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CONTROL SYSTEMS

Oct./Nov. 2010

Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN ELECTRONIC ENGINEERING

DIPLOMA IN TELECOMMUNICATION ENGINEERING

DIPLOMA IN ELECTRICAL ENGINEERING (POWER)

CONTROL SYSTEMS

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:

Answer booklet;

Electronic calculator;

Four cycle log linear graph paper,

Laplace transform tables;

8085 instruction set;

Nichol chart.

*Answer any **FIVE** of the **EIGHT** questions in this paper.*

All questions carry equal marks.

Maximum marks for each part of a question are as shown.

This paper consists of 10 printed pages.

Candidates should check the question paper to ascertain that all the pages are printed as indicated and that no questions are missing.

1. (a) (i) List any **two** unique features of open-loop control systems.
- (ii) State with reasons whether the control system used in each of the following systems is closed or open loop.
- I. Automatic bread toaster;
 II. Autopilot mechanism. (6 marks)
- (b) With the aid of a labelled diagram, explain the operation of a control system that fills a container with water after it is emptied through a tap at the bottom. The system must automatically shut off the water flow when the container is filled. (8 marks)
- (c) Draw block diagrams for each of the following equations:
- (i) $Y_3 = \frac{d^2y_2}{dt^2} + a_1 \frac{dy_1}{dt} - Y_1;$
- (ii) $Y_4 = b \int Y_3 dt.$ (6 marks)
2. A positional control system uses syncros for error detection and viscous friction damping. The syncro output is 0.8 per degree of error and the coefficient of viscous friction is 50 N-m per rad/s. The motor torque constant referred to the load side is 80×10^{-3} N - m/mA and the total inertia of the system is 0.9 kg-m².

The system has a damping ratio of 0.7.

- (a) Draw the block diagram of the system. (2 marks)
- (b) From the block diagram in 2(a) or otherwise determine the:
- (i) differential equation;
 - (ii) transconductance of the amplifier;
 - (iii) undamped natural frequency;
 - (iv) steady state velocity error when the input shaft is rotated at a constant speed of 20 rev/min. (18 marks)

3. (a) An open loop control system is described by the following transfer function:

$$GH(s) = \frac{4}{s(1+s)(1+\frac{s}{3})}$$

For the function:

- (i) draw the db - magnitude - versus phase on a Nichols chart, for values of $\omega = 0.1, 0.2, 0.5, 1.0, 1.5, 2.0, 3.0,$ and 4.0.

(ii) determine the :

- (I) phase crossover frequency;
- (II) gain cross-over frequency;
- (III) phase margin;
- (IV) gain margin;
- (V) bandwidth.

(14 marks)

(b) Figure 1 shows a block diagram of a control system. For the system:

(i) reduce it to its canonical form;

(ii) determine the error ratio. (6 marks)

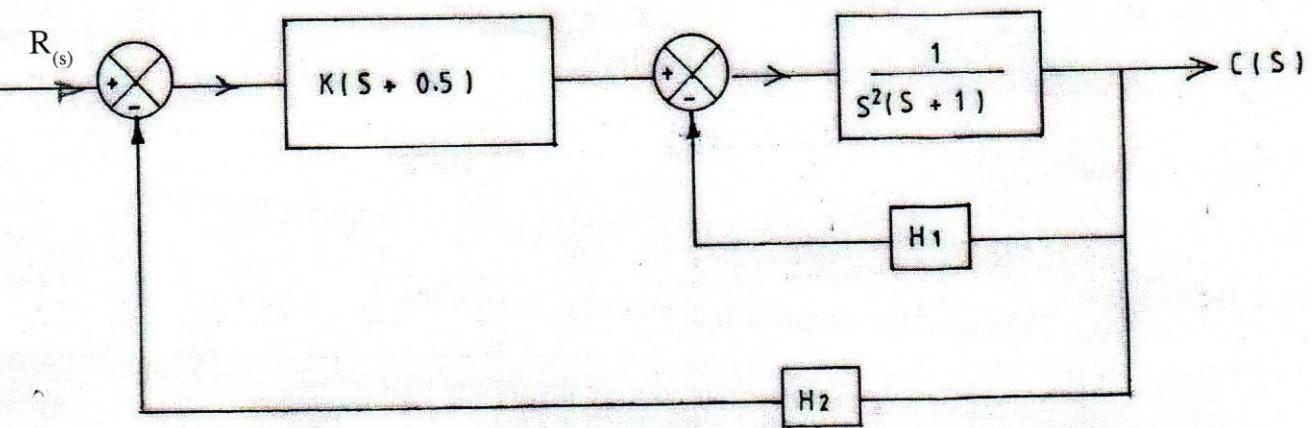


FIG. 1

4. (a) A plant is controlled by digital inputs from four sensors A, B, C and D.

It produces an output F, when:

(i) the output of sensor A is present and output from sensor B is absent;

(ii) the output of sensor B is present and either the output of sensors C or D is present. Otherwise no output. Assume sensor output present = 1, plant output present = 1, otherwise sensor absent = 0, and plant output absent = 0.

For the plant:

- (i) obtain the truth table of the digital controller;
- (ii) obtain a logic expression for the controller output;
- (iii) draw a logic circuit diagram for the controller. (8 marks)

(b) Kamau has always used a driver motor IC to drive a four phase stepper motor. However the driver IC has been burning out and he wishes to use a direct digital controlled (DDC) motor drive, with output port at 21H and input port at port 22. The command port is at 20H with a control word of 01.

(i) draw a flow chart to implement the control for the system in 4(b).

(ii) write a program segment for 4b(i). (12 marks)

5. (a) State:

(i) any **two** characteristics of an ideal operational amplifier (OPAM);

(ii) the need for simulation in analogue computing. (4 marks)

(b) With the aid of a circuit diagram, derive the output expression for a 3-input OPAMP based summing integrator. (6 marks)

(c) Figure 2 shows a graphical representation of two functions. For each function

(i) derive a scaled equation;

(ii) draw the flow diagram. (10 marks)

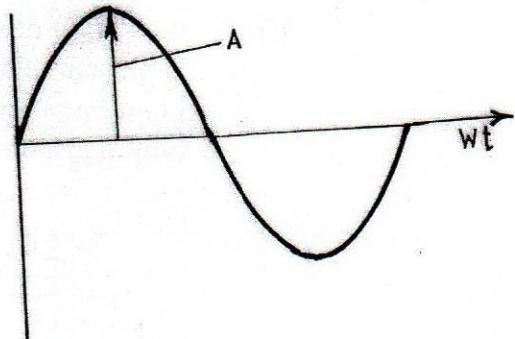
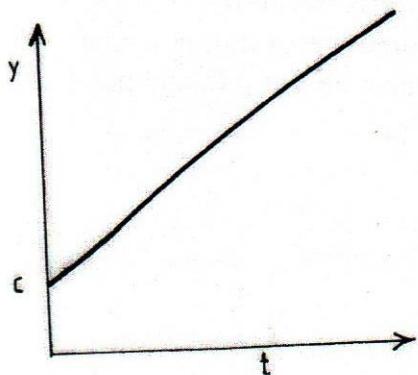


FIG.2

6. (a) Draw a labelled diagram of a programmable logic controller (PLC) and state the function of each block. (10 marks)
- (b) Khadija is a process engineer. She monitors the temperature, pressure, humidity and acidity of a plant process. She manually regulates the variables to within bounds. With the aid of a block diagram describe a computerised solution for the control of the plant. (10 marks)
7. (a) With the aid of a labelled diagram describe the following as applied to a second order control system.
- (i) rise time;
 - (ii) delay time;
 - (iii) time to first overshoot;
 - (iv) percentage overshoot.
- (8 marks)
- (b) A second order positional control system has a damping ratio of 0.7 and an undamped frequency of 6 rad/sec. Determine the output response when the system is subjected to a unit ramp test signal. (8 marks)
- (c) An electrical system has a resistance of 0.2Ω and inductance of 5mH . If the initial voltage on the inductance is 5V , determine the:
- (i) time constant (τ);
 - (ii) the voltage, two time constants later.
- (4 marks)
8. (a) (i) Define compensation.
- (ii) Compare and contrast the effect of phase lead and phase lag network on the system characteristics indicated in Table 1.

Table 1

Characteristics	Phase lead	Phase lag
Relative stability		
Gain		
Bandwidth		
Rise time		

(5 marks)

(b) A control system is described by the expression given by:

$$G(s) = \frac{40}{s(1 + 0.2s)(1 + 0.4s)}$$

For the system, design a phase lag compensation for a phase margin of 15° , using
Bode plot method. (11 marks)

(c) Determine the range of K for which the system with the characteristic equation
 $S^3 + 6S^2 + 16S + K = 0$ remains stable. (4 marks)

TABLE OF LAPLACE TRANSFORM FORMULAS

$$\mathcal{L}[t^n] = \frac{n!}{s^{n+1}}$$

$$\mathcal{L}^{-1}\left[\frac{1}{s^n}\right] = \frac{1}{(n-1)!} t^{n-1}$$

$$\mathcal{L}[e^{at}] = \frac{1}{s-a}$$

$$\mathcal{L}^{-1}\left[\frac{1}{s-a}\right] = e^{at}$$

$$\mathcal{L}[\sin at] = \frac{a}{s^2 + a^2}$$

$$\mathcal{L}^{-1}\left[\frac{1}{s^2 + a^2}\right] = \frac{1}{a} \sin at$$

$$\mathcal{L}[\cos at] = \frac{s}{s^2 + a^2}$$

$$\mathcal{L}^{-1}\left[\frac{s}{s^2 + a^2}\right] = \cos at$$

First Differentiation Formula

$$\mathcal{L}[f^{(n)}(t)] = s^n \mathcal{L}[f(t)] - s^{n-1}f(0) - s^{n-2}f'(0) - \dots - f^{(n-1)}(0)$$

$$\mathcal{L}\left[\int_0^t f(u) du\right] = \frac{1}{s} \mathcal{L}[f(t)]$$

$$\mathcal{L}^{-1}\left[\frac{1}{s} F(s)\right] = \int_0^t \mathcal{L}^{-1}[F(s)] du$$

In the following formulas, $F(s) = \mathcal{L}[f(t)]$ so $f(t) = \mathcal{L}^{-1}[F(s)]$.

First Shift Formula

$$\mathcal{L}[e^{at}f(t)] = F(s-a)$$

$$\mathcal{L}^{-1}[F(s)] = e^{at} \mathcal{L}^{-1}[F(s+a)]$$

Second Differentiation Formula

$$\mathcal{L}[t^n f(t)] = (-1)^n \frac{d^n}{ds^n} \mathcal{L}[f(t)]$$

$$\mathcal{L}^{-1}\left[\frac{d^n F(s)}{ds^n}\right] = (-1)^n t^n f(t)$$

Second Shift Formula

$$\mathcal{L}[u_a(t)g(t)] = e^{-as} \mathcal{L}[g(t+a)]$$

$$\mathcal{L}^{-1}[e^{-as}F(s)] = u_a(t)f(t-a)$$

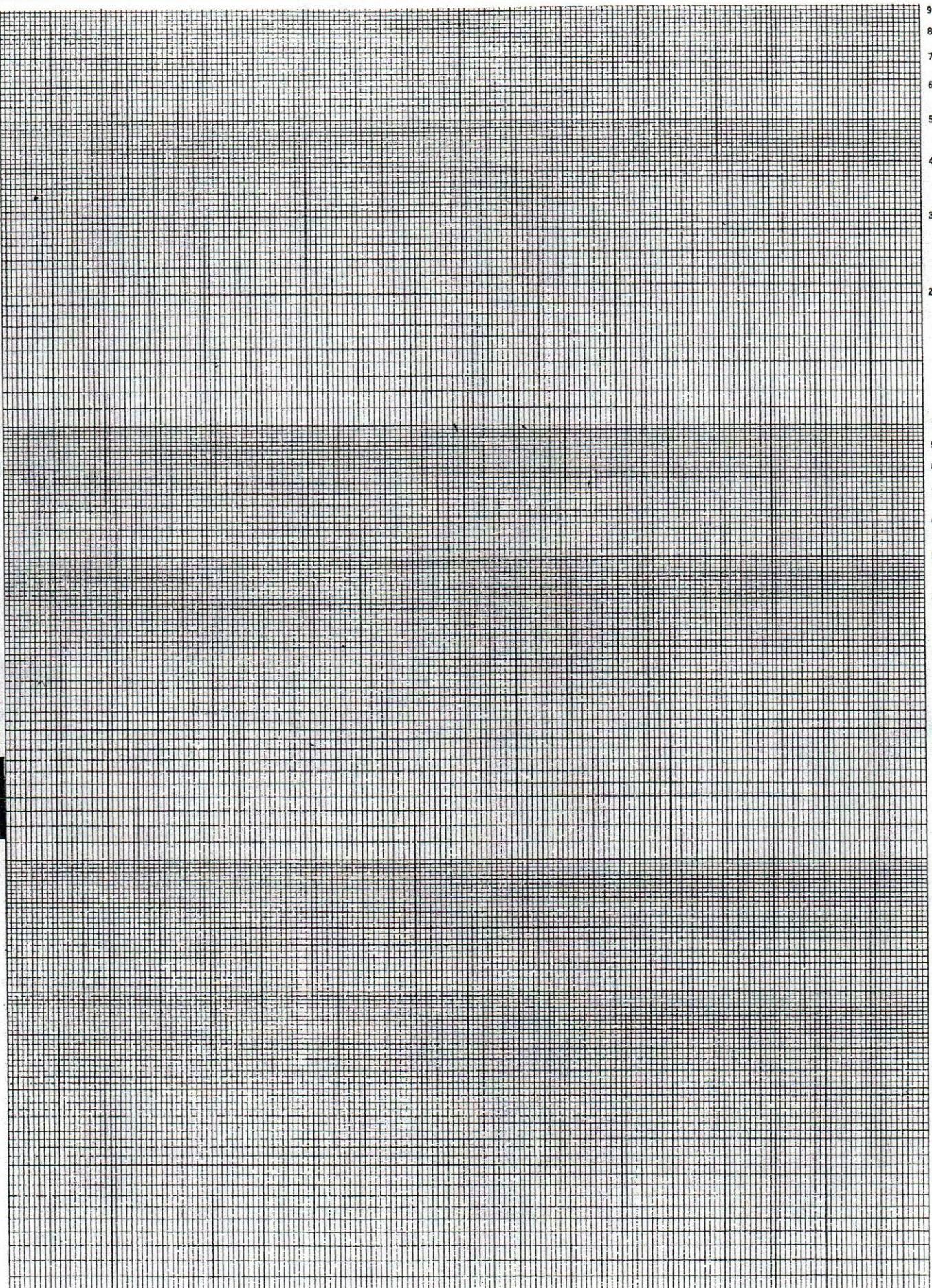
OP CODE	MNEMONIC	OP CODE	MNEMONIC	OP CODE	MNEMONIC	OP CODE	MNEMONIC	OP CODE	MNEMONIC	OP CODE	MNEMONIC
00	NOP	2B	DCX H	56	MOV D,M	81	ADD C	AC	XRA II	D7	RST 2
01	LX1 B,D16	2C	INR L	57	MOV D,A	82	ADD D	AD	XRA L	D8	RC
02	STAX B	2D	DCR L	58	MOV E,B	83	ADD E	AE	XRA M	D9	-
03	INX B	2E	MVI L,DB	59	MOV E,C	84	ADD H	AF	XRA A	DA	JC Adr
04	INR B	2F	CMA	5A	MOV E,D	85	ADD L	B0	ORA B	DB	IN D8
05	DCR B	30	SIM	5B	MOV E,E	86	ADD M	B1	ORA C	DC	CC Adr
06	MVI B,DB	31	LXI SPD16	5C	MOV E,H	87	ADD A	B2	ORA D	DD	-
07	RLC	32	STA Adr	5D	MOV E,L	88	ADC B	B3	ORA E	DE	SBI D8
08	-	33	INX SP	5E	MOV E,M	89	ADC C	B4	ORA H	DF	RST 3
09	DAD B	34	INR M	5F	MOV E,A	8A	ADC D	B5	ORA L	E0	RPO
0A	LDAX B	35	DCR M	60	MOV H,B	8B	ADC E	B6	ORA M	E1	POP H
0B	DCX B	36	MVI M,DB	61	MOV H,C	8C	ADC H	B7	ORA A	E2	JPO Adr
0C	INR C	37	STC	62	MOV H,D	8D	ADC L	B8	CMP B	E3	XTHL
0D	DCR C	38	-	63	MOV H,E	8E	ADC M	B9	CMP C	E4	CPO Adr
0E	MVI C,DB	39	DAD SP	64	MOV H,H	8F	ADC A	BA	CMP D	E5	PUSH H
0F	RRC	3A	LDA Adr	65	MOV H,L	8G	SUB B	BB	CMP E	E6	ANI D8
10	--	3B	DCX SP	66	MOV H,M	91	SUB C	BC	CMP H	E7	RST 4
11	LXI D,D16	3C	INR A	67	MOV H,A	92	SUB D	BD	CMP L	E8	RPE
12	STAX D	3D	DCR A	68	MOV L,B	93	SUB E	BE	CMP M	E9	PCHL
13	INX D	3E	MVI A,DB	69	MOV L,C	94	SUB H	BF	CMP A	EA	JPE Adr
14	INR D	3F	CMC	6A	MOV L,D	95	SUB L	CO	RNZ	EB	XCHG
15	DCR D	40	MOV B,B	6B	MOV L,E	96	SUB M	C1	POP B	EC	CPE Adr
16	MVI D,DB	41	MOV B,C	6C	MOV L,H	97	SUB A	C2	JNZ Adr	ED	--
17	RAL	42	MOV B,D	6D	MOV L,L	98	SBB B	C3	JMP Adr	EE	ERI D8
18	--	43	MOV B,E	6E	MOV L,M	99	SBB C	C4	CNZ Adr	EF	RST 5
19	DAD D	44	MOV B,H	6F	MOV L,A	9A	SBB D	C5	PUSH B	F0	RP
1A	LDAX D	45	MOV B,L	70	MOV M,B	9B	SBB E	C6	ADI D8	F1	POP PSW
1B	DCX D	46	MOV B,M	71	MOV M,C	9C	SBB H	C7	RST 0	F2	JP Adr
1C	INR E	47	MOV B,A	72	MOV M,D	9D	SBB L	C8	RZ	F3	DI
1D	DRC E	48	MOV C,B	73	MOV M,E	9E	SBB M	C9	RET Adr	F4	CP Adr
1E	MVI E,DB	49	MOV C,C	74	MOV M,H	9F	SBB A	CA	JZ	F5	PUSH PSW
1F	RAR	4A	MOV C,D	75	MOV M,L	A0	ANA B	CB	--	F6	ORI D8
20	RIM	4B	MOV C,E	76	HLT	A1	ANA C	CC	CZ Adr	F7	RST 6
21	LXI H,D16	4C	MOV C,H	77	MOV M,A	A2	ANA D	CD	CALL Adr	F8	RM
22	SHLD Adr	4D	MOV C,L	78	MOV A,B	A3	ANA E	CE	ACI D8	F9	SPHL
23	INX H	4E	MOV C,M	79	MOV A,C	A4	ANA H	CF	RST 1	FA	JM Adr
24	INR H	4F	MOV C,A	7A	MOV A,D	A5	ANA L	D0	RNC	FB	E1
25	DCR H	50	MOV D,B	7B	MOV A,E	A6	ANA M	D1	POP D	FC	CM Adr
26	MVI H,DB	51	MOV D,C	7C	MOV A,H	A7	ANA A	D2	JNC Adr	FD	--
27	DAA	52	MOV D,D	7D	MOV A,L	A8	XRA B	D3	OUT D8	FE	CPI D8
28	--	53	MOV D,E	7E	MOV A,M	A9	XRA C	D4	CNC Adr	FF	RST 7
29	DAD H	54	MOV D,H	7F	MOV A,A	AA	XRA D	D5	PUSH D		
2A	LHLD Adr	55	MOV D,L	80	ADD B	AB	XRA E	D6	SUI D8		

D8 = constant, or logical/arithmetic expression that evaluates to an 8-bit data quantity. D16 = constant, or logical/arithmetic expression that evaluates to a 16-bit data quantity. Adr = 16-bit address.

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3 Cycles x mm, $\frac{1}{2}$ and 1 cm

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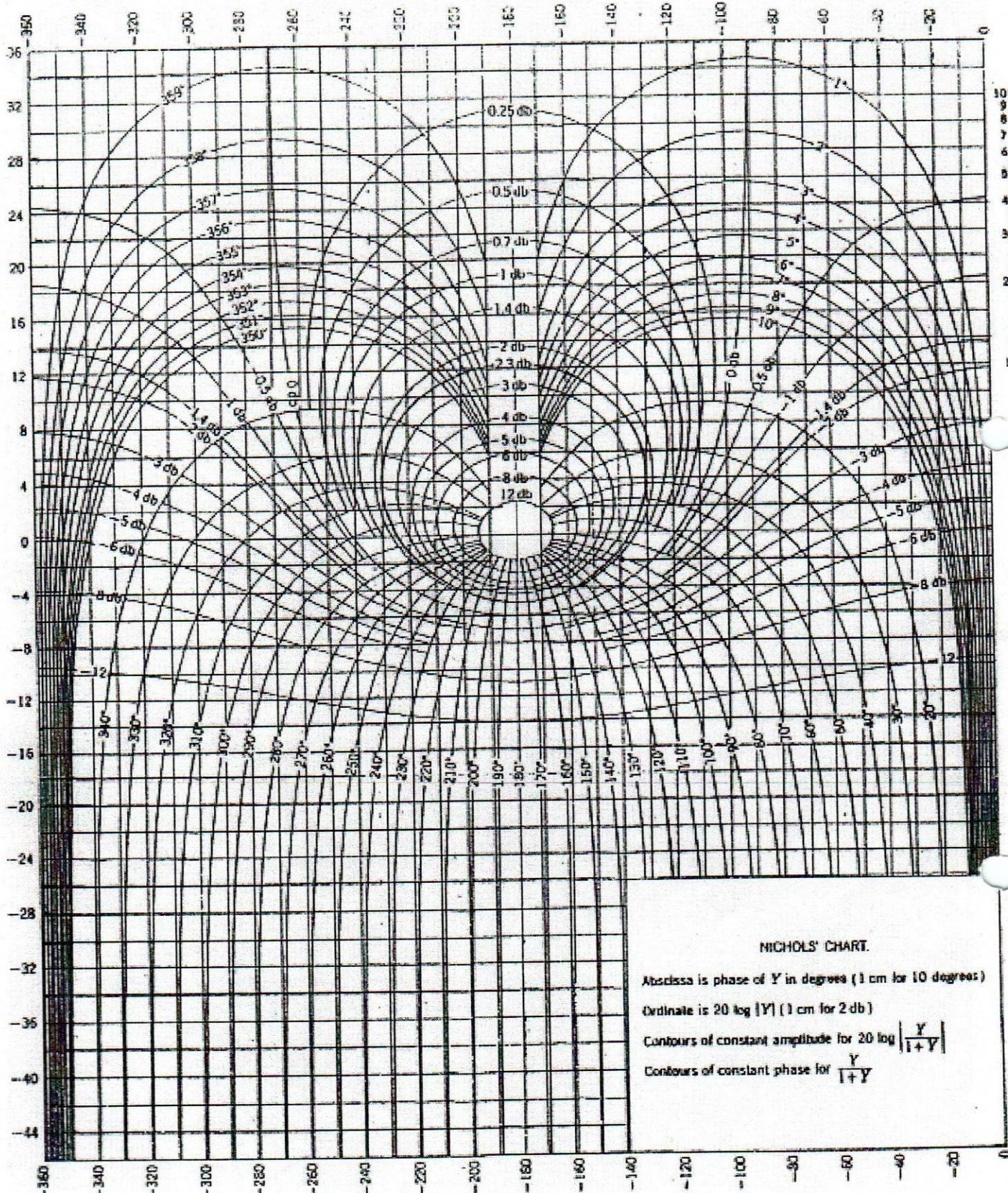


Figure 3 • Pole, Zero, and Nichols' Feedback Control Systems