ESE TOPICWISE
CONVENTIONAL SOLVED PAPER-II
ELECTRONICS & COMMUNICATION ENGINEERING

22 YEARS SOLUTION
COMPLETE SOLUTIONS WITH EXPLANATIONS
THOROUGHLY REVISED AND UPDATED

IES MASTER PUBLICATION
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ELECTRONICS & COMMUNICATION ENGINEERING
ESE TOPICWISE
CONVENTIONAL SOLVED PAPER-II
Engineering Services Exam (ESE) is one of most coveted exams written by engineering students aspiring for reputed posts in the various departments of the Government of India. ESE is conducted by the Union Public Services Commission (UPSC), and therefore the standards to clear this exam too are very high. To clear the ESE, a candidate needs to clear three stages - ESE Prelims, ESE Mains and Personality Test.

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IES Master feels immense pride in bringing out this book with utmost care to build upon the exam preparedness of a student up to the UPSC standards. The credit for flawless preparation of this book goes to the entire team of IES Master Publication. Teachers, students, and professional engineers are welcome to share their suggestions to make this book more valuable.

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New Delhi
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UNIT 1

ANALOG AND DIGITAL COMMUNICATION SYSTEM

SYLLABUS


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A two stage amplifier has the following parameters:

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<td>Output Resistance</td>
<td>25 K ohms</td>
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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.

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, \( R_{i1} = 500 \Omega \)

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

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 2\(^{nd}\) stage] + [equivalent noise resistance of 2\(^{nd}\) stage]

\[ R_2 = \left( \frac{25 \times 80}{105} \right) + 10K \]
\[ R_2 = \frac{2000}{105} + 10K \]
\[ R_2 = 29.04K \]

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

Now, equivalent input noise resistance is given as

\[ R_{eq} = R_1 + \frac{R_2}{A_1^2} + \frac{R_3}{A_2^2 A_2^2} \]
\[ = 2000 + \frac{29.04 \times 10^3}{(12)^2} + \frac{10^6}{(12)^2 \times (20)^2} \]
\[
R_{eq} = 2219.1 \Omega
\]

Noise figure given by,

\[
F = 1 + \left( \frac{R_{eq}^1}{R_a} \right)
\]  ...(1)

When

\[
R_{eq}^1 = R_{eq} - R_{\pi} = (2219.1 - 500) = 1719.1 \Omega
\]

\[R_a = \text{output resistance of generator} = 50 \Omega\]

Hence from (1),

\[
F = 1 + \frac{1719.1}{50} = 35.38
\]

\[F = 35.38 \text{ or } 15.48 \text{ dB}\]  \[\text{[F in dB} = 10 \log_{10} F\]

**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.  \[10 \text{ Marks ESE–2002}\]

**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

\[P_n = \frac{\eta}{2} \int_{-\infty}^{\infty} |H(f)|^2 df\]

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

Now

\[|S_o(T)|^2 = \left| \int_{-\infty}^{\infty} H(f)S_i(f)e^{-2\pi fT} df \right|^2\]

\[\therefore \text{Signal to noise ratio at the output is given as}\]

\[(\text{SNR})_{o/p} = \frac{\int_{-\infty}^{\infty} H(f)S_i(f)e^{-2\pi fT} df}{\left( \frac{\eta}{2} \right) \int_{-\infty}^{\infty} |H(f)|^2 df}\]

\[\therefore \int_{-\infty}^{\infty} |S_i(f)|^2 df = E = \text{Energy of the signal}\]

\[\therefore (\text{SNR})_{o/p} \leq \frac{2E}{\eta}\]

\[(\text{SNR})_{o/p}\bigg|_{\text{max}} = \left( \frac{2E}{\eta} \right)\]  \[\ldots(\text{i})\]

Now the input signal to noise ratio is given as

\[S_i = \frac{1}{T} \int_{0}^{T} S_i^2(t) dt = \left( \frac{E}{T} \right)\]

\[N_i = \left( \frac{\eta}{2} \right) (2B) = (\eta B)\]  \[\text{[B = Noise bandwidth]}\]
\[(\text{SNR})_{i} = \frac{S_i}{N_i} = \left(\frac{E}{\eta BT}\right) \] ... (ii)

Now from (i) and (ii)
\[
\frac{(\text{SNR})_{o/p}}{(\text{SNR})_{i/p}} = \frac{2E}{\eta BT} = 2BT
\]
\[
\therefore \quad \frac{(\text{SNR})_{o/p}}{(\text{SNR})_{i/p}} = 2BT
\]

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

Sol. Given that for amplifier

\[ \text{Noise figure} = (F_n)_{db} = 4 \text{dB} \]
\[ \text{Bandwidth} = B_n = 5000 \text{ kHz} \]

and,
\[ (\text{SNR})_o = \frac{S_o}{N_o} = 1 \]
\[ R_m = 50 \Omega \]

Let \( S_i \) be the input signal power and \( N_i \) be input noise power then,
\[ S_i = \frac{(V_i)^2}{R_i} \]

or
\[ S_i = \frac{1}{R_i} \left(\frac{R_m}{R_m + R_s}\right)^2 V_s^2 \]
\[ = \frac{1}{50} \times \left(\frac{50}{50 + 50}\right)^2 V_s^2 = \left(\frac{V_s^2}{200}\right) \]
\[ \therefore \quad V_s = \sqrt{S_i \times 200} \] ... (i)

Since
\[ \text{Noise figure} = F_n = \frac{(\text{SNR})_i}{(\text{SNR})_o} = \frac{(\text{SNR})_i}{1} = (\text{SNR})_i = \frac{S_i}{N_i} \]
\[ \therefore \quad S_i = F_n \times N_i \]
\[ = F_n \times K T_0 B_n \] ... (ii)

Where \( K = \) Boltzman’s constant = \( 1.38 \times 10^{-23} \)
\[ B_n = \text{Receiver bandwidth} = 500 \times 10^3 \text{ Hz} \]
\[ T_0 = \text{Temperature} = 290 K \]
\[ \therefore \quad (F_n)_{db} = 10 \log_{10} (F_n) \]

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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