ELECTRONICS & COMMUNICATION ENGINEERING

ESE TOPICWISE
CONVENTIONAL SOLVED PAPER-II

1998-2018
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NEW DELHI
<table>
<thead>
<tr>
<th></th>
<th>CONTENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ANALOG &amp; DIGITAL COMMUNICATION SYSTEM ......................................... 01 – 66</td>
</tr>
<tr>
<td>2</td>
<td>CONTROL SYSTEM .................................................................................... 67 – 175</td>
</tr>
<tr>
<td>3</td>
<td>COMPUTER ORGANIZATION &amp; ARCHITECTURE ............................................... 176 – 200</td>
</tr>
<tr>
<td>4</td>
<td>ELECTROMAGNETIC FIELD THEORY .................................................................. 201 – 278</td>
</tr>
<tr>
<td>5</td>
<td>ADVANCE ELECTRONICS ................................................................................. 279 – 286</td>
</tr>
<tr>
<td>6</td>
<td>ADVANCE COMMUNICATION SYSTEM ................................................................ 287 – 331</td>
</tr>
<tr>
<td>7</td>
<td>SIGNAL &amp; SYSTEM ....................................................................................... 332 – 389</td>
</tr>
<tr>
<td>8</td>
<td>MICROPROCESSOR .......................................................................................... 390 – 421</td>
</tr>
</tbody>
</table>
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UNIT 1
ANALOG AND DIGITAL COMMUNICATION SYSTEM

SYLLABUS

Random signals, noise, probability theory, information theory; Analog versus digital communication & applications; Systems-AM, FM, transmitters/receivers, theory/practice/standards, SNR comparison, Digital communication basics: Sampling, quantizing, coding, PCM, DPCM, multiplexing-audio/video; Digital modulation: ASK, FSK, PSK; Multiple access: TDMA, FDMA, CDMA; Optical communication: fibre optics, theory, practice/standards.

CONTENTS

<table>
<thead>
<tr>
<th>Chapter No.</th>
<th>Topic</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Random Variables and Noise</td>
<td>1-10</td>
</tr>
<tr>
<td>2.</td>
<td>Analog Communication System</td>
<td>11-26</td>
</tr>
<tr>
<td>3.</td>
<td>Digital Communication System</td>
<td>27-51</td>
</tr>
<tr>
<td>4.</td>
<td>Fundamentals of Information Theory</td>
<td>52-66</td>
</tr>
</tbody>
</table>
Q-1: A two stage amplifier has the following parameters:

<table>
<thead>
<tr>
<th></th>
<th>First stage</th>
<th>Second stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage gain</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>Input resistance</td>
<td>500 ohms</td>
<td>80 K ohms</td>
</tr>
<tr>
<td>Equivalent Noise Resistance</td>
<td>1500 ohms</td>
<td>10 K ohms</td>
</tr>
<tr>
<td>Output Resistance</td>
<td>25 K ohms</td>
<td>1 M ohms</td>
</tr>
</tbody>
</table>

Calculate:

(i) the equivalent noise resistance of the two stage amplifier;

(ii) the noise figure of the amplifier if it is driven by a generator with output impedance 50 ohms.

[15 Marks ESE–1998]

Sol.

Given:

The voltage gain of first stage = \( A_1 = 12 \)

The voltage gain of second stage = \( A_2 = 20 \)

Input resistance for first stage, \( R_{i1} = 500 \text{ }\Omega \)

Input resistance for second stage, \( R_{i2} = 10 \text{ K} \)

Now,

\[ R_1 = R_{i1} + R_{n1} \]

[Noise resistance is in series with input resistance]

\[ R_1 = 1500 + 500 \]

\[ R_1 = 2000 \Omega \]

Also,

\[ R_2 = (R_{o1} \parallel R_{i2}) + R_{n2} \]

[output resistance of first stage is parallel to input resistance of 2nd stage] + [equivalent noise resistance of 2nd stage]

\[ R_2 = (25\text{K} \parallel 80\text{K}) + 10\text{K} \]

\[ R_2 = \left( \frac{25 \times 80\text{K}}{105} + 10\right) \text{K} \]

\[ R_2 = 29.04 \text{ K} \]

Again, \( R_3 = R_{o2} = 1\text{M} \Omega = 1000\text{K} \Omega \)

Now, equivalent input noise resistance is given as

\[ R_{eq} = R_1 + \frac{R_2}{A_1^2} + \frac{R_3}{A_2^2} \]

\[ = 2000 + \frac{29.04 \times 10^3}{(12)^2} + \frac{10^6}{(12)^2 \times (20)^2} \]
\[ R_{eq} = 2219.1 \Omega \]

Noise figure given by,
\[ F = 1 + \frac{R_{eq}^1}{R_a} \] \hspace{1cm} \text{(1)}

When
\[ R_{eq}^1 = R_{eq} - R_{\text{fl}} = (2219.1 - 500) = 1719.1 \Omega \]
\[ R_a = \text{output resistance of generator} = 50 \Omega \]

Hence from (1),
\[ F = 1 + \frac{1719.1}{50} = 35.38 \]
\[ F = 35.38 \text{ or } 15.48 \text{ dB} \quad [F \text{ in dB} = 10\log_{10} F] \]

**Q–2:** *Show that the input-to-output SNR gain of a matched filter depends on the product of the input signal duration and the noise bandwidth.* 

**[10 Marks ESE–2002]**

**Sol.**

Impulse response of matched filter is
\[
h(t) = S^*(T-t) \
T = \text{Time period of } s(t)\]

Noise power at output of the filter is given as
\[
P_n = \frac{1}{2} \int_{-\infty}^{\infty} |H(f)|^2 \text{df} \]

where \( \frac{1}{2} = \text{Noise power spectral density at output filter.} \)

Now
\[
|S_o(T)|^2 = \left| \int_{-\infty}^{\infty} H(f)S_i(f) e^{-2\pi ft} \text{df} \right|^2
\]
\[
\therefore \text{Signal to noise ratio at the output is given as}

\[
(SNR)_{o/p} = \frac{\int_{-\infty}^{\infty} H(f)S_i(f) e^{-2\pi ft} \text{df}^2}{\left(\frac{1}{2}\right) \int_{-\infty}^{\infty} |H(f)|^2 \text{df}}
\]
\[
\therefore \int_{-\infty}^{\infty} |S_i(f)|^2 \text{df} = E = \text{Energy of the signal}
\]
\[
\therefore (SNR)_{o/p} \leq \frac{2E}{\eta}
\]
\[
(SNR)_{o/p} \bigg|_{\text{max}} = \left(\frac{2E}{\eta}\right)^{\frac{1}{2}} \quad \text{...(i)}
\]

Now the input signal to noise ratio is given as
\[
S_i = \frac{1}{T} \int_{0}^{T} S_i^2(t) \text{dt} = \left(\frac{E}{T}\right)
\]
\[
N_i = \left(\frac{\eta}{2}\right)(2B) = (\eta B) \quad \text{[B = Noise bandwidth]}
\]
(SNR)\_i = \frac{S_i}{N_i} = \left(\frac{E}{\eta BT}\right) \quad \ldots (ii)

Now from (i) and (ii)

\[
\frac{(SNR)_{o/p}}{(SNR)_{i/p}} = \frac{2E}{\eta} \times \frac{BT}{E} = 2BT
\]

\[
\therefore \quad \frac{(SNR)_{o/p}}{(SNR)_{i/p}} = 2BT
\]

**Q-3:** An amplifier has a noise figure of 4 dB, a bandwidth of 500 kHz and an input resistance of 50Ω. Calculate the input signal voltage needed to yield an output SNR = 1 when the amplifier is connected to a signal source of 50Ω at 290 K. \[\text{[8 Marks ESE–2006]}\]

**Sol.**

Given that for amplifier

Noise figure = \((F_n)_{db} = 4\) dB

Bandwidth = \(B_n = 5000 \) kHz

and,

\[(SNR)_0 = \frac{S_0}{N_0} = 1\]

\(R_{in} = 50\) Ω

Let \(S_i\) be the input signal power and \(N_i\) be input noise power then,

\[S_i = \frac{(V_i)^2}{R_{in}}\]

or

\[S_i = 1 \left(\frac{R_{in}}{R_{in} + R_s}\right)^2 V_s^2\]

\[= \frac{1}{50} \times \left(\frac{50}{50 + 50}\right)^2 V_s^2 = \left(\frac{V_s^2}{200}\right)\]

\[
\therefore \quad V_s = \sqrt{S_i \times 200}\]

Since

\[\text{Noise figure} = F_n = \frac{(SNR)_i}{(SNR)_{out}} = \frac{(SNR)_i}{1} = (SNR)_i = \frac{S_i}{N_i}\]

\[
\therefore \quad S_i = F_n \times N_i
\]

\[= F_n \times K T_0 B_n\] \quad \ldots (ii)

Where \(K = \) Boltzman’s constant = \(1.38 \times 10^{-23}\)

\(B_n = \) Receiver bandwidth = \(500 \times 10^3\) Hz

\(T_0 = \) Temperature = 290 K

\[
\therefore \quad (F_n)_{db} = 10 \log_{10} (F_n)
\]

or

\[4 = 10 \log_{10} (F_n)\]

or

\[F_n = (10)^{0.4} = 2.512\]

Hence from eq. (ii)

\[S_i = 2.512 \times 1.38 \times 10^{-23} \times 290 \times 500 \times 10^3\]
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