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A new and inexpensive open source data acquisition and controller for solar research: Application to a water-flow glazing

Luis J. Claros-Marfil [a, b, *], J. Francisco Padial [b], Benito Lauret [a]

[a] Architectural Construction and Technology Department, E.T.S. Arquitectura, Universidad Politécnica de Madrid, Avda. Juan de Herrera, 4, 28040 Madrid, Spain
[b] Applied Mathematics Department, E.T.S. Arquitectura, Universidad Politécnica de Madrid, Avda. Juan de Herrera, 4, 28040 Madrid, Spain

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ABSTRACT

A water-flow window consists of two glass panes making up a chamber in which a water layer flows in a controlled way. Such windows may be considered as Building-Integrated Solar Thermal (BIST) collectors, and could assist to incorporate renewable energy systems in buildings, improving their energy efficiency, especially when they are properly managed by a control system. Despite the need of an automatic controller for this kind of window and the advantages of microprocessor-based control for solar systems, only differential controllers have been described. A novel controller based on an inexpensive open source microcontroller board has been designed, built, programmed and installed in an experimental prototype water-flow window. The proposed data acquisition and control system, the code sequence steps, a model algorithm, and a comparison between the data collected by the system and a commercial datalogger are presented. The advantages of using an open source board for the proposed control system are analysed and the benefits of using a control system based on a microcontroller are discussed.

1. Introduction

Architectural integration of renewable energy systems is an unresolved concern for building designers which, in the last years, has drawn the attention of researchers due to the Energy Performance Buildings Directive (EPBD) [1]. This matter is not only relevant in new buildings but also in retrofitting historic buildings [2], and could lead to the discouragement of potential new users [3]. The use of Building-Integrated Solar Thermal (BIST) collectors [4–6] placed in certain parts of the building envelope has been suggested in order to overcome this concern [7]. One major issue when addressing the building integration of energy efficient systems is their associated cost. In this way low-cost solutions, as renewable energy systems integration into common façade elements, are largely desired against medium or high-cost alternatives, if equal performance of every option is expected. At the same time, the minimal aesthetic impact, which would be especially desirable for retrofitting purposes, could be achieved when the solar thermal system is fully integrated into a common façade element as a smart window [8].

The water-flow window has been proposed as a particular kind of active Transparent Solar Thermal Collector (TSTC) which consists of two glass panes making up a chamber in which a water layer flows in a controlled way. The water circuit allows a stream of water to flow within the space between the two glass panes, providing a transparent physical insulation layer and a façade-integrated solar thermal collector that absorbs a part of the incident solar radiation [9]. Reductions of 52% in space heat gains [10] and 35% in space cooling loads [11] have been achieved by simulation. Therefore, these novel windows may result as an interesting alternative to classic glazings in order to reduce solar gains, to reach significant heating, ventilation and air conditioning (HVAC) energy savings [12–14], and to take advantage of solar energy for domestic hot water (DHW) pre-heating [11,15]. In order to optimise their performance, water-flow windows, as with any other active thermal solar system, need to be operated by a controller which takes into account the internal ambient and the external climatic conditions, among other variables. However, despite the convenience of using an advanced controller to operate this type of dynamic window has already been stated, only the use of simple differential controllers

* Corresponding author. Architectural Construction and Technology Department, E.T.S. Arquitectura, Universidad Politécnica de Madrid, Avda. Juan de Herrera, 4, 28040 Madrid, Spain.
E-mail address: luisj.claros@gmail.com (L.J. Claros-Marfil).

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has been suggested [16–18]. Neither the minimum requirements of the control system, nor the basic features of a controller which is able to perform a set of rules to optimise the behaviour of these windows; for example, coupling the solar energy gained by them with high-efficiency thermal devices such as heat pumps [19], have been addressed.

Systems based on microcontrollers have been widely used for the monitoring of general physical parameters [20] and, in particular, for solar energy applications research and weather data acquisition [21–25]. Such systems enable the use of complex control strategies and can improve significantly the energy efficiency of solar thermal facilities [26–30]. Nevertheless, due to the specific requirements of every particular research work, electronic assemblies are usually developed *ad hoc*, starting from the microcontroller chip and adding later the most appropriate individual electronic components [31]. Fuentes et al. [32], following a slightly different approach, have developed a datalogger for a photovoltaic system in compliance with the standard of the International Electrotechnical Commission (IEC) IEC 61724:1998 [33]. In order to satisfy the IEC requirements for the irradiance sensors, an assembled Arduino UNO board is overhauled, enhancing its analogue-digital converter (ADC) resolution from the native 10-bit Arduino resolution up to an improved 18-bit resolution.

Working along this line of complementing microcontroller assembled boards, Gad et al. [34] have developed a data acquisition system for the monitoring of solar applications using both a PIC family microcontroller, which includes an 8 × 8 hardware multiplier, and a microcontroller from the ATMEL family, assembled on an Arduino Mega board. However, this approach does not take full advantage of the Arduino board features since it is used only as a data storage board and not as the main control board of the system. Furthermore, due to these specifically add-on components, the mentioned systems tend to be more complex, requiring a greater effort to be developed, with a greater length of time for their set-up and, in general, such systems result more expensive than those based entirely on low-cost pre-assembled boards. Additionally, in most of the cases a 10-bit resolution is enough for an ADC with less 1% of error [24], and 8 × 8 hardware multipliers are rarely essential to perform control and monitoring tasks in solar buildings research.

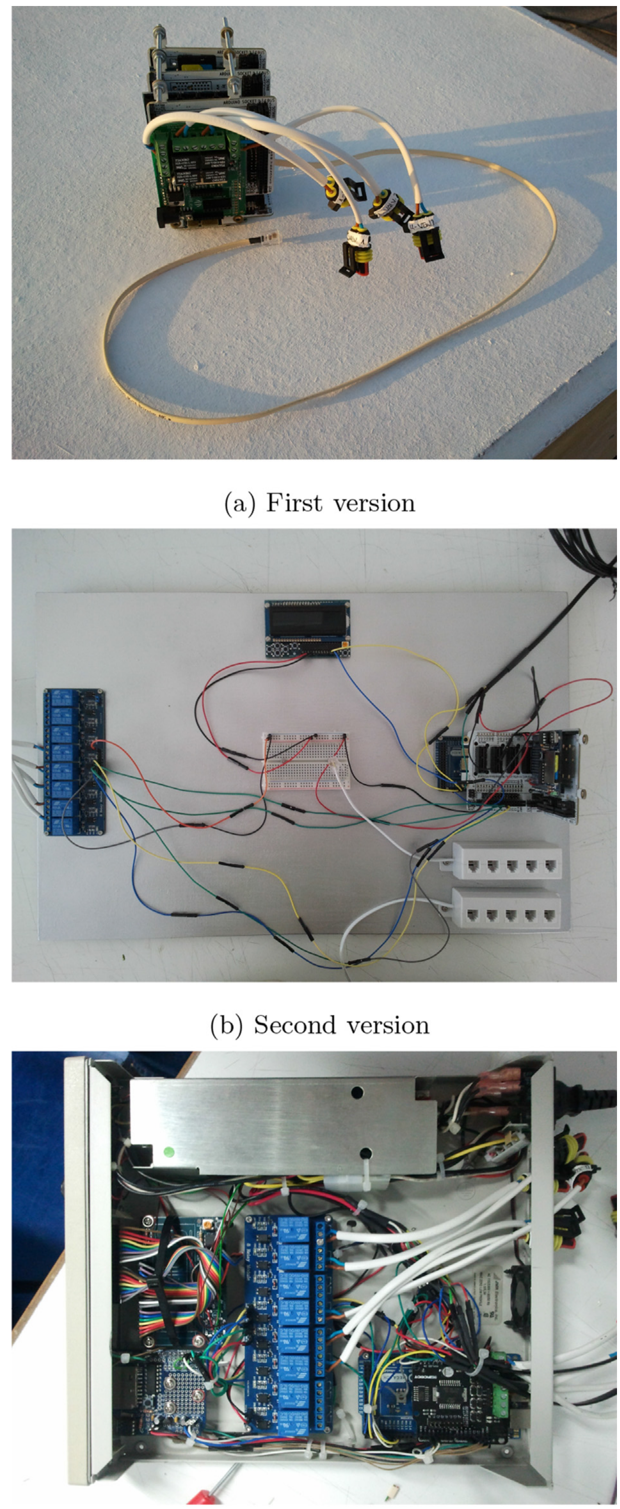
The aim of this work is to propose pre-assembled open source inexpensive prototyping boards, as the only mainboard required to develop stand-alone, inexpensive, reliable, easily-expandable and easily-programmable monitoring and control systems, oriented to solar buildings research in general and water-flow windows in particular. Hence, this paper presents a low-cost data-acquisition and control system for a prototype water-flow glazing, based on the Arduino open source electronic prototyping platform.

2. Materials and methods

The proposed control system is based on the Arduino electronic platform, which is an open source[1] electronic prototyping platform based on ATMEL microcontrollers [37]. It offers several electronic board models and an Integrated Development Environment (IDE) to program them. Because of its uncomplicated programming and low-cost features, this platform has already taken a significant role in solar technologies research applications [32,34,38,39].

2.1. The controller hardware

The presented monitoring and control system has been designed and built to operate a prototype water-flow window as an improvement of two previous simpler prototypes (Fig. 1a and b) [40], and it is based on the Arduino Mega ADK model due to the enhanced features offered. This third version of the controller (Fig. 1c) is able to register and monitor, among other variables, the



(a) First version

(b) Second version

(c) Third version

Fig. 1. Previous prototype versions of the automatic control system developed.

[1] The Arduino hardware is available under a Creative Commons Attribution Share-Alike license [35], while the software is under the LGPL [36].