Examination Sensorics

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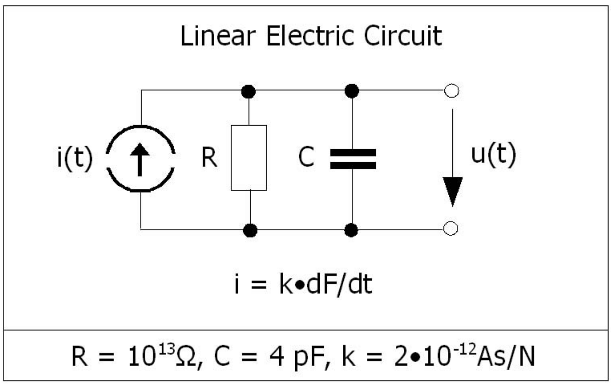
September 22, 2006

Name:	Points	T1	T2	T3	T4	T5	Total
Mat.-No.:	attainable:	20	25	22	10	8	85
Grade:	reached:						

Task 1: Piezo Acceleration Sensor

A piezo acceleration sensor is able to transduce forces F into an electrical signal, esp. voltage u. The physical description is given by a mathematical formula (diffential equation):

$$\frac{du}{dt} + \frac{u}{R \cdot C} = \frac{k}{C} \cdot \frac{dF}{dt} \ .$$



a) Transform the given differential equation with $u(0^-) = 0$ and $F(0^-) = 0$ into the s-domain using the transformation table.

b) Calculate the time dependent output voltage u(t) in the case of a step functional input force (step response): $F(t) = 100N \cdot \sigma(t)$.

c) Sketch u(t) within the time range t ϵ [0 120]s.

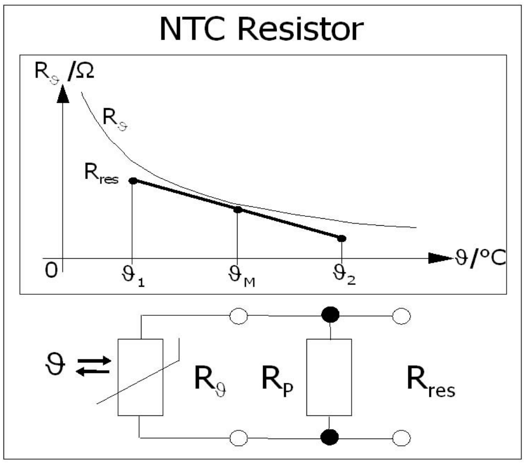
d) Explain whether the time constant τ should be high or low.

Task 2: Resisitve Temperature Sensor

The application of a resistive temperature sensor with a negative temperature coefficient shows a non linear behaviour. A simple lineariziation method can be realized connecting a resistor parallel to the temperature sensor. This approximation can be expressed in the formula:

$$\frac{R_{res}(\vartheta_1) - R_{res}(\vartheta_M)}{\Delta\vartheta} = \frac{R_{res}(\vartheta_M) - R_{res}(\vartheta_2)}{\Delta\vartheta}$$

with $\Delta\vartheta = \vartheta_M - \vartheta_1 = \vartheta_2 - \vartheta_M$.



a) Specify the resulted resistor R_{res} and simplify the given formula.

b) Set the resulted resistor R_{res} into the formula.

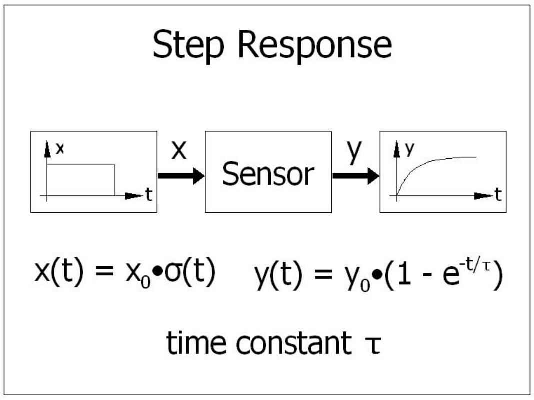
c) Derive from b) the expression of the parallel resistor R_P to bring the expression down to a common dominator.

Task 3: Consistancy of Sensor Signals

During measuring the step response of a sensor an external influence changes its time constant. Because of this the output signals y(t) differ from two experiments:

$$y_1(t) = y_0 \cdot (1 - e^{-\frac{t}{\tau_1}}),\ y_2(t) = y_0 \cdot (1 - e^{-\frac{t}{\tau_2}})$$

with $\tau_1 = 1s$ and $\tau_2 = 2s$.



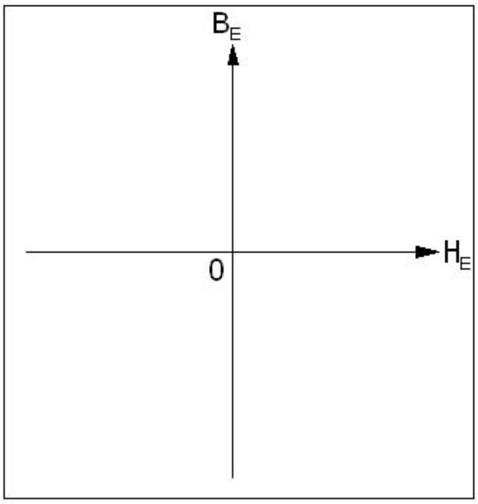
a) Calculate the time value $t = t_m$ where the difference of these two outputsignals reach there maximum.

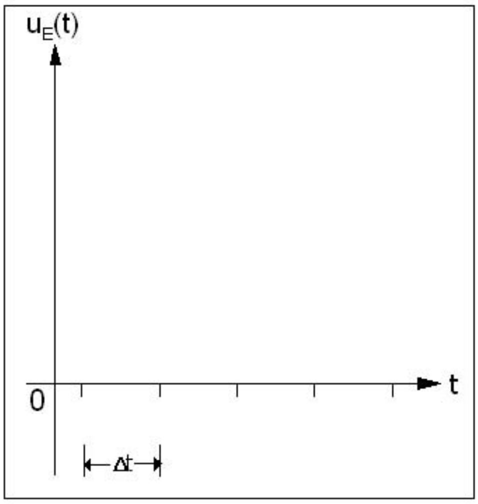
b) Calculate the consistancy $D_{\%}$.

Task 4: Additional Questions

a) WIEGAND Rotational Speed Sensor

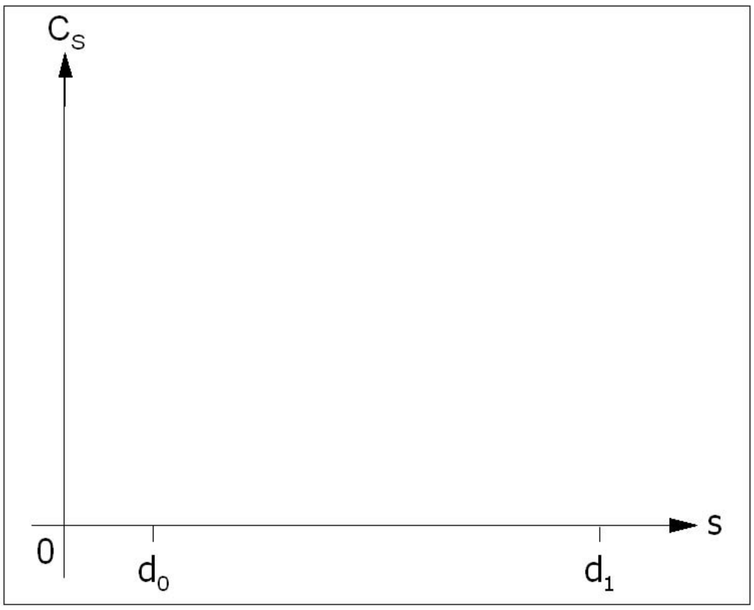
WIEGAND rotational speed sensors locate the alternation of magnetic fields. Sketch qualitatively the magnetiziation characteristic $B_E(H_E)$ and the sensor signal $U_E(t)$.





b) Capacitive Position Sensor

Capacitive position sensors react of variation with reference to the distance. Sketch qualitatively the behaviour of the capacitance $C_s(s)$ in the case of a plate capacitor by variable plate distances s from $d_0 \leq s \leq d_1$.



<u>Task 5</u>: Common Questions

Every question allows one correct answer

a) Optical Angle Sensor

Which measuring principle belongs to an optical angle sensor?

- ☐ Interference
- ☐ incremental
- ☐ DOPPLER effect

b) Radar Position Sensor

Which measuring effect is utilized to the radar position sensor

- ☐ Frequency
- ☐ Magnetitude
- ☐ Duration

of the reflected wave?

c) HALL Generator

Which value can be measured using a HALL generator?

- ☐ electric field density
- ☐ magnetic field density
- ☐ electric resistance

d) Torque Measurement using the Magnetoelastic Effect

On what property is the magnetoelastical effect based on?

- ☐ Permeability
- ☐ Inductance
- ☐ Conductivity

Results of the Examination SENSORICS

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Task 1: Piezo Acceleration Sensor

a) Elementwise transformation of the differential equation

$$\frac{du}{dt} \circ\!-\!\bullet\, s \cdot U(s) - u(0^-)\,,\; u(t) \circ\!-\!\bullet\, U(s)\,,\; \frac{dF}{dt} \circ\!-\!\bullet\, s \cdot F(s) - F(0^-)$$

with $u(0^-) = 0$ and $F(0^-) = 0$ $\Rightarrow$ [3]

$$\boxed{s \cdot U(s) + \frac{U(s)}{R \cdot C} = \frac{k}{C} \cdot s \cdot F(s)}\,.$$ [2]

b) Step function $F(t) = 100N \cdot \sigma(t)$

Due to $\sigma(t) \circ\!-\!\bullet\, s \cdot \frac{1}{s}$ $\Rightarrow$ $s \cdot U(s) + \frac{U(s)}{R \cdot C} = \frac{k}{C} \cdot s \cdot \frac{100N}{s} = \frac{k}{C} \cdot 100N$ [3]

Rearranging to U(s): $U(s) = 100N \cdot \frac{k}{C} \cdot \frac{1}{s + \frac{1}{RC}} = 100N \cdot \frac{k}{C} \cdot \frac{1}{s + \frac{1}{\tau}}$
where τ is the time constant. [2]

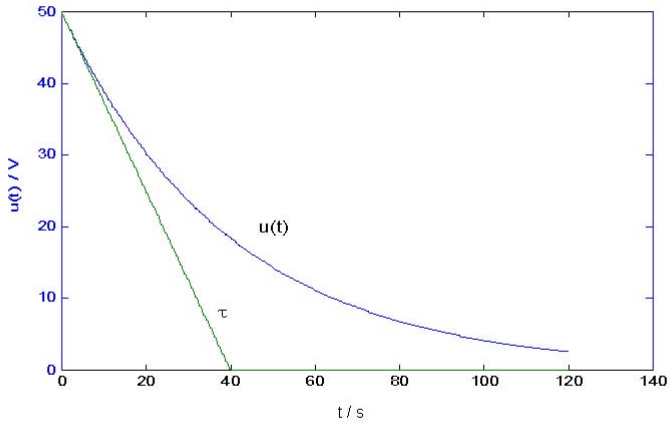
Inverse LAPLACE transfomation:
$u(t) = 100N \cdot \frac{k}{C} \cdot e^{-\frac{t}{\tau}} = 100N \cdot 2 \cdot 10^{-12} \frac{As}{N} \cdot \frac{V}{4 \cdot 10^{-12} As} \cdot e^{-\frac{t}{\tau}}$ [2]

with $\tau = R \cdot C = 10^{13} \frac{V}{A} \cdot 4 \cdot 10^{-12} \frac{As}{V} = 40s$ follows: [1]

$$\boxed{u(t) = 50V \cdot e^{-\frac{t}{40s}}}\,.$$ [1]

c) Sketch of u(t)

With $u(0) = 50V$, $u(\infty) = 0V$ and $\tau = 40s$ the discharchement of the sensor has the following curve shape u(t):



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d) Time constant

The sketch of u(t) shows the discharge of the capacitor C while the force is constant. To avoid fast discharges the time constant should be high as possible, resp. infinite. 2

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Task 2: Resistive Temperature Sensor

a) Resistor R_{res} and simplified formula

$$\boxed{R_{res} = \frac{R_P \cdot R_\vartheta}{R_P + R_\vartheta}} \qquad \boxed{R_{res}(\vartheta_1) + R_{res}(\vartheta_2) - 2 \cdot R_{res}(\vartheta_M) = 0}$$

3

b) Combined expression

$$\frac{R_P \cdot R_\vartheta(\vartheta_1)}{R_P + R_\vartheta(\vartheta_1)} + \frac{R_P \cdot R_\vartheta(\vartheta_2)}{R_P + R_\vartheta(\vartheta_2)} - 2 \cdot \frac{R_P \cdot R_\vartheta(\vartheta_M)}{R_P + R_\vartheta \vartheta_M)} = 0$$

3

c) Parallel resistor

From b) with common dominator follows:

$$\frac{R_\vartheta(\vartheta_1)}{R_P + R_\vartheta(\vartheta_1)} + \frac{R_\vartheta(\vartheta_2)}{R_P + R_\vartheta(\vartheta_2)} = 2 \cdot \frac{R_\vartheta(\vartheta_M)}{R_P + R_\vartheta \vartheta_M)} \Rightarrow$$

$$\frac{R_\vartheta(\vartheta_1) \cdot [R_P + R_\vartheta(\vartheta_2)] + R_\vartheta(\vartheta_2) \cdot [R_P + R_\vartheta(\vartheta_1)]}{[R_P + R_\vartheta(\vartheta_1)] \cdot [R_P + R_\vartheta(\vartheta_2)]} = 2 \cdot \frac{R_\vartheta(\vartheta_M)}{R_P + R_\vartheta \vartheta_M)} \Rightarrow$$ 2

$$R_\vartheta(\vartheta_1) \cdot [R_P + R_\vartheta(\vartheta_2)] \cdot [R_P + R_\vartheta(\vartheta_M)] + R_\vartheta(\vartheta_2) \cdot [R_P + R_\vartheta(\vartheta_1)] \cdot [R_P + R_\vartheta(\vartheta_M)] = 2 \cdot [R_P + R_\vartheta(\vartheta_1)] \cdot [R_P + R_\vartheta(\vartheta_2)] \cdot R_\vartheta(\vartheta_M) \Rightarrow$$ 3

$$R_\vartheta(\vartheta_1) \cdot \left[R_P^2 + R_P \cdot [R_\vartheta(\vartheta_2) + R_\vartheta(\vartheta_M)] + R_\vartheta(\vartheta_2) \cdot R_\vartheta(\vartheta_M)\right] + R_\vartheta(\vartheta_2) \cdot \left[R_P^2 + R_P \cdot [R_\vartheta(\vartheta_1) + R_\vartheta(\vartheta_M)] + R_\vartheta(\vartheta_1) \cdot R_\vartheta(\vartheta_M)\right] = 2 \cdot R_\vartheta(\vartheta_M) \cdot \left[R_P^2 + R_P \cdot [R_\vartheta(\vartheta_1) + R_\vartheta(\vartheta_2)] + R_\vartheta(\vartheta_1) \cdot R_\vartheta(\vartheta_2)\right] = \Rightarrow$$ 6

$$R_\vartheta(\vartheta_1) \cdot R_\vartheta(\vartheta_2) + R_\vartheta(\vartheta_1) \cdot R_\vartheta(\vartheta_M) + R_\vartheta(\vartheta_1) \cdot R_P + R_\vartheta(\vartheta_2) \cdot R_\vartheta(\vartheta_1) + R_\vartheta(\vartheta_2) \cdot R_\vartheta(\vartheta_M) + R_\vartheta(\vartheta_2) \cdot R_P = 2 \cdot R_\vartheta(\vartheta_M) \cdot R_\vartheta(\vartheta_1) + 2 \cdot R_\vartheta(\vartheta_M) \cdot R_\vartheta(\vartheta_2) + 2 \cdot R_\vartheta(\vartheta_M) \cdot R_P \Rightarrow$$ 5

$$R_P \cdot [R_\vartheta(\vartheta_1) + R_\vartheta(\vartheta_2) - 2 \cdot R_\vartheta(\vartheta_M)] = R_\vartheta(\vartheta_M) \cdot [R_\vartheta(\vartheta_1) + R_\vartheta(\vartheta_2)] - 2 \cdot R_\vartheta(\vartheta_1) \cdot R_\vartheta(\vartheta_2)$$ 2

$$\Rightarrow$$

$$\boxed{R_P = \frac{R_\vartheta(\vartheta_M) \cdot [R_\vartheta(\vartheta_1) + R_\vartheta(\vartheta_2)] - 2 \cdot R_\vartheta(\vartheta_1) \cdot R_\vartheta(\vartheta_2)}{R_\vartheta(\vartheta_1) + R_\vartheta(\vartheta_2) - 2 \cdot R_\vartheta(\vartheta_M)}}.$$ 1

$\sum 25$

Task 3: Consistancy of Sensor Signals

a) Time value t_m

$$y_1(t) = y_0 \cdot \left(1 - e^{-\frac{t}{\tau_1}}\right) \ , \ y_2(t) = y_0 \cdot \left(1 - e^{-\frac{t}{\tau_2}}\right)$$

Difference of the output signals

$$y_{Diff}(t) = y_1(t) - y_2(t) = y_0 \cdot \left(e^{-\frac{t}{\tau_2}} - e^{-\frac{t}{\tau_1}}\right)$$

2

Maximum of the difference

$$\frac{\partial y_{Diff}}{\partial t} = 0 \ \Leftrightarrow \ y_0 \cdot \left(-\frac{1}{\tau_2} \cdot e^{-\frac{t_m}{\tau_2}} + \frac{1}{\tau_1} \cdot e^{-\frac{t_m}{\tau_1}}\right) = 0 \ \Rightarrow \ \tau_1 \cdot e^{-\frac{t_m}{\tau_2}} = \tau_2 \cdot e^{-\frac{t_m}{\tau_1}}$$ 3

Using logarithm function with the law

$$ln(a \cdot b) = ln(a) + ln(b) \ , \ ln\left(\frac{a}{b}\right) = ln(a) - ln(b) \ , \ a \cdot ln(b) = ln(b)^a \ \Rightarrow$$

$$ln\left(\tau_1 \cdot e^{-\frac{t_m}{\tau_2}}\right) = ln\left(\tau_2 \cdot e^{-\frac{t_m}{\tau_1}}\right) \ \Leftrightarrow \ ln(\tau_1) - \frac{t_m}{\tau_2} = ln(\tau_2) - \frac{t_m}{\tau_1} \ \Rightarrow$$

2

$$t_m \cdot \left(\frac{1}{\tau_1} - \frac{1}{\tau_2}\right) = ln(\tau_2) - ln(\tau_1) = \ ln\left(\frac{\tau_2}{\tau_1}\right) \ \Rightarrow \ t_m = \frac{\tau_1 \cdot \tau_2}{\tau_2 - \tau_1} \cdot ln\left(\frac{\tau_2}{\tau_1}\right) \ , \ \tau_2 = 2 \cdot \tau_1 \ \Rightarrow$$

5

$$t_m = \frac{2 \cdot \tau_1^2}{\tau_1} \cdot ln(2) \ \Rightarrow \ \boxed{t_m = 2 \cdot ln(2)s = 1.386s} .$$

2

b) Consistancy $D_\%$

$$D_\% = \frac{\Delta y_{max}}{y_E} \cdot 100\%$$

1

$$\Delta y_{max} = y_{Diff}(2 \cdot ln(2)s) = y_0 \cdot \left(e^{-\frac{2 \cdot ln(2)}{2}} - e^{-\frac{2 \cdot ln(2)}{1}}\right) = y_0 \cdot \left(\frac{1}{2} - \frac{1}{4}\right) = \frac{y_0}{4}$$ 4

$$y_E = y(t \to \infty) \ \Rightarrow \ y_1(\infty) = y_2(\infty) = y_0 \ \Rightarrow \ D_\% = \frac{y_0}{4} \cdot \frac{1}{y_0} \cdot 100\% \ \Rightarrow \ \boxed{D_\% = 25\%} .$$

3

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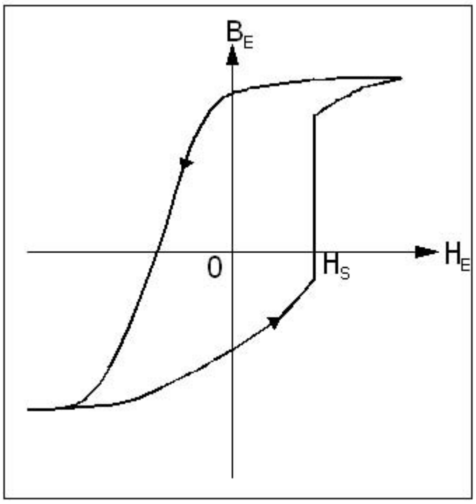
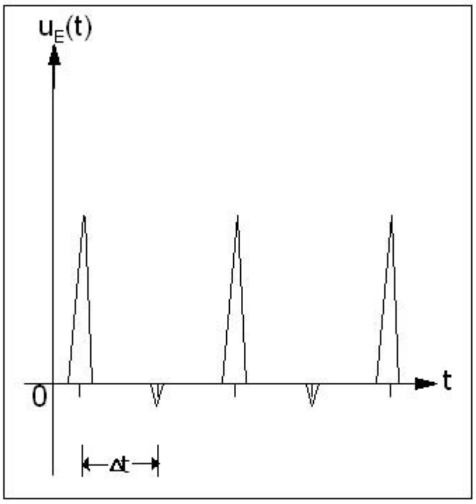
Task 4: Additional Questions

a) WIEGAND Rotational Speed Sensor

The effect of a WIEGAND sensor is based on the sudden change of the magnetic flux. This influences peaks within the output voltage of an enclosing coil.





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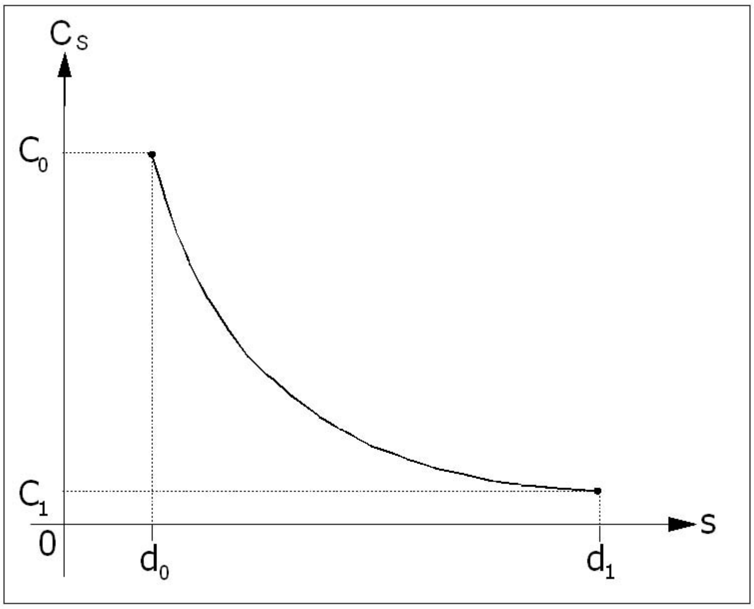
b) Capacitive Position Sensor

The capacitance decreases by increasing the plate distance with $f\left(\frac{1}{s}\right)$.



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Task 5: Common Questions

Every question allows one correct answer

a) Optical Angle Sensor

Which measuring principle belongs to an optical angle sensor?

☐ Interference
■ incremental
☐ DOPPLER effect

2

b) Radar Position Sensor

Which measuring effect is utilized to the radar position sensor

☐ Frequency
☐ Magnetitude
■ Duration

2

of the reflected wave?

c) HALL Generator

Which value can be measured using a HALL generator?

☐ electric field density
■ magnetic field density
☐ electric resistance

2

d) Torque Measurement using the Magnetoelastic Effect

On what property is the magnetoelastical effect based on?

■ Permeability
☐ Inductance
☐ Conductivity

2

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