Real World Classroom Projector Usage: Development of an Intelligent Energy Saving Solution for Projectors

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Background

Digital video projectors and video displays are some of the most common electrical devices used and consume large amounts of energy at a time. Although these devices typically have on-board energy management systems, users may disable them or they may be ineffective, resulting in wasteful energy usage. In a study, we evaluated the energy impact of wasteful usage by projectors in general use in a public high school in California. The results of this study confirmed prevalent situations of wasteful use with digital video projector usage. The flowchart presented in Figure 1 shows multiple strategies of intervention using a multi-stage model to address waste in a generalized plug load device which can be used to address the energy waste in digital video projectors & displays.

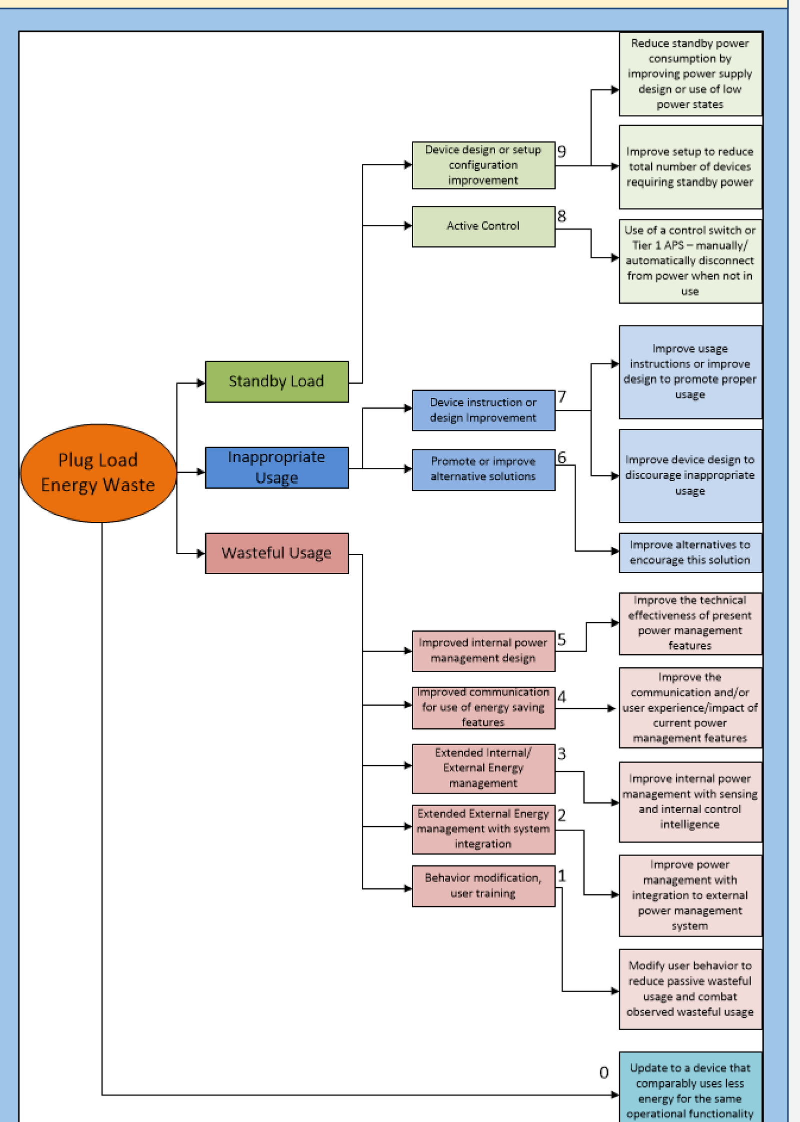

Figure 1: Flow chart showing multiple strategies of intervention to address waste in a generalized plug load model.

Data Analytics

Through an arrangement with the Irvine Unified School District, CalPlug provided observational assistance to the district's sustainability management personnel to help provide insight into classroom energy usage. Beyond energy usage, patterns of device usage are indicative of technology utilization (Figure 2). For this pilot investigation, the goal was to determine if there was evidence of a problem, and if so, to analyze the results in order to justify a future investigation with a larger sample size and run length. Two high school classrooms were selected. *Room 1* was a foreign language classroom, and *Room 2* was a social studies classroom. Data was collected for 18 consecutive days between late April 2017 and early May 2017.

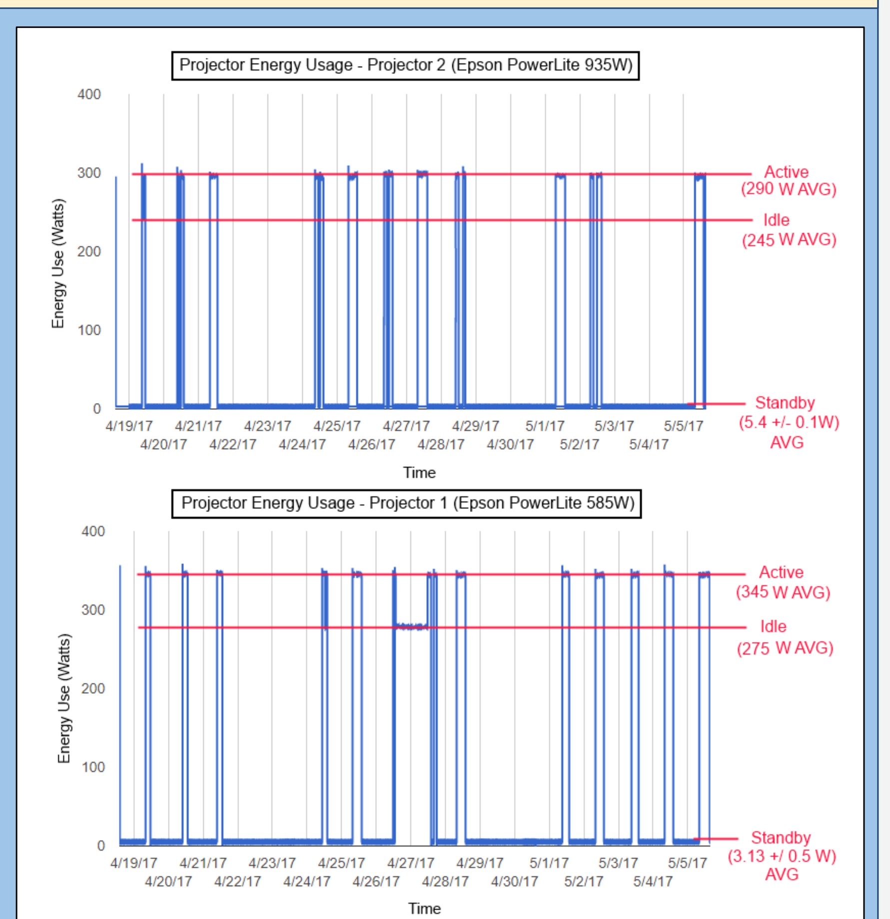

Figure 2: Projector Energy Usage of two Projectors throughout a period of time to acquire data on regular usage

As seen in Figure 3, regular patterns can be observed in the classroom. However, there are situations, where the projector is left on even when there is nobody present in the classroom (as no motion seen). Additionally motion precedes the intentional activation of a projector in all usage cases. Ambient light measurement in the room also provides some level of correlation with projector usage. The use of sensors and logical processing provides the basis for intelligent device control. Continued improvement in data analytics (especially in edge computing/control applications) will continue to improve the power of this control approach.

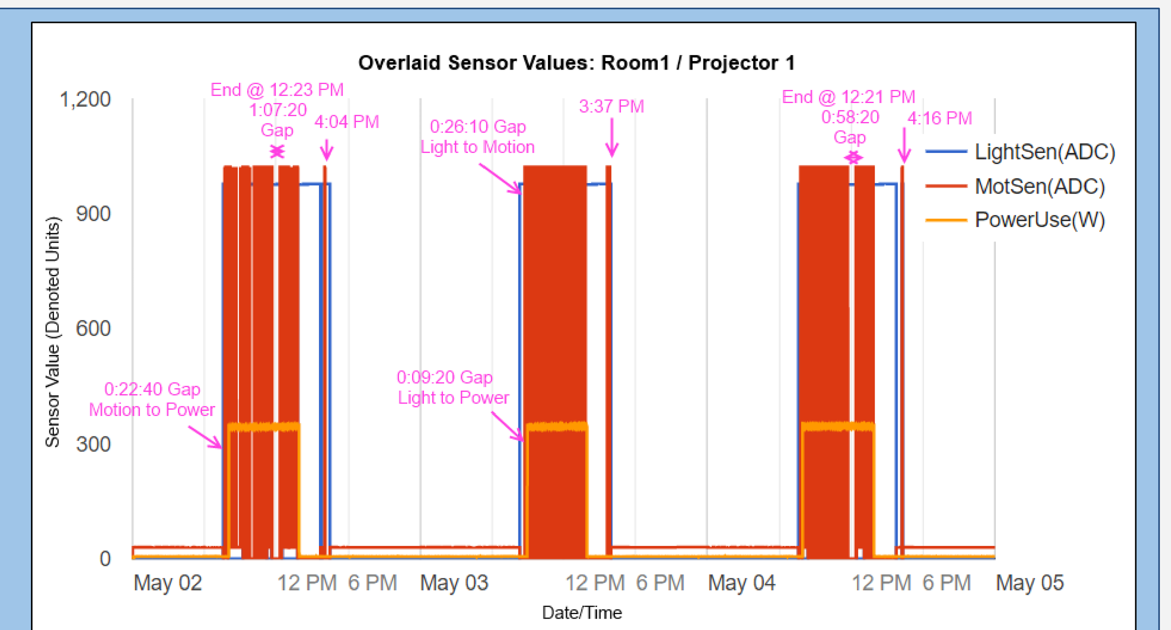

Figure 3: Data shows power usage of a projector while motion and light (human presence) are detected in the room

Proposed Solution

We have developed a system called 'Projector Buddy' to use sensors and logical correlation to detect user engagement with shared-usage and classroom projectors. This system saves energy by intelligently un-powering devices inadvertently left on. Our device uses five main sensory mechanisms as sensor/logical inputs in its machine learning algorithm:

1. Motion: This is used to detect movement to indicated if someone is in the room.
2. Light: This is used to detect environmental changes as well as changes in images on the screen to detect and characterize user presence.
3. Current Flow: This is used to identify the projector's state of operation.
4. Time: This is used to detect idle periods and calculate typical usage schedules.
5. Sound: Using a microphone, we can detect ambient sound levels as well to help determine if people are in the classroom

Generalized behavioral patterns can be derived from the data generated from these sensors. When no activity is detected over a fixed amount of time, a laser will alert the user. If there is no reaction to the laser, then the system will initiate the shut down process. This is done through the use of an Infrared Remote Peripheral which allocates memory blocks for transceiving waveforms which we use to preemptively store the projectors IR signals to mimic the remote and have a safe method for turning off the projector. Figure 4 is a block diagram that shows the inputs and outputs for energy management control.

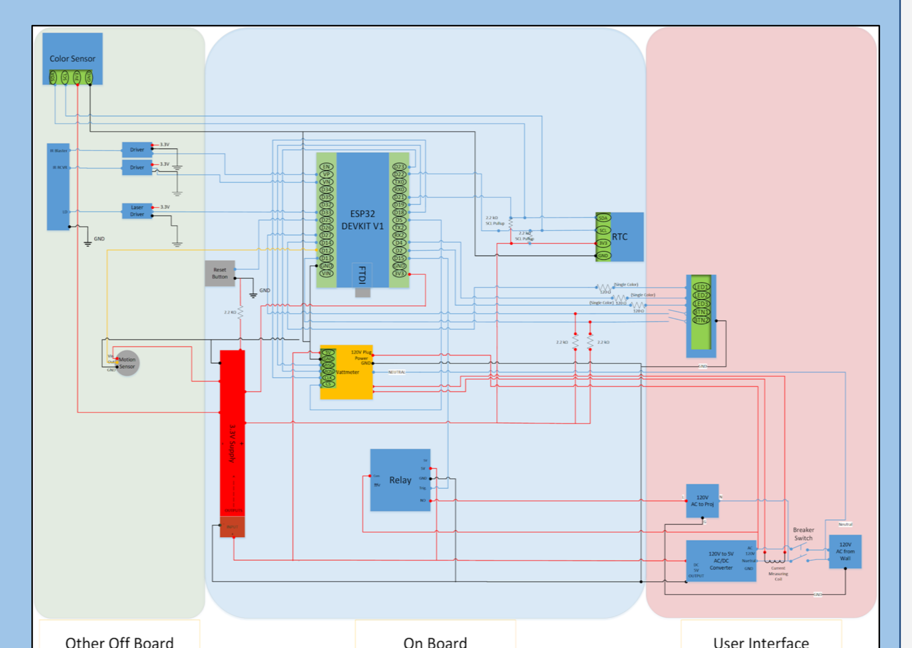

Figure 4: Block Diagram for a projector energy management system (Projector Buddy)

Current Work

The design in Figure 5 was a proof of concept design focused on rapid deployment and simple, transparent operation. Optimizations from previous designs include adapting the system to use less power and adding additional real-time interaction with the environment by implementing a new multi-process algorithm that adds task parallelism and concurrency to the system. Over time, the system will track when the projector is being used through machine learning.. Projector Buddy will then acts as an "Active Controller" (see Figure 1 intervention point 8) and use a relay to reduce standby power inherent of plug load devices. Power to the projector can be removed when fully shut down and restored before the projector is turned back on. The prototype is made using an ESP-32 microcontroller that has built in Wi-Fi capability. The system can therefore utilize MQTT protocols over WiFi link to provide control and management user interfaces.

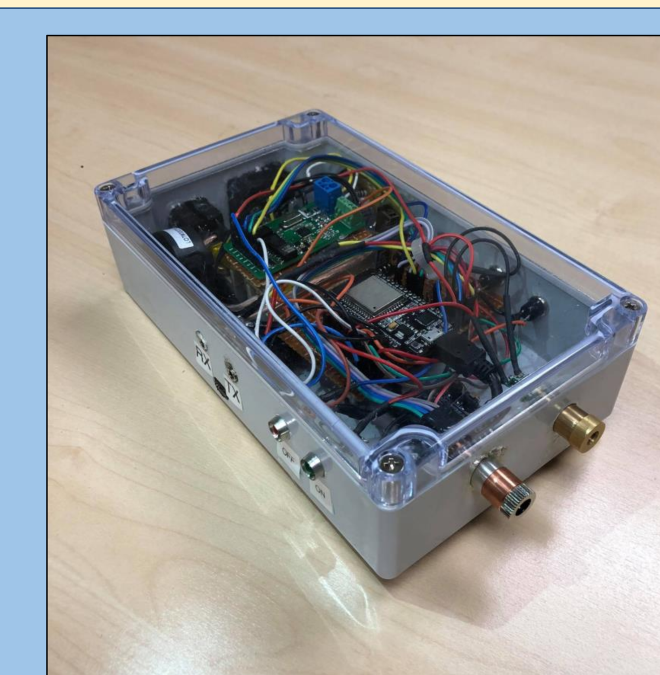

Figure 5 Proof of Concept demonstration device for Projector Buddy system.

Our current Design as shown in Figure 6 involves transferring all circuit components to a two-sided printed circuit board design. External peripherals are installed onto the case and connected to the board via JST connectors. The case for this design is currently 3D printed with the intent of adding mounting holes so that the device can be secured near the projector and mount directly to the ceiling. This version of the device also includes safety measures such as power isolation between power supply and USB port as well as internal fuses for input power

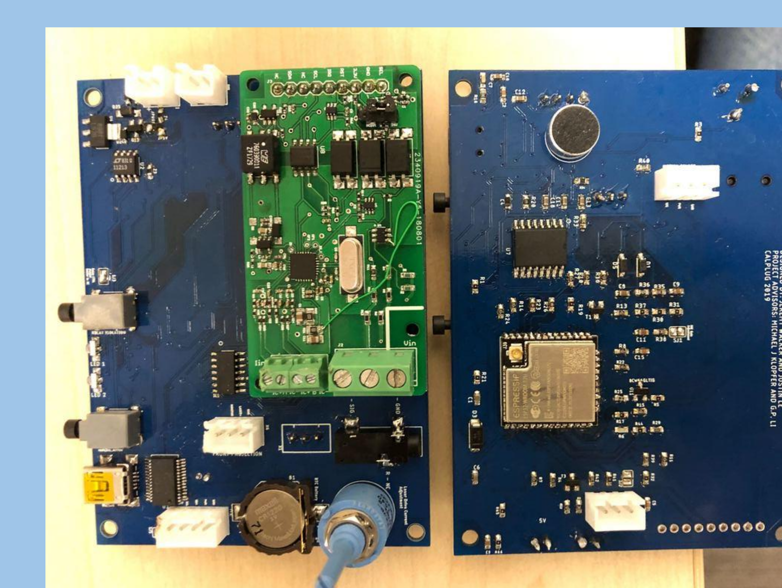

Figure 6 Realized Two Sided PCB
Left: top side with Wattmeter
Right: bottom side

Future Work

Currently, a fully functional, low power prototype has been demonstrated. As development continues, future prospects for the project include further improved energy conservation, expansion on its machine learning algorithm, and reducing the footprint of the device. The overall goal of this effort is to have a system that can be extended upon pre-existing electrical devices as well as be developed to be included in OEM power management systems of projectors and other plug load electrical devices.