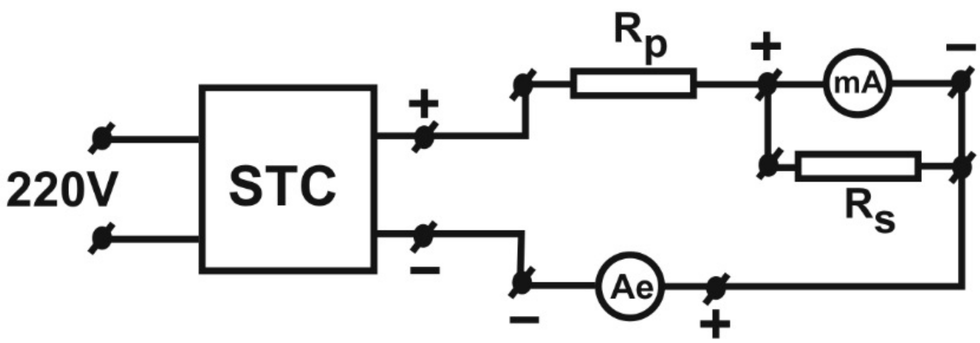
Measurements and Actuators

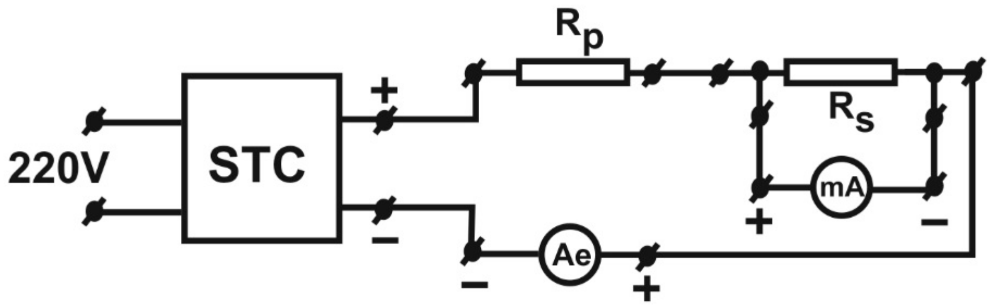
Extension of Domain

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]		[div]	[mA]	[mA]	[div]	[mA]	[mA]	[%]		[Ω]

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]

Formulas used for calculations:

$\boldsymbol{R_a} = \mathbf{10\Omega}$

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

Range			R_a	R_v	R_{wi}	R_{wu}	R_{aw}	R_{vw}
ammeter	voltmeter	wattmeter	Ω	$k\Omega$	Ω	$k\Omega$		

Formulas to be used for calculations:

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

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

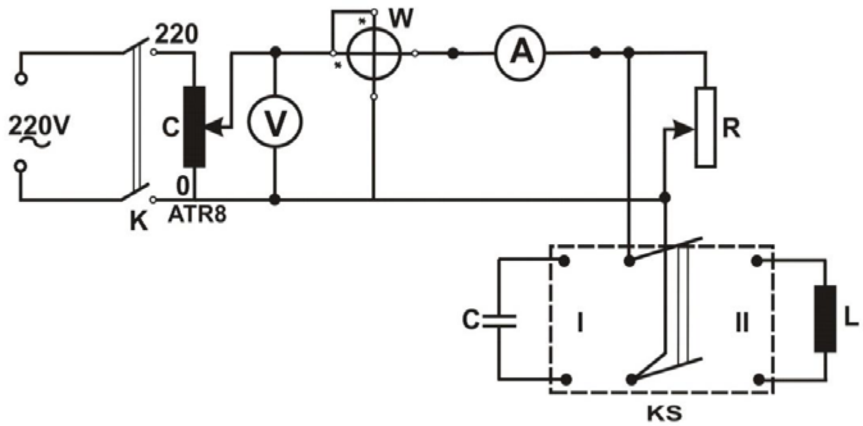
Downstream Connection	Upstream Connection
$\Delta P_{aw} = R_{aw} * I^2$	$\Delta P_{aw} = \frac{U^2}{R_{vw}}$
$Z = \frac{\sqrt{U^2 - R_{aw}(2P - R_{aw}I^2)}}{I}$	$Z = \frac{U}{\sqrt{I^2 - \frac{I}{R_{vw}}(2P - \frac{U^2}{R_{vw}})}}$
$cos\varphi_Z = \frac{P - R_{aw}I^2}{I\sqrt{U^2 - R_{aw}(2P - R_{aw}I^2)}}$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

$$R_Z = Zcos\varphi_Z$$

$$X_Z = Zsin\varphi_Z$$

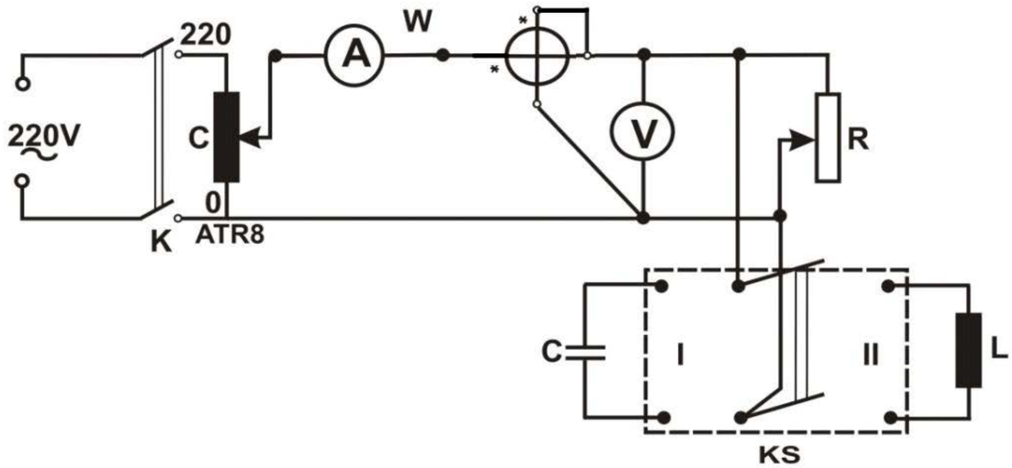
$$P_Z = P - R_{aw}I^2$$

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													
RL													
RC													
RLC													
R													
RL													
RC													
RLC													
R													
RL													
RC													
RLC													

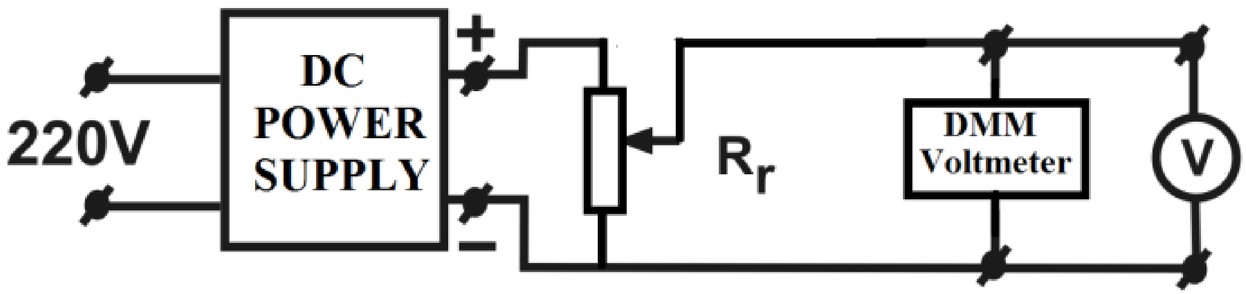
Downstream AC experimental circuit



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



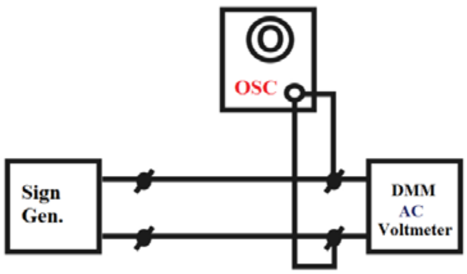
DMM/Digital Voltmeter	Analog voltmeter	$DMM\ U_i$	$Analog\ U_i$		$DMM\ e_{max}$	Analog e_{max}	DMM $e_r[\%]$	Analog $e_r[\%]$	DMM U_m
			[V]				$\frac{e_{max}}{U_i}100$	$\frac{e_{max}}{U_i}100$	$U_i \pm e_{max}$
Range U_N/ Resolution	Range/U_N Resolution	[V]	[div]	[V]	[V]	[V]	[%]	[%]	[V]

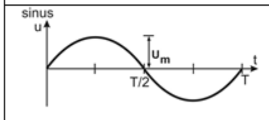
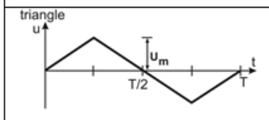
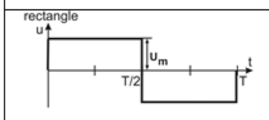
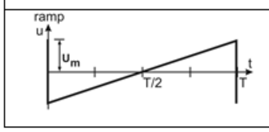
$$Analog\ U_i = [div] * \frac{Range}{Resolution} = [div] * \_\_\_\_\_\_$$

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

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

2. The measurement of periodical signals:



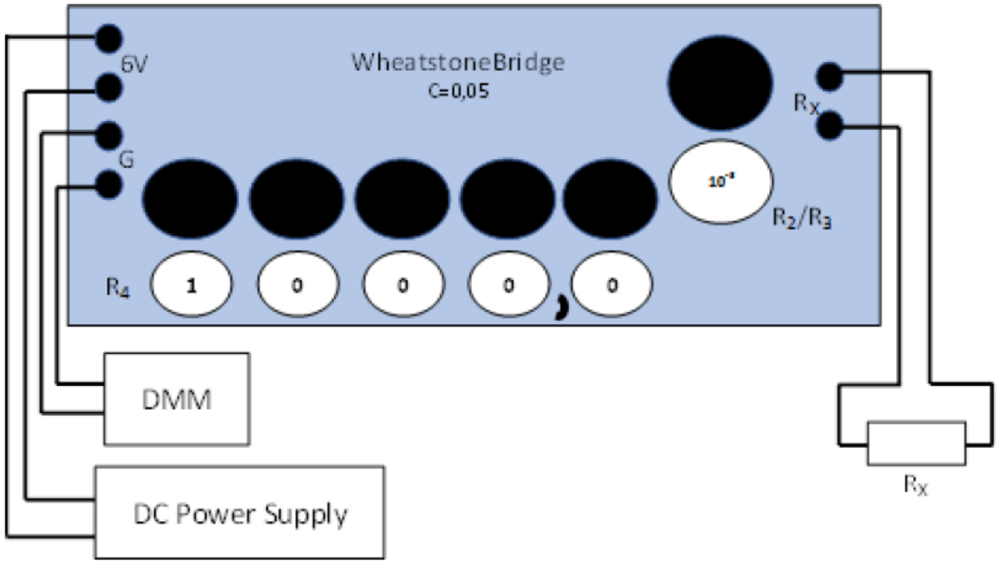
Waveform	Effective value (U)	Mean value (U_{mean})	Crest factor. (k_c)	Form factor (k_f)	Distortion factor (k_d)
	$\frac{U_m}{\sqrt{2}}$	$\frac{2\cdot U_m}{\pi}$	$\sqrt{2}$	$\frac{\pi}{2\sqrt{2}}=$ $=1.11$	0
	$\frac{U_m}{\sqrt{3}}$	$\frac{U_m}{2}$	$\sqrt{3}$	$\frac{2}{\sqrt{3}}=$ $=1.156$	0.12
	U_m	U_m	1	1	0.435
	$\frac{U_m}{\sqrt{3}}$	$\frac{U_m}{2}$	$\sqrt{3}$	$\frac{2}{\sqrt{3}}$	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								

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

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

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

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

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

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