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Open source low-cost power monitoring system

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ABSTRACT

This study presents an entirely open-source, low-cost power monitoring system capable of many types of measurements including both loads and supplies such as solar photovoltaic systems. In addition, the system can be fabricated using only open source software and hardware. The design revolves around the Digital Universal Energy Logger (DUEL) Node, which is responsible for reading and properly scaling the voltage and current of a particular load, and then serializing it via an on-board ATTiny85 chip. The configuration of the DUEL node allows for custom sensitivity ranges, and can handle up to 50 A and 300 V. Up to 127 DUEL nodes communicate via Inter-Integrated Circuit (I2C) on a bus, which can be monitored and logged through an Arduino UNO, or other compatible microcontroller. Using accessible equipment, the DUEL node can be calibrated to a desirable accuracy and error. The DUEL nodes are also completely customizable, making them fit for any input range, where all commercially-available products are fixed range. The open source solution out performs commercial solutions as the price per measurement ($18.25) is significantly smaller, while the number of serviceable channels (1 2 7) is significantly higher.

Specifications table

Hardware name	*Open Source Low-Cost Power Monitoring System*
Subject area	Engineering and Material Science
Hardware type	Electrical Engineering and Computer Science
Open Source License	GNU GPL v3
Cost of Hardware	$155.34
Source File Repository	Open Science Framework: https://osf.io/8keau/

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1. Hardware in context

As the open source method of technological development [1] has moved aggressively into technically-sophisticated scientific hardware [2–8], there has been another push towards open source appropriate technology (OSAT) for sustainable development [9–11]. One leading example of OSAT is the work by Open Source Ecology (OSE) to fabricate the tools needed for civilization itself [12]. OSE has identified the top 50 most relevant machines to comfortably sustain civilization [13]. OSE uses a model where the design is global and open source, but the manufacturing is distributed, local peer production [14,15]. One of the main pillars of OSE's plan is distribution on every level: distributed agriculture, manufacturing, and energy production [12].

The OSE mindset has fostered the development of the Open Building Institute (OBI), which was created to design and build comfortable and highly functional homes, such as their first model shown in Fig. 1 [16]. OBI houses can be built using OSE's Open Village Construction Set and are designed to be ecologically responsible, scalable, and replicable in the fully open source sense. Ideally these houses are constructed and powered using a sustainable source of electric power such as solar photovoltaic (PV) technology [17], which converts sunlight directly into electricity. Thus, the current designs of OBI all utilize building integrated photovoltaics (BIPV) for energy generation as it has distinct advantages in reducing ecological impact [18], net energy [19] and cost [20]. The OBI building is optimized to supply multiple different configurations of power (i.e. 5 V, 12 V, 24 V, 48 V, and 120VAC), in order to cut down on conversion losses (energy conversion processes always result in energy loss [21]). In order to fully understand the designs, and provide valuable feedback in order to enable the OBI design to evolve technically there is a need for a low-cost, flexible an open source monitoring system to log the consumption and generation of electricity.

Some commercial solutions exist for an energy monitoring systems, including the Neurio [22], the Eyedro EHWEM1 [23], the Smappee [24], and CURB [25]. These cost of these solutions range from $200 to $400 [22,25]. The designs are all proprietary, and are capable of taking very few measurements [22] (e.g. the Neurio can only measure 2 AC currents).

There are also many designs for energy monitoring published in the literature. Some of these designs rely on commercially available industrial components [26–28], which severely drive up costs, minimize customization, and decrease accessibility. Many are built around the popular Arduino prototyping platform [29–31]. Some are built for user conveyance by highly integrating the usage of a smartphone [32,33]. Internet of things (IOT) capability is the premier focus of some designs [34,35]. Others rely on software packages such as LabVIEW which is not open source, and has a non-trivial license cost (e.g. $399-$4999) [36–38]. Furthermore, some designs do not provide permanent hardy solutions and lack integration [39].

Lastly, some relevant academic designs only report on results, and do not share details to pertinent components, which limit their utility [40–48]. Finally, there is an open source alternative commercially available, called the OpenEnergyMonitor [49]. The design consists of multiple modules with a relatively high cost of $150 per channel (2 AC current measurements,

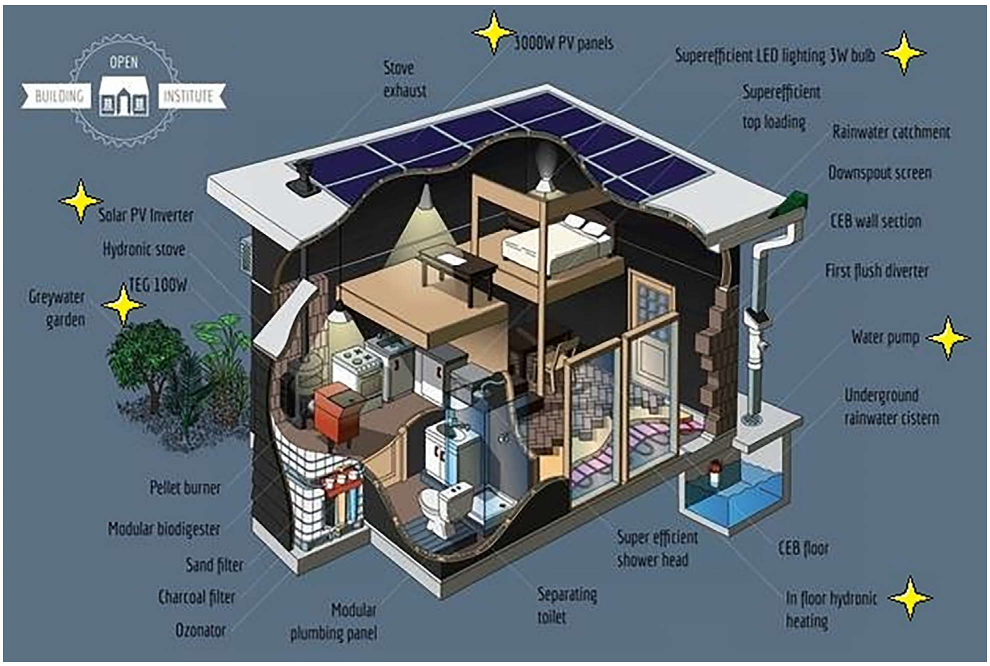

Fig. 1. A simple sustainable house designed by OBI. The proposed system would monitor loads and sources such as the 3000 W PV panels, LED lighting, and water pump. Stars denote measurable electrical devices. . Adapted from [16]