e\textsuperscript{4}Meter - An Intelligent Power Distribution Unit

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Chapter 1

Introduction

Electrical energy consumption is becoming increasingly critical in today’s world. Awareness of power consumption is an important facet in improving our energy efficiency. To this end, we propose an intelligent power distribution unit (PDU) capable of independently measuring and controlling the power consumed by appliances connected to its outlets.

Although there are already numerous devices on the market that can perform this task, they are fraught with problems such as:

- poor accuracy;
- too few outlets;
- difficulty of use, and;
- lacking intelligence.

The e4Meter addresses these issues and brings together the functionality and advantages of existing devices on the market. As a result, it can be effectively used in a range of consumer and research applications.

The next section outlines the main functions of the device and how it can be used. Following the functional description, we discuss the design decisions we were faced with. Important factors needing to be addressed include:

- cost;
- functional simplicity, and;
- safety.
Chapter 2

Functional Description

The \(e^4\) Meter has several levels of functionality. Firstly, it operates as a simple switched power distribution unit. A single power supply provides four independently switched outlets. A small push-button switch near each outlet controls the state of the outlet. Three of the outlets can also be dimmed, which provides more fine-grained power control over certain devices, including lights, fans and heaters.

The second level of functionality is provided by an LCD character display on the top of the unit, which displays outlet information in real-time. A push-button toggles the display between power, current and voltage.

The \(e^4\) Meter incorporates an XPort Pro, allowing it to be connected to a local network or the Internet. The in-built web interface provides more information and control over the device, such as detailed per-outlet graphs which can show power consumption profiles over long periods of time.

A fourth level of functionality is provided by a sensor unit, which collects environmental data such as temperature, light level, and motion. The \(e^4\) Meter can use heuristics based on this data to optimise energy consumption of connected devices. For example, switching off a lamp when ambient light level exceeds a threshold, or when nobody is in the room.

We believe that the \(e^4\) Meter is the only product/prototype that can achieve all of the above. It’s all about raising people’s awareness of how much power everyday devices consume.

By providing a real-time measurement on the high-contrast LCD, users can immediately see how their actions affect power consumption. For example, when turning on a light, heater or TV, you can immediately and easily see how much power the device is consuming, without bending your back or squinting your eyes. Many existing power meters are the “plug-through” type where the LCD is vertically mounted, parallel with the wall outlet. Combined with their lack of an LCD backlight, reading the power consumption is very difficult. The \(e^4\) Meter solves these problems, and more.

Figure 2.1: The front panel of the \(e^4\) Meter.
Figure 2.2: The rear panel of the e\textsuperscript{4}Meter.

Figure 2.3: The internals of the e\textsuperscript{4}Meter.
Chapter 3

Design

3.1 User Interface

There are several aspects to the e4Meter user interface. Firstly, there is the hardware UI, which consists of the high-contrast LCD and the five control switches on the top of the box. These can be seen in Figure 3.1 with the LCD displaying power consumption of each outlet.

The backlight on the LCD automatically turns off after five seconds, and can be switched back on by pressing the white button. This press will not alter the current state of the LCD display, except to turn the backlight on.

Consecutive presses of the white button will cycle the display between voltage (volts RMS), current (amperes) and power (watts).

Figure 3.1: LCD showing power consumption of ports in Watts and their status.
3.1.1 Web Interface

Users can also interact with the e4Meter via the web interface running on the Lantronix XPort Pro. This interface is built using Google’s Web Toolkit and uses AJAX extensively, thus providing a very responsive UI experience. This frees the processor to simply serve up raw data and state information to the browser. The processor is also used for logging and intelligent control, described below.

Data is updated once per second in the background. The status page shows an overview of the e4Meter with dials for power consumption of each outlet, and a graph showing history of the power consumption.

![Image of the web interface](image-url)

Figure 3.2: The dashboard of the web interface served by the XPort Pro.
3.2 Hardware

The e^4 Meter hardware can be divided into several distinct components:

- Power measurement circuitry,
- Intelligent control,
- Sensor board.

These are described in the following sections.

3.2.1 Power measurement circuitry

The heart of the power measurement circuitry is a Teridian 78M6618 power measurement IC. This chip is responsible for sampling voltage and current measurements for each outlet in order to accurately compute the power consumption for each connected device. This real-time processor is also responsible for handling the primary user interface — the buttons and LCD. It communicates with the Lantronix XPort Pro via a serial interface to send it updates and allow it to be controlled remotely. This can be seen in figure 3.4.

3.2.2 Intelligent Control

The Lantronix XPort Pro is responsible for logging power consumption data so that historical records are not lost when the power is removed. It stores records on the flash partition which can be recalled by the web interface. Additionally, the XPort Pro is used for responding to events from the power measurement circuitry and environmental sensors, giving the e^4 Meter its “intelligence”.

Figure 3.3: Past usage history for a specific outlet.
3.2.3 Sensor Board

The sensor board provides sensing of a number of environmental factors including ambient light, temperature and motion. It can be mounted in a remote location (up to 10m away from the e^4Meter). This can allow outlets to be activated in response to changes in the environment. Some examples include:

- Turning lights off when there is no movement in the vicinity;
- Turning lights on or off depending on ambient lighting conditions;
- Controlling a heater with a temperature sensor mounted nearer to the people, rather than using the thermostat on the heater itself.

A prototype sensor board can been seen in figure 3.5.

Figure 3.4: XPort Pro and power measurement circuitry.

Figure 3.5: The sensor board compared to a Lantronix XPort Pro.