## **Microcontroller**

The following tables and justifications are the basis for the decision making process of selecting a suitable microcontroller for Roadie.

### **Items under Consideration**

The following items have been considered for use as a camera on Roadie. Each item has a unique product ID as well as the vendor and a short description of the product, as depicted in **Table 1**

|  |  |  |  |
| --- | --- | --- | --- |
| Item ID | Item Name | Vendor | Description |
| UDOO Quad | UDOO Quad | UDOO | The UDOO Quad is a quad core 1 GHz microcontroller with 1 GB of Random Access Memory (RAM). There are many different types of ports provided on the board, including digital in and out pins, USB, SATA, CSI Camera, HDMI, and analog audio and mic ports. Additionally, the board comes with a Wi-Fi Module, which is great for debugging. [1ud] |
| B00K7EEX2U | BeagleBone Black Rev C | Amazon | The BeagleBone Black Rev C is a high power microcontroller with a 1 GHz CPU clock speed with 1 GB of RAM. Additionally, the BeagleBone Black Rev C comes with 1 GB on-board flash storage, 3D graphics, and digital in and out pins. [4ud] |
| B006H0DWZW | Arduino MEGA 2560 R3 | Amazon | The Arduino MEGA 2560 R3 is [2ud] |
| B009SQQF9C | Raspberry Pi Model B | Amazon | [3ud] |

**Table 1**: Microcontrollers under consideration for Roadie.

### **Decision Matrix**

Since the microcontroller is the brain of Roadie, it represents one of the most critical aspects of the system. The decision matrix used to select a microcontroller for Roadie is depicted in **Table 1**. Factors considered in the decision process of the microcontroller include processing power, RAM, cost, the community support for the microcontroller, the power consumption of the microcontroller, memory, size, Wi-Fi, and availability.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Factor | Processing Power | Memory | Cost | Community | Power Consumption | Ports | Wi-Fi | Availability | Total |
| Weight | 0.2 | 0.2 | 0.1 | 0.15 | 0.05 | 0.15 | 0.05 | 0.1 |  |
| UDOO Quad | 5 | 5 | 1 | 4 | 3 | 5 | 5 | 5 | 4.35 |
| B00K7EEX2U | 4 | 5 | 3 | 2 | 4 | 4 | 1 | 1 | 3.55 |
| B006H0DWZW | 2 | 1 | 5 | 5 | 2 | 2 | 1 | 1 | 2.4 |
| B009SQQF9C | 3 | 3 | 4 | 4 | 4 | 3 | 1 | 1 | 3.2 |

**Table 2**: Decision matrix for microcontroller.

The weighted matrix, or the matrix computed by multiplying the score in each category by its weight is show in **Table #.** The total score for each item in the decision matrix (**Table #**) is calculated by summing the values for each row in the weighted value matrix

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Factor | Processing Power | Memory | Cost | Community | Power Consumption | Ports | Wi-Fi | Availability |
| UDOO Quad | 1.0 | 1.0 | 0.1 | 0.6 | 0.15 | 0.75 | 0.25 | 0.5 |
| B00K7EEX2U | 0.8 | 1.0 | 0.3 | 0.3 | 0.2 | 0.6 | 0.05 | 0.1 |
| B006H0DWZW | 0.4 | 0.2 | 0.5 | 0.75 | 0.1 | 0.3 | 0.05 | 0.1 |
| B009SQQF9C | 0.6 | 0.6 | 0.4 | 0.6 | 0.2 | 0.45 | 0.05 | 0.1 |

**Table #:** Weighted value matrix. It is comprised of the score for each category multiplied by the weight for the category.

The weightings for the decision matrix were created by using the data in **Table #.** The information for the UDOO Quad was taken from [1ud]. The information for the B00K7EEX2U was taken from [4ud]. The information for the B006H0DWZW was taken from [2ud]. The information for the B009SQQF9C was taken from [3ud].

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Factor | Processing Power | Memory | Cost | Community | Power Consumption | Ports | Wi-Fi | Availability |
| UDOO Quad | 1 GHz/4 cores/ 1 GB RAM | 1 GB/ SD card | $ | Good | 6V |  | Yes | Own |
| B00K7EEX2U | 1 GHz/1 cores/ 1 GB RAM | 1 GB/ SD card | $ | Okay | 5V |  | N/A | In Stock |
| B006H0DWZW | 258 MHz/1 cores/ 128 KB RAM | 258KB | $ | Great | 7V |  | N/A | In Stock |
| B009SQQF9C | 700 MHz/1 cores/ 512 MB RAM | 512MB | $ | Good | 5V |  | N/A | In Stock |

**Table #**: Quantitative and qualitative values of the microcontrollers under consideration that led to the decision matrix.

### **Justifications**

The following section represents the reasoning behind each category and how their weights were determined.

#### **Processing Power**

An integral component in Roadie’s ability to quickly decipher and react to events that happen during competition is the processing power of the microcontroller. Since some of the challenges have an underlying time constraint such as the Simon Carabiner, the microcontroller must have enough processing power to allow Roadie to react in time. **Table 3** represents the values for processing power such as the number of cores the microcontroller has, the clock speed of the microcontroller, and the RAM on the microcontroller.

|  |  |  |  |
| --- | --- | --- | --- |
| Factor | Clock Speed | Cores | RAM |
| UDOO Quad | 1 GHz | 4 | 1 GB |
| B00K7EEX2U | 1 GHz | 1 | 1 GB |
| B006H0DWZW | 258 MHz | 1 | 128 KB |
| B009SQQF9C | 700 MHz | 1 | 512 MB |

**Table 3**: Values for processing power for each microcontroller.

Processing Power was given a weight of 20% since the processing power of the microcontroller plays such a large role in Roadie’s challenge completion abilities.

#### **Memory**

Memory is the combination of RAM and any additional memory store that is available to the microcontroller. **Table 4** shows a breakdown of RAM, on board storage and any additional storage that may be available to each microcontroller.

|  |  |  |  |
| --- | --- | --- | --- |
| Factors | RAM | On board storage | Additional storage |
| UDOO Quad | 1 GB | 1 GB | Micro SD Card |
| B00K7EEX2U | 1 GB | 1 GB | Micro SD Card |
| B006H0DWZW | 128 KB | 258 KB | N/A |
| B009SQQF9C | 512 MB | 512 MB | N/A |

**Table 4**: Storage space and RAM available to each microcontroller.

Memory was given a weight of 20% because having a large amount of RAM will enable Roadie to run more robust code without causing a hindrance to the overall performance of the system. Furthermore, having a large amount of additional storage allows more flexibility in code structures.

#### **Cost**

The scores for the cost of the microcontroller were obtained by giving the most expensive microcontroller a score of one and the least expensive microcontroller a score of five. If the price of a microcontroller was within $10 of an item it was awarded the same score as the item it was nearest.

Cost was given a weight of 10% as the cost of items are a very import factor in any budget, but not the most important consideration for this item.

#### **Community**

The community score was based on how much community support is available for each microcontroller. Factors for this decision included how much example code is available as well as how much documentation exists within the community for each microcontroller.

The community was given a weight of 15% as it relates to how many code examples exist as well as how much assistance can be found when problems occur with integrating the microcontroller with all of Roadie’s systems.

#### **Power Consumption**

The power consumption score for each item was obtained from each microcontrollers lowest recommend voltage. Therefore, the higher the voltage need to run the microcontroller the lower the score it received.

Power consumption was given a weight of 5% as it directly relates to how fast Roadie will deplete its power source. However, as the power supply is a piece that is easily reconfigurable, power consumption was not one of the more important considerations for the microcontroller.

#### **Wi-Fi**

The Wi-Fi score for each item was obtained by awarding the microcontroller a five if the microcontroller has Wi-Fi, and a one if the microcontroller does not have Wi-Fi.

Wi-Fi was given a weight of 5% as Wi-Fi is not a requirement for Roadie, however it will be useful for debugging purposes.

#### **Availability**

The availability score for each item was obtained by scoring items on hand as a five, and items that need to be purchased as a one.

Availability was given a weight of 10% as it directly relates to the ability to prototype Roadie.

#### **Ports**

The ports score for each microcontroller was obtained by determining how many input and output ports each microcontroller has. The types of ports included in this decision are general purpose input pins, general purpose output pins, pulse width modulation (PWM) pins, HDMI, USB, Camera, SATA, and Ethernet ports.

Ports was given a weight of 15% as it directly relates to what hardware components can be used on Roadie.

### **Risk Analysis**

The risk analysis section includes information regarding risks related to the line following equipment and solutions to mitigate those risks. Take, for instance, the fact that the microcontroller plays an integral role on Roadie. Therefore, mitigating any and all risks relating to the microcontroller is of the utmost importance. Should the microcontroller become damaged in any way, this would represent an annoying, yet minor failure. It would require the disassembly of essentially the whole system in order to replace the microcontroller. Risks and the methods in which they will be mitigated can be seen in **Table 5** below.

The probability of each occurrence, denoted as **Prob.**, will give the likelihood on the scale of one to nine with one will be the lowest likelihood of occurrence. The severity of an occurrence, denoted as **Sev.,** will give the impact that the event will have on a scale of one to nine with one being lowest impact.

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Prob. | Serv. | Mitigation of Risk |
| CPU Overheating | 3 | 5 | If the CPU of the microcontroller was to overheat, this would pose a large problem to Roadie. This is especially true if this was to occur during competition. In order to mitigate this risk a supplemental heat dissipation system will be installed. This supplemental system, in conjunction with the heat sink already installed on the microcontroller will be robust enough to dissipate the heat generated by Roadie during operation. |
| Short Circuits | 2 | 9 | One of the concerns when working with electrical circuits are shorts. This problem becomes even more prevalent when working with high voltage systems in conjunction with components that do not react well to high voltage such as the microcontroller. To mitigate a short circuit running the microcontroller, a few design methods will be employed. One such method is using a non-conductive chassis. If the chassis does not conduct electricity, it will not allow the chassis to become charged, thus helping to lower the chances of short happening as a result of a wire touching the chassis. Another technique that will be employed is installing motor shields to prevent electrical feedback from the motors to the microcontroller. |
| Physical Damage | 4 | 6 | In order to mitigate physical damage to the microcontroller, a casing will be installed around the microcontroller to help adsorb any impact that may arise as a result of the microcontroller being hit dropped. |

**Table 5**: Risks that can be attributed to the microcontroller and their associated mitigations.

## **Power Source**

The section pertaining to the selection of the power source for the system will be divided into two parts: power source for the microcontroller and power source for the rest of the system.

### **Batteries for Microcontroller**

The following tables and justifications are the basis for the decision making process of selecting a suitable power supply for the microcontroller.

#### **Items under Consideration**

The following items have been considered for use as a power supply for the microcontroller on Roadie. Each product has a unique product ID as well as the vendor and a short description of the product, as depicted in **Table 6** below.

|  |  |  |  |
| --- | --- | --- | --- |
| Item ID | Item Name | Vendor | Description |
| B0027GEY3Y | Venom 800mAh 7.4 LiPo [b1mp] | Amazon | 7.4 volt LiPo battery with a 800 mAh capacity and a 16 A discharge rate. |
| B00DDTKYME | Dynamite 7.4V 180mAh LiPo [b2mp] | Amazon | 7.4 volt LiPo battery with a 180 mAh capacity and a 16 A discharge rate. |
| B0073VCS0O | Eflite Blade 800mAh 7.4V LiPo [b3mp] | Amazon | 7.4 volt LiPo battery with a 800 mAh capacity and a 16 A discharge rate. |

**Table 6:** Power sources under consideration for Roadie.

#### **Decision Matrix**

The decision matrix used to select a battery for Roadie’s microcontroller is depicted in **Table 7**. Factors considered in the decision process of the battery include the power output, cost, safety, and battery life of each battery. The highlighted row is the battery selected to power the microcontroller for Roadie.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Factor | Power | Battery Life | Safety | Cost | Total |
| Weight | 0.40 | 0.25 | 0.20 | 0.15 |  |
| B0027GEY3Y | 4 | 5 | 3 | 5 | 4.2 |
| B00DDTKYME | 1 | 2 | 3 | 3 | 1.95 |
| B0073VCS0O | 4 | 5 | 3 | 1 | 3.6 |

**Table 7**: Decision matrix for microcontroller.

The weighted matrix, or the matrix computed by multiplying the score in each category by its weight is show in **Table #.** The total score for each item in the decision matrix (**Table #**) is calculated by summing the values for each row in the weighted value matrix

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Factor | Power | Battery Life | Safety | Cost |
| B0027GEY3Y | 1.6 | 1.25 | 0.6 | 0.75 |
| B00DDTKYME | 0.4 | 0.5 | 0.6 | 0.45 |
| B0073VCS0O | 1.6 | 1.25 | 0.6 | 0.15 |

**Table #:** Weighted value matrix. It is comprised of the score for each category multiplied by the weight for the category.

The weightings for the decision matrix were created by using the data in Table #.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Factor | Power | Battery Life | Safety | Cost |
| B0027GEY3Y | 7.4V/800 mAh | 0.035 | LiPo | $13.99 |
| B00DDTKYME | 7.4V/180 mAh | 0.00788 | LiPo | $14.99 |
| B0073VCS0O | 7.4V/800 mAh | 0.035 | LiPo | $18.59 |

**Table #**: Quantitative and qualitative values of the batteries under consideration that led to the decision matrix.

#### **Justifications**

The following section represents the reasoning behind each category and how their weights were determined.

##### **Power**

The scores for power of each battery was obtained by examining the voltage of the battery and how many milliamps per hour the battery provides. The battery must have sufficient voltage to power the microcontroller in addition to being below the maximum voltage the microcontroller can handle. Therefore the score of the voltage for each battery is proportional to how far the battery’s voltage is from the recommended voltage for the microcontroller. The milliamps per hour was used to determine how much amperage the batteries can supply at max load capacity.

Power was given a weight of 40% as the power of the battery dictates how long Roadie can run without having to recharge the batteries.

##### **Battery Life**

The score for battery life of each battery was obtained by giving the battery with the lowest battery life a score of five, and the battery with the highest battery life a score of one. The other batteries were given a score proportional to how close their battery life was to the longest battery life. The estimated battery life for each battery is given by the equation below from [] at maximum load.

The battery life for each battery can be seen in **Table 8** below

|  |  |  |  |
| --- | --- | --- | --- |
| Factor | mAh | mA | Life (Hours) |
| B0027GEY3Y | 800 | 16000 | 0.035 |
| B00DDTKYME | 180 | 16000 | 0.00788 |
| B0073VCS0O | 800 | 16000 | 0.035 |

**Table 8**: Battery life for each battery under consideration for powering Roadie’s microcontroller.

Battery life was given a weight of 25% as the battery life is how long a battery will last on a single charge. This translates into how long Roadie will be able to operate.

##### **Safety**

The scores for safety of each battery was obtained by factoring in the inherent risks associated with each variant of battery as well as the impact each variant of battery will have on the environment. The risk for each battery rates to how the battery will react to mishaps. Examples of mishaps would be dropping, shorting out, or overheating the battery. The environmental impact of each battery is dependent upon the materials that the battery is composed of as most batteries contain some type of heavy metal that is harmful to both humans and the environment. [1mp]

Safety was given a weight of 20% as the safety of the team and the environment in which Roadie is worked on are both important aspects of the project.

##### **Cost**

The values for cost of the batteries were obtained by giving the most expensive battery a score of one, and the least expensive battery a score of five.

Cost was given a weight of 15% as the cost of items are a very items are a very important factor in any budget, but not the most important consideration for this item.

#### **Requirements Traceability**

The following requirements traceability refers to the System Requirements Specification for Roadie, revision 1.0.0, published September 18, 2014. As shown in **Table 9** below, the requirement ID is followed by the requirement text and an explanation of how the B0027GEY3Y will fulfill said requirement.

|  |  |  |
| --- | --- | --- |
| ID | Requirement Text | Fulfillment |
| 4.2.1 | The system shall operate for a minimum of [TBD] minutes when the power source starts with a full charge. | By choosing batteries that provide more amperage than what is required to run the microcontroller and motors, it will be possible to ensure that Roadie will be able to operate for at least [TBD] minutes. |

**Table 9**: The requirements that the selection of B0027GEY3Y will fulfill.

#### **Risk Analysis**

The risk analysis section includes information regarding risks related to the line following equipment and solutions to mitigate those risks. Take, for instance,

The probability of each occurrence, denoted as **Prob.**, will give the likelihood on the scale of one to nine with one will be the lowest likelihood of occurrence. The severity of an occurrence, denoted as **Sev.,** will give the impact that the event will have on a scale of one to nine with one being lowest impact.

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Prob. | Sev. | Mitigation of Risk |
| Overheating | 3 | 7 | Batteries can overheat by being left on the charger for too long or by being used for a extend amount of time. To help mitigate this risk the batteries should be taken off of the charger once they are fully charge. Also, to help mitigate overheating from extend usage for a max of [TBD] time. |
| Shorting Out | 2 | 9 | Batteries that are shorted out have a chance to have a thermal runaway, which to ignite and catch on fire. [4mp] To help mitigate this risk proper techniques shall be used when wiring and soldering batteries. |

### **Batteries for Motors**

The following tables and justifications are the basis for the decision making process of selecting a suitable power supply for the motors on Roadie.

#### **Items Under Consideration.**

The following items have been considered for use as a power supply for the motors on Roadie. Each product has a unique product ID as well as the vendor and a short description of the product, as depicted in **Table 10**

|  |  |  |  |
| --- | --- | --- | --- |
| Item ID | Item Name | Vendor | Description |
| B0027G9F9M | Venom 5000 mAh 14.8V LiPo [b4mp] | Amazon | 14.8 volt LiPo battery with a 5000 mAh capacity and a 125 A discharge rate. |
| B003CUB4QO | Venom 5000 mAh 14.8V Hard Case LiPo [b5mp] | Amazon | 14.8 volt LiPo hard case battery with a 5000 mAh capacity and a 175 A discharge rate. |
| B003CUJ1WI | Venom 3800 mAh 18.5V Hard Case LiPo [b6mp] | Amazon | 18.5 bolt LiPo hard case battery with a 3800 mAh capacity and a 133 A discharge rate. |

**Table 10**: Power supplies under consideration for the motors for Roadie.

#### **Decision Matrix**

The decision matrix used to select a battery for the motors on Roadie is depicted in **Table 11**. Factors considered in the decision process of the battery include the power output, cost, safety, and battery life of each battery. The highlighted row is the battery selected to power the microcontroller for Roadie.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Factor | Power | Battery Life | Safety | Cost | Total |
| Weight | .40 | .25 | .20 | .15 |  |
| B0027G9F9M | 5 | 5 | 3 | 5 | 4.6 |
| B003CUB4QO | 1 | 3 | 3 | 1 | 1.9 |
| B003CUJ1WI | 3 | 3 | 3 | 3 | 2.7 |

**Table 11**: Decision matrix for the battery for the motors for Roadie.

The weighted matrix, or the matrix computed by multiplying the score in each category by its weight is show in **Table #.** The total score for each item in the decision matrix (**Table #**) is calculated by summing the values for each row in the weighted value matrix.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Factor | Power | Battery Life | Safety | Cost |
| B0027G9F9M | 2.0 | 1.25 | 0.6 | 0.75 |
| B003CUB4QO | 0.40 | 0.75 | 0.6 | 0.15 |
| B003CUJ1WI | 1.20 | 0.75 | 0.6 | 0.15 |

**Table #:** Weighted value matrix. It is comprised of the score for each category multiplied by the weight for the category.

The weightings for the decision matrix were created by using the data in Table #.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Factor | Power | Battery Life | Safety | Cost |
| B0027G9F9M | 14.8V/5000 mAh | 0.028 | LiPo | $73.43 |
| B003CUB4QO | 14.8V/5000 mAh | 0.02 | LiPo | $99.99 |
| B003CUJ1WI | 18.5V/3800 mAh | 0.02 | LiPo | $99.99 |

**Table #**: Quantitative and qualitative values of the batteries under consideration that led to the decision matrix.

#### **Justifications**

The following section represents the reasoning behind each category and how their weights were determined.

##### **Power**

The scores for power of each battery was obtained by examining the voltage of the battery and how many milliamps per hour the battery provides. The battery must have sufficient voltage to power the motors in addition to being below the maximum voltage the motors can handle. Therefore the score of the voltage for each battery is proportional to how far the battery’s voltage is from the recommended voltage for the motors. The milliamps per hour was used to determine how much amperage the batteries can supply at max load capacity.

Power was given a weight of 40% as the power of the battery dictates how long Roadie can run without having to recharge the batteries.

##### **Battery Life**

The score for battery life of each battery was obtained by giving the battery with the lowest battery life a score of five, and the battery with the highest battery life a score of one. The other batteries were given a score proportional to how close their battery life was to the longest battery life. The estimated battery life for each battery is given by the equation below from [] at maximum load.

The battery life for each battery under consideration for the motors can be seen in **Table 12**below

|  |  |  |  |
| --- | --- | --- | --- |
| Factor | mAh | mA | Life (hours) |
| B0027G9F9M | 5000 | 125000 | 0.028 |
| B003CUB4QO | 5000 | 175000 | 0.02 |
| B003CUJ1WI | 3800 | 133000 | 0.02 |

**Table 12**: Battery life for each of the batteries under consideration for powering Roadie's motors.

Battery life was given a weight of 25% as the battery life is how long a battery will last on a single charge. This translates into how long Roadie will be able to operate.

##### **Safety**

The scores for safety of each battery was obtained by factoring in the inherent risks associated with each variant of battery as well as the impact each variant of battery will have on the environment. The risk for each battery rates to how the battery will react to mishaps. Examples of mishaps would be dropping, shorting out, or overheating the battery. The environmental impact of each battery is dependent upon the materials that the battery is composed of as most batteries contain some type of heavy metal that is harmful to both humans and the environment. [1mp]

Safety was given a weight of 20% as the safety of the team and the environment in which Roadie is worked on are both important aspects of the project.

##### **Cost**

The values for cost of the batteries were obtained by giving the most expensive battery a score of one, and the least expensive battery a score of five.

Cost was given a weight of 15% as the cost of items are a very items are a very important factor in any budget, but not the most important consideration for this item.

#### **Requirements Traceability**

The following requirements traceability refers to the System Requirements Specification for Roadie, revision 1.0.0, published September 18, 2014. As shown in **Table 13** below, the requirement ID is followed by the requirement text and an explanation of how the B0027G9F9M will fulfill said requirement.

|  |  |  |
| --- | --- | --- |
| ID | Requirement Text | Fulfillment |
| 4.2.1 | The system shall operate for a minimum of [TBD] minutes when the power source starts with a full charge. | By choosing batteries that provide more amperage than what is required to run the microcontroller and motors, it will be possible to ensure that Roadie will be able to operate for at least [TBD] minutes. |

**Table 13**: The requirements that the selection of B0027G9F9M will fulfill.

#### **Risk Analysis**

The risk analysis section includes information regarding risks related to the line following equipment and solutions to mitigate those risks. Take, for instance,

The probability of each occurrence, denoted as **Prob.**, will give the likelihood on the scale of one to nine with one will be the lowest likelihood of occurrence. The severity of an occurrence, denoted as **Sev.,** will give the impact that the event will have on a scale of one to nine with one being lowest impact.

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Prob. | Sev. | Mitigation of Risk |
| Overheating | 3 | 7 | Batteries can overheat by being left on the charger for too long or by being used for a extend amount of time. To help mitigate this risk the batteries should be taken off of the charger once they are fully charge. Also, to help mitigate overheating from extend usage for a max of [TBD] time. |
| Shorting Out | 2 | 9 | Batteries that are shorted out have a chance to have a thermal runaway, which to ignite and catch on fire. [4mp] To help mitigate this risk proper techniques shall be used when wiring and soldering batteries. |

[1ud] UDOO Quad. (n.d.). Retrieved October 2, 2014, from <http://shop.udoo.org/usa/product/udoo-quad.html?___from_store=usa&popup=no>

[2ud] Arudino MEGA 2560 R3. (n.d.). Retrieved October 2, 2014, from <http://www.amazon.com/Arduino-MEGA-2560-R3/dp/B006H0DWZW/ref=sr_1_1?s=electronics&ie=UTF8&qid=1412524001&sr=1-1&keywords=arduino+mega+2560+r3#productDetails>

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[4ud] Bealgebone Blakc Rev C. (n.d.). Retrieved October 2, 2014, from <http://www.amazon.com/Beagleboard-BBONE-BLACK-4G-BeagleBone-Rev-C/dp/B00K7EEX2U/ref=sr_1_1?s=electronics&ie=UTF8&qid=1412524078&sr=1-1&keywords=beaglebone+black+rev+c>

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[3mp] Digikey, “Battery Conversion Calculator” Web. Retrieved October 4, 2014, from <http://www.digikey.com/en/resources/conversion-calculators/conversion-calculator-battery-life>

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[b2mp] Dynamite 180mAh LiPo Battery. (n.d). Retrieved October 5, 2014, from <http://www.amazon.com/Dynamite-B0005-7-4V-180mAh-LiPo/dp/B00DDTKYME/ref=sr_1_1?ie=UTF8&qid=1412627434&sr=8-1&keywords=B00DDTKYME>

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