WHITE PAPER

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TEXAS INSTRUMENTS

IEC 60730 and UL 1998 Safety Standard Compliance Made Easier with TI Hercules™ MCUs

Introduction

Many white goods and appliances could be unsafe to operate if one or more of their mechanical or electronic components fail. This is why these applications are now subject to the testing and qualification requirements of the International Electrotechnical Commission (IEC).

Specifically, 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.

Since 2007, home appliances with programmable microelectronics for sale in many European markets are often required by customers and/or regulators to comply with the IEC 60730 "Automatic electrical controls for household and similar use" safety standard. Similar practices are followed in the United States leveraging UL 1998 "Safety Software in Programmable Components."

Home appliances are classified into different categories based on their hazard and risk levels.

IEC 60730 classification:

- Class A: Control functions not intended to be relied upon for the safety of the equipment
- Class B: Control functions intended to prevent unsafe operation of the controlled equipment (e.g., thermal cut-outs and door locks for laundry equipment)
- Class C: Control functions intended to prevent special hazards, such as explosion of the controlled equipment

UL 1998 classification:

- Class 1: Sections of software intended to control function to reduce the likelihood of a risk associated with the equipment. Examples of sections that may be considered Software Class 1 functions are: thermal cut-offs and door locks for laundry equipment.
- Class 2: Sections of software intended to control function to reduce the likelihood of special risks (e.g. explosion) associated with the equipment. Examples of sections that may be considered Software Class 2 functions are: automatic burner controls and thermal cut-off for closed water heater systems (unvented).

The aspects most relevant to microcontrollers (MCUs) are IEC 60730 Annex H and UL 1998 Annex A.2, which detail the diagnostic test requirements to support safe function of home appliances.

IEC 60730 Class B/C and UL 1998 Class 1/2 share similar classification definition and diagnostic test requirements. These requirements are derived from the IEC 61508 standard, "Functional safety of electrical/electronic/programmable electronic (E/E/PE) systems."

To facilitate safe operation of home appliances with programmable components such as MCUs, the safety standards recommend periodic testing of the CPU, clock, volatile and non-volatile memory, internal data path, I/O and external communication interfaces.

Table 1:

Specified requirements of hardware failure detection by IEC 60730/UL 1998 classification.

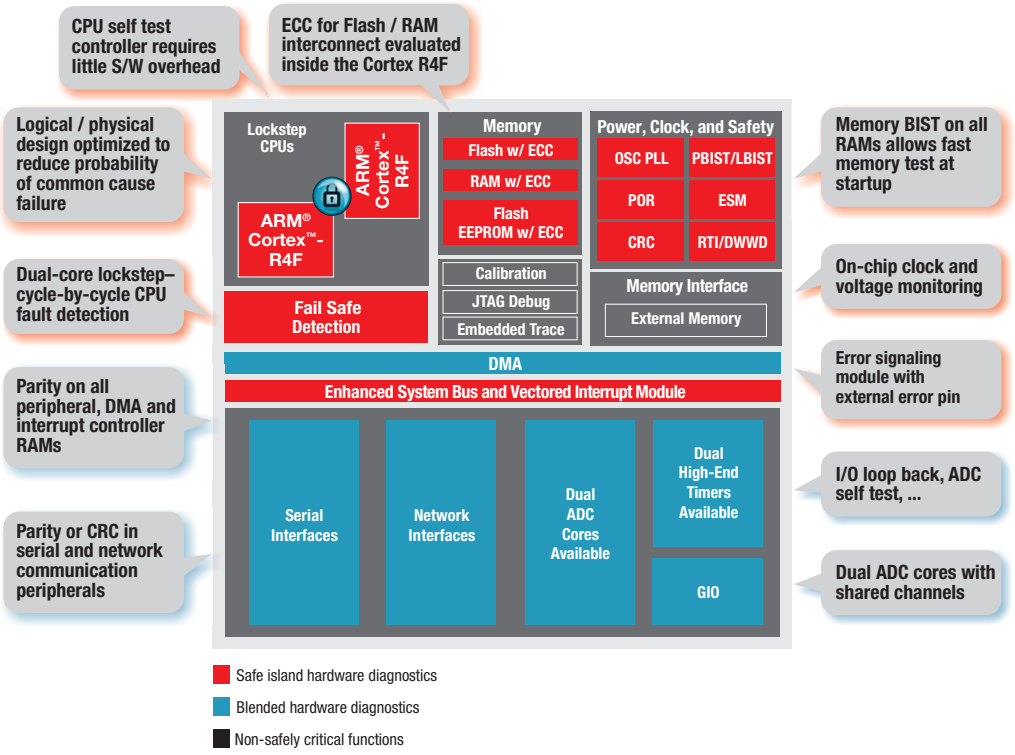
Component	Fault/Error	Class	
		IEC60730-B UL1998-1	IEC60730-C UL1998-2
1. CPU			
1.1 Registers	Stuck-at	X	
	DC fault		X
1.2 Instruction decoding and execution	Wrong decoding and execution		X
1.3 Program counter	Stuck-at	X	
	DC fault		X
1.4 Addressing	DC fault		X
1.5 Data paths	DC fault		X
2. Interrupt handling and execution	No interrupt or too frequent interrupt	X	
	No interrupt or too frequent interrupt and interrupt related to different sources		X
3. Clock	Wrong frequency	X	X
4. Memory			
4.1 Non-volatile memory	All single-bit faults	X	
	All single and double bit errors		X
4.2 Volatile memory	DC fault	X	
	DC fault and dynamic cross links		X
4.3 Addressing	Stuck-at	X	
	DC fault		X
5. Internal data path			
5.1 Data	Stuck-at	X	
	DC fault		X
5.2 Addressing	Wrong address	X	
	Wrong and multiple addressing		X
6. External communication			
6.1 Data	All single-bit faults	X	
	All single and double bit errors		X
6.2 Addressing	Wrong address	X	
	Wrong and multiple addressing		X
6.3 Timing	Wrong point in sequence	X	X
	Wrong sequence	X	X
7. Input/Output periphery			
7.1 Digital I/O		X	X
7.2 Analog I/O			
7.2.1 AD and DA converter		X	X
7.2.2 Analog multiplexer		X	X

In order to satisfy these diagnostic test requirements, a software self-test technique is generally recommended by the majority of the MCU suppliers. A self-test library is provided for CPU and memory (Flash/SRAM) test during MCU startup and or during application run.

The diagnostic coverage of the software based self-test is in general low and hard to quantify. In addition, the diagnostic software consumes valuable memory space and application run time. It runs the risk of interfering with the application program if not implemented correctly. Texas Instruments (TI) Hercules MCU platform was developed to help meet the requirements of IEC 61508 insofar as those requirements apply to components. This helps in systems that need to be IEC 60730 and UL 1998 compliant.

Hercules MCUs offer dual-core CPU lockstep and memory Error Code Correction (ECC) real time diagnostics, with hardware based CPU Logic Built In Self Test (LBIST) and SRAM Programmable Built In Self Test (PBIST).

Hercules Cortex-R4F MCU safety features



These hardware based safety features help diagnose errors in mission critical blocks and offer high diagnostic coverage with minimum software overhead.

- The dual ARM® Cortex™ -R4 lockstep architecture provides cycle-to-cycle high diagnostic coverage.
- The Error Correction Code (ECC) circuit, implemented inside the lockstep Cortex-R4 CPUs, provides bus interconnect and SRAM/Flash single bit error correction and double bit error detection (SECDED) with little to no performance impact.
- The CPU LBIST and SRAM PBIST offer high coverage fault detection.

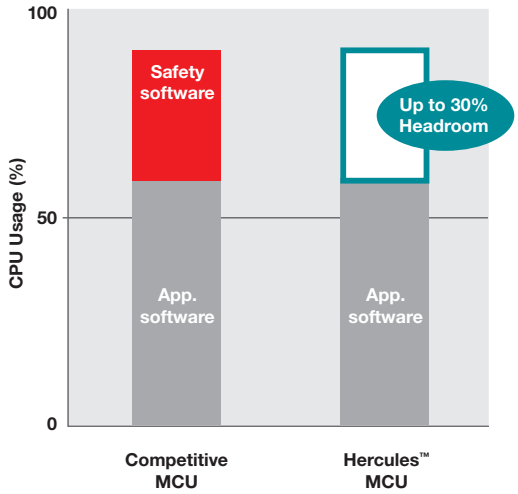
Table 2:

Mapping of TI Hercules MCU features vs the IEC 60730 and UL 1998 hardware diagnostic requirements.

Component/Functions	Examples of acceptable measures with Hercules MCUs	Hardware or software
1. CPU (registers, instructions, decoding and execution, program counter, addressing, data paths)	Lock-step CPU with HW compare Internal and external watchdog CPU LBIST	HW HW HW
2. Interrupt handling and execution	VIM SRAM data parity Internal and external watchdog VIM SRAM PBIST	HW HW HW
3. Clock	LPO clock detect Dual clock compare PLL slip detector	HW HW HW
4. Memory	ECC with address for SRAM/Flash CRC PBIST for SRAM	HW HW/SW HW
5. Internal data paths	Memory with ECC Lock-step CPU with HW compare	HW HW
6. External communication	Information redundancy technique Periodic CRC check of memory Memory with parity	SW HW/SW HW
7. Input/Output	Digital I/O loop-back, ADC converter calibration ADC self-test Information redundancy technique	 HW/SW SW

With the majority of the self tests implemented as hardware in Hercules MCUs, this significantly reduces the safety software development time and the overhead, both in code size and run time.

Safety in hardware maximizes performance and speeds development



- **Significantly reduce safety software overhead with integrated safety features**
- **Improve time to market**
  - Spend less time developing complex safety software
  - Spend less time providing your CPU safety solution to auditors, leaving more time to differentiate
- **Safety manual**
  - Provide substantial help in developing a complete safety system solution

With its unique hardware based diagnostic test features, the Hercules MCU offers:

- Ease of system software development and certification
- High diagnostic coverage with minimum software overhead
- Enhanced system availability with memory ECC

Hercules MCU platform is designed to help support home appliance electronic control designs that require either IEC 60730 Class B/C or UL 1998 Class 1/2 functional safety standard compliance. Its hardware based diagnostic features are designed to meet IEC 61508 requirements and to facilitate IEC 60730 and UL 1998 compliance. The use of Hercules MCUs will allow developers to focus on the application development leaving valuable MCU resources available for the application rather than consuming them with software based diagnostic tests. Use of a Hercules MCU can result in reduced development cycle time and increased availability of MCU resources with high and predictable diagnostic coverage.

For more information

If you'd like to get started developing your latest white good application with a Hercules MCU, try our low-cost Hercules LaunchPad. It's a way to quickly and easily get started.
Visit **http://www.ti.com/ww/en/launchpad/hercules.html** for more information.

If you'd like more information on developing white goods for functional safety, visit TI's SafeTI™ Design Packages website. You can search by safety standard, application or device: www.ti.com/safeti. In fact, there are quite a few TI devices that offer software packages for IEC 60730, including C2000™ MCUs and MSP430™ MCUs: **http://www.ti.com/ww/en/functional_safety/safeti/SafeTI-60730.html.**

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