higher education & training

Department:
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REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

COMMUNICATION-ELECTRONICS N6

(8080246)

10 August 2021 (X-paper)
09:00–12:00

Drawing instruments and nonprogrammable calculators may be used.

This question paper consists of 6 pages and a formula sheet of 5 pages.

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DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
COMMUNICATION-ELECTRONICS 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

1.1 Design a multi-section low-pass filter consisting of two terminating half sections, one prototype section and one *m*-derived section. The filter must have a cut-off frequency of 1 000 Hz and a frequency of infinite attenuation of 1 200 Hz. It must be designed to operate in a 600 Ω transmission line.

Draw the completed filter to include all relevant components. (10)

1.2 Study FIGURE 1 below and choose the correct word from those in brackets in each of the following statements. Write only the answer next to the question number (1.2.1–1.2.2) in the ANSWER BOOK.

1.2.1 FIGURE 1 shows the (input/output) half section for a composite filter.

1.2.2 FIGURE 1 shows a (high/low)-pass filter.

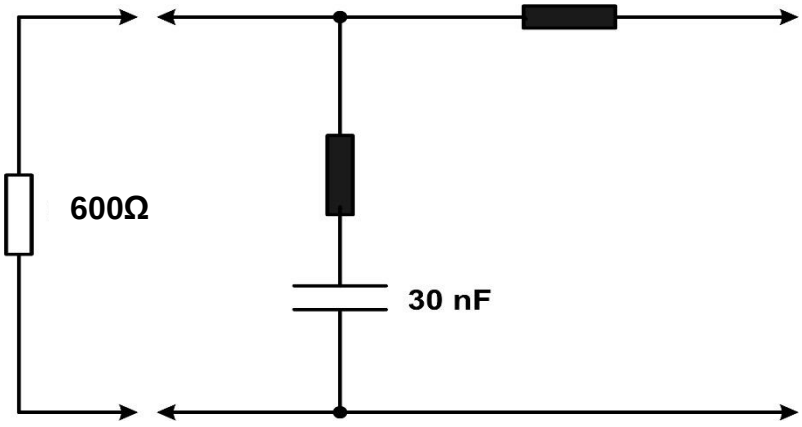


FIGURE 1

(2 × 1) (2)

1.3 What is the main disadvantage of a constant-k filter? (2)

[14]

QUESTION 2

2.1 Name THREE elements that determine the characteristic impedance of a transmission line. (3)

2.2 Explain how the reactive component can be tuned out of a transmission line. Make use of a simple sketch to support your description. (4)

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2.3 Study the attenuator network in FIGURE 2 below.

Determine the values of Z_1, Z_2 and Z_3 if the generator has to supply one-third of the current to load R_L.

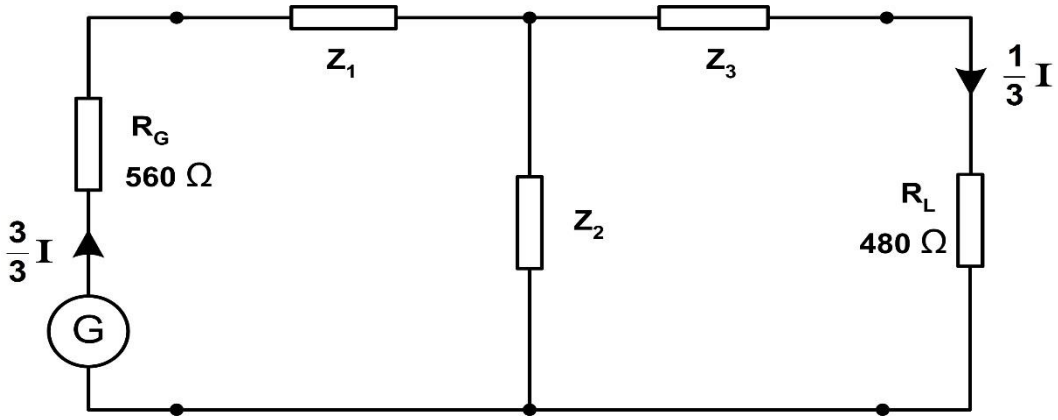


FIGURE 2 (6)

2.4 Is an attenuator frequency-sensitive?

Substantiate your answer. (3)

[16]

QUESTION 3

3.1 A transmission line has the following primary line constants:

R = 30 Ω/km
L = 0,5 mH/km
G = 1,9 × 10^{-6} mho/km (℧/km)
C = 0,045 nF/km

Calculate the following at a frequency of 1,7 kHz:

3.1.1 The characteristic impedance (4)

3.1.2 The phase constant (3)

3.1.3 The attenuation constant (2)

3.2 State the purpose of each of the following transmission components:

3.2.1 A stub

3.2.2 A directional coupler

3.2.3 A balun

3.2.4 A slotted line

(4 × 1) (4)

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3.3 A Smith chart can be used to obtain the standing-wave ratio on a transmission line.

Give a brief description of how this is accomplished. (6)
[19]

QUESTION 4

4.1 Draw a fully labelled circuit diagram of a diode noise generator that is used to determine the noise figure of a receiver under test when it is not practical to calculate the equivalent noise resistance under transit time conditions. (5)

4.2 An FM receiver has an input resistance of 5 kΩ and an equivalent resistance of 7,2 kΩ. The amplifier has a gain of 20, which is developed across a load resistor of 18 kΩ.

Take Boltzmann's constant as $1,38 \times 10^{-23}$ J/K.

Calculate the following:

4.2.1 The RMS noise voltage generated at 25 °C and a bandwidth of 20 kHz

4.2.2 The noise figure if the receiver is connected to a signal generator that has an impedance of 300 Ω

(2 × 3) (6)

4.3 Refer to FIGURE 3 and calculate the following using the given information:

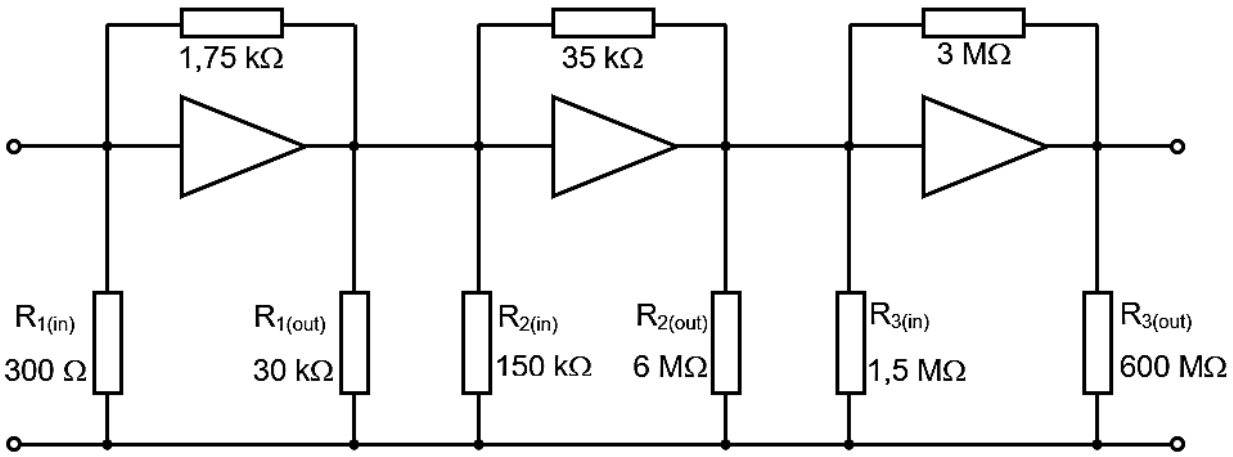


FIGURE 3

4.3.1 The equivalent noise resistance:

Stage 1: Gain = 3
Stage 2: Gain = 6
Stage 3: Gain = 9 (8)

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4.3.2 The RMS voltage that will be generated at 25 °C and a bandwidth of 9 kHz

NOTE: Take Boltzmann's constant as $1,38 \times 10^{-23}$ J/K. (2)
[21]

QUESTION 5

5.1 Discuss sampling with reference to time-division multiplexing and draw neat sketches to support your answer. (6)

5.2 Draw a neat, fully labelled block diagram of a single-channel PCM system. (10)
[16]

QUESTION 6

6.1 A radar installation is used to detect a 9 m^2 target at a distance of 100 km. The frequency of operation is 3 GHz and the transmitter and the receiver antennas have a gain of 20 each. In order to detect the target successfully, a minimum power of $1,8 \times 10^{-18}$ W is needed. There is, however, an attenuation of 0,002 dB/km.

Determine the minimum transmitter power required to detect this target. (10)

6.2 Define the following terms with reference to antennas:

6.2.1 Directive gain

6.2.2 Power gain

(2 × 2) (4)
[14]

TOTAL: 100

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COMMUNICATION-ELECTRONICS N6

FORMULA SHEET

1. Filters

Low-pass

$$f_c = \frac{1}{\pi \sqrt{L \,.\, C}} \qquad Z_o = \sqrt{\frac{L}{C}}$$

High-pass

$$f_c = \frac{1}{4 \,.\, \pi \sqrt{L \,.\, C}} \qquad Z_o = \sqrt{\frac{L}{C}}$$

Low-pass m-derived sections (also for half sections)

T-section *π-section*

$$\textit{Series } L = \frac{m \,.\, L}{2} \qquad \textit{Shunt } C = \frac{m \,.\, C}{2}$$

$$\textit{Shunt } C = m \,.\, C \qquad \textit{Series } L = m \,.\, L$$

$$\textit{Shunt } L = \frac{1 - m^2}{4 \,.\, m} \,.\, L \qquad \textit{Series } C = \frac{1 - m^2}{4 \,.\, m} \,.\, C$$

$$m = \sqrt{1 - \frac{f_c^2}{f_\infty^2}} \qquad L = \frac{Z_o}{\pi \,.\, f_c} \qquad C = \frac{1}{\pi \,.\, Z_o \,.\, f_c}$$

High-pass m-derived sections (also for half sections)

T-section *π-section*

$$\textit{Series } C = \frac{2 \,.\, C}{m} \qquad \textit{Series } C = \frac{C}{m}$$

$$\textit{Shunt } C = \frac{4 \,.\, m}{1 - m^2} \,.\, C \qquad \textit{Series } L = \frac{4 \,.\, m}{1 - m^2} \,.\, L$$

$$\textit{Shunt } L = \frac{L}{m} \qquad \textit{Shunt } L = \frac{2 \,.\, L}{m}$$

$$m = \sqrt{1 - \frac{f_\infty^2}{f_c^2}} \qquad L = \frac{Z_o}{4 \,.\, \pi \,.\, f_c} \qquad C = \frac{1}{4 \,.\, \pi \,.\, Z_o \,.\, f_c}$$

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Band-pass sections

$$Series\ L = \frac{Z_o}{2\,.\,\pi\,[f_2 - f_1]} \qquad Series\ C = \frac{f_2 - f_1}{2\,.\,\pi\,.\,Z_o\,.\,f_1\,.\,f_2}$$

$$Shunt\ L = \frac{Z_o\,[f_2 - f_1]}{4\,.\,\pi\,.\,f_1\,.\,f_2} \qquad Shunt\ C = \frac{1}{\pi\,.\,Z_o\,[f_2 - f_1]}$$

Band-stop sections

$$Series\ L = \frac{Z_o\,[f_2 - f_1]}{2\,.\,\pi\,.\,f_1\,.\,f_2} \qquad Series\ C = \frac{1}{2\,.\,\pi\,.\,Z_o\,[f_2 - f_1]}$$

$$Shunt\ L = \frac{Z_o}{4\,.\,\pi\,.[f_2 - f_1]} \qquad Shunt\ C = \frac{f_2 - f_1}{\pi\,.\,Z_o\,.\,f_1\,.\,f_2}$$

2. *Attenuators* *Symmetrical*

Bridged T-type

$$Z_B = Z_o\,[N - 1]$$

$$Z_c = \frac{Z_o}{N - 1}$$

$$Z_A = Z_o$$

where $dB = 20 \log N$

Asymmetrical

L-type

$$Z_A = \sqrt{R_1\,(R_1 - R_2)}$$

$$Z_B = \sqrt{\frac{(R_1\,.\,R_2^2)}{R_1 - R_2}}$$

T-type

$$Z_1 = R_1\left[\frac{N^2 + 1}{N^2 - 1}\right] - 2\sqrt{R_1\,.\,R_2}\left[\frac{N}{N^2 - 1}\right]$$

$$Z_2 = 2\sqrt{R_1\,.\,R_2}\left[\frac{N}{N^2 - 1}\right]$$

$$Z_3 = R_2\left[\frac{N^2 + 1}{N^2 - \ 1}\right] - 2\sqrt{R_1\,.\,R_2}\left[\frac{N}{N^2 - 1}\right]$$

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where $dB = 20 \log N$

π-type

$$Z_A = R_1 \left[\frac{N^2 - 1}{N^2 - 2 \,.\, N \,.\, S + 1} \right]$$

$$Z_B = \frac{\sqrt{R_1 \,.\, R_2}}{2} \left[\frac{N^2 - 1}{N} \right]$$

$$Z_c = R_2 \left[\frac{N^2 - 1}{N^2 - 2 \,.\, N / S + 1} \right]$$

where $dB = 20 \log N$ *and* $S = \sqrt{\frac{R_1}{R_2}}$

Insertion loss $= 20 \log \frac{I_1}{I_2}$

3. Transmission lines

$$Z_o = \sqrt{Z_{o/c} \,.\, Z_{s/c}} \qquad Z_o = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

$$\gamma = \sqrt{[R + j\omega L]\,[G + j\omega C]} \qquad \gamma = \alpha + j\beta$$

$$\lambda = \frac{2 \,.\, \pi}{\beta} \qquad V = \frac{\omega}{\beta} \qquad t = \frac{d}{v}$$

$L.G = C.R$

$$VSWR = \frac{Z_R}{Z_o} \text{ or } \frac{Z_o}{Z_R}$$

$$\text{Also } VSWR = \frac{1 + \rho}{1 - \rho}$$

$$\rho = \frac{Z_R - Z_o}{Z_R + Z_o}$$

$$\rho = \frac{V_{(reflected)}}{V_{(incident)}}$$

Normalised impedance

$$Z_o^{'} = \frac{R}{Z_o} \pm j \frac{X}{Z_o}$$

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4. Noise

$$E_n = \sqrt{4KT\Delta fR} \qquad E_n = \sqrt{4KT\Delta f\ [R_1 + R_2]}$$

$$R_{eq} = R_A + \frac{R_B}{A_1^2} + \frac{R_c}{A_1^2 \,.\, A_2^2}$$

where $R_A = R_{1in} + R_{1eq}$

$$R_B = \frac{R_{1(out)} \,.\, R_{2(in)}}{R_{1(out)} + R_{2(in)}} + R_{2(eq)}$$

$$R_c = R_{2out}$$

$$F = 1 + \frac{R'_{eq}}{R_a} \qquad R'_{eq} = R_{eq} - R_t$$

$$F = \frac{S/N_{(in)}}{S/N_{(out)}} \qquad F = 1 + \frac{T_{eq}}{T_o}$$

$$C = \Delta f \log_2 [1 + S/N]$$

where $dB = 10 \log S/N$

5. Modulation

$$m = \frac{V_m}{V_c} \qquad \eta = \frac{P_{dc}}{P_c} \times 100\%$$

$$P_{dc} = I_{mean} \times V_{dc} \qquad P_{\text{mod}} = \frac{P_{SB}}{\eta}$$

$$P_{SB} = \frac{m^2 \,.\, P_c}{2}$$

$$P_T = P_c + P_{SB}$$

6. Antennae

$$P_r = P_d \times A \qquad A = \frac{\lambda^2}{4 \,.\, \pi} \qquad \lambda = \frac{c}{f}$$

$$P_r = P_d \times A \,.\, G_r \quad \textit{where} \qquad dB = 10 \log G$$

$$P_d = \frac{E^2}{120 \,.\, \pi} \qquad P_d = \frac{P_t \,.\, G_t}{4 \,.\, \pi \,.\, d^2}$$

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$$P_d = \frac{30 \,.\, G \,.\, P_t}{120 \,.\, \pi \,.\, d^2}$$

$$P_t = \frac{[4 \,.\, \pi]^3 \,.\, d^4 \,.\, P_r}{G_t \,.\, G_r \,.\, Q \,.\, \lambda^2}$$

$$P_r = \frac{10 \,.\, P_t \,.\, G_t}{4 \,.\, \pi \,.\, d^2}$$

$$E_r = \frac{\sqrt{30 \,.\, P_r}}{d}$$

$$E_S = \frac{\sqrt{30 \,.\, P_t \,.\, G_t}}{d}$$

$$A = \frac{G \,.\, \lambda^2}{4 \,.\, \pi}$$

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