Turbocharger Controller Project Proposal

ECE 5780

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Project Background:

One common problem in aviation is that combustion engines lose power at high altitudes due to the decreased air density. Turbochargers provide a solution to this by harvesting energy from the engine's exhaust to compress the intake air. This increases the density, and allows for more fuel to be burnt at high altitudes.

One challenge with this type of system is that the turbocharger can pressurize the air too much, causing the engine to experience extreme stresses. This is mitigated using a waste-gate valve. Essentially, pressurized air is allowed to escape to the atmosphere, instead of into the engine intake. In cars, a mechanical piston can be utilized to control the position of this valve. The piston measures the relative pressure between the outside air, and the compressed intake air. When the intake air is a certain pressure above the outside air, the piston opens the valve. This technique does not work in an aircraft, however. Since the outside pressure can be very low due to high altitudes, the valve would be stuck in an open position the majority of the time. A different solution is needed.

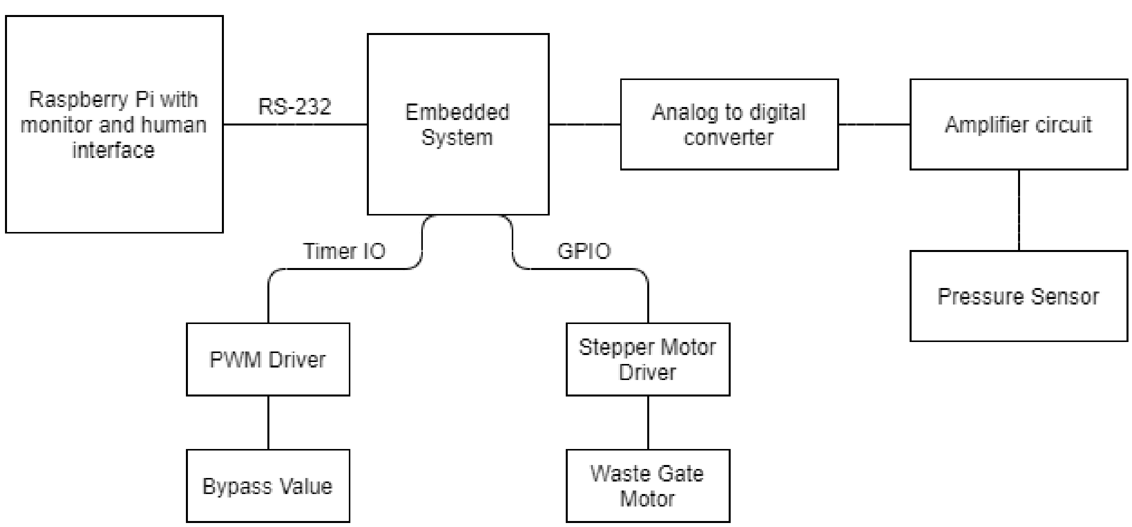
Abstract:

The goal of this project is to design an embedded system that measures the absolute pressure created by the turbocharger, and actuate two valves to maintain the pressure below a value set by the pilot.

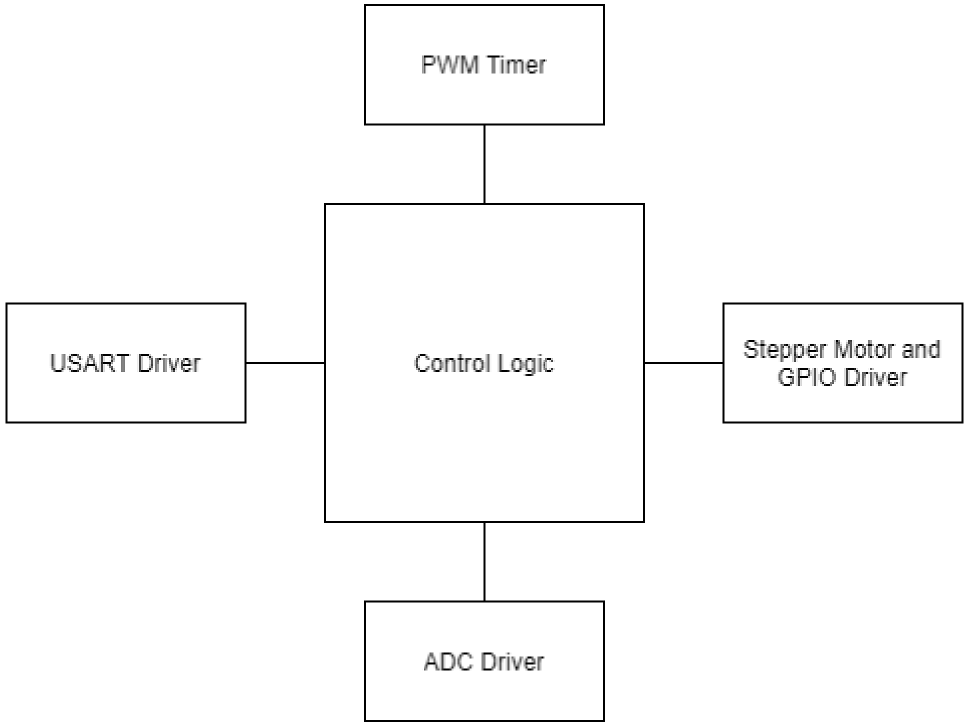
Technical Specification:

- The pressure setting will be sent via an RS232 from an external human interface device (Raspberry Pi with display and mouse). It will be converted to a 3.3 Volt UART connection through the use of a MAX3232.
- The first valve, the bypass valve, is a 12V solenoid that is pulse width modulated at 32Hz. This will be controlled by an onboard timer that drives an external MOSFET to switch the higher voltage signal.
- The second valve, the waste-gate valve, is manipulated through a NEMA 17 Stepper motor. This will be driven by two GPIO pins, and an A4988 motor driver.
- The pressure sensor is an analog whetstone device, whose reading will be amplified through a differential op-amp circuit, and then fed into an onboard ADC.
- A NUCLEO-L412KB will be utilized as the microcontroller.
- A custom circuit board will be created to house the amplification and driving circuitry, with connectors to interface with the valves, pressure sensor, and RS232 link.

Hardware Block Diagram:



Software Block Diagram:



Milestone achievements:

1. RS232 and Stepper Motor Driver Integration
    - Send and receive dummy data (pressure readings, desired pressure, valve positions) between the embedded system and the raspberry pi.
    - Configure general purpose input output pins to drive a stepper motor using the A4988.
2. PWM Integration
    - Configure a timer to produce a 32Hz PWM signal.
    - Step the logic level signal up to a 12V power signal using a MOSFET driver.
3. Pressure Sensor Integration
    - Design an amplification stage for the pressure sensor to scale to 0-3.3V

- Configure an analog input to accept the signal.
- Calibrate the pressure sensor to known pressure values.

4. Final integration testing and demo
   - Integrate the RS232 link to actuate the valves, send pressure readings (transition from dummy data).
   - Verify overall functionality.