Electrical Overview

Year: 2024 Semester: Spring Team: 2 Project: MOUSE

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Author: Christopher Miotto Email: cmiotto@purdue.edu

Assignment Evaluation: See Rubric on Brightspace Assignment

1.0 Electrical Overview

The main control unit of MOUSE will be a 32-bit microcontroller. The purpose of this microcontroller is to send data wirelessly though WIFI via a web server and interfacing with many other hardware components. These hardware components will include the power supply, shift registers, motor drives, and sonar sensors.

Due to MOUSE being a mobile unit the power supply cannot be tethered; thus, we will be using a 12V lead acid battery. The main reason we are using this battery is due to its relatively low cost and high amp hours. Due to this battery being 12V we will need to step down the voltage to 5V to power the hardware components, then step down the 5V to 3.3V to power the microcontroller. We will be building this 12V to 5V to 3.3V converter step down circuit using a transistor, diode, capacitors, resistors, and a 5V to 3.3V linear regulator.

The shift registers will be used to display battery life diagnostics. We will monitor the voltage output of the power supply via an analog I/O pin on the microcontroller and process this information to determine the relatively remaining battery life. The battery life will be displayed by lighting up either green, yellow, or red LEDs via the shift registers parallel outputs. The shift registers will be controlled by the microcontroller via three digital I/O pins, these pins will connect to the serial input, shift register clock, and latch pins on the shift registers.

The motors will be controlled by PWM via the microcontroller. However, due to power limitations the PWM signals will need to be boosted via a motor drive IC before connection to the motors. The PWM signal will be first output by the microcontroller into the motor drive IC, the motor drive IC will be powered 5V and the motor voltage will be powered by 12V. With the combination PWM and these 2 voltages the speed and direction of each motor can be controlled.

The sonar sensors will be controlled via the microcontroller using I2C for the communication protocol. The sonar sensor will be used to detect movement within the vicinity of MOUSE and will communicate these detections to a server via the Wi-Fi module.

2.0 Electrical Considerations

2.1 Operating Frequency

The operating frequency for our system will be 2.4GHz. This is dictated by the maximum operating frequency for our chosen microcontroller which is 2.4Ghz [3]. Due to sending large amounts of information via Wi-Fi we will operate at this maximum frequency. The shift registers operating frequency is 108 MHz; however, the clock frequency will be controlled via an I/O pin from the microcontroller so this will not be an issue. The sonar sensor will be controlled via I2C, the maximum I2C frequency from our microcontroller is 100KHz and 400KHz [3]. However, the maximum I2C frequency for the sonar sensor is 15Hz, thus we will be communicating at a 15Hz frequency to match the sonar sensor [4].

2.2 Power Considerations

Due to MOUSE being mobile the only power source will be a battery. This power source will be a 12V Lead Acid battery with high amp hours. There will be two distinct operating voltages within our design 5V and 3.3V. The 12V output from the power source will be stepped down via a 12V to 5V stepdown circuit and further dropped from 5V to 3.3V using a linear regulator.

A diagram of a circuit

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Figure : 12V to 5V Step Down Pseudo Circuit

2.2.1 Microcontroller Voltage and Current

The 3.3V output will be used for the microcontroller. The maximum voltage is 3.0V and minimum 3.6V [3], due to this small tolerance we will be using a 5V to 3.3V linear regulator. The transmitting current is 340mA, due to this low current we cannot directly control a motor and will need a motor drive to do so.

2.2.2 Motor and Motor Drive IC Voltage and Current

The original 12V output will be used for the motor voltage fed into the motor drive IC. There will be a total of 4 motors used. Separately the operating motor voltage is 2.0-7.5V [1]. The reason we can apply 12V for the motor voltage is because the motors will be controlled via PWM, thus the average voltage will be within the operating voltage as long as the duty cycle is within a reasonable range. Separately the motors have a current stall of 0.9A [1]. The peak output current per channel from the motor drive IC is 3.0A so the current stall should not be an issue [2]. With 4 motors the max current draw should be 3.6A so using a single motor drive IC with two channels should be enough to power all motors. However, the operating current draw may be around 0.5A per motor and the motor drive nonpeak current output is 1.2A; so, running 2 motors per channel may be risky due to operating near the non-peak current output. Therefore, we will use 1 motor per channel and a total of 2 motor drive ICs. The motor drive IC logic has an operating voltage of 2.7-5.5V, and therefore will be powered via the 5V output.

2.2.3 Sonar, Shift Registers and LED Voltage

The sonar sensor has an operating voltage of 3.0-5.5V [4]. The shift registers have an operating voltage of 2.0-6.0V [5]. The RGB LEDs have a forward voltage of 3.4V. Thus, all can all be powered via the 5V output.

2.3 Electrical Loading

The maximum total current draw has been calculated below. The majority of current draw is from the motors which is expected. By using a lead acid battery this maximum current draw should be easily obtainable due to lead acid battery commonly being used for car batteries which require a large current draw.

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Table : Electrical Loading Data

3.0 Interface Considerations

3.1 Microcontroller to Sonar Sensor - I2C

The microcontroller and sonar sensor will communicate via SPI. The microcontroller has two I2C controllers available, one of which will use one to communicate to the sonar sensor [3]. The microcontroller maximum I2C operating frequency is 100KHz-400KHz [3], while the sonar sensors maximum I2C operating frequency is 15Hz [4]. Thus, we will operate at 15Hz to accommodate the sonar sensor.

3.2 Microcontroller to Motor Drive IC – PWM

The microcontroller will control the motor speed and direction via PWM to the motor drive IC. The microcontroller has 8 PWM pins available [3]. We will use one pin for the two left motors and another for the two right motors, allowing us to use 4-wheel drive ‘tank’ controls. The maximum PWM frequency for the motor drive is 100KHz. While the microcontrollers’ PWM frequency range is 10Hz to 40MHz. Thus, we will operate at 100KHz to allow for the most precise control of motors.

3.3 Microcontroller to Shift Registers – Serial Interface

The microcontroller and shift registers will communicate via a serial interface to control all diagnostic LEDs. There will be 3 digital I/O pins connected to the shift register, accounting for serial input (SER), shift clock (SCLK), and register clock (RCLK). The serial information containing which lights to be on will be communicated along the serial input clock. This information will be communicated at the frequency of the shift clock, on each shift clock a new serial value will be shifted into the MSB on the daisy chained shift registers. On each register clock the information available in the shift registers will be pushed and latched to the parallel output, displaying upon the diagnostic LEDs. Due to this being a serial interface via I/O pins there is no inherent data rate.

4.0 Sources Cited:

[1] RobotShop. (2024) “Dagu Wild Thumper 6WD All Terrain Chassis” [Online]. Available: <https://www.robotshop.com/products/dagu-wild-thumper-6wd-all-terrain-chassis> [Jan. 29, 2024]

[2] Pololu. (2024) “TB6612FNG Dual Motor Driver Carrier” [Online]. Available: <https://www.pololu.com/product/713/specs> [Jan. 29, 2024]

[3] Mouser Electronics. (2024) “ESP32-S3” [Online]. Available: <https://www.mouser.com/ProductDetail/Espressif-Systems/ESP32-S3?qs=Rp5uXu7WBW%2FNWuUy%252BBihNw%3D%3D> [Jan. 29, 2024]

[4] MaxBotix. (2024) “MB1222 I2CXL-MaxSonar-EZ2” [Online]. Available: <https://maxbotix.com/products/mb1222?_pos=2&_fid=515fdaf71&_ss=c> [Jan. 29, 2024]

[5] Texas Instruments. (2024) “SN74HC595” [Online]. Available: <https://www.ti.com/product/SN74HC595> [Jan. 29, 2024]

A diagram of a computer system

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