Chapter

2

International Standards and Constants

2.1 Introduction

Standardization usually starts within a company as a way to reduce costs associated with parts stocking, design drawings, training, and retraining of personnel. The next level might be a cooperative agreement between firms making similar equipment to use standardized dimensions, parts, and components. Competition, trade secrets, and the *NIH factor* (not invented here) often generate an atmosphere that prevents such an understanding. Enter the professional engineering society, which promises a forum for discussion between users and engineers while downplaying the commercial and business aspects.

2.2 The History of Modern Standards

In 1836, the U.S. Congress authorized the Office of Weights and Measures (OWM) for the primary purpose of ensuring uniformity in custom house dealings. The Treasury Department was charged with its operation. As advancements in science and technology fueled the industrial revolution, it was apparent that standardization of hardware and test methods was necessary to promote commercial development and to compete successfully with the rest of the world. The industrial revolution in the 1830s introduced the need for interchangeable parts and hardware. Economical manufacture of transportation equipment, tools, weapons, and other machinery was possible only with mechanical standardization.

By the late 1800s professional organizations of mechanical, electrical, chemical, and other engineers were founded with this aim in mind. The Institute of Electrical Engineers developed standards between 1890 and 1910 based on the practices of the major electrical manufacturers of the time. Such activities were not within the purview of the OWM, so there was no government involvement during this period. It took the pressures of war production in 1918 to cause the formation of the American Engineering

Standards Committee (AESC) to coordinate the activities of various industry and engineering societies. This group became the American Standards Association (ASA) in 1928.

Parallel developments would occur worldwide. The International Bureau of Weights and Measures was founded in 1875, the International Electrotechnical Commission (IEC) in 1904, and the International Federation of Standardizing Bodies (ISA) in 1926. Following World War II (1946) this group was reorganized as the International Standards Organization (ISO) comprised of the ASA and the standardizing bodies of 25 other countries. Present participation is approximately 55 countries and 145 technical committees. The stated mission of the ISO is *to facilitate the internationalization and unification of industrial standards*.

The International Telecommunications Union (ITU) was founded in 1865 for the purpose of coordinating and interfacing telegraphic communications worldwide. Today, its member countries develop regulations and voluntary recommendations, and provide coordination of telecommunications development. A sub-group, the International Radio Consultative Committee (CCIR) (which no longer exists under this name), is concerned with certain transmission standards and the compatible use of the frequency spectrum, including geostationary satellite orbit assignments. Standardized transmission formats to allow interchange of communications over national boundaries are the purview of this committee. Because these standards involve international treaties, negotiations are channeled through the U.S. State Department.

2.2.1 American National Standards Institute (ANSI)

ANSI coordinates policies to promote procedures, guidelines, and the consistency of standards development. Due process procedures ensure that participation is open to all persons who are materially affected by the activities without domination by a particular group. Written procedures are available to ensure that consistent methods are used for standards developments and appeals. Today, there are more than 1000 members who support the U.S. voluntary standardization system as members of the ANSI federation. This support keeps the Institute financially sound and the system free of government control.

The functions of ANSI include: (1) serving as a clearinghouse on standards development and supplying standards-related publications and information, and (2) the following business development issues:

- Provides national and international standards information necessary to market products worldwide.
- Offers American National Standards that assist companies in reducing operating and purchasing costs, thereby assuring product quality and safety.
- Offers an opportunity to voice opinion through representation on numerous technical advisory groups, councils, and boards.
- Furnishes national and international recognition of standards for credibility and force in domestic commerce and world trade.

- Provides a path to influence and comment on the development of standards in the international arena.

Prospective standards must be submitted by an ANSI accredited standards developer. There are three methods which may be used:

- **Accredited organization method**. This approach is most often used by associations and societies having an interest in developing standards. Participation is open to all interested parties as well as members of the association or society. The standards developer must fashion its own operating procedures, which must meet the general requirements of the ANSI procedures.
- **Accredited standards committee method**. Standing committees of directly and materially affected interests develop documents and establish consensus in support of the document. This method is most often used when a standard affects a broad range of diverse interests or where multiple associations or societies with similar interests exist. These committees are administered by a *secretariat*, an organization that assumes the responsibility for providing compliance with the pertinent operating procedures. The committee can develop its own operating procedures consistent with ANSI requirements, or it can adopt standard ANSI procedures.
- **Accredited canvass method**. This approach is used by smaller trade associations or societies that have documented current industry practices and desire that these standards be recognized nationally. Generally, these developers are responsible for less than five standards. The developer identifies those who are directly and materially affected by the activity in question and conducts a letter ballot *canvass* of those interests to determine consensus. Developers must use standard ANSI procedures.

Note that all methods must fulfill the basic requirements of public review, voting, consideration, and disposition of all views and objections, and an appeals mechanism.

The introduction of new technologies or changes in the direction of industry groups or engineering societies may require a mediating body to assign responsibility for a developing standard to the proper group. The Joint Committee for Intersociety Coordination (JCIC) operates under ANSI to fulfill this need.

2.2.2 Professional Society Engineering Committees

The engineering groups that collate and coordinate activities that are eventually presented to standardization bodies encourage participation from all concerned parties. Meetings are often scheduled in connection with technical conferences to promote greater participation. Other necessary meetings are usually scheduled in geographical locations of the greatest activity in the field. There are no charges or dues to be a member or to attend the meetings. An interest in these activities can still be served by reading the reports from these groups in the appropriate professional journals. These wheels may seem to grind exceedingly slowly at times, but the adoption of standards that may have to endure for 50 years or more should not be taken lightly.

2.3 References

1. Whitaker, Jerry C. (ed.), *The Electronics Handbook*, CRC Press, Boca Raton, FL, 1996.

2.4 Bibliography

Whitaker, Jerry C., and K. Blair Benson (eds.), *Standard Handbook of Video and Television Engineering*, McGraw-Hill, New York, NY, 2000.

2.5 Tabular Data

Table 2.1 Common Standard Units

Name	Symbol	Quantity
ampere	A	electric current
ampere per meter	A/m	magnetic field strength
ampere per square meter	A/m^2	current density
becquerel	Bg	activity (of a radionuclide)
candela	cd	luminous intensity
coulomb	C	electric charge
coulomb per kilogram	C/kg	exposure (x and gamma rays)
coulomb per sq. meter	C/m^2	electric flux density
cubic meter	m^3	volume
cubic meter per kilogram	m^3/kg	specific volume
degree Celsius	°C	Celsius temperature
farad	F	capacitance
farad per meter	F/m	permittivity
henry	H	inductance
henry per meter	H/m	permeability
hertz	Hz	frequency
joule	J	energy, work, quantity of heat
joule per cubic meter	J/m^3	energy density
joule per kelvin	J/K	heat capacity
joule per kilogram K	J/(kg•K)	specific heat capacity
joule per mole	J/mol	molar energy
kelvin	K	thermodynamic temperature
kilogram	kg	mass
kilogram per cubic meter	kg/m^3	density, mass density
lumen	lm	luminous flux
lux	lx	luminance

Table 2.1 Common Standard Units (continued)

Name	Symbol	Quantity
meter	m	length
meter per second	m/s	speed, velocity
meter per second sq.	m/s^2	acceleration
mole	mol	amount of substance
newton	N	force
newton per meter	N/m	surface tension
ohm	Ω	electrical resistance
pascal	Pa	pressure, stress
pascal second	Pa•s	dynamic viscosity
radian	rad	plane angle
radian per second	rad/s	angular velocity
radian per second squared	rad/s^2	angular acceleration
second	s	time
siemens	S	electrical conductance
square meter	m^2	area
steradian	sr	solid angle
tesla	T	magnetic flux density
volt	V	electrical potential
volt per meter	V/m	electric field strength
watt	W	power, radiant flux
watt per meter kelvin	W/(m•K)	thermal conductivity
watt per square meter	W/m^2	heat (power) flux density
weber	Wb	magnetic flux

Table 2.2 Standard Prefixes

Multiple	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Table 2.3 Common Standard Units for Electrical Work

Unit	Symbol
centimeter	cm
cubic centimeter	cm^3
cubic meter per second	m^3/s
gigahertz	GHz
gram	g
kilohertz	kHz
kilohm	kΩ
kilojoule	kJ
kilometer	km
kilovolt	kV
kilovoltampere	kVA
kilowatt	kW
megahertz	MHz
megavolt	MV
megawatt	MW
megohm	MΩ
microampere	µA
microfarad	µF
microgram	µg
microhenry	µH
microsecond	µs
microwatt	µW
milliampere	mA
milligram	mg
millihenry	mH
millimeter	mm
millisecond	ms
millivolt	mV
milliwatt	mW
nanoampere	nA
nanofarad	nF
nanometer	nm
nanosecond	ns
nanowatt	nW
picoampere	pA
picofarad	pF
picosecond	ps
picowatt	pW

Table 2.4 Names and Symbols for the SI Base Units (*From* [1]. *Used* Used with permission.)

Physical quantity	Name of SI unit	Symbol for SI unit
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

Table 2.5 Units in Use Together with the SI (These units are not part of the SI, but it is recognized that they will continue to be used in appropriate contexts. *From* [1]. *Used* with permission.)

Physical quantity	Name of unit	Symbol for unit	Value in SI units
time	minute	min	60 s
time	hour	h	3600 s
time	day	d	86 400 s
plane angle	degree	°	$(\pi/180)$ rad
plane angle	minute	′	$(\pi/10\,800)$ rad
plane angle	second	″	$(\pi/648\,000)$ rad
length	ångstrom[a]	Å	10^{-10} m
area	barn	b	10^{-28} m^2
volume	litre	l, L	dm^3 = 10^{-3}m^3
mass	tonne	t	Mg = 10^3 kg
pressure	bar[a]	bar	10^5 Pa = 10^5 N m^{-2}
energy	electronvolt[b]	eV (= e × V)	$\approx 1.60218 \times 10^{-19}$ J
mass	unified atomic mass unit[b,c]	u (= $m_a(^{12}C)/12$)	$\approx 1.66054 \times 10^{-27}$ kg

[a]The ångstrom and the bar are approved by CIPM for temporary use with SI units, until CIPM makes a further recommendation. However, they should not be introduced where they are not used at present.

[b]The values of these units in terms of the corresponding SI units are not exact, since they depend on the values of the physical constants e (for the electronvolt) and N_A (for the unified atomic mass unit), which are determined by experiment.

[c]The unified atomic mass unit is also sometimes called the dalton, with symbol Da, although the name and symbol have not been approved by CGPM.

Table 2.6 Derived Units with Special Names and Symbols (*From* [1]. *Used* with permission.)

Physical quantity	Name of SI unit	Symbol for SI unit	Expression in terms of SI base units
frequency[a]	hertz	Hz	s^{-1}
force	newton	N	$m\ kg\ s^{-2}$
pressure, stress	pascal	Pa	$N\ m^{-2} = m^{-1}\ kg\ s^{-2}$
energy, work, heat	joule	J	$N\ m = m^2\ kg\ s^{-2}$
power, radiant flux	watt	W	$J\ s^{-1} = m^2\ kg\ s^{-3}$
electric charge	coulomb	C	$A\ s$
electric potential, electromotive force	volt	V	$J\ C^{-1} = m^2\ kg\ s^{-3}\ A^{-1}$
electric resistance	ohm	Ω	$V\ A^{-1} = m^2\ kg\ s^{-3}\ A^{-2}$
electric conductance	siemens	S	$\Omega^{-1} = m^{-2}\ kg^{-1}\ s^3\ A^2$
electric capacitance	farad	F	$C\ V^{-1} = m^{-2}\ kg^{-1}\ s^4\ A^2$
magnetic flux density	tesla	T	$V\ s\ m^{-2} = kg\ s^{-2}\ A^{-1}$
magnetic flux	weber	Wb	$V\ s = m^2\ kg\ s^{-2}\ A^{-1}$
inductance	henry	H	$V\ A^{-1}\ s = m^2\ kg\ s^{-2}\ A^{-2}$
Celsius temperature[b]	degree Celsius	°C	K
luminous flux	lumen	lm	cd sr
illuminance	lux	lx	$cd\ sr\ m^{-2}$
activity (radioactive)	becquerel	Bq	s^{-1}
absorbed dose (of radiation)	gray	Gy	$J\ kg^{-1} = m^2 s^{-2}$
dose equivalent (dose equivalent index)	sievert	Sv	$J\ kg^{-1} = m^2\ s^{-2}$
plane angle	radian	rad	$1 = m\ m^{-1}$
solid angle	steradian	sr	$1 = m^2\ m^{-2}$

[a]For radial (circular) frequency and for angular velocity the unit rad s^{-1}, or simply s^{-1}, should be used, and this may not be simplified to Hz. The unit Hz should be used only for frequency in the sense of cycles per second.

[b]The Celsius temperature θ is defined by the equation:

$$\theta/°C = T/K - 273.15$$

The SI unit of Celsius temperature interval is the degree Celsius, °C , which is equal to the kelvin, K. °C should be treated as a single symbol, with no space between the ° sign and the letter C. (The symbol °K and the symbol ° should no longer be used.)

Table 2.7 The Greek Alphabet (*From* [1]. *Used* with permission.)

	Greek letter	Greek name	English equivalent		Greek letter	Greek name	English equivalent
Α	α	Alpha	a	Ν	ν	Nu	n
Β	β	Beta	b	Ξ	ξ	Xi	x
Γ	γ	Gamma	g	Ο	ο	Omicron	ŏ
Δ	δ	Delta	d	Π	π	Pi	p
Ε	ϵ	Epsilon	ĕ	Ρ	ρ	Rho	r
Ζ	ζ	Zeta	z	Σ	σ ς	Sigma	s
Η	η	Eta	ē	Τ	τ	Tau	t
Θ	θ ϑ	Theta	th	Υ	υ	Upsilon	u
Ι	ι	Iota	i	Φ	ϕ φ	Phi	ph
Κ	κ	Kappa	k	Χ	χ	Chi	ch
Λ	λ	Lambda	l	Ψ	ψ	Psi	ps
Μ	μ	Mu	m	Ω	ω	Omega	ō

Table 2.8 Constants (*From* [1]. *Used with permission.*)

π Constants										
$\pi =$	3.14159	26535	89793	23846	26433	83279	50288	41971	69399	37511
$1/\pi =$	0.31830	98861	83790	67153	77675	26745	02872	40689	19291	48091
$\pi^2 =$	9.8690	44010	89358	61883	44909	99876	15113	53136	99407	24079
$\log_e \pi =$	1.14472	98858	49400	17414	34273	51353	05871	16472	94812	91531
$\log_{10} \pi =$	0.49714	98726	94133	85435	12682	88290	89887	36516	78324	38044
$\log_{10} \sqrt{2\pi} =$	0.39908	99341	79057	52478	25035	91507	69595	02099	34102	92128
Constants Involving *e*										
$e =$	2.71828	18284	59045	23536	02874	71352	66249	77572	47093	69996
$1/e =$	0.36787	94411	71442	32159	55237	70161	46086	74458	11131	03177
$e^2 =$	7.38905	60989	30650	22723	04274	60575	00781	31803	15570	55185
$M = \log_{10} e =$	0.43429	44819	03251	82765	11289	18916	60508	22943	97005	80367
$1/M = \log_e 10 =$	2.30258	50929	94045	68401	79914	54684	36420	76011	01488	62877
$\log_{10} M =$	9.63778	43113	00536	78912	29674	98645	−10			
Numerical Constants										
$\sqrt{2} =$	1.41421	35623	73095	04880	16887	24209	69807	85696	71875	37695
$\sqrt[3]{2} =$	1.25992	10498	94873	16476	72106	07278	22835	05702	51464	70151
$\log_e 2 =$	0.69314	71805	59945	30941	72321	21458	17656	80755	00134	36026
$\log_{10} 2 =$	0.30102	99956	63981	19521	37388	94724	49302	67881	89881	46211
$\sqrt{3} =$	1.73205	08075	68877	29352	74463	41505	87236	69428	05253	81039
$\sqrt[3]{3} =$	1.44224	95703	07408	38232	16383	10780	10958	83918	69253	49935
$\log_e 3 =$	1.09861	22886	68109	69139	52452	36922	52570	46474	90557	82275
$\log_{10} 3 =$	0.47712	12547	19662	43729	50279	03255	11530	92001	28864	19070