Use of Engineering Standards

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Definitions:

Standards are technical definitions, specifications, or guidelines which have been developed, validated, and accepted by organizations, companies, or jurisdictions. They describe recommended practice for solving classes of problems that may be frequently encountered. Their intention is to provide uniformity, compatibility, interchangeability, and interoperability among components, systems, and users. They may also represent minimum requirements for expected safety and performance criteria.

Codes are standards which can be adopted by governing bodies and made enforceable by law. Codes are written in a specific legal language and format so that their articles can be directly cited by other codes of law.

Standards and codes will say by title which they are.

Examples of standards include:

1. NFPA 58, Standard for the Storage and Handling of Liquefied Petroleum Gases
2. NFPA 70E, Standard for Electrical Safety in the Workplace
3. IEEE 802.11, Standard for Information Technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications

Examples of codes include:

1. NFPA 30, Flammable and Combustible Liquids Code
2. NFPA 54, National Fuel Gas Code
3. NFPA 70, National Electric Code
4. NFPA 101, Life Safety Code
5. IEEE National Electrical Safety Code (NESC)

Local adoption of engineering codes will be listed in the legal codes of the applicable jurisdiction. For example, Chapter 296-46-090 of the Washington Activities Code (WAC) formally adopts the NFPA 70 National Electric Code. The remainder of WAC 296-46 gives additional requirements, definitions, and exceptions to be used along with NFPA 70.

Use and Type:

The use of standards can accelerate the design process, eliminating the need to successively reinvent solutions to commonly encountered problems, *when* the requirements and circumstances align to those known solutions. Specifying a standard component is usually more cost effective and provides longer product serviceability than designing a custom component.

Various organizations and associations have created standards specifically for component interchangeability and system interfacing. These include the National Electrical Manufacturers Association (NEMA), the USB Implementer's Forum (USB-IF), the Secure Data Card Association (SDA), the Advanced Television Systems Committee (ATSC), the Digital Audio-Visual Council (DAVIC), the Moving Picture Experts Group (MPEG), and the International Telecommunication Union (ITU) and its three sectors, Standardization (ITU-T), Radiocommunication (ITU-R), and Development (ITU-D). There are many others as well.

Engineering standards also serve as design references for situations where engineering calculations are not practical. The sizing of conductors is one common example. Ampacity calculations to determine the required conductor cross section to not exceed a certain temperature limit depends critically upon the cooling parameters of the environment the conductors are placed within, and these cooling parameters are notoriously difficult to estimate. Engineering standards allow the conductors to be sized from tables when the installation environment matches to known prior circumstances for which safe operating limits have been established. Such tables are specified in the National Electric Code for residential, industrial, and commercial buildings. Similar tables exist for other environments such as automotive, aerospace, and marine.

Some standards have been developed to specify minimum safety and performance criteria for specific systems. Most of the common FDA regulated medical devices fall into this category. For example, a device marketed and sold as an electronic blood pressure cuff must meet specific performance criteria in order to be FDA approved as an electronic blood pressure cuff. These device specific requirements are developed jointly by the American National Standards Institute (ANSI) and the Association for the Advancement of Medical Instrumentation (AAMI). Other device- and system-specific standards which specify minimum performance and safety criteria are found in various disciplines, such as automotive, aerospace, and electric energy.

Engineering standards may be difficult to locate and interpret. In the majority of cases, specific standards must be purchased from the managing organization. Obtaining the full specification of the standard may require membership in the organization, the SD-card Association and the USB Implementers Forum, being two such examples. Only a limited few engineering standards are available online, and often these are out of date or incomplete versions. Handbooks are often available which explain the articles in the form of examples to illustrate their use and limitations. In many cases, the handbooks are more informative than the actual standards or codes.

ABET Criteria

To satisfy the ABET interpretation of a major design experience, a capstone design final project report must document how engineering standards have been considered in the design process. What is most important is that the engineering standard drives the design, affecting the design choices which are made, and impacting the final solution. It is not required that a final project solution adopts a given standard; only that the standard has been considered. For example, it may be deemed appropriate to comply with only certain articles of a standard. But still the overall standard has been considered in choosing which articles to have the design comply with. In some cases, complying with an engineering standard may be rejected entirely in favor of a unique design which purposefully prevents interchangeability or interoperability. The unique connectors found on Apple Computer products are one such example. Still, the standard has been considered.

Simply using a standard component or process does not satisfy this criteria. The use of standard components, such as standard resistor or capacitor values, or standard programming languages, such as C/C++, are not considered incorporating engineering standards into the design process because their use is only for convenience; those choices are not driving the more important design decisions. For example, simply calling out that a USB 2.0 interface was used does not meet the criteria, whereas specifically designing hardware to support a 480 Mbps data rate for the high speed (HS) USB 2.0 standard would, because various details within the design process would need to have considered those aspects of the standard.

Example Standards Useful for ECE Projects

Safety standards should always appear in any design project whose use or implementation may affect the general public. For ECE projects, electrical safety is a primary focus and concerns the prevention of electric shock, fire, or other physical damage resulting from the operation or installation of electrical equipment. Listed below are a few common standards which cover most of this.

1. NFPA 70, National Electric Code (NEC). This code gives the requirements and recommended practice for the installation of electrical equipment in residential, industrial, and commercial buildings. The NEC also happens to cover motor homes and house boats, both of which may serve as residences.

2. IEEE National Electric Safety Code (NESC). This code gives the requirements and recommended practice for the installation of above-ground or underground wire transmission systems for power or communications. This is the bible for electrical linemen.

3. IEC 61508 Functional Safety Standard. This sets requirements for electrical, electronic, and programmable electronic (E/E/PE) safety systems to meet specific safety integrity levels (SIL).

4. IEC 61140 Protection Against Electric Shock. This standard is normally paired with other primary standards rather than being used on its own. It specifies Class 0, I, II, and III appliances, their required markings, and the insulation requirements for each. It also specifies protective measures and coordination of these measures within an installation.

5. IEC 60529 Protection by Enclosures. Same comments as above.

6. IEC 60664 Insulation Coordination for Equipment within Low Voltage Systems. Same comments as above.

7. IEC 60335 Household Appliances.

8. IEC 60950 Safety of Information Technology Equipment.

9. IEC 60598 Luminaries. This refers to electrical lighting, not inspirational professors.

10. IEC 60601 Medical Electrical Equipment.

Performance standards establish minimum requirements for a particular type of device or system to be legally marketed and sold as such. Most FDA regulated medical devices fall into this category. There are currently about 70 specific medical devices which are covered by this type of performance standard. Any device purporting to offer this named function must deliver that function to meet these specifications in order to be approved for marketing and sales by the FDA. Two examples are below.

1. ANSI/AAMI EC38:1998. Ambulatory electrocardiographs.

2. ANSI/AAMI EC13:2002/(R)2007. Cardiac monitors, heart rate meters, and alarms.

There are numerous health and fitness wearable devices being developed today. But before a device can be marketed and sold as an electrocardiograph (ECG), it must comply with the engineering requirements of the above standard in order to be approved by the FDA. Even if the intention of the device is only for entertainment purposes (as opposed to clinical use), it cannot advertise the function "ECG" without compliance to the above engineering standard and have formal approval by the FDA, usually in the form of a 510(k) certification. The standard includes safety aspects, requirements on signal quality, and on the display of the final waveforms.

<u>Communication and interface standards</u> are commonly used within embedded computing, instrumentation, mixed signal, and networking systems. These may be wired or wireless. Wireless communication systems are additionally subject to FCC frequency and power limitations.

One of the most commonly encountered interface standards is the ANSI/TIA/EIA RS-232-F-1997 Standard Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange (Recommended Standard RS-232-F). The standard specifies bipolar logic levels of greater than ± 3 Volts for mark/space which usually requires a specific line driver IC for its implementation. Very commonly this requirement is skipped in favor of simple 0.0 V/ +3.3 V or 0.0 V/ +5.0 V CMOS or TTL logic levels if the higher noise margins of the bipolar levels are not deemed necessary. The baud rates and byte packet structure are usually maintained. Here is a good example of where only part of a standard might be used, and this choice could easily be discussed in a final project report. Other parts of the standard which could be discussed (and chosen to be compliant with or not) are the source and load impedance restrictions, the slew rate limit of 30 V/μs, unit interval and transition time restrictions, grounding and shielding requirements, as well as the mechanical pin-out standards for the connectors.

Numerous other standards exist for various digital interfaces, including: SPI, I2C, I3C, I2S, IEEE 1394 (Firewire), USB 2.0, USB 3.0, USB OTG, DVI, VGA, HDMI, IDE, EIDE, ATA, SATA, eSATA, SCSI, MIPI-CSI and MIPI-DSI, DDR3, DDR4, and many more. Any of these would be appropriate for demonstrating the use of standards in the final project report, *provided* that the consideration of these standards was driving the final design decisions. Just simply employing one of these named interfaces is not sufficient by itself.

<u>Interference standards</u> are common for commercial and industrial hardware and cover both emission and susceptibility (immunity) aspects of electromagnetic compatibility (EMC). The medium for the transmission of interference can be through power lines, communication cabling, or through the airwaves.

The most thorough set of these are the ANSI/AAMI/IEC 60601-1-2:2015 Medical electrical equipment – part 1-2: General requirements for basic safety and essential performance – Collateral standard: Electromagnetic compatibility – requirements and tests. The particular test methods are described in IEC 61000-4. The standard covers limitations on emissions of RF electromagnetic waves, low frequency magnetic fields, and conducted emissions into the public power mains network. The standard also covers susceptibility to electrostatic discharge (ESD), radiated RF electromagnetic fields, electrical fast transients and bursts, voltage dips, interruptions, and variations on power supply inputs, magnetic fields, conducted disturbances, harmonics, ripple, unbalance, and variations of power frequency. Although the IEC 60601-1-2 standard was developed specifically for medical electrical equipment, it is gaining popularity and is becoming a de-facto standard for many classes of consumer products. Products to be sold in the EU and which require a "CE" mark must comply with the IEC 60601-1-2 standard.

The IEC 60101-1-2:2015 limits on conducted and radiated emissions for Class A and Class B equipment are the same as the Federal Communications Commission (FCC) Part 15 and the International Special Committee on Radio Interference (CISPR) 22 limits. Over the past two decades, most engineering standards have been internationally harmonized, so that the differences across North America, Europe, and Asia are becoming much fewer.

The IEC 60101-1-2:2015 and 61000-4-2:2008 limits on electrostatic discharge (ESD) immunity are now the more commonly adopted specifications, superseding the older MIL-STD-883, MIL-STD-461G, and ANSI C63.16 which described the human body model (HBM), machine model (MM), and capacitive discharge model (CDM) for specifying ESD tolerance.

Software development standards are documentation processes whose use improves the modularity and maintainability of software systems. Their use is generally required for good manufacturing practice (GMP) and ISO-9000 certification and provides interoperability between different programs developed by different developers on different systems. These standards govern the development process, not the final software code itself.

The most commonly used standard in this regard is ISO/IEC/IEEE 12207:2017 ISO/IEC/IEEE International standard – Systems and software engineering – Software life cycle processes. Another closely related and parallel standard is ISO/IEC/IEEE 15288:2015 ISO/IEC/IEEE International standard – Systems and software engineering – System life cycle processes.