Virtual Grand Piano

ECE 445 Design Document

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ECE 445 Project Proposal - Spring 2018
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1. Introduction

1.1. Objective

Digital pianos currently available in the market are expensive, heavy and non-portable devices that require meticulous maintenance and large amounts of power. A piano player may require a portable instrument at short notice to practice or test musical pieces without wanting to travel all the way to a studio. We plan to explore a possible solution to this problem by designing a virtual instrument that contains no moving parts, is extremely portable and contains all the functionality and sound design of a digital keyboard.

We are proposing to implement this virtual keyboard by isolating the movements of the player in 3D space using camera modules and identifying each individual key press and relaying it to a control unit. We will capture information about which key on the piano was struck by the player and the speed with which the key was struck. We are planning to do this by having the player wear a glove with pressure sensors, reflective LEDs on the fingertips and a wireless transmitter on each hand. The player can then virtually play the piano on any flat surface that would be marked with stickers calibrated with the camera modules.

1.2. Background

The digital keyboard is an extremely versatile instrument for any musical artist. It can be used as a MIDI controller for a custom synthesizer or as a digital piano that authentically reflects the sounds of a traditional piano. It is often the case that an artist may want to test out a melody on the fly or practice a piece without having access to a physical keyboard. With the increasing sophistication of image processing techniques and fast processing times provided by hardware components we are planning to overcome this problem completely virtually. The only inputs required by the instrument for emulating a digital keyboard are the movements of the player's fingers. While a flat interface may not provide the feel of a traditional piano it could be immensely useful as a portable solution and may be set-up in compact spaces that may not accommodate a full piano. It is especially suitable as a MIDI controller which has become an essential part of the modern music production process [1]. The player's inputs would be wirelessly transmitted to a central control unit that would process the note and velocity of the player's movements and feed it into an audio synthesizer.

We haven't come across a similar system that implements a digital keyboard using the location of the player's fingers as it is difficult to accurately locate position in 3D space using conventional techniques. In addition the system would need to have high processing capabilities due to the real-time multi-sensor processing requirements of the system. We plan to overcome these challenges by utilizing an FPGA that would be able to process inputs from multiple camera and pressure sensors in real-time and relay them to an audio synthesizer.

1.3. High-Level Requirements

- The system must recognize and trigger the correct note played by the user with the appropriate sensitivity reading.
- The system must be portable and may be deployed on any flat surface if calibrated appropriately.
- The system must reflect the configuration of a traditional piano including both black and white keys and be able to accurately resolve each.
- The system must be reasonably fast, processing the sensor inputs and triggering the appropriate key with minimal delay.

2. Design

The movements of the player are recorded through two glove modules equipped on the player's left and right hands. This glove module consists of LEDs on each of the five fingertips that can be isolated by the camera modules. The pressure response of a key press is recorded by five pressure sensors on each of the fingertips and relayed to an RF module located on a bracelet-like device on the player's hand. This unit is powered by an onboard battery and relays the recorded inputs in real time to the central control unit through an XBee module.

The power to the central control unit is supplied by a power supply module that converts the AC mains voltage to DC voltage and steps down the voltage to the requirements of each of the modules using voltage regulators.

The central control unit is responsible for receiving inputs from the various sensors, processing these inputs to identify the key triggered and the key velocity and relaying this information to a waveform generator implemented on the FPGA. The waveform generator outputs the sound to an audio decoder that converts the digital samples sent by the FPGA into an analog value that can be used by an external speaker. We are planning to use two camera modules to track the left and right hand of the player and process these inputs simultaneously to trigger the musical notes as needed. We are also going to display the captured image on a VGA monitor so that we can view the images in real time to provide the user with feedback about their finger positions and the key boundaries.

2.1. Block Diagram

Our design consists of two main components: the central control unit and the glove unit. Each of the units include a PCB that allows for the integration of the sensors and the processing units of the modules. The following block diagrams depict the organization and inter-connections within and amongst each of the modules.

2.1.1. Central Logic Unit Block Diagram

The central logic unit is the hub of the design that the glove modules interface with. The data captured by the pressure sensors and the camera is processed and integrated in this unit on the FPGA and used to generate the frequency response to be sent to the audio decoder module. All the computations in this unit take place in the FPGA module which is connected to the camera sensor, XBee RF receiver module and the output audio codec and VGA port modules. The FPGA also makes use of an external SDRAM IC to store and process the captured image frame buffer. The power is supplied to the unit through an external 12V source which is in turn stepped down and regulated to power each of the individual modules and sensors in the unit.

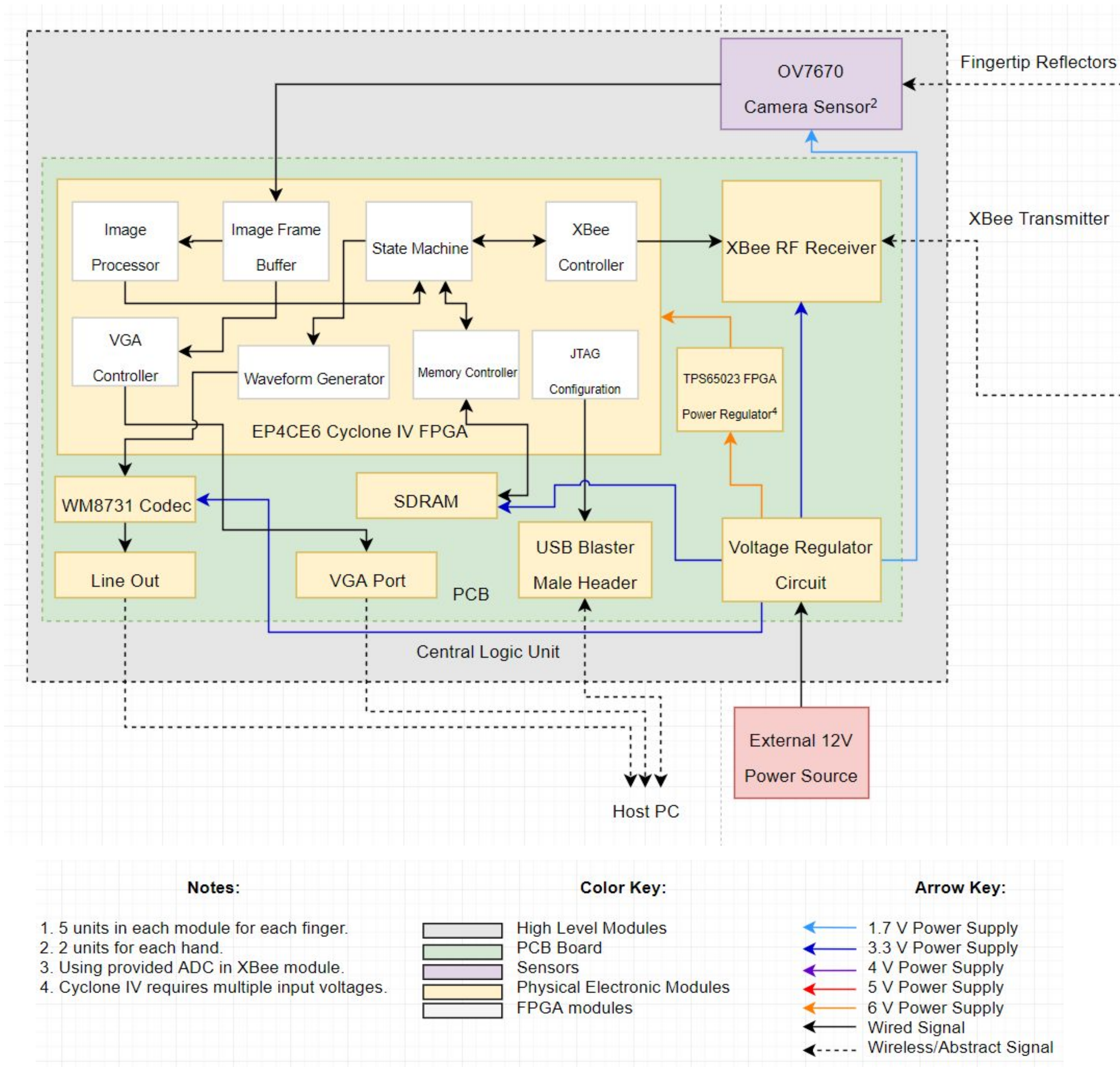

Figure 2.1.1. Central Control Unit Block Diagram

2.1.2. Glove Unit Block Diagram

The glove unit consists of the electronic attachments to each of the player's hands that are used to relay sense input to the central control unit. The key hit pressure is captured through force sensitive resistors that are attached to a circuit that translates the resistance response into a voltage characteristic. This analog data is captured through the ADC ports on the XBee module and transmitted to the central control unit. The unit is powered by an onboard 5V battery which is regulated for each of the individual modules in the unit.

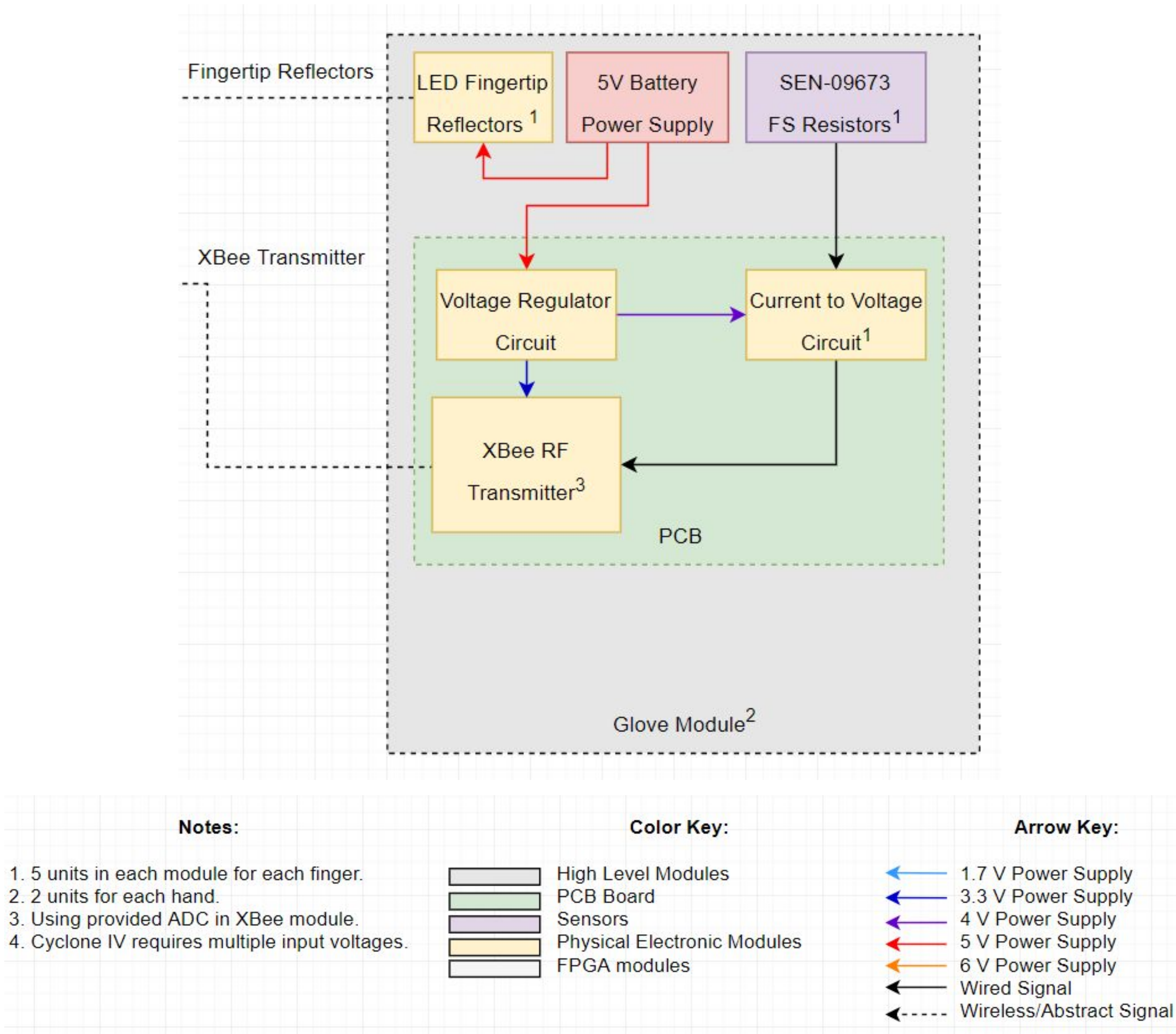

Figure 2.2.1. Glove Unit Block Diagram

2.2. Cyclone IV EP4CE6 FPGA Block Design

2.2.1. Functional Overview

We are planning to use the Altera Cyclone IV EP4CE series FPGA packages in our project due to our familiarity in previous projects with the device and the accompanying software. The FPGA provides the required processing speed for fast processing of image data in real-time and can be used to interface with our peripherals on the PCB. The size of the captured image is about 7 Mb and is too large to be stored on the chip. Consequently, we will be using a 128 Mb SDRAM IC to store and process the image frame buffer.

The FPGA is responsible for processing the image and providing the finger positions to the top level module while also relaying the captured image to a VGA monitor to display the processed image. The FPGA is also responsible for interfacing with the XBee module to process the received digital pressure sensor readings and relaying them to the top level unit for interpretation. The top level of the FPGA integrates these two components and provides the finger location, key trigger and key velocity information to the waveform generator which in turn relays digital amplitude samples at a specific frequency to the audio codec which plays the accompanying waveform on an analog speaker.

2.2.2. Requirements and Verifications

Requirement	Verification
Should be able to process data captured from OV7670 camera sensor in the image buffer at a rate of at least 30 frames per second (222 Mbps).	Cyclone IV internal clock frequency is20 MHz and should be able to process data in parallel for our design. This maximum frequency can be verified on the Quartus timing analysis report.
Should be able to store image data captured in a frame buffer and relay it to a VGA controller at 30fps.	The Cyclone device will be interfaced with an off-chip 128 Mb SDRAM with a max clock frequency of 127 MHz. This should be adequate to store image data. The transfer speed on the SDRAM can also be verified through Quartus timing analysis.
Should be able to configure the FPGA SRAM logic elements in JTAG configuration with the host PC.	We can verify proper configuration by analyzing the uploaded bitstream on Quartus.
Should be able to receive pressure sensor data from the XBee receiver at a rate of 16 Kbps for required resolution.	Verify communication with XBee controller on the FPGA is working as specified in the datasheet through debugging tools in Quartus.
Waveform generator must be able to provide 16 bit digital audio samples generated at a PWM frequency to codec to output the required analog waveform.	The correct functionality can be verified by testing on a line out speaker or through debugging tools in Quartus.

2.3. CMOS OV7670 Camera Sensor

2.3.1. Functional Overview

We are going to be using the CMOS OV7670 camera sensor to isolate the position of the player's fingers from the top view. This data will be processed by the image processing unit on the FPGA to obtain information about which keys are being triggered by the user. Each finger on the glove will be provided with an LED with a unique color which can be deciphered by the image RGB encoding. The pressure sensor will also simultaneously obtain information about whether a particular finger hit a key on the keyboard. Corresponding these two readings with each other we will be able to know which note was triggered by each finger. The frame rate and physical characteristics of the camera sensor are specified quantitatively in the supporting materials.

2.3.2. Requirements and Verifications

Requirement	Verification
Should be able to isolate position in 2D of LED fingertip reflectors with an accuracy of 3mm.	1. Display the captured image after processing on the VGA monitor. 2. Measure the pixel area of the captured image of the LED and test whether it is within 3mm x 3mm.
Should be able to transmit image at 30 FPS with small latency (order of ms).	Test the frequency of the frame_clk signal from the camera module and whether it is in the order of 30 Hz.

2.3.3. Supporting Material

The following calculations describe the physical characteristics of the keyboard layout and the camera lens measurements:

Quantity	Amount
Number of Octaves	7 + minor third
Number of White Keys	52
Number of Black Keys	36

Table 2.3.1. Keyboard Description

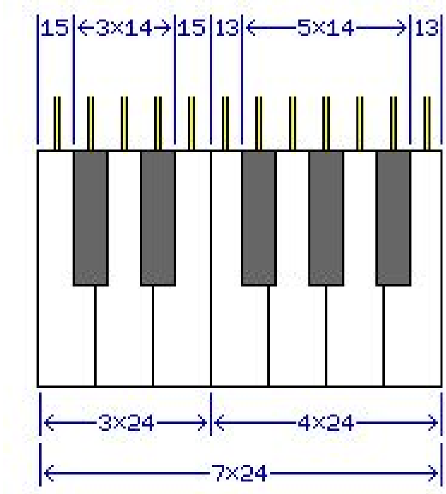

Figure 2.3.1. Piano Key Measurements (mm) [2]

Quantity	Amount
Resolution (pixels)	640 x 480
Field of View (degrees)	2 x 25 = 50
Data per Frame	3 x 8 bit RGB = 24 bits
Frame Rate	30 Hz
Transfer Rate	221.184 (Mbps)

Table 2.3.2. Camera Module Description

Quantity	Amount
Distance from Surface	1 m
Covered Surface Dimensions	0.845 m x 0.845 m
Surface Pixel Dimensions	1.32 mm x 1.32 mm
Keyboard width Covered	67.71 %
LED Reflector Isolation Accuracy	(3 ± 1.32) mm

Table 2.3.3. Camera Module Measurements (mm)

2.4. FSR 400 Force Sensitive Resistors

2.4.1. Functional Overview

We are planning to use the FSR 400 series SEN - 09673 force sensitive resistors by Interlink Electronics to record pressure input data from the user's fingertips. We have chosen these sensors due to their low cost and small size factor. This will grant the player mobility while playing the instrument. The FSR elements will be present on each of the player's five fingers and will be connected to a current-to-voltage circuit that corresponds the conductance of the resistor with a voltage response. The equations and schematics shown in the supporting materials describe this configuration as well as the circuit elements used. The analog voltage value of corresponding to each of the five resistors on one hand is sampled by an ADC unit at about 1 kHz on the XBee RF module which then transmits it wirelessly to the central control unit.

The resistors are integral to the correct functioning of our design as they will allow us to accurately detect when the player presses a virtual key on the keyboard. It will also provide us with information of how hard and fast the key was pressed that can be used to generate a corresponding waveform for the audio unit. The velocity of the key press can be obtained by analyzing the time difference between two successive voltage thresholds. A smaller time difference would correspond to a higher velocity hit of the key. This is the system that is used in most digital keyboards to provide velocity sensitive functionality.

2.4.2. Requirements and Verifications

Requirement	Verification
FSR is connected to operational amplifier with another resistor Rg. In order to map the voltage range we want to have, we first need to check the varying resistance of FSR.	We will use ohmmeter to check varying resistance of FSR from minimum to maximum. Then, we will use specific resistance to get output voltage ranging from 0.1V to 3.5V.
XBee module has range of analog input that won't be cut off. The Maximum is nearly the VCC+0.3V of the XBEE module which is going to be 3.6V in our design. So, resulting voltage output from the op-amp should not exceed 3.6V for proper voltage mapping.	We will check the output voltage of the every op-amp using voltmeter for verification. The specific range that we need to fit into is provided below(see Table 1.)
Force Sensitive Resistor Module is part of glove module and it is required to be mobile. In that sense, the entire module needs to be powered by battery. The battery should be able to supply 3.3V to Xbee module and 4.5V to FSR and finger reflectors. We will use 2 3.7V Li-ion Batteries.	Li-ion Battery is a rechargeable battery. We need Li-poly charger in the module to recharge the battery whenever the battery is low.
All of FSRs needs to have same voltage and approximately 4.5V. Larger Voltage input results in better sensitivity of sensor response. This shall be done by regulating voltage from battery through our voltage regulator unit TPS79930, and then connecting all the FSRs parallely.	Check Vin to FSR using voltmeter.
For proper voltage mapping and greater sensitivity, we need to have linear response. Compared to other circuit configuration, Conductor Circuit Configuration with Operational Amplifier provides most linear response against logarithmic resistance. [logarithmic R creates smaller voltage difference for large change in force]	We will test voltage variation using sample Rg value of 1.5K; larger Rg value may not provide optimal sensitivity. Then we can modify the Rg value for the optimal sensitivity.

2.4.3. Supporting Materials

The following are the resistance and voltage response characteristics of the pressure sensor:

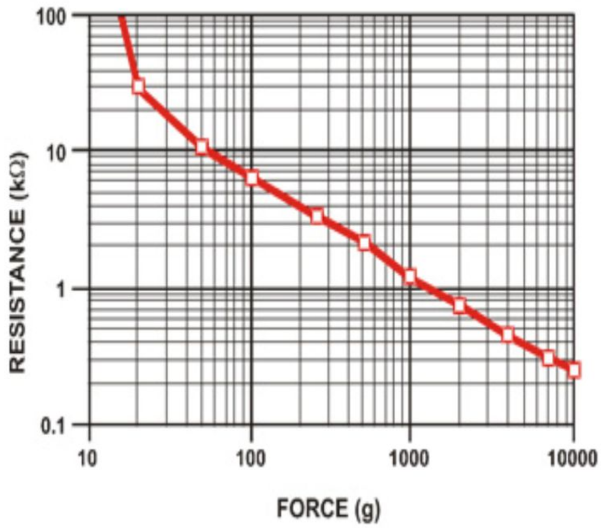

Figure 2.4.1. Force Sensitive Resistor - Resistance Vs. Force [3, Figure 2]

We are going to be using the force sensitive resistors in a current to voltage circuit to sample the voltage corresponding to the conductance of the resistor at any instant. As the resistance characteristic is logarithmic, the conductance would be approximately linear for the initial region which would be utilized by our design.

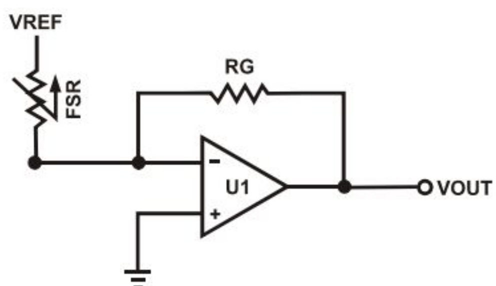

Figure 2.4.2. Current to Voltage Converter Circuit [3, Figure 15]

$$V_{OUT} = V_{REF} \,.\, [\,-R_G \,/\, R_{FSR}]$$

Equation 2.4.1. V_{OUT} for circuit in Figure 2.3.3.2.

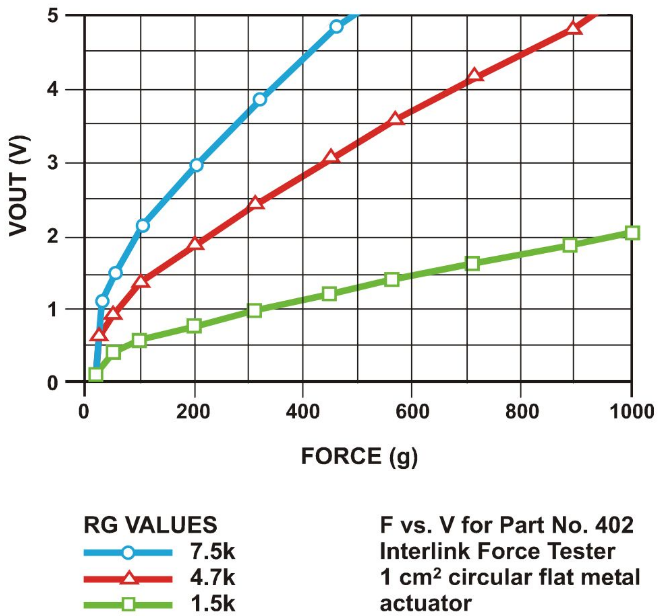

Figure 2.4.3. Voltage Vs. Force for conductance circuit [3, Figure 15]

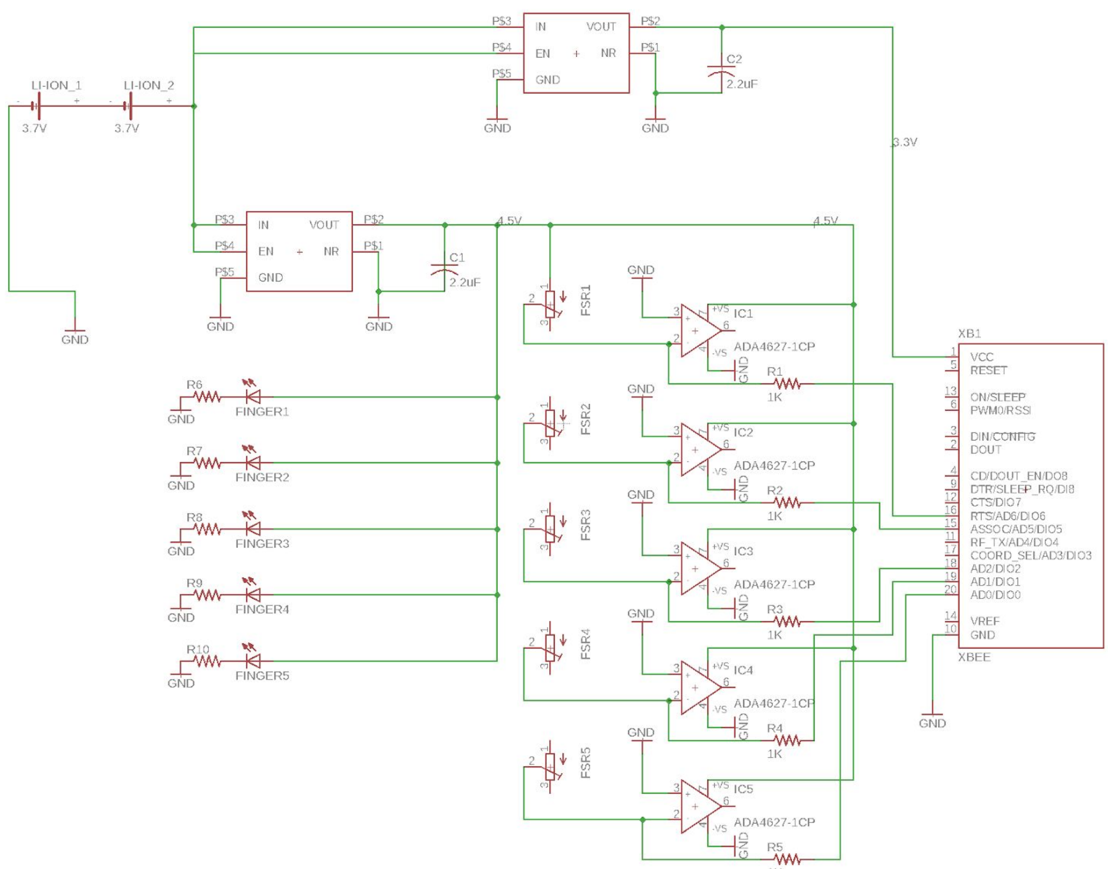

Figure 2.4.4. Force Sensitive Resistor Circuit Schematic

2.4.4. Tolerance Analysis

We are using the force sensitive resistors in our design to gain information about the press of a key on the piano and the velocity with which the key was hit. The key hit velocity will correspond to the amplitude with which the note is played. The force sensitive resistor is connected to the ADC unit through a current-to-voltage circuit as shown above in the supporting materials. This allows our circuit to operate in an approximately linear region required for a key velocity estimation.

At the least we will want to distinguish between five levels of voltage output to correspond to the note amplitude. We believe the precision granted by the resistors and the sampling unit will allow for greater accuracy but we will demonstrate that our design would be able tolerate the deviations of each of the components in the circuit to guarantee at least five levels of voltage distinguishability.

The following figure describes the conductance and resistance characteristic of the FSR resistance (R_{FSR}) against the force applied (measured in grams) and also includes the repeatability tolerance envelope which describes the error range of measurements.

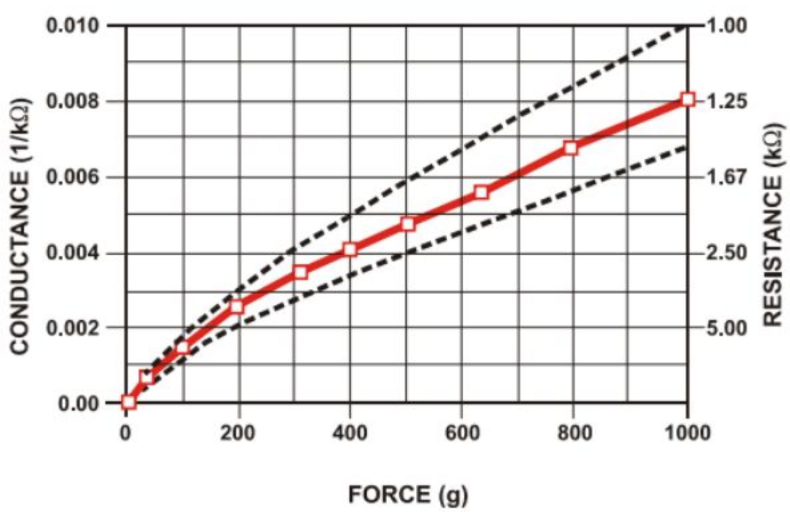

Figure 2.4.4. Conductance vs Force [3, Figure 4]

According to [10], most standard pianos correspond to a touch-weight of 50 grams. We will be using this weight as the starting point to discern whether a key has been pressed by the user. We will further organize each of the 5 amplitude levels at increments of 50 grams from this base touch weight. Therefore, the lowest amplitude will correspond to a force of 50 grams whereas the highest would correspond to a weight of 250 grams.

According to [3], the error envelope measurements for this range of forces is insignificant as human force measurement is inherently erroneous and cannot be detected with repeatability errors of less than ±50%.

Let us consider the intermediate forces of 100 grams and 150 grams. According to Figure 2.4.1 these forces correspond to resistances of 4 K Ohms and 6 K Ohms respectively. For these resistances to conflict with each other we would need to introduce an error of around ±50% according to Equations 2.4.2. While this error grows as we move towards lower force regions and decreases as we move to higher force regions, we can state that within the operation of our design we can tolerate an error of ±50%. This is also approximately the error introduced by human interface force measurement and hence should be adequately responsive for our design.

100 gram FSR Error = (4 K Ohms - 6 K Ohms) / (4 K Ohms) = -50%
150 gram FSR Error = (6 K Ohms - 4 K Ohms) / (6 K Ohms) = 33.33%

Equations 2.4.2. Errors for 100 gram and 150 gram FSR characteristics.

2.5. XBee RF Module

2.5.1. Functional Overview

We will be using the provided XBee S1 (WRL-11215 ROHS) module for converting the analog data collected at the pressure sensors (FSR 400), and transmitting them wirelessly to the FPGA package, for further processing.

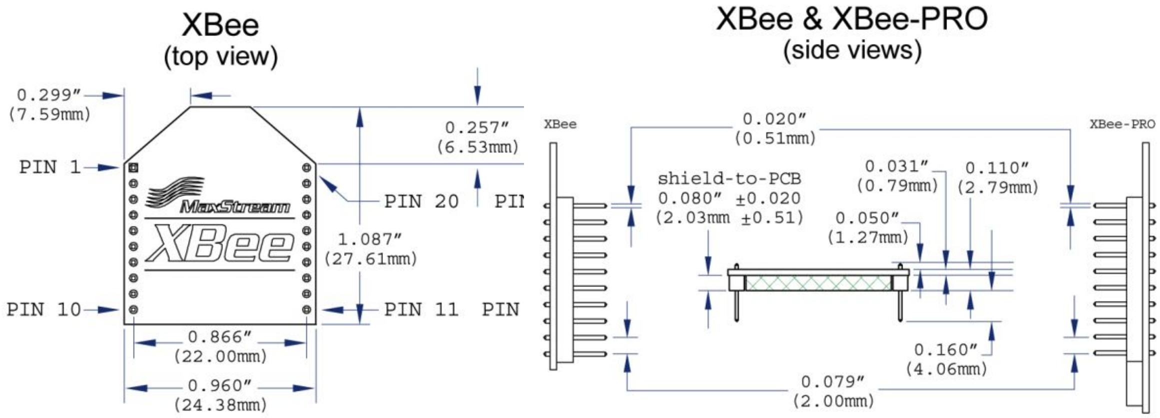

Figure 2.5.1. Mechanical Characteristics of the XBee S1 module [4]

We will be using a total of 3 XBee S1 modules, with 1 on each of the glove module (transmitter) and 1 connected to the central processing unit (receiver). We will be using the XCTU software by Digi [5] to configure each individual device, such as device address, network ID, operation mode, sampling rate, ADC configuration etc.

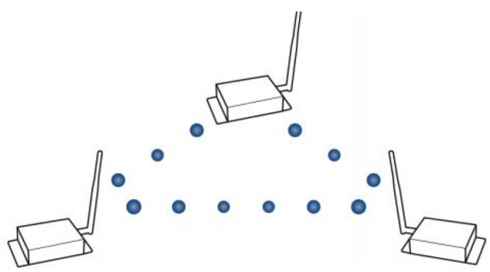

Figure 2.5.2. XBee Network Topology [4]

The network will be set up as Personal Area Network (PAN) [4]. Each device will be configured as an End-Device. Specifically, set parameter End Device (CE = 0), disable End Device Association on all modules (A1 = 0) and set ID and CH parameters to be identical across the network.

XBee Requirements	
Quantity	**Amount**
Sampling Frequency	100 Hz
Data captured each sample	16 bits
Required transfer rate	16 kbps
Maximum transfer rate	250 kbps

Table 2.5.1. XBee Module Calculations

2.5.2. Requirements and Verifications

Requirement	Verification
1. Transmit data within at least 2 meters reliably.	1. Set up the transmitter and receiver with the transmitter connected to the FSRs, and receiver connected to the microcontroller and hooked up to the FPGA. 2. Move the transmitter around the receiver within a 2m radius. Check the data reading through the FPGA.
2. Convert the analog data from the pressure sensors (FSR 400) to digital using on-board ADCs.	1. Same as step 1 from above. Make sure the transmitter and receiver are working properly. 2. Press the FSRs, and make sure the data read on the FPGA is correct.
3. Transmit data at 80 Kbps for the processing of pressure sensor readings	1. Connect both of the transmitting and receiving XBee modules to Arduinos, which will be connected to a PC. 2. Use the XCTU software by Digi, send payloads of predetermined size through the Xbee network, and calculate the performance.

2.6. WM8731 Wolfson Audio Codec

2.6.1. Functional Overview

The WM8731 module is required by our design to convert the digital amplitude signals produced by our FPGA waveform generator into analog signals that may be played on an external speaker. The audio codec receives digital amplitude samples at a specific frequency which it converts into analog waveforms and provides it to the line out port of our central logic PCB. The module consists of two digital to analog converters which it uses to accomplish the transformation. The module is controlled by a serial interface and requires a controller circuit which will be implemented on the FPGA. The module also provides access to other features including volume controls, mutes and power management facilities.

2.6.2. Requirements and Verifications

Requirement	Verification
Should be able to receive digital samples at a modulated frequency from the FPGA waveform generator and produce a corresponding analog signal.	This can be verified separately from the FPGA by sending 16 bit samples at different frequencies for different waveforms and verifying the analog output through a speaker.
Should be able to process input digital samples at a high frequency required for frequency response of piano notes.	Sampling rates from 8 kHz to 96kHz are accepted by the codec and can be verified similar to above by testing analog output.

2.7. MT48LC4M32B2 SDRAM IC

2.7.1. Functional Overview

Our design requires an external SDRAM IC due to the size of the captured image by the camera sensors. The cameras have a resolution of 640 x 480 pixels with each pixel corresponding to a 24 bit RGB value which is serially transmitted from the camera sensor. Therefore, each image requires about 7 Mb to store and process. Due to the small size of on-chip memory we chose to go with an external SDRAM device with a high transfer rate due to our familiarity with the memory controller design in previous projects. The external memory would also allow us to buffer other pieces of data such as the force sensor readings which may not fit into on-chip memory. We are planning to use this memory to implement a FIFO buffer that stores the incoming pixel readings while getting rid of the previous image. This will allow the hardware to process the image as it moves through the buffer.

2.7.2. Requirements and Verifications

Requirement	Verification
Should be have adequate memory space to store one full image buffer for real time processing of camera sensor outputs.	According to the datasheet the chip has 128 Mb of space and one image frame requires 7Mb. This can be verified by checking if the memory locations at higher addresses can be referenced. This can be done using a testbench that issues memory read and write calls to various memory locations allowing us to check the size of memory address space.
Should have a high transfer rate of around 100 Mbps to transfer image data from sensors to SDRAM and back to FPGA.	SDRAM has a clock frequency of 167 Mhz and can be operated in parallel mode. Data transfer rate can be verified through Quartus debugging tools on the FPGA including the timing analyzer.

2.8. Power Supply

2.8.1. Functional Overview

Our entire project is composed of numbers of separate modules. Glove module, camera module, and our central logic unit's power requirement varies. Our glove module is designed to be mobile, hence requires a battery to power the module. On the other hand, our central logic unit and camera module has greater power consumption since more complex operations are held at the central unit and continuously recording image also contributes to great power consumption. Therefore, we decided to share main power supply for both main central logic unit and camera module and make lithium-ion battery power our glove module. However, even within each module, each chip has different voltage requirements and even within chip the voltage requirement varies depending on the purpose of the pin. Hence, we implemented different voltage regulator circuits that satisfy the voltage requirements of each module and each port of chips. In addition to Voltage requirements, each chip has current consumption rating. So for modules like glove modules, choosing which battery to use also depended on the current rating of the battery as well.

2.8.2 Requirements and Verifications of Power Supply for Central Logic Unit

Requirement	Verification
TPS65023 has operational range of Vin (-0.3V - 7.0V). We need Voltage regulator (TPS799-adjustable) to provide 6.0V to TPS65023.	Adjustable Voltage regulator creates Voltage output based on resistor values. Choose appropriate resistor values based on the calculation. For further verification, we may use Voltmeter to check the voltage output. (see attached Eq. 2..8.1 and sample circuit below)
All of the voltage output of the supply rail into the FPGA should fit into the range of Vin and Vmax of Cyclone IV E series.	See Table 1 Below.
TPS65023 is a chip with multiple switching and LDO regulators whose regulated voltage is determined by user. TPS65023's DEF ports are labeled as follows: DEFDCDCx and DEFLDOx. The first one sets regulated voltage for switching regulators while the second one sets voltage for LDO regulators. These values are value to be loaded into FPGA from the chip. Therefore, the value loaded into DEF ports needs to satisfy the requirements of FPGA input ports.	Check which output of the chip is connected to the input of the FPGA and check whether the input to the DEF ports are fed by proper voltage that meets FPGA input voltage specifications. Check with the voltage meter and before wiring, check register values connected to the port.
TPS65023's supply voltages are directly synced to the voltages applied to DEF ports. In order to sync voltage supplies with proper values, we need voltage divider circuits with different resistor values for each of DEF ports. (Eq. 2.8.2)	Vin of voltage drop 6V directly comes from voltage regulator. Along with the current consumption provided on the Table 1 (from TPS65023 datasheet), R1 and R2 was calculated. (See Table 1 and Eq. 2.8.2).

2.8.3. Supporting Materials

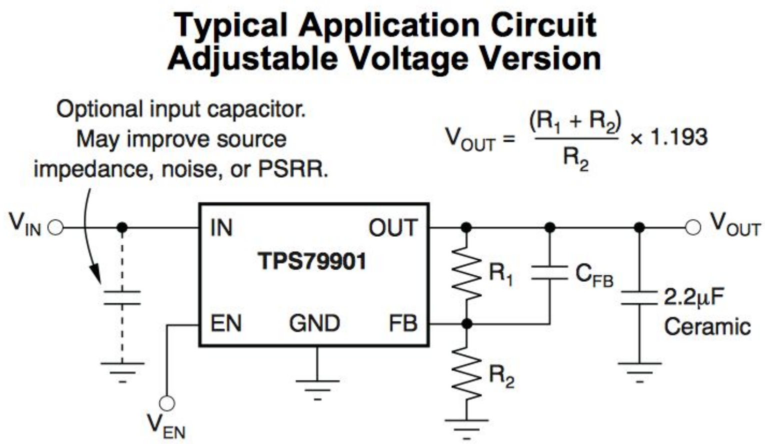

Figure 2.8.1. TPS79901 Voltage Regulator Circuit [6, Figure 2]

$$V_{out} = 1.193 \,.\, (R_1 + R_2) / R_2$$
R2 = 1.0 K Ohms
R1 = 4.0 K Ohms
$$V_{out} = 6.0 \text{ V}$$

Equations 2.8.1. Voltage regulator circuit calculations

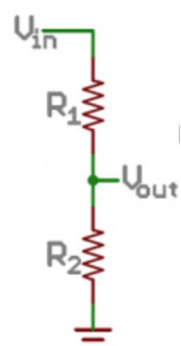

Figure 2.8.2. TPS65023 Voltage divider circuit for user defined voltage regulation. [7, Figure 1]

$$V_{out} = V_{in} \,.\, (R_2/(R_1+R_2))$$

Equations 2.8.2. Voltage divider for input calculations.

TPS65023 Power Management IC V_{out}			**Cyclone IV EP4CE6 V_{req}**				
Supply Rails	Voltage	Current	Symbol	Min	Max	R2(Ohms)	R1(Ohms)
VCC	1.2V	1.7A	VCCINT	-0.5V	1.8V	0.7	2.8
VCCA	2.5V	10A	VCCA	-0.5V	3.75V	2.5	3.5
VCC_CLKIN	2.5V	1.0A	VCC_CLKIN	-0.5V	4.5V	2.5	3.5
VCCD_PLL	1.2V	1.2A	VCCD_PLL	-0.5V	1.8V	1	4
VCCL_GXB	1.2V	1.2A	VCCL_GXB	-0.5V	1.8V	1	4
VCCA_GXB VCCH_GXB	2.5V	1.0A	VCCA_GXB VCCH_GXB	-0.5V	3.75V	2.5	3.5
VCCIO_1.8	1.8V	0.2A	VCCIO	-0.5V	3.75V	9	21
VCCIO_3.3	3.3V	0.2A				16.5	13.5

Table 2.8.1. Power Requirement for FPGA and Power Supply Output Comparison

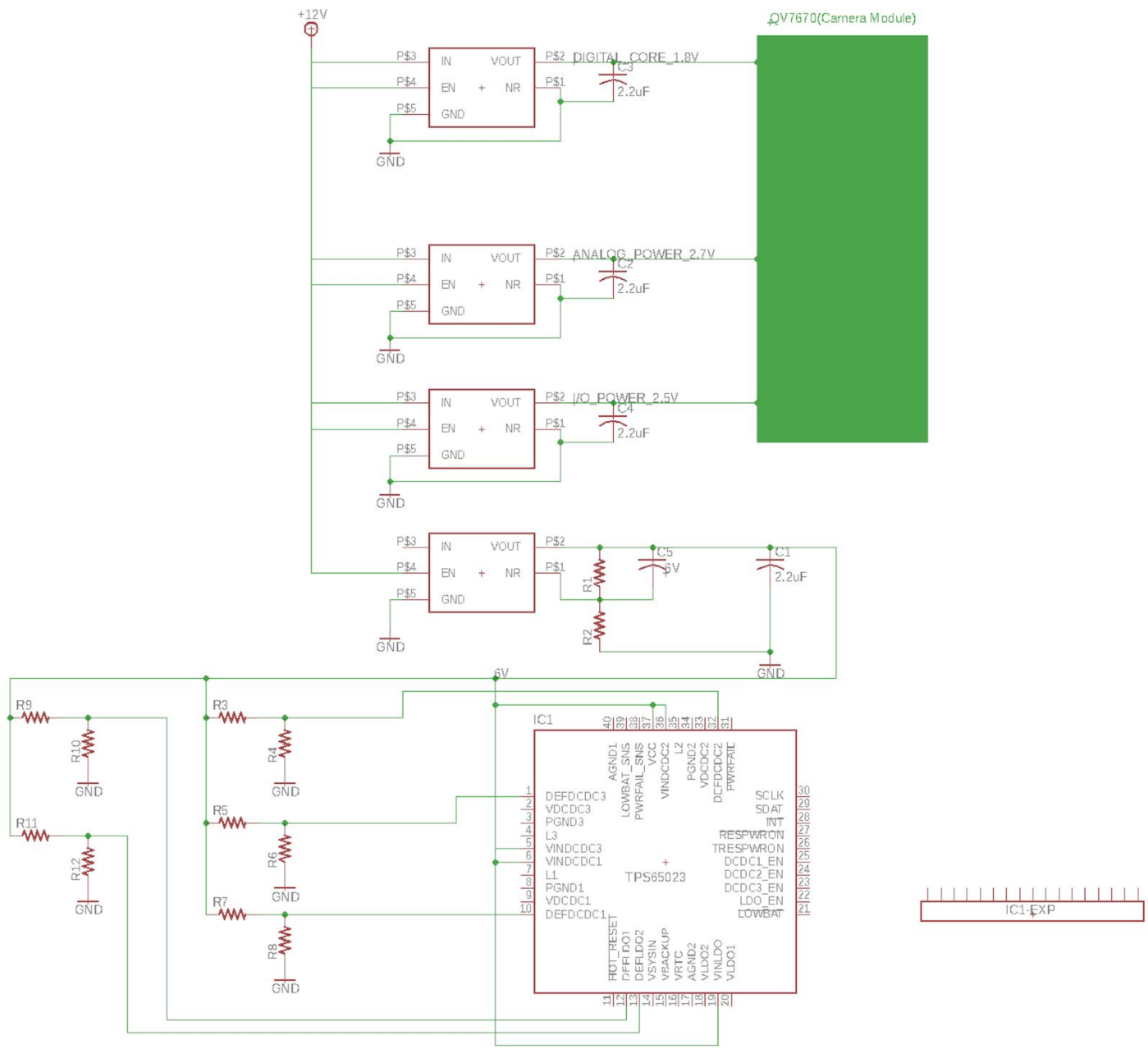

Figure 2.8.3. Circuit Schematic for power supply to camera module and FPGA
(the schematic only shows regulated input to the TPS65023 chip that is to be fed into FPGA)

2.8.4 Requirements and Verifications of Power Supply for Camera Module

Requirement	Verification
Voltage input for the Voltage regulator has to be within the operational range.	Our Provided Power Supply lies within the range of Voltage input for TPS799 which can be verified by a voltmeter.
Power supplied to Camera module has to meet the voltage requirement for the QV7670.	See the attached table below (Table 2.8.2).

2.8.5. Supporting Materials

	Vout From Voltage Regulators	QV7670 Voltage Requirements
Digital Core	1.8V	1.8V +/- 10%
Analog	2.7V	2.45V to 3.0 V
I/O	2.5V	1.7V to 3.0V

Table 2.8.2. Power Requirement for QV7670 and Voltage Regulator Output Comparison

2.8.6. Requirements and Verifications of Power Supply for Glove Unit

Requirement	Verification
We are using two of 3.7V Li-ion battery to power each glove module. Power supplied from battery should regulated and meet the requirements for both XBee module and input voltage requirement for our voltage regulator TPS799.	Parallely connected batteries create 7.4V and it is regulated through TPS799 whose maximum input rating is greater than the supplied power. To check whether XBee module is fed by correct power, use voltmeter.
Our Li-ion battery needs to charged when the battery is low.	LiPo Charger will charge the batteries at 500mAh when connected to micro-usb.
Our Li-ion battery supplies power at current rate of 1A to the circuit.	Check with Ammeter.

3. Costs

Part Costs: $268.1				
Part Name	Unit Price	Number	Subtotal	Note
FSR 400 Pressure Sensor	$5.95	12	$71.4	2 extra for safety Source
EP4CE6E22C8N	$11.95	1	$11.95	Source
TPS65023	$5.12	1	$5.12	Source
TPS799	$0.70	10	$7.00	Source
XBee S1 RF Module	$24.95	3	$74.85	In ECE 445 Stock Source
MT48LC4M32B2 SDRAM	$10.93	1	$10.93	Source
OV7670 Camera	$14.00	2	$28.00	In ECE 445 Stock Source
WM8731 Audio Codec	$4.15	1	$4.15	Source
PRT13813 Li-Ion Battery(1Ah)	$9.95	4	$39.8	Source
PRT-10217 LiPo Charger Basic - Micro-USB	$7.95	2	$15.9	Source
Labor Costs: $10,800				
Number of Team Members	Hourly Wage	Total Hours (Estimated)	Total	Note
3	$30	120*	$10,800	
Grand Total: $10,868.1				

* Estimated 15 hours/week * 8 weeks

4. Schedule

Week	Due Dates	Hammad	Jeongsub	Zhi
2/19		Assign tasks and formulate design plan.	Finalize design of Power Supply for modules.	Research more into XBee protocol.
2/26	Design Review	All necessary parts must be decided.		
3/5	Soldering Assignment	Design FPGA software in SystemVerilog.	Work on the PCB design for the central control unit and glove unit.	Test initial setup of XBee network and data transmission. Help building the transmission flow from glove to FPGA.
3/12	First PCB order	Test functionality of software on DE2 board and integrate board components.	Work on PCB schematics and finalize to place board order.	Continue building data transmission flow.
3/19	Spring Break			
3/26	Final PCB Order	Finish designing software and implement on PCB FPGA.	Test PCB design and integrate components for glove and central unit.	Finalize transmission implementation.
4/2		Integrate central unit and glove unit to test and debug.	Integrate central unit and glove unit to test and debug.	Integrate central unit and glove unit to test and debug.
4/9		Continue testing and debugging.	Continue testing and debugging.	Continue testing and debugging.
4/16	Mock Demo	Continue testing and debugging.	Continue testing and debugging.	Continue testing and debugging.
4/23	Mock Presentation	Continue testing and debugging.	Continue testing and debugging.	Continue testing and debugging.

5. Ethics and Safety

The following are the potential safety hazards with our project:

- Battery and Power Supply Unit:
  - We will be using batteries in our project and li-ion batteries are known to become highly volatile at extreme temperatures or if overcharged.
  - For this reason we will be closely monitoring the battery temperature and charge throughout the project where batteries are used.
  - We will also be making use of the mains load voltage to power our central logic board. We will take the recommended precautions into account to safely access the power supply as well as charge and discharge the batteries.
- Glove Unit:
  - Our glove unit may pose hazard as well in terms of the power from battery which may become volatile.
  - In order to avoid any possible hazard we have to comply with the expected range of the resistance that the FSR can vary and regulate the voltage output of the circuitry.

The following are the potential ethics concerns with our project:

- To comply with IEEE Code of Ethics #1, “to strive to comply with...sustainable development practices” [8], we will be using gloves that are sustainably sourced.
- Since we will very likely be dealing with copyrighted music, we will make sure that what we do during implementation and testing comply with the Digital Millennium Copyright Act (DMCA).

6. References

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