Homework 3: Design Constraint Analysis and Component Selection Rationale

Due: Friday, February 10, at NOON

Team Code Name: Digital Real-time Intelligent Networked Kegerator **Group No. 4**

Team Member Completing This Homework: Ian Snyder

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. It should be a minimum of five printed pages.

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:

1.0 Introduction

The Digital Real-time Intelligent Networked Kegerator is a modular addition to any existing beverage dispensing device. With the DRINK system, the owner is able to control, monitor, and record draft beverages on a per user basis through a web interface. Users are able to view various consumption statistics and other information through a graphical LCD interface and pushbutton RPG. The system authenticates users by using a short range, low frequency RFID located on the bottom of their cup and a PIN entered via the system's pushbutton RPG.

2.0 Design Constraint Analysis

This report outlines the software, hardware, product packaging, and cost requirements of our design. Computational requirements and limitations are discussed, followed by requirements for hardware interfacing between the system components and microcontroller peripherals. Maximum current requirements and heat dissipation are presented along with packaging and cost limitations. This report also details our rationale for selecting our microcontroller, LCD screen, and RFID reader.

2.1 Computation Requirements

During operation, the kegerator will be responsible for logging pours and calculating user statistics. All pour logging will be stored into flash memory with a time stamp. Many common calculations using this data will require a significant amount of unit conversion and averaging of data over multiple time periods. Some example calculations include, predicting when a keg will expire under current average consumption rates, creating data points for the plotting of a user's blood alcohol level, and converting statistics from the metric system to the English standard system. This information will be constantly calculated and updated for all users in the system.

Interrupts from flow meters must be counted as they are triggered. Each flow meter I/O line can potentially send one hundred pulses per second to the microprocessor. Temperature readings will need to be polled at various intervals and inputs from the user interface's control knob and pushbutton will trigger changes in the system.

The kegerator's user interface will be able to redraw portions the graphical LCD screen as a user operates the device. Depending on the screen type, the transmission of graphic data from the microprocessor to LCD controller can be a significant resource requirement. For example, assuming that we have a color screen using an 8-bit color depth, drawing a bitmap would require at least the start x-y position of the picture, picture dimension information, and a byte for the color of each pixel [1].

Refreshing a screen in this manner would quickly saturate a serial communications interface, even at 115.2k baud. Depending on the size of the screen, it is possible that one could only refresh a fraction of the screen at one frame per second. In order to support fast screen redraws, our LCD controller must be advanced enough to allow either an SPI interface from the microcontroller or provide onboard flash or SRAM to offload some of the bandwidth requirements. Advanced LCD controller functions that allow capabilities such as the ability to draw lines from point to point are also favorable.

The microprocessor must have enough processing capability left after all of these tasks to host the administrator's webpage. Commands sent from the administrator via the web interface must update the system in real time.

2.2 Interface Requirements

General I/O pins will be needed for each of the flow meters and solenoids. Each beverage line will require one flow meter and one solenoid. Since we would like to support up to four beverage lines with our design, 8 general I/O lines will be required. Two additional I/O pins will be needed for our temperature probe network and contactor. Some of the remaining I/O pins will be used to interface to a PLD to allow future beverage line expandability. All I/O pins will accept 5V. All off-board inputs must be optically isolated to help reduce noise and prevent damage from ESD. This means all flow meters, solenoids, and PLD pins will need optocouplers.

2.3 On-Chip Peripheral Requirements

An embedded web server with an Ethernet connection to the internet will be at the heart of our system. Additionally, three serial communications interface ports will be needed for an RFID reader, graphical LCD display, and bill acceptor. A single quadrature input will be required to interpret signals from the optical encoder knob that will provide our human-machine interface. Multiple timer channels will be essential for tracking the time between system events.

2.4 Off-Chip Peripheral Requirements

Data stored in SRAM will need to be backed up by a battery to prevent data loss in the event that the system loses main power. An LCD controller will be required to accept serial communication from our microcontroller and drive the LCD to create text and graphics. RS-232 transceiver chips will need to be used to communicate with serial devices if our microcontroller lacks of transceivers.

2.5 Power Constraints

Not all of the devices in our design call for the same operating voltage. Table 2.5.1 summarizes the individual device voltage and maximum current requirements. Our device will have a 12V DC power supply that is capable of providing 8.3A of current. This power supply will tap into the freezer's AC power line from the inside of our refrigeration device, near the compressor. This area must be able to dissipate heat efficiently enough to keep the compressor temperature below 65 degrees C, its operating maximum. This temperature will be monitored by the microcontroller. Fans on the existing vents may be required if the temperature is increased due to the heat dissipated by the DC power supply.

Part	Voltage (V)	Max Current (mA)	Quantity	Total Current (mA)
ezLCD-001 Display Module	3.3	100	1	100
Rabbit RCM3315	3.3	273	1	273
RS-232 Transceiver	3.3	1	2	2
Vision 2000 Flowmeter	5	80	4	320
TI S2000 Microreader	5	100	1	100
Grayhill RPG	5	30	1	30
Maxim Digital Thermometer	5	4	3	12
Solenoid Valve	12	1200	4	4800
ICT Bill Acceptor	12	3000	1	3000
Omicron SPST-NO Contactor	12	160	1	160

Figure 2.5.1 – Individual Component Current Requirements

Figure 2.5.2 shows the total current requirements by voltage, along with the total current required from our 12V power source, assuming 90% efficient onboard DC to DC transfer of 12V to 3.3 and 5V. Due to the high maximum current requirement in the scenario where all beverage lines are locked out and the solenoids are on, the bill acceptor will be shut down via software. This will save 3A of current at 12V and insure that we do not approach our DC power supply's maximum current rating of 8.3A.

Total Current Requirements	(mA)
3.3V	375
5V	462
12V	7960
12V Supply Current	8349

Figure 2.5.2 – System Current Requirements Worst Case

2.6 Packaging Constraints

This device needs to be designed in a modular fashion to allow easy installation and expandability. Installation constraints require that the entire module, consisting of the PCB, LCD, bill acceptor, and RPG, bolt directly to the top of any standard freezer. The power supply will be placed in the bottom of the freezer and plug into the top unit. Solenoids, flow meters, temperature probes, and all additional hardware must have consolidated wiring that minimizes the amount of plugs to the top unit. All electronics need to be sealed from the outside world to guard from potential spills. The top unit must have a locking door for bill retrieval.

2.7 Cost Constraints

Due to the fact that our product is designed for the high end consumer and commercial applications, we have set our prototype budget goal to $1000. Primary reasons for our project's high cost include the need for support on two beverage lines rather than one, our RFID reader's evaluation kit, our high quality graphical LCD/LCD controller, and our storage abundant microcontroller module. We feel comfortable with this prototype's cost due amount of added value and functionality that it will be able to contribute to users and the fact that crude commercial versions of our system retail for prices upwards of $4000.

Figure 2.7.1 shows estimated costs of various single build systems and various mass produced (Qty 1000) systems. The cost to produce a second unit with one beverage line is $738, but if that unit is produced in a quantity of 1000, the production cost would only be $404. On the other side of the spectrum, a mass produced commercial system with 32 beverage lines could be produced for $2,125.95. A system of this size could commercially sell for tens of thousands of dollars. This chart does not include packaging costs. [2]

Part	Prototype	Qty 1	Qty 1000
Microcontroller	$99	$99	$69
Graphical LCD Display/Controller	$150	$200.00	$100.00
Temp Sensors (3x)	$15.12	$15.12	$6.84
Optical Encoder Switch	$36.99	$36.99	$22.20
Flow meters (each)	$25	$40	$26
Solenoids (each)	$56.15	$56.15	$30
Bill Acceptor	Free	$200.00	$100
RFID	$284	$71.48	$40
Contactor	$19.66	$19.66	$10
Total Cost for 1 Beverage	N/A	**$738**	**$404**
Total Cost for 2 Beverage	**767.07**	**$815.39**	**$451.35**
Total Cost for 8 Beverage	N/A	**$1,411.45**	**$792.52**
Total Cost for 32 Beverages	N/A	**$3,719.05**	**$2,125.96**
Note: Prototype costs reflect student discounts. Select Qty 1000 prices are estimated			

Figure 2.7.1 – Cost Breakdown Varying Quantity Produced and Number of Beverage Lines

3.0 Component Selection Rationale

Microprocessor Selection

Figure 3.0.1 shows a feature breakdown between two core module boards based off the Rabbit 3000 and Freescale HCS12NE64 microprocessors, and the individual HCS12NE64. The RCM3315 is a Rabbit 3000 module featuring 512K of SRAM, flash, and program memory. Five serial ports provide extensive interfacing capabilities. The CM-HCS12NE64 is a core module produced by Softec Microsystems, which offers significantly less on-chip memory and serial interfacing resources. This module only offers 8K of SRAM, 64K of flash memory, and three serial ports. Both modules feature extended flash memory through an on module serial interface and Ethernet capability. The Rabbit product has 4 Mbytes while the Softec module has 8 Mbytes of additional storage. The individual HCS12NE64 does not include extended flash memory but is capable of supporting it with an external boot loader, much like the hardware on both core modules [3] [4] [5].

We have selected the RCM3315 as our microprocessor of choice. The large battery backed SRAM will allow us to store comprehensive user and system statistics without having to parse through a large pour log stored in flash to update calculations. Additionally, the large SRAM will allow us to avoid 100,000 write cycle limitation of flash because we will be updating our flash infrequently. In the event of power loss, the SRAM data will be preserved due to the battery backup. The HCS12NE64 based solutions do not offer us this flexibility

The Softec module's 4 MByte flash memory lead over the Rabbit does not offer a significant advantage, as 4 MBytes is already enough memory to store hundreds of thousands of time-stamped pour database entries, customizable user icons/pictures, and a robust web interface. Using the additional 4 Mbytes for more complex LCD graphics is not practical due to our

115200 baud communication limitation. It is simply not possible to refresh the screen fast enough with large bitmaps being sent from flash to the LCD.

Finally, the RCM3315 decision was strengthened due to the availability of a 3300 series Rabbit development board and the large cost of acquiring a Softec module. The lab staff was able to provide the 3300 series Rabbit development board free of charge. The cost to purchase the AK-S12NE64-A development kit from Softec is $450. Also, Softec has a minimum order quantity of five units for their CM-HCS12NE64 modules. The cost for the Rabbit was only $99. The individual HCS12NE64 is only $8 but requires at least $25 in additional components to achieve the same functionality as the Softec module. Due to availability issues for the supporting components and added complexity of implementation, we have ended our pursuit of this option.

Device Model	RCM3315	CM-HCS12NE64	HCS12NE64
Module Manufacturer	Rabbit Semiconductor	Softec Microsystems	N/A
Packaging	Core Module Board	Core Module Board	112-Pin LQFP
SRAM	512K Program + 512K data	8K	8K
Flash	512K	64K	64K
Extended Memory	4 Mbyte Serial Flash (single chip)	8 Mbyte Serial Flash (1 Mbyte x 8)	None
General-Purpose I/O	49	Up to 70	Up to 70
Serial Interfaces	5 total with 5 configurable as SCI, 3 as SPI	2 SCI, 1 SPI, 1 I^2C	2 SCI, 1 SPI, 1 I^2C
Real-Time Clock	Yes	No	No
SRAM Battery Backup	Yes	No	No
Timers	Ten 8-bit and one 10-bit	Ten 8-bit and four 16-bit	Ten 8-bit and four 16-bit
Pulse-Width Modulators	10-bit free-running counter and 4 PW registers	None	None
Analog to Digital	No	Yes	Yes
Quadrature Decoder	Yes	No	No
Ethernet	10/100	10/100	10/100
Power	3.15-3.45V DC, 275 mA @ 3.3V	3.3V	3.3V
Cost	$99	$600 @ $120 each (Minimum Qty 5)	8 (+$25 for components)

Figure 3.0.1 – Feature Comparison of Microcontroller Modules

LCD Selection

Figure 3.0.2 shows a feature breakdown of three LCD modules from ezLCD, Apollo Displays, and Crystalfontz. The ezLCD module contains a Sony 2.7”, 240x160 pixel active matrix TFT screen. The Apollo Displays module contains an Optex 5.7”, 240x64 pixel STN transmissive screen. Finally, the Crystalfontz module is based off of their 320x240 STN transmissive screen [6] [7].

LCD screens is a place where bigger is not always better. As you can see from figure 3.0.2, both the Optrex and Crystalfontz screen are significantly larger than the Sony screen in terms of both diagonal screen size and total screen area. The Crystalfontz screen even has more pixels than the Sony screen. But after examining the contrast ratio and response times of both the Crystalfontz and Optrex LCD screens, we can see that they are both dismal compared to the Sony. The Sony LCD’s response time is over twenty times faster and the contrast ratio is over twice that of the alternatives. The result is that the Sony is much more viewable and capable of refreshing the screen much faster [8] [9].

But perhaps the most important aspect of our LCD component selection is the interfacing and control options available on each module. The Crystalfontz module only allows parallel communications with no high level control functions or additional features. The Apollo Displays module is significantly more advanced with both serial and parallel, along with the capability to plot lines from X-Y coordinates, draw circles, and upload bitmaps.

The ezLCD display is the most advanced of the three, with a whole variety of interfacing options, including parallel, serial, USB, and I^2C. It allows shape and graphics drawing functions that are similar to the Apollo Displays module, but its control feature that places it firmly above the rest is the ability to flash the firmware of the device with your own fonts and bitmaps. This means you can almost instantly recall frequently used icons and bitmaps without having to send serial data from the microprocessor. The end result is a more interesting and interface user interface. The ezLCD-001 is our LCD of choice.

Device Model	ezLCD-001	F-51851GNFQJ-LY-AND	CFAG320240C-FMI-T
Module Manufacturer	ezLCD	Apollo Displays	Crystalfontz
Screen Manufacturer	Sony	Optrex	Crystalfontz
Screen Technology	Active Matrix TFT	STN Transmissive	STN Transmissive
Color	Yes	No	No
Resolution (pixels)	240x160	240x64	320x240
Diagonal Size	2.7"	5.7"	5.7"
Viewable Area (cm^2)	37.03	48.96	110.4
Contrast Ratio	13 to 1	6 to 1	3 to 1
Response Time (ms)	15	310	350
Controller	ezLCD-001	CDS-51405	S1D3305
Controller Flash	94k	None	None
Interface	Serial, USB, I^2C, Parallel	Serial, Parallel	Parallel
High level control functions	Yes	Yes	No
Evaluation Board	Yes	No	No
Samples Available	Yes	Cannot get controller	Yes
Cost	$200 ($150 for students)	$171	$142.73

Figure 3.0.2 – Feature Comparison of Graphical LCD Modules

RFID Selection

Figure 3.0.3 shows a feature comparison of three RFID evaluation kits. Unfortunately, the market's current selection of low cost RFID reader modules is very limited. We were able to limit the possible choices to two Texas Instruments RFID evaluation kits and a kit offered by Phidget USA. All of the kits operate at low frequencies, with the exception of the RX-MFR-RNLK kit, which read both low and high frequency transponders [10] [11].

While the Phidget USA module is by far the cheapest solution, the read range is approximately four centimeters. While this could work, we believe that a larger detection range would be more appropriate for our application. The antenna is non-removable and the interfacing is only offered through USB [12].

That leaves us with the two Texas Instruments kits. Both have comparable read ranges of at least 10 cm. Both come with everything you need to get setup and running. The only real difference in reading capability is the RX-MFR-RNLK's ability to read both high and low frequency transponders. As far as packaging, the RI-K3A-001A comes with a DIP packaged reader that would be easy to solder into our PCB. The RX-MFR-RNLK comes with a small PCB module that would have to be screwed down to our board [13] [14].

We have decided to go with the RI-K3A-001 based on its adequacy for our application since we do not believe we need high frequency capability. The price point on this reader is more attractive even after receiving a student discount on the RX-MFR-RNLK.

Device Model	RI-K3A-001A Low Frequency Micro RFID Kit	Phidget USB RFID Kit	RX-MFR-RNLK
Module Manufacturer	Texas Instruments	Phidget USA	Texas Instruments
Module Package	32 pin DIP	PCB	PCB
Frequency	134.2 kHz	125 kHz	134.2 kHz/13.56 Mhz
Antenna	80mm Disk	63mm Onboard Coil	LF/HF Antennas
Replaceable Antenna	Yes	No	Yes
Interface Board	RS232 IF Port, Power and Antenna Connectors	USB	RS-232, RS-485
Typical Read Range (cm)	15	4 cm	10+ cm
Transponder Samples	Yes	Yes	Yes
Software	Yes	No	Yes
Cables	Yes	Yes	Yes
Cost	$284	$76.95	$625 ($350 for students)

Figure 3.0.3 - Feature Comparison of RFID Readers

4.0 Summary

The DRINK system design constraints and component selection rationale have allowed us to select the Rabbit RCM3315 as our microprocessor, the ezLCD-001 as our graphical LCD, and the RI-K3A-001A Low Frequency Micro RFID Kit as our RFID solution. These components were selected based off of their appropriateness for our application based off computational capabilities, hardware interfacing considerations, packaging needs, and electrical characteristics.

List of References

[1] EarthLCD. (2005). ezLCD-001 Data Sheet. Available:
http://www.earthcomputer.com/public_html/downloads/ezLCD-001_DataSheet.pdf
Feburary 10th, 2005. [Data accessed]

[2] Digi-Key. (2005). Volume pricing information. Available:
http://www.digikey.com/
Feburary 10th, 2005. [Date accessed]

[3] Rabbit Semiconductor. (2005). RCM User Manual. Available:
http://www.rabbitsemiconductor.com/products/rcm3305/
Feburary 10th, 2005. [Date accessed]

[4] Softecmicro. (2005). CM-HCS12NE64 Product Brief. Available:
http://www.softecmicro.com/downloads/doc/cm-hcs12ne64_brief.pdf
Feburary 10th, 2005. [Date accessed]

[5] Freescale Semiconductor. (2005). MC9S12NE64 Product Summary. Available:
http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=MC9S12NE64&srch=1
Feburary 10th, 2005. [Date accessed]

[6] Apollo Displays. (2005). Available:
http://www.apollodisplays.com/pdf/OPA-stepprod.pdf
Feburary 10th, 2005. [Date accessed]

[7] Crystalfontz. (2005). CFAG320240CFMIT Data Sheet. Available:
http://www.crystalfontz.com/products/320240c/CFAG320240CFMIT.pdf
Feburary 10th, 2005. [Date accessed]

[8] Optrex. (2005). 51553 Product Information. Available:
http://www.optrex.com/pdf/51553.pdf
Feburary 10th, 2005. [Date accessed]

[9] EarthLCD. (2005). Sony ACX705AKN-7 Product Datasheet. Available:
http://www.earthlcd.com/downloads/acx705akm-7.pdf
Feburary 10th, 2005. [Date accessed]

[10] Texas Instruments. (2005) S4100 Multi-Function RFID Evaluation Kit. Available:
http://www.ti.com/rfid/docs/manuals/pdfSpecs/RF-MFR-RNLK-00.pdf
Feburary 10th, 2005. [Date accessed]

[11] Texas Instruments. (2005) S2000 Low Frequency RFID Micro Evaluation Kit. Available:
http://www.ti.com/rfid/docs/manuals/pdfSpecs/RI-K3A-001Apb.pdf
Feburary 10th, 2005. [Date accessed]

[12] Phidgets. (2005) RFID Reader Product Datasheet. Available:
http://www.phidgets.com/documentation/1023.pdf
Feburary 10th, 2005. [Date accessed]

[13] Texas Instruments. (2005) S4100 Multi-Function RFID Reader Datasheet. Available:
http://www.ti.com/rfid/docs/manuals/refmanuals/rf-mgr-mnmn_ds.pdf
Feburary 10th, 2005. [Date accessed]

[14] Texas Instruments. (2005) S2000 Low Frequency RFID Reader Datasheet. Available:
http://www.ti.com/rfid/docs/manuals/pdfSpecs/RI-STU-MRD1.pdf
Feburary 10th, 2005. [Date accessed]

Appendix A: Parts List Spreadsheet

Vendor	*Manufacturer*	*Part No.*	*Description*	*Unit Cost*	*Qty*	*Total Cost*
EarthLCD	ezLCD	ezLCD-001	ezLCD-001 Intelligent Display Module	$150	1	$150
N/A	Remag AG	Vision2000 4F23	3/8” Inline Flow meter	$25	3	$75.00
Newark	Omron	89C758	30A Contactor – Normally Open	$19.66	1	$19.66
Texas Instruments	Texas Instruments	RI-K3A-001A	Texas Instruments S2000 Micro RFID	$284.29	1	$284.29
Digi-Key	Maxim	DS18S20	Maxim IC THERM MICROLAN HI-PREC TO-92	$5.04	4	$20.16
McMaster-Carr	Delrin	7876K24	Delrin Solenoid Valve – Normally Open 3/8” NPT thread with quick disconnects	$56.15	2	$112.30
N/A	Rabbit Semicond.	RCM3315	Rabbit 3315 Microcontroller	$99	1	$99
Newark	Grayhill	62S11-M5-050C	Grayhill Series 62S Optical Encoder	$37.81	1	$37.81
Newark	XP	AED100US12	12V 8.3A DC Power Supply	$88	1	$88
Newark	N/A	MC18S-2D	Aluminum Knob with Indicator Line	$2.26	1	$2.26
Lowes	Various	N/A	Tubing and Hardware	$30	1	$30
Newark	N/A	N/A	Optocouplers	$0.50	8	$4
ICT	ICT	A623-S0R-US4	ICT Bill Acceptor (donated)	$0	1	$0
				TOTAL		922.48