Component Analysis

Year: 2017 Semester: Fall Team: 3 Project: Virtual Sport

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Assignment Evaluation:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Item** | **Score (0-5)** | **Weight** | **Points** | **Notes** |
| **Assignment-Specific Items** | | | | |
| **Analysis of Component 1** | 5 | x2 | 10 |  |
| **Analysis of Component 2** | 5 | x2 | 10 |  |
| **Analysis of Component 3** | 5 | x2 | 10 |  |
| **Bill of Materials** | 5 | x6 | 30 |  |
| **Writing-Specific Items** | | | | |
| **Spelling and Grammar** | 5 | x2 | 10 |  |
| **Formatting and Citations** | 5 | x1 | 5 |  |
| **Figures and Graphs** | 5 | x2 | 10 |  |
| **Technical Writing Style** | 5 | x3 | 15 |  |
| **Total Score** | 100 | | |  |

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

General Comments:

*Very well written with rationale clearly identified.*

IMPORTANT NOTE: The Bill of Materials is a separate document and should be downloaded and filled out for another assignment. The Bill of Materials is to be submitted separately, per the course calendar (possibly on a different week), and will graded collectively with this assignment.

1.0 Component Analysis:

The primary hardware components of our design include an accelerometer, a Bluetooth LE module, a haptic driver, vibration motors, linear actuators, and a microcontroller. The accelerometer is the device that will track the hand orientation. The Bluetooth LE module is what will communicate to the VR app, gather the hand orientation data, and transmit haptic feedback instructions. The haptic driver is device that sends pulses to vibration motors and provides touch feedback when the user spars the sword at a digital opponent. The linear actuators are the devices that slide the contact handle and simulate shear and friction forces. Finally, the microcontroller is the core that governs all these peripherals.

1.1 Analysis of Accelerometer:

Table 1 Analysis of Accelerometers

|  |  |  |  |
| --- | --- | --- | --- |
| Feature | ADXL345 [1] | MPU 6050 [2] | BMA 220 [3] |
| Full Resolution | 16 bits | 16 bits | 16 bits |
| Power Supply | 2.0 – 3.6 V | 2.375 – 3.46 V | 1.62 – 3.6 V |
| Current Consumption | 34 – 90 µA | 34 – 90 µA (Acc.)  3.6 mA (Gyro) | 250 µA |
| 0g Bias Level | +-40 mg for x, y  +-80 mg for z axis | +- 50 mg for x, y  +- 80 mg for z axis | +- 95 mg |
| Non Linearity | 0.5 % | 0.5% | +- 2% |
| Serial Interfaces Supported | I2C and SPI | I2C | I2C and SPI |
| Max SCL Frequency | 400 kHz | 1MHz | ~333 kHz |
|  | Chosen |  |  |

The accelerometer module is a critical component that will track the user's hand orientation. It measures the difference between the acceleration applied on the module and the earth’s gravitational field. According to the BMA 220 datasheet [3], the values can be easily converted to tilting angles. The VR application will use the data to rotate the digital sword. The module requires a low non-linearity and a low 0-g bias level in order to reduce the calibration work and to have the VR app smoothly display the movement. The BMA 220 module is excluded from the candidate list as it has the worst performance in all the categories. MPU 6050 is a silicon chip that contains both gyroscope and accelerometer but consumes more current. Considering that the user’s vision is completely immersed in the virtual environment, as long as the digital sword movement displayed in the headset and the touch feelings the user perceives are matched, the design specification is satisfied. Having a standalone accelerometer should be enough to satisfy the requirement. Ultimately, the ADXL345 accelerometer module is chosen as it has a lower bias level and a lower current consumption.

1.2 Analysis of Bluetooth:

Table 2 Analysis of Bluetooth

|  |  |  |  |
| --- | --- | --- | --- |
| Feature | nRF8001 [4] | HM10 [5] | RN4020 [6] |
| BT Version | BLE 4.0 | BLE 4.0 | BLE 4.0 |
| Power Supply | 3.6 V | 3.3 V | 3.3 V |
| Current | 20 mA | 50 mA | 30 mA |
| Typical/ Max Baud Rate | 19200/ 19200 | 9600/ 230400 | 115200/ 115200 |
| Interface to Micro | SPI, UART | UART | UART, I2C |
| Max Length of Transmission | Not identified in the datasheet | 80 or more bytes | 20 bytes |
|  |  | Chosen |  |

The Bluetooth LE module is the most critical component of the device. The microcontroller will transmit the hand tilting information to the VR app. The VR app will also use this module to send haptic feedback instructions back to the microcontroller. The Bluetooth version must be BLE 4.0 in order to connect to a Unity app on an iOS device. The ability to transmit a longer message at an instance will be ideal as it gives more flexibility in changing the transmitting pocket data structure. Ultimately, all the selected candidates use the BLE 4.0 version meet the basic requirement. The HM10 module is chosen because it can transmit a longer message at an instance and this provides more flexibility in modifying the transmitting pocket data structure.

1.3 Analysis of Haptic Driver and Vibration Motors:

Table 3 Analysis of Haptic Driver

|  |  |  |  |
| --- | --- | --- | --- |
| Feature | DRV2605 [7] | DRV2603 [7] | DRV2604 [7] |
| Voltage (min / max) | 2.5 – 5.5 V | 2.5 – 5.2 V | 2.5 – 5.5 V |
| Current | 0.6 mA | 1.7 mA | 0.6 mA |
| Input Signal | PWM, Analog, I2C | PWM, Analog | PWM, Analog, I2C |
| Haptic Actuator Type | ERM, LRA | ERM, LRA | ERM, LRA |
| Special Feature | Integrated Haptic Effects  Smart Loop | Auto Resonance | Smart Loop  RAM Available |
|  | Chosen |  |  |

The Virtual Sport project requires using vibration motors to provide feedback to digital object collisions. The microcontroller will use a DRV26xx family haptic driver to drive the vibration motors. According to the product descriptions [7] by Texas Instrument, the three modules described in the table are functionally equivalent. All the three haptic drivers support both ERM and LRA actuator types. The DRV2605 module is selected because it has a special integrated haptic effect. This enables the microcontroller to easily adjust the vibration duration and magnitude through I2C.

Table 4 Analysis of Vibration Motors

|  |  |  |
| --- | --- | --- |
| Feature | Cylindrical Core SMT Motor [8] | Coin Type Vibration Motor [9] |
| Type | Eccentric rotating mass type | Linear resonant actuator type |
| Power Supply | 2.7 V | 3.0 V |
| Voltage Range for Use | 2.3 V - 3.2 V | 2.7 V – 3.3 V |
| Rated Current | 85 mA | 90 mA |
| Rated Speed | 14000 +- 2500 rpm | 9000 rpm |
| Operating Temperature | -20 – 70 C | -20 – 60 C |
| Typical Mechanical Noise | 20 dB | 28 dB |
|  |  | Chosen |

The eccentric rotating mass (ERM) and linear resonant actuator (LRA) are two of the most common types of haptic motors used in the market. Both motors have similar characteristics in terms of operating voltage range, operating temperature, mechanical noises, etc. There isn’t really an electrical or mechanical factor that will have either one stand out more. However, from a haptic researcher point of view, the LRA motor has a more average vibration amplitude and frequency that make the user feel more comfortable. The LRA motor has a greater performance and a longer operational lifetime than the ERM motor because the ERM motor generates the illusion of vibration by the displacement of the unbalanced weight attached to the shaft when the motor itself is rotating at a high speed [10]. As a result, the Virtual Sport project choses to use the LRA Type vibration motor.

1.4 Analysis of Linear Actuator:

Table 5 Analysis of Linear Actuator

|  |  |  |  |
| --- | --- | --- | --- |
| Feature | Linear Actuator Servo GS-1502 [11] | Haydon 15000 Stepper Motor [12] | L12-S Micro Linear Actuator [13] |
| Motor Type | Servo | Stepper | Servo |
| Power Supply | 3.7V / 5V | 4V / 5V / 12V | 6V / 12V |
| Size | 1.8\*1.4\*0.05 mm | 15 mm | 10 mm |
| Weight | 1.5g | 28g | 28g |
| Torque or Force | 80g-cm | Not Specified | 22N (Max) |
| Closed Feedback Loop | Yes | No | Yes |
| Approximate Price | $10 | $40 | $70 |
|  | Chosen |  |  |

The Virtual Sport project also requires using linear actuators to mimic shear and friction forces when the user spars the digital sword at the opponent. This component slides the contact handle and uses linear and rotating motions to provide touch feedbacks. The ideal candidate needs to have the following characteristics. First, the component needs to be small and light in order to make the embedded haptic controller portable. Second, the component must generate a significant amount of torque to effectively provide the touch feedback. Third, the component must keep the applying force magnitude at a level which the user can feel comfortable. In addition, having a closed feedback loop mechanism are more preferred. The GS-1502 linear actuator servo is chosen because it has a lighter weight. Its size is also a better fit for a remote controller. Having the feedback mechanism also allows the system knowing the exact moving position and this enhances the haptic feedback quality. The price is also much cheaper than the other two candidates.

1.5 Analysis of Microcontroller:

Table 6 Analysis of Microcontroller

|  |  |  |  |
| --- | --- | --- | --- |
| Feature | STM32F407 [14] | STM32F302 [15] | STM32F0-Discovery [16] |
| Clock Speed | 168 MHz | 72 MHz | 48 MHz |
| SRAM | 192 kb | 40 kb | 8 kb |
| Flash | 1 Mb | 256 kb | 64 kb |
| Pinout | 25 x 25 | 16 x 16 | 16 x 16 |
| Number of Timers | 12x | 11x | 8x |
| Number of I2C | 3x | 2x | 2x |
| Number of UART | 4x | 5x | 2x |
| PWM/ DAC Notes | 2x 12-bit DAC  2x PWM timer for motor control | 1x 12-bit DAC  2x 16-bit timers with up to 4 IC/OC/PWM our pulse counter | 1x 12-bit DAC |
| Power | 5V, 3.6V | 5V, 3.6V | 5V, 3.6V |
| Approximate Price | $20 | $15 | $10 |
|  | Chosen |  |  |

A wide range of microcontrollers are available, but the choices were narrowed down to STM32 series because this family has various peripherals required by the Virtual Sport project. There are also helpful tools and libraries that can help simplify the design work. The project requires at least one I2C, one UART, four PWM or DAC, and multiple GPIO pins. Having extra pins for theses peripherals, especially PWM, is preferable as it provides the flexibility to add additional components. The selected microcontroller also needs to have both 5V and 3.3V power sources and logic families. Faster clock rate and more memory are preferred. A list of characteristics for the selected candidates are described in the table above. The STM32F407 microcontroller is chosen as it has a lot more interfaces and input/ output pins available and this provides more flexibility in modifying or adding additional features for the design. A high-performance microcontroller also has a significantly faster clock speed and more memory than the other two candidates.

2.0 Sources Cited:

1. Analog Devices. *3-Axis Digital Accelerometer ADXL345 datasheet* [Online]. Available: <http://www.analog.com/media/en/technical-documentation/data-sheets/ADXL345.pdf>
2. InvenSense. *MPU-6000 and MPU-6050 Product Specification Revision 3.4* [Online]. Available: <https://www.invensense.com/wp-content/uploads/2015/02/MPU-6000-Datasheet1.pdf>
3. Bosch Sensortec. *BMA 220 Digital triaxial accelerometer sensor*. [Online] Available: <http://image.dfrobot.com/image/data/SEN0168/BMA220%20datasheet.pdf>
4. Adafruit. *Getting Started with the nRF8001 Bluefruit LE Breakout* [Online]. Available: <https://cdn-learn.adafruit.com/downloads/pdf/getting-started-with-the-nrf8001-bluefruit-le-breakout.pdf>
5. JNHuaMao Technology. *Bluetooth 4.0 BLE module datasheet* [Online]. Available: <http://fab.cba.mit.edu/classes/863.15/doc/tutorials/programming/bluetooth/bluetooth40_en.pdf>
6. Microchip (2015). *RN4020 Bluetooth Low Energy Module* [Online]. Available: <http://ww1.microchip.com/downloads/en/DeviceDoc/50002279B.pdf>
7. Texas Instrument. *Haptic Driver for ERM/LRA with Built-In Library and Smart Loop Architecture*. [Online]. Available: <http://www.ti.com/product/DRV2605>
8. Jinlong Machinery and Electronics. *Cylindrical Core SMT Motor Product Specification* [Online]. Available: <http://www.vibration-motor.com/products/download/Z30C1T8219731.pdf>
9. Jinlong Machinery and Electronics. *Coin Type Vibration Motor Product Specification* [Online]. Available: <http://www.vibration-motor.com/products/download/C0720B015F.pdf>
10. Precision Microdrives (2017). *Haptic Feedback and Vibration Alerting for Handheld Products* [Online]. Available: <https://www.precisionmicrodrives.com/sites/default/files/haptic-feedback-vibration-alerting-for-handheld-products_0.pdf>
11. GoTeck. *Micro Servo GS-1502* [Online]. Available: [http://www.goteckrc.com/ProductShow.asp?ID=1#](http://www.goteckrc.com/ProductShow.asp?ID=1)
12. Electromate. *Stepper Motor Linear Actuators* [Online]. Available: <https://www.electromate.com/assets/catalog-library/pdfs/haydon-kerk/Haydonkerk_CanStack_Actuators_catalog.pdf>
13. Actuonix. *L12-S Micro Linear Actuator with Limit Switches* [Online]. Available: <https://www.actuonix.com/L12-S-Micro-Linear-Actuator-with-Limit-Switches-p/l12-s.htm>
14. STMicroelectronics (2017). *STM32F407VG* [Online]. Available: <http://www.st.com/en/microcontrollers/stm32f407vg.html>
15. STMicroelectronics (2017). *STM32F302RC* [Online]. Available: <http://www.st.com/en/microcontrollers/stm32f302rc.html>
16. STMicroelectronics (2017). *STM32F051R8* [Online]. Available: <http://www.st.com/en/microcontrollers/stm32f051r8.html>