Homework 3: Design Constraint Analysis and Component Selection Rationale

Due: Friday, September 15, at NOON

Team Code Name: Digital Sheet Music Reader and Player **Group No. 4**

Team Member Completing This Homework: Daryl Sielaff

NOTE: This is the first in a series of four "professional component" homework assignments, each of which is to be completed by one team member. The completed homework will count for 10% of the team member's individual grade. The body of the report should be 3-5 pages, **not** including this cover page, references, attachments or appendices.

Evaluation:

Component/Criterion	**Score**	**Multiplier**	**Points**
Introduction	0 1 2 3 4 5 6 7 8 9 10	X 1	
Analysis of Design Constraints	0 1 2 3 4 5 6 7 8 9 10	X 3	
Rationale for Component Selection	0 1 2 3 4 5 6 7 8 9 10	X 3	
List of Major Components	0 1 2 3 4 5 6 7 8 9 10	X 1	
List of References	0 1 2 3 4 5 6 7 8 9 10	X 1	
Technical Writing Style	0 1 2 3 4 5 6 7 8 9 10	X 1	
		TOTAL	

Comments:

Comments from the grader will be inserted here.

1.0 Introduction

Our project is intended for musicians or teachers who wish to hear what a piece of sheet music sounds like. The user will scan the sheet music using a computer and put the image on a USB thumb drive. Once the thumb drive is connected to our device the user can select the image file and our device will read the image, find the notes, and play it via a speaker or a headphone jack. The uploading of standard printed sheet music will use a USB thumb drive, which will require a USB interface. The processing of the sheet music image will be done by a digital signal processor while the large image file will be stored on an external memory chip. The creation of an audio output of that sheet music will be accomplished using an audio chip with MIDI wavetable lookups.

2.0 Design Constraint Analysis

The final project is not intended to be handheld or battery powered, which alleviates numerous power and packaging constraints. The device will be relatively low power with the audio amplifier and DSP consuming the majority of the power.

One of the main issues that was first considered was how to interface the chips together. Our design requires an LCD, DSP microprocessor, USB host controller, external memory and an audio chip. Using serial transmission for each device requires a DSP with at least 4 serial ports. All of these parts are easy to obtain in a parallel interface, thus the decision was made to use a parallel address/data bus to link the chips together.

2.1 Computation Requirements

We can expect that the processing of the image will require a good deal of computations, so it's important to choose a DSP that will be able to perform these calculations in a reasonable timeframe. Using an 8.5 x 11 inch piece of music scanned at 200 DPI gives us a 1700 by 2200 pixel image. A resolution of this size is required to accurately distinguish between different note types. Based on current algorithms, it's estimated to take as many as 152 million simple arithmetic cycles to convert a grayscale image to black and white, detect the staffs, measures and filter out erroneous lines. A grayscale bitmap image of this size can be as large as 4MB while a black and white image is only around 500 KB. The external RAM chip will need to be large enough to hold the entire picture while it's being processed.

2.2 Interface Requirements

The nature of this project will be focused on software development concerning the image processing, thus the number of general-purpose I/O functions will be limited. We will require 4 general purpose I/O pins: 2 for a rotary pulse generator which will navigate menus and alter the volume, and 2 other pins for pushbuttons required to navigate the menus. A serial interface will be used for the LCD and will require level translating because the DSP I/O runs at 3.3V and the LCD uses 5V TTL logic levels.

The decision to use an 8-bit bus is derived from the choice of USB controller and audio chips, both of these chips require an 8-bit data bus. A multiplexed bus will require 19 pins[1] and will cut down the number of pins by as much as 36 pins[2]. The multiplexed bus will require a latch to hold the address lines while the data is being transferred. Also, all pins connected to the address/data bus must be three-state so that there isn't any "bus fighting".

2.3 On-Chip Peripheral Requirements

- External Bus Interface: 8-bit data, address at least 4MB, 3 Chip Selects available
- SPI/USART: At least 1 for the LCD. Depending on the debugging software available, an additional serial line could be used for RS-232 for console based debugging.
- General Purpose I/O: 4 I/O pins for rotary pulse generator and navigation buttons
- RAM: enough to store part of the image being processed, 100-200+KB would be ideal
- External Interrupt: 1 interrupt, the USB controller will be interrupt driven

2.4 Off-Chip Peripheral Requirements

This device will require a few peripherals outside of the DSP controller. The main components are the USB controller, memory, audio chip and LCD. All chips on the address/data bus will be 3.3V parts, thus a level translator will not be necessary. However, the LCD uses 5V TTL levels and will require the SPI signals (data and clock) to be shifted from 3.3V to 5V. A transistor in an open-collector configuration on each of the two signals will suffice.

To make the audio processing relatively easy, we chose to use the MIDI standard. MIDI will allow our device to choose between 128 instruments and play up to 16 different instruments at the same time. A standard MIDI command will need a note, volume, channel and whether that note is being turned on or off. These MIDI commands can easily be generated by the DSP and sent to an audio chip via data bus. [8]

2.5 Power Constraints

This device is not intended to be hand held, so it will be powered using an A.C wall-wart. A regulated 5V wall-wart will provide power for the LCD and audio amplifier. Two separate LDO regulators will be used to obtain the 3.3V and 1.2V required by the rest of the circuit. By keeping the audio amplifier at 5V, the noise on the 3.3V and 1.2V power lines should be minimal. Current considerations are as follows: [1], [4], [5], [7]
3.3V: 160mA (DSP) + 25mA (USB Host) + 200mA (Memory) + 20mA (Audio chip) = 405mA
1.2V: 500mA (DSP Core)

2.6 Packaging Constraints

The intended use of this project is for a classroom, music instructor, or personal musician and will be a desktop application. The enclosure will need to be able to house the PCB, LCD, navigation buttons and a speaker capable of playing music for a group. There will need to be access on the outside of the enclosure to an external power jack, USB connector and 1/8" headphone jack (for optional headphone use). The PCB is estimated to be 4 x 6 inches at a maximum once completed.

2.7 Cost Constraints

Currently there are no products like ours on the market, so we aren't competing with an existing product. The prototype will cost approximately $100 for all the parts. That price would drop significantly once the unit moves into mass production due to the fact that components bought in bulk are much less expensive.

3.0 Component Selection Rationale

<u>Microprocessor</u>

There were many things to look at while considering a microprocessor, first and foremost was that we needed an external bus interface. This requirement adds many pins to the package, so we knew that we'd be working with a larger package. The nature of this project is more intensive on array and vector calculations because of the image processing. A RISC architecture would not be efficient at these calculations, while a DSP architecture would be much better suited because of the more extensive instruction set offered.

	ADSP-21262	AT91R40008	PIC24F	Constraints
Architecture	32-bit Floating-Point SHARC DSP	32-bit RISC ARM7	16-bit Microcontroller	DSP Not RISC
On-chip RAM	250KB RAM 500 KB ROM	256 KB RAM	8 KB RAM 128 KB Flash	200+ KB
External Bus	8/16-bit bus 4 flags/chip selects Multiplexed	8/16-bit bus 64 MB addressable 8 chip selects	8/16-bit bus 2 chip selects multiplexed	8-bit bus 3 chip selects
Serial Interface	2 SPI	2 USARTS	1 SPI & 1 UART while bus is enabled	2 SPI/UART
Package	144-LQFP	144-LQFP	80 & 100 LQFP	Non-BGA
Price	$19.26	$9.91	$5.71	

[1], [2], [3]

The PIC24F is a smaller package size but doesn’t have enough on-chip RAM nor does it have enough chip selects. The AT91R40008 has a very limited instruction set, the external bus isn’t multiplexed and 64MB of addressable RAM is overkill. The SHARC is the most appealing because it is a DSP and meets all other constraints of the project. It also has the most elaborate development tools available, which will prove invaluable as this project is very concentrated on the coding.

Memory

Our device will operate such that the data on the external memory will not need to be saved once the device is turned off. The DSP will copy the image from the thumb drive onto the memory chip. It will then process the image and store that processed information back on the thumb drive to save for later. This means that we can use a run-time SRAM memory instead of a storage Flash memory. The SRAM should be arranged in 8 bit words to match the 8-bit data bus. 3.3V SRAM chips above 4MB are very rare unless they use words larger than 8 bits. So I found a few chips with the following specifications: SRAM, 4MB (512Kx8), 3.3V, parallel interface.

Cypress: CY7C1049BV33 (36-pin SOJ or 44-pin TSOP II)

Renesas: R1RW0408D (36-pin SOJ)

The preferred package type is the TSOP package and it's relatively easy to obtain samples of Cypress parts. So we will use the Cypress CY7C1049BV33. [5], [6]

Audio Chip

Once MIDI was chosen as the method of audio playback we began looking for chips that would interface with an 8-bit data bus, accept MIDI commands and output an audio signal. All of our options came from the cell phone market:

Winbond W56964: Polyphonic ringtone ICs, 64 note wavetable synthesizer, 32-pin QFN

Fangtek FT1770N: Compatible with MP3 and MIDI, 32-pin LPCC

NEC uPD9992: Ring Tone Generator LSI, 65-pin FBGA

All three chips perform very similar functions so the main distinguishing factors are the package types and documentation available. Most chips had limited documentation, but Winbond was quick to respond via email and supplied us with five sample chips, an evaluation board, numerous documents, and sample code. The QFN package of the Winbond will be a challenge to solder, but it is our chip of choice. [7]

4.0 Summary

This report focused on the design constraints for the hardware of the Digital Sheet Music Reader. After evaluating the constraints of the design and making the necessary choices, we should have an efficient digital system. The amount of research done on each selection should ensure that we won't run into issues later in the design process. Our next step is to obtain the parts so that we can start prototyping and continue developing the code necessary to bring our project to life.

List of References

[1] Analog Devices, "ADSP-2126x SHARC Processor Peripherals Manual", **http://www.analog.com/UploadedFiles/Associated_Docs/624414032755326387ADSP_2126x_HRM.pdf**, December 2005.

[2] Atmel, "AT91 ARM Thumb Microcontrollers," **http://www.atmel.com/dyn/resources/prod_documents/doc1354.pdf**, August 2002.

[3] Microchip, "PIC24FJ128GA Family Data Sheet", **http://ww1.microchip.com/downloads/en/DeviceDoc/39747C.pdf**, June 2006.

[4] Cypress, "SL811HS Embedded USB Host/Slave Controller," **http://download.cypress.com/publishedcontent/publish/design_resources/datasheets/contents/sl811hs_8.pdf**, June 2005.

[5] Cypress, "CY7C1049BV33: 512K x 8 Static RAM," **http://download.cypress.com/publishedcontent/publish/design_resources/datasheets/contents/cy7c1049bv33_8.pdf**, September 2002.

[6] Renesas, "R1RW0408D Series: 4M High Speed SRAM (512-kword x 8-bit)," **http://documentation.renesas.com/eng/products/memory/rej03c0111_r1rw0408d.pdf**, March 2004.

[7] Winbond Electronics Corp., "64-Note Polyphonic Ringtone Chip," June 2006. (Obtained via email with a Winbond employee)

[8] MIDI Manufacturers Association, **http://www.midi.org**, September 2006.

IMPORTANT: Use standard IEEE format for references, and CITE ALL REFERENCES listed in the body of your report.

Appendix A: Parts List Spreadsheet

Vendor	*Manufacturer*	*Part No.*	*Description*	*Unit Cost*	*Qty*	*Total Cost*
Digi-Key	Analog Devices	ADSP-21262	32-bit Floating-point SHARC DSP	19.26	1	$19.26
Arrow Electronics	Cypress	CY7C1049BV33	512K x 8 Static RAM	15.96	1	$15.96
Digi-Key	Cypress	SL811HS	Embedded USB Host/Slave Controller	8.56	1	$8.56
Winbond	Winbond	W56964	64-Note Polyphonic Ringtone Chip	Sample	1	$0
Crystal Fontz	Crystal Fontz	CFA-632	Serial LCD Module 16 x 2	33.00	1	$33.00
				TOTAL		**$76.78**