ECE/CS 5780/6780: Embedded System Design

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Review 3

Chapter 1 Topics

- Embedded microcomputer architecture
- I/O ports
- 6812 architecture
- Digital representations of numbers
- Addressing modes (INH, IMM, DIR, EXT, REL)
- Top-down and bottom-up design process

Chapter 2 Topics

- Assembly language basics
- Several types of indexed addressing modes
- 6812 assembly language and pseudo-ops
- Coding style, naming conventions, and comments
- FSM abstraction
- Modular software development
- Global and local variables
- Layered software systems
- Device drivers
- Debugging
- Power of 10

Chapter 3 Topics

- Blind cycle synchronization
- Gadfly synchronization

Chapter 4 Topics

- Basics of interrupts and ISRs
- Reentrant programming
- FIFOs
- 6812 interrupts
- Polled and vectored interrupts
- Priority
- Real-time interrupts and periodic polling

Chapter 5 Topics

- Multithreaded preemptive schedulers
- Semaphores and their applications
- Fixed scheduling

Chapter 6 Topics

- Input capture
- Output compare
- Frequency measurement
- Pulse accumulator
- Pulse-width modulation

Chapter 7 Topics

- Serial communication basics
- Serial communication interface (SCI)
- Serial peripheral interface (SPI)

Chapter 8 Topics

- Switch and keyboard interfacing
- Hardware and software debouncing methods
- Output LEDs
- Liquid crystal displays
- Relays, solenoids, and DC motors
- Stepper motors

Chapter 9 Topics

- Address decoding
- Timing diagram syntax
- Using expanded mode to interface with memory mapped devices

Chapter 11 Topics

- Operational amplifiers
- Analog filters
- Digital-to-analog converters
- Analog-to-digital converters

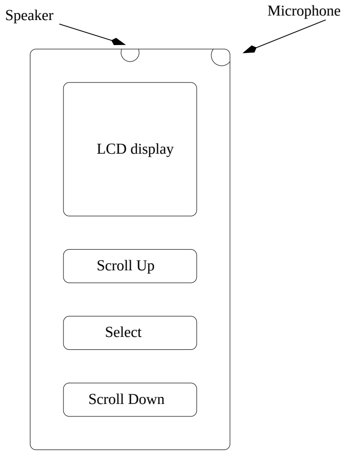
Design Problem

You are an engineer at Digital Recording, Inc. in charge of the design of a sound recorder (see diagram below). The user interface software displays menus of options in an LCD display. There are three keys to scroll up and down these options and select the desired menu entry. These three keys can appear on your schematic as switches, and they should cause interrupts whenever they change value. The recorder also includes a microphone for recording sound and a speaker for playing it back. Finally, assume that you have a 8K EPROM to store the software and a 32K FLASH memory for storing global variables and the recorded sound. Therefore, you will need to run your microcontroller in expanded mode. The basic behavior of this device is that the user should be able to select from a menu that includes:

- Record
- Playback
- Erase

Other functionality may be added later, but this is all you need to worry about for this exam.

Design Problem



Question 1(a)

Analog Interfacing (20 points) The microphone produces a voltage between 0 to 50mV with a desired resolution of 0.25mV which you should sample at 8KHz. The speaker requires an analog voltage between -12V and +12V.

(a) What is the needed ADC precision? How many bits does the ADC need to be? Will the ADCs on the 68HC11 be sufficient?

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$$\begin{aligned} \text{precision} &= \frac{50mV}{0.25mV} \\ &= \text{200 values (1pt)} \\ log_2(200) &\approx \text{8 bits (1pt)} \end{aligned}$$

Yes, they are sufficient (1 pt).

Question 1(b)

Analog Interfacing (20 points) The microphone produces a voltage between 0 to 50mV with a desired resolution of 0.25mV which you should sample at 8KHz. The speaker requires an analog voltage between -12V and +12V.

(b) Show a detailed schematic for the microphone interface. Be sure to include the amplifier and filter. These should be designed with discrete components (i.e., OpAmps, resistors, and capacitors). Remember to label resistance and capacitance values.

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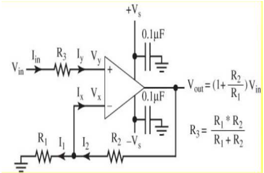
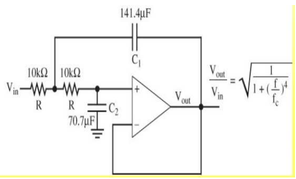


Microphone connected to V_{in}. $R_1 = 1K\Omega$ and $R_2 = 100K\Omega$.



C_1 and C_2 divided by $2\pi f_c = 50,240$.

Question 1(c)

Analog Interfacing (20 points) The microphone produces a voltage between 0 to 50mV with a desired resolution of 0.25mV which you should sample at 8KHz. The speaker requires an analog voltage between -12V and +12V.

(c) Show a detailed schematic for the speaker interface. Again show all components with labels. You may assume the existance of an integrated DAC chip.

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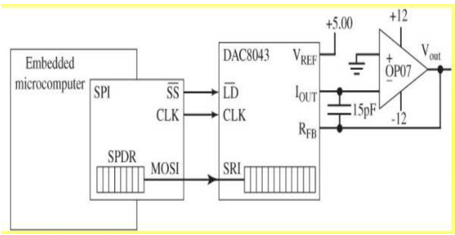

V_{out} should be connected to the speaker.

Question 2(a)

Memory Mapped Interfacing (20 points)

(a) Show your memory map. Hint: be sure to consider how all components that you need are to be interfaced. All memory mapped components should appear in your memory map.

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ANSWER: Many possible, but must avoid certain ranges that conflict with the internal addresses of the device (i.e., $0000-$01FF, $1000-$103F, and $B600-$B7FF).
- FLASH $2000 to $9FFF (2pts)
- EEPROM $B800 to $D7FF (2pts)
- LCD $E000 (2pts)
- Avoid internal addresses (2pts)

Question 2(b)

Memory Mapped Interfacing (20 points)

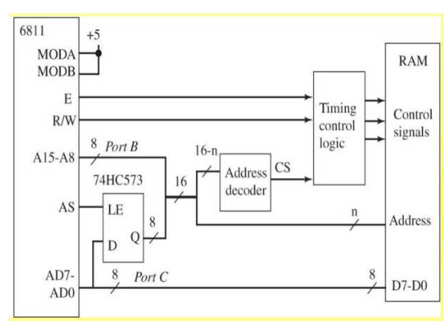
(b) Design your address decoder and other logic for controlling the signals to your memory mapped devices. Show a schematic that includes your address decoder, other glue logic, and the memory-mapped devices. You may assume that the 8K EPROM has read timing similar to Figure 9.48 in the book. You may also assume that the 32K FLASH memory and other memory mapped devices have timing as shown in Figures 9.53 to 9.55.

Question 2(b)

- FLASH $2000 to $9FFF:
  `001X XXXX XXXX XXXX`
  `01XX XXXX XXXX XXXX`
  `100X XXXX XXXX XXXX`
- EEPROM $B800 to $D7FF:
  `1011 1XXX XXXX XXXX`
  `1100 XXXX XXXX XXXX`
  `1101 0XXX XXXX XXXX`
- LCD $E000:
  `1110 0000 0000 0000`
- Minimal decoder logic assuming these are only external addresses:

$$\text{FLASH\_CS} = \overline{A15} + \overline{A14}\,\overline{A13}$$
$$\text{EEPROM\_CS} = A15\overline{A14}A13 + A15A14\overline{A13}$$
$$\text{LCD\_CS} = A15A14A13$$

Question 2(b)

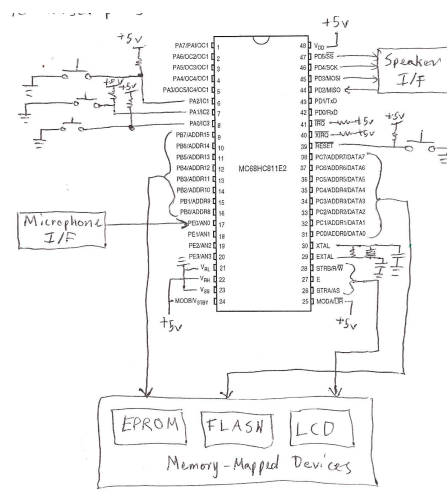


- In figure above, replace RAM with FLASH, add EEPROM, and add LCD.
- Address decoder produces FLASH_CS, EEPROM_CS, and LCD_CS.
- EEPROM interface similar but does not need timing control.
- LCD interface similar but does not need address bits.

Question 3

- **Hardware (30 points)** Draw a schematic for the sound recorder. Include as much detail as possible including all external circuitry and any connections to any pin used. You may show your microphone, speaker, and memory-mapped devices as one block each as their internal implementation is shown in the previous problems. For this problem, you may assume the existence of any basic component that you need as long as you describe what it does.

Question 3



Question 4(a)

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    ANSWER: location to store keystroke (1pt), buffer for playback and record data (1pt), buffer for LCD (1pt).

Question 4(b)

- **Software (20 points)** Answer the following questions about the software for the sound recorder.
  - (a) What global data structures would you provide?
    ANSWER: location to store keystroke (1pt), buffer for playback and record data (1pt), buffer for LCD (1pt).
  - (b) What initialization routines would you provide? What would they do?

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  - (b) What initialization routines would you provide? What would they do?
    ANSWER: depends on design but typically ADC, SPI, and input capture for keys (6pts).

Question 4(c)

- **Software (20 points)** Answer the following questions about the software for the sound recorder.
  (a) What global data structures would you provide?
  ANSWER: location to store keystroke, buffer for playback and record data, buffer for LCD (3pts).
  (b) What initialization routines would you provide? What would they do?
  ANSWER: depends on design but typically ADC, SPI, and input capture for keys (6pts).
  (c) What regular I/O calls would you provide that the client software could use to perform I/O? Describe each in a few words.

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  ANSWER: GetKey, PrintChar, GetSoundSample, PutSoundSample, ClearSoundBuffer, Record, Play (7pts).

Question 4(d)

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  (d) What software support (interrupt handlers) would be needed? Assume that gadfly is not an acceptable option.

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  ANSWER: GetKey, PrintChar, GetSoundSample, PutSoundSample, ClearSoundBuffer, Record, Play (7pts).
  (d) What software support (interrupt handlers) would be needed? Assume that gadfly is not an acceptable option.
  ANSWER: Input capture, output compare (for record and playback), and SPI (for an external device) (4pts).

Question 5

- **Rituals (20 points)** While it is not good style, you have decided to combine all the initializations that you need into a single ritual. Show the assembly code for this ritual.

Question 5

```
init sei                  Make atomic         (0.5 pts)
     lds \#stack
     ldaa \%11010000      Setup SPI           (3 pts)
     staa SPCR
     ldaa \%10000000      Setup ADC           (3 pts)
     staa OPTION
     clra                                     (3 pts)
     staa ADCTL
     ldaa TMASK1          Setup input capture
     ora \$07                                  (3 pts)
     staa TMASK1
     ldaa \$3F                                 (3 pts)
     staa TCTL2
     ldaa \$07                                 (3 pts)
     staa TFLG1
     cli                  Enable interrupts   (0.5 pts)
     rts                  Return              (1 pt)
```

Question 6(a)

- **ARM versus 6811 (10 points)** Assume that you are going to redesign the sound recorder using the ARM board that Professor Regehr described in class.
  (a) What are some advantages of using this board?

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  ANSWER: Many answers accepted. Examples include (1) more internal memory, (2) 10-bit ADC, and (3) faster processor.

Question 6(b)

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  (a) What are some advantages of using this board?
  ANSWER: Many answers accepted. Examples include (1) more internal memory, (2) 10-bit ADC, and (3) faster processor.
  (b) In what ways would you need or want to change the design to use the ARM board?

Question 6(b)

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  ANSWER: Many answers accepted. Examples include (1) more internal memory, (2) 10-bit ADC, and (3) faster processor.
  (b) In what ways would you need or want to change the design to use the ARM board?
  ANSWER: Many answers accepted, but had to mention removal of external memory for full credit.