# ADSP - Exercise 2: Peer Oral-Examination Cards

## Instructions

Work in pairs: 3 min with card A, then change roles and use card B for 3 min. Use the final 2 min for feedback. The examiner may use the printed notes but should not show them to the examinee during the answer.

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## Card A - Additive white-noise model

### Questions to ask

#### Main question

Under which assumptions may the quantization error be modeled as additive white noise, and when does this model fail?

#### Follow-up questions

1. What can an error histogram tell you, and what can it not tell you?
2. Why can a sinusoid with a short integer period (e.g. 48 samples) produce spectral lines in the error?
3. Why does a very small input often violate the model assumptions?
4. How would you use the time signal and error spectrum to support your assessment?

Choose two follow-up questions, depending on the first answer.

### Notes for the examiner

The lecture defines

$$e_q(n) = v(n) - v_q(n), \qquad v_q(n) = v(n) - e_q(n).$$

Expected key ideas:

- no overload, so that $-\Delta/2 < e_q(n) \leq \Delta/2$ (lecture, slide 25),
- approximately uniform error distribution,
- stationary and temporally uncorrelated error, hence an approximately flat spectrum,
- weak correlation between $e_q(n)$ and $v(n)$,
- a zero-mean input for identifying $P_v$ with $\sigma_v^2$ in the stated lecture SNR formula,
- assumptions become more plausible when many levels are exercised in a sufficiently irregular way,
- failure for small, constant, periodic (short integer period), or strongly correlated inputs.

A uniform-looking histogram does not establish whiteness. It contains no information about sample order. A periodic error may have a broad-looking histogram while still producing spectral lines. Likewise, a flat-looking Welch estimate supports but does not prove whiteness, and the displayed plots do not establish stationarity. Even a correct noise power does not confirm the model: for the very small sinusoid the error power is close to $\Delta^2/12$, although the error is tonal and strongly correlated with the input.

Useful prompt if the examinee is stuck:

> If the same set of sample phases is repeated every period, what happens to the quantization-error sequence?

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# Card B - Resolution, utilization, and clipping

## Questions to ask

### Main question

Explain how word length and signal amplitude affect quantization error and SNR. Distinguish poor utilization from overload.

### Follow-up questions

1. Why does one additional bit ideally improve the SNR by approximately $6\,\mathrm{dB}$?
2. Why can a small signal have a poor SNR even when the word length is unchanged?
3. How can you distinguish granular quantization error from clipping in the time signal and spectrum?
4. Which assumption used in $P_n = \Delta^2/12$ fails during clipping?

Choose two follow-up questions, depending on the first answer.

## Notes for the examiner

Expected chain of reasoning:

$$b \uparrow \Rightarrow L = 2^b \uparrow \Rightarrow \Delta = R/2^b \downarrow \Rightarrow P_n = \Delta^2/12 \downarrow.$$

One additional bit halves $\Delta$ and ideally quarters $P_n$. For unchanged signal power, the SNR therefore increases by

$$10 \log_{10}(4) \approx 6.02\,\mathrm{dB}.$$

Expected distinctions:

- Poor utilization: the signal occupies only a small part of $R$, visits few levels, and has low power relative to the granular error.
- Overload: the input exceeds the converter range; waveform peaks flatten and $|e_\mathrm{q}|$ can exceed $\Delta/2$.
- Clipping produces deterministic nonlinear distortion and harmonics. It is not merely a larger realization of the assumed white quantization noise.
- Increasing signal amplitude helps only until the available range is used safely. For a full-scale sinusoid, the lecture formula gives $SNR/\mathrm{dB} \approx 6.02\,b + 1.76$.
- In general $P_v = E\{v^2(n)\}$. For the zero-mean input assumed by the lecture, $P_v = \sigma_v^2$.

Useful prompt if the examinee is stuck:

> What happens first to $\Delta$, then to $P_n$, when the word length increases by one bit while $R$ remains fixed?

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## Peer feedback checklist

For each item, mark **secure**, **partly secure**, or **not yet clear**.

| Criterion | Secure | Partly secure | Not yet clear |
|---|---|---|---|
| The lecture sign convention for $e_q(n)$ is used correctly. | ☐ | ☐ | ☐ |
| Distribution, whiteness, and input-error correlation are distinguished. | ☐ | ☐ | ☐ |
| The 6 dB-per-bit rule is explained through $\Delta$ and error power. | ☐ | ☐ | ☐ |
| Poor utilization and clipping are clearly distinguished. | ☐ | ☐ | ☐ |
| Claims are linked to observable time-domain or spectral evidence. | ☐ | ☐ | ☐ |
| The explanation is concise and uses appropriate technical language. | ☐ | ☐ | ☐ |

Give one short positive observation and one suggestion for improvement.