How IEC 60730 Impacts Appliance Design and MCU Selection

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With white goods and industrial appliance safety now regulated by the IEC, choosing the right microcontroller is more important than ever to market success.

Motor drives, white goods, and other appliances that could be unsafe to operate if one or more of their mechanical or electronic components fail are now subject to the testing and qualification requirements of the International Electrotechnical Commission (IEC).

The IEC 60730 standard covers mechanical, electrical, electronic, EMC, and abnormal operation of ac appliances. Although certification is attained at a system level, understanding the correct criteria for choosing a microcontroller (MCU) will have a direct impact on achieving IEC 60730 compliance and the equally important goal of fast time-to-market.

While IEC standards and certification criteria are primarily used in Europe, companies wishing to market products worldwide typically opt to comply with IEC criteria rather than to have separate designs and manufacturing plans for every geographic region of the world. Small, inexpensive, and safety-conscious controllers are destined to play a critical role in IEC 60730 qualification because of their ability to sense a malfunction and switch the appliance off -- under virtually any circumstances.

The aspects most specifically relevant for MCUs are spelled out in IEC 60730 Annex H: Briefly, these new tests and diagnostics specify the safe operation of embedded control hardware and software for appliances.

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1.1 Safety Classification

To create a foundation for control operations, Annex H. defines three classifications for automatic electronic controls that effect both hardware and software:

1. Class A functions such as room thermostats, humidity controls, lighting controls, timers and switches. These are distinguished by not being relied upon for the safety of the equipment.
2. Class B functions such as thermal cut-offs are intended to prevent unsafe operation of appliances such as washing machines, dishwashers, dryers, refrigerators, freezers and cookers/stoves.
3. Class C functions are intended to prevent special hazards such as explosions. These include automatic burner controls and thermal cut-outs for closed, unvented water heaters.

Table 1-1 shows the 15 specific criteria for IEC 60730 compliance along with the applicability of hardware and/or software to attaining compliance. (Five criteria -- 8, 9, 12, 14, and 15 -- may not apply to all microcontroller designs.)

Table 1-1. Requirements for IEC 60730 Compliance

	Item	Test Item	What to Test	How Current C2000 Supports system-level Compliance
1.	1.1	CPU Registers	Stuck at fault	Software
2.	1.3	PC	Stuck at fault	Software
3.	2.0	Interrupt handling and execution	Timing	Hardware and software
4.	3.0	Clock frequency	Accuracy	Software, external WD, etc.
5.	4.1	Memory Testing (Flash)	Stuck at	Software (check sum)
6.	4.2	Memory Testing (RAM)	Stuck at	Software (march)
7.	4.3	Memory addressing	Stuck at	Software
8.(1)	5.0	Memory (external)	Stuck at	N/A
9.(1)	5.2	Memory Addressing (ext.)	Stuck at	N/A
10.	6.0	Communication	Corruption	Software - CRC
11.	6.3	Timing of communication	Proper timing/interval	Software
12.(1)	7.0	Input/output periphery	Production hardware tests	System tests
13.	7.2.1	A/D tests	Preproduction fault	Software
14.(1)	7.2.2	Analog multiplexer	Production fault	N/A
15.(1)	9.0	Custom chip	ASIC, GAL, FPGA	N/A

(1) This criteria may not apply to all microcontroller designs.

Certain tests are not relevant to MCUs because the function is implemented by another chip external to the MCU -- usually memory of a custom chip. From a design perspective, IEC 60730 allows manufacturers to take one of three approaches to address these issues.

- A dual-channel architecture that utilizes two MCUs, each performing related tasks in lock step and one checking the other but in a highly cost-sensitive market such as white goods, it would be expensive.
- A single-channel architecture accompanied by functional testing at the point of manufacture is the option used most frequently today. While it is a way to clear certification testing, it has the drawback of not being able to address problems once the appliance is in the field.
- A single-channel with periodic self-test architecture addresses the problem of in-service operation by having firmware that regularly checks critical functions of the electronic control.

Microcontrollers (MCUs) that support the single-channel self-test option provide the highest level of consumer protection at the lowest cost.

1.2 Software Considerations

Because firmware plays a critical role in self-test and the IEC 60730 does not specify how the tests are made -- only that they be executed successfully -- the software test libraries that accompany an MCU play a key role in making a MCU choice.

Assessing the value of libraries goes beyond simply knowing that they will do their part in helping the system level product pass conformance tests. Individual test routines are relatively straight forward, so the main challenge is to integrate these routines without impacting actual system operation. This requires extensive system knowledge and direct customer involvement.

In price-sensitive applications such as white goods, a small memory footprint translates directly into a low electronic bill-of-materials (eBOM). Even though the semiconductor vendor may write the test routines, the system designer is responsible for integrating them into the system. Usually, this means writing code in assembly language, but a very efficient C complier can help a design achieve two goals that are normally in conflict: Writing code in C and producing very dense code.

1.3 Hardware Functionality

Additional hardware functionality built into an MCU can also provide not just a road to compliance but a reduction in the number of components as well. The most obvious is to have enough on-chip memory to avoid tests involving external memory. Another good example is any instance of time-related testing.

The expensive way to do this is with dual MCUs but this architecture has the disadvantage of being expensive. A typical workaround is to use a single MCU in conjunction with a watchdog timer external to the MCU.

An even better solution is to integrate two very accurate oscillators on the MCU -- one to operate the appliance and the other to supply an independent time base when periodic tests are executed.

The goal of IEC 60730 is to assure safe operation by shutting the system down if a fault is detected. When this occurs and the MCU initiates a system shut down, then the limp mode allows the shut down to proceed gracefully without damaging other components or, in some instances, configuration information.

On-chip supervisory circuits such as brown-out reset and power-on reset are two additional features that preserve the MCU and the surrounding system. By constantly monitoring supply voltage, and shutting down if it exceeds specified values, the MCU protects not only itself from damage. Perhaps more important, in the case of motor control applications, fast PWM shut down will also preserve the expensive IGBTs or MOSFETs in the power converter.

1.4 Piccolo Plays the Perfect Tune

Many designs teams have been addressing IEC 60730 requirements with the single channel architecture mentioned early aided by off-chip peripheral devices. From a software perspective, significant engineering time investments have been made in code development. And it is well known that code compatibility is an important consideration in evaluating the costs and benefits of migrating to a new architecture.

Texas Instruments' most appropriate controllers for white goods, motor control and similar applications have traditionally been members of TI's TMS320C2000™ MCU family. Designers have adopted these devices to achieve the benefits of a high performance 32-bit architecture that combines the advantages look and feel of a MCU along with the computational power necessary for high-energy efficiency motor control.

TI's newest series of C2000™ MCUs named Piccolo™ bring this 32-bit real-time control at lower price points and smaller package sizes than ever before, helping deliver advanced processing to applications typically unable to justify the associated cost. The Piccolo or TMS320F2803x/F2802x microcontrollers can replace multiple electronic components to lower overall system cost while enabling advanced power electronics management in white goods applications including: air conditioners, washing machines, induction cooking, fridge compressors and more. For more information on Piccolo microcontrollers, please see: www.ti.com/piccolo.

To view a C2000 microcontroller-based refrigerator system block diagram, see: http://focus.ti.com/docs/solution/folders/print/403.html.

For a block diagram of a typical C2000-controller based washing machine system, see: http://focus.ti.com/docs/solution/folders/print/397.html.

For example, in a variable frequency air conditioning unit, a single F2803x/F2802x MCU can precisely control two electric three-phase motors as well as perform power factor correction (PFC) calculations. Currently required in approximately 30 percent of the world's markets - including Europe, China, Japan and India -- PFC improves the efficiency of the load to make the best use of power from the utility.

Piccolo devices also add hardware enhancements specifically targeted at making IEC 60730 system-level compliance easier and more cost effective. The simple power architecture eliminates the need for external power ICs and uses a single 3.3-V supply with an internal regulator down to 1.9V as well as brown-out protection and power-on reset.

Piccolo devices operate and integrate:

- Best-in-class PWM and event capture capability
- 150-ps resolution on PWM frequency and duty cycle
- High-accuracy on-chip oscillators (3% over the temperature range)
- 12-bit ratio-metric ADC with individual channel triggers
- Up to three analog comparators with 10-bit reference
- Single 3.3-V supply with BOR/POR supervision
- Robust serial communication interfaces
- Up to 22 general purpose I/Os

A programmable control law accelerator (CLA) is designed to offload control algorithms from the main CPU. The CLA can run complex, high-speed control algorithms and free the main CPU to handle I/O and feedback loop metrics, resulting in a 5x performance increase for common closed-loop applications when compared to standard architecture core based devices.

Two on-chip oscillators are integrated on chip to address the time-base requirements of IEC 60730. Other hardware features mentioned above -- write-protected registers, limp mode and supervisory circuits -- have all been integrated as well. These features, tailored to the test requirements of IEC 60730, make compliance in the electronic segment of the tests easier and the results more predictable.

Hardware enhancements are matched on the software side with a new version of the firmware library that is still compatible with C2000 code but even more code efficient. Assembly language is available, but the library is also C-callable and a very efficient complier turns the C code written by design teams into dense assembly code.

Software libraries of pre-written digital power and motor specific algorithms available free at www.ti.com/c2000appsw. TI offers application-specific notes for the development and implementation of embedded control designs that cover most motor types as well as a variety of digital power applications, available at www.ti.com/mcappnotes. TI also offers the Code Composer Studio™ integrated development environment that can be enhanced with TI and third party plug-ins. Code Composer Studio supports all C2000 controllers and features powerful compilers for the most optimized control code.

From a product roadmap perspective, the Piccolo series of microcontrollers is constructed to provide white goods designers with platform strategy that addresses multiple market segments. Package size on Piccolo devices will range from 38 to 80 pins, for example, and on-chip memory from 32 to 128K bytes.

The introduction of IEC 60730 into white goods and other appliances will add a new level of safety for consumers operating their ever-more-sophisticated appliances. By taking advantage of TI's Piccolo series of MCUs, design teams will be able to comply with the regulations while at the same time maintaining or reducing electronic system cost, creating a strong system-level development platform and providing superior performance and energy efficiency.

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