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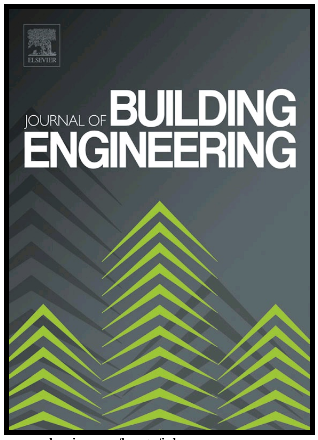

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Design, fabrication, and testing of an electronic device for the automatic control of electrochromic windows

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Abstract

In this study, an electronic apparatus for transmittance control of electrochromic windows is presented. The system is based on a microcontroller that, combined with a suitable interface, allows the user to choose among different operating modes. In addition, either voltage or current control can be performed, counting six different modes in total. Silicon photodiodes are used for sensing both the incident radiation and the transmittance of the window. Furthermore, the electronic device can be re-programmed to perform different tasks, providing a versatile tool for real time testing of electrochromics in outdoor conditions. The proposed controller can be combined with different electrochromic devices, regardless of their fabrication method or size. To test the controller, an electrochromic prototype 10cm by 10cm was used as a load. The experimental set-up has been tested in real time outdoor conditions and the system stability was verified, regardless of fluctuations of the incident radiation, partial shading of the system and ion diffusion effects. For the electrochromic window tested, a transmittance change from 60% to 10% or vice versa lasts approximately 210 seconds with voltage control, while the same operation lasts 600 seconds with current control, as in that case, the applied current is limited to 2.5mA.

Keywords

Electrochromic device, Smart window, Daylight control, EC control system, Control strategies

1. Introduction

Heating, cooling and lighting of buildings require considerable amounts of energy and there is a global trend towards improving energy efficiency in the building sector. Of all building components, windows can be regarded as the weak link, since they allow heat losses to the environment and admit excessive solar irradiation. To rectify this situation, a large range of heat insulating windows have been developed and are commercially available [1]. However, seasonal and diurnal variations of weather conditions require dynamic control of the building heat load for optimum operation. To this end, smart windows, characterized by their ability to change their optical properties in response to external stimuli, have emerged in recent years. Their use may lead to reduced heating and cooling loads and, in some cases, to a reduced demand for electric lighting [1,2]. Electrochromic (EC thereafter) windows belong in the extended category of smart windows and have the potential to become the leader in fenestration industry. The advantages of EC windows and their superior performance compared to other similar technologies have been demonstrated over and over again, through modeling and experiment [3–7].

1.1. Generic electrochromic device design and equivalent circuit

In general, an EC device consists of two conductive glass pieces, one with an EC thin film, the other with an ion storage and/or protective film, laminated by an

electrolyte (solid, liquid or gel), which usually contains Lithium ions (Li^+) [2]. Tungsten oxide (WO_3) is the most promising EC material, widely used in smart windows. The transmittance of WO_3 films can be altered by the intercalation/de-intercalation of small cations (H^+, Li^+, Na^+) into the film. The reversible EC effect in the case of tungsten oxide and Lithium ions can be expressed as a redox reaction [8]:

$$WO_3 + xe^- + xLi^+ \leftrightarrow Li_xWO_3 \qquad (1)$$

Given the aforementioned structure of an EC device, it is concluded that all the individual layers should be considered when designing an equivalent circuit. Thus, the structure and the equivalent circuit of a small EC device are presented in Fig. 1.