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for the electrotechnical, electronic  
and information technology trades

# Electrical Engineering

## Tables, Standards, Formulas

**2<sup>nd</sup> English edition**

Prepared and revised by teachers in vocational colleges and  
engineers from the production industry (see next page).

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This edition is based on the 26<sup>th</sup> German edition of "Tabellenbuch Elektrotechnik", a leading compendium in German-speaking countries. The English edition addresses professionals in the various fields of electrical engineering, such as power and building engineering, field engineering, automation systems, machinery, drive systems, components and other electronic systems. This book is intended to

- prepare professionals for an activity in an international environment and
- help make the world's leading work processes and standards known outside of the German-speaking region.

Despite the harmonisation of the most important European standards, local regulations may differ slightly from German standards under certain circumstances, which means that where safety matters are concerned, the user has to check whether any other local regulations exist.

The book is divided into the following main sections focusing on the specified subjects:

- **Section M: mathematics, physics, theory of circuits, components** Formula symbols, units and quantities, mathematical symbols, exponents, unit prefixes, logarithmic unit decibel, force, moment of force, motion rules, work, power, heat, charge, voltage, current, resistance, electric and magnetic fields, alternating quantities, switching capacitors and coils, three-phase current, diodes, transistors, IGBTs, thyristors, magnetic field-dependent and photoelectronic components.
- **Section TM: technical documentation, measuring** Technical drawing, dimensioning, circuit diagrams, circuit symbols, comparison of circuit symbols, preparing documentation, measuring instruments and systems, measuring categories, measurement in electrical installations, power meters, bidirectional watt meters, ripple control receivers, oscilloscopes, measuring with sensors.
- **Section EI: electrical installations** Working in electrical installations, laying of cables, cable routing, installation circuits, intercom systems, types of dimmers, electrical installation with low-voltage halogen lamps, field-reducing electrical installation, building management and automation, project design based on KNX, house connection, foundation earth electrode, electrical installations in residential buildings, calculation of circuit loading, ampacity of cables and wires, lighting engineering, LED lighting.
- **Section SE: safety, energy supply** First aid, workplace health and safety, personal protective equipment, signs for accident prevention, differential current devices, basic protection, fault protection, additional protection, conductors for protective measures, types of power stations, insulator classes, transformers, overhead power cables, buried cables, private power generating systems, smart grids, fuel cells, primary cells, accumulators, UPS systems, electromagnetic compatibility EMC, lighting protection, quality of power supply, harmonics, power factor correction, smoke alarms, AFDD, AFCl, security and monitoring devices, energy conservation directive, energy efficiency, household appliances, electricity tariffs.
- **Section IC: information and communication technology systems** Number systems, codes, Boolean algebra, flip-flops, D/A converters, A/D converters, modulation and demodulation, IT networks, components for data networks, Ethernet, wireless LAN, AS-i bus system, interbus, PROFIBUS, identification systems, connection to the telephone network, internet, aerial systems, satellite systems, safe communication across different field busses.
- **Section AC: automation, drive and control systems** Rectifier, switch-mode power supplies, multivibrators, control relays, programmable logic controllers PLC, word processing in PLCs, control engineering, auxiliary circuits, sequence control with GRAFCET, contactors, motor protection, electrical equipment of machines, automatic control engineering, three-phase motors, single-phase A.C. motors, D.C. motors, efficiency of drive systems, servomotors, micro-motors, linear drives, design of automation systems, EC Machinery Directive.
- **Section MC: materials, connection, joining and bonding** Periodic table, specific material values, steel standardisation, magnetic materials, insulators, cables and wires, buried cables, connectors, solderless connection technology, ISO threads, screws, bolts and nuts, dowels and plugs.
- **Section CE: the company and its environment, environmental technology, annex** Organisational structures of companies, teamwork, job planning, cost accounting and key numbers, skills of electrical specialists, realisation of projects, conflict management, communication with customers, environmental terms, hazardous materials, electronic waste products, standards, glossary, subject index.

We have integrated modifications of standards, e.g. in the terms taken from DIN VDE 0100-200. It should be noted in general that standards allow different ways of representation, e.g. DIN EN 610892 (Documents in Electrical Engineering, Rules) allows the representation of electricity branching with or without a point. As in professional practice, we have taken advantage of this freedom also in the book.

The publisher and authors would be grateful for any suggestions and constructive comments.

Summer 2015

The authors' working group

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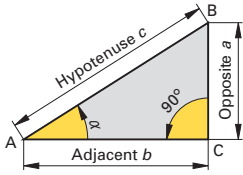
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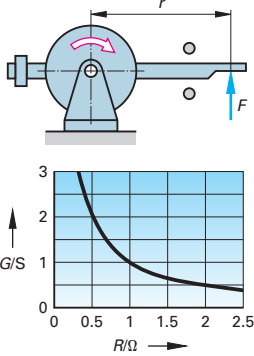
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**Mathematics**



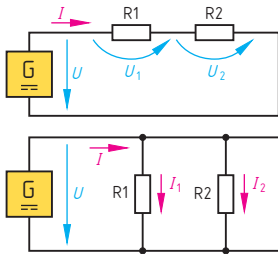
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**Physics**



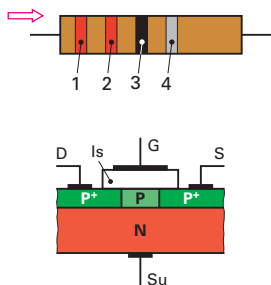
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## Symbols in this Book

Symbol	Meaning	Symbol	Meaning	Symbol	Meaning
<b>Lower-case letters</b>		<b>Upper-case letters</b>		<b>Lower-case Greek letters</b>	
<i>a</i>	acceleration	<i>A</i>	1. area, 2. cross section 3. attenuation constant	$\alpha$ (alpha)	1. angle 2. temperature coefficient 3. triggering angle
<i>c</i>	1. spec. heat capacity 2. electrochemical equivalent 3. propagation velocity of waves 4. coefficient	<i>B</i>	1. magn. flux density 2. current gain 3. number base 4. phase of three-phase system	$\beta$ (beta)	1. angle 2. short-circuit current amplification factor
<i>d</i>	1. diameter 2. distance 3. dissipation factor 4. duty cycle	<i>C</i>	1. capacitance 2. thermal capacity 3. constant 4. coupling factor 5. phase of three-phase system	$\gamma$ (gamma)	1. angle 2. conductivity
<i>e</i>	elementary charge	<i>D</i>	1. electric flux density 2. damping factor 3. deflection coefficient	$\delta$ (delta)	angle for losses
<i>f</i>	1. frequency 2. filter factor	<i>E</i>	1. electric field strength 2. illuminance	$\epsilon_0$	electric field constant
<i>g</i>	1. gravitational acceleration, position	<i>F</i>	1. force, 2. factor, 3. fault	$\epsilon$ (epsilon)	permittivity
<i>h</i>	height	<i>G</i>	1. conductance 2. amplification factor 3. gravitational force	$\zeta$ (zeta)	work ratio, utilisation ratio
<i>i</i>	time-controlled current	<i>H</i>	magnetic field strength	$\eta$ (eta)	efficiency
<i>l</i>	1. length 2. spacing	<i>I</i>	1. electric current 2. light intensity	$\kappa$ (kappa)	conductivity (optional symbol)
<i>m</i>	1. mass 2. number of strands	<i>J</i>	1. current density 2. mass moment of inertia	$\vartheta$ (theta)	temperature in °C
<i>n</i>	1. speed, number of revolutions 2. integer 1, 2, 3, ... 3. refractive index	<i>L</i>	1. level 2. inductance	$\lambda$ (lambda)	wavelength
<i>o</i>	overdrive factor	<i>M</i>	1. moment of force 2. memory capacity	$\mu$ (mu)	1. permeability 2. friction coefficient
<i>p</i>	1. number of pole pairs 2. pressure 3. percentage rate	<i>N</i>	number of turns	$\mu_0$	magnetic field constant
<i>q</i>	1. quantity 2. shunt current ratio	<i>P</i>	1. active or effective power 2. process value in controller circuits, often also PV	$\pi$ (pi)	number 3.1415926...
<i>r</i>	1. radius 2. rate 3. differential resistance	<i>Q</i>	1. electric charge 2. heat 3. reactive power 4. resonant circuit quality	$\rho$ (rho)	1. specific resistance 2. density
<i>s</i>	1. section, strength 2. normalized slip 3. correction	<i>R</i>	1. active resistance 2. spring rate 3. rigidity	$\sigma$ (sigma)	1. leakage factor 2. stress
<i>t</i>	1. time 2. transformation ratio	<i>S</i>	1. susceptance 2. steepness 3. slip (absolute) 4. transmission quantity 5. set value in controller circuits, often also SV	$\tau$ (tau)	time constant
<i>v</i>	1. velocity 2. time-controlled voltage	<i>T</i>	1. cycle time 2. transmission factor 3. temperature in K 4. torque	$\varphi$ (phi)	angle, particularly phase-shift angle
<i>w</i>	1. width 2. energy density 3. command variable	<i>U</i>	voltage	$\omega$ (omega)	1. angular velocity 2. angular frequency
<i>x</i>	controlled variable	<i>V</i>	volume	<b>Upper-case Greek letters</b>	
<i>y</i>	correcting variable	<i>W</i>	1. energy 2. work	$\Delta$ (Delta)	difference
<i>z</i>	integer, e.g. number of teeth of a gear	<i>X</i>	reactance	$\Theta$ (Theta)	current linkage, (phase-shift angle in NA)
		<i>Y</i>	admittance	$\Phi$ (Phi)	1. magnetic flux 2. luminous flux
		<i>Z</i>	1. impedance 2. wave impedance 3. oscillation impedance	$\Psi$ (Psi)	electric flux
				$\Omega$ (Omega)	1. solid angle 2. resistance

Special symbols are created by adding one or more subscripts or other signs to the symbol.

## Subscripts and Signs for Formula Symbols in this Book

Subscript, sign	Meaning	Subscript	Meaning	Subscript	Meaning
<b>Numerals, symbols</b>		max	maximum	F	1. forward, 2. fault 3. (negative) feedback
0	1. idle 2. vacuum 3. reference variable	mec	mechanical	G	gate
1	1. input	min	minimum	H	1. hysteresis 2. Hall, 3. height 4. heat sink
2	1. order, sequence	o	oscillator	K	cathode
3, 4, ...	order, sequence	off	switch off, turn off	L	1. inductive 2. load 3. left 4. Lorentz 5. loop
$\hat{\ } , \text{ e.g. } \hat{u}$	peak value	out	output	N	nominal, rated
$\check{\ } , \text{ e.g. } \check{u}$	minimum value	p	1. parallel, 2. pause 3. pulse, 4. potential 5. pressure, 6. pre-	O	1. operation, 2. operational earthing (network)
$\hat{\ } , \text{ e.g. } \hat{u}$	1. peak-to-peak value 2. oscillation width	per	permissible	P	positive feedback
$' , \text{ e.g. } u'$	1. related to 2. note 3. derivation	q	quality	R	1. reverse, reward 2. active resistance 3. right 4. regular 5. red
$\Delta$	delta connection	r	1. reactive quantity 2. relative, related to 3. rise, 4. resonance 5. remanence, retentivity 6. reception	S	1. source, 2. saddle ... 3. smoothing 4. switching 5. sluice ... 6. sector 7. system earthing 8. scanning
Y	star connection	s	1. screen... 2. signal... 3. specific	T	1. transformer ... 2. transverse 3. track 4. test ...
<b>Lower-case letters</b>		sh	short circuit	V	voltage meter
a	1. armature, 2. ambient, 3. actual	st	step	W	weight
ab	absorbed	t	1. test, 2. transverse 3. time	X	at the x-port
adm	admissible	th	thermal, heat ...	Y	1. at the y-port 2. star connection
del	delivered	tot	total	Z	Zener ...
amb	ambient air ...	v	1. voltage 2. visual		
b	1. bit 2. brake ...	w	1. command variable 2. wind... 3. wave ...		
c	1. cut-off, 2. crest, 3. comparison 4. centripetal...	x	1. unknown variable 2. in x-direction		
d	1. referring to DC 2. duration, 3. digit 4. damping, 5. direction 6. desired 7. derivation, derived	y	1. correcting variable 2. in y-direction		
e	1. exterior, 2. effective, 3. error	z	zigzag connection		
eff	effective value	<b>Upper-case letters</b>		<b>Lower-case Greek letters</b>	
f	1. frequency 2. fall ...	A	1. ammeter 2. aerial 3. armature, 4. anode 5. acceleration, 6. area 7. amplifier, amplifying	$\alpha$ (alpha)	in direction of the angle $\alpha$
h	high, upper	B	1. base 2. building	$\sigma$ (sigma)	leakage
i	1. inner, internal 2. induced, 3. current 4. ideal, 5. intermediate 6. impulse	C	1. collector, 2. capacitive 3. clock pulse, 4. coercitive 5. cluster, 6. channel 7. maximum (max) contact voltage 8. carrier	$\varphi$ (phi)	phase-shift related
in	input	D	1. drain, 2. data, 3. discharge	<b>Upper-case Greek letters</b>	
j	junction	E	1. emitter 2. environment 3. earth	$\Delta$ (Delta)	1. referring to a difference 2. configuration of a three-phase system
k	kinetic				
l	1. low, lower, 2. loss				
m	1. magnetic 2. mean value 3. measuring, measured				

Subscripts may be combined, e.g.  $V_{CE}$  for collector-emitter voltage. Subscripts that consist of several letters may be reduced to the first letter.

Quantity	Symbol until September 2010	Symbol after September 2010		Unit, unit symbol
		Preferred symbol	Reserve symbol	
<b>Current and related quantities</b>				
Rated current	$I_n$	$I_{rat}$ or $I_r$	$I_N$	Ampere, A
Nominal current	$I_N$	$I_n$ or $I_{nom}$	–	
Sustained short-circuit current	$I_{kd}$	$I_k$	$I_{SC}$	
Maximum aperiodic short-circuit current	$I_s$	$\hat{I}_k$	$\hat{I}_{SC}$	
Initial periodic short-circuit current	$i_s$	$I_{k0}$	$I_{SCO}$	
Transient current	$i$	$I_k'$	$I_{SC}'$	
Subtransient current	$i_s$	$I_k''$	$I_{SC}''$	
Current load	$I'$	A	Not applicable	Amperes per metre, A/m
<b>Voltage and related quantities</b>				
Rated voltage	$U_N$	$U_{rat}$ or $U_r$	$U_N$	Volt, V
Nominal voltage	$U_n$	Not applicable	Not applicable	
Induced voltage	$U_i$	$U_g$		
Open-loop voltage	$U_0$	$U_0$		
<b>Power and related quantities</b>				
Rated power	$P_N$	$P_{rat}$ or $P_r$	$P_N$	Watt, W
Rated apparent power	$S_N$	$S_{rat}$ or $S_r$		Volt-ampere, VA
Nominal power	$P_n$	$P_n$ or $P_{nom}$	Not applicable	Watt, W
Input power	$P_1$ or $P_i$	$P_{in}$		
Output power	$P_2$ or $P_o$	$P_{out}$		
Mechanical power	$P$	$P_{mec}$		
Dissipation	$P_v$	$P_t$		
Power factor (P.F.)	$\cos \varphi$	$\lambda$ (lambda)		
Active factor	–	$\cos \varphi$		One (no unit)
<b>Moments of force, torques</b>				
Torque, moment of force	$M$	$T$	$M$	Newton meter, Nm
Nominal moment/torque	$M_n$	Not applicable	Not applicable	
Rated moment/torque	$M_N$	$T_{rat}$ or $T_r$	$M_{rat}$ or $M_r$	
Breakdown torque	$M_K$	$T_b$	$M_b$	
Holding torque	$M_H$	$T_H$	$M_H$	
Pull-up torque	$M_S$	$T_u$	$M_u$	
Breakaway torque	$M_A$	$T_l$	$M_l$	
nom = nominal, rat = rated, $T$ = torque, active factor = cosine of fundamental (without overtones), power factor (P.F.) = relation of wattage to apparent power (with overtones)				

## Quantities and Units 1

Quantity	SI unit (other unit)	Unit symbol, unit equation	Quantity	SI unit (other unit)	Unit symbol, unit equation
<b>Length, area, volume, angle</b>			<b>Electricity</b>		
length	metre (sea mile) (mile) (inch) (foot)	m 1 sm = 1,852 m 1 mi = 1,609.344 m 1" = 25.4 mm 1 ft = 12 x 1" = 0.3048 m	electric charge, electric flux	coulomb	1 C = 1 A · 1 s = 1 As
area	square metre	m <sup>2</sup>	electric charge density, electric flux density	coulombs per square metre	C/m <sup>2</sup>
volume	cubic metre (litre)	m <sup>3</sup> 1 l = 1 dm <sup>3</sup> = 1/1000 m <sup>3</sup>	space charge density	coulombs per cubic metre	C/m <sup>3</sup>
angle (plane) (see page 20)	radian (degree)	rad 1° = $\frac{\pi}{180}$ rad	electr. voltage, electr. potential	volt	1 V = 1 J/C
solid angle	steradian	sr	electr. field strength	volts per metre	1 V/m = 1 N/C
<b>Time, frequency, velocity, acceleration</b>			electr. capacitance	farad	1 F = 1 As/V = 1 C/V
time	second (minute) (hour) (day)	s 1 min = 60 s 1 h = 60 min = 3,600 s 1 d = 24 h	current loading	amperes per metre	A/m
frequency	hertz	1 Hz = 1/s	permittivity, dielectric constant	farads per metre	1 F/m = 1 C/(Vm)
rotational speed-rotational frequency	per second (per minute)	1/s = 60/min	electric current	ampere	1 A = 1 C/s
angular frequency	per second	1/s	electric current density	amperes per m <sup>2</sup>	A/m <sup>2</sup>
velocity	metres per second (knot)	m/s 1 kn = 1 sm/h = 0.5144 m/s 1 km/h = $\frac{1}{3.6}$ m/s	electric resistance, active resistance, reactance, impedance	ohm	1 Ω = 1 V/A
angular velocity	radians per second	rad/s	electric conductance, susceptance, admittance	siemens	1 S = $\frac{1}{1 \Omega}$
acceleration	–	m/s <sup>2</sup>	specific electric resistance	ohmmetre	1 Ωm = 100 Ωcm 1 Ωmm <sup>2</sup> /m = 1 μΩm
<b>Mechanics</b>			electric conductivity	siemens per metre	1 Sm/mm <sup>2</sup> = 1 MS/m
mass	kilogram (carat) (tonne)	kg 1 Kt = 0.2 g 1 t = 1,000 kg	power	watt	1 W = 1 V · 1 A
density	–	kg/m <sup>3</sup> , kg/dm <sup>3</sup>	reactive power	(var)	1 var = 1 V · 1 A
moment of inertia	–	kg · m <sup>2</sup>	apparent power	(VA)	1 VA = 1 V · 1 A
force	newton	1 N = 1 kg · m/s <sup>2</sup>	inductance	henry	1 H = 1 Vs/A
moment of force, torque	–	Nm	work, energy	joule (watt-hour) (electron volt)	1 J = 1 Ws 1 Wh = 3.6 kNm 1 eV = 0.1602 aJ
impulse	newton sec.	1 Ns = 1 kg · m/s	<b>Magnetism</b>		
pressure	pascal (bar)	1 Pa = 1 N/m <sup>2</sup> 1 bar = 0.1 MPa = 10 N/cm <sup>2</sup>	current linkage	ampere	A
surface pressure, rigidity, modulus of elasticity	–	N/mm <sup>2</sup>	magnetic field strength	amperes per metre	A/m
work, energy	joule (electron volt)	1 J = 1 Nm = 1 Ws 1 eV = 0.1602 aJ	magnetic flux	weber	1 Wb = 1 T · 1 m <sup>2</sup> = 1 Vs
power	watt	1 W = 1 J/s = 1 Nm/s	magn. flux density magn. polarisation	tesla	1 T = 1 Wb/m <sup>2</sup> = 1 Vs/m <sup>2</sup>
			inductance	henry	1 H = 1 Vs/A
			permeability	henrys per metre	1 H/m = 1 Vs/(Am)
			magn. resistance	–	1/H = A/Vs

## Quantities and Units 2

M

Quantity	SI unit (other unit)	Unit symbol, unit equation	Quantity	SI unit (other unit)	Unit symbol, unit equation
<b>Electromagnetic radiation (except light)</b>			<b>Nuclear reaction, ionising radiation</b>		
radiant energy	joule	1 J = 1 Nm = 1 Ws	activity of a radioactive substance	becquerel	1 Bq = 1/s
radiant power	watt	1 W = 1 J/s	absorbed dose	gray	1 Gy = 1 J/kg
radiant intensity	watt/sterad.	W/sr	absorbed dose rate	grays per second	Gy/s
radiant intensity	–	W/(sr · m <sup>2</sup> )	dose equivalent	sievert	1 Sv = 1 J/kg
irradiance	–	W/m <sup>2</sup>	dose equivalent rate	sieverts per second	1 Sv/s = 1 J/(kg · s)
<b>Light, optics</b>			ion dose	coulombs per kilogram	C/kg
light intensity	candela	cd	ion dose rate	amperes per kilogram	1 A/kg = 1 C/(kg · s)
luminance	candelas per m <sup>2</sup>	cd/m <sup>2</sup>	<b>Acoustics</b>		
luminous flux	lumen	lm	sound pressure	pascal	1 Pa = 1 N/m <sup>2</sup>
luminous efficacy	lumens per watt	lm/W	sound particle velocity	metres per second	m/s
illuminance	lux	1 lx = 1 lm/m <sup>2</sup>	sound velocity (propagation velocity)	metres per second	m/s
optical power of lenses	– (diopetre)	1/m 1 dpt = 1/m	volume velocity	–	1 m <sup>3</sup> /s = 1 m <sup>2</sup> · 1 m/s
<b>Heat</b>			sound intensity	–	W/m <sup>2</sup>
centigrade temperature	degree centigrade	°C	specific sound impedance	–	Pa · s/m
thermodynamic temperature	kelvin	K (0 K ≐ – 273.15 °C)	acoustic impedance	–	Pa · s/m <sup>3</sup>
temperature difference	kelvin	K	mechanical impedance	–	N · s/m
heat, inner energy	joule	1 J = 1 Ws	equivalent absorption area	square metre	m <sup>2</sup>
heat flow	watt	1 W = 1 J/s	<b>Chemistry, molecular physics</b>		
thermal resistance (of components)	kelvins per watt	K/W	quantity of substance	mol(e)	mol
thermal conductivity	–	W/(K · m)	concentration of quantity of substance	–	mol/m <sup>3</sup>
heat transfer coefficient	–	W/(K · m <sup>2</sup> )	molar volume	–	m <sup>3</sup> /mol
thermal capacity, entropy	joules per kelvin	J/K	molality	–	mol/kg
specific thermal capacity	–	J/(kg · K)	molar mass	–	kg/mol
<b>Chemistry, molecular physics</b>			molar thermal capacity	–	J/(mol · K)
<b>Chemistry, molecular physics</b>			diffusion coefficient	–	m <sup>2</sup> /s
<b>Chemistry, molecular physics</b>			<b>Other disciplines</b>		
<b>Chemistry, molecular physics</b>			distance in astronomy	(astronomical unit) parsec	1 AU = 149.6 Gm 1 pc = 30.857 Pm
<b>Chemistry, molecular physics</b>			velocity of light	km/s	c = 3 × 10 <sup>8</sup> m/s ≈ 300,000 km/s
<b>Chemistry, molecular physics</b>			light year l.y.	km	1 l.y. = 9.461 · 10 <sup>12</sup> km
<b>Chemistry, molecular physics</b>			mass in nuclear physics	(nuclear mass unit)	1 u = 1.66 · 10 <sup>-27</sup> kg
<b>Chemistry, molecular physics</b>			mass per unit length of textile fibres and threads	tex	1 tex = 1 g/kg
<b>Chemistry, molecular physics</b>			area of plots of land	are hectare	1 a = 100 m <sup>2</sup> 1 ha = 100 a



## Mathematical Symbols

Symbol	Meaning	Example	Symbol	Meaning	Example
<b>General symbols</b>					
... $n$	and so on until $n$	$k = 1, 2, 3, \dots, n$	$\infty$	infinite	$n = 1, 2, 3, \dots, \infty$
...	and so on until infinity	$n = 1, 2, 3, \dots$ $\sqrt{2} = 1.41421 \dots$	$\rightarrow$	versus, approaches, exceeds	$x \rightarrow a$ , $x$ approaches the value $a$
			$f(x)$	function of $x$	$f(I) = I^2 \cdot R$
			$i$ or $j$	imaginary unit	$i^2 = j^2 = -1$
			$Z$	complex quantity $Z$	$Z = R + jX$
<b>Boolean algebra</b>					
$\neg a, \bar{a}$	NOT $a$	$\overline{a \wedge b} = \neg (a \wedge b)$	<b>Geometry, vectors</b>		
$\wedge$	AND	$a \wedge b$ or $\wedge (a, b)$	$\parallel$	parallel	$g_1 \parallel g_2$ , $R_1 \parallel R_2$
$\vee$	OR	$a \vee b$ or $\vee (a, b)$	$\uparrow\uparrow$	parallel in the same dir.	$g \uparrow\uparrow h$
$\overline{\wedge}$	NOT AND (NAND)	$a \overline{\wedge} b = \overline{a \wedge b}$	$\uparrow\downarrow$	parallel in opposite dir.	$g_1 \uparrow\downarrow g_2$
$\overline{\vee}$	NOT OR (NOR)	$a \overline{\vee} b = \overline{a \vee b}$	$\perp$	orthogonal, perpendicular	$g \perp h$
<b>Set theory</b>					
$\in$	element of	$a \in M$ : $a$ is element of $M$	$\triangle$	triangle	$\triangle ABC$
$\subset$	subset	$M_1 \subset M_2$ : $M_1$ is subset of $M_2$	$\cong$	congruent	$\triangle ABC \cong \triangle DEF$
$\cup$	union of sets	$\{1, 2\} \cup \{3, 4\} = \{1, 2, 3, 4\}$	$\sim$	similar	$\triangle P_1P_2P_3 \sim \triangle ABC$
$\Rightarrow$	from this follows that	$a \cdot b = c \Rightarrow a = c/b$	$\sphericalangle$	angle	$\sphericalangle ABC = \sphericalangle (BA, BC)$ , $\sphericalangle (\vec{a}, \vec{b})$
<b>Arithmetic</b>					
$=$	equal to	$P = U \cdot I$	$\overline{AB}$	line segment AB	$\overline{P_1P_2}$
$\neq$	not equal, unequal	$4 \neq 5$	$\widehat{AB}$	arc AB	$\widehat{AB} = \sphericalangle \gamma$
$\sim$	proportional	$u \sim r$	$\vec{A}, \vec{B}$	vector $A$ , vector $B$	$\vec{C} = \vec{A} + \vec{B}$
$\approx$	approximately	$\pi \approx 3.14$	$ \vec{A} $	absolute value of vector $A$	$ \vec{F}  = 50 \text{ N}$
$\cong$	corresponds to	$1 \text{ cm} \cong 20 \text{ N}$	<b>Differentiation, integration</b>		
$<$	less than	$2 < 3$	$\Delta$	difference	$\Delta U = U_2 - U_1$
$>$	greater than	$5 > 2$	$y'$	$y$ prime	$y'$ is the first derivation of $y$ , first derivative
$\leq$	less than or equal to	$a \leq 10$	$\frac{dy}{dx}$	$dy$ by $dx$ or $dy$ over $dx$	quotient $y' = dy/dx$
$\geq$	greater than or equal to	$n \geq 7$	$\int$	integral	$\int f(x) dx, \int_a^b f(x) dx$
$\ll$	considerably less than	$R \ll 100 \text{ k}\Omega$	<b>Exponents, logarithms</b>		
$\gg$	considerably greater than	$R_x \gg R_n$	$a^x$	$a$ to the power of $x$	$5^3, 10^x$
$\cdot, \times$	times, multiplied	$a \cdot b = ab, 12 \times 3 = 36$	exp	exponential function	$\exp x = e^x$ , with $e = 2.718\dots$
$-, /, :$	divided by	$\frac{7}{2} = 7/2 = 7 : 2$	log	general logarithm	
%	per cent	$1\% = 10^{-2}, 50\% = 0.5$	$\log_a$	logarithm to the basis $a$	$\log_3 9 = 2$
‰	per thousand, per mil	$1\text{‰} = 10^{-3}, 8\text{‰} = 0.8\%$	lg	common logarithm	$\lg 2 = 0.30103\dots$
( ), [ ], { }	round, squared, curly, pointed brackets	$[a(b-c) + d]^2$	lb	dyadic logarithm	$\text{lb } 8 = 3$
$ z $	amount of $z$	$ 4  = 4,  -7  = 7$	ln	natural logarithm	$\ln 10 = 2.3025\dots$
$n!$	$n$ factorial	$n! = 1 \cdot 2 \cdot 3 \cdot \dots \cdot n, 3! = 6$	<b>Trigonometry</b>		
$\Sigma$	sum	$\Sigma I = I_1 + I_2 + I_3 + \dots$	sin	sine	$\sin \alpha$
$\Pi$	product	$\Pi k = k_1 \cdot k_2 \cdot k_3 \cdot \dots$	cos	cosine	$\sin^2 \alpha + \cos^2 \alpha = 1$ $= (\sin \alpha)^2 + (\cos \alpha)^2 = 1$
$\sqrt{\quad}$	square root of	$\sqrt{16} = 4$	tan	tangent	$\tan \alpha = \sin \alpha / \cos \alpha$
$\sqrt[n]{\quad}$	$n$ th root of	$\sqrt[3]{8} = 2$	cot	cotangent	$\cot \alpha = 1 / \tan \alpha$
$\pi$	pi	$\pi = 3.14159\dots$	arcsin	arc sine	$\sin \alpha = x \Rightarrow \arcsin x = \alpha$
			arccos	arc cosine	$\cos \alpha = x \Rightarrow \arccos x = \alpha$
			arctan	arc tangent	$\tan \alpha = x \Rightarrow \arctan x = \alpha$
			arccot	arc cotangent	$\cot \alpha = x \Rightarrow \text{arccot } x = \alpha$

# Exponents, Unit Prefixes, Logarithms, Calculations According to the Rule of Three

## Exponents

Values less than 1 can be expressed by multiples of decimal powers with negative exponents.  
 Values greater than 1 can be expressed by multiples of decimal powers with positive exponents.

Value	0.001	0.01	0.1	1	10	100	1,000	10,000	100,000	1,000,000
Decimal powers	$10^{-3}$	$10^{-2}$	$10^{-1}$	$10^0$	$10^1$	$10^2$	$10^3$	$10^4$	$10^5$	$10^6$

Powers of two are used in digital engineering. The base here is 2.

Value	1/128	1/64	1/32	1/16	1/8	1/4	1/2	1	2	4	8	16	32	64	128
Powers of two	$2^{-7}$	$2^{-6}$	$2^{-5}$	$2^{-4}$	$2^{-3}$	$2^{-2}$	$2^{-1}$	$2^0$	$2^1$	$2^2$	$2^3$	$2^4$	$2^5$	$2^6$	$2^7$

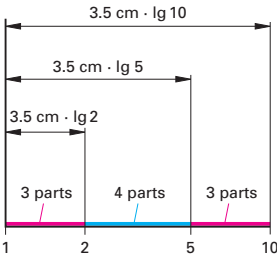
## Metric prefixes

## Binary prefixes

Prefix symbol	Prefix	Meaning (factor)	Prefix symbol	Prefix	Meaning (factor)	Prefix symbol	Prefix	Meaning (factor)
y	Yokto	$10^{-24}$	da	deca	10	-	-	-
z	Zepto	$10^{-21}$	h	hecto	$10^2$	-	-	-
a	atto	$10^{-18}$	k	kilo	$10^3$	Ki	kibi	$2^{10}$
f	femto	$10^{-15}$	M	mega	$10^6$	Mi	mebi	$2^{20}$
p	pico	$10^{-12}$	G	giga	$10^9$	Gi	gibi	$2^{30}$
n	nano	$10^{-9}$	T	tera	$10^{12}$	Ti	tibi	$2^{40}$
μ	micro	$10^{-6}$	P	peta	$10^{15}$	Pi	pebi	$2^{50}$
m	milli	$10^{-3}$	E	exa	$10^{18}$	Ei	exbi	$2^{60}$
c	centi	$10^{-2}$	Z	zetta	$10^{21}$	Zi	zebi	$2^{70}$
d	deci	$10^{-1}$	Y	yobi	$10^{24}$	Yi	yobi	$2^{80}$

Prefixes may not be combined. You can assign only one prefix per unit.

## Logarithms



Logarithmic sectioning

The logarithm (log) indicates to which power a base has to be raised in order to obtain the logarithm argument. The following applies

$$a^b = c, \log_a c = b$$

The common logarithm (lg) has the base 10. The natural logarithm (ln) has the base of the e-function (e=2.718...). The dyadic logarithm (lb) has the base 2.

Extensive number ranges can be represented in a more structured way when using a logarithmic scale.

$$\log_a c = \frac{\ln c}{\ln a} = \frac{\ln c}{\lg a}$$

$$\log_a(cd) = \log_a c + \log_a d \quad 1$$

$$\log_a \frac{c}{d} = \log_a c - \log_a d \quad 2$$

$$\log_a(c^m) = m \cdot \log_a c \quad 3$$

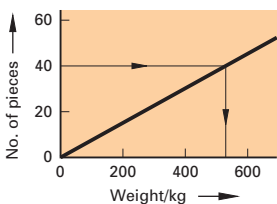
$$\log_a \sqrt[n]{c} = \frac{1}{n} \log_a c \quad 4$$

$$\lg x = \ln x / \ln 10 \quad 5$$

$$\ln x = \lg x / \lg e \quad 6$$

$$\text{lb} x = \lg x / \lg 2 \quad 7$$

## Calculation according to the rule of three

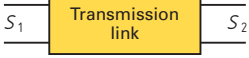


Calculation acc. to the rule of three of a proportional relation

Steps of approach	Example
<b>Proportional relation</b> (unit obtained by division)	
1. Statement 2. Calculation for 1 object 3. Calculation for z objects	n elements have a weight of a kg 1 element has a weight of a/n kg z elements have a weight of z · a/n kg
<b>Inverted proportional relation</b> (unit obtained by multiplication)	
1. Statement 2. Calculation for 1 object 3. Calculation for z objects	n workers need a hours 1 worker needs n · a hours z workers need n · a/z hours

## Logarithmic Unit Decibel

### Logarithmic unit decibel

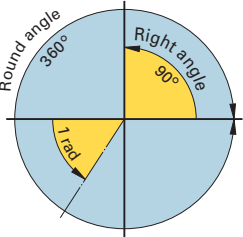
Term, definition	Formula, note	Comments, example
<b>Transmission factor <math>T</math></b> <b>Gain factor <math>V</math></b> <b>Attenuation factor <math>D</math></b>	Increase $> 1$ and decrease $< 1$ : $T = V = S_2/S_1$ <span style="float: right; border: 1px solid red; padding: 2px;">1</span> $D = S_1/S_2$ <span style="float: right; border: 1px solid red; padding: 2px;">2</span>	 <p><math>S_1</math>, <math>S_2</math> quantities referring to transmission</p>
<b>Power-related measures</b>  Gain ratio $G$ Attenuation ratio $A$  In order to identify the value as a logarithmic quantity, dB is added instead of a unit, because the value actually has no unit.	<b>Gain ratio</b> $G = 10 \lg (P_2/P_1)$ <span style="float: right; border: 1px solid red; padding: 2px;">3</span> <b>Attenuation ratio</b> $A = 10 \lg (P_1/P_2)$ <span style="float: right; border: 1px solid red; padding: 2px;">4</span> $G = -A$ <span style="float: right; border: 1px solid red; padding: 2px;">5</span> $A = -G$ <span style="float: right; border: 1px solid red; padding: 2px;">6</span> dB refers to decibel (one tenth of a bel, a unit named after the American scientist Alexander Graham Bell)	<b>Example 1:</b> A filter circuit has an input of 500 mW and an output of 250 mW. What are a) the attenuation factor $D$ and b) the attenuation ratio $A$ ?  a) $D = S_1/S_2 = 500 \text{ mW}/250 \text{ mW} = 2$ b) $A = 10 \lg (500 \text{ mW}/250 \text{ mW}) = 3.01 \text{ dB}$
<b>Voltage-related measures, pressure-related measures</b>  Gain ratio $G$ Attenuation ratio $A$ Sound pressure transmission ratio $T_p$  For these quantities, dB is also used instead of a unit.	<b>Gain ratio</b> $G = 20 \lg (U_2/U_1)$ <span style="float: right; border: 1px solid red; padding: 2px;">7</span> $G = -A$ <span style="float: right; border: 1px solid red; padding: 2px;">8</span> <b>Attenuation ratio</b> $A = 20 \lg (U_1/U_2)$ <span style="float: right; border: 1px solid red; padding: 2px;">9</span> $A = -G$ <span style="float: right; border: 1px solid red; padding: 2px;">10</span> Sound pressure transmission ratio $T_p = 20 \lg (p_2/p_1)$ <span style="float: right; border: 1px solid red; padding: 2px;">11</span>	<b>Example 2:</b> An amplifier has an input of 3 mV and an output of 5 V. What is a) the gain factor, b) the gain ratio?  a) $V = U_2/U_1 = 5 \text{ V}/3 \text{ mV} = 1,667$ b) $G = 20 \lg (U_1/U_2) = 20 \lg (5 \text{ V}/3 \text{ mV}) = 64.4 \text{ dB}$

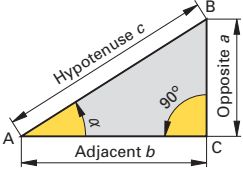
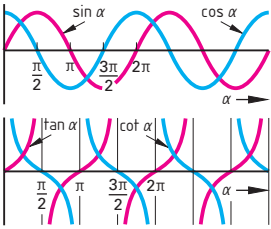
### Level in dB(\*) (\* place holder for additional specifications)

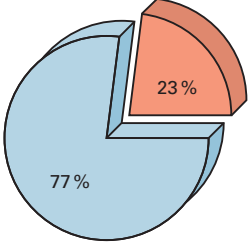
<b>Sound level, general</b>	This quantity expresses the ratio between two values, one of which is an agreed reference value.	The reference value should be indicated in level specifications.
<b>Power level <math>L_p</math></b> Identified by dB (1 mW) or dBm, Voltage level $L_U$ , identified by dB (1 $\mu$ V) or dBm = dB (1 mV) Sound-pressure level $L_p$ actually identified by dB (20 $\mu$ N/m <sup>2</sup> )	<b>Power level</b> $L_p = 10 \lg (P/1 \text{ mW})$ <span style="float: right; border: 1px solid red; padding: 2px;">12</span> <b>Voltage level</b> $L_U = 20 \lg (U/1 \mu\text{V})$ <span style="float: right; border: 1px solid red; padding: 2px;">13</span> <b>Sound-pressure level</b> $L_p = 20 \lg (p/20 \mu\text{N/m}^2)$ <span style="float: right; border: 1px solid red; padding: 2px;">14</span>	The agreed reference values are 1 mW for $L_p$ , 1mV for $L_U$ and 20 $\mu$ N/m <sup>2</sup> for $L_p$ .  <b>Example 3:</b> An aerial has an output of 80 mV. $L_U = ?$ $L_U = 20 \lg (U/1 \text{ mV}) = 38 \text{ dBm}$
<b>Rated sound-pressure level</b> Identified by dB(A), dB(B) or dB(C), depending on the correction	The measured quantity is the sound-pressure level. The measuring values are modified with the help of filters A, B or C for frequencies other than 1,000 Hz.	The rated sound-pressure level in dB(A) corresponds to a great extent to the human loudness sensation in phon.
A attenuation ratio D attenuation factor G gain ratio $L_p$ power level $L_p$ sound-pressure level	$L_U$ voltage level lg common logarithm P power p pressure T transmission factor	U voltage V gain factor Subscripts: 1 input, 2 output of the transmission link

# Angles, Trigonometric Functions, Percentage Calculation

M

Figures	Explications	Notes, formulas												
<b>Angles</b>														
 <p><b>Angle dimensions</b></p>	<p>The units referring to angles are degree, centesimal degree and radian.</p> <p>The <i>round angle</i> has</p> <ol style="list-style-type: none"> <li>360 ° (degrees)</li> <li>400 gon (centesimal degrees)</li> <li>2π rad (radian)</li> </ol> <p>The unit radian corresponds to the proportion of the circular arc length to the radius in a circle.</p> $\alpha_r = \alpha^\circ \cdot \frac{\pi}{180^\circ}$ <p>1 rad = <math>\frac{360^\circ}{2\pi} = 57.296^\circ</math></p>	<p><b>Important angles</b></p> <table border="1"> <thead> <tr> <th>Round angle</th> <th>Straight angle</th> <th>Right angle</th> </tr> </thead> <tbody> <tr> <td>360°</td> <td>180°</td> <td>90°</td> </tr> <tr> <td>2 · π rad</td> <td>π rad</td> <td><math>\frac{\pi}{2}</math> rad</td> </tr> <tr> <td>400 gon</td> <td>200 gon</td> <td>100 gon</td> </tr> </tbody> </table> <p>Still customary in survey engineering: 1 gon = (π/200) rad</p>	Round angle	Straight angle	Right angle	360°	180°	90°	2 · π rad	π rad	$\frac{\pi}{2}$ rad	400 gon	200 gon	100 gon
	Round angle	Straight angle	Right angle											
360°	180°	90°												
2 · π rad	π rad	$\frac{\pi}{2}$ rad												
400 gon	200 gon	100 gon												

<b>Angle functions</b>		
 <p><b>Right-angled triangle</b></p>	<p>The longest side (c) of the right-angled triangle is referred to as the <i>hypotenuse</i>. It is the side opposite the right angle. The two other sides (a and b) of the triangle form the right angle. These sides are referred to as the <i>catheti</i> or simply <i>legs</i> of the triangle. The leg (a) opposite the acute angle α is the <i>opposite</i>. The leg contiguous to the angle α is the <i>adjacent</i> (b).</p>	<p>An angle in a right-angled triangle can be defined by its angle degrees or as a <i>ratio of two triangle sides</i>. The ratio of the sides depends on the size of the angle. That is why the ratios of two sides in a right-angled triangle are referred to as <i>angle functions</i> (function = dependence) or trigonometric functions.</p>
 <p><b>Trigonometric functions</b></p>	<p>Sine = <math>\frac{\text{opposite}}{\text{hypotenuse}}</math></p> <p>Cosine = <math>\frac{\text{adjacent}}{\text{hypotenuse}}</math></p> <p>Tangent = <math>\frac{\text{opposite}}{\text{adjacent}}</math></p> <p>Cotangent = <math>\frac{\text{adjacent}}{\text{opposite}}</math></p>	$\sin \alpha = \frac{a}{c}$ $\cos \alpha = \frac{b}{c}$ $\tan \alpha = \frac{a}{b}$ $\cot \alpha = \frac{b}{a}$

<b>Percentage calculation</b>		
	<p>Per cent (pro cent in Latin) means "per hundred". The total quantity (basic quantity) is always equal to one hundred, the partial quantity (percentage) is expressed in per cent (= hundredths).</p> <p>23% of 300 € is equal to <b>69 €</b></p> <p>percentage = <math>\frac{100 \cdot \text{percentage amount}}{\text{basic value}}</math></p>	<p>Percentage calculation</p> $p = \frac{P \cdot 100\%}{B}$ <p>Calculation of interest</p> $I = \frac{C_0 \cdot p \cdot n}{100\%}$ <p>Calculation of compound interest</p> $C_n = C_0 \cdot \left(1 + \frac{p}{100\%}\right)^n$

a, b, c legs of a right-angled triangle  
 B basic amount  
 C<sub>0</sub> starting capital  
 C<sub>n</sub> capital after n years

I interest per year  
 n term in years  
 P percentage amount  
 p percentage in %, interest rate in %

α, β, γ angles in a triangle  
 α° degrees of an angle  
 α<sub>r</sub> radian of an angle