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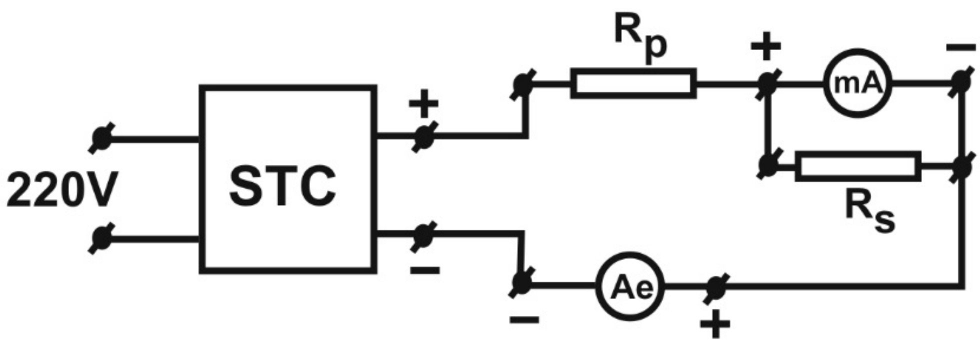
Measurements and Actuators

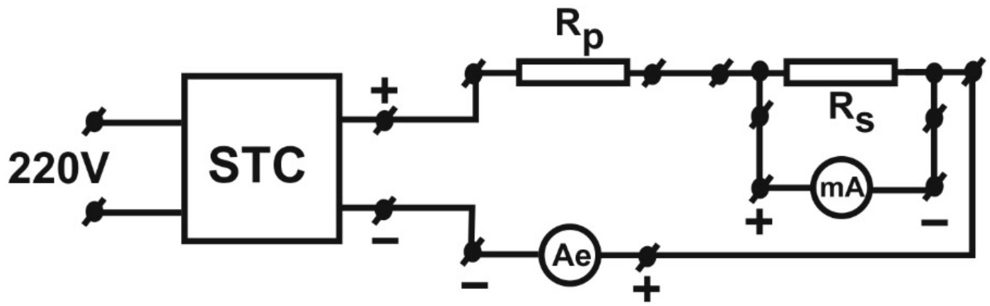
Extension of Domain

1. Two terminal connections



I_{SN}	n	The extended device			The standard device		ε_a (rel 20)	ε_r (rel 21)	n` (rel 22)	R_c (rel 25)
		I_a		I	I_e					
[mA]	$6/I_{SN}$	[div]	[mA]	[mA]	[div]	[mA]	[mA]	[%]		[Ω]
75	6/75	30	6	15	24	12	3	89,41	10	0,4
		70	6	35	60	30	5	83	10,71	0,26
		100	6	50	87	43,5	6,5	78	10,875	0,23
		130	6	65	113	56,5	8,5	71	10,86	0,24
150	6/150	30	6	30	20	20	10	66	16,66	0,755
		70	6	70	50	50	20	32	17,85	0,28
		100	6	100	74	74	26	12	18,5	0,24
		130	6	130	98	98	32	7,5	18,84	0,22
300	6/300	30	6	60	16	32	28	5,88	26,66	0,28
		70	6	140	48	96	44	47	34,28	0,14
		100	6	200	62	124	76	152	31	0,12
		130	6	260	81	162	38	289	31,15	0,19

2. Four terminal connections



I_{SN}	n	The extended device			The standard device		ε_a (rel 20)	ε_r (rel 21)	n` (rel 22)	R_c (rel 26)
		I_a		I	I_e					
[mA]		[div]	[mA]	[mA]	[div]	[mA]	[mA]	[%]		[Ω]
75	6/75	30	6	15	28	14	1	52	11,66	-0,36
		70	6	35	69	34,5	0,5	76	12,32	-0,0
		100	6	50	99	49,5	0,5	76	12,37	0,0
		130	6	65	129	64,5	0,5	5	12,4	0,0
150	6/150	30	6	30	28	28	2	5	23,33	0,0
		70	6	70	68	68	2	5	24,28	0,0
		100	6	100	98	98	2	5	24,5	0,0
		130	6	130	129	129	1	52	24,80	0,0
300	6/300	30	6	60	28	56	4	8 8	46,66	0,3
		70	6	140	68	136	4	8 0	48,57	0,1
		100	6	200	98	196	4	8 0	49	0,1
		130	6	260	128	256	4	8 8	49,23	0,0

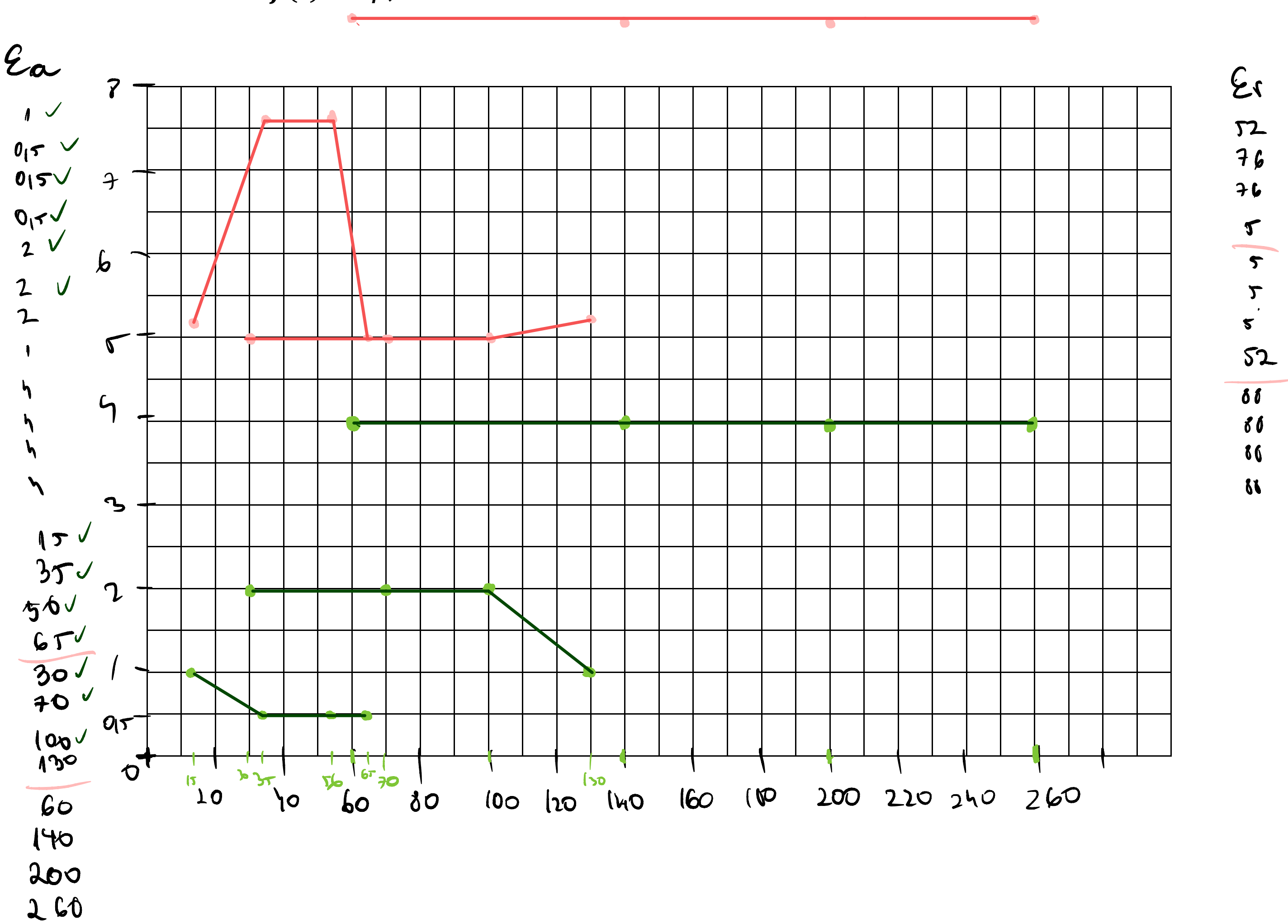
Formulas used for calculations:

$\boldsymbol{R_a = 10\Omega}$

$I \,\&\, I_e = [div] * \_\_\_\_ \rightarrow for\ I_{SN} = \_\_\_\_\_\_;$
$I \,\&\, I_e = [div] * \_\_\_\_ \rightarrow for\ I_{SN} = \_\_\_\_\_\_;$
$I \,\&\, I_e = [div] * \_\_\_\_ \rightarrow for\ I_{SN} = \_\_\_\_\_\_;$
$\varepsilon_a = I - I_e\ [mA];$
$\varepsilon_r = \frac{I - I_e}{I_e} * 100\ [\%];$
$n' = n - \frac{\varepsilon_a}{I_a};$
$n'' = n - \frac{\varepsilon_a}{I_e};$
$R_c = \frac{3}{2} * \frac{n - n'}{(n-1)*(n'-2)} * R_a$ - for ammeter circuit with simple shunts.
$R_c = \frac{1}{2} * \frac{n'' - n}{n-1} * R_a$ - for ammeter circuit with double terminals.

Graphics to be traced for both tables on a single sheet:

$\boldsymbol{f(I) = \varepsilon_a;}$
$\boldsymbol{f(I) = \varepsilon_r\,;}$



Upstream AC experimental circuit with different loads

NR.	Meter	Range X_N	Max. defl. α_{max}	Instr. Constant $C = \frac{X_N}{\alpha_{max}}$	Accuracy Class c	Max. abs. error $\varepsilon_{max} = \frac{cX_N}{100}$
	type	[X]	[div.]	[X/div]	[%]	[X]
1	U	300	60	5	1	3
2	A	5	50	0,1	1	0,05
3	W	750	75	10	0,5	3,75

Range			R_a	R_v	R_{wi}	R_{wu}	R_{aw}	R_{vw}
ammeter	voltmeter	wattmeter	Ω	$k\Omega$	Ω	$k\Omega$		
5	300	750	7,2	12	7,2	18,78	14,4	7321,66

Formulas to be used for calculations:

$$R_{aw} = R_a + R_{wi}$$

$$R_{vw} = R_V \| R_{wu} = \left(\frac{1}{R_v} + \frac{1}{R_{wu}}\right)^{-1}$$

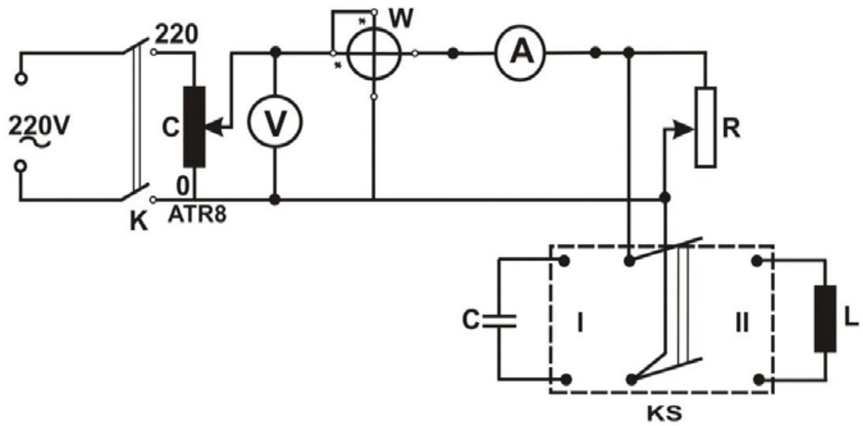
Downstream Connection	Upstream Connection
$\Delta P_{aw} = R_{aw} * I^2$	$\Delta P_{aw} = \frac{U^2}{R_{vw}}$
$Z = \frac{\sqrt{U^2 - R_{aw}(2P - R_{aw}I^2)}}{I}$	$Z = \frac{U}{\sqrt{I^2 - \frac{I}{R_{vw}}(2P - \frac{U^2}{R_{vw}})}}$
$cos\varphi_Z = \frac{P - R_{aw}I^2}{I\sqrt{U^2 - R_{aw}(2P - R_{aw}I^2)}}$	$cos\varphi_Z = \frac{P - \frac{U^2}{R_{vw}}}{U\sqrt{I^2 - \frac{1}{R_{vw}}(2P - \frac{U^2}{R_{vw}})}}$

$$R_Z = Zcos\varphi_Z$$

$$X_Z = Zsin\varphi_Z$$

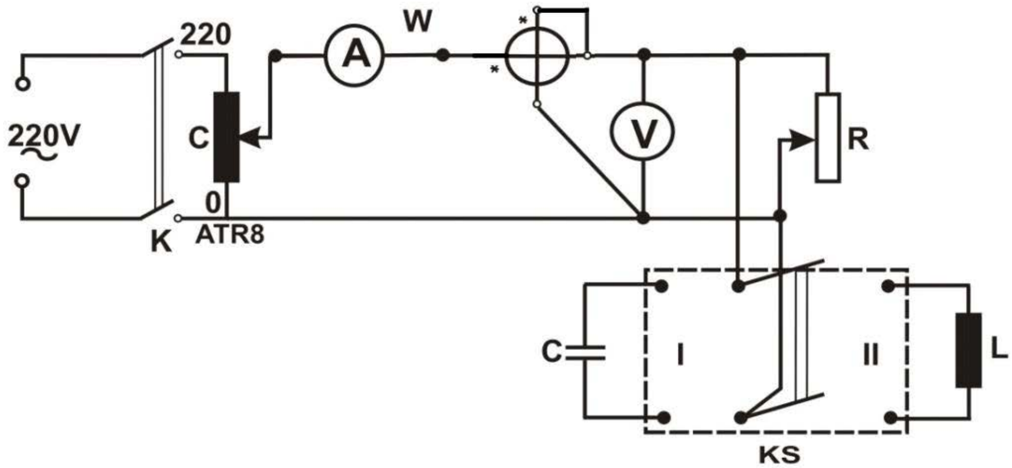
$$P_Z = P - R_{aw}I^2$$

Upstream AC experimental circuit



Load	U	I	P		ΔP_{aw}	ε_{rp}	Z	R_Z	X_Z	$\cos\varphi_Z$	P_Z	S_Z	Q_Z
			[W]=[div]*C		Rel (1.15)	$\frac{\Delta P_{aw}}{P} * 100$	Rel (1.5)	Rel (1.7)	Rel (1.8)	Rel. (1.6)	Rel (1.3)	U*I	$\sqrt{S_Z^2 - P_Z^2}$
type	[V]	[A]	[div]	[W]	[W]	[%]	[Ω]	[Ω]	[Ω]		[VA]	[Var]	[VA]
R	145	2	28	280	57,6	20,57	58,71	55,6	18,87	0,94	222,4	290	186,11
RL	138	2	25	250	57,6	23,04	56,28	48,1	29,23	0,85	192,4	276	197,08
RC	140	2	25	250	57,6	23,04	57,5	48,1	38,52	0,83	192,4	280	203,42
RLC	146	2	27	270	57,6	21,33	96,24	53,1	18,54	0,94	212,4	280	182,49
R	145	3	43	430	129,6	30,13	34,16	33,37	7,3	0,97	300,4	290	78,35
RL	136	3	39	390	129,6	33,23	31,85	28,93	13,31	0,9	260,4	408	314,09
RC	136	3	39	390	129,6	33,23	31,85	28,93	13,31	0,9	260,4	408	314,09
RLC	139	3	41	410	129,6	31,6	32,28	31,13	8,4	0,96	280,4	417	308,65
R	140	4	57	570	230,4	40,42	20,15	21,22	7,4	1,05	339,6	560	445,27
RL	135	4	53	530	230,4	43,47	19,8	18,72	6,46	0,94	299,6	540	488,75
RC	135	4	53	530	230,4	43,47	19,8	18,72	6,46	0,94	299,6	540	488,75
RLC	136	4	55	530	230,4	41,89	19,32	19,97	8,10	1,03	319,6	544	440,21

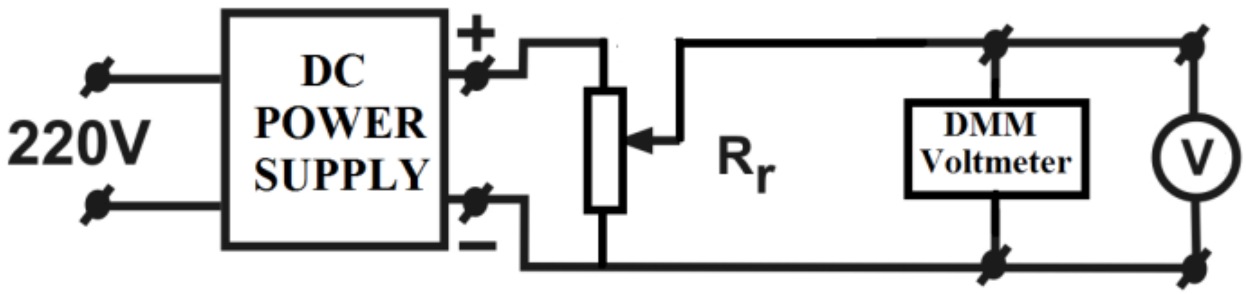
Downstream AC experimental circuit



Load	U	I	P		ΔP_{aw}	ε_{rp}	Z	R_Z	X_Z	$\cos\varphi_Z$	P_Z	S_Z	Q_Z
			[W]=[div]*C		Rel (1.15)	$\frac{\Delta P_{aw}}{P} * 100$	Rel (1.5)	Rel (1.7)	Rel (1.8)	Rel. (1.6)	Rel (1.3)	U*I	$\sqrt{S_Z^2 - P_Z^2}$
type	[V]	[A]	[div]	[W]	[W]	[%]	[Ω]	[Ω]	[Ω]		[VA]	[Var]	[VA]
R													
RL													
RC													
RLC													
R													
RL													
RC													
RLC													
R													
RL													
RC													
RLC													

ANALOG AND DIGITAL MEASUREMENT DEVICES

1. Experimental circuit for digital DC voltmeter



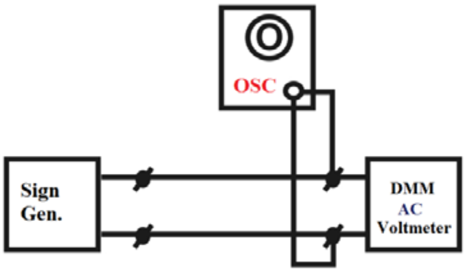
DMM/Digital Voltmeter	Analog voltmeter	$DMM\ U_i$	$Analog\ U_i$		$DMM\ e_{max}$	Analog e_{max}	DMM $e_r[\%]$	Analog $e_r[\%]$	DMM U_m
			[V]				$\frac{e_{max}}{U_i}100$	$\frac{e_{max}}{U_i}100$	$U_i \pm e_{max}$
Range U_N/ Resolution	Range/U_N Resolution	[V]	[div]	[V]	[V]	[V]	[%]	[%]	[V]

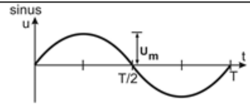
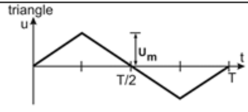
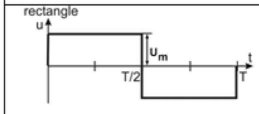
$$Analog\ U_i = [div] * \frac{Range}{Resolution} = [div] * \frac{}{}$$

$$DMM: e_{max} = 0.012\% * U_i + 5 * digits\ , where\ 1\ digit = values\ from\ first\ column$$

$$Analog: c = \frac{Range}{Resolution} = \_\_\_\_\_\_;\ U_N = \_\_\_\_\_ V, e_{max} = \frac{c * U_N}{100}$$

2. The measurement of periodical signals:



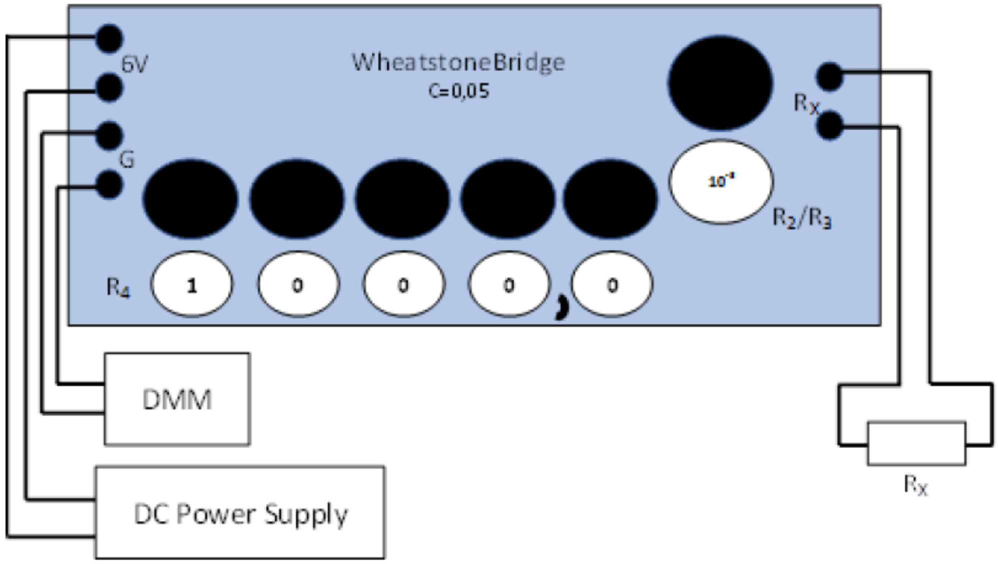
Waveform	Effectiv e value (U)	Mean value (U_{mean})	Crest factor. (k_c)	Form factor (k_f)	Distorti on factor (k_d)
sinus 	$\frac{U_m}{\sqrt{2}}$	$\frac{2\cdot U_m}{\pi}$	$\sqrt{2}$	$\frac{\pi}{2\sqrt{2}}=$ $=1.11$	0
triangle 	$\frac{U_m}{\sqrt{3}}$	$\frac{U_m}{2}$	$\sqrt{3}$	$\frac{2}{\sqrt{3}}=$ $=1.156$	0.12
rectangle 	U_m	U_m	1	1	0.435
ramp 	$\frac{U_m}{\sqrt{3}}$	$\frac{U_m}{2}$	$\sqrt{3}$	$\frac{2}{\sqrt{3}}$	0.626

Pick three different values of Amplitudes (1-10V) on the Signal Generator and note them here:

_____________ V; _____________ V; _____________ V.

Waveform	Pick coeff (k_v) (table)	Shape coeff (k_f) (table)	Indicated value (U_i)	Mean value $U_{mean} = \frac{U_i}{k_{f\ sin}}$	RMS value $U = \frac{k_f}{k_{f\ sin}} * U_i$	Max. value $U_m = \frac{k_f * k_c}{k_{f\ sin}} * U_i$	Osc. Pk to pk (U_{v-v})
			[V]	[V]	[V]	[V]	[V]

Wheatstone Bridge



Measured resistance	The ND (null detector) α deviation after the adjustment of:					
	R_2/R_3 [mV]	**The first** decade (the most significant) α1 [mV]	**The second** decade α2 [mV]	**The third** Decade α3 [mV]	**The fourth** decade α4 [mV]	**The fifth** Decade α5 [mV]
R_1						
R_2						
R_3						
R_4						
R_5						
R_6						

Meas R esist. R_{xN}	Measured values						Computed values						
	R_2/R_3 (1)	R_{4e} (2)	α_l left	R_{4l} left	α_r right	R_{4r} right	R_{4i}	R_{mas} (1) *(2)	e_{rc}	e_{rd}	e_{rRx}	e_a	R_x
	[Ω/Ω]	[Ω]	[div]	[Ω]	[div]	[Ω]	[Ω]	[Ω]	[%]	[%]	[%]	[%]	[Ω]
R_1										0			
R_2										0			
R_3										0			
R_4										0			
R_5										0			
R_6										0			

Meas. resist. R_{xN}	R_2/R_3	$\alpha_l(\alpha_j)$ [mV]	$R_{4l}(R_{4j})$	$\alpha_r(\alpha_j+1)$ [mV]	$R_{4r}(R_{4j}+1)$	S_l	S_r	S
R_1								
R_2								
R_3								
R_4								
R_5								
R_6								

$$e_{rRx} = e_{rc} + e_{rd}$$

$$e_a = \frac{e_{rRx} R_{mas}}{100}$$

$$R_X = R_{mas} \pm e_a$$

$$S_r = \frac{\alpha_r}{\frac{R_{4r} - R_{4e}}{R_{4e}}};$$

$$S_l = \frac{\alpha_l}{\frac{R_{4e} - R_{4l}}{R_{4e}}};$$

$$S = \frac{\alpha_r - \alpha_l}{\frac{R_{4r} - R_{4l}}{R_{4e}}}$$

Temperature measurement

a) Measuring

t [min.]	$R_{T(Pt100)}$ [Ω]	U_T [mV]	T_{Pt100} [^{0}C]	T_T [^{0}C]
0				
1				
2				
3				
4				
5				
6				
9				
12				
15				
18				
21				
24				
27				
30				

$$R_T = R_0(1 + \alpha \cdot \Delta T), where\ \alpha_{Pt} = 3,5 \cdot 10^{-3}\ ^{1}/_{K}$$

$$U_T = k \cdot \Delta T, where\ k = 5,37\ ^{mV}/_{100°C}$$

T [^{0}C]	150	140	130	120	110	100	90	80	70	60	50	40	30	20
R_{NTC} [kΩ]														

b) Simulation

T [^{0}C]	20	30	40	50	60	70	80	90	100	110	120	130	140	150
U_T [mV]														
$R_{T(Pt100)}$ [Ω]														

Level and flow measurements

Table 1

Switch	U_{M1} (V)	t (s)	Q (ml/s)	$U_{CFlowRate}$ (V)
Closed Loop	1	65,3	1,914	0,41
	2	46,5	2,685	1,32
	3	43,9	2,84	2,6
	4	32,8	3,81	2,95
	5	28,2	4,432	3,76
	6	24,2	5,125	4,54
	7	23,9	5,23	5,30
	8	20,8	6	6,27
	9	16,9	7,39	6,91
	10	15,1	8,27	7,71
Open Loop	3	∞	∞	∞
	5	39,3	3,18	2,02
	8	17,5	7,14	6,43

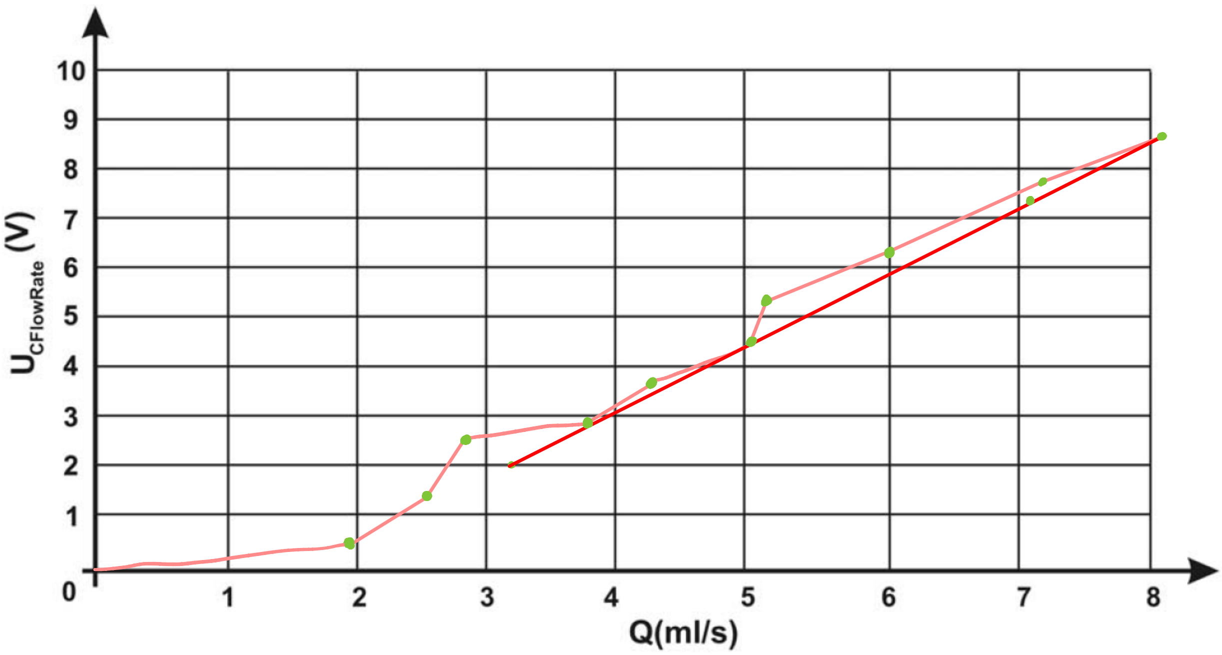


Figure 1. *The characteristic of the blade flowmeter*

Table 2

	Closed Loop	Open Loop
UM1 (V)	UCFlowRate (V)	UCFlowRate (V)
0	—	—
1	—	nu a pornit
2	1,3	—
3	2,06	—
4	2,88	—
5	3,6	2,25
6	4,5	3,7
7	5,3	5,2
8	6,05	6,8
9	6,9	8,4
10	7,77	9,6

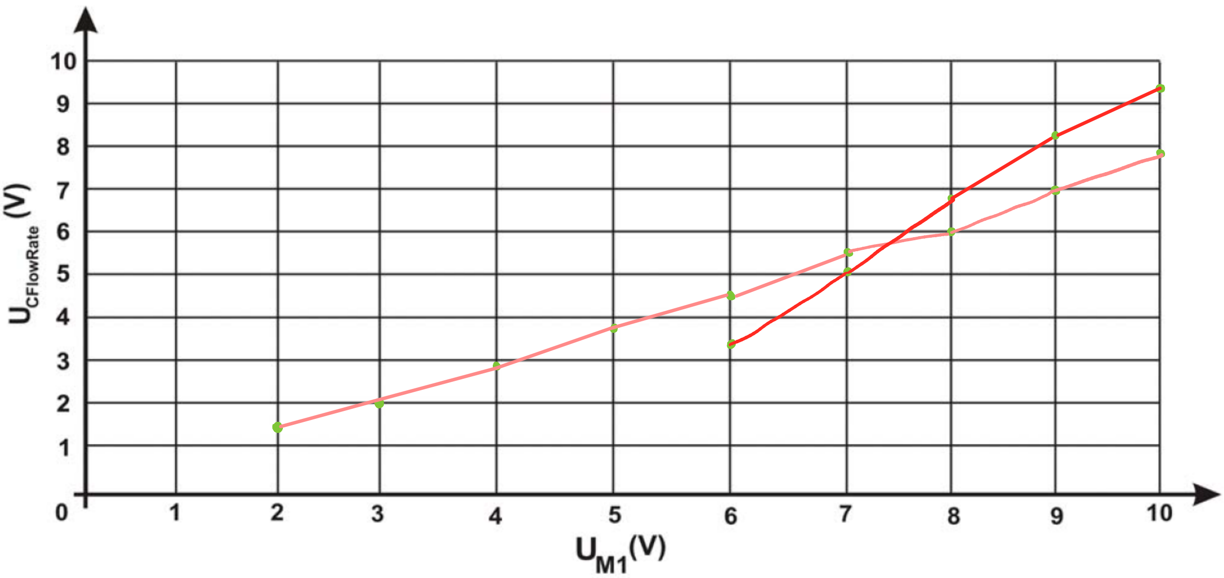


Figure 2. The static characteristic of the blade flow meter

Lab 7 Displacement measurement

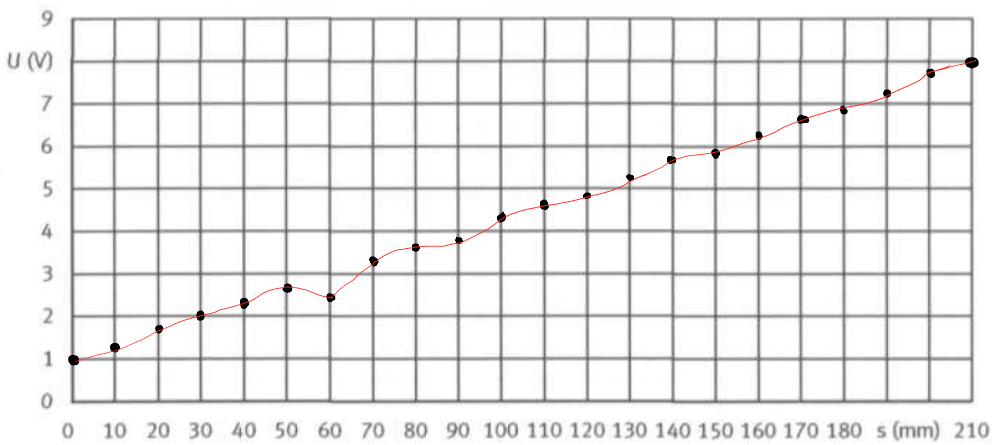
Resistive sensor

Measured Data:

Measurement series

d (mm)	0	10	20	30	40	50	60	70	80	90	100
U(V)	1,019	1,34	1,68	2	2,33	2,66	2,48	3,33	3,63	3,93	4,31
d (mm)	110	120	130	140	150	160	170	180	190	200	210
U(V)	4,621	4,97	5,3	5,59	5,9	6,25	6,58	6,91	7,2	7,62	7,9

The variation curve of the linear potentiometer:



Ultrasonic sensor

Measured Data:

Measurement series: With a 60 mm reflector

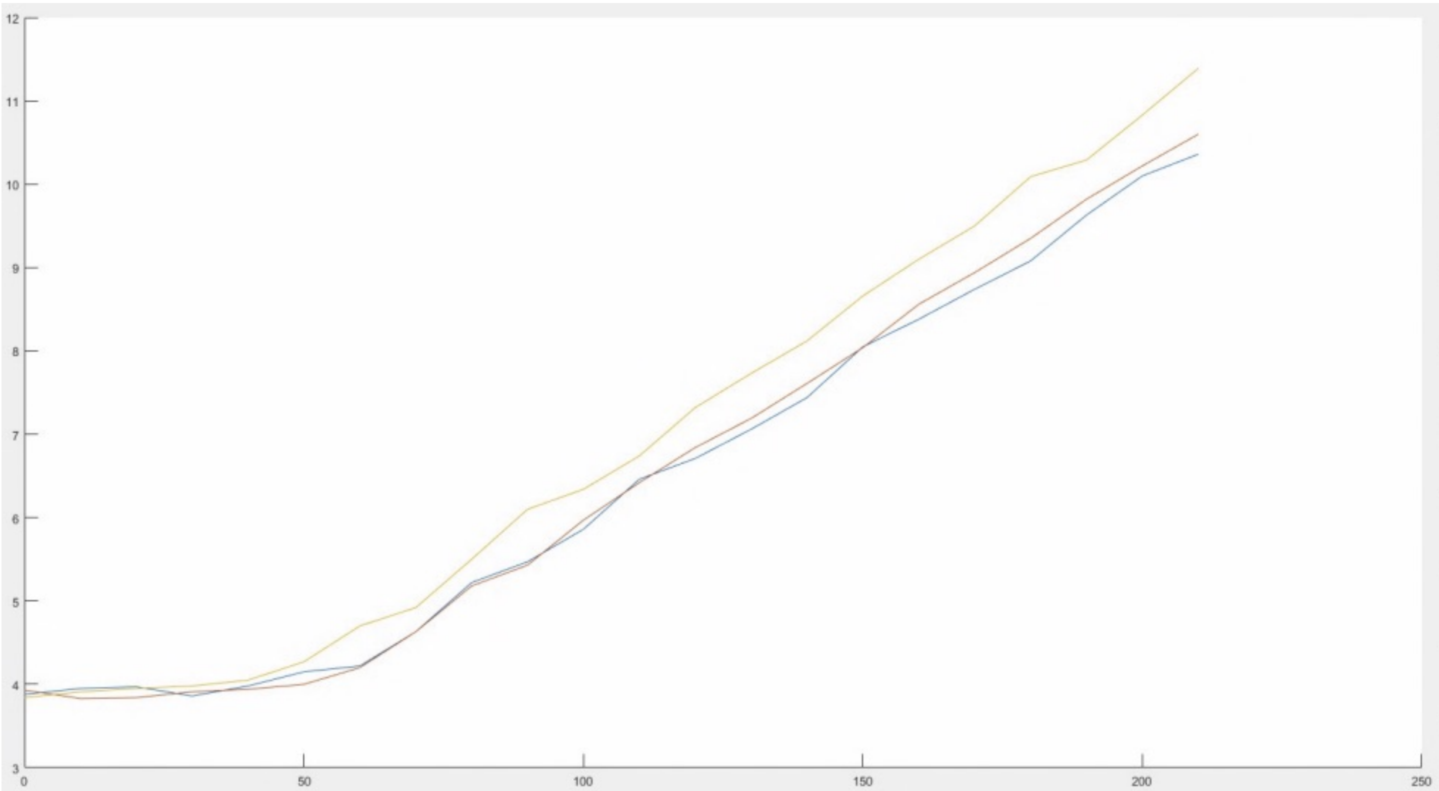
d (mm)	0	10	20	30	40	50	60	70	80	90	100
I (mA)	3,88	3,95	3,97	3,87	3,98	4,15	4,22	4,63	5,22	5,47	5,86
d (mm)	110	120	130	140	150	160	170	180	190	200	210
I (mA)	6,46	6,71	7,06	7,46	8,05	8,38	8,74	9,08	9,63	10,10	10,36

Measurement series: With a 40 mm reflector

d (mm)	0	10	20	30	40	50	60	70	80	90	100
I (mA)	3,93	3,83	3,84	3,91	3,94	4	4,2	4,63	5,18	5,43	5,97
d (mm)	110	120	130	140	150	160	170	180	190	200	210
I (mA)	6,42	6,84	7,19	7,61	8,04	8,56	8,94	9,35	9,8	10,22	10,69

Measurement series: With a 20 mm reflector

d (mm)	0	10	20	30	40	50	60	70	80	90	100
I (mA)	3,84	3,91	3,95	3,98	4,05	4,27	4,70	4,92	5,50	6,1	6,34
d (mm)	110	120	130	140	150	160	170	180	190	200	210
I (mA)	6,73	7,32	7,73	8,12	8,66	9,01	9,50	10,09	10,29	10,83	11,39



Inductive sensor

Measured Data:

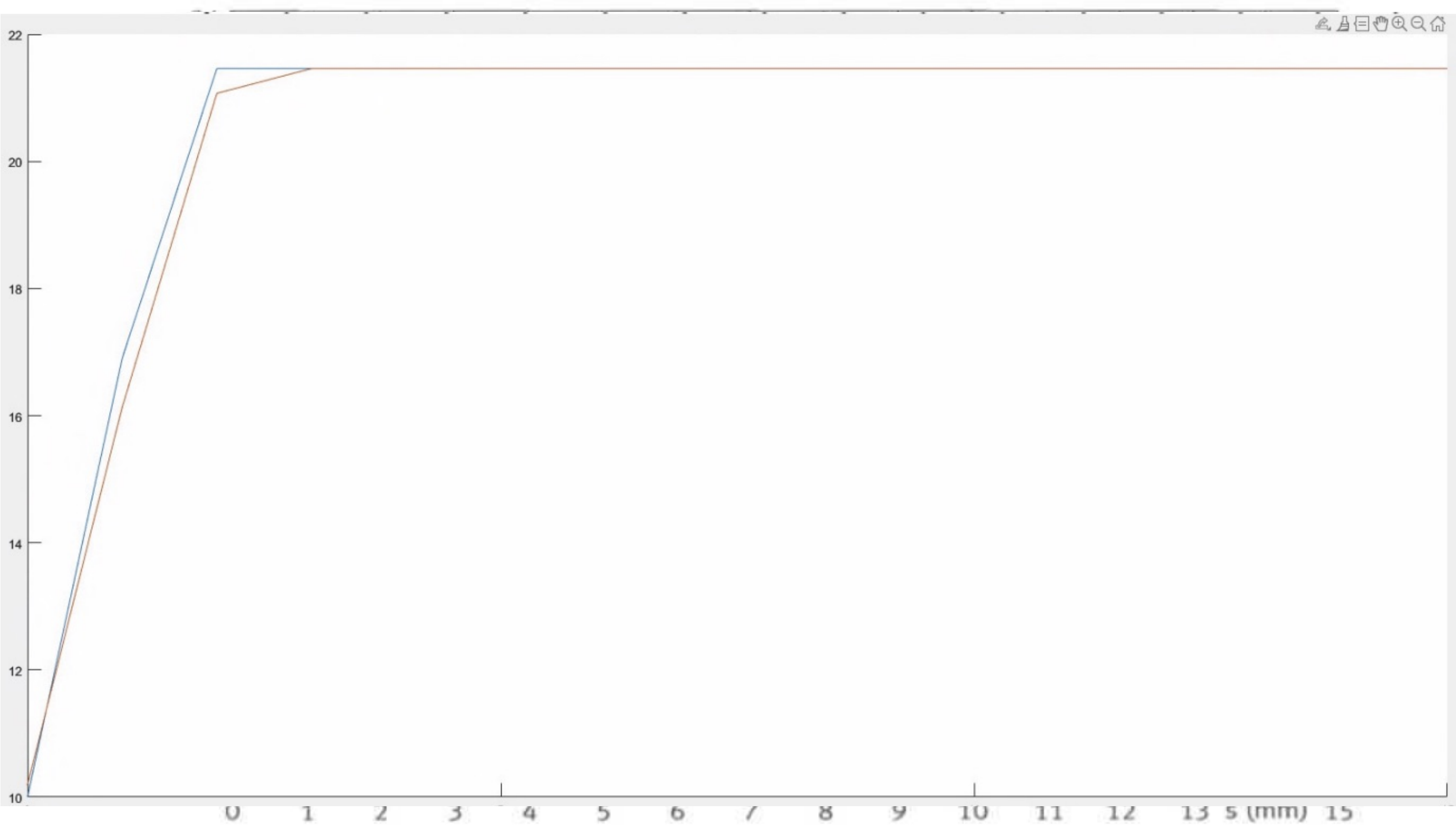
First measurement series:

d (mm)	0	1	2	3	4	5	6	7
I (mA)	10	16,9	21,46	21,46	21,46	21,46	21,46	21,46
d (mm)	8	9	10	11	12	13	14	15
I (mA)	21,46	21,46	21,46	21,46	21,46	21,46	21,46	21,46

Second measurement series (reverse direction):

d (mm)	0	1	2	3	4	5	6	7
I (mA)	10,19	16,13	21,03	21,46	21,46	21,46	21,46	21,46
d (mm)	8	9	10	11	12	13	14	15
I (mA)	21,46	21,46	21,46	21,46	21,46	21,46	21,46	21,46

Variation Curve:



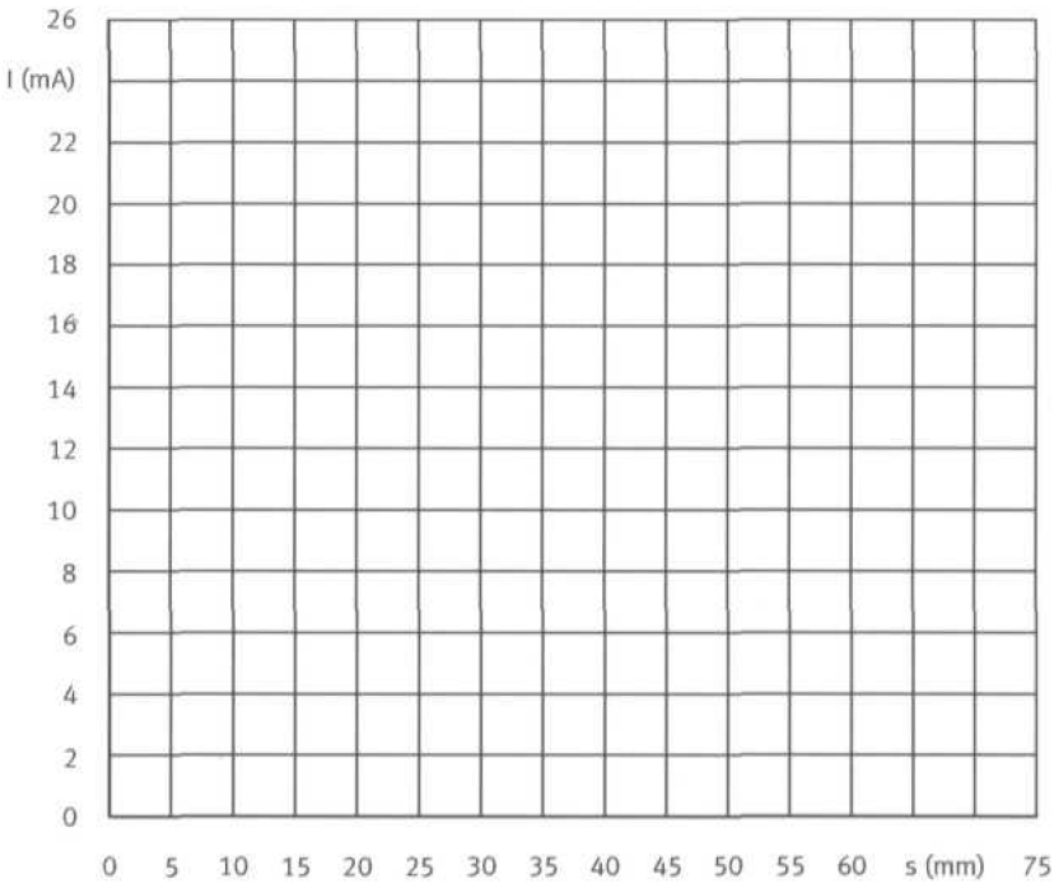
Fiber-optic sensor

Measured Data:

First measurement series (current – distance):

d (mm)	0	5	10	15	20	25
I (mA)						
d (mm)	**30**	**35**	**40**	**45**	**50**	**55**
I (mA)						

Variation Curve



Tachometers

1. What is a tachometer?

____

2. Complete the phrase:

Digital tachometers are usually ………….instruments. Various types of sensor are used, such as _______, _______and _______ones. They use the _________________principle.

3. The synchronous speed n[rpm] for an electric induction motor with p=4 poles, at f=50Hz is:

n = f (2 / p) 60=____

4. What is a Variable frequency drive (VFD)

____

____

____

5. What are the main parts of a VFD?

____

____

6. The inverter usually uses the principle of generating a signal of what type?

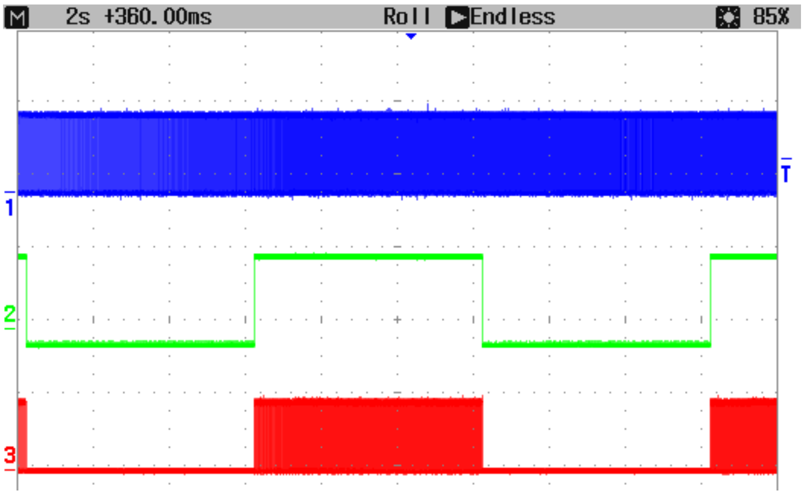
____

7. If a digital signal has f=83,333mHz then the period of the signal is:

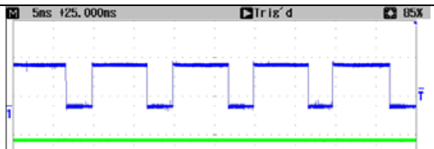
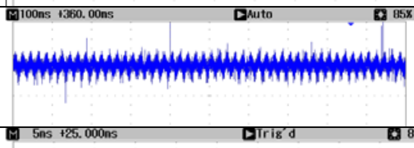
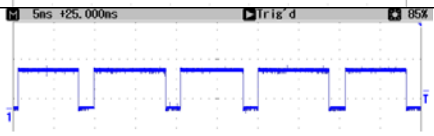
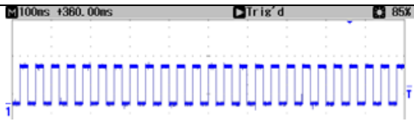
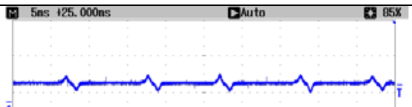
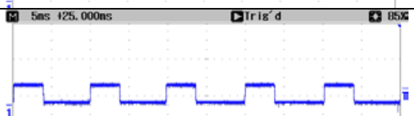
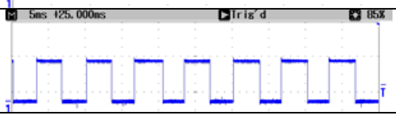
T=______________

8. How much is the gate opened?

____



9. Complete the table:

	Signal	Sensor type	Nr. of marks	Result
1		Inductive		
2		Hall (analog)		
3		Hall (Digital) Switch (magnet)		
4		Hall (Digital) Switch (ferrous vane):		
5		Magnetoresistive		
6		Transmissive photo-interrupter		
7		Reflective photo-interrupter		