

Embedded Systems United

Wes Petree
Embedded Systems United, Inc.
123 South St. 316
Norman, OK 73019
owpetree@esu.com
405-308-7412

November 30, 2011

Mobile Systems, LLC
I. Needshelp
345 Oak Road
Pleasanton, CA 94588-2708

Dear Mr. Needshelp,

Embedded Systems United is happy to report that the HC11 musical memory game that was contracted has been completed. Attached you will find a completion report of the entire project.

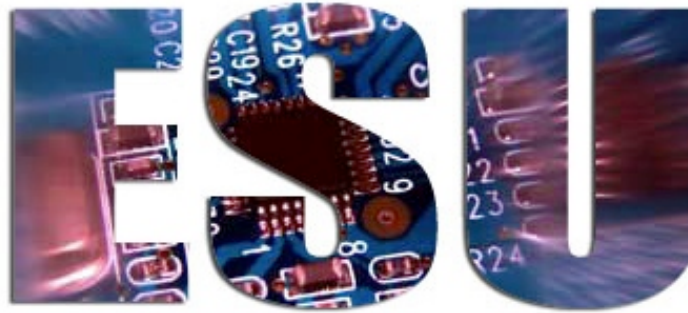
We, at Embedded Systems United, would like to thank Mobile Systems for the opportunity to design and develop this device.

Please feel free to contact me to answer any and all of your questions you may have in regards to any part of the project.

Sincerely,

Wes Petree
Engineering Project Manager

Embedded Systems United, Inc.
123 South St. 316
Norman, OK 73019
405-598-7135



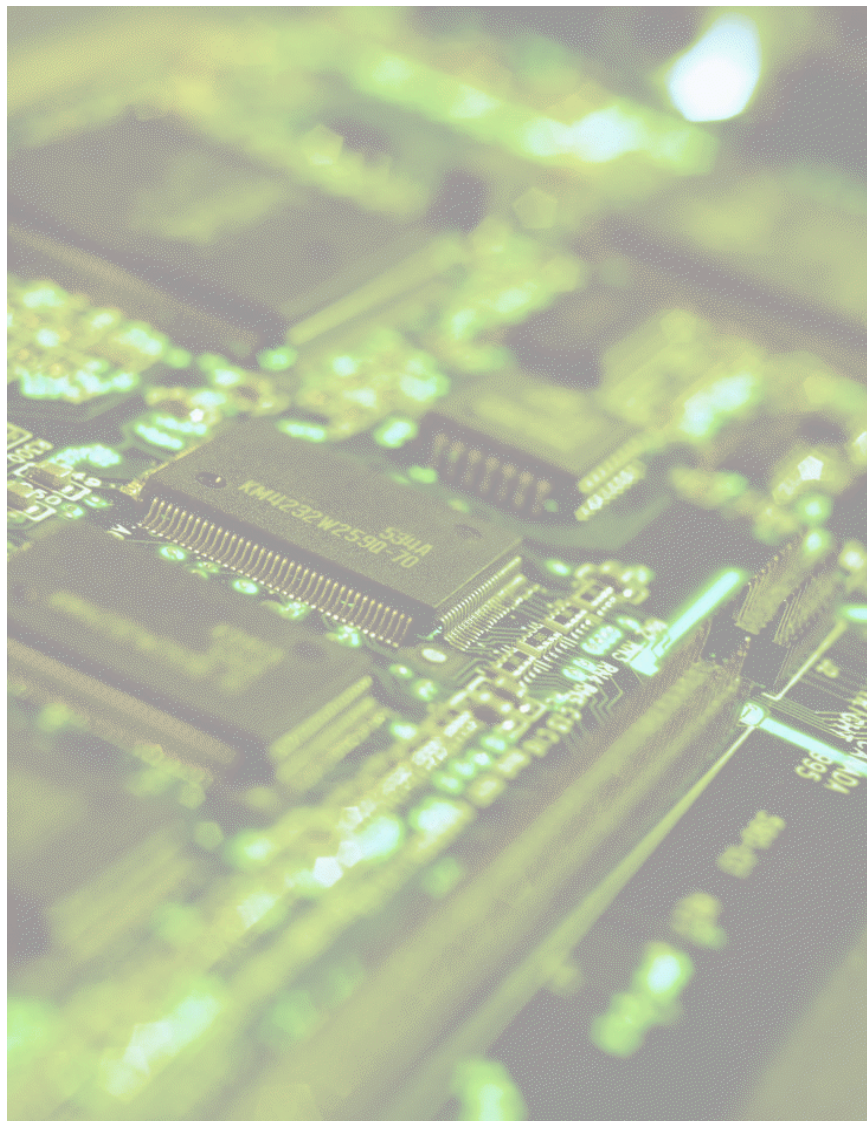
Embedded Systems United

Completion Report for the Design of HC11 Musical Rhythm Game

November 30, 2011

**Embedded Systems
United, Inc.**

123 South St. 316
Norman, OK 73019
405-598-2135



EXECUTIVE SUMMARY

Embedded Systems United is reporting the completion of the design and development of the HC11 musical memory device as contracted by Mobile Systems. The project was divided into two phases – hardware and software.

The hardware phase was completed on November 26th, one day ahead of schedule. All components were chosen and the circuit was tested. One issue arose, but not until the software phase was completed. A debounce issue with the buttons surfaced. The choice was made to solve the problem with software, instead of adding additional hardware. This solution was the most cost effective approach with no added cost in components.

The software phase was completed on November 29th. When the software was completed and tested, the only issue to be found was the debounce issue.

ACKNOWLEDGEMENTS

Embedded Systems United would like to thank Mobile Systems for the opportunity to serve in the capacity of the design of the HC11 musical memory game.



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Background

Embedded Systems United has developed a musical memory game based off Freescale's HC11 microprocessor as contracted by Mobile Systems.

The game is a handheld musical memory game that requires the user to replicate an increasing random sequence of notes. As the user successfully replicates the sequence by pressing the appropriate buttons, a new note is added until the sequence has reached 25 notes, at which point the user has won.

The project was divided into two phases. Phase one included the design and construction of the hardware that was used. The second phase dealt with developing the software to control the chosen hardware and make decisions based on the input of the user.

Problem Statement

The requirements, as set forth by Mobile Systems, were to be able to play four tones at three different waveforms – sine wave, saw-tooth wave, and square wave – and to be able to play a 25 note random sequence that the user must replicate to successfully complete; beginning with one tone and gradually increasing to 25 by the addition of a new tone with each successful attempt.

Each of the four tones were able to be played with one of the above mentioned waveforms and had one LED correspond to each – a total of 12 switches and LEDs consisting of 4 colors with three of each.

Methods

The switches were implemented using one 74HCT574 octal D flip-flop and one 74HCT541 octal buffer controlled with two Chip Select signals and the Read/Write signal. The flip-flop and the buffer allowed the use a 3 x 4 matrix to implement the 12 switches on an 8 bit expanded mode data bus. The program would write a one to one of the columns connected to the flip-flop and then check the state of the switches by the buffer and moved to the next column if no switch was found to be pressed.

In a similar fashion, the LEDs used one 74HCT574 octal D flip-flop to control 12 LEDs in another 3 x 4 matrix. Once, the state of the switches was known, the appropriate value could be sent to the flip-flop to light the corresponding LED(s).

There were two MCP4261-103E digital potentiometers that were implemented using the SPI subsystem. A new Slave Select signal needed to be generated for the second potentiometer chip. Port A bit 7 was used to generate the required signal. Three output



compare interrupt routines were used to write the appropriate value to the potentiometers from three different look-up tables – one for sine, saw, and square. The actual OC pin on Port A was used to drive one pin of the potentiometer high while the other pin was tied to ground. This assured that when the interrupt routine was turned off, the signal would stop.

One 74HCT14 Quad inverter was used to invert the R/W* signal on the buffer to activate it when called by the software. One 74HCT08 Quad AND gate chip was used for the logic to enable the flip-flops when called by the software. One LM324 quad op-amp chip was used for replicating the output from the digital potentiometers. A TDA7052A audio/power amplifier was utilized to drive a two inch 8 Ω speaker.

Also utilized, was a character LCD display that was connected via the expanded mode bus.

Main Sections of Data

The design of the system consisted of two phases – hardware and software. A certain portion of the hardware needed to be completed before the software could begin.

Hardware

To begin the hardware, we knew we would need a way to implement 12 switches with LEDs corresponding to them, as well as a digital to analog converter to output a digital signal to a speaker.

The project began by implementing a matrix for the switches and LEDs. This was needed, as there are only 8 data bits available from the HC11.

The next task was to design a digital to analog converter. The decision was made to use digital potentiometers and update the wiper position periodically to create the waveform. This idea was chosen over an R-2R resistor ladder due to cost. The cost of the potentiometer chip was approximately 30% cheaper than implementing an 8 bit R-2R ladder with 1% resistors.

Software

Once the hardware was designed, the next task was to write software that not only controlled the hardware, but also allowed the user to input the sequence.

The software also used an 8-bit linear feedback shift register to create the random sequence. It was decided that to save the cost of additional hardware to create a shift



register, the software utilized the built in function of the microprocessor to create a linear feedback shift register. Although the cost is miniscule for one unit, in mass production, the savings are tremendous.

Four modes of gameplay were implemented into the system:

- **Easy mode:** The beginner mode played only the square waves – a total of four tones
- **Medium mode:** The medium mode played all available notes and waveforms – a total of 12 tones
- **Hard mode:** The hard mode plays only the square waves like the easy mode, but without the LEDs lighting
- **Just Notes mode:** Just notes mode allows the user to push the buttons and play the corresponding tones and waveforms without having to play in a game mode.

Management Plan

Included is a Gantt chart that shows the project timeline and its completion and the project budget summary.

As previously reported, there was one week of dead time due to some internal issues with accounting personnel. All personnel involved have been relieved of their employment.

The schedule has completed within the specified deadline.

Chart 1: Project Management Timeline and Completion Dates.

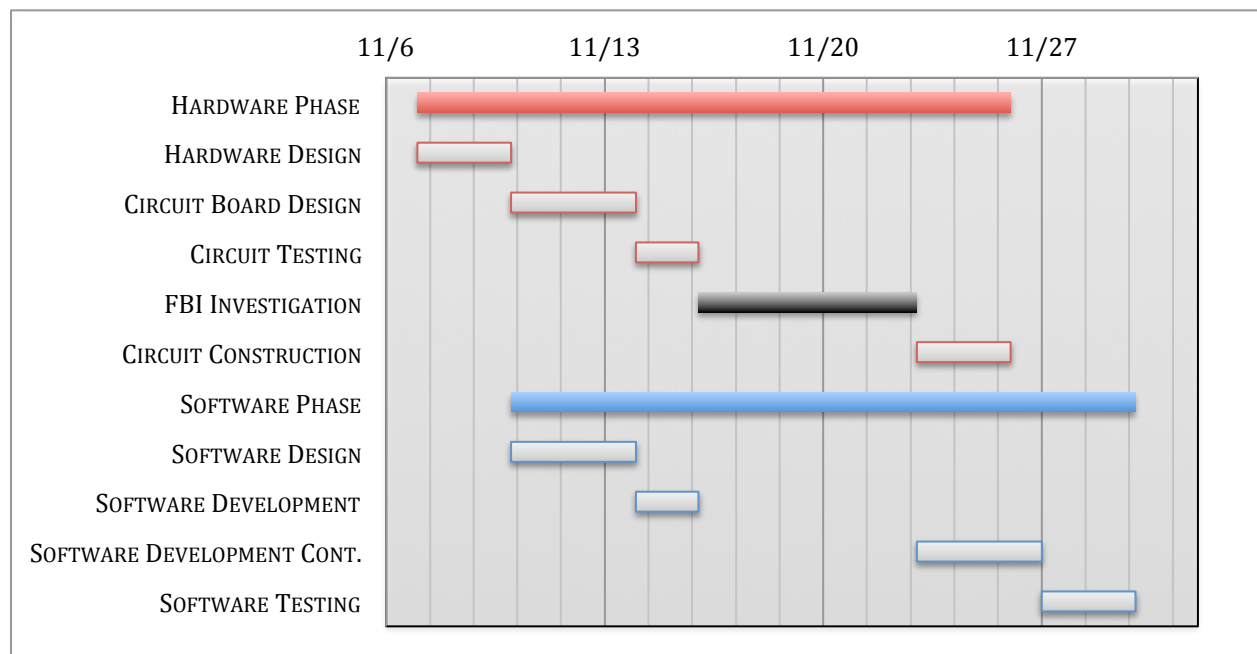


Table 1: Budget Summary

Budget Summary	
Personnel	
Engineering	\$90,232.00
Other Direct Expenses	
Travel	\$1,200.00
Supplies	\$2,500.00
Communication	\$800.00
Computer Services	<u>\$1,500.00</u>
Total:	\$6,000.00
Overhead	\$74,562.00
Contingency and Profit	\$34,400.00
Total:	\$199,194.00
Engineering Personnel Detail	
Senior Engineer	\$22,978.00
Hardware Engineers	\$34,186.00
Software Engineers	<u>\$33,068.00</u>
Total:	\$90,232.00

Results

The design of the hardware began with choosing the components. Once the parts were chosen and assembled, the circuit was tested to ensure that it was able to communicate with the processor as designed. No issues were found with the hardware.

During the design of the software, it was discovered that there was a debounce issue with the switches. Although, there was no issue aurally with the switches, the processor was able to pick up multiple pressing of the switch, although it was pressed only once.

This problem was solved with software, rather than by hardware, to save on the cost of additional components. Again, the single cost of the additional hardware is insignificant, but the mass production costs would grow significantly. A small delay, unnoticeable to a human, was added to the end of each sequence to find if a switch was pressed before



looking again, which solved the debounce issue. By approaching the solution with software, rather than by hardware, there was no additional cost.

Conclusions

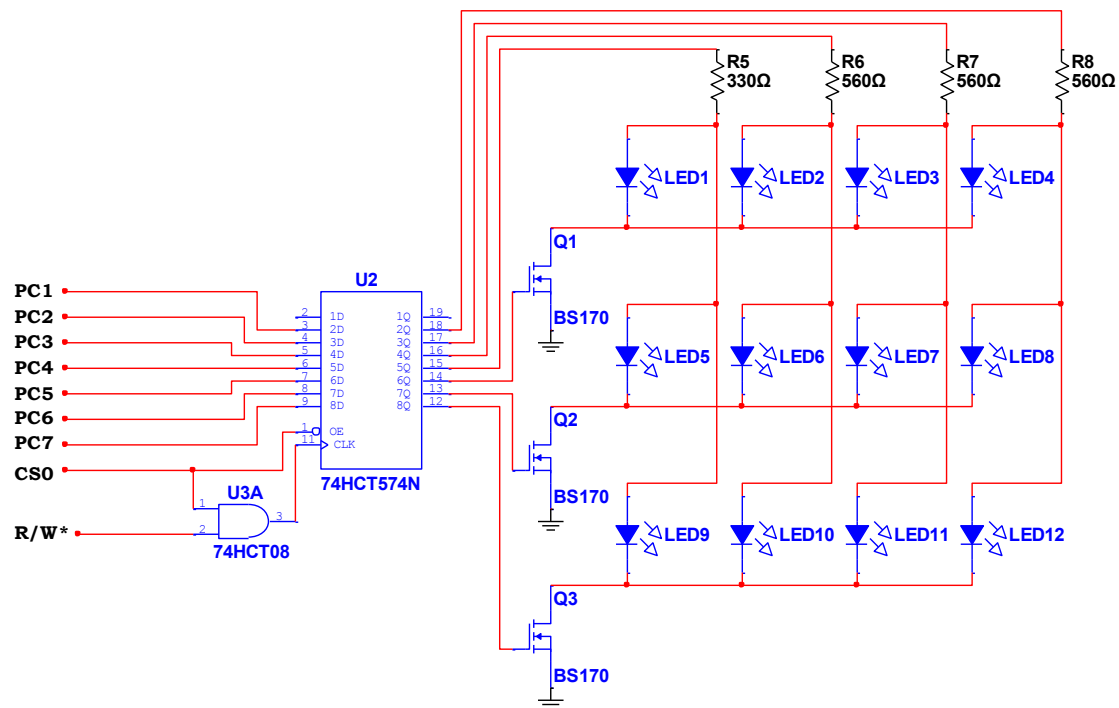
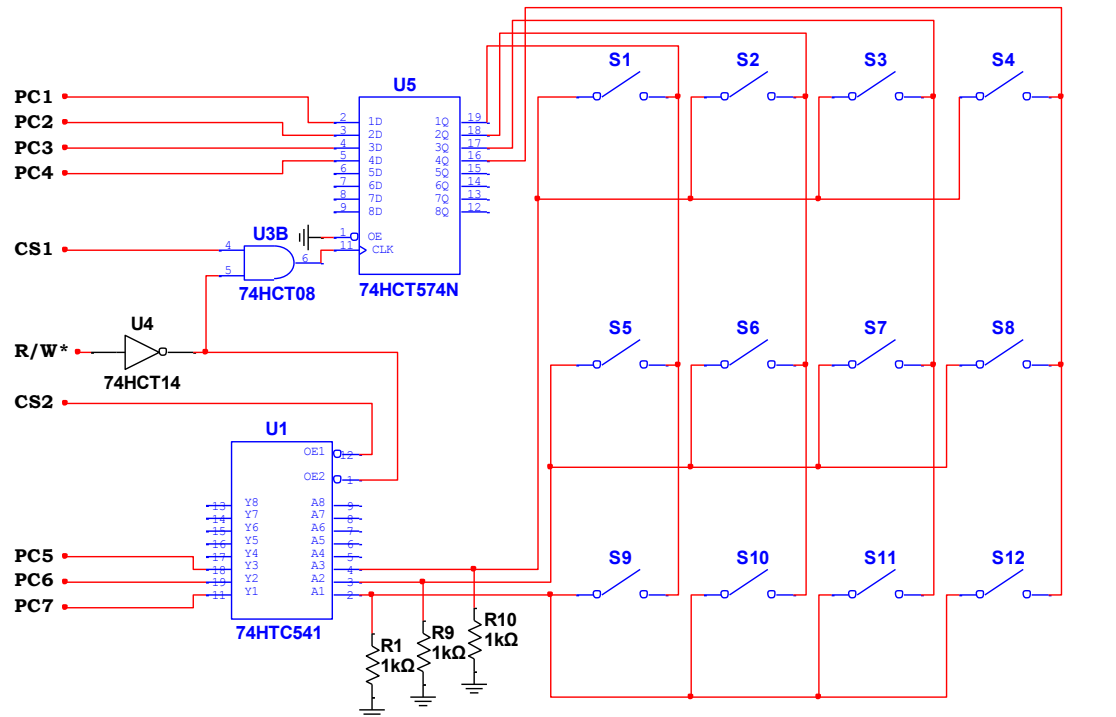
Mobile Systems contracted embedded Systems United for the design and development of an HC11 musical memory system. The system was to utilize 12 switches and create four tones by way of three different waveforms – saw-tooth, sine, and square waveforms. A random sequence of up to 25 notes was to be played requiring the user to replicate that sequence.

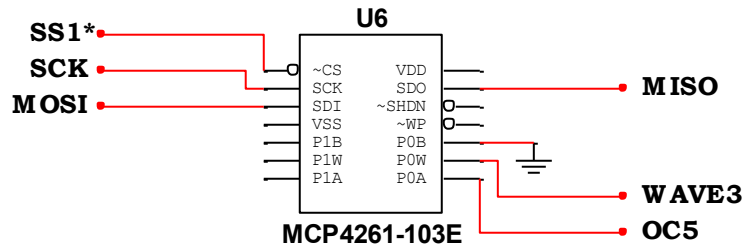
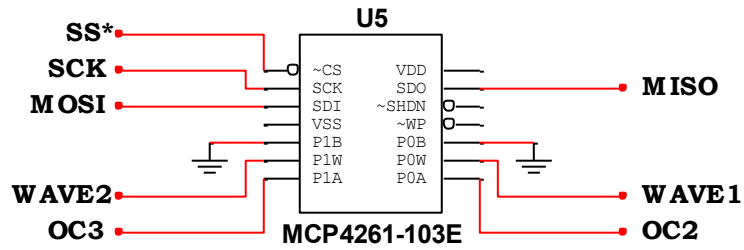
The project met no major complications that threatened its completion. Only two minor complications arose – both met with satisfying results. The project was completed on the agreed upon date.

The HC11 musical memory game system has completed on time. All of the required specifications were accomplished. All the known issues from testing the device have been solved and the device is ready for production.



Appendix 1 – Schematic





Ground:

U5/U6 - VSS
U7 - GRND1, GRND2
U8A,B,C- Pin 11

5V:

U5/U6 - VDD, ~SHDN, ~WP
U7 - Vp
U8A,B,C- Pin 4

