

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 <i>Digital Systems Senior Design Project</i>
Semester / Year	Spring 2017
Advisors	George Hadley, Prof. Meyer
Team Number	12
Project Title	Guitutar

Senior Design Students – Team Composition			
Name	Major	Area(s) of Expertise Utilized in Project	Expected Graduation Date
Jennifer Isaza	EE	PCB design, Hardware	Spring 2017
Brian Rieder	CmpE	Software development	Spring 2017
Austin Peterson	EE	PCB design, Hardware	Spring 2017
Cole Giannotti	EE	App development	Spring 2017

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

- (a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

Guitutar is designed to serve as a supplement to learning how to play the guitar and as an alternative to learning through a teacher or reading tablature music on his or her own. Our target demographic for Guitutar is for all ages and for anyone that is aspiring to learn the guitar or if they are a beginner to guitar. Anyone at any skill level would be able to use Guitutar. The user would attach Guitutar to his/her guitar, restring his/her guitar, turn the device on, connect their smartphone to Guitutar through Bluetooth, select their song and play mode on the phone application, and start learning how to play their favorite song through the use of LEDs that highlight the chords and notes. The device will allow the user to select between two modes: learning mode and full playback. Learning mode would wait for the user to press the correct notes/chord and wait for a strum. A switch matrix using the guitar's strings and frets serves as the chord/note detection; when the string touches a fret, the pin on the microcontroller is pulled to ground, which will indicate a note press. An amplifier circuit connects to the guitar's pickup and serves as the method of strum detection (the strum will provide an induced current that the microcontroller will detect). Full playback mode will play the full song and light up the chords and notes at the right time. The application would also convert the user's song from tablature format into a format that the microcontroller will be able to understand.

- (b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

Guitutar incorporates most skillsets learned from our ECE classes including schematic design, power considerations, C programming with microcontrollers, working with electronic measuring devices, and circuit analysis. Schematic design and hardware considerations were most crucial in the development stage of Guitutar. Choosing compatible hardware and accounting for any power differences was an important step in assuring that our circuits do not fail by static shock and that all parts would work together. Once we determined the major parts for our Guitutar system such as the Bluetooth module, microcontroller, LEDs, and power supply, we used circuit analysis to choose necessary resistors, capacitors, and diodes in order to integrate all major parts into one design. The preparation from 362 and 270 is especially helpful for interfacing with the microcontroller. Most problems that we have faced with circuitry were mitigated by using electronic measuring devices. These include the oscilloscope to check clocking signals and the amplifier, the power supply to check if certain

parts that we have ordered are working as planned, and the digital multi-meter to determine if certain parts of the PCB have correct voltages without shorts.

- (c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

Although Austin had some previous experience with Eagle, Jennifer and Austin both improved their skills with PCB design and circuit design. Familiarity with different types of devices increased after some of the senior design lectures. These lecture slides helped us figure out that we would need a PowerBoost 1000 boost converter for the circuit, started our brainstorming for choosing either a piezoelectric device versus an amplifier, and helped us choose which type of Bluetooth module to use. Austin also gained power electronics experience by designing and selecting components with power constraints. We also gained some mechanical experience from cutting the PCBs and the acrylic overlay. Austin gained experience with the PCB shear for cutting the PCBs and Jennifer gained experience with the Dremel saw when cutting the acrylic overlay. Brian gained experience in working with MPLab, the Harmony library, and the PIC development, while Cole gained experience with Android app development.

- (d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

We followed the engineering process in the weekly documentation of the homework assignments. The beginning documentation involved the creation of our requirements, scope, and PSSCs or minimum goals that we should meet. Our analysis of our idea and goals were done in preparing for circuit and mechanical design, which followed through in hardware considerations, and ordering. Synthesis occurred when combining and integrating our system goals into better methods of implementation. Examples of this is seen in using the already existing pickup and an amplifier on the electric guitar instead of using a piezoelectric device, as well as using the strings and frets as a switch matrix for note indication. Construction was done by removing the top guitar neck layer, designing and ordering the PCBs, soldering parts onto PCBs, placing the plastic overlay on top, attaching the system to the power supply box and amplifier, and making the Guitutar app. Testing will be done by checking communication with the microcontroller and connecting Bluetooth with the app. To test the controller, we would run a song in either learning mode or full playback mode. Evaluation after testing will determine if we need to reiterate any steps after evaluating our design against our required PSSCs.

- (e) Summary of how realistic design constraints were incorporated into the project (consideration of most of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: A primary economic constraint was keeping the price of the entire project at a low margin. On an economic standpoint, our goal is to have the price of the device be low for us to manufacture and build. In addition, we wanted the product to be low enough for the user to be able to consider using Guitutar over spending the time and money to learn through a teacher or spending the time learning tablature formatted music. To achieve this goal, we used a cheaper PCB manufacturer that would manufacture and ship our PCBs in a quick and cheap manner. We also used low cost components and tried to use as much of the guitar as possible (i.e. strings and frets for string matrix and pickup for strum detection).

Environmental: Due to the nature of a guitar's construction, there is limited capability for the team to incorporate changes that affect the manufacturing process outside of the avoidance

of materials with diminishing supply such as Brazilian rosewood for the fretboard. To meet this constraint, the guitar that embodies the final product uses a synthetic fretboard comprised of the PCBs that build the entirety of the learning device. Printed circuit board manufacturing is a process done outside of the production of Guitutar with many known hazardous waste streams and, as such, cannot be controlled as a constraint of the project. The production of Guitutar leaves the general manufacturing process of a guitar mostly intact. The existing process is simply augmented post-production through the addition of product PCBs, independent power circuitry, and a basic amplifier, thus minimizing the environmental footprint of Guitutar.

Ethical: Guitutar's primary engine of unethical usage comes in the form of song presentation and licensing. In order to present a song to a consumer and market a device based on its capacity to contain that song, there is the potential need for licensing. Just as the lawsuits with tablature, or informal transcription of songs for guitar in a string-by-string and fret-by-fret format, where the music industry pursued tablature sites who displayed tabs without licensing, the inclusion of tabs in the device at the time of shipping would infringe upon the copyright of the artist who wrote the song. In Guitutar's case, however, the songs are not preprogrammed, but are rather user-input. There are no songs to be included on the final device, but the capacity of the consumer to copy a tab and input it into the device via the application is unrestricted. This leaves open an opportunity for an ethical breach on the part of the consumer, but is not endorsed by the producers and designers of Guitutar - a similar philosophy to that of BitTorrent.

Health & Safety: Since static shock could ruin the Guitutar device, safety considerations regarding ESD were put into place. A plastic overlay placed on top of the PCBs is there to protect the user when they touch the electric parts. This plastic overlay and the resistors that we have added to the fret connections also protect the boards from static shock that the user may provide.

Social: Guitutar makes playing guitar more social than ever! Using this device with a normal electric guitar makes learning songs easy to do with any user. Instead of having one person able to play the guitar out of a group of friends, all friends would be able to attempt at playing the guitar with the help of Guitutar.

Political: Similar to the ethical issues associated with Guitutar, the same political considerations come into play: a device marketed for its capacity to contain and present songs merits the potential for licensing issues. Politically, this means considerations regarding existing artists who own the work they created as well as the Music Publishers' Association. Guitutar's consideration regarding the politics of intellectual property owners extends to the point of producer and designer immunity. No songs are included on the final device, leaving any ethical or political breach only on the part of the consumer.

Sustainability: The Guitutar system should be operable until the power circuit, one of the shift registers, the microcontroller, Bluetooth module, or discrete components die. The product is rechargeable, and it allows the user to restring the device similar to the original guitar neck so that it lasts as long as a regular guitar would last.

Manufacturability: Due to PCB size restrictions on free versions of Eagle, we were limited to the size and number of layers of our PCBs. We also purchased premade guitar necks and manually removed the fretboards. For a full-scale product, using multiple layers and using a single board that spanned the entire guitar neck would be a lot more effective than using multiple two-layer boards. It would take a considerable amount of time for full-scale manufacturing of the current design as it takes a lot of time to remove the fretboard on the neck, connect all of the boards, attach them to the neck, and verify for quality and troubleshoot. A multi-layered, single board cut to the shape of the guitar neck would be the

ideal design for full-scale manufacturing. A custom-made guitar neck that did not include the fretboard would also be useful in full-scale manufacturing.

(f) Description of the multidisciplinary nature of the project.

The Guitutar project was multidisciplinary in that it utilized both knowledge of hardware and software. Hardware design included power electronics design, amplifier and filter analysis, and PCB design. We needed to select a sufficient battery and boost converter in order to power about 138 LEDs, 23 shift registers, the microcontroller, and a separate amplifier circuit. Using an amplifier and high pass and low pass filter, we were able to detect strums and filter out low frequency waveforms that could result from bumping the guitar or accidentally hitting strings. The strum frequencies needed to be analyzed and the filters needed to be designed to allow amplitudes that were high enough to be easily recognizable yet low enough that it did not destroy the microcontroller. Since we were limited to the size of the guitar's fretboard, we had to be able to design the circuit so that we were able to fit all of the necessary components on the device and design the board layout so that everything would fit within this constraint. Software design consisted of programming with the usage of a development stack presented by PIC: the legacy library plib, the library infrastructure Harmony, the XC32 compiler, and the MPLAB IDE. This utilized Object-Oriented Programming concepts as well as microcontroller interfacing that is integral to computer engineering. In order to communicate with the LED and switch arrays, we employed GPIO ports libraries within Harmony to input serial data, input, and output clocks to the associated shift registers. Additionally, we used UART to communicate with the Bluetooth module whose purpose therein was to communicate with the Android phone that provided an interface for the user to control device interaction.

(g) Description of project deliverables and their final status.

As of the time of this document, the final project deliverable is still largely in progress but many individual parts are functional awaiting integration into the final product. Currently, notes can be displayed on an LED matrix based on port assignments to shift registers and are transitioned by switch contact in the correct locations. Note triggers through amplified magnetic feedback in the built-in pickups are currently functional and are able to trigger when to read user input. All of the physical components, namely the four custom shaped PCBs, are machined and ready for attachment in place of the fretboard. Finally, the user input interface through the Android phone app is currently awaiting connection via Bluetooth to drive the control flow of the entire product - a necessary component for full integration.