higher education
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Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T430**(E)**(A15)T

NATIONAL CERTIFICATE

CONTROL SYSTEMS N6

(8080016)

15 April 2019 (X-Paper)
09:00–12:00

REQUIREMENTS: 3-cycle semi-logarithmic graph paper

This question paper consists of 7 pages, 1 diagram sheet, a formula sheet of 2 pages, 1 Nichols chart and 3 Laplace transform pages.

DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
CONTROL SYSTEMS N6
TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer ALL the questions.
2. Read ALL the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. Neat, labelled circuit diagrams must be used in the explanation of answers only where they are requested.
5. Use only BLUE or BLACK ink.
6. Make use of drawing equipment and a pencil for ALL sketches and diagrams.
7. Write neatly and legibly.

QUESTION 1

Indicate whether the following statements are TRUE or FALSE. Choose the answer and write only 'True' or 'False' next to the question number (1.1–1.10) in the ANSWER BOOK.

1.1 A system is a combination of components that act together to perform a function not possible with any of the individual parts.

1.2 A system may become unstable if the output grows although no signal is applied to the system.

1.3 An input is the quantity that must be maintained at a prescribed value.

1.4 In a closed-loop system the output signal has no effect on the input signal.

1.5 A block diagram is a shorthand pictorial representation of the cause and effect relationship between the input and output of a system.

1.6 A phase margin is when the gain corresponds to the point where the phase crosses the 180° line.

1.7 Underdamping is where the response tends to overshoot the goal with oscillations decaying very slowly or not at all.

1.8 A sine function is a function of time that rises or falls in a linear fashion at a constant rate.

1.9 In a derivative control the controlled output varies directly with the input or system error.

1.10 In an integral control the correction that is made is proportional to the time integral of the error.

(10 × 1) **[10]**

QUESTION 2

2.1 Determine, with the aid of an algebra reduction block diagram, the control ratio of the block diagram in FIGURE 1.

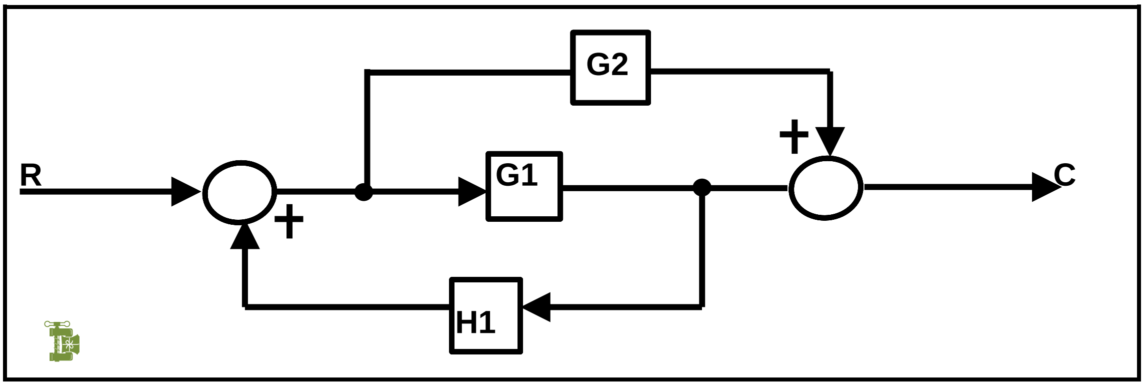


FIGURE 1 (5)

2.2 What do the symbols G and H in FIGURE 1 represent? (2)

2.3 State TWO uses of block diagrams in control systems. (2)

2.4 State the function of a summing network or summing junction. (1)
[10]

QUESTION 3

The DIAGRAM SHEET (attached) shows a gain versus frequency and a phase versus frequency curve of a system.

Determine the following from the graph:

3.1 The slope of the gain versus frequency response between 1 rad/s and 10 rad/s (1)

3.2 The slope of the phase versus frequency response between 5 rad/s and 15 rad/s (1)

3.3 The gain crossover frequency (1)

3.4 The phase crossover frequency (1)

3.5 The phase value at the gain crossover frequency (1)

3.6 The value of the gain where the phase value is -180° (1)

3.7 The gain margin (1)

3.8 The phase margin (1)

3.9 The stability of the system (2)
[10]

QUESTION 4

4.1 The derived closed-loop response values of a certain control system test are shown in the table below.

Plot the log magnitude versus phase plot on the Nichols chart (attached).

ω (rad/sec)	5	24	56	98	134
Magnitude in dB	- 0,5	- 0,75	2,5	3,5	-13,5
Phase in degrees	- 2°	- 10°	- 35°	-132°	-187°

4.2 Use the plot in QUESTION 4.1 to tabulate the open-loop gain and phase values for the same frequencies as used in the closed-loop plot.
(2 × 5) **[10]**

QUESTION 5

An open-loop transfer function for a root locus is given as follows:

$$\frac{C(s)}{R(s)} = \frac{30\,AB}{S(S+25)}$$

Use the given transfer function to answer the questions:

5.1 Determine the open-loop poles and the zeros. (2)

5.2 Calculate the centre of asymptotes on the real axis. (2)

5.3 Calculate the asymptotic angles. (2)

5.4 Construct the root locus for the given system. (4)
[10]

QUESTION 6

6.1 Convert the given Laplace transform functions to a function of time:

6.1.1 $F(s) = \frac{25}{(3s+1)(2s+1)}$

6.1.2 $F(s) = \frac{100\omega}{(s^2 + \omega^2)(s + 20)}$

(2 × 3) (6)

6.2 Convert the given Laplace transform functions to a function of 's':

6.2.1 $F(t) = 15te^{-2t}$

6.2.2 $F(t) = 90(1 - e^{\frac{t}{2}})$

(2 × 2) (4)
[10]

QUESTION 7

An integrator operational amplifier is subjected to a square-wave input voltage of ± 6 V. The amplifier has a resistor of 2 MΩ, a capacitor of 2 μf and an input frequency of 5 kHz.

7.1 Draw a neat, labelled diagram of the circuit. (3)

7.2 Calculate the following:

7.2.1 The time period in seconds (2)

7.2.2 The time constant (2)

7.2.3 The output voltage of the positive and negative phase period of the input (3)
[10]

QUESTION 8

8.1 The capacitance of a capacitor is proportional to TWO items.

Name these TWO items. (2)

8.2 FIGURE 2 shows a diagram of a capacitive transducer using the dielectric method of liquid-level monitoring.

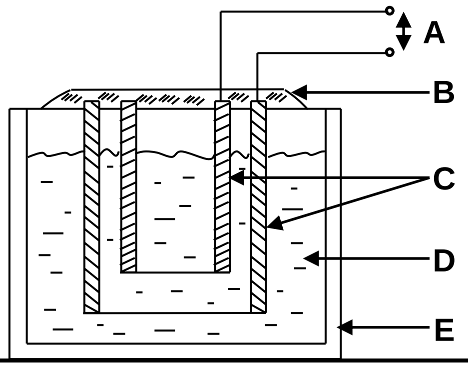


FIGURE 2

8.2.1 Name the parts indicated on the sketch in FIGURE 2 by writing only the answer next to the letter (A–E) in the ANSWER BOOK. (5)

8.2.2 Explain the operating principle of the capacitive transducer using the dielectric method of liquid-level monitoring. (3)
[10]

QUESTION 9

9.1 Define the term *hydraulics.* (2)

9.2 State THREE disadvantages of using fluid power. (3)

9.3 Explain what a *hydraulic motor* is. (2)

9.4 Name THREE components of a basic hydraulic system. (3)
[10]

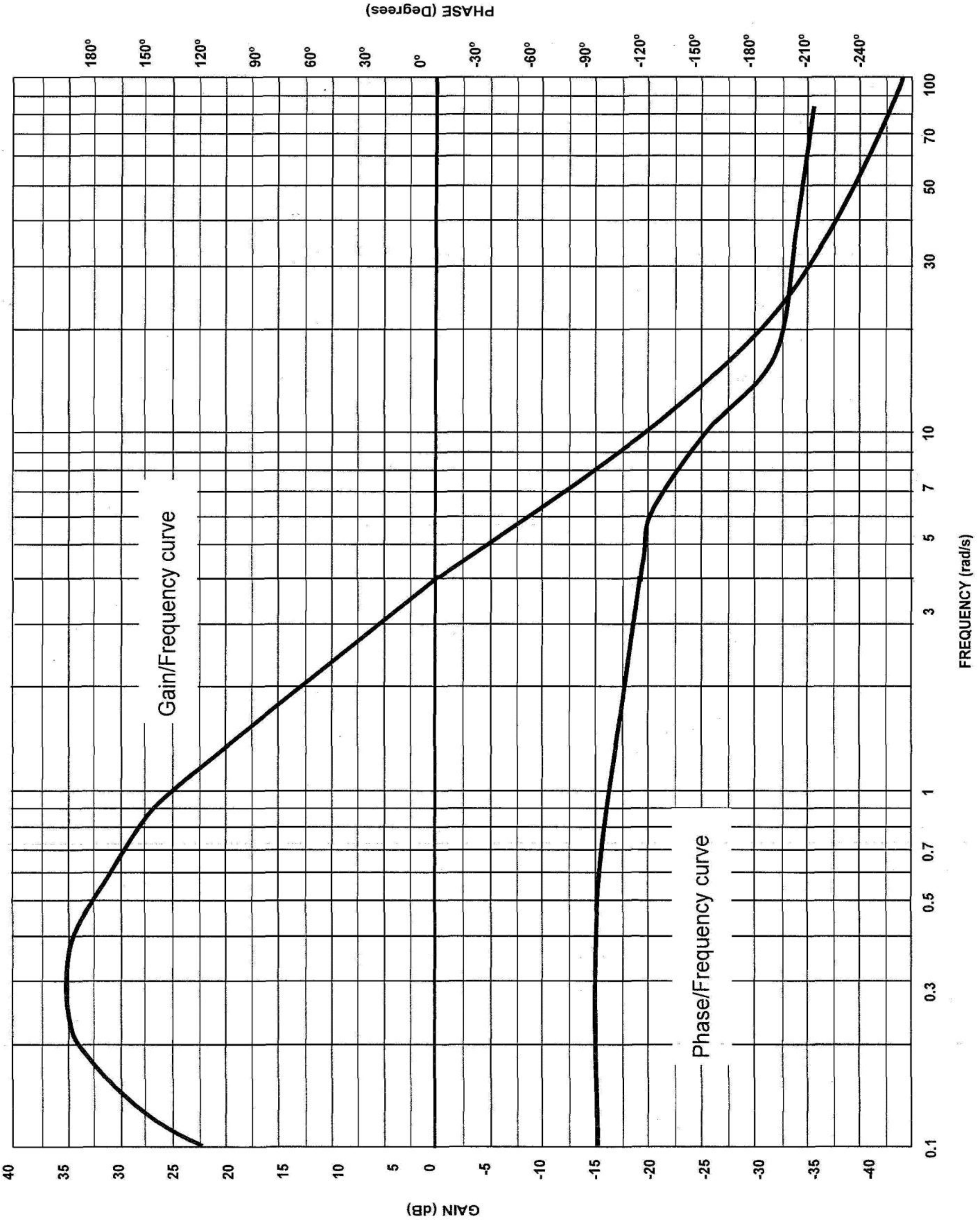
QUESTION 10

10.1 Define the term *ramp function* applicable to DC waveform functions that are supplied by signal generators. (2)

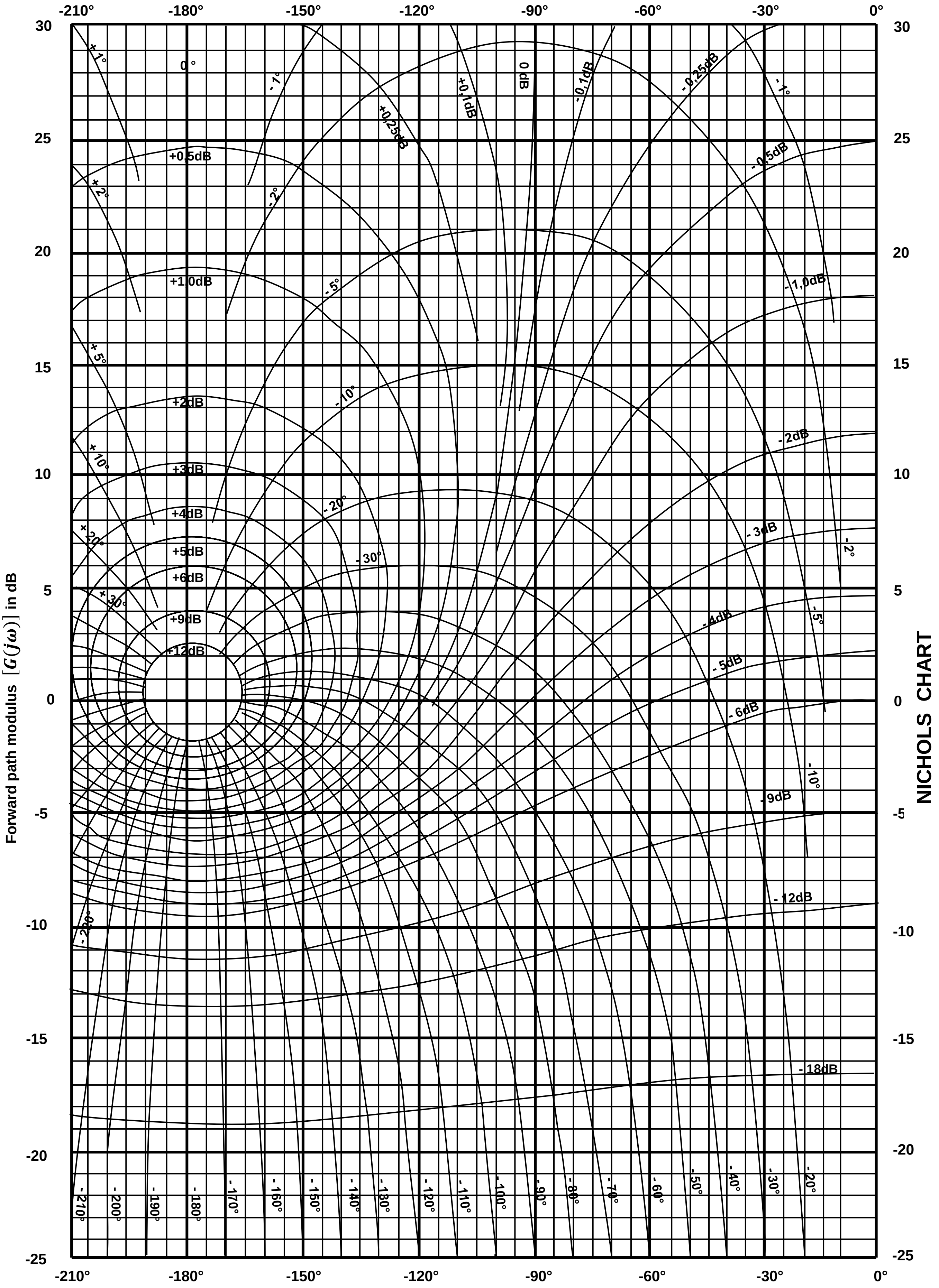
10.2 Draw a neat, labelled block diagram of the cathode-ray oscilloscope. (8)
[10]

TOTAL: 100

DIAGRAM SHEET



4.1 **EXAMINATION NUMBER:**



CONTROL SYSTEMS N6

FORMULA SHEET

$\omega_d = \omega_n\sqrt{1-\zeta^2} = 2\pi f$ $\quad t_p = \frac{1}{f}$

Number of oscillations $\frac{t_s}{t_p}$ or $\frac{2\sqrt{1-\zeta^2}}{\pi.\zeta}$

Damping coefficient $(\alpha) = \zeta\,.\,\omega_n = \frac{1}{\pi}\,\tau$

Overshoot $= e^{\frac{-\zeta\,\pi N}{\sqrt{1-\zeta^2}}}$

$$\Psi = tan^{-1}\left[\frac{\sqrt{1-\zeta^2}}{-\zeta}\right] + \pi\, rad$$

$$\text{Amplitude} = \varphi\left[1 + e^{\frac{-\zeta\pi N}{\sqrt{1-\zeta^2}}}\right]$$

$\omega_n = \sqrt{\frac{Ko}{\tau}}$ $\quad \tau + \frac{t_s}{4} = \frac{1}{\zeta\,.\,\omega_n}$

$$\omega_p = \omega_n\sqrt{1-2\,\zeta^2}$$

$$\omega_b = \omega_n\sqrt{1-2\zeta^2 + \sqrt{2-4\zeta^2 + 4\zeta^4}}$$

$\frac{C}{R} = \frac{G}{1 \pm - \,GH}$ $\quad Sc = \frac{\sum P - \sum Z}{NP - NZ}$

$\zeta = COS\,\varphi$ $\quad \Psi = \frac{(2Ko+1)180°}{NP-NZ}$

$$Ko = \frac{\Delta P_1\,.\,\Delta P_{2....}}{\Delta Z_1\,.\,\Delta Z_{2....}}$$

AMPLIFIERS

$$\text{Vo} = -V_i \frac{\text{R}_f}{\text{R}_1}$$

$$\text{Vo} = V_i \left[\frac{\text{R}_f}{\text{R}_1}\right]$$

$$\text{Vo} = -R_f \left[\frac{\text{V}_1}{\text{R}_1} + \frac{V_2}{R_2} + \cdots \frac{V_N}{R_N}\right]$$

$$\text{Vo} = -\frac{1}{RC} \int V_i\,(t)dt + V_c$$

$$\text{Vo} = -RC\ \frac{dV_i(t)}{dt}$$

$$\text{i}_e = \frac{V_e}{R_e}$$

$$R_c = \frac{V_c}{i_c}$$

$$\text{gm}R_L = \frac{hfe}{hie}.R_L$$

$$\text{t} = \frac{1}{f}$$

BODE AND NICHOLS CHARTS

$$Gain = 20\log\left[\frac{output}{input}\right]\ db$$

$$Phase = \text{Sin}^{-1}\left[\frac{phase\ shift}{input}\right] - 180°$$

$$\tau = R.C$$

LAPLACE TRANSFORM TABLE

No	F(s)	f(t)
1.	1	$\delta(t)$
2.	$\frac{A}{s}$	$A(t)$ $\{0 \ \ t < 0\}$ $\{A \ \ t \geq 0\}$
3.	$\frac{1}{s}$	$U(t)$ $\{0 \ \ t < 0\}$ $\{1 \ \ t \geq 0\}$
4.	$\frac{A}{s^2}$	At
5.	$\frac{2A}{s^3}$	At^3
6.	$\frac{A_\omega}{s^2 + \omega^2}$	$A \sin \omega t$
7.	$\frac{A_s}{s^2 + \omega^2}$	$A \cos \omega t$
8(a).	$\frac{A}{\tau s + 1}$	$\frac{A}{\tau} e^{\frac{-t}{\tau}}$
8(b).	$\frac{A}{s + a}$	Ae^{-at}
9(a).	$\frac{A}{(\tau_1 s + 1)(\tau_2 s + 1)}$	$\frac{A}{\tau_1 - \tau_2} \left[e^{\frac{-t}{\tau_1} - \frac{-t}{\tau_2}} \right]$
9(b).	$\frac{A}{(s + a)(s + b)}$	$\frac{A}{(b - a)} \left[e^{-at} - e^{-bt} \right]$
10(a).	$\frac{A}{(\tau_s + 1)^2}$	$\frac{At}{\tau^2} \left[e^{\frac{-t}{\tau}} \right]$
10(b).	$\frac{A}{(s + a)^2}$	Ate^{-at}
11.	$\frac{A{\omega_n}^2}{s^2 + 2 \zeta \omega_n s + {\omega_n}^2}$	$\frac{A\omega_n e^{-\zeta \omega_n t}}{\sqrt{1 - \zeta^2}} \sin(\omega_n \sqrt{1 - \zeta^2 t}$
12(a).	$\frac{A}{s(\tau s + 1)}$	$A(1 - e^{\frac{-t}{\tau}})$
12(b).	$\frac{A}{s(s + a)}$	$\frac{A}{a}(1 - e^{-at})$
13(a).	$\frac{A}{s^2(\tau s + 1)}$	$A\tau \left[e^{\frac{-t}{\tau}} + \frac{t}{\tau} - 1 \right]$
13(b).	$\frac{A}{s^2(s + a)}$	$\frac{A}{a^2} (e^{-at} + at - 1)$

14(a).	$\frac{A\omega}{(s^2+\omega^2)(\tau s+1)}$	$\frac{A\omega\tau}{1+\omega^2\tau^2}e^{\frac{-t}{\tau}}+\frac{A}{\sqrt{1+\omega^2\tau^2}}\sin(\omega t-\Psi)$ *where* $\Psi=\tan^{-1}\omega\tau\ (0<\Psi<\pi)$
14(b).	$\frac{A\omega}{(s^2+\omega^2)(s+a)}$	$\frac{A\omega e^{-at}}{(\omega^2+a^2)}+\frac{A}{\sqrt{\omega^2+a^2}}\sin(\omega t-\Psi)$ *where* $\Psi=\tan^{-1}\frac{\omega}{a}\ (0<\Psi<\pi)$
15(a).	$\frac{A}{s(\tau_1 s+a)(\tau_2 s+1)}$	$A\left[1+\frac{\tau_1 e^{\frac{-t}{\tau_1}}-\tau_2 e^{\frac{-t}{\tau_2}}}{\tau_1-\tau_2}\right]$
15(b).	$\frac{A}{s(s+a)(s+b)}$	$\frac{A}{ab}\left[1+\frac{ae^{-bt}-be^{-at}}{b-a}\right]$
16(a).	$\frac{A}{s(\tau+a)^2}$	$A\left[1-\frac{(\tau+t)}{\tau}e^{\frac{-t}{\tau}}\right]$
16(b).	$\frac{A}{s(s+1)^2}$	$\frac{A}{a^2}[1-(1+at)e^{-at}]$
17.	$\frac{A\omega_n{}^2}{s(s^2+2\zeta\omega_n s+\omega_n{}^2)}$	$A\left[1+\frac{e^{-\zeta\omega_n t}}{\sqrt{1-\zeta^2}}\sin(\omega_n t\sqrt{1-\zeta^2}-\Psi\right]$ *where* $\Psi=tan^{-1}\frac{\sqrt{1-\zeta^2}}{-\zeta}$ $(0<\Psi<\pi)$
18(a).	$\frac{A}{s^2(\tau_1 s+1)(\tau_2 s+1)}$	$A\left[t-\tau_1-\tau_2-\frac{\tau_2{}^2 e^{\frac{-t}{\tau_2}}-\tau_1{}^2 e^{\frac{-t}{\tau_1}}}{\tau_1-\tau_2}\right]$
18(b).	$\frac{A}{s^2(s+a)(s+b)}$	$\frac{A}{ab}\left[t-\frac{a+b}{ab}-\frac{\frac{b}{a}e^{-bt}-\frac{a}{b}e^{-at}}{b-a}\right]$
19(a).	$\frac{A}{s^2(\tau s+1)^2}$	$A\left[t-2\tau+(t+2\tau)e^{\frac{-t}{\tau}}\right]$
19(b).	$\frac{A}{s^2(s+a)^2}$	$\frac{A}{a^2}\left[t-\frac{2}{a}+\left(t+\frac{2}{a}\right)e^{-at}\right]$
20.	$\frac{A\omega_n{}^2}{s^2(s^2+2\zeta\omega_n s+\omega_n{}^2)}$	$A\left[\tau-\frac{2\zeta}{\omega_n}+\frac{e^{-\zeta\omega_n t}}{\omega_n\sqrt{1-\zeta^2}}\sin(\omega_n t\sqrt{1-\zeta^2}-\Psi\right]$ *where* $\Psi=2tan^{-1}\frac{\sqrt{1-\zeta^2}}{-\zeta}$ $(0<\Psi<\pi)$

21(a).	$\frac{A\omega}{(s^2+\ \omega^2)(\tau_1 s+1)(\tau_2 s+1)}$	$A\left[\frac{{\tau_1}^2\omega e^{\frac{-t}{\tau_1}}}{(\tau_1-\tau_2)(1+\omega^2{\tau_1}^2)}+\frac{{\tau_2}^2\omega e^{\frac{-t}{\tau_2}}}{(\tau_1-\tau_2)(1+\omega^2{\tau_2}^2)}\right.$ $\left.+\frac{\sin(\omega t-\ \Psi)}{(1+\omega^2\ \tau^2)(1+\omega^2{\tau_2}^2)^{\frac{1}{2}}}\right]$ *where* $\Psi=tan^{-1}\ \omega\tau_1+\ tan^{-1}\omega\tau_2$
21(b).	$\frac{A\omega}{(s^2+\ \omega^2)(s+a)(s+b)}$	$A\left[\frac{\omega e^{-at}}{(b-a)(\omega^2+a^2)}+\frac{\omega e^{-bt}}{(a-b)(\omega^2+\ b^2)}\right.$ $\left.+\frac{\sin(\omega t-\ \Psi)}{(\omega^2+a^2\ )(\omega^2+b^2)^{\frac{1}{2}}}\right]$ *where* $\Psi=tan^{-1}\ \frac{\omega(a+b)}{ab-\ \omega^2}$ $(0<\Psi<\pi)$
22(a).	$\frac{A\omega}{(s^2+\ \omega^2)(\tau s+1)^2}$	$\frac{A}{1+\omega^2\tau^2}\left[\frac{\omega t+\ 2\omega\tau}{1+\ \omega^2\tau^2}\ e^{\frac{-t}{\tau}}+\sin(\omega t-\ \Psi\right]$ *where* $\Psi=2tan^{-1}\ \omega\tau$
22(b).	$\frac{A\omega}{(s^2+\ \omega^2)(s+a)^2}$	$\frac{A}{\omega^2+a^2}\left[\frac{a\omega(at+2)e^{-at}}{\omega^2+\ a^2}+\sin(\omega t-\ \Psi\right]$
23.	$\frac{A\omega{\omega_n}^2}{(s^2+\ \omega^2)(s^2+2\zeta\omega_n s+\ {\omega_n}^2)}$	$\frac{A{\omega_n}^2}{[({\omega_n}^2-\ \omega^2)^2+4\ \zeta^2\omega^2\ {\omega_n}^2]^{\frac{1}{2}}}$ $\left[\sin(\omega t-\Psi)+\frac{\omega e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\ t-\Psi_2)}{\omega_n\sqrt{1-\zeta^2}}\right]$ *where* $\Psi_1=tan^{-1}\left[\frac{2\zeta\omega\omega_n}{{\omega_n}^2+\ \omega^2}\right]\ (0<\Psi_1<\pi)$ and $\Psi_2=tan^{-1}-\frac{2\zeta{\omega_n}^2\sqrt{1-\zeta^2}}{\omega^2-{\omega_n}^2(1-2\zeta^2)}\ (0<\Psi_2<\pi)$