Electric Water Blaster

Team #19

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ECE 445

Introduction:

Problem:

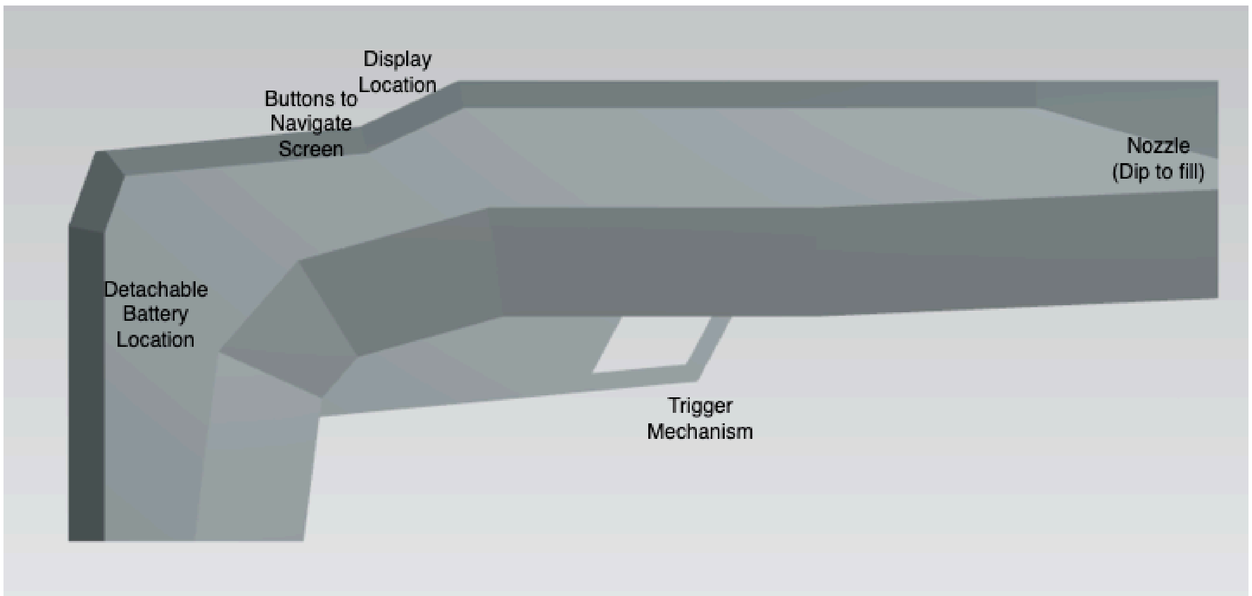
Common problems with traditional water guns are that they rely on manual pumping and squeezing, leading to inconsistent water pressure, limited range, and user fatigue. They also provide no feedback on the water level or have any interface for the users. Our project is to build a fully electric, high-pressure 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.

Solution:

For our project, we will develop an electric water blaster. At a high level, it will have a 12V DC electric pump. The pump will fill the tank and pressurize the water up to 60 PSI. A solenoid valve will control the release of water to allow it to fire powerful bursts of water.

Our project will make use of an array of sensors to detect internal leaks and the current water level of the tank. The water blaster will also feature an OLED display which will display the current state (filling, firing, idle, etc) of the water blaster to the user so they can understand what is happening at all times. The OLED display will also display the fill level of the water blaster so the user knows how many bursts of water remain in the tank. There will also be buttons below the OLED to allow the user to navigate through the menus and make adjustments to the firing logic of the water blaster. We plan to power the water blaster through an off-the-shelf battery, likely from electric tools due to its more durable and high output characteristics. A microcontroller will be responsible for monitoring the sensors, changing the state, and ultimately controlling the output through the use of the solenoid valve and the electric pump.

Visual Aid:

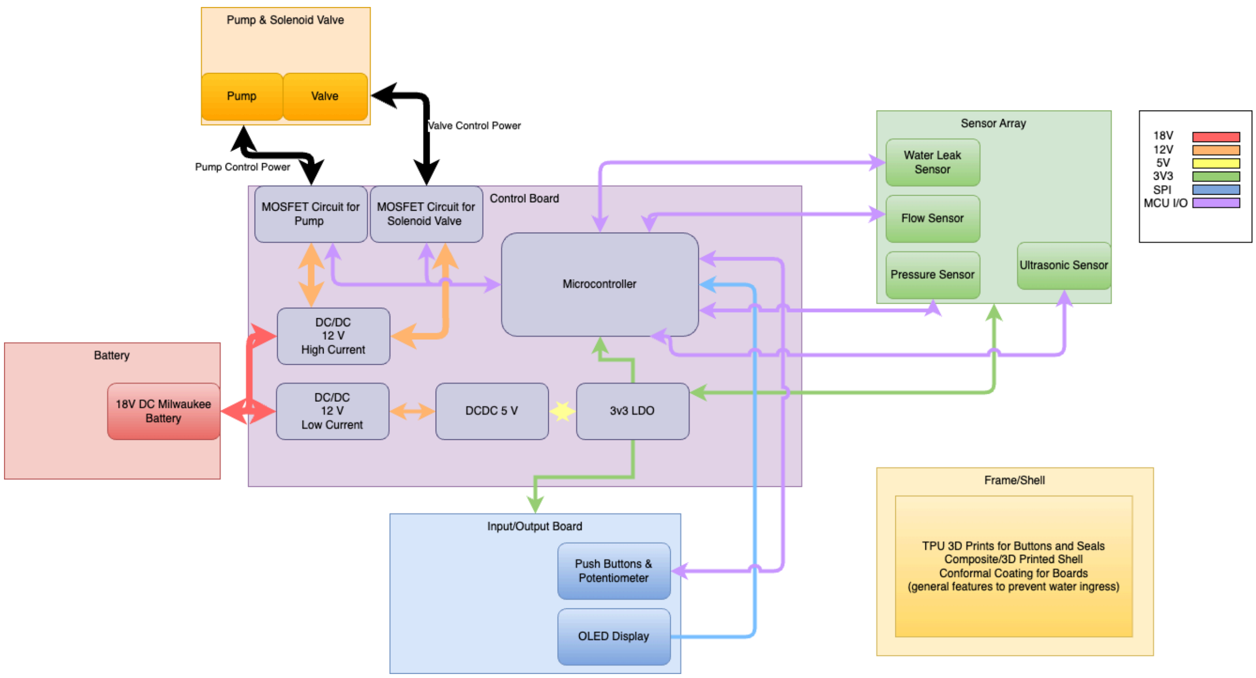


High-level requirements list:

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

Design

Block Diagram:



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**

Requirements:

1. **Power Supply:** Must operate with a voltage range of **3 V** to **4 V** and consume <**300 mA** of current for reliable operation.
2. **Data Processing:** Must be able to process sensor data at a frequency of **X Hz**.
3. **Control Accuracy:** Must control the solenoid valve with a response time of <**200 ms**.
4. **Display Interface:** Must interface with the SPI display to update in real-time with a response time of **<200 ms**.

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**.

Requirements:

1. **Display Update Rate:** Must update the display at least one time every **1 second** based on new sensor data.
2. **Button Interface:** Must register button presses with a response time of **<200 ms**.
3. **Potentiometer Sensitivity:** Must detect changes in potentiometer values with accuracy within **10%**.

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.

Requirements:

1. **Voltage Output:** Must provide a stable voltage of **18 V** (nominal) with a tolerance of **±15%**.
2. **Current Output:** Must be capable of supplying at least **10 A** continuously without excessive voltage drop.
3. **Run Time:** Must power the system for at least **30 minutes** of continuous operation.

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.

Requirements:

1. **Waterproofing:** Must prevent water ingress for being submerged for 5 seconds
2. **Impact Resistance:** Must withstand impacts from drops of up to **1 meters**.
3. **Weight:** Must weigh no more than **10 lbs** to ensure portability.

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.

Requirements:

1. **Water Level Measurement:** Must report water levels with an accuracy of **±.5 L**.

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 release 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.

Requirements:

1. **Pressure Generation:** Must generate a minimum pressure of **20 PSI** at the pump output.
2. **Burst Control:** The solenoid valve must open and close within **200 ms** of receiving a control signal.

Risk Analysis

Implementing the sensor array - specifically leakage detection - will be the most difficult. We would need to cover multiple potential leakage points such as near the water tank and the pump and valve to properly detect leaks. We also need to ensure that the sensors are accurate and that there are no false positives.– from condensation.

Tolerance Analysis: To minimize the risk of false positives, our model should operate within the following environmental conditions:

- **Temperature:** 32 to 122 degrees Fahrenheit
- **Humidity:** Up to 95%

Despite the difficulty and tolerance, we aim our water tank leakage detection to be complete - detecting any leakage in the water tank if the event arises.

Ethics and Safety:

We are going to ad~~d~~here to guidelines from the IEEE and ACM codes of Ethics to ensure the safety consideration of the electric water blaster. While it may be a toy, it is still important to consider the safety aspects of it. By following the principles, we can ensure that the project does not pose any risks to users and bystanders~~,~~ and that it upholds honesty and fairness.

For example, the IEEE Code of Ethics, Section I.1 emphasizes the importance of holding paramount the safety, health, and welfare of the public. For our product, we need to ensure the functionality does not pose any risks to users, especially children. It will go to proper testing and adherence to safety standards to prevent injuries from the mechanical and electrical components of the design.

Our product will have water pressure that is appropriate for a toy water blaster to prevent a risk of injury. We'll also ensure that the materials used are non-toxic and that all electrical components are in a safely enclosed box to prevent shocks and short circuits. To prevent electrical danger, we are implementing an auto shut-off mechanism when the water blaster detects a leakage. The product's safety will be guaranteed by adhering to toy safety standards