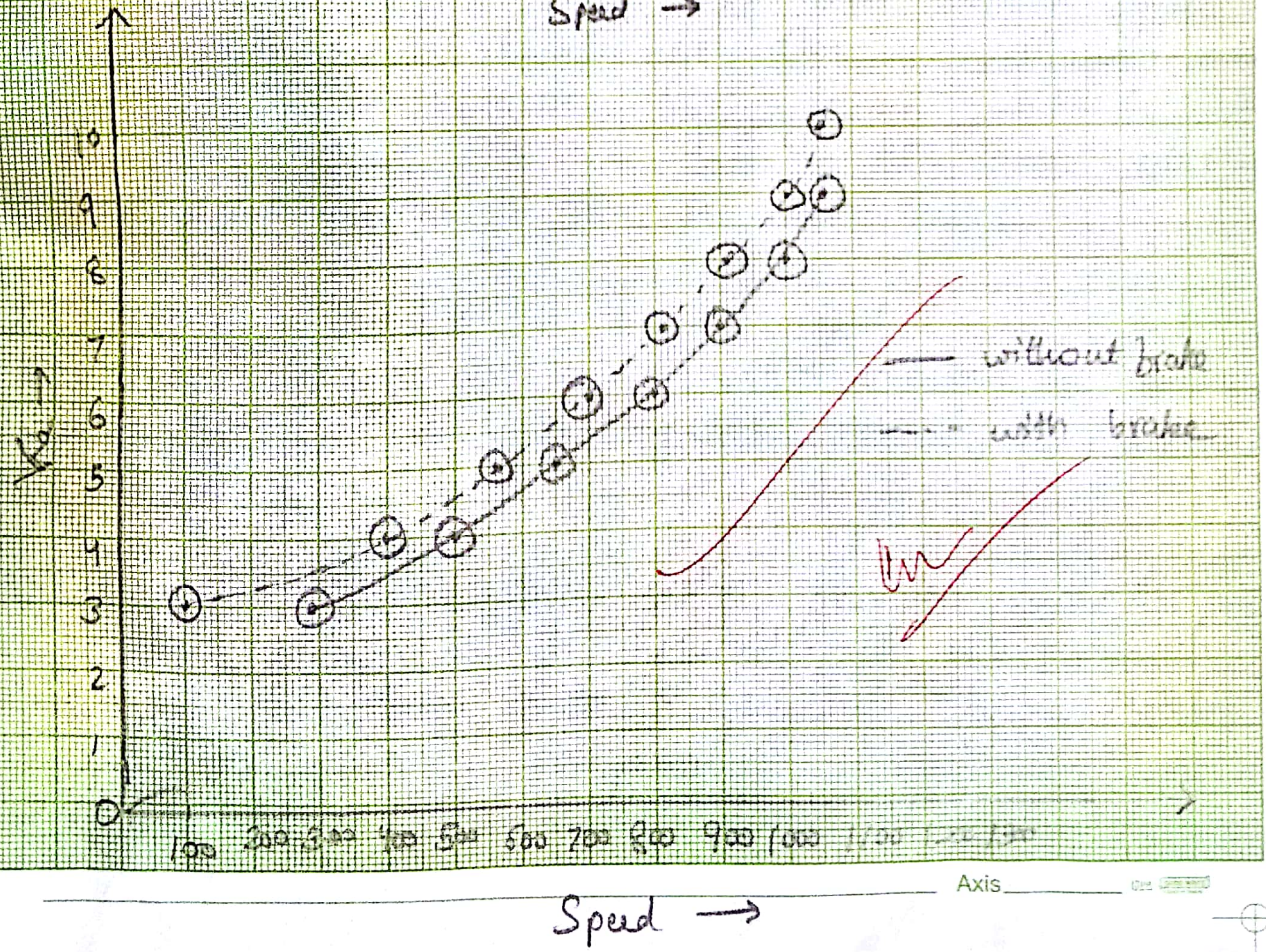


Axis



Axis

Experiment - 2

- **Aim** : To study the characteristics of positional error detector by angular displacement by two potentiometer exciting with AC.

- **Apparatus** : AC servomotor & potentiometer.

- **Theory**

1. **Command Signal** : There are two command signals provided in the control unit. One is continuous command 'Vr', which is given by reference potentiometer. The reference potentiometer is also a 360° servo potentiometer of same value as fitted in motor unit.

2. **Error Detector** : It is a two input & one output block. One of them is positive oriented for command signals Vr, & one negative oriented for feedback Vo.

3. **Gain Block** : The gain settings provided upon the panel. This block provides forward path gain KA in equal steps from 3 to 10 selected by a rotatory selector provided on panel.

$K_A = 3$

θ_R	θ_0	$\Delta\theta$
30	37	2
60	59	1
90	94	4
120	123	3
150	160	10
180	193	13

$K_A = 4$

θ_R	θ_0	$\Delta\theta$
30	31	1
60	64	4
90	103	13
120	114	106
150	148	10
180	192	13

$K_A = 5$

θ_R	θ_0	$\Delta\theta$
30	35	5
60	67	7
90	94	4
120	119	1
150	156	6
180	176	4

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4. Servo Amplifier Block : The servo amplifier is a push-pull transistorized amplifier operating from 36 V DC supply. Its voltage gain Ks is fixed at 20 & its output has quadrature phase.

5. Waveform Capture / display block : This memory card can capture the event, store it in RAM & then display the stored contents on CRO for detailed studies. The stored data is erased when new capture performed.

• Result
Characteristic of potential error detector by ang. disp. of two servo potentiometers excited with AC have been studied.

• Precautions & sources of Error

1. Servo potentiometer have 360° angular rotation but electrical travel is near 340°.

2. Due to gear backlash & intensity of potentiometer.

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Experiment 3

- **Aim**: To study the characteristics of potential error detector by angular displacement of two servo potentiometer excited with DC.

- **Apparatus**: DC motor position control - control unit, DC motor position control - Motor unit, power supply.

- **Theory**

This setup is designed to study DC motor position control system known as servo mechanism & is known as first in the automatic control system. Setup comprises of 2 parts -

(a). Motor Unit (b) Control unit.

* The motor unit consists of permanent magnet armature called geared servo motor & has technical specifications as follows -
  - Operating Voltage → 12V DC, 5W
  - Rated Shaft Speed → 50 RPM.
  - Torque → 3.5 kg/cm at load shift

The angular displacement is densed by a 360° servo potentiometer to indicate angular position with resolution.

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* **Control Unit** : This unit has reference servo potentiometer, voltage source, error detector, amplifier, motor driver circuit, RAM card, necessary regulated supplies for the circuit. The details of control unit are as follows –

Command Signal : There are 2 command signals which are provided in control unit. One is the continuous command signal given by the reference potentiometer also a 360° servo potentiometer of same values filled in the motor unit. Other command is in the form of a step signal of 11 sec duration.

• **Error Detector** : It is a 4 I/P 1 O/P block. Two of them are +ve oriented for command signals & two are –ve oriented for feedback.

Gain Blocks : There are 2 gain settings provided in the control unit of a DC motor position control. One block provides forward path gain K_A from 3–10 selected by a rotary switch provided on the panel. The other gain block is meant for tacho & has gain K_T selected from 0–1 in 10 steps.

Motor Driver Block : This driver unit has gain equal to one & is in the form of complementary push/pull stage to run the motor in either dir^n^.

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DVM : A 3 ½ digital voltmeter is provided to take readings of command & feedback voltage.

* Conclusion

(a). The angle θ has linear relationship with gain KA.

(b). The error in θ decreases as gain KA ↑ses.

* Result

The characteristics of positional error detector by angular displacement of two servo potentiometer excited with DC has been studied successfully & after the study, we found that increase in gain decreases the error but the system tends towards unstability.

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Experiment 4

- Aim : To perform basic operation used in MATLAB.

- MATLAB Code

```
g1 = tf ([4], [1 2 1])
g2 = tf ([4], [1 5])
g3 = series (g1, g2)
gp = g1 + g2
gf = feedback (g1, g2)
```

$$gs = \frac{28}{s^3 + 7s^2 + 11s + s}$$

Continuous - time transfer function.

$$gp = \frac{7s^2 + 18s + 27}{s^3 + 7s^2 + 11s + 5}$$

Continuous - time transfer function.

$$gf = \frac{4s + 20}{s^3 + 7s^2 + 11s + 33}$$

Continuous time transfer function.

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n1 = 6 * conv ([1, 1], [1,3])

n1 = 6 24 18

d1 = conv([1,2], conv ([1, 7], [1, 4]))

d1 = 1 13 50 56

G = tf (n1, d1)

$$G = \frac{6s^2 + 24s + 18}{s^3 + 13s^2 + 50s + 56}$$

Continuous time transfer fn.

[z, p, k] = tf2zp[n1, d1]

z = −3
−1

p = − 7.0000
− 4.0000
− 2.0000

k = 6

z = [−1, −2]

z = −1
−2

p = [1; 2; 3]

p = 1
2
3

k = 7

[n, d] = zp2tf (z, p, k)

n = 0 7 21 14
d = 1 -6 11 -6
g1 = tf (n, d)

$$g_1 = \frac{7s^2 + 21s + 14}{s^3 - 6s^2 + 11s - 6}$$

Continuous time transfer function.

Result

The basic operations in MATLAB have been performed in control system.

14/3/2017

Experiment 5

- **Aim**: Plot impulse response, unit step response, unit ramp response of any 2^{nd} order transfer function on same graph using MATLAB.

- **Given**: System gain, $K = 15$
  Damping ratio, $\Sigma = 0.65$
  Unbounded natural frequency, $\omega_4 = 4\ Hz$

- **Theory**: For unit step input,
  $$r(t) = u(t)$$
  $$\mathcal{L}\{r(t)\} = R(s) = 1/s$$
  For unit impulse input:
  $$r(t) = u(t) = 1$$
  For unit ramp input:
  $$r(t) = u(t)$$
  $$\mathcal{L}(r(t)) = R(s) = 1/s^2$$

Transfer function:
$$G(s) = \frac{K \times \omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2}$$

MATLAB Code:

```
s = tf('s');
k = 15
```

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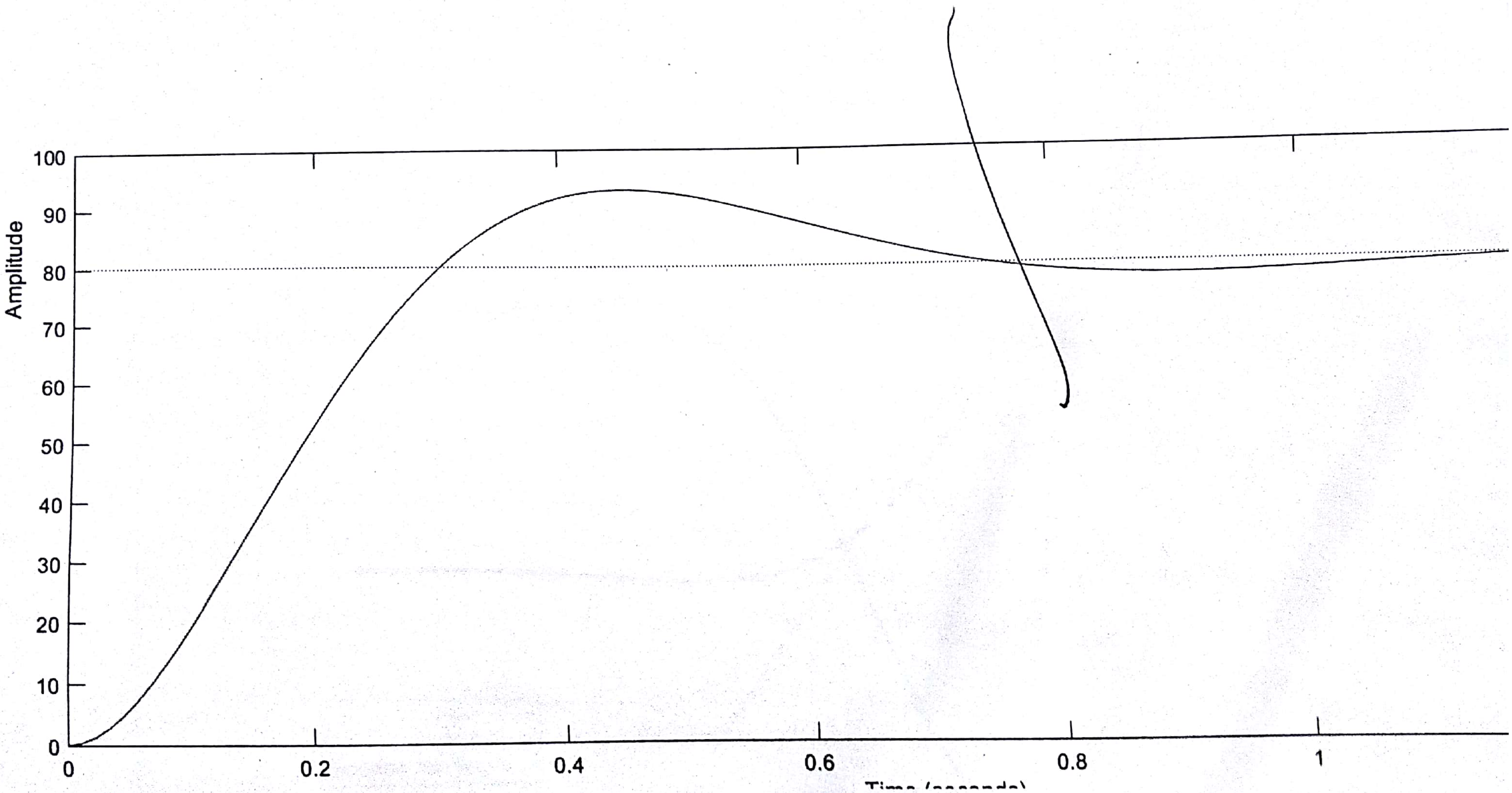
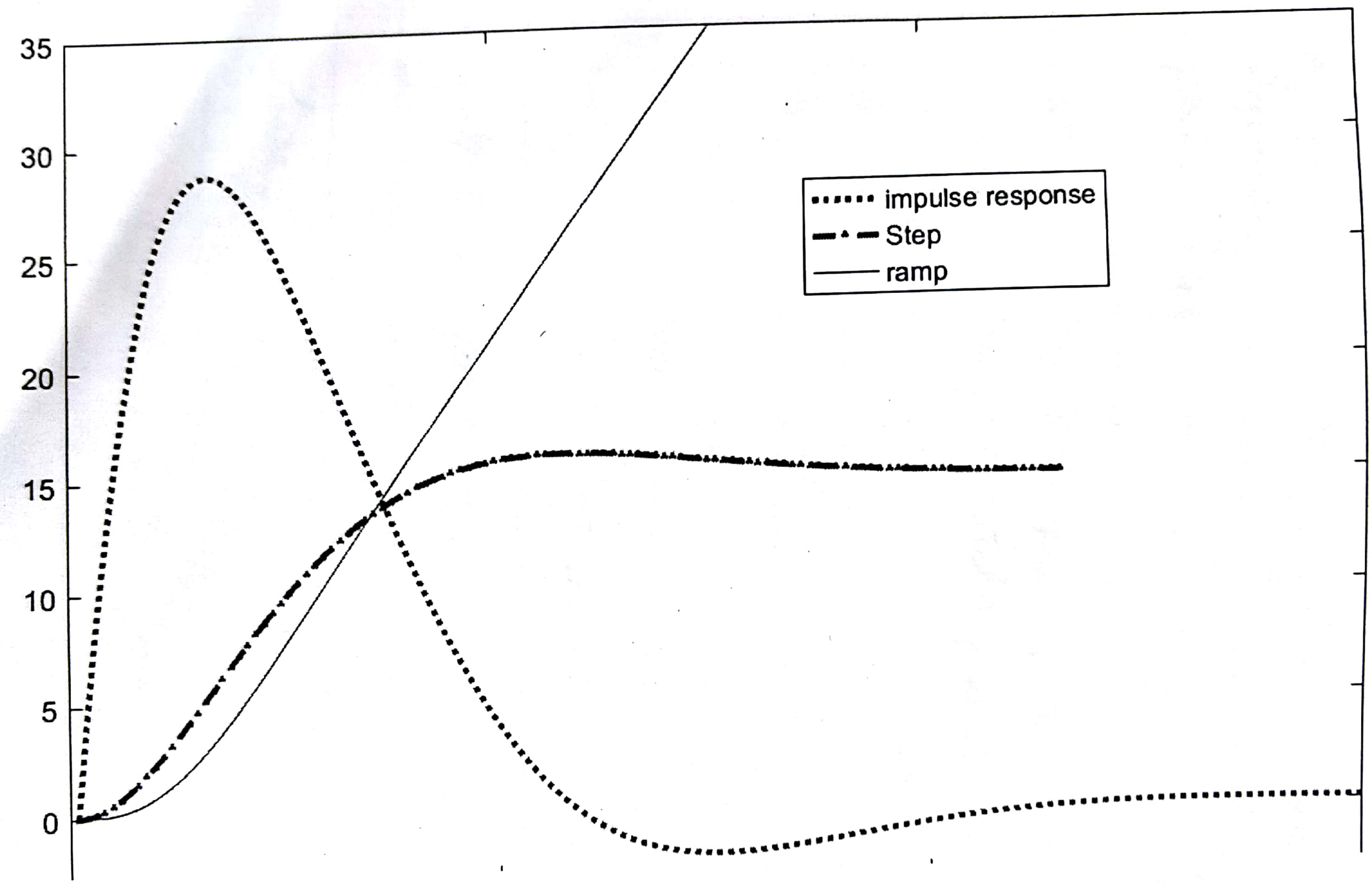
```
z = 0.65;
ω = 4;
G = k*ω*ω /((s^2)+2*z*ω*s)+(ω^2)
plot(impulse(G));
hold on
plot(step(G));
hold on
plot(step(G/s));
hold on
axis([0 140 -1 15])
```

Result

Unit Step response, unit ramp response, & impulse response of given 2nd order transfer function has been calculated & plotted successfully on MATLAB.

14/3/2018


Amplitude
100
90
80
70
60
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1



35
30
25
20
15
10
5
0
impulse response
Step
ramp

Experiment - 6

- Aim : To study AC motor position control & plot dynamic response & calculate peak time, settling time, peak overshoot, damping frequency, steady state err, etc.

Given : System gain, $k = 80$
damping ratio, $\delta = 0.5$

Theory

Transfer function (2nd order), $G(s) = \frac{k \times \omega_n^2}{s^2 + 2\delta\omega_n s + \omega_n^2}$

Using given values,

$$G(s) = \frac{80 \times 8^2}{s^2 + 2 \times 0.5 \times 8 \times s + 8^2} = \frac{5120}{s^2 + 8s + 64}$$

Output response $c(t)$ for unit step input $r(t) = u(t)$ is

$$c(t) = 80\left[1 - \frac{e^{-4t}}{0.866}\sin(6.928\,t + 1.732)\right]$$

where,

- Peak Time : It's the time required for the purpose to reach the first peak of overshoot, (Tp) peak time.

$$T_p = \frac{\pi}{\omega_d} = \frac{3.14}{6.928} = 0.45346 \text{ sec.}$$

- Delay Time : Is the time required for response to reach half the final value the very first time.

$$T_D = \frac{1 + 0.7\delta}{\omega_n} = \frac{1.35}{8} = 0.16875 \text{ sec}$$

Overshoot : is when a signal or function exceeds the target. It is often associated with ringing

$$M_p = e^{-\pi\delta/\sqrt{1-\delta^2}} \times 100\% = 16.13\%$$

Settling Time : is time elapsed from application of an ideal instantaneous step input to time at which output has entered & remained within error band.

$$T_s = \frac{4}{\delta\omega_n} = \frac{4}{0.5\times 8} = 1 sec$$

Matlab Code

```
s = tf('s');
k = 80;
z = 0.5;
w = 8;
G = k*w*w/(s^2)+(2*z*w*s)+(w^2);
step(G);
hold on
stepinfo(G);
```

Result

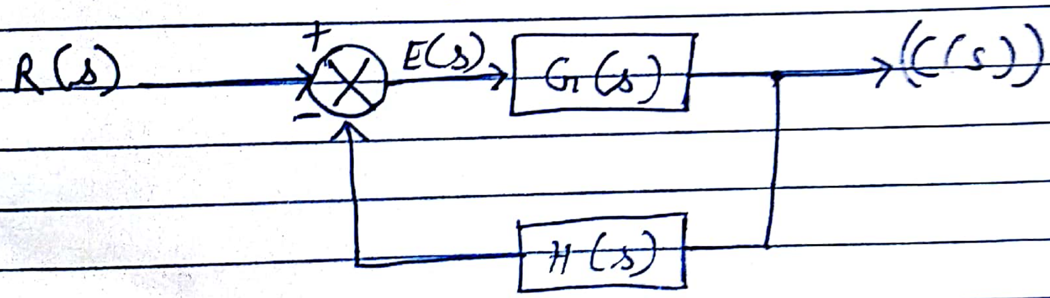
The peak time, settling time peak overshoot, ess, etc for AC motor position control has been has been calculated.

Experiment 6 (b)

- **Aim**: To determine the steady state error of the system where forward path function is given by $G(s) = 20/s(s+2)(s^2+2s+20)$ where I/Ps are – (i) 5 (ii) 5t (iii) $3t^2/2$.

- **Theory**: The steady state error is the difference between the input & output of system during steady state. For accuracy, the steady state error should be maximum.

It is represented by e_{ss}.



- **MATLAB Code**

```
clear
clc
numg = [20];
deng = conv(cov([1 0], [1 2]), [1 2 20]);
G = tf(numg, deng)
kp = dcgain(G)
```

'steady state error for s is'

↳ ess

```
numsg = conv([1 0], [20]);
densg = deng;
sG = tf(numsg, densg);
Kv = dcgain(sG);
```

'steady state error for st is'

↳ ess = 5/kv

```
nums2g = conv([1 0], numsg);
dens2g = deng;
ka = dcgain(s2g)
```

'steady state error for 3t^2/t is'

↳ ess = 3/ka.

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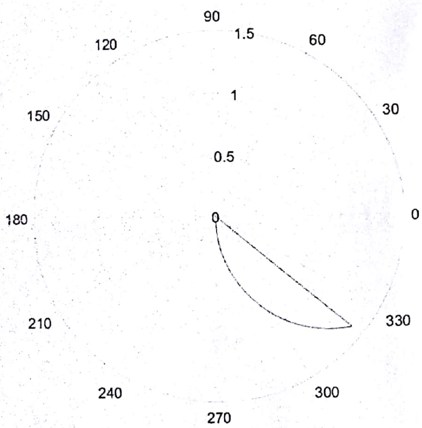
$$G(s) = \frac{20s}{(1+s)(10+s)}$$



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Experiment - 7

- **Aim** : To sketch polar plot of $20s/(1+s)(10+s)$
- **Software Used** : MATLAB
- **Source Code**

```
Clear all
x = [1:1000]
for i = 1 : 1000
    xx(i] = i/(i+i+4);
  end
    plot (x, xx);
    ω = [0.1: 0.01 :1000];
    n = length(ω)
    m(i) = abs ((20x ω*j) /((complex(2, ω(i)) )*
                                   ((complex(10, ω(i))));
    ph (i)= angle (20/complex (2, ω(i)))*(i complex
                                   10, ω(i))));

    end;
    polarplot(ph, m)
```

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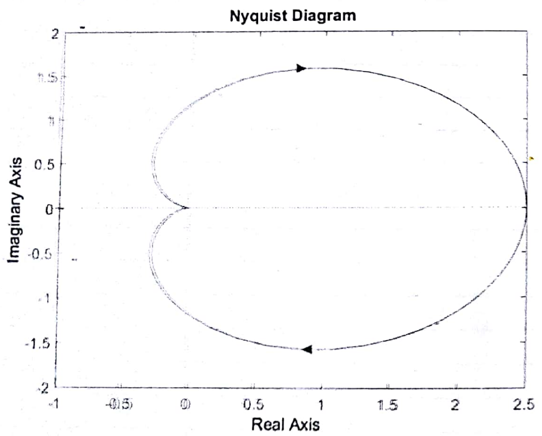

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Experiment 8

- **Aim** : To sketch nyquist plot for $20/(s+2)(s+4)$
- **Software Used** : MATLAB
- **Source Code**

```
Clear all;
n = [20];
d = conv [1,2] ,[1 4];
t = tf(n,d);
nyquist (t);
```

Result

Nyquist plot for the given function has been performed.

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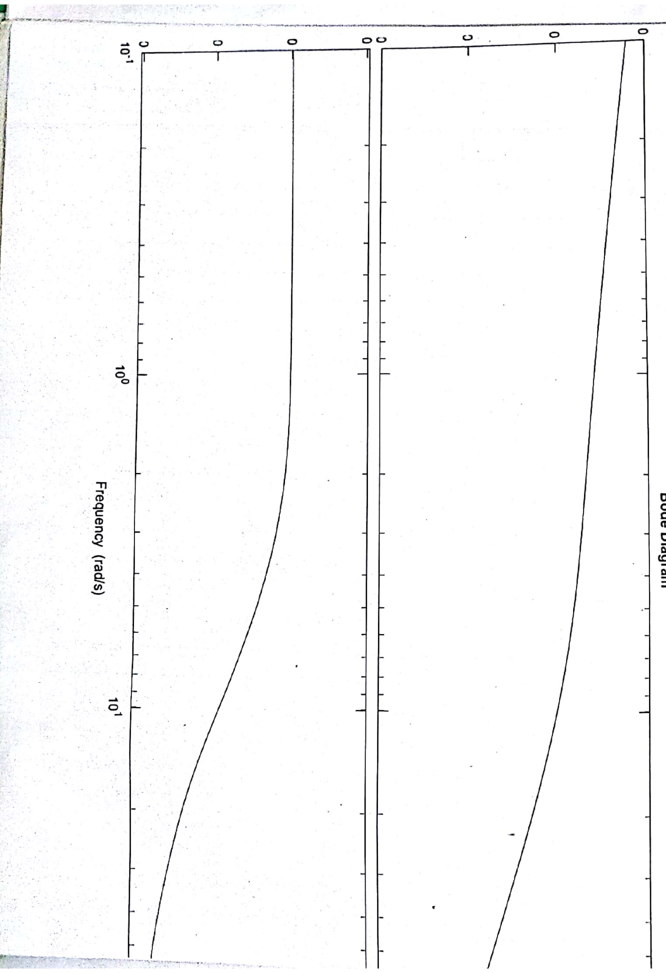

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Experiment 9

- **Aim** : To sketch Bode Plot of the given function using MATLAB.

$$G(s) = \frac{6(s+2)}{s(s+4)(s+10)^2}$$

- **S/w Used** : MATLAB

- **Source Code**

```
clear all;
n = conv([1 2], [0 6])
d = conv(conv(conv([1 0], [1 4]), [1 10]), [1 10]);
t = tf(n,d);
bode (t);
```

- **Result**

The Bode plot of the given function has been plotted successfully.

- **Theory**

bode(sys) creates a bode plot of frequency response of a dynamic system. Plot displays the magnitude in dB & phase in degrees.

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