A Non-invasive Appliance and Application for Remote Washing Machine Monitoring

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ABSTRACT

Non-invasive Appliances are devices, used on machines, that do not require the opening of that machine for installation. This project involves the creation of a non-invasive appliance to be used on washing machines to determine if and when the machines are in use. This appliance and its associated web application will remove the problem of students in dorms having to repeatedly carry their dirty clothes to various washing machines to see if they are available or not. Existing solutions require expensive pieces of hardware and the applications specific to those hardware do not integrate easily with other applications and platforms. Data was collected, an algorithm for detecting when the machine is on was implemented, a device based on the Arduino platform was utilized to collect and send data to a database through an API implemented in this project. Lastly, a web application was designed to display information on the monitored washing machines. In this poster, I present an algorithm, appliance, and application based on collected data to solve the aforementioned problem.

INTRODUCTION

Energy Monitoring systems are vital technologies in all fields. The ability to know the efficiency and power usage of machines in this day and age is highly sought after and essential. As energy prices increase and shortages affect more of the world, being the appliance or the system with the lowest power usage will become the goal for all [2]. To determine this energy usage, extensive energy monitoring systems are being developed and used in all industries [3].

The motivation behind this project stems from a problem I've noticed while living in residence halls. With washing machines on only the basement floor, one would have to walk down many flights of stairs with their laundry to the machines only to discover all the machines are taken. This process would be repeated multiple times until an open machine appeared. For myself and other busy students, this problem is both an aggravation and huge waste of time. To solve this problem, data was collected and analyzed to influence the design of a universal non-invasive appliance [1] using an Arduino microcontroller to monitor current being drawn by a specific washing machine. The appliance constantly takes measurements and sends that data to a database via an API [5], implemented in this project for receiving information. Lastly, a web application that displays the status of the washing machines being monitored was created.

EXPERIMENT

Before work was started on the device, an understanding of washing machines needed to be gained. Namely, what changes during a cycle and by how much. To determine what current ranges indicate a washing machine in use, an experiment was set up watching the current flow over time on various washing machines with various cycle types. To measure the current being drawn by a machine, a Watts Up Pro meter was used. Once plugged in, the Watts Up displays instantaneous current being drawn by the machine that is plugged into the Watts Up. Figure 1 displays a graph of current usage over time of a single cycle.

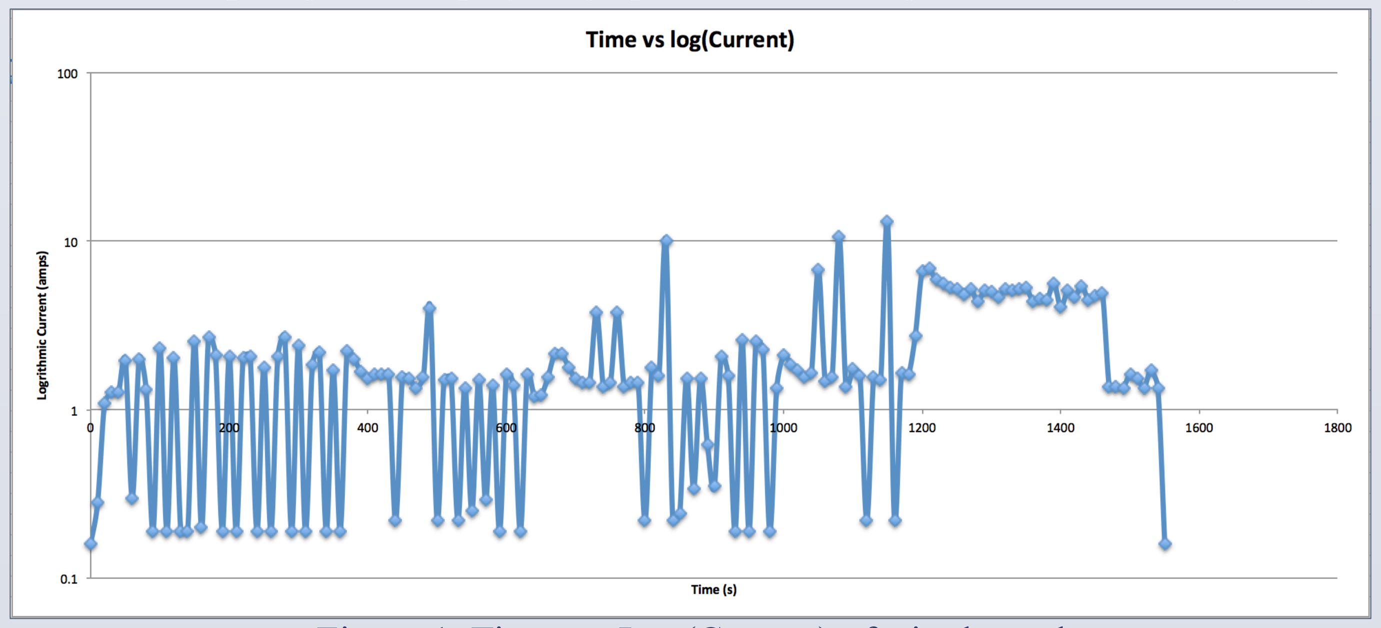

Figure 1. Time vs. Log(Current) of single cycle

From the data shown in Figure 1, three critical points were determined. First, the current that indicates a machine is on, indicated by the first and last data points in Figure 1, 0.16 amps. Second, the smallest current that occurs during a cycle, 0.19 amps. Lastly, the largest current that occurs during a cycle, 14.8 amps. To design a circuit that can handle this high of current as well as distinguish between the critical values, knowing the Arduino's sensitivity to be 0.0048V, the data was analyzed to determine the following:

- Internal resistance of the washing at each critical value
- Possible different resistor values to be used in the added component and their associated voltage drop and power dissipation at each critical values

Current(amps)	Resistance(ohms)
0.16	756
0.19	637
14.8	8

Figure 2. Resistance in the Washing Machine at the critical points

Ohm's laws, V=IR, was used to calculate the internal resistance of the washing machines, knowing V stayed constant at 121 V through the entire cycle, shown in figure 2. Using each critical points associated resistance, the relative voltage drop across possible resistor values was calculated using the following equation, $V_x = (R_x * V_s)/(R_t)$ displayed in figure 3. Power dissipation of the same possible resistor values at each critical point was calculated with the following equation , $P = V^2/R$, displayed in figure 4.

	Voltage at		
Resistance (ohms)	0.16 amps	0.19 amps	14.8 amps
1	0.159	0.189	13.187
0.5	0.079	0.094	6.973
0.25	0.039	0.047	3.590
0.01	0.00159	0.0019	0.147

Figure 3. Voltage across the possible resistances at critical points

	Power Dissipation at		
Resistance (ohms)	0.16 amps	0.19 amps	14.8 amps
1	0.025	0.036	173.89
0.5	0.0127	0.018	97.26
0.25	0.0064	0.009	51.56
0.01	0.003	0.0036	21.378

Figure 4. Power dissipation across the possible resistances at critical points

DESIGN

Influence by the results of the experiment, the ideal resistance of 0.25 ohms was determined. By placing four 1-ohm resistors in parallel, the ideal resistance was achieved to give the voltage drop needed to distinguish between the critical values. As well, with four resistors the power dissipation of each of them is low enough not to cause damage to the resistors at the highest critical value. Thus the circuit displayed in figure 5 was designed to meet those specifications.

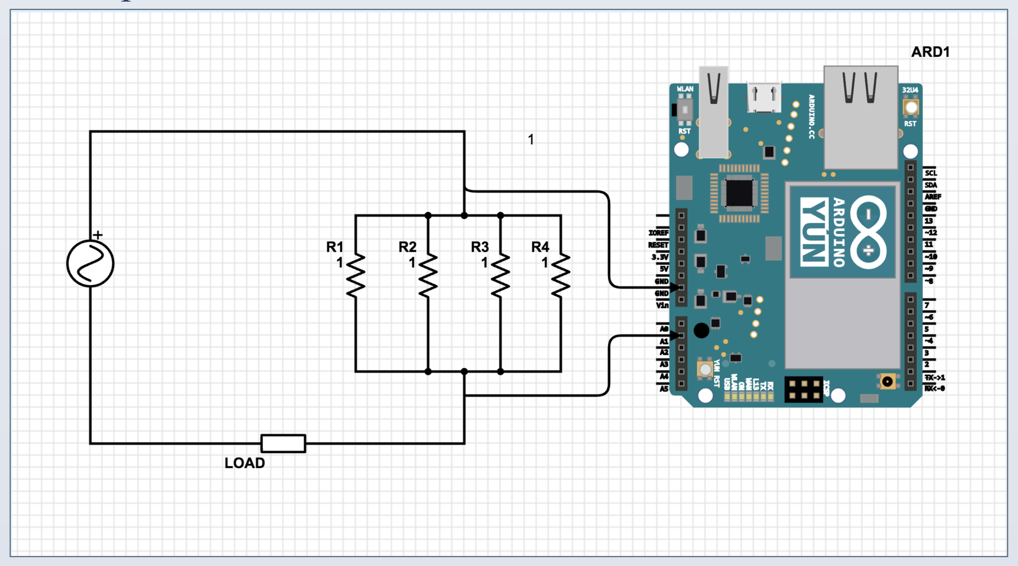

Figure 5. Circuit design of Appliance

To achieve the non-invasive nature of the project, an extension cord was used as the base of the appliance. The use of an extension cord allowed for the wires to be opened on the extension cord rather than having to cut the wires of the specific washing machine to redirect the flow of current through the designed circuit. Thus, my device is inserted into the system by cutting the wire of the extension cord and soldering one end of the wire to one end of the circuit and the other end of the wire to the other end of the circuit. Figure 6 demonstrates the described design of the appliance.

Figure 6. Circuit and Arduino connected to extension cord

A cutoff voltage of 0.20 amps averaged over a 15 second period of time was determined to be the cutoff for determining if a washing machine is on or off. This value allows enough space to ensure that all machines and all cycles that were analyzed can be determined to be on or off. In addition, taking an average of the readings ensures that random spikes do not cause errors in the reading, as well as limits the number of times the Arduino has to access the API through its internet connection. Figure 8 displays the algorithm being used in the Arduino, programmed in C, over the Arduino IDE, to take readings and send them to the API.

```
state = False;
machineId = 1;
cutoff = 0.20;
while True do
    count = 0;
    total = 0;
    avg = 0;
    while count < 150 do
        total += (analog read of port *
          0.00488758553)/(0.25)
        wait(100) //0.1 second pause
        count ++;
    end
    avg = total/150
    if avg >= cutoff and state==False then
        visit the api to change the state of the machine
          in the database to on
        state=True;
    end
    if avg <cutoff and state==True then
        visit the api to change the state of the machine
          in the database to off
        state=False;
    end
end
```

Figure 7. Algorithm running on the Arduino

Lastly, An API (Application Program Interface) was developed as a mediator between the database, that stores the state of the washing machines, and the Arduino. The API was developed using the PHP programming language to interact with a PostgreSQL database. In addition, a web application was developed to display the state information of the machines being monitored with the non-invasive appliance described in this project. The web application, written in the PHP programming language and in the same manner as the API, connects to the PostgreSQL database

CONCLUSION AND FUTURE WORK

An experiment was completed and data analyzed to provide insight into the inner workings of washing machines. In addition, a non-invasive appliance is combined with an API and a web application, designed based on the information collected from the experiment, to solve a problem many college students face on a weekly basis. Not knowing when a washing machine is available is a wasting and this machine will solve that problem.

I plan to continue to scale this system by producing additional appliances to attach to more washing machines. I plan to add additional features and functionality to the web application, including email and text message alerts, upon request, when a machine is done with a cycle, and communication between devices to limit the number of API access calls [4]. I plan to redesign the front end interface of the web application to make it more user-friendly.

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