ECE 445: Auto-Played Guitar

Design Document Check

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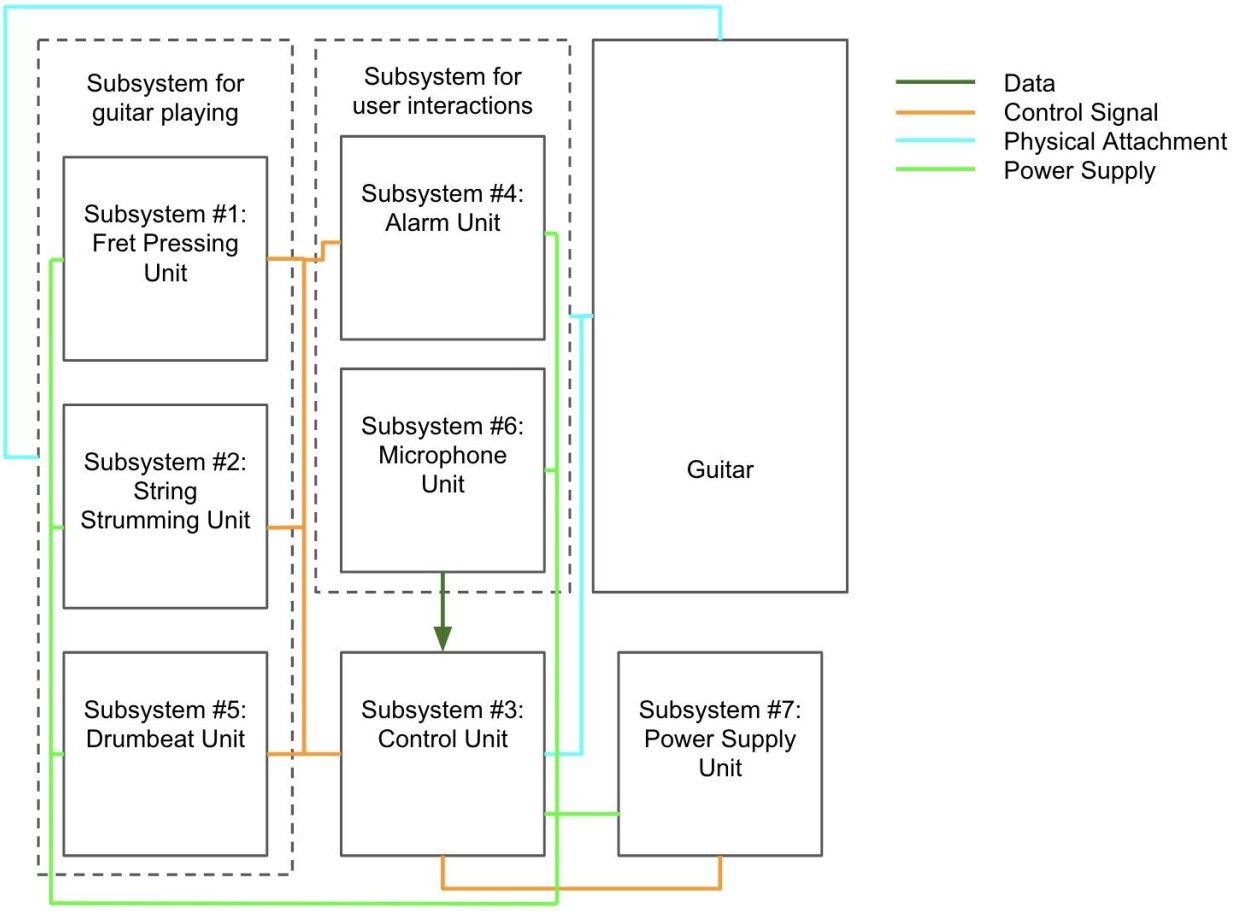
1. Introduction

We will build an auto-played guitar for those people or places that need it for the purpose of demonstration or entertainment. Our customers face a lot of situations that an auto-played guitar can help: Some people love the original sound of guitar music but lack the time and energy to practice it; Just like the existence and common use of auto-played piano in the lobby of grand hotels[1], some places may need a playing guitar for entertainment or creating atmosphere; Guitar stores want to show the good sound quality of the guitars they are selling but it is usually very expensive to hire someone to play for a long period of time; Music creators want to hear the sound of their customized guitar for testing or for remix; Some people may want to hear the authentic sound of guitar music as their wake up alarm; Some new guitar learners wish to hear a demonstration of the musical piece that they are practicing on while watching the notes they should play. Although the idea of listening to guitar music can be easily realized by using music players, the beautiful original sounds from different real guitars are irreplaceable. Our product solves our customer's problem by presenting the auto-played guitar. Although the idea of auto-played guitar, just like the auto-played piano that many hotels have for lobby decoration, is not an innovation, all the existing auto-played guitars are expensive to make, too ponderous to be portable, and the auto-played unit has no compatibility to be reinstalled on a variety of guitars. Therefore, the pivot of our design is to build a piece of automatic guitar playing unit that is affordable, portable and compatible with any type of guitar.

2. High-level requirements

- Be able to play the correct notes on the guitar in tune (an electric tuner should show the notes from auto-played guitar has within 5% discrepancy with the theoretical value) and loudly.
- Be able to deliver the drumbeat and guitar note at the correct rhythm, with adjustable tempo.
- Alarm functionality with synchronized time in the guitar.
- *Additional: Be able to record a piece of music with the microphone and replay with auto-played guitar

3. Block Diagram:



As illustrated in the figure, a high level design of our system consists of mainly four parts: Subsystem for guitar playing, Subsystem for user interactions, Control unit and Power supply unit. All other Subsystems are controlled collectively by Subsystem #3 Control Unit, which is attached to the body of the guitar. Subsystem for guitar playing, as its name indicates, is responsible for playing music at the correct pitch and rhythm, **which meets our high-level requirement 1 and 2**. Included modules are: Subsystem #1 Fret Pressing Unit: installed on the fretboard (neck) of the guitar for pressing and releasing the strings; Subsystem #2 String Strumming Unit: installed on the body of the guitar for strumming and making sound of the strings. These two units work together to play clear and correct notes according to the program; Subsystem #5 Drumbeat Unit: on the bottom of the guitar, it can periodically strike the guitar body to make drum beats. This unit outputs the tempo and adds some taste to the music being played. In Subsystems for User Interactions, Subsystem #4 Alarm Unit is on the head of the

guitar with a LED screen for the user to present the time for alarm (play the guitar). **The Control Unit keeps synchronized time and compares that with the set alarm time for the alarm functionality**. Subsystem #6 Microphone Unit is installed on the guitar body for recording and sound input, it should also interact with the control unit, which will analyze the signal and replay the music according to our plan. **This is for the additional functionality.**

actuator

Subsystem #1: Fret Pressing Unit

This unit is in charge of controlling the actuators attached to the fretboard of the guitar, and it is a crucial part to decide whether the auto-play guitar can play each notes correctly and pellucidly [4]. The initial goal for this unit is to be able to play relatively complex music pieces on the first six frets of the guitar. Given that there are 6 strings on a regular guitar, this unit need to drive at least 6 * 6 = 36 actuators that are hung on the top of the fretboard, pressing or releasing the strings on each fret. If time allows and everything goes smoothly, the project will support more than just 6 frets.

Subsystem #2: String Strumming Unit

This unit is the part responsible for strumming strings and getting quality sound out of the guitar. The main components of this unit is the signal amplifier and 6 servos (SG90 9G Micro Servo Motor) [5]. Each servo is connected to a guitar pick that is in charge of strumming one string. Other than the power supply, each servos should receive an analog signal from the control unit indicating how much and how fast it should turn. There should be at least 4 preset behaviors for servos: quickly strumming, slowly strumming, staying on the string (to mute the sound), and stop in the air (do nothing). It will also instantly react to the analog signal from the control unit.

Subsystem #3: Control Unit

The Control Unit is the pivotal part of the project. It is a ATMega board that provides the signals to activate the Fret Pressing Unit, String Strumming Unit and Drumbeat Unit. Also it should be programmed from a laptop to import different music pieces. It takes in data from the Alarm Unit to determine when to play what piece of music as the alarm. It also controls the Microphone Unit in terms of recording and sending the data back to the laptop for analysis.

Subsystem #4: Alarm Unit

The Alarm Unit is one of the advanced functionalities of the project. It puts a small LED screen on the head of the guitar to show the alarm time and two push buttons for adjusting that time. A user can use the push buttons to set the alarm. When there is a change of the time, the Alarm Unit will send the updated time as data into the Control Unit. When the system time of the Control Unit matches the set alarm time, the guitar will play a piece of preset music. Pushing any of the two buttons while the music is playing will stop the performance.

Subsystem #5: Drumbeat Unit

The aim of this unit is to put a servo that connects to a drumstick on the guitar body. It would hit the guitar surface at a certain frequency while playing guitar music. The drum beat serves as an adjunction and enriches the vividity of the performance, while it can be used as a metronome for guitar practicing. It can be activated by the programs in the control unit. Also the angle and speed of servo rotation should be directly controlled by the analog signal from the Control Unit.

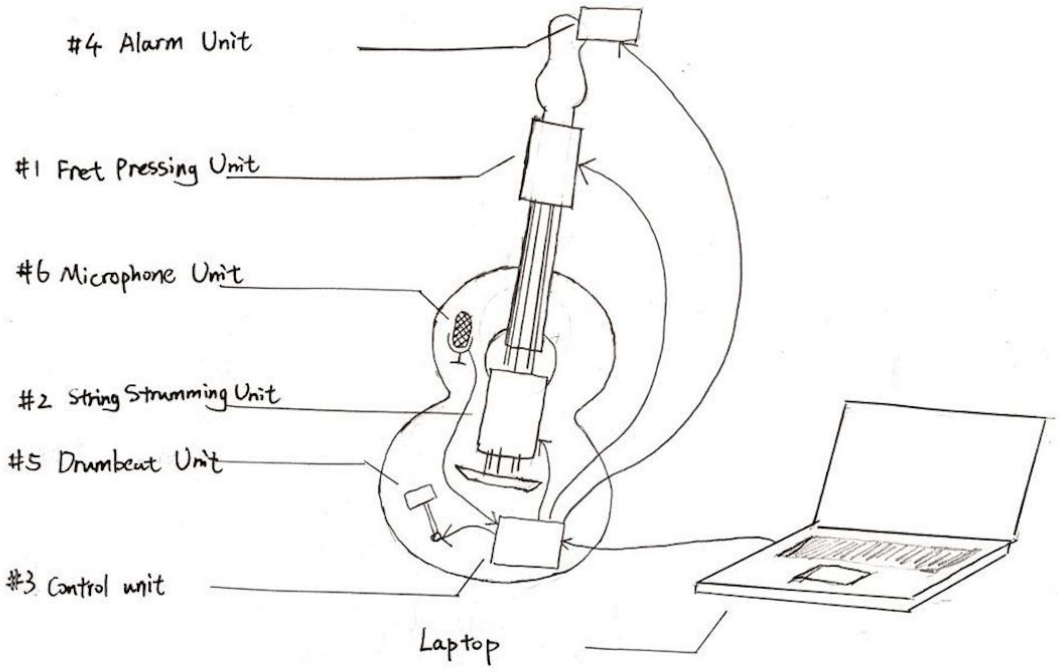
Subsystem #6: Microphone Unit

This unit can record the music piece from the guitar and send this music data back into the Control Unit. The control unit should send it to a laptop when requested to do so. The purpose for this unit is for the music writer or singer who wants a record of real guitar sound or a mixture of guitar and other instrument while the guitar is automatically playing.

Subsystem #7: Power Supply Unit

This unit provides power to all other units. Aiming at portability but also considering that there might be occasions of long time consistent usage, this unit would be the combination of chargeable battery and direct power. Both would supply 5V through USB or direct wiring through PCB to other units.

4. Physical Design (if applicable)



The six units of our design should be able to attach to any type of guitar as the above graph shows. The Control Unit will be programmed through the laptop, and is also in charge of sending records from the Microphone Unit to the laptop. The Control Unit and Microphone Unit all connect to the laptop through USB cables.

5. Block Requirements:

Subsystem #1: Fret Pressing Unit

Requirements	Verification
1. The actuators should be stably fixed and hanged precisely on each string of each fret. 2. The 36 actuators should be able to work individually without breaking the consistency of music.	1. A. Simple shaking of the guitar would not cause the actuators to move or detach. B. The actuators, when activated, hold the string firmly on the fret bars. C. While the guitar is in subtle movement, each note played from the guitar has the frequency discrepancy of 5% of the theoretical value in Hz. 2. A. Each actuator can work on its own and up to all 36 actuators can work at the same time. There should be no delay between the activation between two different actuators. B. The activate-deactivate-reactivate period on the same actuators should take less than 0.5 second. C. Since there is no way to have 36 I/O pins on the ATMega, we are using 3 16-Channel 12-Bit PWM/Servo Driver [6] that we can control 36 actuators with limited I/O pins.

Subsystem #2: String Strumming Unit

Requirements	Verification
1. The servos should be working and attached firmly above the strings on the guitar body.	1. A. Simple shaking of the guitar would not

2. Each servo should respond fast and correctly to the signal of rotation. The delay in performing several actions should be short.	cause the servos to move or detach. B. The tips of the guitar picks attached to the servos should just touch the string when the servos are activated. 2. A. Each servo should be able to work on its own and experience no delay. B. Two successive plays of the same servo should suffer no more than 0.5 second gap in between.

Subsystem #3: Control Unit

Requirements	Verification
1. This unit needs to provide the correct behavior signal to Fret Pressing Unit, String Strumming Unit and Drumbeat Unit. 2. It will play a preset alarm when alarm time matches the real world time. 3. **Optional:** it should save the records from microphone unit	1. A. When a piece of music is programmed into the control unit, the control unit should correctly figure out the output signals. When FPU, SSU and DU is correctly figured, the produced music should be correct. B. To ensure the consistency of music pieces, there should be less than 0.5 delay between signals when activating the same piece, such as actuators and servos. 2. A. When LED in the alarm unit is set to a time, the monitor program in control unit should receive and store the changes. B. The clock in the alarm unit should also be monitored and stored by a piece of program in the control unit. C. The control unit should check the

	clock value and the user-set value, when they are equal, it activates a program to play the alarm. 3. **Optional:** A. When the recording from the microphone unit ends, the control unit should process the sound signal and save it as an mp3 file to the laptop signal. The mp3 file should be clear enough in terms of replaying the music

Subsystem #4: Alarm Unit

Requirements	Verification
1. It should contain a LED screen that allows the user to set the clock.	1. A. The time shown on the LED screen should be able to be changed by two push buttons. When the two buttons are pushed, the changes should be instantly reflected on the LED screen. B. A piece of clock device must record the real time of the day in hours and minutes. C. The user-set time should be compared with the real time, when they are equivalent, a signal should be delivered to the control unit for the alarm to start. D. While the alarm is playing, pushing either button will not change the user-set time, but to stop the alarm.

Subsystem #5: Drumbeat Unit

Requirements	Verification
1. This unit should be able to play the drumbeat at the right tempo. 2. Should be able to provide two kinds of drumbeat (hit on the surface of the guitar & hit on the side of the guitar).	1. Play several pieces of music with the drumbeat unit and check the tempo. 2. The two kinds of drumbeat should be clear enough to tell from each other.

Subsystem #6: Microphone Unit

Requirements	Verification
1. **Optional:** This unit should be able to record the play music 2. **Optional:** This unit should be able to analyze and replay a piece of recorded music with the same tune and rhythm	1. **Optional:** The recording is clear and recognizable as the original piece of music 2. **Optional:** The replay should sound the same as the original piece of music at least in tune and rhythm

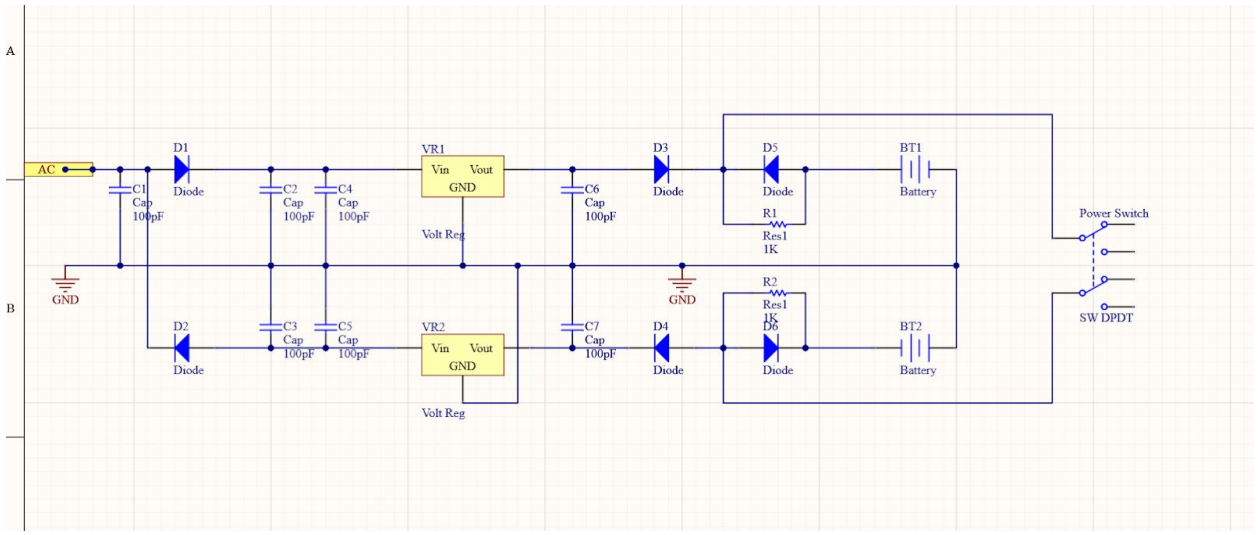
Subsystem #7: Power Supply Unit

1. The Power Supply Unit must be able to supply a voltage of 5V for a current load up to 5A.

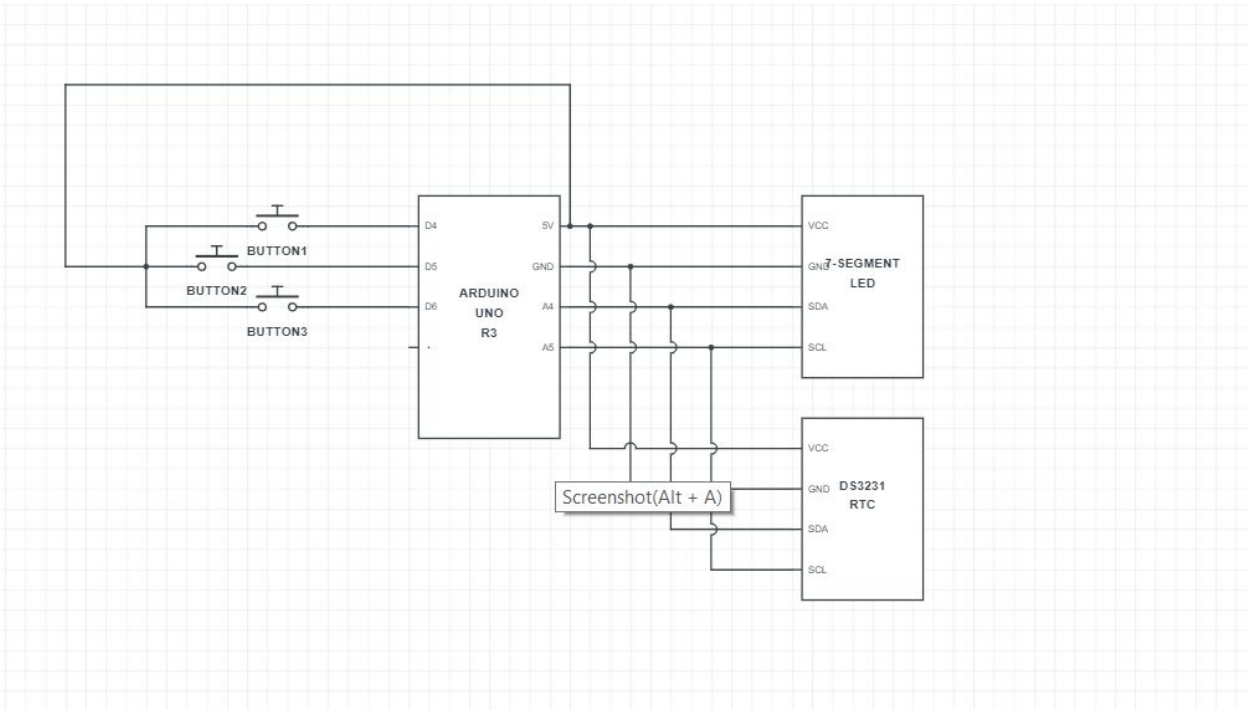
2. The Power Supply Unit must be able to either charge from or convert 120AV voltage to 5V DC.

6. Circuits

Power Supply Unit Circuit



Alarm Unit Circuit



7. Tolerance Analysis

One important concern we have is the attachment of the Fret Pressing Unit and String Strumming Unit. In order to play the music correctly, we need the units to be firmly attached to the guitar. Otherwise during playing a piece of music, the units might move on the guitar. This will negatively influence the functionality since we would no longer have guarantee to play the correct notes or hit the correct string. We have weighed some of the sample actuators, and the average weight is about 30 grams. For the Fret Pressing Unit, we need 36 of these aligned in a 5x6 matrix. Therefore, the weight of the unit is over 1 kilogram. We should attach the unit to the guitar by either tying the unit to the guitar or using some extra supporting frames. The trade-off here is that tying the unit costs less and the structure is more portable as well, while extra frames will provide a more solid support to the unit so that it is less likely to move during the play.

Another problem we need to take into consideration is the power of the actuators. The ROB-11015 actuator we plan to use has a power consumption of 5.5W according to the datasheet. Therefore, the overall power consumption of our design might be pretty large. For example, if we plan to have up to 7 actuators work at the same time (not all the actuators have to work at the same time), then the power consumption should roughly be 7x5.5, which is about 40W. This calculation does not include the power of other units, such as the control unit, alarm unit and drumbeat unit. If we want to make our design more power-friendly, we might want to switch to some actuators with less power consumption. However, according to our initial test with ROB-11015, this type of actuator is just able to press the string. We are afraid that actuators with less power consumption will not be able to even press the string.

8. Ethics and Safety

Our Auto-played guitar module itself is a compact and lightweight device that will attach directly to a guitar. Therefore, it is very hard for the device to cause harm to the user even under situations of misuse. The main concern is the misuse of the device might cause damage to the device itself as well as the guitar.

- The Fret pressing unit utilizes some small motors that should be aligned to the guitar strings. If this unit is not properly placed, the motor might hit some fragile parts of the guitar. During our design, we will make the alignment of the motors on the frame robust enough so that the motors will not shift their place on the frame, also, we will tune the strength of the motion of pressing the string in an attempt to prevent potential damage during misuse.
- The units are connected through physical wires, which might stumble the users if placed wrongly. We will create a physical frame to stabilize the wires in the structure so that the users has much less chance to touch or break the wires.

We anticipate concerns about our work going against #2.6 in ACM Code of Ethics[2] since some people think that machines should never replace human beings in terms of creating art and music. However, in our opinion, the project's purpose is never to replace the human efforts in creating and performing fine music. In contrast, it is rather a means for many more people to enjoy music and get more access to the beautiful and original sound of guitars.

Reference:

[1] Autoplay piano: https://www.youtube.com/watch?v=sxI0PIPZjBQ

[2] Acm.org. (2019). ACM Code of Ethics and Professional Conduct.: https://www.acm.org/code-of-ethics

[3] O2 details (2011): http://nwavguy.blogspot.com/2011/08/o2-details.html#resources

[4] ROB-11015 actuator: https://cdn.sparkfun.com/datasheets/Robotics/ZHO-0420S-05A4.5%20SPECIFICATION.pdf

[5] Servo motor SG90: http://www.ee.ic.ac.uk/pcheung/teaching/DE1_EE/stores/sg90_datasheet.pdf

[6] PCA9685: https://cdn-shop.adafruit.com/datasheets/PCA9685.pdf