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Performance evaluation of a cheap, open source, digital environmental monitor based on the Raspberry Pi

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We report on the design, construction and evaluation of a low-cost digital environmental monitoring system based on a popular micro-computer board and mass market digital sensors. The system is based around the use of open source software and readily available digital sensors, providing key parameters required for environmentally-controlled calibration laboratories: air temperature, pressure and humidity. Each system logs data at set intervals with front-panel display, web page graphical display and email alerting when exceeding set tolerances. The sensors have been calibrated at the National Physical Laboratory using standards traceable to the SI. Long term stability of the system is estimated and in addition to monitoring of laboratory environments for regulatory purposes, the systems can also be used to provide on-demand values for local refractive index with an expanded (k = 2) uncertainty of 1.1× 10^{-7} as required for many optical-based measuring systems.

Keywords: environment, calibration, metrology, air sensor, open source, data logging

1. INTRODUCTION

In many calibration laboratories the environment has to be maintained within specified tolerances in order to guarantee safe, reliable and accurate operation of instruments and equipment within the laboratory. For example, in most high-accuracy dimensional calibration laboratories, it is necessary to stabilize the equipment temperature close to 20 °C [1], in order to minimize uncertainties due to thermal expansion compensation and humidity is often required to be controlled to a maximum level (typically 50 % RH) in order to prevent corrosion of exposed surfaces on test artefacts *e.g.* gauge blocks, step gauges, polygons. There is often a minimum specified humidity level to prevent static build up or discomfort to operators. In laboratories where a clean dust-free environment is required, the laboratory is often maintained at a positive pressure with respect to the surrounding to prevent the ingress of dirt. For accredited calibration laboratories, compliance with the requirements of internationally accepted quality standards such as ISO 17025 [2] requires that the laboratory environment is both measured during calibration processes (to provide calibration corrections) and also recorded to demonstrate compliance.

The National Physical Laboratory (NPL) operates 15 dimensional calibration laboratories which have environmental control specifications of 20 °C ± 0.1 °C air temperature, 45 % RH ± 5 % RH humidity and are maintained at a positive differential pressure of around 20 Pa. Although the building management system has inbuilt temperature and humidity logging, these parameters are logged in the centre of each room and logging is not available when the system is taken offline for maintenance. During system down time it is vital to monitor the temperature of equipment such as coordinate measuring machines because temperature deviations as small as 5 °C can cause hysteretic geometric distortions which will result, after the machine cools to normal operating temperature of 20 °C, in degraded measurement accuracy, outside the maximum permissible error specified by the manufacturer.

Furthermore, in many dimensional calibration laboratories, lasers are used in the measuring process and the effect of the air refractive index on the laser wavelength has to be taken into account. For the most precise

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