higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

CONTROL SYSTEMS N6

(8080016)

2 December 2022 (X-paper)
09:00–12:00

This question paper consists of 8 pages, 2 diagram sheets (a Bode diagram and a Nichols chart), a 2-page formula sheet and 3 pages of a Laplace transform table.

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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. Start each question on a new page.
5. Use only a blue or black pen.
6. Write neatly and legibly.

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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 Critical damping is where the response is as quick as possible without overshooting or oscillations.

1.2 A sine function is a function of time which changes periodically in a sinusoidal fashion at a frequency of ω rad/s and may be leading or lagging.

1.3 First-order systems contain components that will cause fluctuations in the steady-state conditions.

1.4 A unit-impulse function of a control system is a mathematical equation containing elements of the system to be transferred from the input to the output, assuming all the initial conditions to be zero.

1.5 Overdamping is where the response is very sluggish and oscillations never occur.

1.6 Bandwidth is defined as the ratio between the actual amount of damping and the critical amount of damping.

1.7 In a derivative control, the correction made is proportional to the time derivative of the error.

1.8 A ramp function is a function of time that has a value of zero up to time equal to zero, and for any value of time greater than zero, it has a constant value of one.

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

1.10 A phase margin is the point at which the magnitude graph cuts the zero $\alpha\beta$ line.

(10 × 1) **[10]**

QUESTION 2

2.1 FIGURE 1(a) shows a first order RC integrator circuit diagram.
FIGURE 1(b) shows the resulting block diagram for this system.

Find the transfer function for this system by using block diagram algebra reduction.

Let: $\boldsymbol{\tau = RC}$

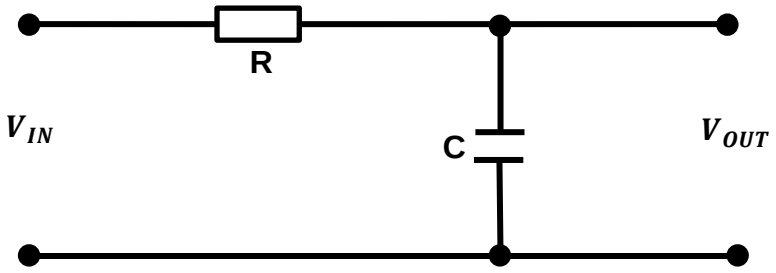


FIGURE 1(a)

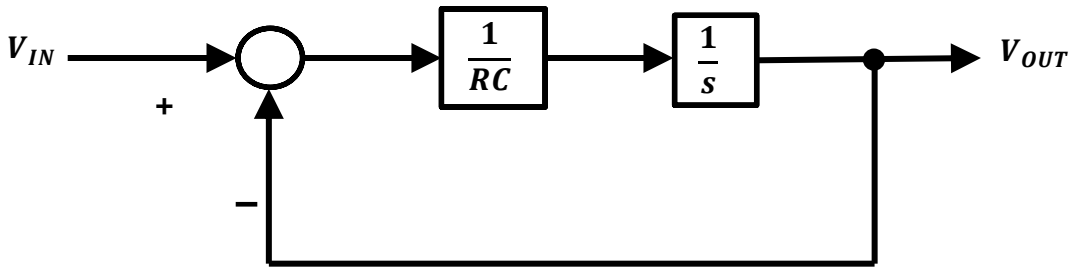


FIGURE 1(b) (6)

2.2 Express the given Laplace function in terms of the equivalent time function.

$$\mathrm{F}(s) = \frac{135}{(3s+1)^2} \quad (2)$$

2.3 Express the given Laplace function in terms of the equivalent s-domain.

$$F(t) = 15\left[1 - \frac{(3+t)}{3}\, e^{\frac{-t}{3}}\right] \quad (2)$$

[10]

QUESTION 3

DIAGRAM SHEET 1 illustrates a gain versus frequency, and a phase versus frequency curve for a system.

Determine from the graph the following:

3.1 The gain peak value (Mp) (1)

3.2 The TWO corner frequencies (2)

3.3 The gain crossover frequency (ω_1) (1)

3.4 The phase crossover frequency (ω_π) (1)

3.5 The resonant frequency (ω_p) (1)

3.6 The gain margin (1)

3.7 The phase margin (1)

3.8 The stability of the system (2)

[10]

QUESTION 4

DIAGRAM SHEET 2 (attached) illustrates a closed-loop gain versus phase plot on a Nichols chart.

4.1 Use the plot to tabulate the closed-loop gain and phase values when:

ω = 25 rad/s, 50rad/s, 90 rad/s and 150 rad/s (4)

4.2 Use the Nichols chart to determine the following:

4.2.1 The gain margin

4.2.2 The phase crossover frequency

4.2.3 The un-damped resonant frequency

4.2.4 The bandwidth

4.2.5 The peak magnitude gain value

4.2.6 The peak magnitude phase value

(6 × 1) (6)

[10]

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QUESTION 5

A closed-loop transfer function for a system is given as:

$$\frac{C}{R} = \frac{5A}{S^2 + 2S + 5A}$$

5.1 Calculate the closed-loop roots if A = 0; 4; 16 and ∞. (Tabulate your answers) (5)

5.2 Plot the closed-loop roots on the s-domain graph as A varies from 0 to infinity. (5)

[10]

QUESTION 6

6.1 List the FOUR main groups of transducers. (4)

6.2 Draw a neat, labelled diagram of an AC tacho-generator. (3)

6.3 Explain the term *resolution* with regard to potentiometers. (2)

6.4 Name the transducer responsible for converting information-bearing light rays into electrical signals. (1)

[10]

QUESTION 7

7.1 State the main function of a transducer. (2)

7.2 State the TWO conditions a rectifier has to satisfy in order to convert the AC signal into a DC signal. (2)

7.3 Control systems can be used to control electrical concept systems.

Name TWO other concept control systems that can be controlled. (2)

7.4 Name TWO disadvantages of potentiometers. (2)

7.5 List TWO practical applications of an electronic self-balancing potentiometer. (2)

[10]

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QUESTION 8

8.1 Name TWO classes of gear-type pumps. (2)

8.2 FIGURE 2 below shows a certain type of hydraulic pump. Study the diagram and answer the questions.

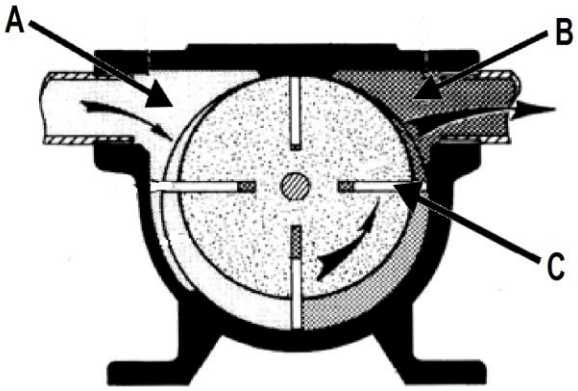


FIGURE 2

8.2.1 Name the pump in FIGURE 2. (1)

8.2.2 Identify the parts labelled A, B and C. (3)

8.2.3 Explain the operation of the pump identified in QUESTION 8.2.1. (4)
[10]

QUESTION 9

9.1 State SIX advantages of using pneumatic systems. (6)

9.2 State the purpose of introducing a derivative controller into a proportionally controlled pneumatic system. (2)

9.3 Give TWO common errors found in pneumatic systems. (2)
[10]

QUESTION 10

10.1 The sine wave is one of the most commonly used waveforms in signal generation. ☆

Name THREE other types of waveforms. (3)

10.2 Name the TWO main groups into which electronic voltmeters are classified. (2)

10.3 State THREE advantages of sine waves in signal generation. (3)

10.4 Name the TWO stability measurements which can be obtained when using a sine function to test the stability of a control system. (2)

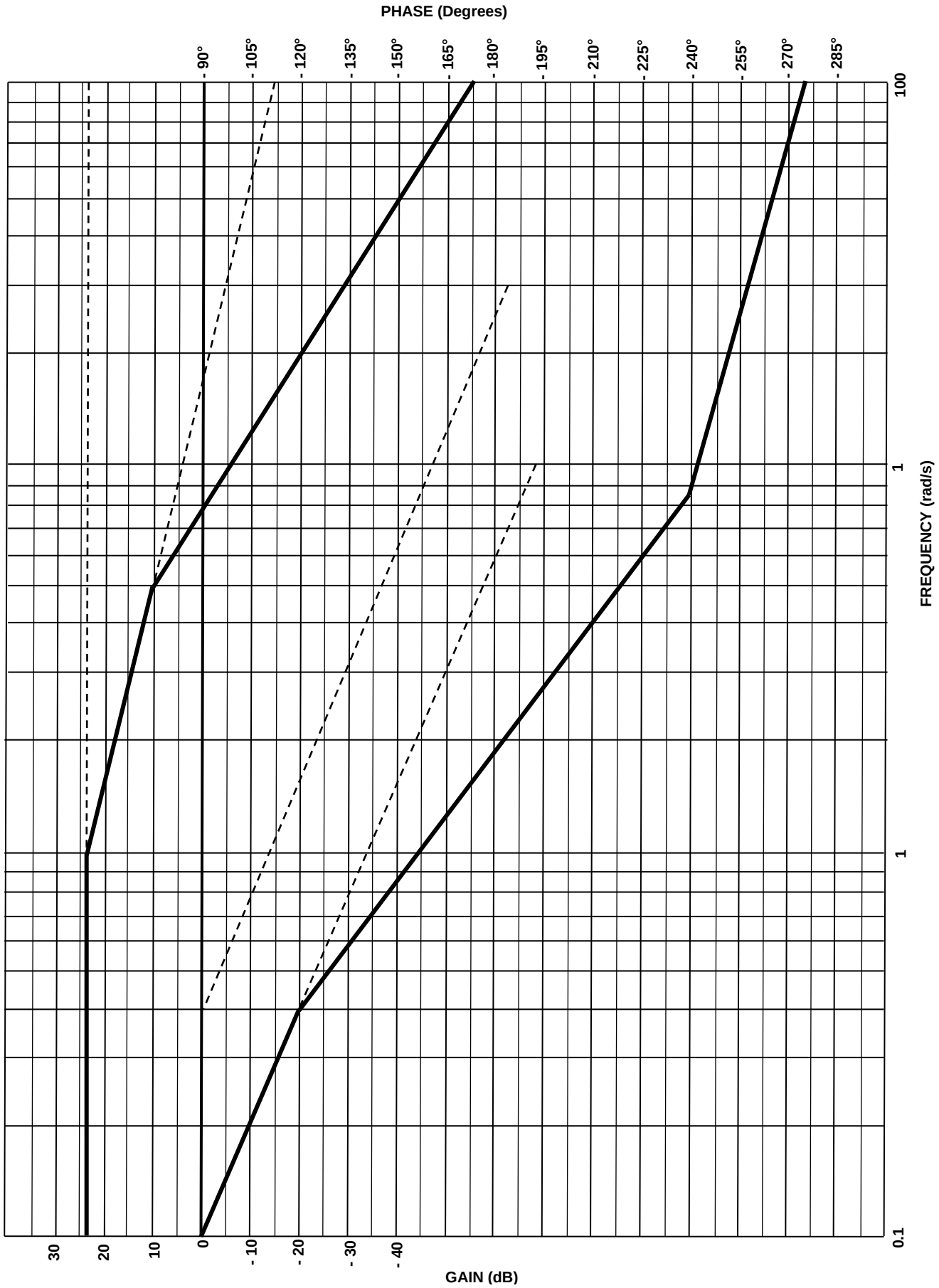
[10]

TOTAL: 100

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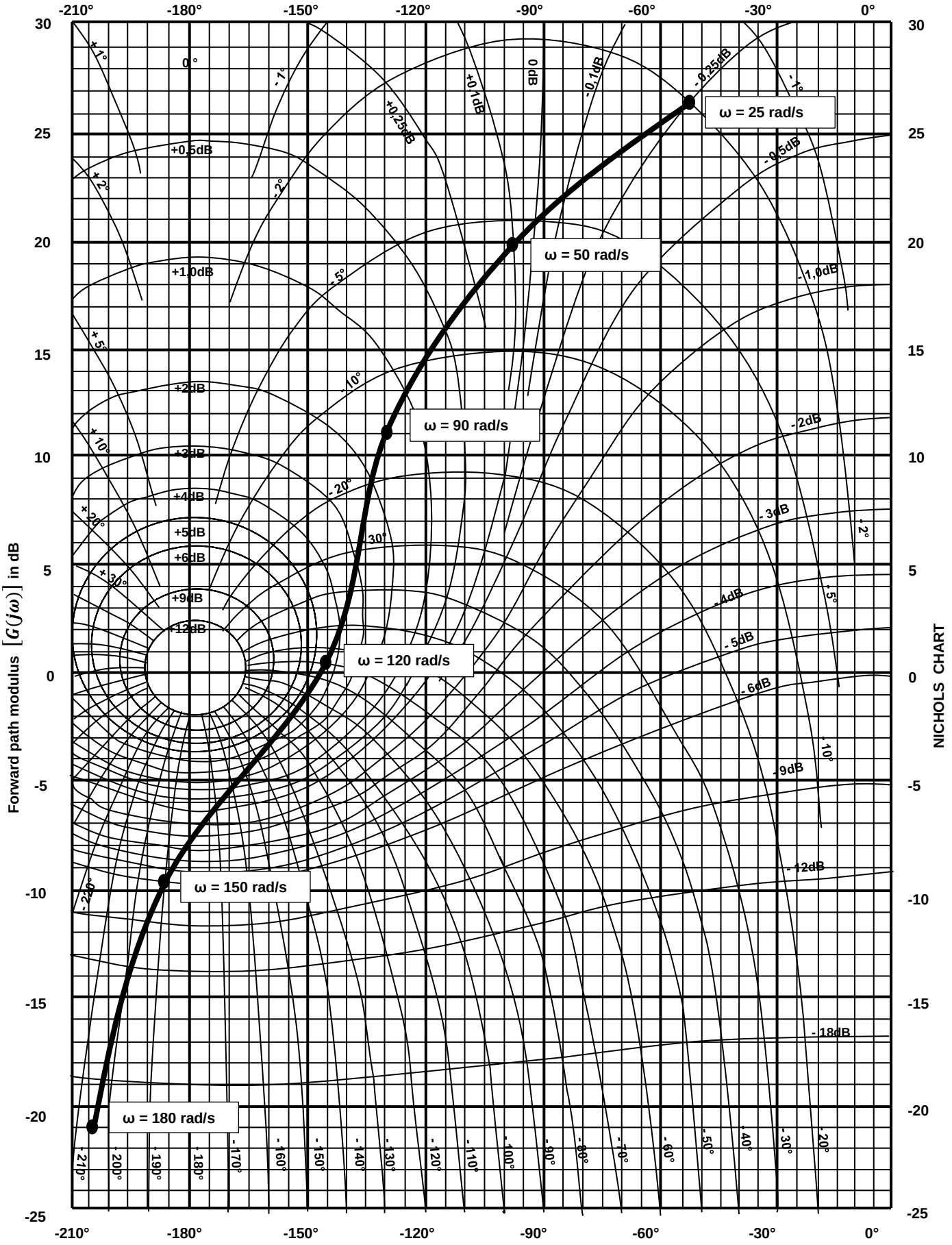
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DIAGRAM SHEET 1



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DIAGRAM SHEET 2



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CONTROL SYSTEMS N6

FORMULA SHEET

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

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

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

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

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

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

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

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

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

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

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

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

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AMPLIFIERS

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

$$\mathrm{Vo} = V_i \left[1 + \frac{\mathrm{R}_f}{\mathrm{R}_1}\right]$$

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

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

$$\mathrm{Vo} = \frac{R_f}{R_1}[V_2 - V_1]$$

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

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

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

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

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

BODE- AND NICHOLS CHARTS

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

$$Wins = 20\log\left[\frac{uitset}{inset}\right] db$$

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

$$Fase = \mathrm{Sin}^{-1}\left[\frac{faseverskuiwing}{inset}\right] - 180°$$

$$\tau = R.C$$

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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).	$\frac{A}{(s + a)(s + b)}$	$\frac{A}{(b - a)} \; [e^{-at} - e^{-bt}]$
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).	$\frac{A}{s^2(s + a)}$	$\frac{A}{a^2} (e^{-at} + at - 1)$

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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/waar* $\Psi = \tan^{-1}\omega\tau \ (0 < \Psi < \pi)$
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/waar* $\Psi = \tan^{-1}\frac{\omega}{a} \ (0 < \Psi < \pi)$
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/waar* $\Psi = tan^{-1}\frac{\sqrt{1-\zeta^2}}{-\zeta} (0 < \Psi < \pi)$
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/waar* $\Psi = 2tan^{-1}\frac{\sqrt{1-\zeta^2}}{-\zeta} (0 < \Psi < \pi)$

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

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