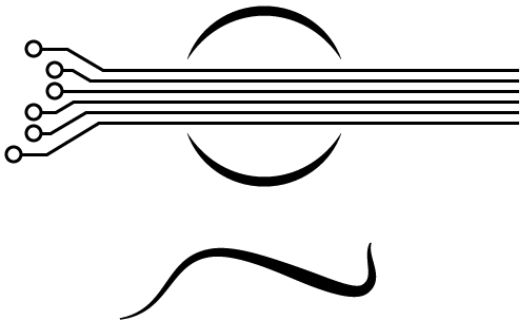
Expression System Modification Proposal



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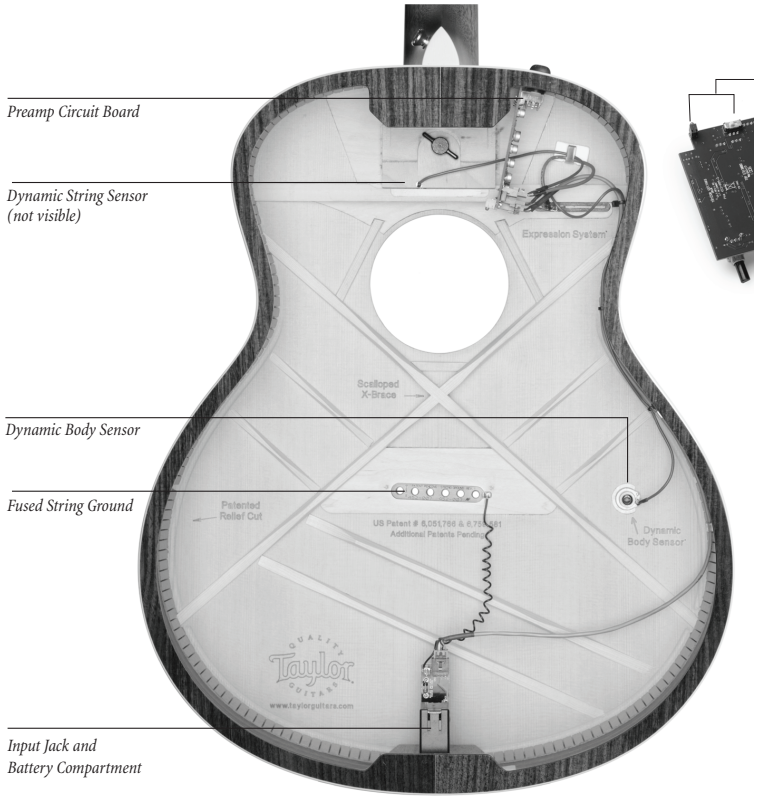
Contents

Background

High-end Taylor acoustic-electric guitars are equipped with a pickup and preamplification system that Taylor calls the Expression System (ES). The Expression System consists of three magnetic pickups inside the body of the guitar that are wired into an internal preamplifier with bass, treble, and volume controls that are accessible on the side of the guitar's body. This system's design and sound starkly contrasts the industry standard design, which consists of a single piezoelectric transducer positioned below the saddle of the guitar, where it is known as an under-saddle transducer (UST). USTs are generally regarded to produce a somewhat thin and synthetic sound, so Taylor's Expression System was designed to have a more natural and dynamic character. My personal opinion is that neither design sounds very natural, and that the traditional UST sound, while admittedly a little foreign, has become iconic in its own right, and is more pleasing to my ears anyway.



Taylor Expression System

So, in the spring of 2012, I attempted to modify my Taylor 614ce's Expression System to accommodate an under-saddle transducer. I rerouted one of the magnetic pickups' cables onto a circuit board I fabricated, where it and the UST I added could be switched on or off before the signal continued into the ES's preamp. The advantages of this design were that I could choose what combination of pickups I wanted to hear, and that no matter what I chose, I could still use the convenient onboard preamp with its equalization (EQ) and volume control. The disadvantage was that changing the pickup configuration required removing the battery compartment with a screwdriver. Over time, a bigger problem arose: some connection I made came loose, and my guitar no longer sent any sound to the amp.

Statement of Work

My goal now is to rebuild what I built in 2012 with significant improvements, and, of course, increased reliability. The basic requirements are

- **pleasing sound quality**,
- **low power consumption** so as not to shorten significantly the battery life of the guitar's preamplification system,
- **durable construction** to withstand the vibration associated with transporting and playing the instrument,
- **small form factor** so as not to interfere with the guitar's acoustic resonance,
- **low noise floor**, comparable to the original pickup system (a notable weakness of my original design—the hiss was quite loud), and
- **integration** with the onboard preamp's EQ and volume controls.

Once a proof of concept demonstrating that my design meets these requirements is attained, I will shift my focus to a new phase of design: adding a *Bluetooth*®-enabled digital switching or mixing circuit that will allow me to switch between the original magnetic pickups and my added UST, or to mix the signal of multiple pickups, with an app on my phone.

Essentially, there are four tasks at hand:

1. Design the system on a macroscopic scale, determining how and where (both physically and schematically) my circuitry will integrate into the existing electronics.
2. Design and build a buffer amplifier for the UST. Piezoelectric transducers have a much higher output impedance than the magnetic pickups (and produce an extraordinary amount of high-frequency audio energy), so the UST will have to be buffered and filtered before it can effectively be handled by the existing preamp.
3. Design and implement the digital switching or mixing circuit to be controlled by the Nordic nRF51822 Bluetooth Low Energy microcontroller.
4. Write the software for the nRF51822 and Apple iOS to enable wireless control of the switching circuit.

Timeline

2/7/14 Finalize block circuit diagram, physical dimensions and connection points of circuit board. Include rough board layout, reserving space for all components to be added later.

3/1/14 Finish design and assembly of amplifier. Product should be functional as-is at this point.

4/7/14 Complete addition of digital switching circuit, including a beta version of the embedded software.

4/25/14 Finish project with the completion of the iOS app and the finalization of the embedded software.

Budget

The most expensive part of the development of this project is the development kit for the nRF51822, which the Electrical Engineering department already owns (and will be returned to the department at the completion of this project), which leaves only the cost of components and PCB fabrication. I own some of the required components from my previous attempt at this project, some can be obtained for free as samples from the manufacturer, and I will cover the rest of the expenses out-of-pocket. My estimated budget follows:

Development tools and materials	$20.00
PCB fabrication	$20.00
nRF51822-QFAA-R7	$4.95
Digital potentiometers	$9.25
Other components	$20.00
Total	**$74.20**

Deliverables

Documentation

- This proposal
- Weekly progress reports
- Midterm design report
- Final design report
- Blog containing project updates and supporting media

Hardware

- Various development-grade circuit boards demonstrating functionality of parts of the final design
- Final fabricated PCB including buffer amplifier, switching circuit, and nRF51822 controller, eventually to be installed in my guitar

Software

- Embedded software for nRF51822
- iOS app to be installed on my phone

Disposition

This project is not usable without being installed in a Taylor guitar equipped with an Expression System, so I plan to keep the final circuit board and use it. In return, I will leave ample video footage of product development and demonstration on the project website (coming soon).

References

References are informal at this stage in the project, but the following links may be helpful to someone trying to understand the background of the project and component/cost considerations. Should the links stop working, search the Internet for the title of the document.

[1] *Understanding The Taylor Expression System.*
http://www.taylorguitars.com/sites/default/files/10_UnderstandingES.pdf

[2] *Analog Devices Digital Potentiometers.*
http://www.analog.com/en/digital-to-analog-converters/digital-potentiometers/products/index.html

[3] *OSH Park.*
http://oshpark.com

[4] *Nordic Semiconductor nRF51822.*
https://www.nordicsemi.com/eng/Products/Bluetooth-R-low-energy/nRF51822

Appendices

A Old Design

Purely for reference, I'm including the notes and buffer amplifier schematic *from my original design* here.

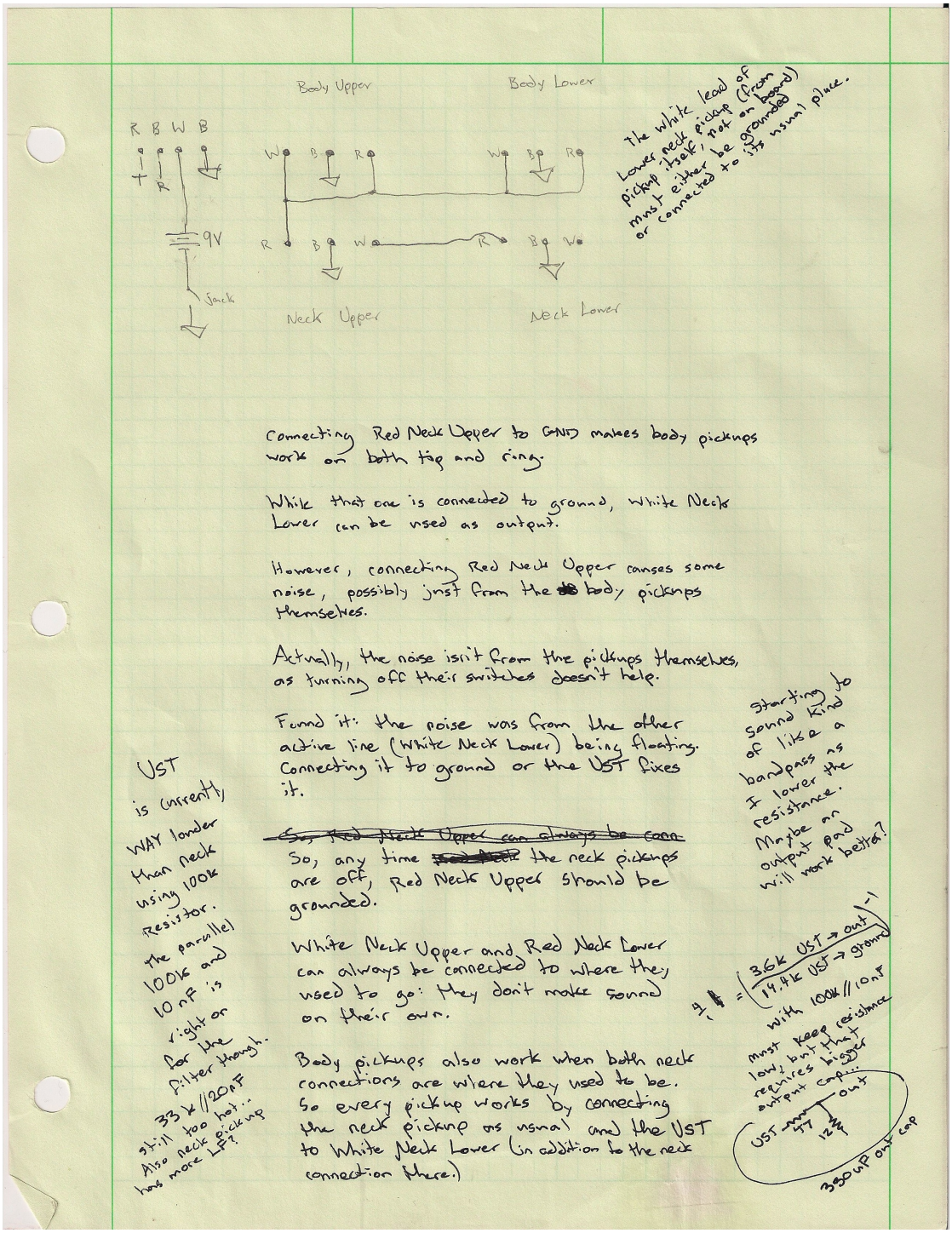


Figure A.1: Page 1 of my original design notes

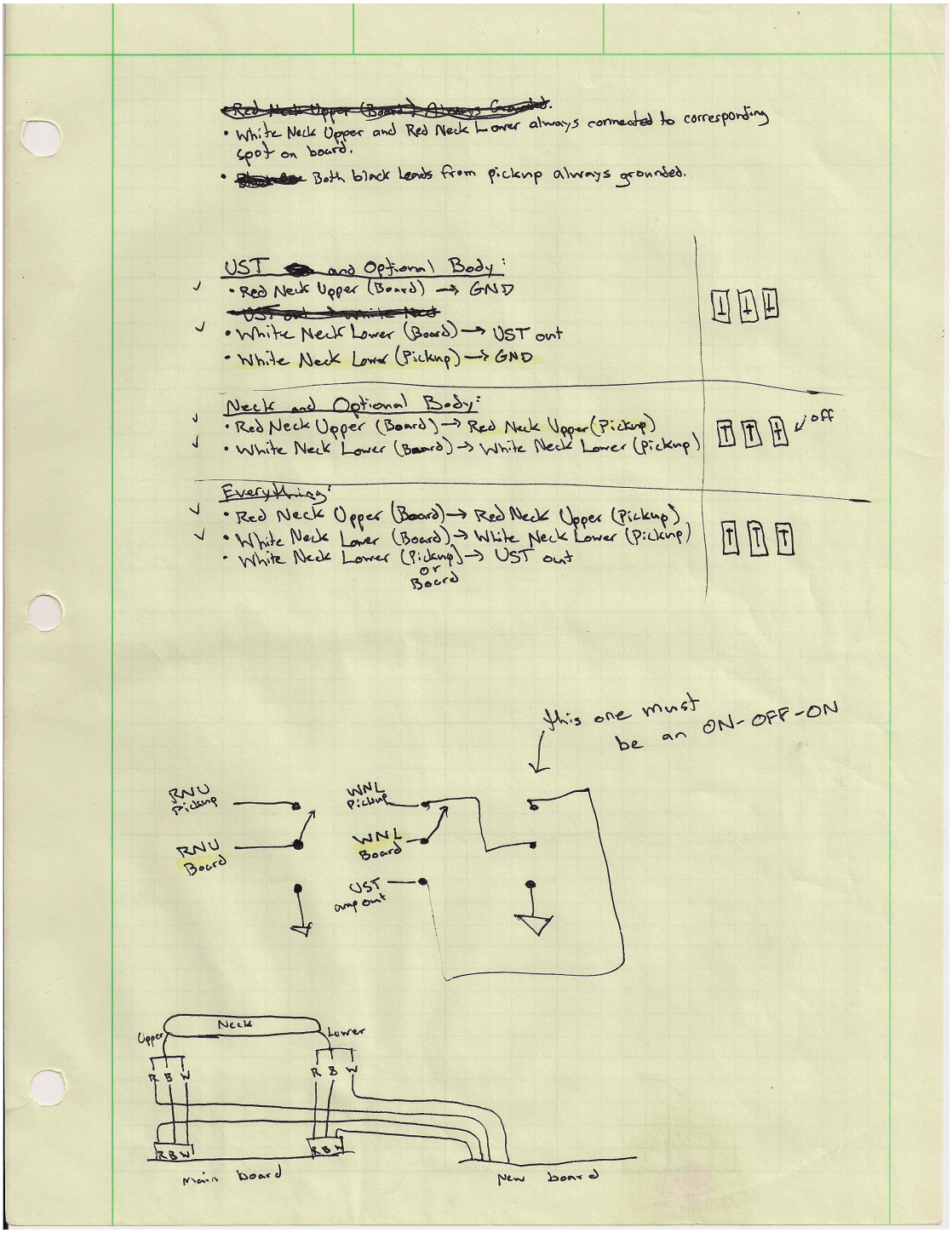


Figure A.2: Page 2 of my original design notes

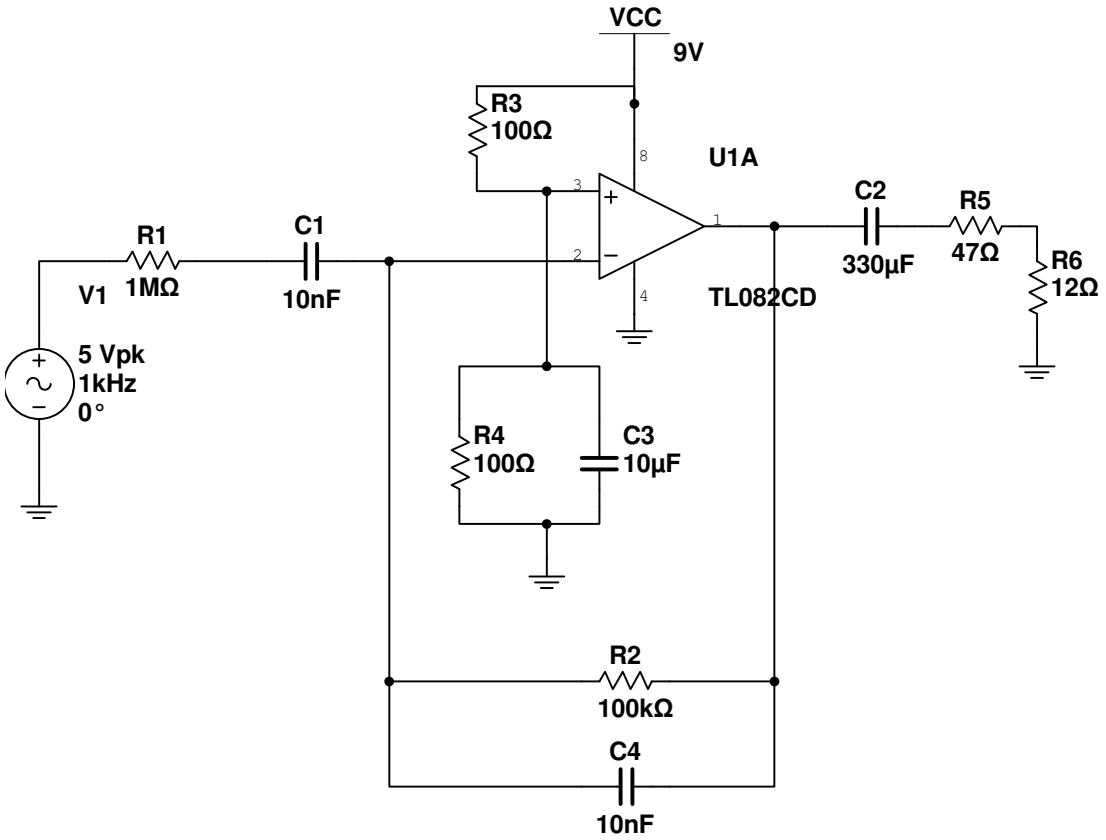


Figure A.3: Buffer amplifier schematic from my old design.