

Is Your Type Approved Computer Really Seaworthy?

Introduction

As more critical shipboard functions such as navigation are being computerized, performance, reliability and integrity of these systems are crucial in maintaining continual operation. IEC 60945 was developed to assist in meeting the Safety Of Life At Sea (SOLAS) convention adopted by the International Maritime Organization (IMO). It defines minimum performance standards and testing requirements for shipboard radio and navigation systems, as well as systems which may be mounted near these systems.

IMO Resolution A.694(17) *Equipment shall be capable of continuous operation under the conditions of various sea states, ships' motion, vibration, humidity and temperature likely to be experienced in ships.*

Classification Societies award Type Approval based on a set of minimum requirements derived from IEC 60945, but are quick to point out that this approval does not necessarily certify fitness of purpose or seaworthiness. In a world where technology sometimes moves faster than regulations, computers can meet the requirements to be Type Approved, but not operate in all conditions they may encounter at sea. It is ultimately up to the buyer to ensure the computer they are installing is fit for its intended use. After all, a frozen navigational display can have much worse consequences than a frozen spreadsheet.

Temperature

IEC 60945 has determined the likely temperature for protected equipment on ships to be between -15°C to +55°C. A computer can pass this test by running briefly during these extremes at any CPU utilization. During this test, there is no requirement that key components remain in their specified limits, only that the unit can perform a functional test defined by the manufacturer. Some manufacturers will even add a note in their operating documentation not to operate their Type Approved computer above 25°C. Others have even managed to get office grade computers Type Approved. The design of a typical office grade computer is optimized for that environment. Running at higher temperatures decreases their reliability and useful life. Figure 1 shows a photograph of leaking and bloating capacitors in a motherboard from a major desktop computer manufacturer. The 2-year-old computer exhibited intermittent behavior for several months before finally failing to boot.



Figure 1 - The consequences of running a computer above its rated temperature

Processor Selection

All processors use power, which can vary greatly with CPU utilization, and is eventually dissipated as heat. In addition, CPUs have maximum operational temperatures, which if exceeded, can result in soft failures, device damage or self protect clock throttling, which can cause the computer to slow down, sometimes causing unpredictable behavior. For marine computing, mobile processor technology offers the optimal mix of performance and power, albeit at a slightly higher cost.

	Desktop Processor	Mobile Processor
Performance	Pentium 4, Core 2 Duo, Core 2 Quad	Pentium Mobile, Core 2 Mobile
Power Consumption	Up to 100 Watts	Up to 35Watts
Maximum Operating Temperature (at chip)	65°C	100°C

Processor Speed and Clock Throttling

Many CPUs have the ability to monitor internal temperature and adjust their clocks to protect against damage. This process occurs transparently to the user with the only indication being the system running slowly. A computer not designed for continuous operation at elevated temperatures can throttle down during use causing at best, slow operation, and worst case, software crashes due to lack of CPU availability.

Fans

In order to remove heat from the processor chip and the enclosure itself, some computers use fans. Computer reliability and integrity are directly related to these devices. With today's complex electronic processors and devices, an un-announced fan failure can result in unpredictable behavior ranging from software crashes to slow CPU performance. There are many factors that affect fan performance. Some common factors include:

- Bearings – Sleeve bearings are half as reliable as ball bearings.
- Temperature – Fan reliability and useful life are reduced by temperature extremes, both hot and cold.
- Humidity – Fan reliability and useful life are reduced by humidity, especially in sea air environments.
- Monitoring – Using unmonitored fans can compromise even redundant systems due to a common cause event such as loss of bridge air conditioning. A redundant system without fault detection is not fault tolerant.

Fanless Computers

Some marine computers eliminate the unreliability of fans by using a so-called “fanless” approach to cooling. This involves moving heat from high power chips, mainly the processor chip, as well as power generated by the rest of the logic, peripherals and power supply, to the ambient surroundings. The most popular techniques involve some kind of heat sink, heat pipes or both.

Heat sinks and physics – Heat is transferred from the computer to the outside world mainly based on thermal resistance and the effective area of the heat sink. Small or no fins transfer less heat than large fins. If the fins are too tight together, heat transfer is reduced unless an external fan is used. Since 50% of the heat generated in a computer can come from and affect the CPU, it is important to ensure this heat is managed.

Heat pipes – Heat pipes are effective in moving heat from a hot spot in the box to a heat sink. Copper is one of the most effective materials to do this. There are also heat pipes based on phase change which are effective but require specific orientation to work properly.

Mass Storage

Mass storage for computers is required for the operating system, application software and data. The most popular forms of mass storage are Hard Disk Drives, which rely on rotating media, and Flash Drives made from solid-state memory. Some systems use a hybrid approach of partitioning critical functions such as operating system and application on Flash, while storing bulk data on Hard Disk.

Hard Disk Drives

Temperature

Many commercial disk drives have a rated temperature of 0°C to 55°C. At low temperature, especially at start-up, the lubrication of the rotating platter that spins between 5000-10000 RPM can break down, significantly shortening the life of the drive or causing intermittent failures on boot-up of computers on a cold day. At high temperature, such as 55°C, which is the maximum required temperature determined by IEC 60945 for equipment used in most marine computer areas, and computers having a 10-20°C rise inside the enclosure, the disk will run significantly over its rated temperature by 15°C or more. Special high temperature drives are a viable alternative to drives designed for office environments, but are generally slower, have less capacity and additional cost.

Vibration

Vibration in marine vessels is caused by natural resonances of the hull excited by the energy of engines and propellers. IEC 60945 specifies vibration requirements for equipment at 0.71G from 13-100Hz. Modern disk drives can spin at 10,000 RPM and have up to 100,000 tracks per inch. Writing to the adjacent track due to a shock or vibration event can cause permanent corruption of data or critical file, which may not be detected until the next re-boot. Drive manufacturers tout their advancements to minimize this problem, but many do not specify their vibration limits, and in addition, a little known fine print note is that some manufacturers maximum vibration specification is only for read operations, not for the more critical write function.

Vibration Isolators All vibration mounts have a natural resonance frequency. At frequencies above this resonance, these mounts attenuate shock and vibration but at their resonance frequency they will actually amplify the vibration. The solution is to have an isolation system with the lowest possible natural frequency. A system with <10Hz is preferred. Unfortunately due to physics, this increases the size of the mounting apparatus so if the computer uses small rubber mounts, the vibration isolators are actually vibration amplifiers.

Flash Drives

Flash drives are an array of solid-state read/writeable, non-volatile memory configured to look to the computer like a hard drive. They are available in IDE, SATA, and Compact Flash interfaces.

Industrial vs. Commercial

Flash drives typically come in two grades, commercial and industrial. When comparing the two, commercial flash has lower temperature ratings, slower speed and less tolerance for the continuous erase cycles required in a computer. For this reason, industrial grade devices are preferred in a marine computer.

Cost Impact

With the price of flash memory continuing to fall, it has become a viable alternative to rotating media, even for data hungry applications such as navigation.

	Consumer Grade Hard Disk Drive	High Temp Hard Disk Drive	Commercial Flash Drive	Industrial Flash Drive
Cost/100MB	\$0.04	\$0.22	\$0.64	\$0.94
Temperature rating	0°C to +50°C	-30°C to +85°C	0°C to +70°C	-30°C to +85°C
Useful Life	3 Years	3 Years	5+ Years	10+ Years

Circuits and Connectors

Humidity is common in most areas of marine operation. This mixes with salt in the air and can find itself on connectors and electronic circuits leading to corrosion, or dendritic growth, the formation of a metallic path between conductors due to the presence of moisture and ionic substance (salts).

Conformal coating

Conformal coating is a substance, which is sprayed on exposed electronic circuits to prevent oxidation due to salty or humid air. It is effective at forming a barrier between conductors and the humidity and salts.

Summary

Although the use of Type Approved Computers, when required, facilitates overall certification, engineers and designers must be diligent in the selection process to ensure the computers they deploy meet the requirements for the intended use throughout the computer's useful life cycle. The rest of this paper describes a fairly easy test to run to see if your computer is really as good thermally as you think.

Is your Computer thermally capable? Check for yourself.

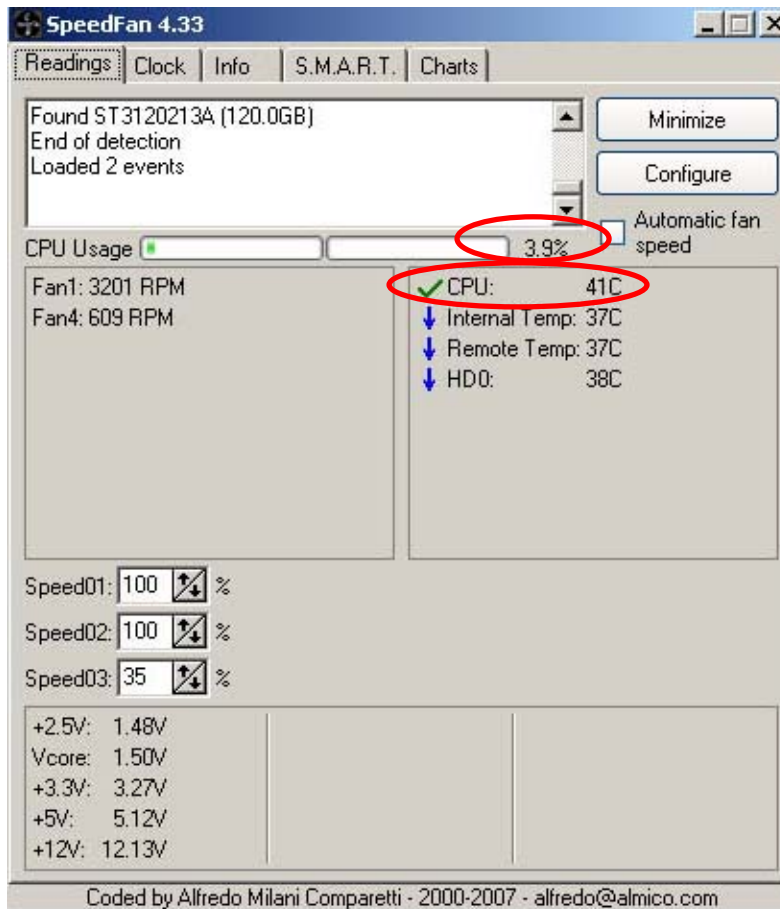
Find your CPU's maximum temperature as specified by the manufacturer

Consult manufacturer's data for the specific chip, but as a rule of thumb, use 65°C for Intel desktop CPUs and 100°C for Intel mobile CPUs.

Measure your CPU Temperature

There are several free monitoring devices, which run under Windows, which will report the CPU temperature. One of the most popular is SpeedFan. It can be downloaded from:

<http://www.almico.com/sfdownload.php>

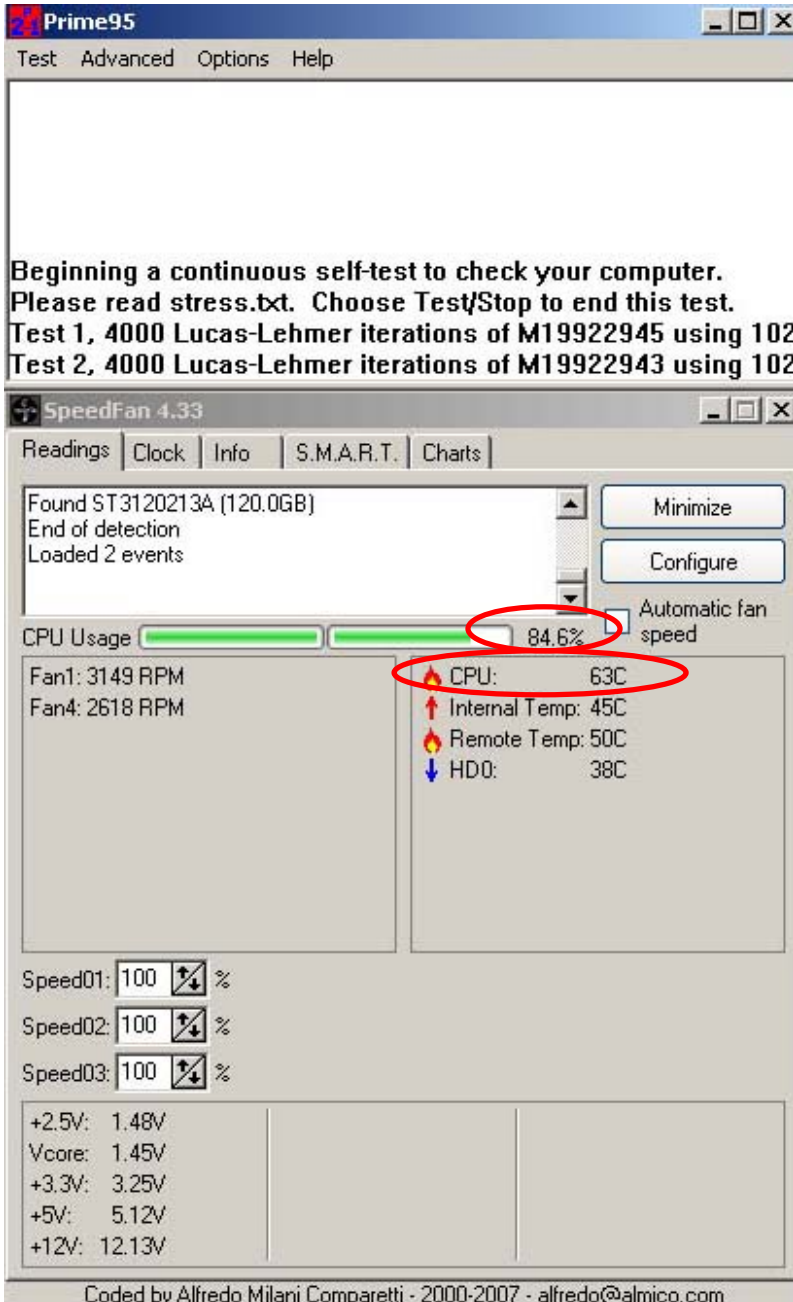


Notice that at Windows Idle, the utilization is 3.9% and the temperature is 41C.

Increase your CPU utilization

Increase CPU utilization by using a program such as Prime95. If using a dual core system, make sure both cores are running. Prime95 can be downloaded from:

http://www.freewarefiles.com/Prime-V_program_19638.html



Notice that while running Prime95, the CPU utilization jumps to 84.6% and the CPU temperature jumps almost instantly an additional 22°C to 63°C!

See for yourself - calculate your true maximum operating temperature

R=Measured CPU temperature rise at max load

L=CPU limit defined by manufacturer

A=Ambient temperature of the computer when the test was run.

Maximum Ambient = $L - R + A$

Example 1 – Desktop Processor

From the system measured before, (an office computer):

R=63°C using Speedfan while running Prime95

L=70°C – Intel’s maximum temperature for the Pentium 4 Chip

A=23°C – Ambient temperature of the office

Maximum Ambient = $70 - 63 + 23 = 30^\circ\text{C}$

Example 2 – Mobile Processor

If this was a mobile processor such as the Pentium M or Core 2 Mobile:

R=63°C using Speedfan while running Prime95

L=100°C - Intel’s maximum temperature for the Core 2 Mobile Chip

A=23°C – Ambient temperature of the office

Maximum Ambient = $100 - 63 + 23 = 60^\circ\text{C}$

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