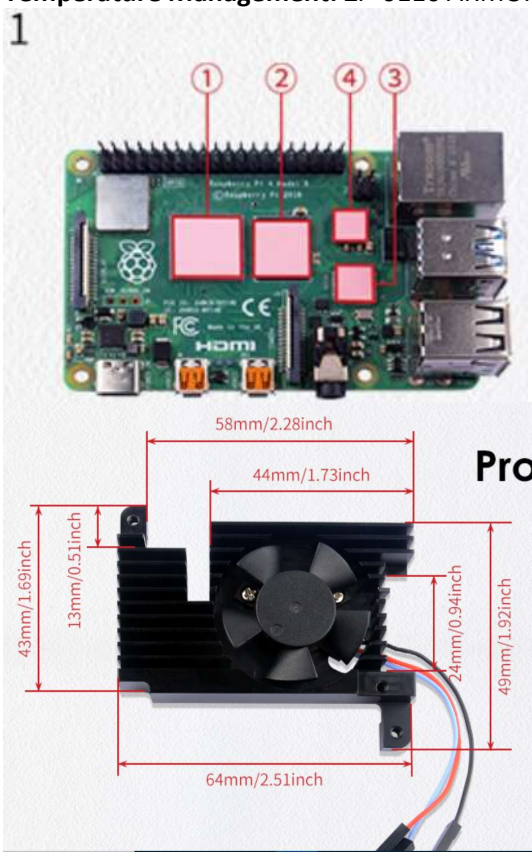
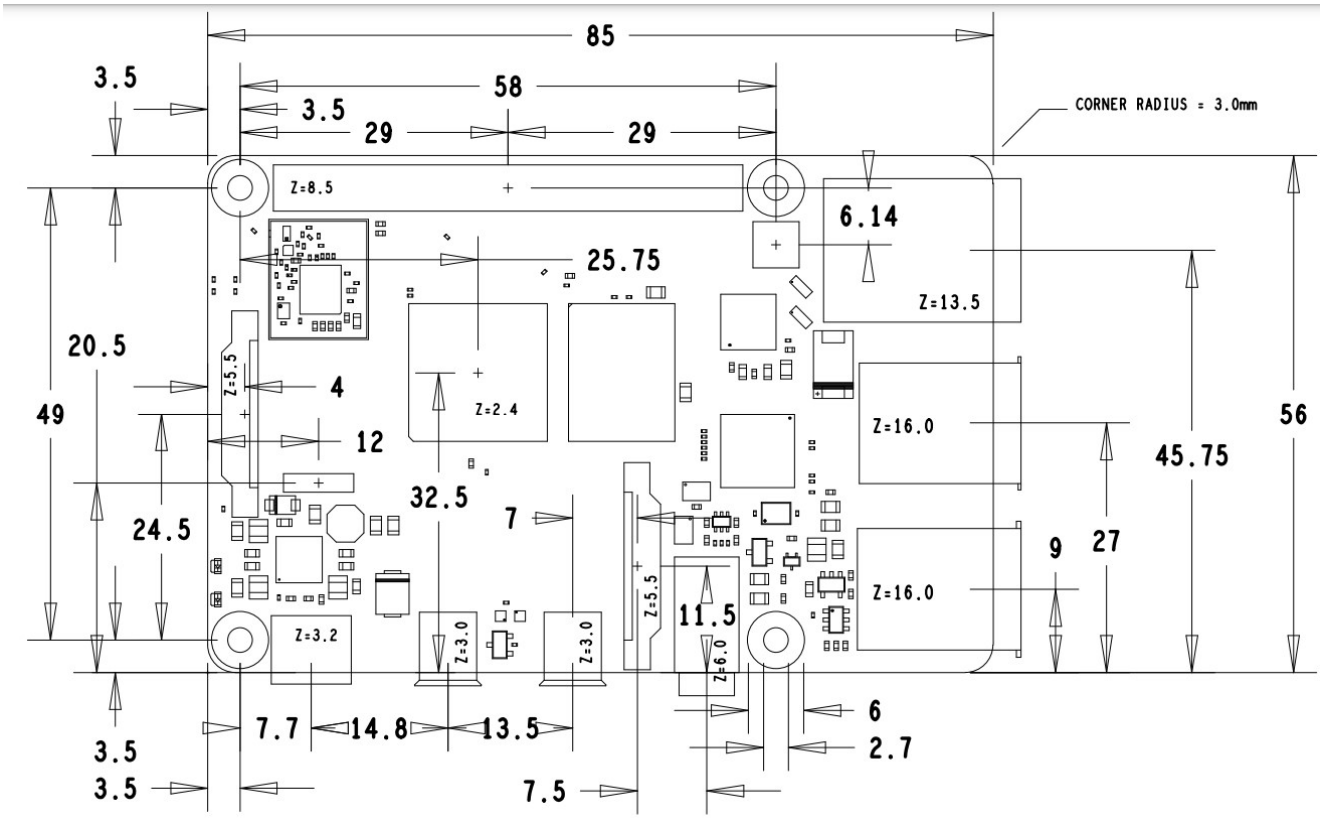
Signoff Request - April 4th, 2022 - Navigation (Main MCU)

Saturday, April 2, 2022 10:25 AM

This signoff request is for the Main MCU for the Autonomous Crawl Space Inspection Robot. This main MCU resides in the "Navigation Subsystem" on our block diagram and will be responsible for processing sensor information which is input from all navigation sensors. The main MCU will also be responsible for outputting the calculated movement protocols to the movement subsystem and for storing the recorded characteristics of the crawl space environment. The 4 GB Raspberry Pi 4B Model has been selected due to its processing capabilities which are made possible by its processor, RAM, and storage. The 4 GB Raspberry Pi 4B also includes 26 GPIO pins which can be used to collect sensor information and directly execute command signals to external hardware components and initiate master-slave communication with other microcontrollers. The needed technical information for why the Raspberry Pi is a proper fit for this project, as well as techniques for properly mitigating the risks of using the Raspberry Pi, are listed below.

Temperature Management: ZP-0110 ARMOR LITE HEAT SINK WITH PWM FAN (114992661 on digikey)





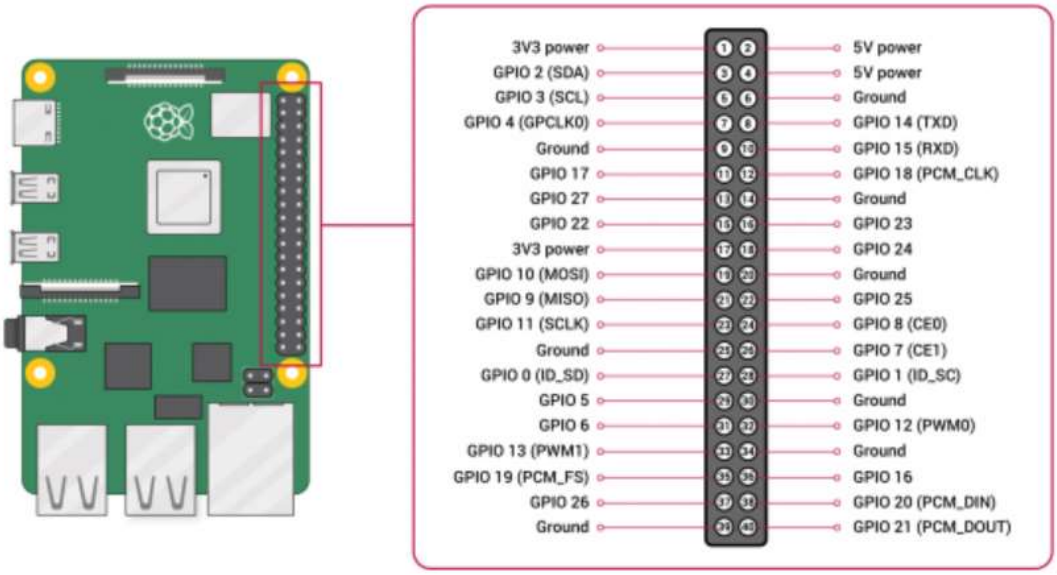
This product consists of a 3510 DC Fan along with heat sink regions over the CPU, memory chip, USB controller, and an ethernet controller. This provides heat dissipation on all processors which have the chance of getting hot. The specific 114992661. It can also be seen from the dimensioned figure that the fan dimensions match the raspberry pi dimensions meaning it will fit on the top correctly. PWM is also featured which can allow fan speed to be variably controlled based on the current heat of the CPU.

The DC Fan can be connected to the GPIO pins on the Pi, and can then be enabled in the terminal as well as creating a python program to control the fan when a certain temperature is reached. This operates the same way a thermostat would in a home, so the team will be able to directly control the fan's output. An example of a python program to control the fan can be found at https://wiki.52pi.com/index.php?title=ZP-0110. The fan connects to GPIO 14 for the motor control, and the Power and Ground wires will connect to 5V and Ground pins on to the Pi.

Hardware Connections and Capabilities:

The Raspberry Pi 4B 4 GB model uses the BCM2711 Quad-Core 64-Bit ARM Processor which can operate at a speed of 1.5 GHz. The Raspberry Pi 4B 4 GB model uses 4 GB of LPDDR4-2400 SDRAM. SDRAM is RAM and has 80 KB cache. The SD storage of the device is dependent on the size of the microSD card, with most devices commonly including a 32 or 64 GB card. The pin layouts of the Raspberry Pi are described in the following and are shown in the pictures below:

Raspberry Pi 4B Pinout: https://learn.sparkfun.com/tutorials/introduction-to-the-raspberry-pi-gpio-and-physical-computing/gpio-pins-overview



26 GPIO Pins
4 PWM pins with only 2 PWM channels meaning only two devices can be controlled at once. This is why a separate MCU will be used for the motor control.
2 5V pins, 2 3.3V pins, 8 ground pins
2 pins for EEPROM
SPI, I2C, and Serial Capabilities - Provides standard bus communication protocols for data received from multiple peripherals.
3 USB ports
2 Micro HDMI Ports
Ethernet

The current plan accounts for a spinning LIDAR sensor, an IR sensor and 4 ultrasonic sensors which will take 9 GPIO pins and a USB port. This means there are plenty of pins available for the necessary communications along with the bus communication needed to receive information from the environmental sensing subsystem.

Schematic - https://datasheets.raspberrypi.com/rpi4/raspberry-pi-4-reduced-schematics.pdf

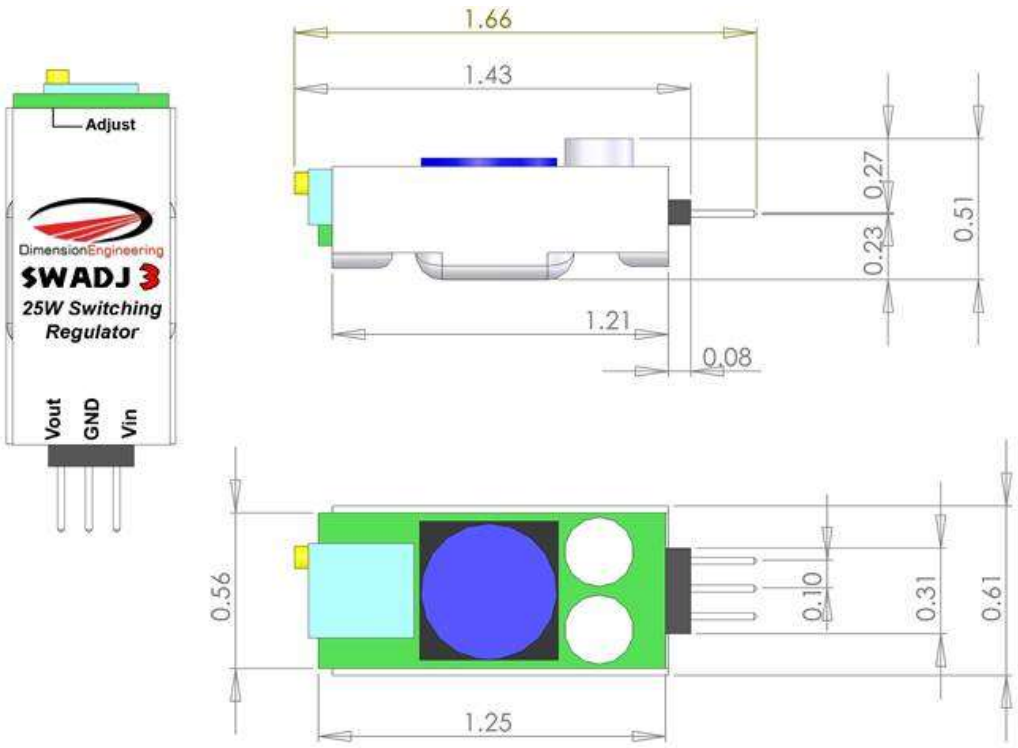
Processing Capabilities and Possible Software Specifications:
As mentioned before, the Raspberry Pi 4B 4 GB model uses the BCM2711 Quad-Core 64-Bit ARM Processor which can operate at a speed of 1.5 GHz. The Raspberry Pi 4B 4 GB model is also available in 2 GB and 8 GB models, however, the 4 GB model is enough for all processing needs. The SD card that is used with the Raspberry Pi 4B can be easily changed and flashed with a new OS, thus allowing for a robust amount of memory available for the device. The capstone team believes that a 32 GB SD card is large enough for the applications of this project, however, a 64 GB SD card can be chosen for redundancy and for a potential of additional memory.

The actual software that will be installed on the device will be the Ubuntu operating system (OS) as well as the robot operating system (ROS) application. Ubuntu 20.04 is a Linux-based operating system that will be used with our Raspberry Pi 4B, as it will allow for the team to take advantage of the interfacing software for robots, ROS. Ubuntu 20.04 has the suggested system specifications of a minimum of 25 GB of disk allocation (SD Card), 4 GB of SDRAM, and 1.5 GHz to 2.0 GHZ processing speed. In addition to Ubuntu, the team will also be installing ROS on the Raspberry Pi 4B. ROS is an interfacing software which allows for individuals who are not familiar robotics to easily interact with a robot and its peripherals. While ROS is referred to as the Robot Operating System, this software is not actually an operating system, it is a mid-level interfacing software that allows for simplification of interacting with robotic devices. The system requirements to run ROS are the following: 1 GB to 1.5 GB of storage for all ROS dependencies and 4 GB of SDRAM. A specific processing speed for ROS is not stated, however, the official ROS webpage states that the Raspberry Pi 4B 4 GB

model is sufficient for running and interfacing ROS with external robot devices. In order to interface with the camera that will be attached to the Raspberry Pi 4B, the team will utilize Python 3 libraries and packages which should take up no more than 25 MB of space on the SD card. It is possible that the team members will utilize the Pycharm IDE on the Raspberry Pi 4B in order to easily install packages and program directly on the Raspberry Pi. If installed, the Pycharm IDE would take up 2.5 GB of space with a recommended allocation of 5 GB in order to allow for additional packages and libraries which can be installed through the IDE.

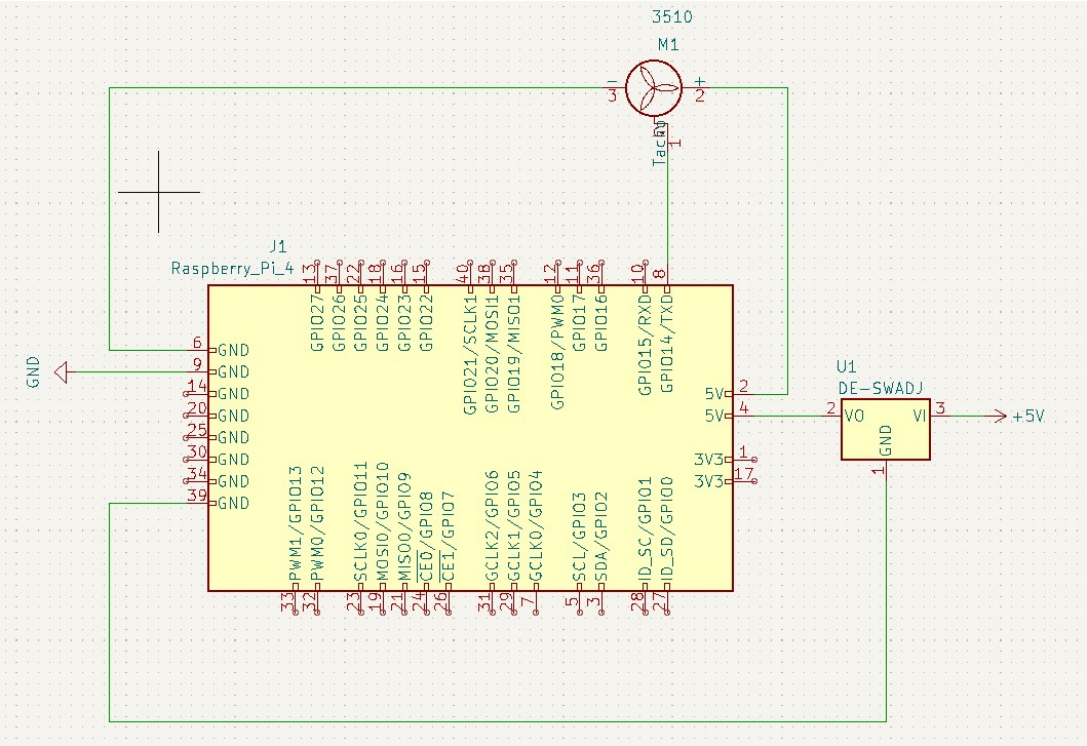
Important Sources For This Section:
Raspberry Pi 4B Specs: https://www.raspberrypi.com/documentation/computers/processors.html
BCM2711 Processor: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=https%3A%2F%2Fdatasheets.raspberrypi.com%2Fbcm2711%2Fbcm2711-peripherals.pdf&clen=1329416
Ubuntu Specifications and Requirements: https://www.linuxtechi.com/ubuntu-20-04-lts-installation-steps-screenshots/
Ubuntu Specs: https://help.ubuntu.com/community/Installation/SystemRequirements
ROS Specs and Instillation: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=http%3A%2F%2Fwww.cs.cornell.edu%2Fcourses%2Fcs4758%2F2011sp%2Fmaterials%2FROS_Install.pdf&clen=73932
Pycharm IDE Specs: https://www.jetbrains.com/help/pycharm/installation-guide.html

Powering MCU:
The Raspberry Pi will require 5.1 V with a recommended PSU current capacity of 3.0 Amps and uses an USB-C power port and/or a 5 Volt pin for powering the device. We have selected the DE-SWADJ 3A Adjustable Voltage Regulator to help regulate power of our MCU. https://www.dimensionengineering.com/products/de-swadj3



The regulator chip is advertised to be 96% efficient with a 25 mV ripple in the output voltage and 3.0 Amp output. The chip will be tested using a bench power supply and oscilloscope before connecting to the Raspberry Pi. Various voltage and current inputs will be applied to the terminals and the response will be observed across a load resistor.

Final Schematic:



Sources:

Heat sink datasheet - https://wiki.52pi.com/index.php?title=ZP-0110#Features

Fan pics - https://www.amazon.com/GeeekPi-Raspberry-Aluminum-Heatsink-Controllable/dp/B091L1XKL6

Raspberry pi datasheet - https://www.raspberrypi.com/documentation/computers/raspberry-pi.html

Voltage Regulator datasheet - https://www.dimensionengineering.com/datasheets/DE-SWADJ3.pdf