Water Analogy Project

Group: 12

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Objective

Create a mechanical system for easier visualization of current flow by using water, to demonstrate circuit theory and components (resistors, inductors, capacitors, diodes, transistors, etc) responses. This project would be used for educational purposes. It will help new students understand and physically visualize how circuit components behave given certain conditions.

Project Description

A board will be created containing clear pvc pipes which will be connected to the various representation of components. A pump will supply water from the lower retention tank to the main line that will feed the components. Valves will be set up in each one of the components lines to control their state and rate at which the water will flow representing the current. These valves will be controlled by using stepper motors, which will open at certain angles to allow a controlled current set by the user through the components. Measurements will be made by the use of gauges, which will give students/users a visual representation of the voltage (pressure) as well as the rate of current flow at the various lines. These measurements will be correlated to component equations such as Ohm's Law to facilitate the students understanding of circuit theory. Each component will have a plaque explaining the component, its function, and equations. LED's will be allocated through each one of the lines, they will be programmed to easier display the intensity of water flow to show an increase or decrease of current. The system will contain a fully interactive user friendly dashboard from which the student/user can control the circuits parameters, turn on/off components, see equations, cross reference values displayed in pressure gauges to the calculated ones displayed on the dashboard, etc. The overall system will be mounted to a frame with wheels to allow it to be portable, and be set at a height that will be easy for the user/student to operate and watch the whole system function without any difficulty.

This idea originated based on a visit to Eaton Experience Center in Pittsburgh, PA. The Experience Center has a system containing only resistor, KVL, KCL, inductor, capacitor representations without any user control in the dashboard aside from turning on/off the system (See Fig. 1). We will be improving this system by adding MOSFET, BJT, and diode, as well as allowing the user to have control over the systems parameters, and all the other features displayed above.

Figure 1: Eaton Water Analogy System

Requirements Specifications

1) <u>Overall Design:</u>
    a) Overall cost of the system should be kept to the minimum while also providing an aesthetically pleasing and functional product.
    b) Overall size should be approximately 3.5 inches deep, 5 feet wide, and 6 feet 4 inches tall.

2) <u>Hardware functions:</u>
    a) Single board computer (Raspberry Pi 3).
    b) External 7 inch touch screen display to interface with the device allowing user control over components parameters such as beta values for BJT, voltages across different junctions, as well as voltages across the device as a whole.
    c) Trigger the following events using general purpose input and output pins:

i) Adjust the valves of the systems to reflect the user's input in the interface (Latency < 750 ms).

(1) Trigger stepper motors using relays and adjusting the amount the motor turns to allow different amounts of water to flow representing set current.

(2) Trigger start and stop of the system's pump using a relay

ii) Control light emitting diodes to accentuate the current flow throughout the system (Latency < 750 ms).

(1) LEDs flash in the direction of current flow through the devices.

(2) As the "voltage" (pressure) increases across the device, the LEDs will flash faster representing an increase in current flow through the various components. This speed will represent a value set by the user predetermined by the programmer.

d) Power PCB.

i) Manage power distribution to the various components such as LEDs, stepper motors, Raspberry Pi, touchscreen, and pump.

ii) A seamless operation under any conditions. (Power Requirement < 75 W)

3) <u>Software functions:</u>

a) Clean user friendly graphical user interface. (Size Requirement < 250 MB)

b) Ability to navigate quickly and seamlessly through menu options.

c) Set component values with visual feedback and store them in memory.

d) Provide a visual representation of the overall circuit for the user to set parameters and components to be used before starting the system.

e) Allow the user to start and stop the system when desired. (Latency < 750 ms)

f) Create safety standards so the user is not able to trigger all the components at once, limit each component parameter options. This will reduce the probability of errors in the system since all the parameters will be predetermined and calculated.

g) Parameters for each component will be provided to the user by using a dropdown bar displaying all the options the user has.

h) Provide users with information about the components in a clear and concise fashion (summarize important component information as well as display what the current flow through and pressure "voltage" across the system should be). This includes component related equations, stage of operation of the transistors, etc.

i) Ability to control the system via a remote desktop.

i) Setup an adhoc network connection to access the Raspberry Pi 3.

ii) Ability to mirror the graphical user interface and project it.

iii) Interact with the interface with minimum delay.

House of Quality

The requirements of the House of Quality were chosen based on the software and hardware requirements. Input power refers to the power necessary to feed the overall system given that is composed of many motors, LED strips, etc. Cost refers to the total cost of building the system, based on the required parts. Graphical User Interface (GUI) is the visual application which the user will interact with on the 7 inch touch screen. This interface must be as smooth as possible containing high resolution graphics to reflect when screen sharing, while being able to fit under the size constraint of 250 MB. Latency refers to the maximum time permitted for the physical system to reflect the user's action on the graphical user interface. This time constraint is 750 ms to allow adequate time to begin the process, but still optimum performance from the user's perspective. Setup time refers to the overall time the user would spend setting up the system in a new environment, it includes the screen sharing setup time as well as system turn on; it directly correlates to installation effort. Performance takes into to account the overall behavior of the system included but not limited to response time, user friendliness, and accuracy.

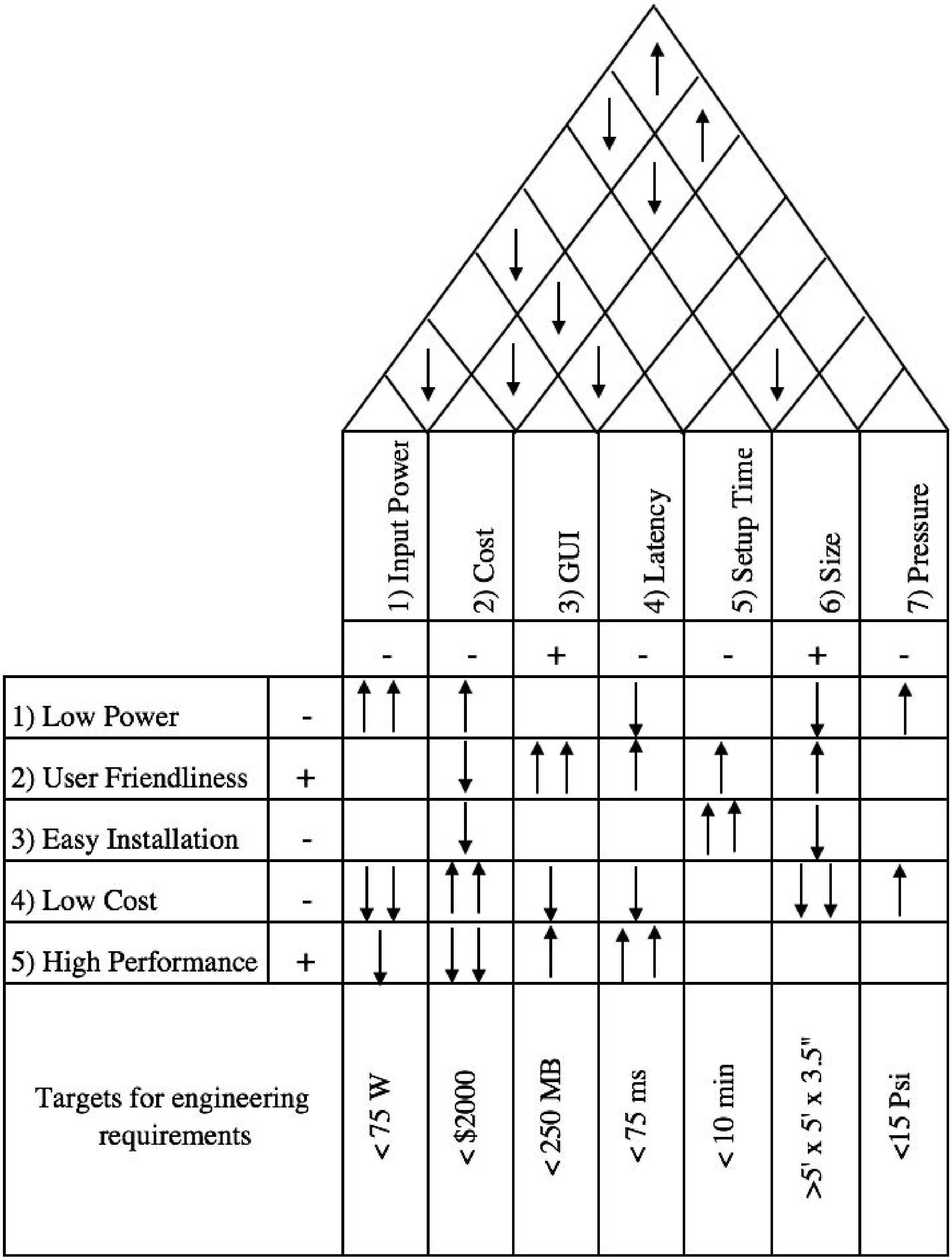

Figure 2: House of Quality

Block Diagrams

Legend

Blue: Control
Red: Power
Green: PES Relation
Black: Other Relation

Responsibilities

System	Primary	Secondary
Raspberry Pi	Richard	Zac
Power PCB	Justin	Inalvis
Signal PCB	Inalvis	Justin
Drivers	Zac	Richard
Water Pump	Inalvis	Justin
Motors	Inalvis	Justin
Valves	Justin	Inalvis
Touch Screen	Richard	Zac
LEDs	Zac	Richard
Component Systems	Justin	Inalvis

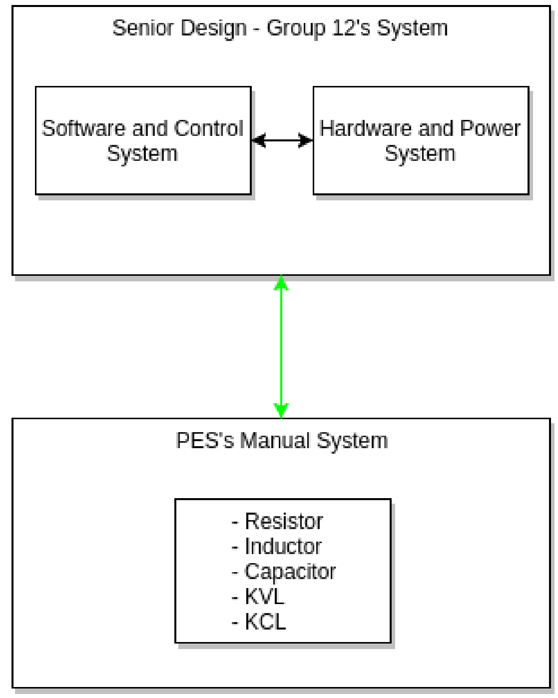

Figure 3: Block Diagram Legend

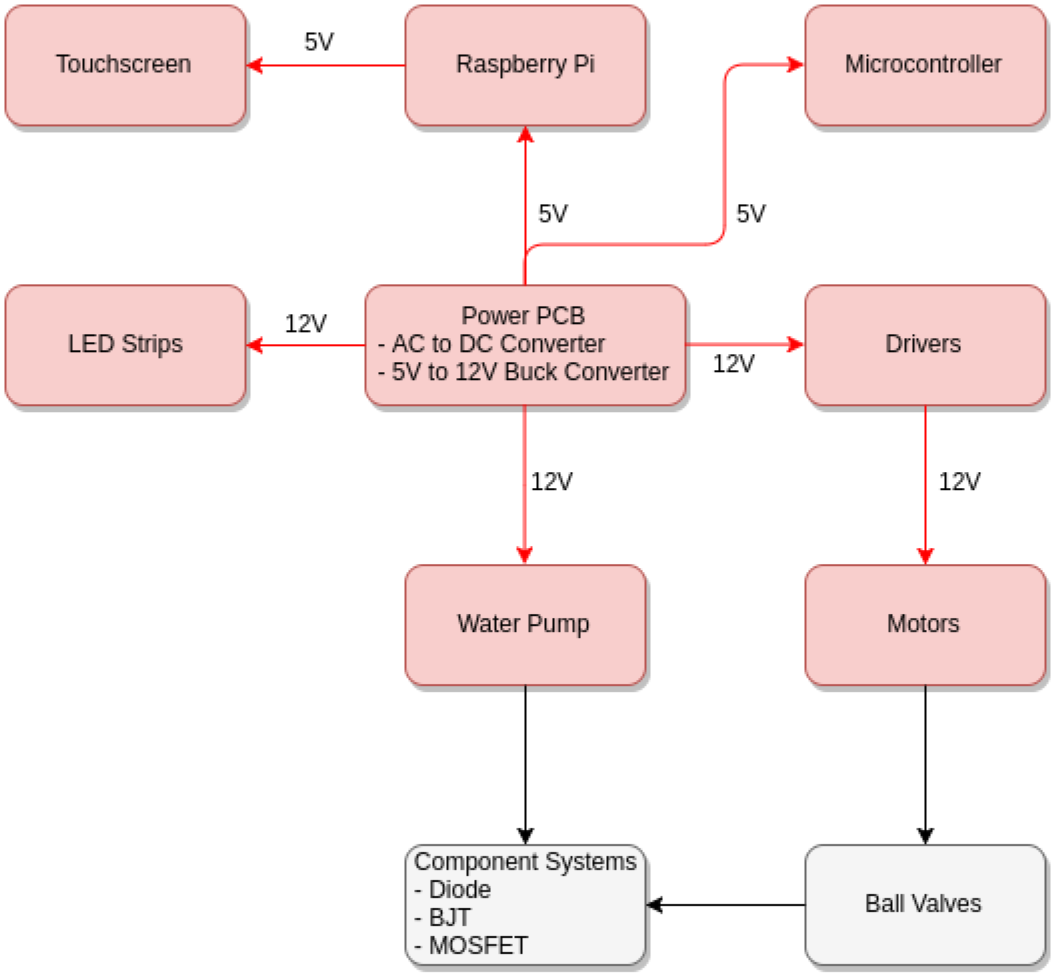

Figure 4: Hardware and Power System Block Diagram

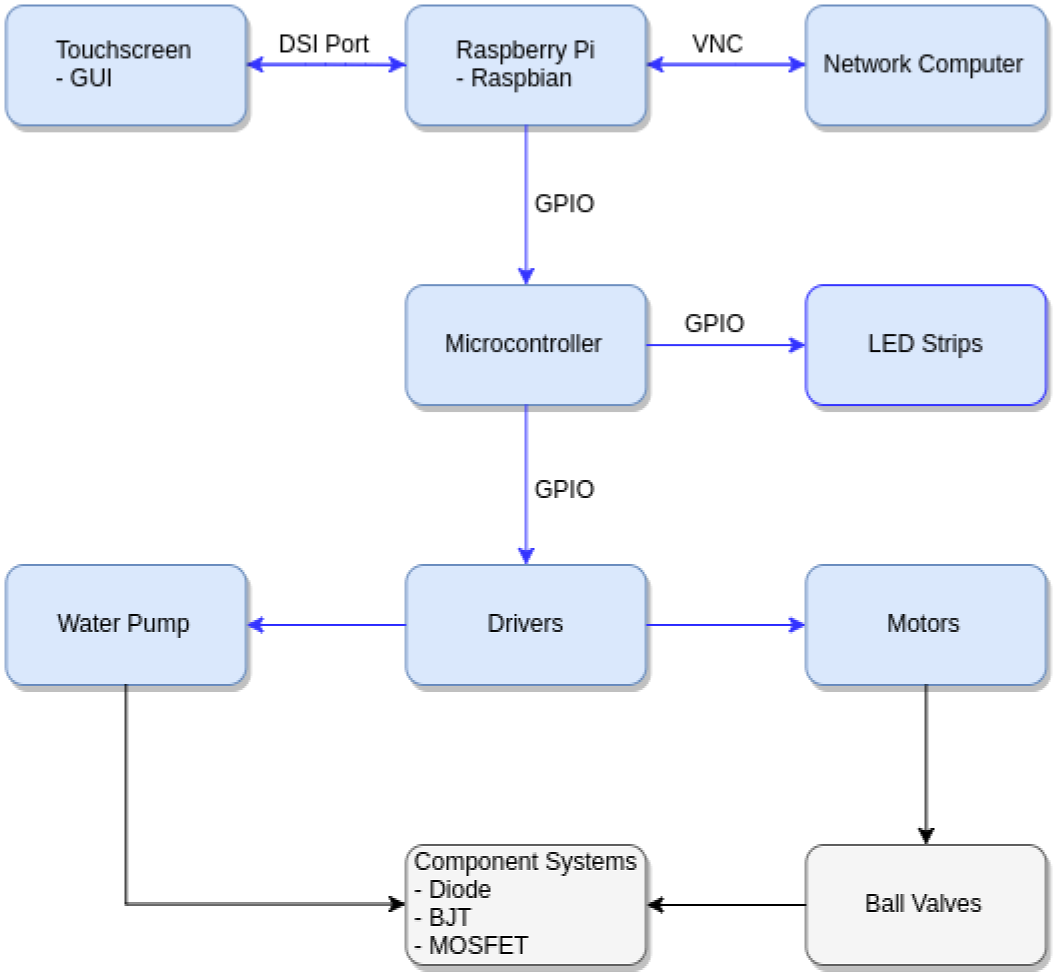

Figure 5: Software and Control System Block Diagram

Bill of Materials

The following table shows an estimated quantity of the materials needed to build the proposed project. It also contains the price per unit of each material, providing an overall project estimated cost. This estimate was created based on the current design of the project containing only the MOSFET, BJT and diode representations.

System	Description	Quantity	Price/Unit	Subtotal
Miscellaneous	Step Down Transformer (120Vrms - 12Vrms)	1	$21.34	$21.34
	Raspberry Pi 7" Touchscreen Display	1	$69.99	$69.99

	8 oz. PVC Clear Cement	1	$4.94	$4.94
	Raspberry Pi 3 - Model B - ARMv7 w/ 1G RAM	1	$35.00	$35.00
	1/2" x 520" Thread Seal Tape	1	$1.38	$1.38
	Alitove 16.4' LED Strip	4	$26.99	$107.96
	Power PCB	1	$150.00	$150.00
	Low Current Nema 23 CNC Stepper Motor 1.8A 340oz.in/2.4Nm CNC Mill Lathe Router + driver	6	$86.00	$516.00
	500 GPH Fountain Pump	1	$42.98	$42.98
	15 PSI Pressure Gauge	1	$9.66	$9.66
	1/2" Clear PVC 90 degree Elbow	3	$6.09	$18.27
	1/2" x 10' Clear PVC Pipe, Sch. 40	3	$20.74	$62.22
	1/2" Clear PVC Male Adapter 436-010L	14	$4.62	$64.68
	1 in. x 1/2 in. PVC Sch. 40 Reducer Bushing	12	$1.38	$16.56
	1/2 in. Schedule 40 PVC Tee (threaded)	5	$0.66	$3.30
	1/2 in. Male x 1/4 in. Female NPT Coupler	5	$3.98	$19.90
	1/2" Clear PVC True Union Ball Valve	1	$14.02	$14.02
BJT	1/2" x 10' Clear PVC Pipe, Sch. 40	2	$20.74	$41.48
	1/2" Clear PVC 90 degree Elbow	2	$6.09	$12.18
	1/2" Clear PVC Tee Fitting	4	$7.47	$29.88
	1/2" Clear PVC 45 degree Elbow	4	$10.24	$40.96
	1/2" NPT Polypropylene Bulkhead Fitting w/ NBR Gasket	2	$5.25	$10.50
	Fill-Rite Digital Display, In-Line Digital Meter	3	$81.00	$243.00
	1/2" Clear PVC True Union Ball Valve	2	$14.02	$28.04
	15 PSI Pressure Gauge	2	$9.66	$19.32
MOSFET	1/2" Clear PVC 45 degree Elbow	0	$10.24	$0.00
	1/2" Clear PVC 90 degree Elbow	5	$6.09	$30.45
	1/2" Clear PVC Tee Fitting	4	$7.47	$29.88
	1/2" NPT Polypropylene Bulkhead Fitting w/ NBR Gasket	2	$5.25	$10.50
	1/2" Clear PVC True Union Ball Valve	1	$14.02	$14.02
	15 PSI Pressure Gauge	2	$9.66	$19.32
	Fill-Rite Digital Display, In-Line Digital Meter	2	$81.00	$162.00
Diode	Fill-Rite Digital Display, In-Line Digital Meter	1	$81.00	$81.00
	1/2" Clear PVC True Union Ball Valve	2	$14.02	$28.04
	1/2" Clear PVC 90 degree Elbow	2	$6.09	$12.18
	1/2" Clear PVC Tee Fitting	1	$7.47	$7.47
	1/2" NPT Polypropylene Bulkhead Fitting w/	1	$5.25	$5.25

	NBR Gasket			

Estimated Total Cost	$1,983.67

Table 1: Bill of Materials

Milestones

The following table displays the milestones that have been determined by the team based on the current status of the project and block diagram.

	Description	Due Date
Spring 2018	Final Presentation	4/25/2018
	Final Product Complete	3/25/2018
	Final Checkoff	3/18/2018
	Testing	2/20/2018
	Software/Hardware Integration	2/13/2018
	Software Deliverable (Raspberry Pi Control/Application)	2/7/2018
	Hardware Deliverable	2/7/2018
	Power/ Signal PCB received	1/1/2018
Fall 2017	Order PCBs/Start Construction	12/10/2017
	Finish Designing Signal/Power PCBs	12/10/2017
	Final Paper Due	12/4/2017
	UI Completed	12/1/2017
	100 Page Submission	11/17/2017
	Finish Ordering Parts	11/10/2017
	60 Page Submission	11/3/2017
	UI Rough Draft	10/30/2017

	Finalize Motor	9/15/2017
	Autocad Design	9/8/2017
	Send out Proposal	9/8/2017
	Finish Proposal	9/5/2017

Table 2: Milestones

Remarks

Our team is designing only the BJT, MOSFET, and diode component representations of the system. However, PES is currently working on KVL, KCL, resistor, capacitor, and inductor representations. PES system will be completely manual; all the valves will be operated manually by the user instead of the user having control of the parameters through the dashboard. PES system will also not include the use of LEDs. Our collaboration with this group is simply to create two parts of a conjuncted system, therefore, both systems will have the same visual design and will be able to function together or separately. Once our system is completed, PES can adopt the system automation, LED integration and dashboard integration. The conjuncted system can be used as teaching aid that can be rented out to teachers, which makes it essential for the system to be easy to transport and have a very user friendly setup. In the meantime, the system will remain at UCF.