The Guitar Chord Learning System

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Senior Project Description
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Electronics Engineering Technology
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INTRODUCTION

The ability to utilize a six stringed instrument as a medium to express soul, energy, and internal emotions has given individuals the desire to learn how to play the guitar. This instrument, however, is generally difficult to learn and difficult to teach. Beginners often become discouraged and lose interest after battling the frustration of learning basic guitar chord positions.

I propose to develop a system that will eliminate this displeasure. The Guitar Chord Learning System (GCLS) will be an educational tool designed to teach individuals basic guitar chord positioning techniques. This system will not only eliminate the hassle of using chord positioning look-up tables, but it will also give the user an opportunity to acquire guitar playing skills while supplementing, or even replacing, traditional one-on-one guitar lessons.

Chord progression patterns from a song would be typed into a user interface on a PC and downloaded into the GCLS. The GCLS would then output the proper finger positions utilizing a matrix of LEDs embedded into the fretboard. A foot switch would change the chord position output with respect to the downloaded chord progression. This system will give the user the ability to learn any desired song by obtaining chord progression sequences from the internet. Because the GCLS can be used as a form of independent learning, the user will be able to grasp and improve guitar chord skills at his or her pace.
FUNCTIONAL DESCRIPTION

The Guitar Chord Learning System will be a stand-alone unit that initially retrieves user input from a computer terminal program. The user input contains chord sequence information, which is downloaded into the microcontroller unit, as represented in the block diagram of Figure 1. Upon download completion, the unit can run independently from the computer, allowing the user to practice the downloaded song in a desired location.

The computer terminal program will allow the user to store guitar chord sequence information into three channel locations. Each channel is designed to provide the user with the ability to organize a song into three parts: one channel for the verse, one channel for the chorus, and one channel for the bridge. The foot pedal input unit controls the guitar chord patterns displayed on the LCD and embedded LED fretboard output. The Guitar Chord Learning system will be powered by its own supply.
Figure 2 displays the preliminary product sketch of the GCLS. As shown in this diagram, the GCLS unit will involve three I/O peripheral systems: the foot pedal, LED fretboard display, and desktop computer connection. The microcontroller unit governing this embedded system will be enclosed in a chassis containing the LCD display and power switch.

Figure 2: GCLS Product Sketch

The Embedded LED diagram, illustrated in Figure 2, depicts the fretboard configuration. The LED array contains a 4 x 6 matrix embedded into the guitar fretboard, which is connected to the GCLS chassis. Each individual LED represents the string and fret position on the guitar fretboard respectively. The embedded LED fretboard will be further examined later in this document.
Figure 3a displays the product sketch of the GCLS chassis unit with its maximum dimensions. This metal chassis will serve as a durable enclosure to protect all of the components housed: the microcontroller unit and external circuitry. The power switch, LED fretboard connection, foot pedal connection, power supply, and the serial port connection are located on the chassis.

Figure 3a: GCLS Chassis

Figure 3b: Foot Pedal Unit

The foot pedal unit is represented in Figure 3b with its maximum dimensions. This unit consists of the foot pedal and the three channel buttons as previously described in Figure 2. The foot pedal unit will be further explained in the User Interface Description.
The Guitar Chord Learning System will be controlled by the MC9S12DP256B (9S12) as displayed in Figure 4. This microcontroller was selected for its various resource capabilities, extensive memory capacity, and my familiarity with this particular microcontroller unit family. The 9S12 features a 256K EEPROM, 12K bytes of RAM, and 4K bytes of EEPROM.
The detailed functional block diagram displays the resources that will be utilized in the GCLS. As represented, the 9S12 will receive data input from the computer terminal via the Serial Communications Interface (SCI), and the foot pedal input signals will be sent to Port T. Port A and Port K will control the LCD screen, and the Serial Peripheral Interface (SPI) will control the embedded LED fretboard output.

Asynchronous serial communication between the 9S12 and the PC will be established through the SCI. The guitar chord sequence information will be transmitted to the SCI through the RS232 serial port connection from the PC. The I/O pin connections in the SCI include the RX Data In (RXD) and the TX Data Out (TXD) as displayed in Figure 4.

The foot pedal, which controls the LED fretboard display and channel selection, is essentially a unit made up of switches. Therefore, the high or low signals set by the user will be detected by Port T, as shown in the detailed functional block diagram. Because the foot pedal is an input peripheral unit in the GCLS, the Data Direction Register of Port T will be configured appropriately.

A 2-line by 20-character LCD module will be implemented to display GCLS output information. The LCD module will receive information from 8 pins connected to Port A and 3 pins connected to Port K, as depicted in Figure 4. The display information will be further examined in the User Interface description.
The embedded LED fretboard will be controlled by the 9S12 through the SPI. An LED Driver specifically designed for activating LEDs individually within an array will be utilized, such as the MAX7221 Serially Interfaced LED Display Driver produced by Maxim. The LED Driver will be connected to the following output SPI connections: the select signal (/SS), clock (SCK), and MOSI. Surface-mount LEDs will be implemented for space efficiency management.

The other resources in the 9S12 utilized, as represented in the block diagram, include the /Reset, XTAL, and BDM in. Because the 9S12 contains an on-chip power-on detector circuit, the reset circuitry connected to /Reset will only consist of a pull-up resistor tied to the 5 volt source. The 9S12 will be clocked by a 16 MHz crystal through the XTAL, and the BDM in will be connected to the Noral BDM connector to load the final program into the 256K byte Flash EEPROM.

The microcontroller and external circuitry of the GCLS will be powered by a wall transformer power supply. The wall transformer power supply will require a steady 5 volt DC output, 120 volt AC input, and a 1.0 A maximum output current.
Software Description

The Guitar Chord Learning System will be programmed in C for complex tasks and assembly language for lower level applications. Task scheduling management will be implemented through the MicroC/OS-2 pre-emptive kernel. The following modules will be developed to control the functions of the GCLS:

<table>
<thead>
<tr>
<th>Module</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>KERNAL</td>
<td>The MicroC/OS pre-emptive kernel will control all software modules through task scheduling management.</td>
</tr>
<tr>
<td>SERIAL_INTERFACE</td>
<td>Provides the computer terminal user interface. Chord sequence information is entered and stored into a desired channel by the user.</td>
</tr>
<tr>
<td>CHORD_TABLE</td>
<td>Stores chord sequence information entered in by the user as ASCII characters in the byte-erasable EEPROM. Space will be allocated to save information into three “channels.” The string of ASCII characters representing guitar chords is translated into fretboard position patterns stored in RAM. The chord patterns will be 4 bits x 6 bits to represent the first 4 frets and 6 strings on a guitar.</td>
</tr>
<tr>
<td>Module</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>FRET_DISPLAY</td>
<td>Sends data to the LED driver, thus controlling the LED fretboard output display. This module utilizes user input information stored and translated by the CHORD_TABLE module.</td>
</tr>
<tr>
<td>LCD_DISPLAY</td>
<td>Governs the LED fretboard output information displayed on the LCD module. This information includes the current chord position, channel selected, and chord progression sequence data.</td>
</tr>
<tr>
<td>PEDAL_DETECT</td>
<td>Detects the user input information from the foot pedal unit. The selected channel and next chord state will be detected in this module.</td>
</tr>
<tr>
<td>BASICIO</td>
<td>Written by Professor Morton, the BASICIO module will be responsible for translating user input from the INTERFACE module and the terminal program output display.</td>
</tr>
</tbody>
</table>
User Interface Description

The user interface of the GCLS can be organized into two categories: the user input interaction and the output display system. The input system includes the terminal program which communicates with the GCLS and the foot pedal unit which governs the chord position change. The output display system includes the LCD display attached to the GCLS unit and the LED fretboard display.

As previously described, the terminal program allows the user to input guitar chord sequence information into three channel locations. Figure 5 displays the start up menu display of the user interface terminal program. The menu prompts the user to either select a channel to view for editing or exit.

![Figure 5: Program Terminal - Menu](image-url)
If the user selects option “5,” the program exits. If option “4” is selected, all chord sequence information stored in each channel will be cleared. However if option “1,” “2,” or “3” is selected, the appropriate channel information will display, as shown in Figure 6.

![Figure 6: Program Terminal – Channel Selection](image)

In this example, Channel 1 is blank. The user is prompted to edit the chord sequence stored in the channel. If “N” is selected, the program returns to the menu. “Y” allows the user to enter in a chord progression sequence, as depicted in Figure 7.
Chord sequence input is entered into the user interface until a carriage return is detected. Each chord is separated by “white space” in the sequence information, as shown in Figure 8. For this example, the chord patterns for the verse of a song will be entered into Channel 1: Am, C, and G.

As displayed in Figure 8, the updated channel information is displayed after the sequence input is entered. The user is then given the option to edit the channel once again. This process continues, until the user is satisfied with all channel input conditions.
The foot pedal unit consists of four different switches as discussed in the Hardware Description. The single step pedal allows the user to advance through each chord position in the progression sequence. This information is displayed on the LCD screen and LED fretboard. Separate chord progression sequences are stored into three separate channels and can be accessed by selecting the appropriate channel switch.

Figure 9: LCD display

Figure 9 depicts the LCD display. The LCD display enables the user to obtain information regarding the current chord position, channel selected, and next chords in the chord progression sequence stored in the selected channel. Figure 10 illustrates how the user is prompted to select the next channel at the end of the chord progression. Figure 11 displays an example of the overall user interface system.

Figure 10: LCD display – End of Sequence
Example

Song X has the following Chord Progression Patterns:
Verse 1: Am C G
Chorus: F C G
Verse 2: Am C G
Chorus: F C G
Bridge: D G
Chorus: F C G

Organize Song by Chord Sequence:
Channel 1: Am C G - Verse
Channel 2: F C G - Chorus
Channel 3: D G - Bridge

Load Information Into GCLS

Channel 1
VERSE
CHORD: Am       CH: 1
SEQ: C G

Channel 2
CHORUS
CHORD: C       CH: 1
SEQ: G

Channel 3
BRIDGE
CHORD: G       CH: 1
SEQ: SELECT CHANNEL

LCD DISPLAY

LED FRETBOARD

START
Verse 1

Page 1

Figure 11: LCD display – Example Flow Chart Diagram of Song
DEVELOPMENT PLAN

Project Development Tasks

The project development tasks required for the GCLS can be organized into hardware and software development tasks. The hardware development tasks include: a task for constructing the embedded LED fretboard, a task for interfacing the fretboard with the LED driver and 9S12, and a task for constructing the foot pedal unit, chassis and PCB layout. The software development tasks include: a task for establishing a computer terminal user interface, a task for initializing output communication with the 9S12, which involves controlling the LCD module and LED driver, and a task for developing the digital guitar chord look-up table.

Hardware/Software Development Requirements

All hardware and software development tasks will be performed in Western Washington University’s Electronics Engineering Technology laboratory facilities in the Engineering Technology Department building. These facilities have all of the equipment necessary for development of the GCLS prototype.
The equipment necessary for the hardware development includes the mixed-signal oscilloscope, power supply, and digital multimeter. An LED array test circuit will be constructed utilizing this equipment before the full development of the LED fretboard prototype, which will be discussed in the Prototype Description. Simple switching circuitry will also be constructed to replicate the foot pedal input prior to prototype development.

The software development tools required include the Noral debugging pod, PC, CodeWrite software, and C compiler. All software, as discussed in the Software Description, will be written in C and assembly language. I will be enrolled in Western Washington University’s Embedded Systems course during Winter Quarter to learn how to write code for the 9S12 using the C language.
Development Schedule

The following tables display the GCLS Development Schedule. This schedule provides a weekly agenda from Winter Quarter to Spring Quarter. Winter Break will be designated for accomplishing three tasks: ordering parts, constructing the LED fretboard prototype, and constructing of the foot switch.

WINTER QUARTER

<table>
<thead>
<tr>
<th>Week</th>
<th>Development Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Research and order any remaining components</td>
</tr>
<tr>
<td>2</td>
<td>Design LED test circuitry</td>
</tr>
<tr>
<td>3</td>
<td>Finalize LED fretboard prototype design</td>
</tr>
<tr>
<td>4</td>
<td>Design switching test circuitry</td>
</tr>
<tr>
<td>5</td>
<td>Foot pedal prototype and chassis construction</td>
</tr>
<tr>
<td>6</td>
<td>Continue w/ prototype hardware construction</td>
</tr>
<tr>
<td>7</td>
<td>Complete bulk of prototype hardware construction</td>
</tr>
<tr>
<td>8</td>
<td>Begin software design</td>
</tr>
<tr>
<td>9</td>
<td>Implement LED test circuitry w/ 9S12 – functional test</td>
</tr>
<tr>
<td>10</td>
<td>Begin writing main module and computer user interface</td>
</tr>
</tbody>
</table>

SPRING BREAK: Compile Notes from Embedded Systems course for software design preparation.

SPRING QUARTER

<table>
<thead>
<tr>
<th>Week</th>
<th>Development Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Develop chord look-up table module</td>
</tr>
<tr>
<td>2</td>
<td>Develop chord switching module</td>
</tr>
<tr>
<td>3</td>
<td>Finalize hardware design for review, continue writing code</td>
</tr>
<tr>
<td>4</td>
<td>Develop code for LCD module</td>
</tr>
<tr>
<td>5</td>
<td>Continue software development</td>
</tr>
<tr>
<td>6</td>
<td>Begin final prototype construction, software development</td>
</tr>
<tr>
<td>7</td>
<td>Preliminary version of final prototype completed</td>
</tr>
<tr>
<td>8</td>
<td>Final software design for review</td>
</tr>
<tr>
<td>9</td>
<td>Final test and construction of GCLS</td>
</tr>
<tr>
<td>10</td>
<td>Senior Project Demonstration</td>
</tr>
</tbody>
</table>
Prototype Description

The prototype will resemble the GCLS image represented earlier in Figure 2. The microcontroller 9S12 development board and all external circuitry will be enclosed in a metal chassis as described. More attention will be required for the prototype development of the LED fretboard and foot pedal unit due to their unique features. All circuitry assembly will utilize prototype circuit boards and point-to-point soldering.

Surface-mount LEDs were selected as a specification requirement for the LED fretboard due to their conservative dimensions. Producing such a unit would require extensive time, precision, and professional manufacturing tools; therefore, the construction of the LED fretboard output display prototype will utilize standard LEDs. Holes will be drilled into the fretboard of an old guitar, which I possess, with respect to the LED array layout described in Figure 2. The convex exterior of the LEDs will be ground flat with a mechanical sander to allow the LEDs to be mounted flush with the fretboard, shown in Figure 12. The LEDs that will be implemented were donated by Micro-Radian Instruments during a summer internship.

![Figure 12: LED Fretboard Prototype Construction](image)
The foot pedal input device is a unit made up of switches. To avoid manufacturing such a unit from scratch, a sewing machine pedal will be implemented in the prototype foot pedal construction with added channel selection buttons.

The GCLS prototype will be displayed during the Senior Project Demonstration Day at the end of Spring Quarter. During the senior project demonstration, a chord look-up chart will be provided for the audience to observe. This chart is illustrated in the Appendix of this document. A list of guitar chord websites and songs will also be compiled to demonstrate how the internet can be used as an inexpensive tool to acquire chord sequence input for the GCLS.
ELECTRICAL SPECIFICATIONS

Project Specifications

GCLS Display Specifications:

Notes Represented: 24 individual guitar notes, first 4 frets

Chords Represented: 108 basic guitar chords, see Appendix

Major: A Bb B C Db D Eb E F F# G Ab

Minor: Am Bbm Bm Cm C#m Dm Em Fm F#m Gm Abm

Major 6: A6 Bb6 B6 C6 Db6 D6 Eb6 E6 F6 F#6 G6 Ab6

Minor 7: Am7 Bbm7 Bm7 Cm7 C#m7 Dm7 Em7 Fm7 F#m7 Gm7 Abm7

Dominant 7: A7 Bb7 B7 C7 Db7 D7 Eb7 E7 F7 F#7 G7 Ab7

Major 7: Amaj7 Bb maj7 B maj7 C maj7 Dbmaj7 Dmaj7 Bbmaj7 Emaj7 Fmaj7 F#maj7 Gmaj7 Abmaj7

Ninth: A9 Bb9 B9 C9 Db9 D9 Eb9 E9 F9 F#9 G9 Ab9

Diminished: A0 Bb0 B0 C0 Db0 D0 Eb0 E0 F0 F#0 G0 Ab0

Augmented: A+ Bb+ B+ C+ Db+ D+ Eb+ E+ F+ F#+ G+ Ab+

Channels Represented: Channels 1, 2, 3
GCLS Computer User Input Specifications:

Saved Chord Sequences: 3 sequences maximum
Individual Chord Sequence Length: 100 chords maximum
Valid Chord Input: See GCLS Display Specifications and Appendix

Serial Port Specifications:
Interface: RS232
Baud Rate: 9600 bps
Data: 8 bits
Parity: none
Protocol: Asynchronous Stat/Stop

Power Requirements
Supply Source: Wall Transformer Power Supply, UL/CSA standard
Input: 120 V AC, 60 Hz
Output: 5 V DC, 1.0 A
Worst Case Power Dissipation: 256 mA

Special Environmental Requirements
Operating Temperature Range: 0 °C – 50 °C

PCB Size Limits
Maximum PCB dimensions: 7” x 5” x 4”
## PRELIMINARY PARTS LIST

<table>
<thead>
<tr>
<th>Description</th>
<th>Part #</th>
<th>Source</th>
<th>Qnt</th>
<th>Price</th>
<th>Max Power Dissipation</th>
<th>Lead Time</th>
</tr>
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<tbody>
<tr>
<td>Microcontroller</td>
<td>MC9S12DP256B</td>
<td>Motorola</td>
<td>1</td>
<td>$14.08</td>
<td>68 mA</td>
<td>1 week</td>
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<td>Wall Transformer</td>
<td>22E009</td>
<td>Alltronics</td>
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<td>$7.95</td>
<td>-</td>
<td>2 weeks</td>
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<td>LCD Module, Backlit</td>
<td>LCM-S02002DSF</td>
<td>Digikey</td>
<td>1</td>
<td>$20.58</td>
<td>3 mA</td>
<td>2 weeks</td>
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<tr>
<td>Surface Mount LED</td>
<td>12-215SYGC/S530-E4/TR8</td>
<td>Mouser</td>
<td>24</td>
<td>$0.19</td>
<td>30 mA</td>
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<td>LED Driver</td>
<td>MAX7221</td>
<td>Maxim</td>
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<td>$3.99</td>
<td>125 mA</td>
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<td>Push Button</td>
<td>EG1411-ND</td>
<td>Digikey</td>
<td>3</td>
<td>$3.04</td>
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<td>16 MHz Crystal Oscillator</td>
<td>300-6034-ND</td>
<td>Digikey</td>
<td>1</td>
<td>$0.65</td>
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<tr>
<td>Resistors</td>
<td>Variable</td>
<td>Digikey</td>
<td>30</td>
<td>$0.30</td>
<td>30 mA</td>
<td>1 week</td>
</tr>
<tr>
<td>232 Interface</td>
<td>MAX232A</td>
<td>Maxim</td>
<td>1</td>
<td>$1.85</td>
<td>25 uA</td>
<td>1 week</td>
</tr>
</tbody>
</table>

**Total**

- **$71.78**
- **256.025 mA**

Note that this list is specifically for the hardware components required. The guitar is not included in calculation. Quality beginner guitar prices range from $200-$500.
APPENDIX

Table of Guitar Chords – For Beginners

MAJOR

<table>
<thead>
<tr>
<th>A</th>
<th>Bb</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram" /></td>
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<td><img src="image4.png" alt="Diagram" /></td>
</tr>
<tr>
<td>Db</td>
<td>D</td>
<td>Eb</td>
<td>E</td>
</tr>
<tr>
<td><img src="image5.png" alt="Diagram" /></td>
<td><img src="image6.png" alt="Diagram" /></td>
<td><img src="image7.png" alt="Diagram" /></td>
<td><img src="image8.png" alt="Diagram" /></td>
</tr>
<tr>
<td>F</td>
<td>F#</td>
<td>G</td>
<td>Ab</td>
</tr>
<tr>
<td><img src="image9.png" alt="Diagram" /></td>
<td><img src="image10.png" alt="Diagram" /></td>
<td><img src="image11.png" alt="Diagram" /></td>
<td><img src="image12.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>
MINOR SEVEN

Am7  Bbm7  Bm7  Cm7

C#m7  Dm7  Ebm7  Em7

Fm7  F#m7  Gm7  Abm7
DOMINANT SEVEN

A7  Bb7  B7  C7

Db7  D7  Eb7  E7

F7  F#7  G7  Ab7
MAJOR SEVEN

Amaj7  Bbmaj7  Bmaj7  Cmaj7

Dbmaj7  Dmaj7  Ebmaj7  Emaj7

Fmaj7  F#maj7  Gmaj7  Abmaj7
NINTH

A9  Bb9  B9  C9

Db9  D9  Eb9  E9

F9  F♯9  G9  Ab9
DIMINISHED

A0  Bb0  B0  C0

Db0  D0  Eb0  E0

F0  F♯0  G0  Ab0