Mittuniversitetet
MID SWEDEN UNIVERSITY

Försättsblad Prov Original

Kurskod	Provkod	Tentamensdatum
ET044G	T102	2018-08-27

Kursnamn	Elektroteknik GR (B), Mätteknik
Provnamn	Tentamen
Ort	Sundsvall
Termin	H18
Ämne	Elektroteknik

8982538474

0027782

<u>Exam time</u>: 5 hours
<u>Aids</u>: Electronic calculator
<u>Teacher</u>: Börje Norlin

<u>Number of tasks</u>: 5

<u>Number of pages</u>: 6

<u>Maximum points</u>: 100 (50 points required to pass)

<u>Instructions for submitted solutions</u>:

• Rationale and justifications may not be so scarce that they become difficult to follow.

• The reasoning behind your solutions should be explained.

• Calculations must be sufficiently complete to show how the final result was obtained.

1. a) The dependency for a resistive temperature sensor can be characterized by $R = C_0 + C_1\,T + C_2\,T^2$. This second order polynomial is used to fit data acquired for series observations on temperature and resistance.
   Define the matrixes for an overdetermined equation system TC=R and define those matrixes for N number of observations.

   10p

   b) Explain what is meant by *Measurement data matrix, Coefficient matrix* and *Observation matrix*.

   10p

2. Explain by using the properties of the *Expected value* and *Variance* why the Signal-to-Noise-Ratio is improved for a signal Y that is calculated as mean value taken from samples of signal X according to $Y = \frac{X_1 + X_2 + \mathrm{K} + X_N}{N}$ where all samples contain equal amount of white noise. The answer must be a developed mathematical expression for how the SNR_Y of Y relates to the SNR_X of X.

   20p

3. a) You are sampling a signal consisting of the sum of a 1 kHz sine wave, a 2 kHz sine wave and a 4 kHz sine wave. Your sampling frequency is 3 kHz. For which sine wave(s) do you get an accurate representation after sampling? Explain.

10p

b) What happens with the other sine wave(s)?

5p

c) With this sampling frequency, what should you do to ensure that this(ese) other sine wave(s) do not interfere with the one(s) that are accurately represented?

5p

4. a) The figure below shows the autocorrelation of a signal. Based on this autocorrelation, give a description of the signal in the time domain with as much detail as you can (you can select your own scales for the axes). Explain which part of the autocorrelation each piece of information comes from.

15p

b) Name two methods that can be applied to improve this signal's SNR in the time domain. Explain how they will help.

5p

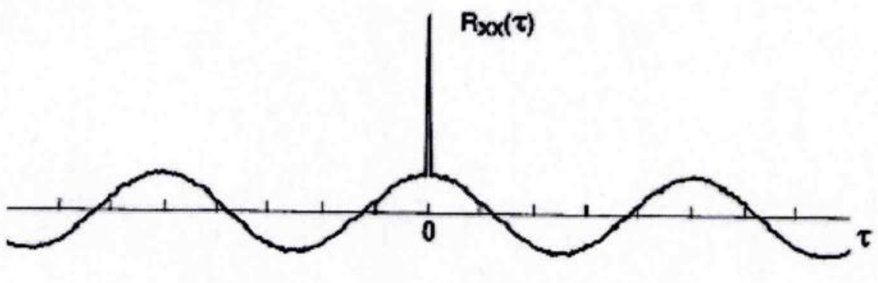

Figure autocorrelation signal

5. The figure below depicts a measurement system that consists out of two sensors, two amplifiers and a shielded cable for transmission of signals from the sensors to the amplifiers. The sensor signals will be partly mixed and the sensors are thus disturbing each other. Describe using an equivalent circuit how this mutual disturbance propagates. The description must also include an analytical expression that describes how the disturbance from sensor 1 propagates into amplifier 2. Both sensor grounding is connected to the cable shield.

20p

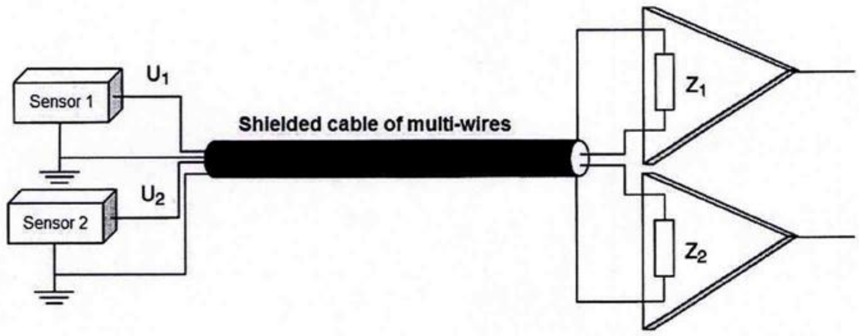

Figure A shielded measurement system

Good Luck!
/BÖRJE

Properties for the *Expected value*

$$E(X) \equiv \int_{-\infty}^{\infty} x \cdot f(x) \cdot dx\ ,\ f(x)\ is\ the\ pdf\ of\ X$$

$E(a \cdot X) = a \cdot E(X)$, a is a constant

$E(X + Y) = E(X) + E(Y)$

$E(X \cdot Y) = E(X) \cdot E(Y)$, only if X and Y are statistica lly independen t

Properties for the *Variance*

$V\{X + Y\} = V\{X\} + V\{Y\}$, only if X and Y are statistica lly independent

$V\{aX\} = a^2 \cdot V\{X\}$, a is a constant

$V\{X\} = \sigma^2$, σ is the standard deviation

$$V\{X\} \equiv E\{(X - \mu)^2\}$$

$$V\{X\} = E\{X^2\} - \mu^2$$

Autocorrelation

For an analog energy signal, it is defined as: $$R_{xx}(\tau) \equiv \int_{-\infty}^{\infty} x(t) \cdot x(t+\tau)\, dt$$

For an analog power signal, it is defined as: $$R_{xx}(\tau) \equiv \frac{1}{T}\int_{0}^{T} x(t) \cdot x(t+\tau)\, dt$$

For a time discrete energy signal, it is defined as: $$R_{xx}[k] \equiv \sum_{n=-\infty}^{\infty} x[n] \cdot x[n+k]$$

For a time discrete power signal, it is defined as: $$R_{xx}[k] \equiv \frac{1}{N}\sum_{n=0}^{N-1} x[n] \cdot x[n+k]$$

For an analog power signal Described as a stochastic process: $$R_{xx}(\tau) \equiv E\{x(t) \cdot x(t+\tau)\}$$

For a time discrete power signal Described as a stochastic process: $$R_{xx}[k] \equiv E\{x[n] \cdot x[n+k]\}$$

The autocorrelation function for the sum of several statistically independent signals equals the sum of the autocorrelation for each of the signals. $$R_{(x+y)(x+y)}(\tau) = R_{xx}(\tau) + R_{yy}(\tau)$$

Laplace transforms

$$X(s) = L\{x(t)\} \equiv \int_{-\infty}^{\infty} x(t) \cdot e^{-st} dt$$

$x(t)$	$X(s)$
step function $u(t)$	$\frac{1}{s}$
$e^{-\alpha t}u(t)$	$\frac{1}{s+\alpha}$
impulse function $\delta(t)$	1

Fourier transforms

$$X(j\omega) = F\{x(t)\} \equiv \int_{-\infty}^{\infty} x(t) \cdot e^{-j\omega t} dt \quad , \quad x(t) = F^{-1}\{X(j\omega)\} \equiv \frac{1}{2\pi} \int_{-\infty}^{\infty} X(j\omega) \cdot e^{j\omega t} d\omega$$

Signal to Noise ratio:

$$SNR = 10 \log\left(\frac{P_{signal}}{P_{noise}}\right) = 20 \log\left(\frac{U_{signal}}{U_{noise}}\right)$$

Noise power (from autocorrelation):

$$R_{xx}[0] = x_{RMS}^2 = W_{tot}$$