NTNU

Department of Physics

Examination paper for TFY4190 Instrumentation

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Permitted examination support material:

Alternative C, Approved pocket calculator

K. Rottmann: Mathematical formulas (or equivalent)

English dictionary

Language: English

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Informasjon om trykking av eksamensoppgave
Originalen er:
1-sidig ☐ **2-sidig** ☐
sort/hvit ☐ **farger** ☐
skal ha flervalgskjema ☐

Checked by:

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Date Signature

Students will find the examination results in Studentweb. Please contact the department if you have questions about your results. The Examinations Office will not be able to answer this.

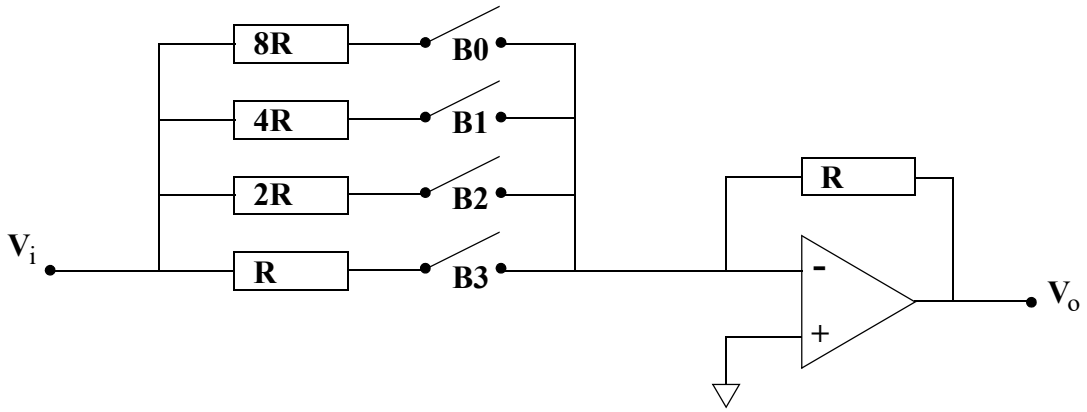
Problem 1

a) A "double-precision" binary number is represented by the hexadecimal number C00F 0000 0000 0000. The most significant bit gives the sign, the next 11 bits give the exponent, whereas the remaining 52 bits give the fraction. The exponent is unsigned and a bias of 1023 is used. What is the decimal value of the number?

b) Use the 2-complement method to perform a binary substration of 121_{10} from 42_{10}.

c) Convert decimal 0.73 to binary format.

Problem 2



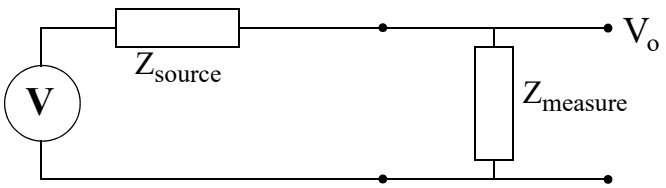
The figure above shows a circuit consisting of an operational amplifier and resistors of values R, 2R, 4R and 8R as indicated. In addition there are switches B0, B1, B2 and B3. The input voltage is V_i and the output voltage is V_o.

a) What is the purpose of the circuit?

b) What is the value of the transfer function V_o/V_i when switches B0 and B3 are closed (B2 and B1 are open)? How can this be expressed in binary form?

Problem 3

a)



The figure above shows an equivalent circuit for a voltage source and a measurement circuit.

How should the impedances be chosen to minimize inaccuracy in the ouput signal V_o?

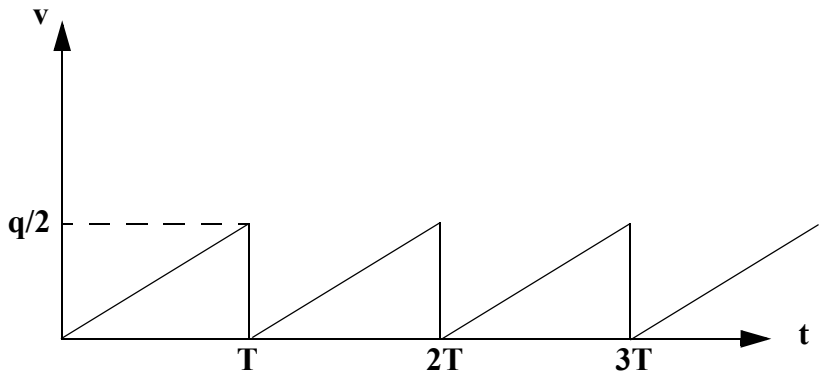
How should the impedances be chosen to maximize the transfer of power?

b) Give a brief description of the sampling theorem (Nyquist's sampling theorem).

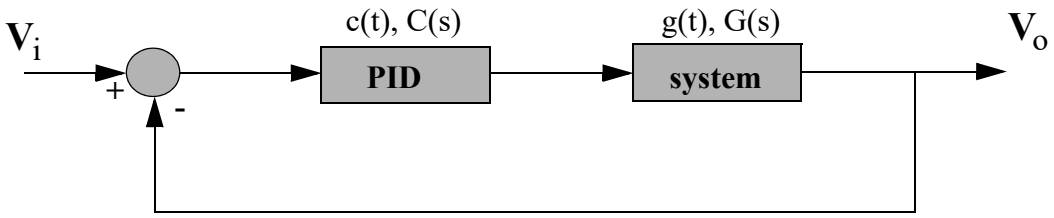
Problem 4

a) A 16bit AD converter has a voltage range from -10 to 10 V. What is the resolution?
The output voltage is given by 2-complement binary format.
What is the analogue input voltage when the output is 1011 0011 1001 0100?
How many significant digits should be used in the answer?

b) A noise signal v of period T and amplitude q/2 as shown in the graph below is superposed on a voltage signal V. What is the RMS value of the noise signal (quantization noise)?



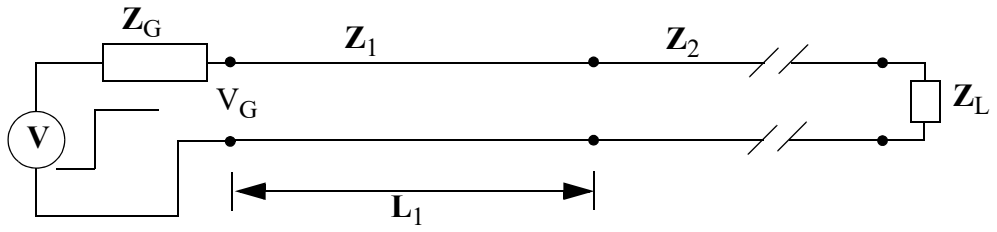
Problem 5



a)
A system is regulated by a PID-controller as shown above.
Give an expression for the transfer function of the PID controller and describe the different terms.
Find the total transfer function $H(s) = V_o(s)/V_i(s)$ for the regulated system.

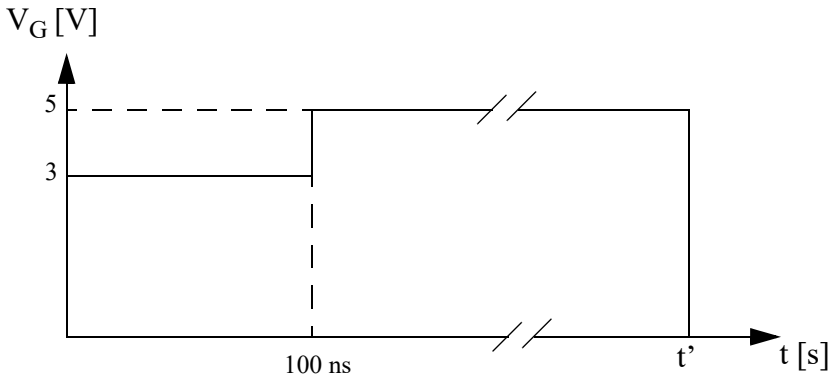
b)
Determine the output signal y(t) when a unit step (in the time domain) is incident on a system of transfer function $F(s) = \frac{1}{(s+1)^2}$.

Problem 6



A voltage step of 6V is sent from a source to a transmission line with real impedance Z_1 and length L_1 as shown in the figure above. The first transmission line is connected to another transmission line of real impedance Z_2. At the end of the second transmission line is a load of impedance Z_L.

In the figure below is shown how the voltage V_G after the source varies with time.



a) Assume that impedances $Z_G = Z_1 = 50\ \Omega$, and give an expression for the reflection coefficient when the signal passes from transmission line 1 to transmission line 2. Find the impedance Z_2 of the second transmission line.

b) Find the speed of the signal in transmission line 1 if L_1=10 m.

c) What is the significance of the signal going to zero after time t'?

Appendix: Laplace transforms

Y(s)	y(t), t>0
$Y(s) = \int_0^\infty \exp(-st)y(t)dt$	$y(t)$
$Y(s)$	$y(t) = \frac{1}{j2\pi}\int_{c-j\omega}^{c+j\omega} \exp(st)Y(s)ds$
$sY(s) - y(0)$	$\frac{\mathrm{d}}{\mathrm{d}t}y(t)$
$s^2Y(s) - sy(0) - y'(0)$	$y''(t)$
$\frac{1}{s}Y(s)$	$\int_0^t y(\tau)d\tau$
$F(s)G(s)$	$\int_0^t f(t-\tau)g(\tau)d\tau, \quad convolution$
$\frac{1}{s}$	$u(t), \quad unit\ step$
$\frac{1}{s}\exp(-\alpha s)$	$u(t-\alpha)$
$\frac{1}{s+\alpha}$	$\exp(-\alpha t)$
$\frac{1}{(s+\alpha)^2}$	$t\exp(-\alpha t)$
$\frac{\alpha}{s^2+\alpha^2}$	$\sin(\alpha t)$

Løsningsskisse - Eksamen 7. juni 2018

Oppg.1a
C00F 0000 0000 0000 (hex)=> 1|100 0000 0000|111 1 0000 0000
MSB (most significant bit) gir fortegnet: 1 = negative number
De neste 8 bits gir eksponenten: 100 0000 0000 = 2^{10} (dec) - bias(1023) = 1
De neste 23 bits gir fraksjonen: 11110000001 = .11110100001 = 1/2+1/4+1/8+1/16 = 0.9375..
Dermed fås: $-1.9375*2^1 = -3.8750$

Oppg.1b
42-121 = 101010 - 1111001 -> 00101010 (add one 0 to left)
+10000111 (2-komp., one 0 to left added)
=1|0110001 -> - 1001111 = -79 (MSB=1 => negative number)

Oppg.1c
0.73:

fraksjonen
0.73*2 = 0.46 + 1
0.46*2 = 0.92 + 0
0.92*2 = 0.84 + 1
0.84*2 = 0.68 + 1
0.68*2 = 0.36 + 1
0.36*2 = 0.72 + 0
0.72*2 = 0.44 + 1
0.44*2 = 0.88 + 0

10111010..

0.73 (desimalt) = 0.10111010.... (binært)

Oppg.2a
Kretsen er en DAC.

Oppg.2b
B0 og B3 er lukket. B1 og B2 er åpen. $V_o/V_i = -(1/8+1) = -(1+8)/8 = -9/8$.
Binært er dette proporsjonalt med 1001 (binært 9).

Oppg.3a
Redusere unøyaktighet: $Z_{measure} >> Z_{source}$
Maximum effekt overføring $Z_{measure} = Z_{source}$*

Oppg.3b
Nyquist: samplingsfrekvens $f_s > 2f_{max}$.
Benytt lavpassfilter med cut-off frekvens $f_s/2$ for å fjerne høyfrekvente komponenter.

Oppg.4a
Oppløsning for en 16 bit AD spenningsomformer.

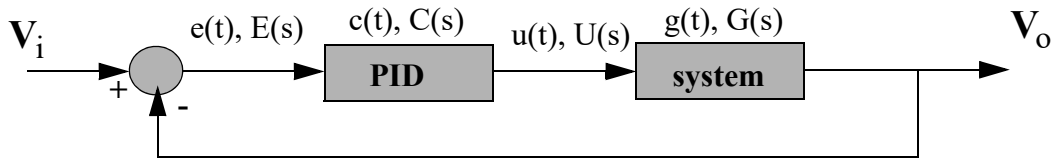
$$\Delta V = \frac{10-(-10)}{2^{16}-1}V = 3{,}052 \cdot 10^{-4}V$$

Utgangsspenningen gis ved 2komplement binært format og er:
1011 0011 1001 0100 -> negativ inngangsspenning,
2komp. gir: 0100 1100 0110 1100 = $2^{14} + 2^{11} + 2^{10} + 2^6 + 2^5 + 2^3 + 2^2 = 19564$.
Analog innspenning er dermed: -0.0003052*19564V = - 5.9709 V.
Benytter 4 desimaler i svaret.

Oppg.4b
Kvantiseringsstøy.

$$v_{RMS} = \sqrt{\frac{1}{T}\int_0^T \left(\frac{q}{2T}t\right)^2 dt} = \sqrt{\frac{q^2}{12}} = \frac{q}{\sqrt{12}}$$

Oppg.5a



$$u(t) = K_P e(t) + K_I \int_0^t e(t)dt + K_D \frac{\mathrm{d}}{\mathrm{d}t} e(t)$$

$$U(s) = K_P E(s) + K_I \frac{E(s)}{s} + K_D s E(s) = C(s)E(s)$$

ledd: K_P proporsjonal, K_I integral, K_D derivativ kontroll

$$(V_i(s) - V_o(s))C(s)G(s) = V_o(s)$$

therefore

$$\frac{V_o(s)}{V_i(s)} = \frac{C(s)G(s)}{1 + C(s)G(s)}$$

Oppg.5b
Ved bruk av appendiks fås

$$Y(s) = \frac{1}{s}F(s) = \frac{1}{s} \cdot \frac{1}{(s+1)^2} \rightarrow f(t) = t\exp(-t) \qquad (fra\ \ tabell)$$

$$som\ \ gir \qquad y(t) = \int_0^t t\exp(-t)dt = -t\exp(-t)\Big|_o^t + \int_0^t \exp(-t)dt = 1 - (t+1)\exp(-t))$$

Oppg.6a

$$\Gamma = \frac{Z_2 - Z_1}{Z_2 + Z_1} = \frac{Z_2 - 50}{Z_2 + 50} = \frac{2}{3} \Rightarrow Z_2 = 250\Omega$$

Oppg.6b

Signalet trenger tiden t=100 ns på å tilbakelegge strekningen $2L_1$ = 20m, som gir

1. at v=20m/100ns = 200km/s = 66% av lyshastigheten.

Oppg.6c

Signalet vil gå mot null hvis den andre transmisjonslinja blir kortsluttet, dvs. refleksjonskoeffisient Γ = -1.