Component Analysis

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Assignment Evaluation:

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| --- | --- | --- | --- | --- |
| **Item** | **Score (0-5)** | **Weight** | **Points** | **Notes** |
| **Assignment-Specific Items** | | | | |
| **Analysis of Component 1** |  | x2 |  |  |
| **Analysis of Component 2** |  | x2 |  |  |
| **Analysis of Component 3** |  | x2 |  |  |
| **Bill of Materials** |  | x6 |  |  |
| **Writing-Specific Items** | | | | |
| **Spelling and Grammar** |  | x2 |  |  |
| **Formatting and Citations** |  | x1 |  |  |
| **Figures and Graphs** |  | x2 |  |  |
| **Technical Writing Style** |  | x3 |  |  |
| **Total Score** |  | | |  |

5: Excellent 4: Good 3: Acceptable 2: Poor 1: Very Poor 0: Not attempted

General Comments:

*Relevant overall comments about the paper will be included here*

1.0 Component Analysis:

1.1 Analysis of Component 1: MCU

For the microcontroller selection the main stipulations are comfortability with device, low powered, pin space, and storage space. Each of these chips offers 2 I2C lines, a SPI, and at least 2 USARTs. Additionally, each chip should have enough space to host the lookup tables, sampling storage and program data; however, only two chips are low powered, and the STM32L081KZ has ample storage space for any other possible improvements.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Chip | Bus Width | CLK Speed | Timers | SRAM | Flash | Power Consumption | Cost |
| STM32L081KZT [13] | 32 | 32 MHz | 6 | 20 KB | 192 KB | 87 uA/MHz | $6.07 |
| STM32F030R8 [11] | 32 | 48 MHz | 7 | 8 KB | 64 KB | 250 uA/MHz | $10.99 |
| STM32F031K6T7[12] | 32 | 48 MHz | 9 | 4 KB | 32 KB | 110 uA/MHz | $4.31 |

1.2 Analysis of Component 2: Bluetooth Chip

A bluetooth module is used to communicate between the wearable device and the host computer. There are only a few specifications that are input for the selection of the Bluetooth module: low powered, low latency, and low cost. Each of these candidates are Bluetooth Low Energy modules running some version of Bluetooth 5 and operate at 1.8 V. The main motivating factor in the decision for the ZB7412-00 is availability. While each Bluetooth chip offers extremely low power consumption and low latency, the availability helps tip the scales towards the ZB7412-00.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Module** | **Market Availability** | **FF** | **Transmit Power** | **Active Current** | **Sleep Current** | **Cost** |
| CC2640 [14] | Good | 7 x 7 mm | 5 dBm | 9.1 mA | 1.4 uA | $6.49 |
| nRF5340 [8] | Low | 4.4 x 4 mm | 3 dBm | 5.3 mA | 2.3 uA | $7.87 |
| ZB7412-00 [15] | Great | 16.9 x 11 mm | 5 dBm | 9.4 mA | 1.6 uA | $9.86 |

1.3 Analysis of Component 3: Energy Harvesting Chip

An energy harvesting chip is used to generate useful power from the residual back-emf of the stepper motor. There were three major candidates for the energy harvesting chip: LTC3588-1, NH2D0245-004, and BQ25504. Based-off the functional specifications and practical considerations, the following criteria were used for energy harvesting chip selection:

* Market Availability
* Cost
* Chip Footprint
* Input Voltage Range
* Input Voltage Type (AC/DC)
* Voltage Output Range
* Max Current Output

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Chip** | **Market Availability** | **Cost** | **Footprint** | **Input Voltage/Type** | **Output Voltages** | **Max Current Output** |
| LTC3588-1 | Good | $7.06 | Great (MSOP) | 2.7-20 VAC | 1.8 V, 2.5 V, 3.3 V, 3.6 V | 100 mA |
| NH2D0245-004 | Good[[1]](#footnote-1) | $4.95 | Good (QFN) | 1.4-5.0 VDC | 2.5-4.5 V | <100 uA |
| BQ25504 | Great | $5.67 | Good (VQFN) | 0.13-3 VDC | 2.5-5.25 V | 300 mA |

The **LTC3588-1** was chosen as the energy harvesting chip because it can harvest from AC sources and can tolerate a large input voltage; due to our gear reduction system, we will be generating a large back-emf from the stepper motor (in the 10 VAC range), and we do not wish to step-down the voltage with a transformer due to the additional weight/volume. The downsides of our chosen chip are that it does not have built-in battery power management and that it has a high cost. NH2D0245-004 was not preferable, since it is a new product. The BQ25504 is good overall, but has a prohibitively restrictive voltage input range and is not designed for harvesting energy from AC sources (if the LTC3588-1 does not work properly, we may try using this chip with an external bridge rectifier).

1.4 Analysis of Component 4: Optoelectronic Relay

We needed a relay to conduct the AC current coming from the passive braking system of the motor (i.e. to short our stepper motor). We could not use just a MOSFET due to the fact that our current would be AC, so a bi-directional relay was needed. There were several considerations that needed to be taken to select an adequate relay:

* Market Availability
* Minimum Required Input Current
* Switching Speed
* On-State Resistance
* Cost

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Chip** | **Market Availability** | **Input Current** | **Switching Speed** | **On-State Resistance** | **Cost** |
| CPC1020NTR [4] | Great | .13mA | .48ms | 116mΩ | $2.65 |
| G3VM-41DR [9] | None Available | 5mA | .8ms | 50mΩ | $11.48 |
| G3VM-41BR [10] | Running Low | 5mA | 2ms | 30mΩ | $11.32 |

Due to the great availability, lower cost, and lower required input current, we decided to go with the **CPC1020NTR** as our optoelectronic relay.

1.5 Analysis of Component 5: IMU

An inertial measurement unit (IMU) will be used to determine the orientation of the upper arm. There were three major candidates for the IMU: BHI160B, ICM-20948, and BNO055. Based-off the functional specifications and practical considerations, the following criteria were used for IMU selection:

* Degrees of Freedom (DOF)
* Power supply considerations
* Market availability
* Chip footprint
* Communication protocol (SPI is preferred over I2C for simplicity)
* Cost

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Chip** | **DOF** | **Supply Voltage, Total Power** | **Market Availability** | **Footprint** | **Comms Protocol** | **Cost** |
| BHI160B [2] | 6[[2]](#footnote-2) | 1.8 V, 2.8 mW | Great | Bad[[3]](#footnote-3) (BGA) | I2C | $6.71 |
| ICM-20948 [5] | 9[[4]](#footnote-4) | 1.8 V, 2.5 mW | Only Boards in Stock | Great (QFN) | SPI, I2C | $16.95\* |
| BNO055 [1] | 9 | 2.5 V (Analog), 31 mW | Limited Board Stock | Ok (LGA) | I2C, UART | $40.00\* |

\* Price of the boards from which the chips must be desoldered.

Due to its high DOF, low power consumption, easy-to-solder footprint, and easy communication protocol, we chose the **ICM-20948**. The downside of this chip is that we would need to desolder it from a breakout board (major vendors have >70,000 of these chips on order), which inflates the per-unit price three-fold. Also, it does not have easy integrated sensor fusion (there is a way to program an FPGA on the chip to do it); hence, we would need to transmit more data to the host computer, increasing power draw.

1.6 Analysis of Component 6: Battery

RevEx is powered via a central battery connected to the elbow node (which has the energy harvesting chip). The mean power draw per node is not expected to exceed 15 mW (conservative estimate). So, if the central battery must power two nodes (30 mW total power draw) for eight hours (see functional specification), then a battery with at least 0.3 WHr of capacity (81 mAh @ 3.7 V nominal voltage) is desired (accounting for voltage conversion efficiency). A lithium-polymer (LiPo) battery chemistry was selected because it has a good compromise between weight, durability, and safety compared to other battery chemistries. Amazon has a lot of cheap LiPo battery vendors. Among these vendors, EEMB has a remarkable amount of characterization data on their devices (their product comparison chart is below); hence, we chose to get a battery from EEMB. Our main criteria were capacity, availability, weight, and size. We chose the **LP402535** [3] because it was nearly as compact and light-weight as the low-capacity models, yet offered nearly four times the battery capacity needed for our application. At $8.99, this battery was inexpensive as well.

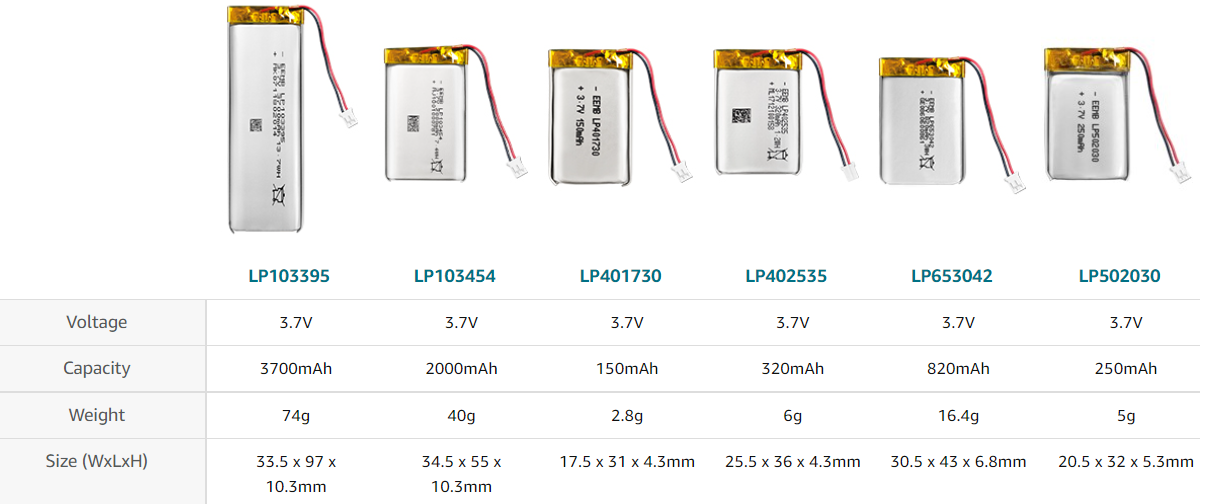


Figure 1. Battery Comparison Chart [3]

1.7 Analysis of Component 7: Potentiometer

In order to determine the absolute elbow joint rotation, we need a rotary potentiometer to measure the angle. This potentiometer needs to be only a single turn and will be rigidly mounted to the rotational shaft of the device. This potentiometer will also need to be able to be mounted to a shaft so that it will not be an obstacle for the system and will keep the design simple. Here are a few traits that we are looking for in a potentiometer:

* Market Availability
* Total Resistance
* Number of Turns
* Cost

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Chip** | **Market Availability** | **Total Resistance** | **Number of Turns** | **Cost** |
| EWV-YG8U03B14 [6] | Okay | 10kΩ | 1 | $5.70 |
| EWV-YG9U04B14 [7] | Running Low | 10kΩ | 1 | $5.70 |

Although we would have liked to have a higher total resistance, 10kΩ is acceptable since there were no center-spaced potentiometers with higher total resistance available. Both of these selections were extremely similar and would have worked for our application, but one was more available than the other. Therefore, we decided to choose the **EWV-YG8U03B14** as our center-spaced potentiometer for measuring absolute elbow angle.

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mΩ ON Resistance.” G3VM-41BR/ER datasheet. [[Datasheet Link](https://datasheet.octopart.com/G3VM-41BR-Omron-datasheet-17019901.pdf)]

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[15] ZB7412-00 Simplelink Bluetooth Low Energy Wireless MCU Module, ZB7412-00

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1. Experiencing large shipping delays. Also a new part, so there is a scarcity of documentation. [↑](#footnote-ref-1)
2. Must also get an external magnetometer chip to make this IMU 9 DOF. Nevertheless, this chip has sensor fusion. [↑](#footnote-ref-2)
3. The problem is that the recommended magnetometer has a bad footprint. [↑](#footnote-ref-3)
4. Sensor fusion is quite complex, since one must flash the FPGA on this chip with Invensense’s proprietary software on startup. It may be better to do sensor fusion on the host if using this chip. [↑](#footnote-ref-4)