Electric Water Blaster
Design Document

Team #19
Clark Taylor, Jaejin Lee, John Lee

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ECE 445

TA: Rui Gong

Professor: Michael Oelze

1. Introduction

1.1
Problem Statement:

Some common problems with traditional water guns are that they rely on manual pumping and squeezing, leading to inconsistent water pressure, limited range, and user fatigue. They also provide no feedback on the water level or have any interface for the users. Our project is to build a fully electric, high-pressure water blaster that aims to fix those issues and add additional features. It will deliver consistent, controlled bursts of water while providing real-time feedback along with improved ergonomics and enhanced water resistance. We will integrate intelligent electronics with a robust mechanical system to provide a more engaging and reliable experience for users. Our solution differs from preexisting commercial products in several ways. While commercial water blasters put emphasis on the shooting ability and have no advanced integration of sensor arrays, our model is designed to detect internal leaks and alert the user in real time using various sensors. By combining our innovative features and mechanical design, users can expect a user-friendly, engaging, and reliable experience.

Solution:

Some common problems with traditional water guns are that they rely on manual pumping and squeezing, leading to inconsistent water pressure, limited range, and user fatigue. They also provide no feedback on the water level or have any interface for the users. Our project is to build a fully electric, high-pressure water blaster that aims to fix those issues and add additional features. It will deliver consistent, controlled bursts of water while providing real-time feedback along with improved ergonomics and enhanced water resistance. We will integrate intelligent electronics with a robust mechanical system to provide a more engaging and reliable experience for users. Our solution differs from preexisting commercial products in several ways. While commercial water blasters put emphasis on the shooting ability and have no advanced integration of sensor arrays, our model is designed to detect internal leaks and alert the user real time using various sensors. By combining our innovative features and mechanical design, users can expect a user-friendly, engaging, and reliable experience.

1.2
Visual Aid:

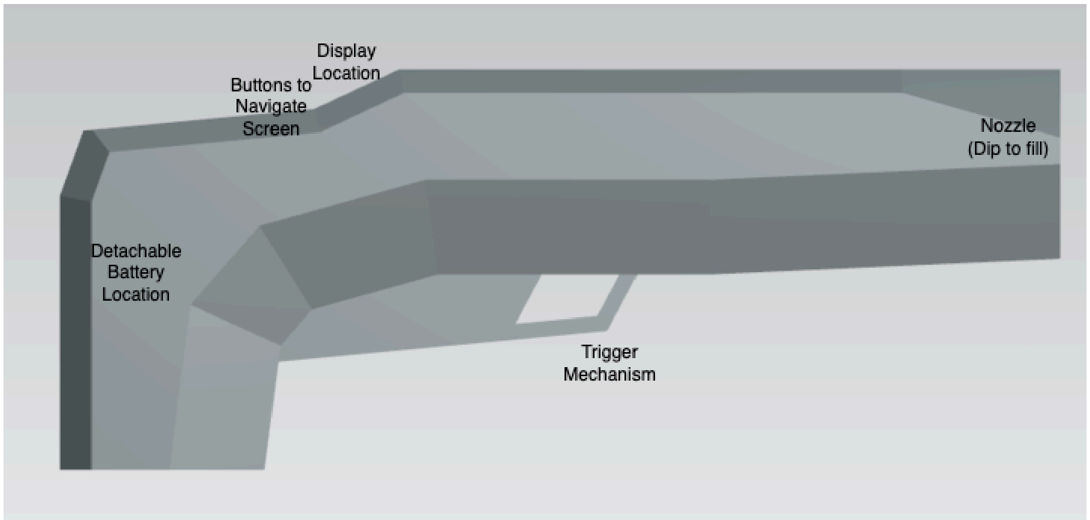

Figure 1: High-level prototype

1.3
High Level Requirements:

1. The blaster should consistently shoot water bursts covering a distance of over 20ft.
2. The blaster must be lightweight with a total weight not to exceed 10lbs.
3. The display must accurately reflect the state of the state machine and update in under 1 second to ensure accurate data is displayed.

2. Design

2.1
Block Diagram:

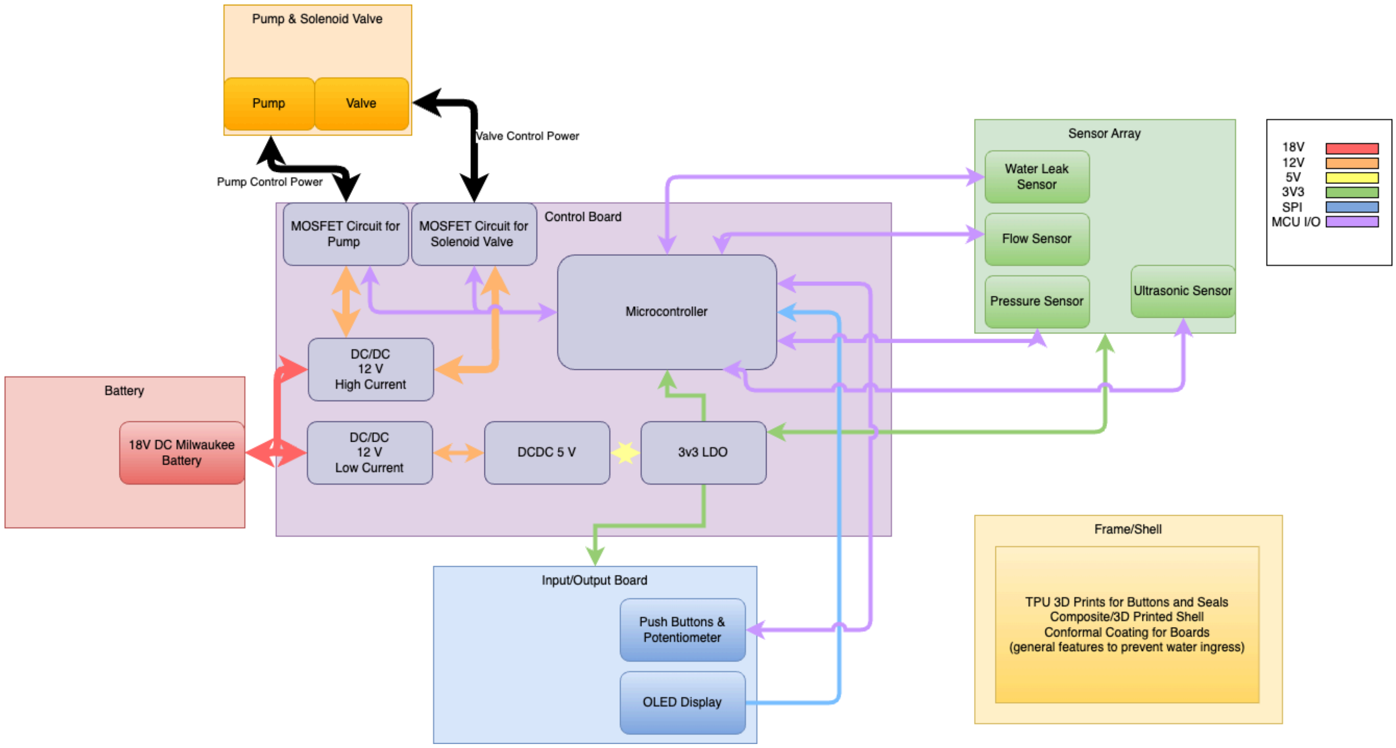

Figure 2: Electric Water Blaster Block Diagram

2.2 Subsystems:

Subsystem 1: Control Board

Function Description:

The control board is the brain of the system, processing data from sensors and user inputs and controlling the operation of other subsystems. It coordinates the flow of information from the sensor array, user I/O, and the pump and solenoid valve. The control board uses a microcontroller (STM32G070KBT6) to execute the state machine that determines system behavior based on sensor data and user commands. The control board manages key operations like adjusting water pressure, activating the solenoid valve for bursts, and updating the SPI display to show real-time status.

Contribution to the Overall Design:

The control board is essential to managing the functionality of the water blaster. It ensures that the system responds to user inputs (via the I/O subsystem) and sensor data (from the sensor array) in real-time. The accurate processing of inputs and controlling outputs to the pump, valves, and display is necessary to meet the high-level system requirements of burst accuracy, user interaction, and safety monitoring.

Interfaces:

- **Inputs:** Sensor data from the Sensor Array (e.g., water level, pressure, leak detection).
- **Outputs:** Enable signal to the pump and solenoid valve MOSFET circuit, update signals for the SPI display.
- **Power Requirements:** Must receive at least **3.3 V**

Subsystem 2: Input & Output (I/O)

Function Description:

The I/O subsystem allows the user to interact with the water blaster. It consists of a display for showing system status (e.g., water fill level, pressure, firing mode) and user controls such as buttons and potentiometers. The user inputs allow for adjustments in firing power, burst length, and mode, ensuring that the system can be customized based on the user's preferences. The push button is used to trigger the water blaster's firing action. The system continuously sends user input data to the control board, which processes it and adjusts the system accordingly.

Contribution to the Overall Design:

The I/O subsystem contributes by allowing the user to control the water blaster's operation in an intuitive and customizable way. It provides real-time feedback and manual overrides, ensuring the system's flexibility and user-friendliness. If the user cannot interact with the system effectively, the design would fail to meet its high-level requirement of customizable operation.

Interfaces:

- **Inputs:** Push button trigger, potentiometer (adjust firing power), buttons (mode selection).

- **Outputs:** Display update signals to the SPI display, control signals to the control board for changing firing mode and power.

Power Requirements:

Must receive at least **3v3 V** to ensure display and buttons work correctly. Total current consumption should not exceed **300 mA**.

Subsystem 3: Battery

Function Description:

The battery subsystem powers the entire water blaster, supplying the necessary energy to all components, including the pump, solenoid valves, and control board. The system uses a rechargeable tool battery (e.g., Milwaukee® M18™) for high current capabilities, which is stepped down to the required voltage by a DC-DC converter. The battery must be able to supply enough energy to the system during extended use, ensuring the system operates continuously for a desired duration without significant power drops.

Contribution to the Overall Design:

The battery is critical for ensuring that the system remains operational for long enough to meet the requirements of burst power, sustained performance, and user interaction. If the battery cannot supply sufficient current or energy, the system will fail to operate effectively. The battery ensures portability and independence from external power sources.

Interfaces:

- **Inputs:** Battery Voltage (monitored by the control board).
- **Outputs:** Power distribution to control board

Power Requirements:

The battery should output **18 V** and provide at least **10 A** of current to support all components simultaneously.

Subsystem 4: Frame & Shell

Function Description:

The frame and shell of the water blaster provide structural support and protection for the internal components. It prevents water ingress and ensures that all components are securely housed. The frame is made from 3D-printed or composite materials, which offer a lightweight yet durable solution. TPU-sealed buttons and NPT fittings are incorporated to prevent leaks. A conformal coating protects the electronics from potential moisture exposure.

Contribution to the Overall Design:

The frame and shell are essential for protecting sensitive components from water damage and providing a durable and ergonomic housing. The structural integrity of the shell ensures that all subsystems remain securely in place and safe from external forces. Without a proper enclosure, the system could be damaged or rendered inoperable due to exposure to water.

Interfaces:

- **Inputs/Outputs:** None (structural component).
- **Power Requirements:** No power input.

Subsystem 5: Sensor Array

Function Description:

The sensor array provides essential feedback to the system regarding the water blaster's operation. It monitors water levels, leak detection, and pressure, providing real-time data to the control board. This data ensures that the system operates safely and efficiently. If a leak is detected, the control board will trigger a shutdown or warning signal to prevent further damage. The water level and pressure sensors help maintain optimal performance, while additional sensors can be added for further performance tuning.

Contribution to the Overall Design:

The sensor array contributes to the overall safety and efficiency of the water blaster. It ensures that the system never operates beyond safe limits, and it provides the control board with crucial information to adjust operations dynamically. Without this feedback, the system may operate unsafely or inefficiently.

Interfaces:

- **Inputs:** Water level, leak detection, and pressure sensor data to the control board.
- **Outputs:** Feedback to the user via the I/O subsystem and updates to the control board for safety management.

Power Requirements:

The sensors will require **3.3 V** and **15 mA** of current to operate effectively.

Subsystem 6: Pump, Solenoid Valve & Tank

Function Description:

This subsystem is responsible for pressurizing and delivering water through the system. The 12V diaphragm pump pressurizes the water to the required level, while the fast-actuating solenoid valve releases water in short bursts. The tank stores pressurized water, and its operation is monitored to ensure safe performance. The subsystem works closely with the control board to deliver precise water bursts when triggered by the user.

Contribution to the Overall Design:

The pump, solenoid valve, and tank subsystem are crucial for the water blaster's core functionality—delivering pressurized bursts of water. The accurate pressurization and controlled release of water are essential to achieving the performance required by the user, and any failure in this subsystem will lead to an inoperable water blaster.

Interfaces:

- **Inputs:** Control signals from the control board to activate the pump and solenoid valve.
- **Outputs:** Water is released via the solenoid valve to the nozzle.

Power Requirements:

The pump and solenoid valve should operate on **12 V** and draw **9 A** of current during operation.

2.3 Requirements and Verifications:

Subsystem 1 Control Board Requirements:
System Responsiveness: The control board must process inputs and update outputs within 100 ms of receiving sensor data.

Verification: Observe system behavior with button presses and sensor inputs to ensure there is no noticeable lag.

Reliable Actuation: The control board must activate the pump and solenoid valve correctly 100% of the time when triggered.
Verification: Run 50 activation cycles and verify that all commands result in the expected action.

Display Communication: The control board must correctly send data to the SPI display without noticeable glitches or missing updates.
Verification: Operate the system for 5 minutes, ensuring that display information updates smoothly without flickering or freezing.

Subsystem 2 Input & Output (I/O) Requirements:
Button Functionality: The trigger button must activate the water blaster every time it is pressed, with no missed inputs (it will either fire or display that the state does not allow firing).

Verification: Press the button 50 times and confirm that every press results in activation of some sort.

Potentiometer Adjustment: The potentiometer must allow smooth control over firing power with noticeable differences between minimum and maximum settings.

Verification: Adjust the potentiometer and confirm that different power levels produce visibly different water blasts, the water quantity can be measured using a beaker to ensure quantity of water fired has increased.

Subsystem 3 Battery Requirements:

Power Capacity: The battery must power the system for at least 30 minutes of continuous firing operation.

Verification: Fully charge the battery, operate the system continuously, and record runtime on a stopwatch.

Voltage Regulation: The battery system must provide a stable 12V +- 1V output under normal load.
Verification: Measure voltage before and after 10 minutes of operation to ensure no significant drop.

Safe Connection: The battery must not overheat or disconnect unexpectedly during operation.
Verification: Run the system for 30 minutes and ensure the battery remains securely attached and does not overheat. (Can run concurrently with Subsystem 3 verification #1)

Subsystem 4 Frame & Shell Requirements:
Water Resistance: The enclosure must prevent leaks when sprayed with water from all angles for 5 minutes.

Verification: Spray test the assembled device and inspect for internal moisture. Ensure a maximum of 15ml of water ingress.

Durability: The shell must not crack or deform if dropped from 1 meter onto grass or pavement.

Verification: Drop test from 1 meter height and confirm no functional damage.

Subsystem 5 Sensor Array Requirements:
Water Level Detection: The system must accurately indicate the capacity of the tank within 25%.

Verification: Fill and empty the tank to these levels and confirm the display updates correctly with the indicated water level after water in/water out is measured.

Leak Detection: The system must alert the user within 10 seconds of detecting internal water leakage.

Verification: pour 100ml of water into the system, hold the water blaster vertically as if in firing position. The system should shut down within 10 seconds of the blaster being held vertically, or never power on to begin with. Time with a stopwatch to ensure timely powerdown sequence.

Subsystem 6 Pump, Solenoid Valve & Tank Requirements:

Pump Functionality: The pump must fill the tank from empty within 30 seconds.

Verification: Time how long it takes to fill the tank and ensure it meets the requirement using a stopwatch. Ensure the tank is completely empty prior to this test.

Solenoid Valve Timing: The valve must open and close within 100 ms of being triggered.

Verification: Fire the blaster and use a stopwatch to time the delay between button press and water visibly leaving the blaster. It should be within 100ms.

Firing Power Consistency: The blaster must shoot water at least 15 feet when fully pressurized, a maximum shot distance of 20 feet should be able to be recorded in at least one running configuration.

Verification: Fire the blaster and measure the distance reached. Tune to achieve 5 powerful bursts and record the distance to ensure 15 feet is recorded. Then refill and tune the settings for the maximum power and fire one shot to ensure 20 feet is recorded.

2.4
Tolerance Analysis:

Since we want the water blaster to achieve a minimum range of 20 feet (6.1 meters), we can find our desired velocity at the optimal angle of 45 degrees to be at least ***7.75 m/s*** using

$$R = v^2 sin(2\theta)/g$$

Water Pressure:
The water pressure from the pump determines the initial velocity of the water stream. The velocity of the water stream can be calculated using Bernoulli's equation:

$$v = \sqrt{\frac{2P}{\rho}}$$

Where
P = pressure in Pa

$\rho = 1000 kg/m^3$

Tolerance:
Our system will operate at a nominal pressure of 30 PSI ($\pm\ 5\ PSI$).
The pressure change will lead to proportional velocity change. For example, a 5 PSI drop will reduce the range by approximately 1.25 feet.

Nominal Pressure (30 PSI)

$$P = 30 * 6895 = 206,850 Pa$$

$$v_{nominal} = \sqrt{\frac{2*206,850}{1000}} = \sqrt{413.7} = 20.33 m/s$$

Worst Case Pressure Drop (25 PSI)

$$P = 25 * 6895 = 172,375 Pa$$

$$v_{nominal} = \sqrt{\frac{2*172,375}{1000}} = \sqrt{344.75} = 18.57 m/s$$

The calculation above is ideal and depending on our nozzle design and air resistance, the actual velocity out of the blaster would be a lot slower. If the projectile speed is too fast after intial design, we will downgrade our blaster by decreasing the pressure accordingly while still meeting our high-level requirement.

3. Cost and Schedule

3.1

Cost Analysis:

Item	Quantity	Description	Note/Cost
1	2	CAP CER 1UF 10V X5R 0603	In digi order
2	1	CAP CER 10UF 100V X5R 0603	In digi order
3	2	CAP CER 4.7UF 50V X5R 0603	In digi order
4	1	LED BLUE CLEAR 0603 SMD	In digi order
5	1	LED RED CLEAR 0603 SMD	In digi order
6	1	LED YELLOW CLEAR 0603 SMD	In digi order
7	1	LED GREEN CLEAR 0603 SMD	In digi order
8	1	3220-10-0100-00	In digi order
9	1	1231AS-H-120M=P3	In digi order
10	1	RES SMD 0 OHM 5% 1/4W 0603	In digi order
11	10	RES SMD 1K OHM 5% 1/10W 0603	In digi order
12	6	RES SMD 10K OHM 5% 1/10W 0603	In digi order
13	1	AZ1117EH-3.3TRG1	In digi order
14	1	Solenoid Valve	EST COST: 30
15	1	Pump	EST COST: 80
16	1	Cherne 2IN Expandanble Bladder	69.89
17	1	OLED Display NewHavenDisplay Blue	36.27
18	1	Conformal Coating MG Chemical	19.76
19	1	MISC 3D Printer Filament	EST COST: 100
20	1	Tubing and Misc Fittings	EST COST 50
21	1	Check Valve Water/Fuel/Air	21.49
22	1	Wiring Spool	EST COST 10
23	5	PCB from JLC PCB	21.37

Table 1: Item and Cost

(Digi order total + all parts in BOM above)
Cost Including DigiPart Order: $547.36.
Labor Cost: Each team member will receive $45 an hour, working 25 hours a week. We expect the project to take 5 weeks to complete.
45 x 25 x 5 x 3 = $16,875

Total Cost: $16,875 + $547.36 = $17,422.36

3.2
Schedule:

Product roadmap			
Project	Status	Assignee	Notes
PCB Sent Out	In progress	Clark	Week 8
Basic Firmware Setup	In progress	John	Week 8
CAD Review	In progress	Jaejin	Week 8
PCB Assembly Power	Not started	Clark	Week 9
PCB Assembly Control	Not started	John	Week 9
PCB Assembly MCU	Not started	Jaejin	Week 9
PCB Testing Power	Not started	Clark	Week 10
PCB Testing Control	Not started	John	Week 10
PCB Testing MCU	Not started	Jaejin	Week 10
CAD Enclosure	Not started	Clark	Week 11
Firmware OLED	Not started	John	Week 11
Firmware Buttons	Not started	Jaejin	Week 11

Product roadmap			
Project	Status	Assignee	Notes
Print Enclosure	Not started	Clark	Week 12
Firmware Testing on Bench	Not started	John	Week 12
GUI Testing on Bench	Not started	Jaejin	Week 12
Final Integration	Not started	Clark	Week 13
Validation Efforts	Not started	John	Week 13
Validation Efforts	Not started	Jaejin	Week 13
Fix any issues	Not started	Clark	Week 14
Fix and issues	Not started	John	Week 14
Fix and issues	Not started	Jaejin	Week 14
Fix any issues & Finalize Documentation	Not started	Clark	Week 15
Fix any issues & Finalize Documentation	Not started	John	Week 15
Fix any issues & Finalize Documentation	Not started	Jaejin	Week 15

Table 2: Product Schedule

4. Ethics and Safety

We will commit to adhering to the IEEE and ACM Codes of Ethics in designing the electric water blaster, which will allow us to ensure ethical considerations and safety for all users and bystanders. Section l.1 of the IEEE Code of Ethics tells us the importance of prioritizing the safety, health, and welfare of the public, and that will form the foundation of our approach. We will be able to create a safe product while upholding honesty and fairness by integrating those principles stated.

We are implementing several safety measures to mitigate potential dangers that can come from the product. The water pressure will be calibrated to levels that are appropriate for a toy water blaster, making sure that there is no risk of physical harm, especially knowing the majority of the users will likely be children and teenagers. Additionally, comprehensive testing will be done to ensure the mechanical components are safe and reliable. The materials used will be non-toxic, which will safeguard users from harmful substances. Furthermore, we are taking a step further in the electrical department to prevent electrical water hazards. The water blaster will feature an auto shut-off mechanism that activates when water leakage is detected. Electrical components are going to be securely enclosed to eliminate the risk of short circuits and electric shocks.

Our design also complies with relevant safety standards and regulations. For example, we are adhering to ASTM F962, which is the standard Consumer Safety Specification for Toy Safety, to ensure the product meets the industry requirements. We will also reference OSHA (Occupational Safety and Health Administration) guidelines to ensure workplace safety during the development process. The compliance will ensure we’ll follow electrical safety standards such as proper grounding, insulation, and safe handling of electrical components.

The development of our product will have all of the ethical and safety considerations incorporated along with thoughtful design decisions that prioritize the well-being of users. These measurements will mitigate potential dangers and reflect our commitment to producing a reliable and ethical product.

5. Citations

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