CLASSIFICATION OF SERVICES IN ELECTRICITY AND MAGNETISM

Version No 8 (dated 26 June 2017)

METROLOGY AREA: ELECTRICITY AND MAGNETISM

BRANCH: DC VOLTAGE, CURRENT, AND RESISTANCE

1. DC voltage (up to 1100 V, for higher voltages see 8.1)
   1.1 DC voltage sources
       1.1.1 Single values: standard cell, solid state voltage standard
       1.1.2 Low value ranges (below or equal to 10 V): DC voltage source, multifunction calibrator
       1.1.3 Intermediate values (above 10 V to 1100 V): DC voltage source, multifunction calibrator
       1.1.4 Noise voltages (for noise currents see 3.1.5, for RF noise see 11.4): DC voltage source, DC amplifier
   1.2 DC voltage meters
       1.2.1 Very low values (below or equal to 1 mV): nanovoltmeter, microvoltmeter
       1.2.2 Intermediate values (above 1 mV to 1100 V): DC voltmeter, multimeter, multifunction transfer standard
   1.3 DC voltage ratios (for input voltages up to 1100 V)
       1.3.1 Up to 1100 V: resistive divider, ratio meter
       1.3.2 Attenuation: attenuators

2. DC resistance
   2.1 DC resistance standards and sources
       2.1.1 Low values (below or equal to 1 Ω): fixed resistor, resistance box
       2.1.2 Intermediate values (above 1 Ω to 1 MΩ): fixed resistor, resistance box
       2.1.3 High values (above 1 MΩ): fixed resistor, three terminal resistor, resistance box
       2.1.4 Standards for high current: DC shunt
       2.1.5 Multiple ranges: multifunction calibrator
       2.1.6 Temperature, power and pressure coefficients: fixed resistor
   2.2 DC resistance meters
       2.2.1 Low values (below or equal to 1 Ω): microohmmeter, multimeter, multifunction transfer standard, resistance bridge
       2.2.2 Intermediate values (above 1 Ω to 1 GΩ): ohmmeter, multimeter, multifunction transfer standard, resistance bridge
       2.2.3 High values (above 1 GΩ): multimeter, multifunction transfer standard, teraohmmeter, resistance bridge
   2.3 DC resistance ratios
       2.3.1 DC resistance ratios: resistance ratio devices

3. DC current (up to 100 A, for higher currents see 8.7)
   3.1 DC current sources
       3.1.1 Low values (below or equal to 0.1 mA): current generator, multifunction calibrator
       3.1.2 Intermediate values (above 0.1 mA to 20 A): current generator, multifunction calibrator
       3.1.3 High values (above 20 A to 100 A): current generator
       3.1.4 Transconductance ratio
       3.1.5 Noise currents (for noise voltages see 1.1.4, for RF noise see 11.4): DC current source, DC amplifier
   3.2 DC current meters
       3.2.1 Low values (below or equal to 0.1 mA): picoammeter, nanoammeter, multimeter, multifunction transfer standard
       3.2.2 Intermediate values (above 0.1 mA to 20 A): current comparator
       3.2.3 High values (above 20 A to 100 A): current transducer, dedicated equipment for heavy current
   3.3 DC current ratios
       3.3.1 Ratios up to 100 A: resistive dividers, DC current comparators, current transducers

For each service, the instruments or artefacts are indicated in italic characters.
BRANCH: IMPEDANCE UP TO THE MEGAHERTZ RANGE

4. Impedance (up to the MHz range)
   4.1 AC resistance
      4.1.1 Real component (or modulus) and imaginary component (or argument or time constant): fixed resistor
      4.1.2 AC/DC difference: fixed resistor
      4.1.3 Resistors for high current: AC current shunt
      4.1.4 Meters: LCR meter (LCR: Inductance, Capacitance, Resistance)
      4.1.5 AC resistance ratios: resistance ratio devices
   4.2 Capacitance
      4.2.1 Capacitance and dissipation factor for low loss capacitors: standard capacitor (sealed, dry-nitrogen or fused silica dielectric)
      4.2.2 Capacitance and dissipation factor for dielectric capacitors: fixed capacitor, switched capacitor, capacitance box
      4.2.3 Capacitance and dissipation factor for transformed capacitors: fixed capacitor, switched capacitor
      4.2.4 Meters: capacitance bridge, LCR meter (LCR: Inductance, Capacitance, Resistance)
   4.3 Inductance
      4.3.1 Self inductance and equivalent series resistance, low values (lower than 1 mH): fixed inductor, variable inductor, inductance box
      4.3.2 Self inductance and equivalent series resistance, intermediate values (above or equal to 1 mH to 1 H): fixed inductor, variable inductor, inductance box
      4.3.3 Self inductance and equivalent series resistance, high values (higher than 1 H): fixed inductor, variable inductor, inductance box
      4.3.4 Mutual inductance: fixed mutual inductor
      4.3.5 Meters: LCR meter (LCR: Inductance, Capacitance, Resistance)
      4.3.6 Quality factor: Q-standards

BRANCH: AC VOLTAGE, CURRENT, AND POWER

5. AC voltage (up to the MHz range)
   5.1 AC/DC voltage transfer (for frequencies higher than 1 MHz see 11.7.1)
      5.1.1 AC/DC transfer difference at low voltages (typically below or equal to 0.5 V): thermal converter with amplifier, micropotentiometer, AC/DC transfer standard
      5.1.2 AC/DC transfer difference at medium voltages (typically above 0.5 V to 5 V): thermal converter (directly connected), AC/DC transfer standard
      5.1.3 AC/DC transfer difference at higher voltages (typically above 5 V): thermal converter with range extender, AC/DC transfer standard
   5.2 AC voltage up to 1100 V (for high voltage see 8.3)
      5.2.1 Sources: multifunction calibrator
      5.2.2 Meters: AC voltmeter, multimeter, multifunction transfer standard
   5.3 AC voltage ratio up to 1100 V (voltage transformers excluded), attenuation and gain (for high voltage and voltage transformers, see 8.3)
      5.3.1 Real component (or modulus) and imaginary component (or argument): inductive voltage divider, AC bridge standard, attenuator box, syncroresolver
      5.3.2 Attenuation and gain: passive device, attenuator box, inductive voltage divider

6. AC current
   6.1 AC/DC current transfer
      6.1.1 AC/DC transfer difference: thermal converter plus shunt, AC/DC transfer standard plus shunt
   6.2 AC current up to 100 A (for high current see 8.6)
      6.2.1 Sources: multifunction calibrator, transconductance amplifier
      6.2.2 Meters: AC ammeter, multimeter, multifunction transfer standard
   6.3 AC current ratio up to 100 A (current transformers excluded, for high current and current transformers, see 8.6)
      6.3.1 Real component (or modulus) and imaginary component (or argument)

For each service, the instruments or artefacts are indicated in italic characters.
7. **AC power**

7.1 **AC power and energy**

7.1.1 Single phase (frequencies below or equal to 400 Hz): *power meter, energy meter, power converter, wattmeter*

7.1.2 Single phase (frequencies above 400 Hz): *power meter, energy meter, power converter, wattmeter*

7.1.3 Three phase: *power meter, energy meter*

**BRANCH: HIGH VOLTAGE AND CURRENT**

8. **High voltage and current**

8.1 **High DC voltage** (for voltages lower than 1100 V see 1)

8.1.1

8.1.2

8.1.3 High DC voltage ratio: *DC high voltage divider, DC high voltage probe*

8.1.4 Average value of DC voltage: *DC voltage measuring system, DC voltage source, DC voltmeter*

8.1.5 RMS value of DC voltage ripple: *DC voltage measuring system, DC voltage source, DC voltmeter*

8.2 **High voltage impedance** (for low voltages see 4)

8.2.1 Capacitance and dissipation factor: *compressed gas capacitor, capacitor for high voltage, capacitance bridge, dissipation factor standard*

8.2.2 Inductance and loss angle: *high voltage reactor, inductance bridge*

8.2.3 Burden: real and imaginary component: *instrument transformer burden*

8.2.4 Resistance: *high voltage resistor*

8.3 **High AC voltage** (for voltages <= 1100 V see 5.2 and 5.3) and **voltage transformers**

8.3.1

8.3.2

8.3.3 Peak value of high AC voltage: *AC peak voltage responding measuring system, AC peak voltmeter*

8.3.4 Voltage transformers: ratio error and phase displacement: *voltage transformer, voltage transformer bridge, voltage divider, voltage probe*

8.3.5 RMS value for high AC voltage: *RMS responding measuring system, AC voltmeter, AC voltage source*

8.3.6 Rectified average value of high AC voltage: *AC rectified average voltage responding measuring system, AC rectified average voltmeter*

8.4 **Pulsed high voltage and current**

8.4.1 Parameters for lightning impulse voltage: *lightning impulse voltage measuring system, impulse calibrator, digital recorder*

8.4.2

8.4.3 Parameters for switching impulse voltage: *switching impulse voltage measuring system, impulse divider, impulse calibrator, digital recorder*

8.4.4

8.4.5 Parameters for impulse current: *impulse current measuring system, impulse shunt/divider, digital recorder*

8.4.6

8.4.7

8.4.8

8.4.9 Parameters for other impulse voltage types: *other impulse measuring systems*

8.5 **Electric discharge**

8.5.1 Apparent charge: *partial discharge calibrator, partial discharge measuring instrument*

8.5.2 Response: *electrostatic discharge target*

8.5.3 Rise time of partial discharge pulse: *partial discharge calibrator*

*For each service, the instruments or artefacts are indicated in italic characters.*
8.6 High AC current (for currents <= 100 A see 6.2 and 6.3) and current transformers
  8.6.1
  8.6.2
  8.6.3 Current transformers: ratio error and phase displacement: current transformer, current transformer bridge
  8.6.4
  8.6.5 High AC current RMS value: AC current measuring system, AC current meter, AC current source
  8.6.6 Other AC current parameter: AC current measuring system

8.7 High DC current (for currents below or equal to 100 A see 3, for shunts see 2.1.4)
  8.7.1
  8.7.2
  8.7.3 High DC current ratio: DC current transformer
  8.7.4 High DC current average value: DC current measuring system, DC current probe, DC source

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BRANCH: OTHER DC AND LOW FREQUENCY MEASUREMENTS

9. Other DC and low frequency measurements
  9.1 Electric charge
    9.1.1 Sources: q-source
    9.1.2 Meters: q-meter
  9.2 Phase angle
    9.2.1 Sources: phase source
    9.2.2 Meters: phase meter
    9.2.3 Phase shift: phase shifters, phase shift measuring devices
  9.3 Current and voltage waveform
    9.3.1 Main frequency harmonics: mains frequency harmonics analyzer
    9.3.2 Mains frequency harmonic distortion: mains frequency harmonic analyzer, signal generator, distortion meter, level meter
    9.3.3
    9.3.4 Mains frequency fluctuating harmonics: mains frequency harmonics analyzer
    9.3.5 Mains frequency voltage fluctuations, square / sine wave / other modulation: flicker meter
    9.3.6
    9.3.7 Mains frequency interharmonic: mains frequency analyzer

BRANCH: ELECTRIC AND MAGNETIC FIELDS

10. Electric and magnetic fields
  10.1 Electric fields below 50 kHz
    10.1.1 Electrostatic field strength: electrostatic field meter, electrostatic generator
    10.1.2 Electric field strength: field strength probe, electric field meter
  10.2 Magnetic fields below 50 kHz
    10.2.1 Magnetic flux: flux meter, flux etalon
    10.2.2 DC magnetic flux density and applied magnetic field strength: magnetic flux density meter, magnetic field strength meter
    10.2.3 AC magnetic flux density and applied magnetic field strength: magnetic flux density meter, magnetic field strength meter
    10.2.4 DC shielding factor (ratio of DC magnetic flux density)
    10.2.5 AC shielding factor (ratio of AC magnetic flux density)
    10.2.6 Turn area (ratio of magnetic flux and magnetic flux density): pick up coil
    10.2.7 Magnetic flux density or magnetic field strength per unit current: field coils
    10.2.8 Magnetic field gradient: gradiometers

For each service, the instruments or artefacts are indicated in italic characters.
10.3 Electromagnetic fields above 50 kHz
10.3.1 Electric field strength: field probe
10.3.2 Magnetic field strength: field probe
10.3.3 Power flux density: field probe
10.3.4 Magnetic flux density
10.3.5 Magnetic field strength per unit current
10.3.6 Turn area (ratio of magnetic flux and magnetic flux density)

**BRANCH: RADIO FREQUENCY MEASUREMENTS**

11. Radio frequency measurements
11.1 Radio frequency power
   11.1.1 Absolute power in coaxial line: power meter, power source
   11.1.2 Absolute power in waveguide: power meter, power source
   11.1.3 Calibration factor and effective efficiency in coaxial line: thermistor, barretter and power sensor
   11.1.4 Calibration factor and effective efficiency in waveguide: thermistor, barretter and power sensor
   11.1.5 Non-CW power (absolute or relative): peak power sensor, sensors with time resolution
   11.1.6 Power measurements in balanced lines: power meter (e.g. in 150 ohm)
11.2 Scalar RF reflection coefficient and attenuation (not using a VNA or similar device) (magnitude)
   11.2.1 Reflection coefficient in coaxial line (values in linear terms): passive device
   11.2.2 Reflection coefficient in waveguide (values in linear terms): passive device
   11.2.3 Attenuation in coaxial line (values in dB): passive device
   11.2.4 Attenuation in waveguide (values in dB): passive device
   11.2.5 Directivity, effective source match: multiports, splitter
   11.2.6 Reflection and attenuation measurements in balanced lines
11.3 Scattering parameters (vectors)
   11.3.1 Reflection coefficient (S\(_{11}\)) in coaxial line (values in linear terms: real and imaginary or magnitude): passive device, generator
   11.3.2 Reflection coefficient (S\(_{21}\)) in waveguide (values in linear terms: real and imaginary or magnitude): passive device, generator
   11.3.3 Transmission coefficient (S\(_{12}\)) in coaxial line (values in linear terms: real and imaginary): passive devices
   11.3.4 Transmission coefficient (S\(_{21}\)) in waveguide (values in linear terms: real and imaginary): passive devices
   11.3.5 Directivity, effective source match: multiports, splitter
   11.3.6 Reflection coefficient (S\(_{0}\)) for common mode systems: common mode absorbing devices (CMAD), coupling-decoupling network (CDN)
   11.3.7 Transmission coefficient (S\(_{0}\)) for common mode systems: common mode absorbing devices (CMAD)
11.4 Noise (for LF noise voltages and currents see 1.1.4 and 3.1.5)
   11.4.1 Noise temperature or excess noise ratio in coaxial line: noise source
   11.4.2 Noise temperature or excess noise ratio in waveguide: noise source
   11.4.3 Amplifier noise parameters: two-port amplifier, mixers
   11.4.4 Phase noise: oscillator, two-port device
   11.4.5 Radio brightness temperature, spectral radiance in free space: wide aperture noise radiometer
11.5 Antenna properties
   11.5.1 Antenna factor: antenna dipole, loop antenna, log antenna
   11.5.2 Antenna gain: antenna dipole, horn antenna, log periodic
   11.5.3 Other properties (pattern, beam width, …): antenna dipole, horn antenna, log periodic

For each service, the instruments or artefacts are indicated in italic characters.
11.6 Signal and pulse characteristics (phase noise see 11.4.4)
   11.6.1 Pulse amplitude: oscilloscope, pulse and function generator
   11.6.2 Pulse time parameters: oscilloscope, pulse and function generator
   11.6.3 Modulation, AM and FM: signal generator, spectrum analyser, modulation meter, jitter meter
   11.6.4 Distortion and harmonic content: signal generator, spectrum analyser, distortion meter

11.7 Radio frequency voltage and current (for frequencies lower than 1 MHz see 5 and 6)
   11.7.1 RF/DC difference: thermal voltage converter, AC/DC current standard
   11.7.2 RF voltage sources: RF generator
   11.7.3 RF voltage meters: RF voltmeter
   11.7.4 RF current: RF current generator
   11.7.5 RF transfer impedance: RF current clamp, ESD target
   11.7.6 RF voltage division factor: burst adaptor, oscilloscope probes
   11.7.7 RF coupling factor: coupling-decoupling network (CDN), EM current clamp, absorbing clamp
   11.7.8 Flatness of RF voltage sources: RF voltage sources
   11.7.9 Flatness of RF voltage meters: RF voltage meters

11.8 Lumped impedance/admittance (using RF techniques)
   11.8.1 Resistance or conductance (R, G)
   11.8.2 Inductance (L)
   11.8.3 Capacitance (C)
   11.8.4 Quality factor (Q): Q-standard, Q-meter

11.9 Characteristic impedance
   11.9.1 Mechanical dimensions: coaxial airline, waveguide
   11.9.2 Electrical parameters: coaxial airline

BRANCH: MATERIALS

12. Measurements on materials
   12.1 Electrical conductivity
      12.1.1 Metallic materials: metallic bar, sheet, reference material
      12.1.2 Liquids (see also subject field “Amount of Substance”): liquid, reference material, electrolytic cell
      12.1.3 Semiconducting and similar materials: reference wafers
   12.2 Dielectric properties
      12.2.1 Relative permittivity: real and/or imaginary part: solid materials, liquid materials
      12.2.2 Dielectric loss tangent: tan δ solid materials, liquid materials
   12.3 Soft magnetic sheet and powder materials
      12.3.1 Specific total power loss: Epstein, ring and single sheet sample
      12.3.2 Peak value of DC magnetic polarisation: Epstein, ring and single sheet sample
      12.3.3 Peak value of AC magnetic polarisation: Epstein, ring and single sheet sample
      12.3.4 Peak value of magnetic field strength: Epstein, ring and single sheet sample
      12.3.5 RMS value of magnetic field strength: Epstein, ring and single sheet sample
      12.3.6 Specific apparent power: Epstein, ring and single sheet sample
      12.3.7 Relative peak permeability: Epstein, ring and single sheet sample
      12.3.8 Complex relative permeability
      12.3.9 Density: Epstein, ring and single sheet sample
      12.3.10 Resistivity: Epstein, ring and single sheet sample
   12.4 Soft magnetic bulk material
      12.4.1 Magnetic polarisation: rod, cylinder
      12.4.2 Magnetic field strength: rod, cylinder
      12.4.3 Remanent magnetic flux density: rod, cylinder
      12.4.4 Coercive magnetic field strength: rod, cylinder
      12.4.5 Magnetic saturation polarisation: rod, cylinder
      12.4.6 Relative permeability: rod, cylinder

For each service, the instruments or artefacts are indicated in italic characters.
12.5 Feebly magnetic, paramagnetic and diamagnetic material
   12.5.1 DC magnetic susceptibility or relative magnetic permeability: rod, cylinder

12.6 Hard magnetic material
   12.6.1 Remanent magnetic flux density: cylinder, rectangular parallelepiped
   12.6.2 Coercive field strength ($H_{CB}$, $H_{CJ}$): cylinder, rectangular parallelepiped
   12.6.3 Maximum energy product ($B_\text{H}_{\text{max}}$): cylinder, rectangular parallelepiped
   12.6.4 Magnetic moment: cylinder, rectangular parallelepiped
   12.6.5 Magnetic flux density: cylinder, rectangular parallelepiped
   12.6.6 Magnetic polarisation: cylinder, rectangular parallelepiped
   12.6.7 Relative recoil permeability

12.7 Magnetic data storage media
   12.7.1 Signal amplitude of magnetic stripes: magnetic stripes
   12.7.2 Surface profile of magnetic stripes: magnetic stripes
   12.7.3 Reference field of diskettes: diskettes
   12.7.4 Signal amplitude of diskettes: diskettes
   12.7.5 Resolution of diskettes: diskettes
   12.7.6 Peak shift of diskettes: diskettes
   12.7.7 Overwrite of diskettes: diskettes
   12.7.8 Video and audio tapes

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