LOW ENERGY ANDROID GAMEPAD

Project Proposal

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Introduction

The proposed project idea is to create a semi-soft silicon controller that fits tightly around most Android devices. Core required functionality for demonstration will include a collection of analog inputs via a microcontroller, and transmission of data using a wireless communications medium to an android device. The goal is to communicate with the Android device and send data wirelessly to Android applications with minimal power usage.

This controller is aiming for a better feel and control of applications that the ordinary touch screens cannot provide. Issues with touch screens such as reading multiple inputs and blocking large portions of the screen can be overcome with a wireless controller. With more powerful, multi-core smart phones on the horizon, game developers would be able to provide the feel of portable gaming consoles on virtually any Android device.

Hardware design will consist of implementing embedded game controls using a low energy wireless communications medium, Near Field Communications (NFC), to communicate to the host Android device. The hardware will also be designed to accompany Bluetooth Low Energy (BLE) and Bluetooth v2.1+EDR, but the focus of this project will be based on the low power NFC.

A microcontroller will be used for reading analog input signals from multiple push buttons and a joystick. This information will be sent to a wireless transmission microcontroller, the NFC chip, which uses a handshake protocol with the Android device.

Software components include application development that will utilize the Android SDK and demonstrate wireless communication between the controller and Android device. A standard interface that can be used by a variety of applications and emulators will be developed. The handshake protocol between the controller and phone will be based on sending and receiving packets of data. This will have to be interpreted into specific commands and status updates.

The following requirements are the ideal goals, but are not necessarily core demonstration requirements. If NFC succeeds as the communications medium, power consumption experiments will be performed, and results will be noted during demonstration. Haptic feedback support may be implemented using a vibration motor, but the downside is that this will increase power usage. Additional driver software would allow for a generic template others could use to communicate between the controller and Android device.

Implementation

Target Platform and Wireless Medium

Why use near field communication? NFC, used in passive mode, and BLE have similar data rates and power consumption (about 15mA peak) [3]. Range should not be an issue for either technology, due to the close proximity of the device to the host. Initial calculations indicate that our implementation should yield 30 or more continuous operating hours off of a single CR2025 lithium button-cell battery for either technology. A notable difference between NFC and BLE is the power consumption required by the host: BLE requires a dual-mode Bluetooth v4.0/BLE chip to be powered up on the host device [2], requiring significantly more power than NFC. Bluetooth v2.1+EDR can expand battery life up to five times over older Bluetooth standards.

NFC is already available on the Google Nexus S [4], and the upcoming Samsung Galaxy S II is expected to ship with NFC in selected markets [5]. BLE enabled devices are rumored to arrive at an unspecified time in 2011. Bluetooth v2.1+EDR is well established in the Android market.

Due to immediate availability of a target platform, and enhanced power consumption over Bluetooth v2.1+EDR, we have decided to utilize NFC. A variety of NFC enabled devices may be targeted, as the baseline circuitry may be embedded into inexpensive silicon molds for specific devices. In case of unforeseen problems with this relatively new technology, Bluetooth v2.1+EDR may be used instead.

Figure 1. Concept design by Tuyet Nguyen

Hardware

The controller will contain an analog joystick and at least six buttons. There will also be 2 triggers on the back of the controller. The standard "Start" and "Select" buttons would not be needed because the touch screen can still handle this without much visual restriction. A concept game controller design can be seen above in Figure 1. The Android device will be seated in the center, with inputs along both sides and trigger on the back of the controller.

We will use the Microchip PIC16F727 8-bit microcontroller for this project. It will collect data from the analog inputs and communicate with the NFC chip using a serial port interface. It was chosen because of a large input/output bus and very low power usage. Figure 2 shows the interface for the microcontroller. Below are the technical specifications.

- Wide operating voltage (1.8 to 5.5V)
- Low power consumption (6uA @ 32KHz)
- 500KHz or 16MHz internal oscillator or 32KHz crystal oscillator
- 35 I/O pins, ADC, PWM, Capture/Compare
- SPI Master/Slave capability

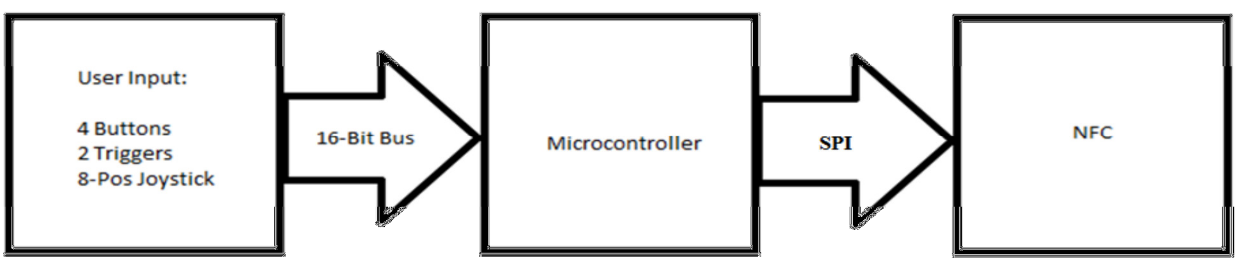

Figure 2. Microcontroller Interface

An economy custom printed circuit board (PCB) will be needed for the NFC chip, as well as a custom laser cut plastic solder stencil. Preliminary estimates for the PCB and stencil are about $30 each, but the stencil sheet will be used for multiple copies of the PCB to allow for multiple controllers. A reflow oven needs to be used to reflow NFC chip. A communications antenna will have to be routed appropriately and connected to the appropriate NFC pins, so connections for an appropriate RF connector will be included into the PCB design for the antenna connection, as well as any headers required for I/O to the NFC chip.

Since we will already need to have a PCB fabricated, we will likely include the microcontroller and analog joystick onto the same PCB, along with any protection diodes, signal conditioners, and I/O headers for the microcontroller. The other inputs will be connected via the I/O headers on the PCB.

The PN531 microcontroller based NFC transceiver will be used to transmit information between the controller and the Android device. It will be programmed to read packets from the main microcontroller and send them to the Android device. The input/output pins are displayed in Figure 3. An antenna coil will also need to be developed to transmit signals. The antenna will need to function at a specified 13.56 MHz.

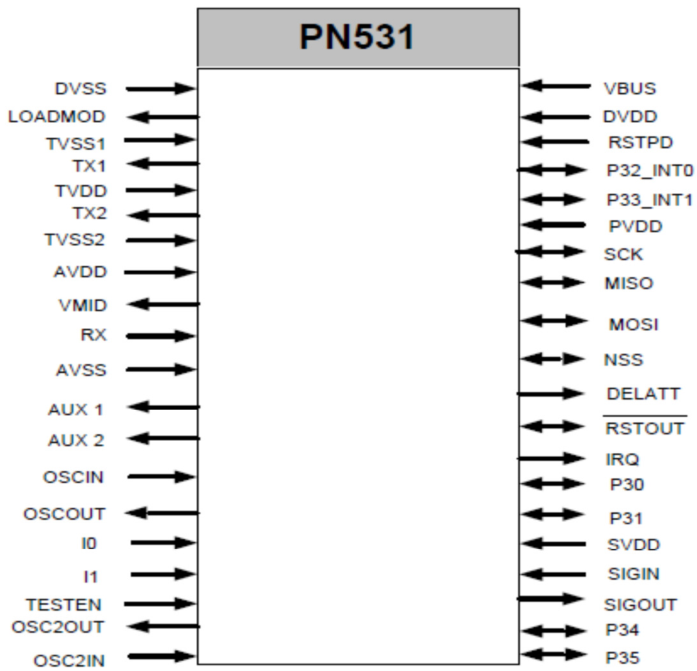

Figure 3. NFC I/O Interface

NFC may be used in passive mode, wherein the host generates a field to stimulate the device and read it's data, or in active mode, wherein both host and device generate fields for two way communication [1]. Passive mode requires less power consumption for the device and slightly more power consumption for the host, while active mode requires significantly more power on the device and slightly less on the host. Basic operation will use passive NFC, while haptic feedback will require active NFC. Since this will decrease battery life, both modes will need to be supported if haptic feedback is implemented, such that passive mode will be used whenever haptic feedback is not in use. Figure 4 shows the NFC interface.

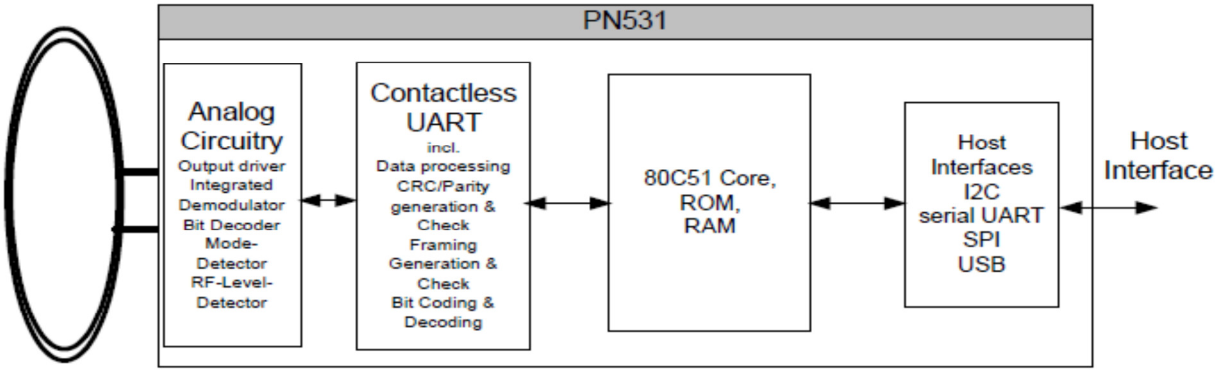

Figure 4. NFC Interface

NFC will only require a single button-cell lithium battery for long term operation. A microcontroller will be used to process user input, so protection diodes, and possibly signal conditioners will be needed on digital input lines. The prototype silicon glove will be constructed using a hobbyist silicon mold kit available on the internet. If time permits, a vibration motor may be integrated for haptic feedback.

Software

Microcontroller software will be written to collect user input, de-bounce buttons (if needed), and send via RS-232 to the wireless communications module. Information packets will be constructed using start, stop, and data bits. These will be sent between the microcontroller and NFC chip to relay user input and Android status information.

A keyboard emulation driver for the wireless communications medium will be written for the Android system, and a game or application utilizing the driver will be written to demonstrate functionality. This demo will need to show full functionality of the controller working along features already found on Android devices such as motion controls and touch screen.

If haptic feedback is included, a driver and SDK will need to be written to support communications back to the device from the host. Microcontroller software will need to toggle between active and passive communication modes, as well as receive haptic requests and generate appropriate signals for the vibration motor.

Energy saving techniques will be implemented in the microcontroller software whenever possible. These will consist of implementing an efficient switching scheme between passive and active modes along with stand-by and inactivity features.

User Interface Specifications

Hardware

User inputs include a two-axis resistive joystick, 4 primary buttons, and two trigger buttons. All other hardware will be hidden from the user and encased in the silicon controller. The user will grip the controller as it sits around the Android device.

Software

User inputs will be mapped as keystrokes by a device driver on the Android host. The default key map can be seen in Table 1. A graphical user interface for Android will be written to provide user control over the key mapping. An API will not be necessary, as applications and games will be able to utilize the device via the key map.

Joy (-1,0) = key_left	Joy(1, 0) = key_right
Joy(0, -1) = key_up	Joy(0, 1) = key_down
Joy(-1, 1) = key_down+key_left	Joy(1, 1) = key_down+key_right
Joy(-1, -1) = key_up+key_left	Joy(1, -1) = key_up+key_right
Button 1 = key_a	Button 2 = key_s
Button 3 = key_d	Button 4 = key_f
Trigger Left = key_j	Trigger Right = key_k

Table 1. Default Key Map

Schedule Flow

Phase 1

The initial planning portion of the schedule will consist of researching parts, designing the antenna coil and PCB layout, generating and ordering a bill of material as seen in Figure 2. Parallel processes can be viewed vertically, while the process flow moves horizontally.

Documentation will take place throughout the entire process. A web-based scrum system will be used to track progress and set a time table for left over tasks.

Tasks will be divided such that one person will design a component and the other will review for functionality and potential compatibility issues.

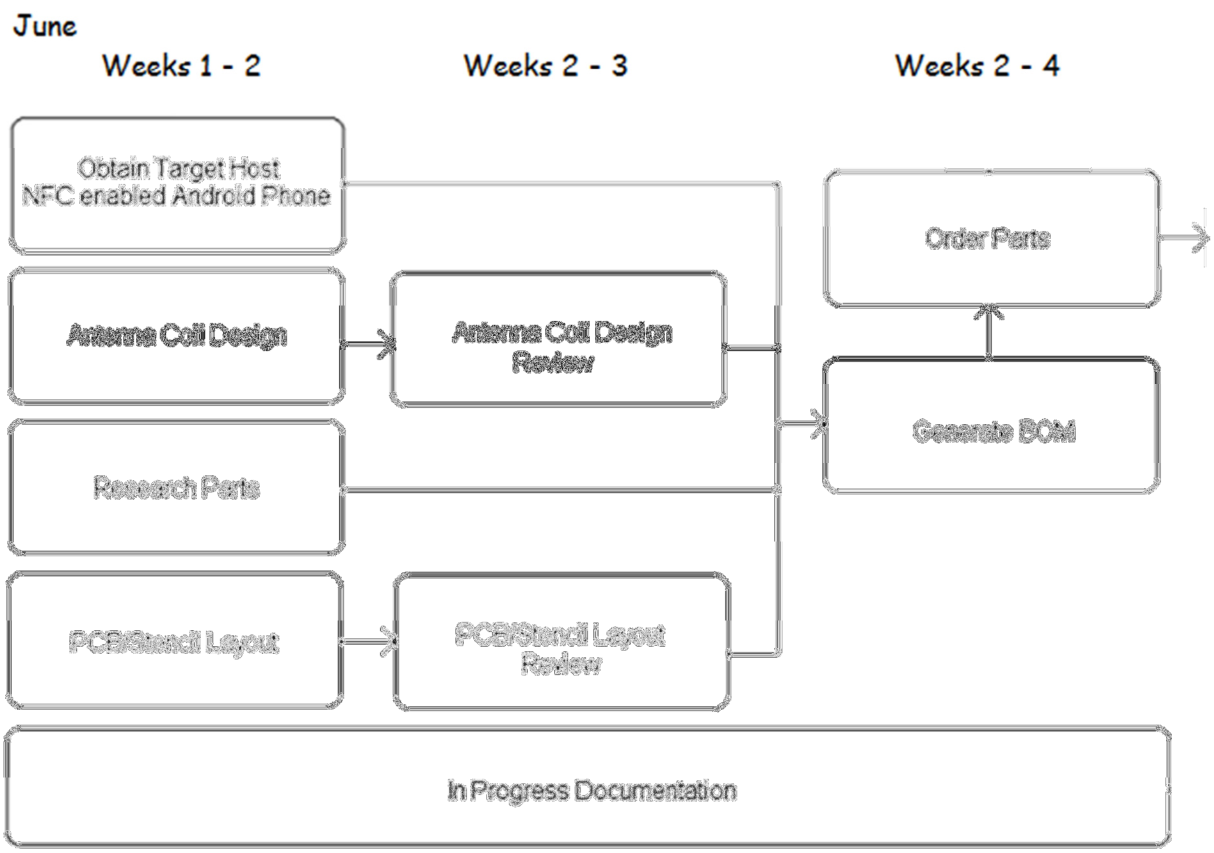

Figure 2: Phase 1 – Tasks and Schedule

Phase 2

The next phase will contain the majority of hardware and software components. The microcontroller needs to be integrated with the analog input signals, custom PCB, and wireless communication medium. Antenna coil integration needs to be developed for use with the NFC.

The controller itself will first need concept designs before the final silicon molds are formed. This will be tested to create the most ergonomic design for the user.

While hardware is being developed, initial software can be started. This will consist of drivers and applications for the Android device.

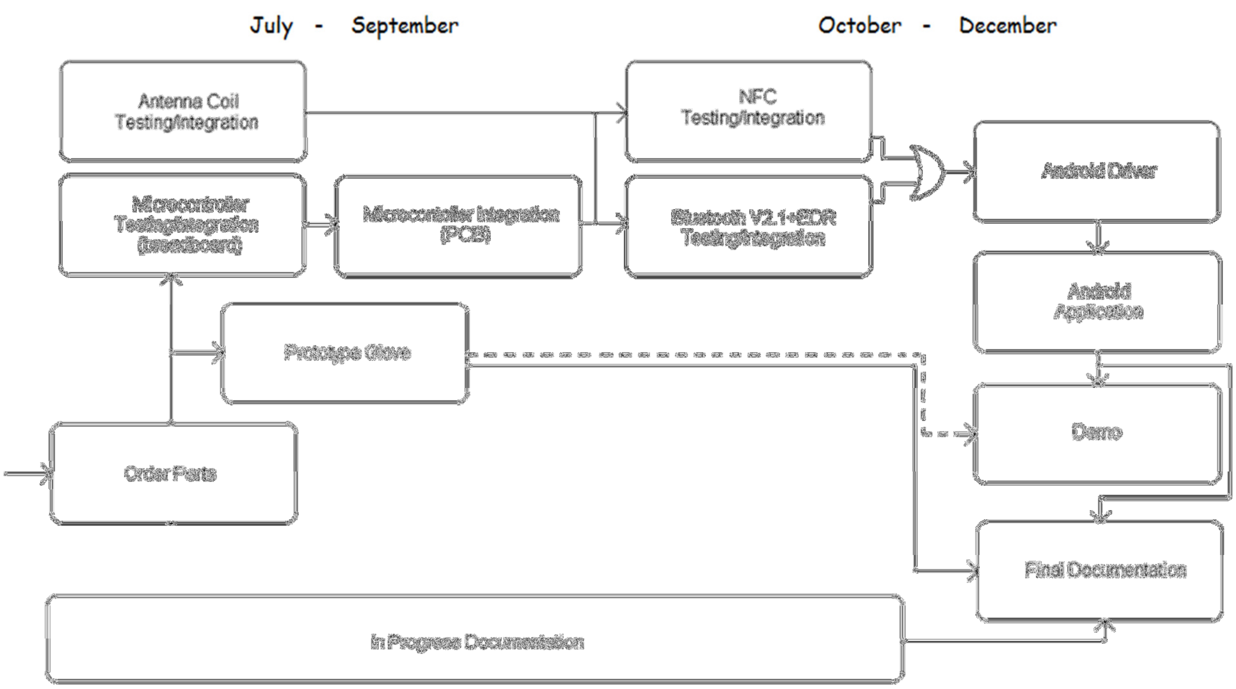

Figure 3: Phase 2 – Tasks and Schedule

Weekly Checkpoints

Weeks 1 – 2
- Preliminary PCB/stencil layout
- Preliminary antenna coil design
- Finalized PCB/stencil layout (ordered)
- Finalized antenna coil design (ordered / built)

Weeks 3 – 4
- Gather complete microcontroller documents
- Begin simple code testing on microcontroller
- Breadboard microcontroller testing – I/O
- Breadboard analog input to microcontroller - pushbuttons

Weeks 5 - 6
- Integrate analog input with PCB
- Integrate microcontroller with PCB
- Integrate wireless transmitter with PCB

Weeks 7 – 8
- Design ergonomic game pad and create preliminary molds
- Finished game pad design and prototype silicon game pad created

Weeks 9 – 10
- Assemble antenna
- NFC chip testing – I/O
- Android device driver

Weeks 11 – 12
- Integrate antenna with NFC
- Integrate electronics with silicon game pad

Weeks 13 – 14
- Preliminary Android application
- Application graphics

Weeks 15 - 16
- Integration of controller with application
- Test Wireless signal processing
- More functionality and more apps

Demo
- Fully functional wireless controller for Android device and demo application

Risk Assessment

There are multiple risks that can be encountered throughout this project. A summary of the project risk assessment is in Table 2. The goal is to follow the mitigation plans which will allow the project to be completed with specifications matching those planned originally. Backup plans are in place which are in place when all else fails. Core functionality will still be achieved but features may be severely limited with the backup plans.

Risk	Mitigation Plan	Backup Plan
A few Surface mount components	Custom PCB/Stencil	Other communication mediums, WIFI, USB
New use for NFC, will it work like we think?	Implement Bluetooth V2.1+EDR in tandem	Other communication mediums, WIFI, USB
No HVQFN40 PCB template	Find one	Make one, Other communication mediums, WIFI, USB
Need to design antenna coil, not well versed in antenna design	Study NFC Antenna Design Papers	Bluetooth V2.1+EDR only
Will silicone molding turn out ok?	Start early, don’t let it consume too much time	Demo without enclosure
Both teammates have hectic schedules	Work over summer	Core requirements only

Table 2: Risks, Mitigation, and Alternatives

Bill of Material

The following tables show the proposed bill of material for the core features in this project. Quantities allow for multiple game pads to be built which takes account for items dead on arrival, damaged caused by integration, and a wider testing spectrum.

Each component listed below includes manufacturer, supplier, part number, quantity, and price information.

Common Parts										
Index	Quantity	Reference	Value / Generic Part Number	Package / Class	Manufacturer	Manufacturer's ordering code / Orderable Part Number	Supplier	Supplier's ordering code	Unit Cost	Cost
38	1	uC1	Microcontroller	PDIP 40 (Thru-hole)	Microchip	PIC16F727-I/P	Mouser.com	579-PIC16F727-I/P	$ 2.6600	$ 13.30
39	6	PB1:PB6	Push Button	Thru-hole	E-Switch	320.08E11BLK	Digikey.com	320.08E11BLK-ND	$ 1.4650	$ 43.95
40	1	JOY	2-axis Joystick	Thru-hole	Paralax	27800	Mouser.com	619-27800	$ 4.6900	$ 23.45
41	1	PCB	Custom PCB	2 Layer Economy	Silver Circuits	PCB Production	Custompcb.com	PCB Production	$ 17.0000	$ 85.00
42	1	SW1	7-pos DIP Switch	Thru-hole	CTS	208-7	Mouser.com	774-2087	$ 0.7700	$ 3.85
43	1	LED1	Green	Thru-hole	KingBright	WP3A8GD	Mouser.com	604-WP3A8GD	$ 0.0600	$ 0.30
44	1	LED2	Red	Thru-hole	KingBright	WP7104LID	Mouser.com	604-WP7104LID	$ 0.0500	$ 0.25
45	1	LED3	Yellow	Thru-hole	KingBright	WP7104LYD	Mouser.com	604-WP7104LYD	$ 0.0600	$ 0.30
									QTY:	5
									Parts Cost:	$ 170.40
									Cost Per Unit:	$ 34.08

Table 3. Common Parts to all Designs

46	1	N/A	Custom Stencil	Plastic Film - Laser Cut	Polulu Robotics	446	Polulu.com	446	$ 37.00	$ 37.00
47	1	N/A	Solder Paste	Pb-No Clean 500g	Manncorp	SH-6309RMA	smtsolderpaste.com	SH-6309RMA	$ 49.00	$ 49.00
48	1	N/A	Hobby Silicone	Medium 122 Shore A 10 Lbs Kit	MPK Enterprises	N/A	hobbysilicone.com	N/A	$ 116.98	$ 116.98
49	1	N/A	Gram Scale	Pocket	American Weigh	SC-2KG	amazon.com	AMW-SC-2KG	$ 23.13	$ 23.13
50	1	N/A	Silicone Release Agent	LPS – Dry Film Silicone - 16 oz aersol can	LPS	N/A	hobbysilicone.com	N/A	$ 14.99	$ 14.99
51	1	N/A	Latex Gloves	XL - Box 100	McKesson	N/A	hobbysilicone.com	N/A	$ 11.99	$ 11.99
52	1	N/A	Mixing Sticks	Bag 100	Generic	N/A	hobbysilicone.com	N/A	$ 3.99	$ 3.99
53	1	N/A	Modeling Clay	Air Dry - 10Lb Box	AMACO	B001O5QIT2	Hobby Lobby	N/A	$ 7.47	$ 7.47
54	1	HOST	NFC Capable Android Phone	CDMA Nexus S 4G (no contract)	Google/Samsung	Nexus S 4G	Sprint Wireless	Nexus S 4G	$ 699.99	$ 699.99
									Setup Cost:	$ 964.54
									Total Cost:	$ 1,694.99

Table 4. One Time Purchase Parts

NFC Parts										
Index	Quantity	Reference	Value / Generic Part Number	Package / Class	Manufacturer	Manufacturer's ordering code / Orderable Part Number	Supplier	Supplier's ordering code	Unit Cost	Cost
1	1	NFC	PN531	SMT - 40-HVQFN (6mm x 6mm x 0.85mm)	NXP	PN5310A3HN/C203,55	Mouser.com	771-5310A3HNC203551	$ 8.8100	$ 44.05
*2	1	ANT1	NFC Atnenna	TBD	TBD	TBD	TBD	TBD	TBD	TBD
3	1	BAT1	Li-On Battery	20mm Button-cell	Panasonic	CR2025	Digikey.com	P188-ND	$ 0.2700	$ 1.35
4	1	PS1	Battery Holder	20mm Button-cell Holder Thru-Hole	Eagle Plastic Devices	122-2520-GR	Mouser.com	122-2520-GR	$ 0.9100	$ 4.55
5	1	XTAL1	27.12 MHz	SMT - 1.6mm x 2mm x 0.65mm	Murata	XRCGB27M120F3M00R0	Mouser.com	81-XRCGB27M120F3M0R0	$ 0.7900	$ 3.95
									QTY:	5
									Parts Cost:	$ 224.30
									Cost Per Unit:	$ 44.86

Table 5. NFC Parts

Table 6 shows parts that will be needed for implementing haptic feedback in the controller. This is a feature we would like to implement so parts will be purchased and used time permitting.

Haptic Parts										
Index	Quantity	Reference	Value / Generic Part Number	Package / Class	Manufacturer	Manufacturer's ordering code / Orderable Part Number	Supplier	Supplier's ordering code	Unit Cost	Cost
33	1	BAT2	Li-On Battery	20mm Button-cell	Panasonic	CR2025	Digikey.com	P188-ND	$ 0.2700	$ 1.35
34	2	M1:M2	Haptic (Vibration) Motor	8mm x 3.4mm Adhesive	Polulu Robotics	1637	Polulu.com	1637	$ 3.1400	$ 31.40
*35	2	U2:U3	DAC	TBD	TBD	TBD	TBD	TBD	TBD	TBD
*36	2	Various	DC Motor Driver	TBD	TBD	TBD	TBD	TBD	TBD	TBD
37	2	PS2	Battery Holder	20mm Button-cell Holder Thru-Hole	Eagle Plastic Devices	122-2520-GR	Mouser.com	122-2520-GR	$ 0.9100	$ 9.10
									QTY:	5
									Parts Cost:	$ 41.85
									Cost Per Unit:	$ 8.37

Table 6. Haptic Feedback Parts

Table 7 shows the parts that will be used as a backup to the NFC implementation if too many unforeseen problems develop. The BLE implementation will be similar to the proposed NFC implementation.

BLE Parts										
Index	Quantity	Reference	Value / Generic Part Number	Package / Class	Manufacturer	Manufacturer's ordering code / Orderable Part Number	Supplier	Supplier's ordering code	Unit Cost	Cost
6	1	BLE	BLE Module	SMT -VQFN40 (6mm x 6mm x 0.5mm)	TI	CC2540F256RHAT	Mouser.com	595-CC2540F256RHAT	$ 8.8800	$ 44.40
7	1	ANT2	BLE Antenna	SMT - 2.4GHz Antenna 1.2 dBi (7.8mm x 3.6mm x 0.9mm)	Yageo	240-4311-115-00245	Mouser.com	240-4311-115-00245	$ 2.4800	$ 12.40
8	1	BAT1	Li-On Battery	20mm Button-cell	Panasonic	CR2025	Digikey.com	P188-ND	$ 0.2700	$ 1.35
9	1	PS1	Battery Holder	20mm Button-cell Holder Thru-Hole	Eagle Plastic Devices	122-2520-GR	Mouser.com	122-2520-GR	$ 0.9100	$ 4.55
10	1	XTAL2	32 KHz	Cylinder Thru-hole	ECS	ECS-.320-12.5-13X	Mouser.com	520-ECS-32-12.5-13X	$ 0.7600	$ 3.80
11	1	XTAL3	32 MHz	SMT - 5mm x 11.5mm x 3.5mm	Abracon	ABL-32.000MHZ-B2	Mouser.com	815-ABL-32-B2	$ 0.3900	$ 1.95
12	2	C1:C2	12pF	Ceramic Disc	Xicon	140-50N5-120J-TB-RC	Mouser.com	140-50N5-120J-TB-RC	$ 0.0600	$ 0.60
13	3	C3:C5	1pF	Ceramic Disc	Xicon	140-50S2-510J-RC	Mouser.com	140-50S2-510J-RC	$ 0.0600	$ 0.90
14	1	C6:C7	15pF	Ceramic Disc	Xicon	140-50N5-150J-TB-RC	Mouser.com	140-50N5-150J-TB-RC	$ 0.0600	$ 0.30
15	1	C8:C9	18pF	Ceramic Disc	Xicon	140-50N5-180J-TB-RC	Mouser.com	140-50N5-180J-TB-RC	$ 0.0600	$ 0.30
16	1	C10	1uF	Ceramic Disc	Xicon	140-50P5-182K-RC	Mouser.com	140-50P5-182K-RC	$ 0.0800	$ 0.40
17	1	L1	1nH	SMT - 0.8mm x 1.6mm x 0.8mm	Bourns	CI160808-1N0D	Mouser.com	652-CI160808-1N0D	$ 0.0500	$ 0.25
18	2	L2:L3	2nH	SMT - 0.5mm x 1mm x 0.5mm	TDK	MLG1005S2N0S	Mouser.com	810-MLG1005S2N0S	$ 0.0600	$ 0.60
19	1	L4	3nH	SMT - 0.5mm x 1mm x 0.5mm	TDK	MLK1005S3N0S	Mouser.com	810-MLK1005S3N0S	$ 0.0300	$ 0.15
20	2	R1	56k	Thru-Hole	KOA Speer	CFS1/4CT52R563J	Mouser.com	660-CFS1/4CT52R563J	$ 0.0500	$ 0.50
									QTY:	5
									Parts Cost:	$ 242.85
									Cost Per Unit:	$ 48.57

Table 7. BLE Parts

References

[1] (2011, February 25) Near Field Communication PN531- UC Based Transmission Module -- Objective Short Form Specification Rev. 2.0. [Online]. Available: http://www.nxp.com/acrobat_download2/other/identification/sfs_pn531_rev2.0.pdf

[2] (2011, February 25) BLUETOOTH Low Energy-technical Facts. [Online]. Available: http://www.bluetooth.com/SiteCollectionDocuments/Bluetoothlowenergyfactsheet.pdf

[3] (2011, February 25) Near Field Communication. [Online]. Available: http://en.wikipedia.org/wiki/Near_field_communication

[4] (2011, February 25) Google Nexus S Tecnnical Specifications. [Online]. Available: http://www.google.com/nexus/#/tech-specs

[5] (2011, February 25) Samsung Galaxy S II Tecnnical Specifications. [Online]. Available: http://galaxys2.samsungmobile.com/html/specification.html