Mittuniversitetet
MID SWEDEN UNIVERSITY

Försättsblad Prov Original

Kurskod	Provkod	Tentamensdatum
ET044G	T102	2018-10-29

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

ARKIV

Exam time: 5 hours
Aids: Electronic calculator, if relevant, a dictionary or electronic dictionary between English and the students home language.
Teacher: Börje Norlin

Number of tasks: 6

Number of pages: 6

Maximum points: 30 (15 points required to pass)

Instructions for submitted solutions:

• 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. Explain three different methods to detect a signal coming from a resistive sensor. Draw sketches. Explain differences, advantages and disadvantages. (Hint: What methods were used in the temperature measurement lab and the load measurement lab.)

3p

2. a) A certain metal resistance sensor is to be used to measure temperatures between 0 and 200 °C. Given that the resistance R_T Ω at T °C is given by $R_T = R_0(1 + \alpha T + \beta T^2)$ and $R_0 = 100.0$, $R_{100} = 133.41$, $R_{200} = 169.24$ Ω. Calculate the values of α and β.

3p

b) Define the matrixes for an overdetermined equation system TC=R and define those matrixes for N number of observations.

2p

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

1p

3. A certain wireless technique used the transmitting power P = 35 mW for communication between units. The magnitude of the electrical field emitted by the "Bluetooth-like" wireless equipment is given by:

$$E = 7 \cdot \frac{\sqrt{P}}{d}$$

where d is the distance from the transmitter.

Assume that the actual equipment is intended for medical purpose, and that the sensor and the readout is design to fulfil the demand on medical equipment. Assume that the demands on medical equipment is to be immune to electrical fields of magnitude up to 3 V/m. Argue about which considerations that has to be made in the construction of the equipment, to not violate the regulation about maximum electric field affecting the equipment.

5p

4. Explain *Common Mode Rejection Ratio (CMRR)* when it comes to the properties of a difference amplifier. Define also CMRR expressed as decibel. Your answer must be short and accurate!

3p

5. A sinusoidal signal of amplitude 1.3 mV and frequency 15 kHz is difficult to detect with your readout since it is affected by Gaussian noise. The noise has a uniform power spectral density of 250 pW/Hz up to a cut-off frequency of 500 kHz.
   - Find the total power, r.m.s. value and standard deviation for the noise signal. Calculate the signal-to-noise ratio in dB?
   - Sketch both the fourier transform and the autocorrelation function for the signal, for the noise and for the combined signal.
   - The combined signal is passed through a band-pass filter with centre frequency 15 kHz and a bandwidth 750 Hz. What improvement in signal to noise ratio is obtained?
   - The filtered signal is then passed through a signal averager which averages corresponding samples of 500 sections of signal. What further improvement in signal-to-noise ratio is obtained?

7p

6. a) You are sampling a signal consisting of the sum of a 500 Hz sine wave, a 2 kHz sine wave and a 4 kHz sine wave. Your sampling frequency is 1.5 kHz. For which sine wave(s) do you get an accurate representation after sampling? Explain.

   2p

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

   2p

   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?

   2p

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):

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