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Advances in Space Research 54 (2014) 2007–2016

ADVANCES IN SPACE RESEARCH
(a COSPAR publication)

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A novel wireless light sensing device for planetary and astronomical observations

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Received 13 December 2012; received in revised form 19 April 2013; accepted 30 April 2013
Available online 18 May 2013

Abstract

A novel and versatile wireless light sensing device has been designed and tested for stellar and planetary photometric observations. The device weighing few 10 s of grams finds a number of potential applications in the fields of astronomy and in situ planetary exploration. A Wireless Sensor Network (WSN) using a number of these devices has been deployed to successfully carry out simultaneous photometric observations under different conditions viz. sunlight, twilight, moonlight etc. Observation of a star of known magnitude for flux calibration at low intensity has been carried out by coupling the device to a 1.2 m telescope which demonstrates its sensitivity. A WSN using these devices is further capable of spatio-temporal investigations of sky background intensities. Such a network can also be used to effectively monitor certain astronomical events (lunar eclipse, asteroid occultation etc.) simultaneously from several locations. The capability of the device, level of miniaturization and its versatility makes it a potential tool for many photometric applications.

Keywords: Photometry; Planetary exploration; Light sensing; Wireless Sensor Networks; Sky background; Light pollution

1. Introduction

The science of measuring the light flux received from an object is known as 'Photometry'. 'Stellar Photometry' refers to the measurement of light from stellar objects, which is important in the fields of Astronomy and Planetary sciences. Photometric/Light measurements are essential during planetary exploration for many applications (Durga Prasad et al., 2012a,b; Hapke, 1966; Holte, 1970; Kreslavasky et al., 2000; Rekleitis et al., 2007; Thomas et al., 1999). In stellar astronomy many stars (e.g. α-Lyra (Vega)) with well calibrated fluxes at several wavelengths in visible and near infrared are called standard stars and are used to derive fluxes of unknown stars or to obtain the flux calibration of the light curve of a variable star (Wang et al., 2011). Also photometry of the Moon during a lunar eclipse helps in understanding the geometry and kinematics of the earth-moon system (Hernitschek et al., 2008). A device that can address all the above tasks needs a good sensitivity and a wide dynamic range. Also, development of such payloads/instruments onboard planetary missions need to comply with stringent requirements in terms of miniaturisation and power consumption, without compromising in performance. From thermometric measurements to modern Charge coupled devices (CCD), Astronomical photometry is continuously developing with time in terms of both resolution and sensitivity of measurement (Bessel, 2005; Lindemann and Lindemann, 1926; Romanishin, 2006; Weaver, 1946). The most acceptable and commonly used technique for photometry, both for astronomy and planetary sciences nowadays is CCD devices, because of their high-precision, linearity over a wide dynamic range and 2D nature (imaging capability) (Everett and Howell, 2001; Howell, 2006; Romanishin, 2006). CCDs are basically imaging devices and are generally not preferred for photometric observation where a very high-precision is not needed. For such photometric applications, a novel light sensing device with wireless networking capabilities has been designed and evaluated in this

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http://dx.doi.org/10.1016/j.asr.2013.04.028

study. Each device is self-reliant, weighing just few grams (∼50–100 g) and capable of remote and unattended deployment. These devices can independently operate for point-to-point communication of the observed data or can become individual nodes of a large homogenous/heterogenous Wireless Sensor Network (WSN) (Durga Prasad and Murty, 2011). These devices coupled with large telescopes and used in point-to-point wireless mode can accomplish high resolution photometric observations of stellar objects. A number of these devices deployed in a remote and unattended planetary terrain form a Wireless Sensor Network (WSN) for spatio-temporal investigations as proposed in Durga Prasad and Murty (2011). A similar network of these devices used with portable telescopes can help us in simultaneous observation of some astronomical events like asteroid occultation (Chandrasekhar, 2007; Chandrasekhar et al., 2003). The performance of the designed device has been evaluated by measuring luminous intensities of objects under various conditions such as bright sunlight, cloud cover, sunrise, sunset, moonlight, eclipse, artificial lighting etc. and the results are in good agreement. Hereafter these devices will also be referred as "Nodes" for their analogy to Wireless Sensor Nodes. The design and implementation details of these sensor nodes are the focus of this paper.

2. Node design and implementation

A prototype of an ambient light sensing module has been designed for planetary exploration and its performance was evaluated (Durga Prasad et al., 2012a). The present design follows an architecture similar to that discussed in Durga Prasad et al. (2012a), in terms of data-handling and wireless communication but with a completely different sensing front-end to achieve better sensitivity, particularly at low light levels. This device has an advantage of being used as a complete stand-alone device and also at the same time can be a part of a large heterogenous sensor network. The block schematic of the designed sensor node is shown in Fig. 1 and the designed node is shown in Fig. 2. It essentially contains three blocks: (i) Sensing front-end (ii) Data-handling and processing (iii) Wireless communication along with power and other auxiliary systems.

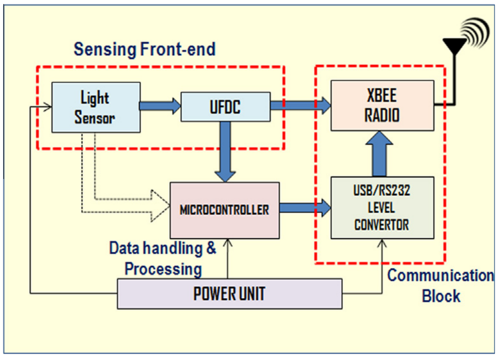

Fig. 1. Schematic block diagram of the designed node.

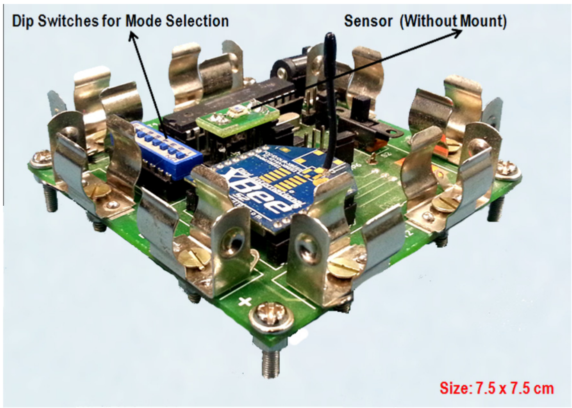

Fig. 2. Designed Wireless Sensor Node (Without sensor mount).

2.1. Sensing front-end

This block consists of a sensor/detector and signal handling electronics. This block detects the incident light and converts into a suitable format before transmitting to next block for data-handling and further processing. The key aspect for the design of this block is the choice of a suitable miniature sensor which is sensitive to extremely low light levels. Next is the ability of converting the signal to a digital value with a high resolution. The details of the choice of the sensor and technique of signal conversion are briefly explained below:

2.1.1. Sensor

Silicon photodiodes are considered as the most popular candidates for precision photometry in a wide spectral range. Silicon photo-detectors exhibit sensitivity over a wide spectral range from ultraviolet (UV) to near infrared (IR) covering the entire visible band. Besides having a low dark current and internal noise, these devices when integrated with appropriate electronics facilitate a compact circuit design (http://www.hamamatsu.com/resources/pdf/ssd/e02_handbook_si_photodiode.pdf). Keeping in view the characteristics of Silicon photodiodes and the detection requirements, TSL237 sensor from TAOS Inc. was chosen as the sensing element. TSL237 is a monolithic CMOS IC with a wide field of view (FOV) silicon photodiode detector (60° FOV on the sky)) and current-to-frequency converter, all integrated on a single chip (TSL 237 Datasheet at http://www.ams.com/eng/Products/Light-Sensors/Light-to-Frequency). The output of the sensor is a square wave (50% duty cycle) with frequency directly proportional to the irradiance incident on the photodiode. The detector is sensitive over the wavelength range of 320 nm to 1050 nm with a high irradiance responsivity of 1.2 kHz/(μW/cm^2) at peak wavelength of 640 nm. The maximum output frequency range of the device is 1000 kHz with an extremely low dark frequency and high thermal stability. The wavelength response and the linearity curve are shown in Fig. 3. The frequency output facilitates sensitive and high-resolution measurements compared to that of a digital output.