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Department of Physics, NTNU

Examination paper for TFY4190 Instrumentation

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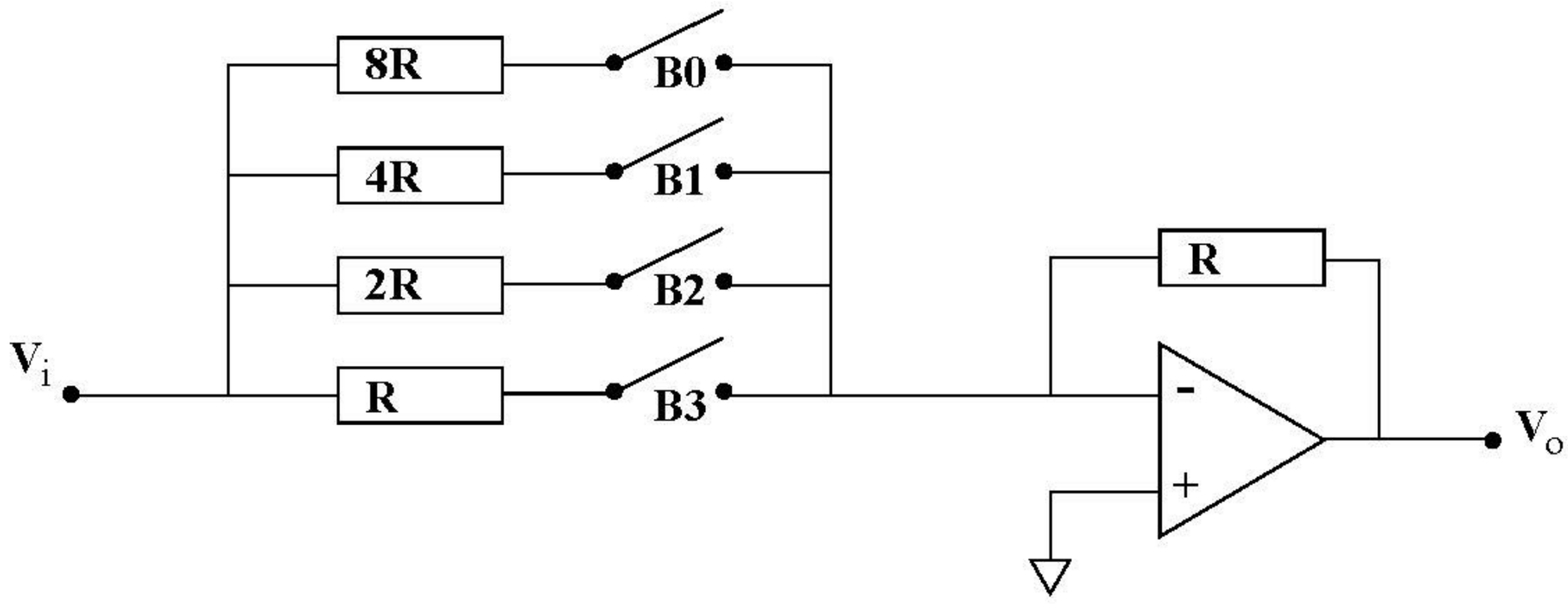
Examination date: May 29, 2019
Examination time (from-to): 9-13
Permitted examination support material:

Alternative C, Approved pocket calculator
K. Rottmann: Mathematical formulas (or equivalent)
English dictionary

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.

1

P1-TFY4190



The figure above shows a circuit consisting of an ideal operational amplifier, resistors and switches B0 to B3. V_i = 8V and V_o are the input and output voltages, respectively, and the value of R = 100Ω.

What is the output voltage V_o when switches B0 and B3 are closed and switches B2 and B4 are open?

Enter the answer here:

What is the binary equivalent of the output voltage V_o when switches B0 and B3 are closed and switches B2 and B4 are open?

Enter the answer here:

Maximum marks: 2

2 P2-TFY4190

What is the binary 2-complement representation of the decimal number -44?
Select one alternative:

- 010100
- 010011
- 1010100
- 1010011
- 1011011

Maximum marks: 1

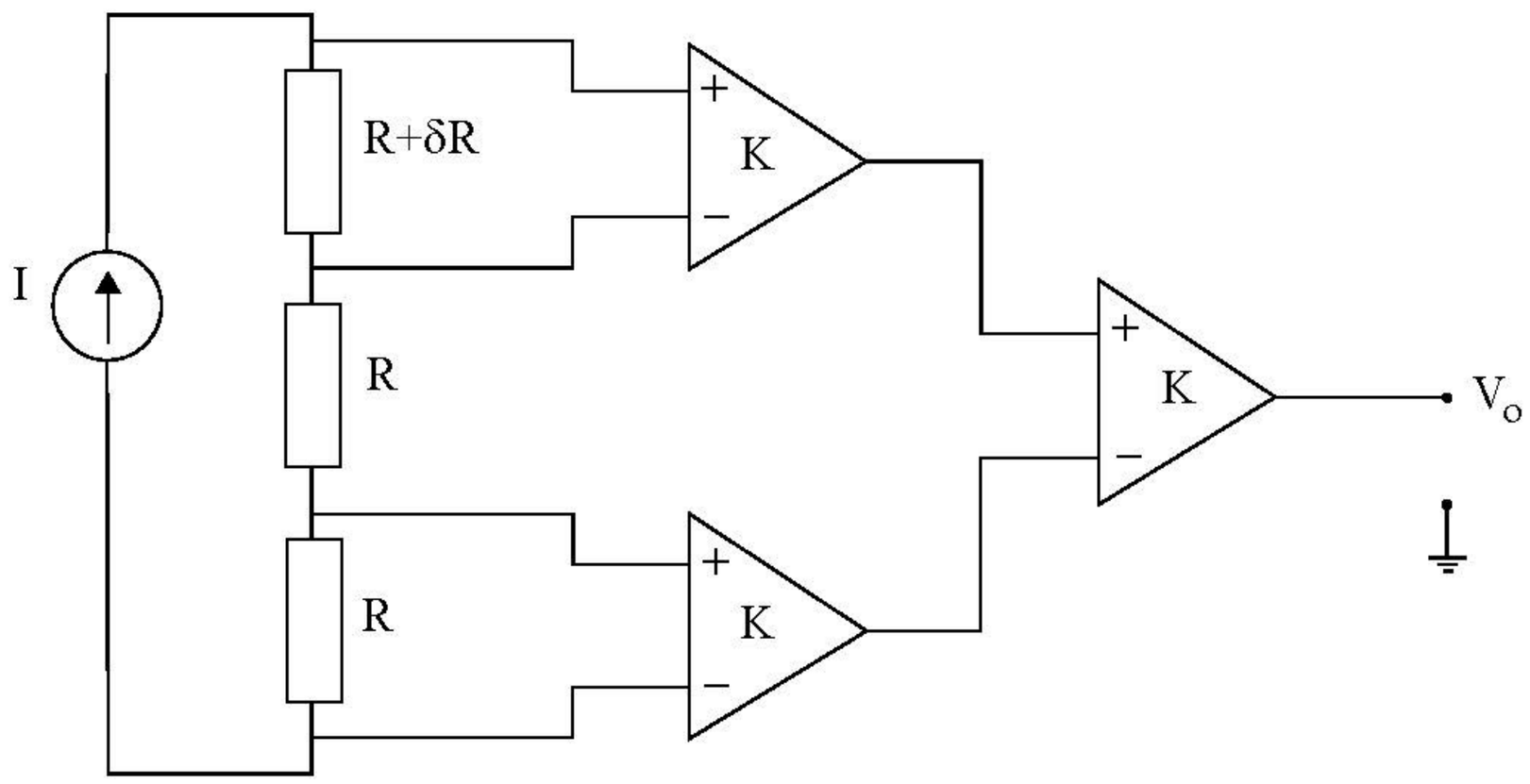
3 P3-TFY4190

A single-precision binary number is representet by the hexadecimal number B81A0000. The MSB gives the sign, the next 8 bits give the exponent, whereas the remaining 23 bits give the fraction. A bias of 127 for the exponent is used. What is the decimal value of the number?

Enter the number here:

Maximum marks: 1

4 P4-TFY4190



The above figure shows an “Anderson loop” circuit having three differential amplifiers of gain K and resistors of values R and R+δR and a current source of current I.
What is the output voltage V_o for K = 5, I=0.2A, R = 1000Ω, and δR= 0.3Ω?

Enter the answer here: V_o = V

Maximum marks: 1

5 **P5-TFY4190**

A 14bit AD converter operates in a voltage range from -5 to 5 V.
What is the resolution of the ADC?

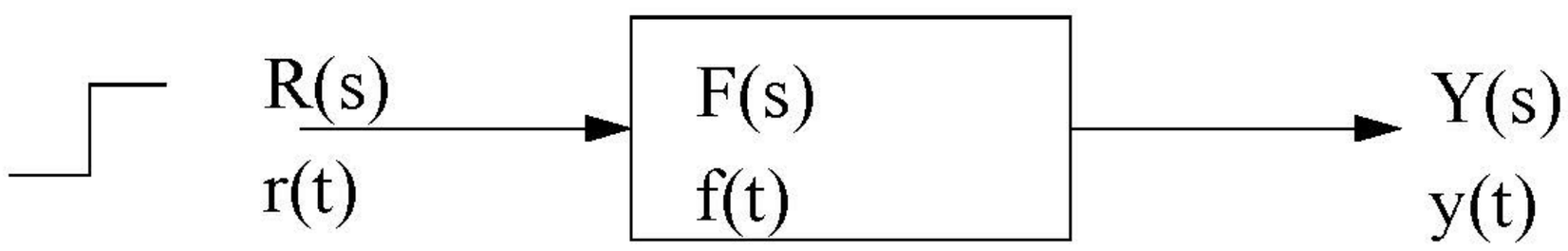
Enter the number here: [ ] V

The output voltage is given in binary 2-complement form. What is the analogue input voltage when the output is given by the binary number 11 1111 1001 0000?

Enter the number here: [ ] V

Maximum marks: 2

6 **P6-TFY4190**



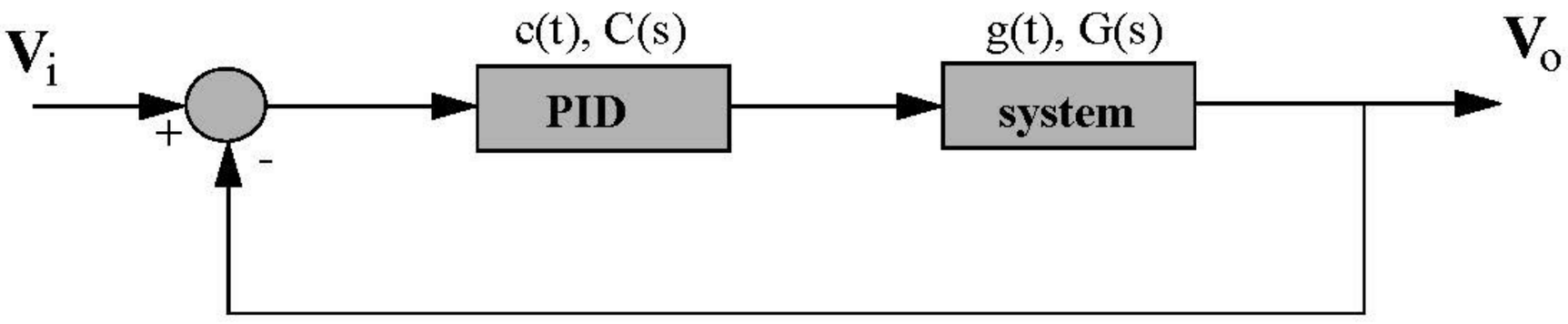
A unit step signal (in the time domain) is impinging onto a system of transfer function given by $F(s) = \frac{1}{s(s+1)}$. What is the value of the output signal y(t=1s)?

Select one alternative:

- 1.63
- 0.63
- 0.37
- 1.37
- 0.5

Maximum marks: 1

7 P7-TFY4190



A system is controlled by use of a PID controller as shown in the figure above.

Write down the expression for the transfer function C(s) of the PID controller in the frequency (Laplace) domain.
Use parameters Kp=2, Kd=4, and Ki=5, and s=1 and calculate a number.

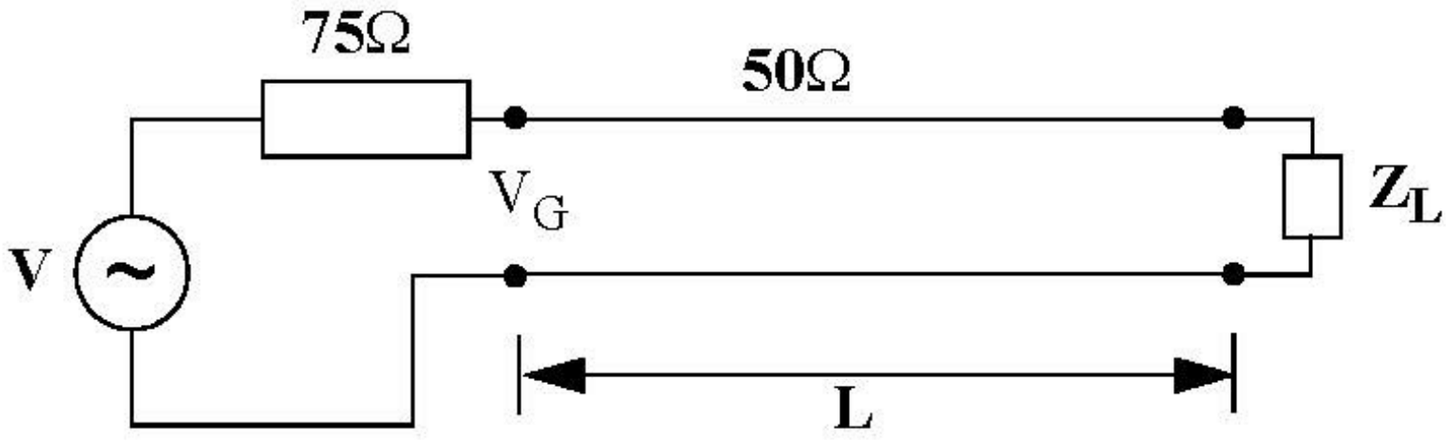
Enter the answer here:

Find the transfer function for the total system (PID controller and system) in the frequency (Laplace) domain.
Use parameters C(s) = 2 and G(s) = 3 and calculate a number.

Enter the answer here:

Maximum marks: 2

8 P8-TFY4190



A high frequency voltage signal of amplitude 10V is sent from a source to a transmission line of impedance 50 Ω and length L as shown in the figure above. The impedance of the source is 75Ω. At the end of the transmisison line is a load impedance Z_L.

The reflection coefficient at the load Γ_L=0.3.

What is the load impedance Z_L?

Enter the answer here: Ω.

What is the reflection coefficient at the source?

Enter the anser here:

What is the VSWR (voltage standing wave ratio) at the load?

Enter the answer here:

Maximum marks: 3

9 P9-TFY4190

Find the dynamic range for a 12-bit AD voltage converter. Give the answer in Decibel.

Enter the answer here: dB

Maximum marks: 1

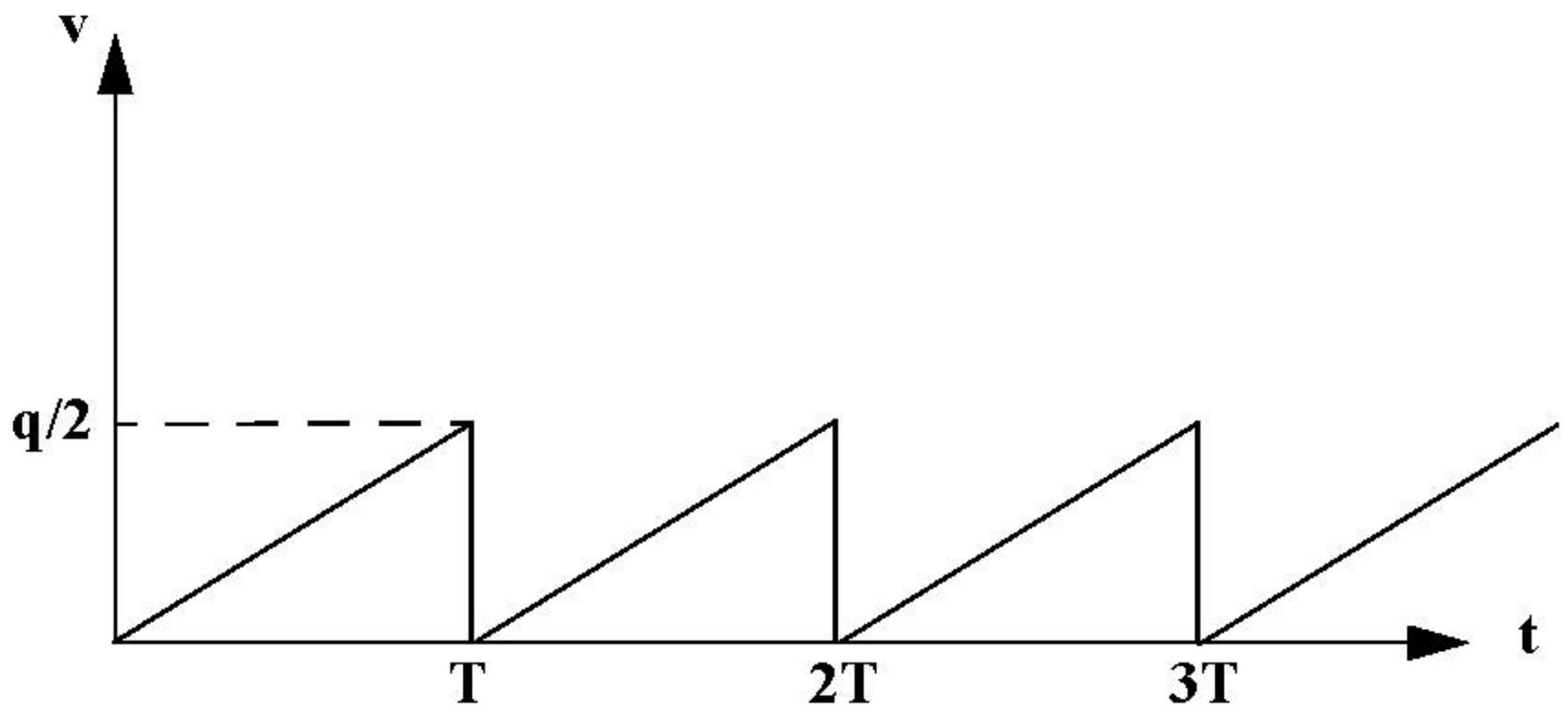
10 P10-TFY4190

Convert decimal 27.456 to binary format.

Enter the answer here: .

Maximum marks: 1

11 P11-TFY4190



A noise signal v of period T and amplitude q/2 (as shown in the figure above) is superposed on a voltage signal V. What is the RMS value of the noise signal (quantization noise)?
Use q = 2V and calculate a number.

Enter the answer here: V.

Maximum marks: 1

12 P12-TFY4190

A signal has bandwidth from 20 to 10000Hz. Assume that a digital sampling is to be done of the signal. What should the minimum sampling frequencey be to avoid aliasing?

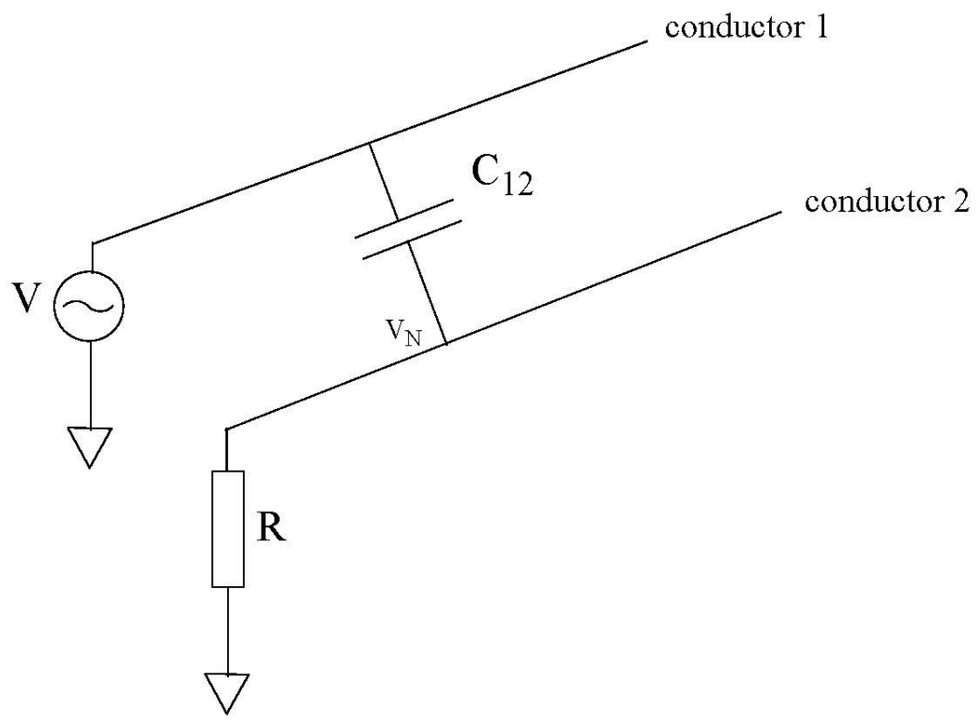
Enter the answer here: Hz

What should the cut-off frequencey be for the low-pass filter?

Enter the answer here: Hz

Maximum marks: 2

13 P13-TFY4190



A high frequency voltage signal V is transmitted on "conductor 1". Due to capacitive coupling which is modelled by the capacitor C_{12} the signal is picked up by a nearby "conductor 2", as shown in the figure above. The signal on "conductor 2" may be considered as a noise signal V_N. The resistance to ground of conductor 2 is given by the resistor R.

Estimate the amplitude of the noise signal V_N for the following parameter values: AC voltage of amplitude V = 100 V and angular frequency ω = 10000 1/s, stray capacity C_{12} = 100 pF, and resistance R = 1000 Ω.

Enter the answer here: V

Maximum marks: 1

14 P14-TFY4190

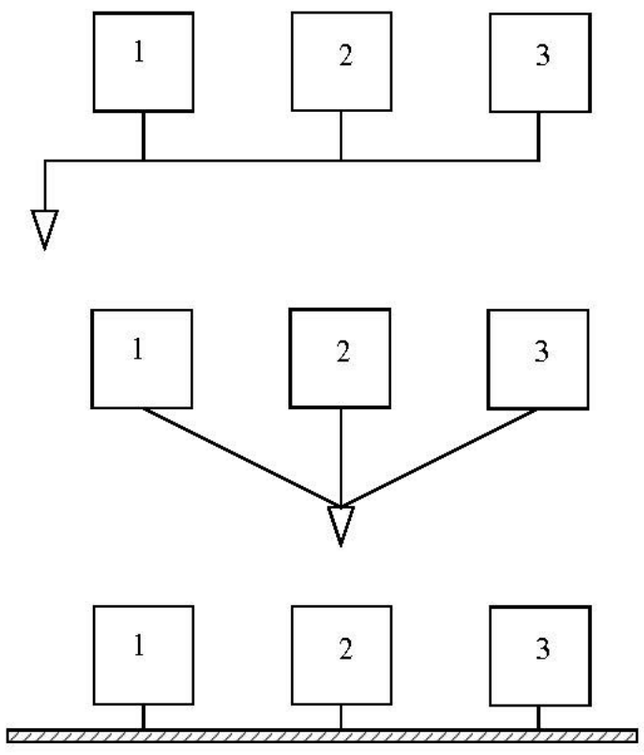
In the figure to the right below are shown three grounding schemes.
Which statement belongs to each figure?

Place the statements on top of the correct figure (drag and drop):

Low ground currents

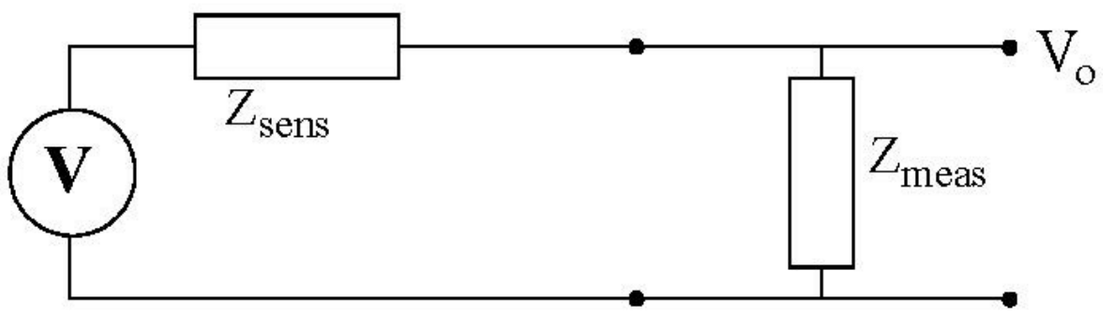
High frequency signal

High ground currents and low frequency



Maximum marks: 3

15 # P15-TFY4190



The figure above show an equivalent circuit for a voltage source and a measurement circuit. The impedance for the source Z_{sens} = 100Ω

What should the impedance Z_{meas} be for transfer of maximum power from the source to the measurement cirrcuit?

Enter the answer here: Ω

What should the impedance Z_{meas} be for maximum accuracy of the output signal V_o?

Select one alternative

- $Z_{meas} >> Z_{sens}$
- $Z_{meas} = Z_{sens}$
- $Z_{meas} << Z_{sens}$

Maximum marks: 2

TFY4190 Instrumentering Solution - Exam May 29, 2019

Problem 1

B0 og B3 closed. B1 og B2 open. V_o/V_i = - (1/8+1) = - (1+8)/8= -9/8.

The output voltage is V_o = -9V for V_i = 8V.

This may be represented binary as 1001 (decimal 9).

Problem 2

Decimal number -44. The number 44 = 32+8+4 = 101100. By adding one digit we get 0101100.
The 2-complement value of -44 may then be written 1010100.

Problem 3

B81A0000 (hex)=> 1011 1000 0001 1010 0000 0000 0000 0000
The MSB (most significant bit) give the sign: 1 = negative number
The next 8 bits give the exponent: 01110000 = 112 (dec) - bias(127) = -15
The next 23 bits give the fraction: 001 1010 0000 0000 0000 0000 = .0011011 = 1/8+1/16+1/64 = 0.2031

The answer is then: -1.2031*2**-15 = -1.2031*3.052*10^{-5} = -3.672*10^{-5}

Problem 4

Vo =K^2IδR = 5x5x0.2*0.3 = 1.5V.

Problem 5

Resolution: 10V/(2^14-1) = 0.00061V
11 1111 1001 0000 (2-compl. binary) => negative number 00 0000 0111 0000 = - 112 (dec)
Analogue input is -112*0.00061 V = -0.068 V

Problem 6

Unit step input onto a system of transfer function F(s):

$$Y(s) = \frac{1}{s}F(s) = \frac{1}{s}\cdot\frac{1}{s(s+1)} = \frac{1}{s^2(s+1)}$$

Using table of Laplace transforms we get:

$$y(t) = t-(1-e^{-t})$$

Inserting t=1 we get y(1) = exp(-1) = 0.37

Problem 7

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

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

Using Kp=2, Kd=4, Ki=5, s=1 we get C(s)=11

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

therefore

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

Using C(s)=2, G(s)=3 we get for the total transfer function 6/7 = 0.86

Problem 8

$$\Gamma_L = \frac{Z_L - 50}{Z_L + 50} = 0{,}3 \Rightarrow Z_L = \frac{1{,}3 \cdot 50}{0{,}7} = 92{,}86$$

$$\Gamma_G = \frac{75 - 50}{75 + 50} = 0{,}2$$

$$VSWR = \frac{V_{max}}{V_{min}} = \frac{1 + |\Gamma_L|}{1 - |\Gamma_L|} = \frac{1 + 0{,}3}{1 - 0{,}3} = 1{,}857$$

Problem 9

Dynamic range = Largest number / smalles number = 2^n-1 for n-bit AD voltage transformer.
dB = 20log(2^n-1) = 20log2^n = n20log2 = n6 = 72 for 12bit AD.

Problem 10

Convert decimal 27.456 to binary: 11011.011101.....

Problem11

Quantization noise:

$$v_{RMS} = \sqrt{\frac{1}{T}\int_0^T \left(\frac{q}{2T}t\right)^2 dt} = \sqrt{\frac{q^2}{12}} = \frac{q}{\sqrt{12}} = 0{,}577$$

Problem12

Nyquist: sampling frequency $f_s > 2f_{max}$. Use low-pass filter where cut-off frequency is $f_s/2$ to remove high frequency components. Therefore f_s = 20000Hz and low-pass filter where f_{cutoff} = 10000Hz.

Problem13

We may write: $(V-V_N)/(j\omega C_{12}) = V_N/R$, which gives $V_N = j\omega RC_{12}V = 10^4 10^3 10^{-10} = 0.1$ V where we have used that $V_N << V$.

Problem14

Grounding schemes. Drag and drop problem.

Problem 15

To maximize power transfer $Z_{meas} = Z_{sens}^*$ = 100Ω
For maximum accuracy of output signal V_o we require that $Z_{meas} >> Z_{sens}$