signals and systems

Gate2021-ec-Q52

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Question:

A message signal having peak-to-peak value of 2 V, root mean square value of 0.1 V, and bandwidth of 5 kHz is sampled and fed to a pulse code modulation (PCM) system that uses a uniform quantizer. The PCM output is transmitted over a channel that can support a maximum transmission rate of 50 kbps. Assuming that the quantization error is uniformly distributed, calculate the maximum signal-to-quantization noise ratio (rounded off to two decimal places).

solution:

Term	Description	Formula	Value
Peak-to-Peak	Peak-to-peak value of the message signal (in volts).	$\sqrt{2} \times \text{RMS}$	1.414 V
RMS	Root mean square value of the message signal (in volts).	$\frac{2}{2\sqrt{2}}$	0.707 V
Bandwidth	Bandwidth of the message signal (in kilohertz).	-	-
N	Number of bits per sample used in quantization.	-	5
Quantization range	Range of values in which the quantized signal falls (in volts).	$2 \times \text{Peak-to-Peak}$	2.828 V
Step size	The size of each quantization interval (in volts).	$\frac{\text{Quantization range}}{2^N}$	-
Sampling rate	Rate at which the message signal is sampled (in kilohertz).	-	10 kHz
Maximum transmission rate	Maximum transmission rate supported by the channel (in kilobits per second).	-	50 kbps
SQNR	Signal-to-quantization noise ratio.	$6.02 \times N + 1.76$	31.86

TABLE I
INPUT PARAMETERS

1) **Calculate Peak and RMS values:**

$$\text{RMS} = \frac{\text{Peak-to-Peak}}{2\sqrt{2}} \tag{1}$$

2) **Calculate Peak Value:**

$$\text{Peak} = \sqrt{2} \times \text{RMS} \tag{2}$$

3) **Calculate Quantization Range:**

$$\text{Quantization range} = 2 \times \text{Peak} \tag{3}$$

4) **Determine Number of Bits (N):**

$$N = \log_2(\text{quantization levels}) \tag{4}$$

5) **Calculate Step Size:**

$$\text{Step size} = \frac{\text{Quantization range}}{2^N} \tag{5}$$

6) **Calculate SQNR:**

$$\text{SQNR} = 6.02 \times N + 1.76 \tag{6}$$

$\implies$ SQNR = 31.86