Homework 5: Circuit Design and Theory of Operation
Due: Friday, February 24, at NOON

Team Code Name: __RFID Xpr3ss_____ **Group No.** __10__

Team Member Completing This Homework: ___Jennifer Tietz_____

NOTE: This is the second in a series of four "design 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 report itself should be a minimum of five printed pages, **not** including the cover sheet, references, or any attachments (DRC, BOM). **Electronically submit the ".DSN" schematic file along with the ".doc" version of this report zipped into one file.**

Evaluation:

Component/Criterion	Score	Multiplier	Points
Introduction & Theory of Operation	0 1 2 3 4 5 6 7 8 9 10	X 4	
Documentation for Circuit Design	0 1 2 3 4 5 6 7 8 9 10	X 4	
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:

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1.0 Introduction

The RFID Xpr3ss is a state-of-the-art self-checkout station utilizing RFID technology in place of UPC labels that will enhance the retail store customer's checkout experience. Once the customer is finished shopping, he or she will simply swipe a key fob with an embedded RFID tag within a few inches of the "mouse pad" transceiver. The unique serial number on the key fob will identify the customer and link to his or her pertinent information in an external customer database. The customer will then be prompted to input his or her PIN on a 16-key keypad as an added security measure, which will be checked against the database. Then, the customer can begin swiping products past the mouse pad-like receiver, and the RFID tags with unique serial numbers on each product will link to its title, description, and price within a similar external database. As products are scanned, the information will appear for the customer on the LCD screen. After all of the product scanning is complete, the customer's total price will be displayed and he or she will be prompted for their preference of an email or printed receipt. If selected, an email receipt will be sent to the customer's email address on file in the customer database; if the printed receipt is selected, one will be generated with the thermal printer. More specific details on the circuit design and theory of operation will be discussed in this report.

2.0 Theory of Operation

Power Supply Circuit

Due to the need for several different regulated supply voltages ranging from 3.3 V to 12 V, the design of the power supply circuit was very important. Since the printer chosen for the design was provided with its own wall-wart, the design utilizes a second power cube to produce these other signals. The printer is powered by a 7 V DC regulated supply. Rather than risk performance loss or power issues by running the entire circuit from this source, a second 7 V DC wall-wart is used for the circuit components. The printer supply is rated at only 1.6 A, which is on the low end of acceptable values if this source was to be used for the overall design. The second supply is connected to a TI dc-dc switching regulator [1] that, with the help well-documented circuitry, increases the output voltage to a regulated 12 V DC at 175 mA. The

second wall-wart also provides power for two Fairchild Semiconductor low drop-out voltage regulators [2] that decrease the supply down to 5 V at 1.5 A and 3.3 V at 1.5 A. Since only 80 mA at 12 V are needed for the RFID reader [3], 517 mA at 5 V are needed for the LCD [4] and keypad [5], and 285 mA at 3.3 V are needed for the microcontroller [6], the supplied voltages and currents will more than suffice.

Microcontroller (Freescale MC9S12NE64)

The MC9S12NE64 80-pin microcontroller has been chosen for its selection of features that closely meet the design constraints of the RFID Xpr3ss system. As suggested by the data sheet, it operates at 3.3 V and a frequency of 25 MHz [6], neither of which will have a severe impact on the power dissipation of the system. The presence of the background debug module (BDM) is ideal for in-circuit programming and debugging. The circuitry for the oscillator and the BDM is designed in accordance with the microcontroller data sheet [6].

One major criterion for microcontroller selection was the need for Ethernet connectivity to send emails and access external databases. The microcontroller's embedded web server communicates via an RJ-45 connector to send emails to customers and query the databases. The circuitry used in this design was adapted directly from the Ethernet physical transceiver circuit on the microcontroller data sheet [6]. The RFID reader utilizes the SCI1 port to receive and transmit data to the microcontroller as the customer key fobs and products are scanned. When the scanned serial number on the RFID tag is transmitted to the microcontroller from the RFID reader, the external database is queried to find the customer or product information. Once that is successfully located and transmitted back to the microcontroller, it is transferred to the LCD through several of the more than 70 general I/O pins available.

The 16-key keypad also interfaces using an encoder to the microcontroller through general I/O pins. Similar to the reader, the thermal printer receives data to print receipts from the SCI0 port. That data will only be transmitted to the printer if the customer selects to print a receipt by pressing the appropriate button on the keypad.

RFID Reader (Intersoft USA Medium Range WM-RO-MR-2 RFID Reader)

The RFID reader is intended for reading and decoding passive RFID tags. The reader and antenna are housed within a rugged, yet slim, enclosure that lays flat on a table-top surface.

The reader operates on 12 V regulated DC with a maximum of 80 mA [3], which is supplied by the power circuitry as explained earlier. The estimated supply current of 175 mA at 12 V should be more than adequate for proper operation. The reader communicates with the microcontroller via RS232 protocol, and therefore a DB9 connector is used to route signals to a MAX233A level translator [7] and then on to the microcontroller.

An interrupt is triggered when a valid key fob or product tag is scanned and detected within range of the reader, and a built-in green LED on the mouse pad is illuminated. The decoded serial number, in the form of 8 data bits, 0 parity bits, and 1 stop bit, is transmitted to the microcontroller via the SCI1 port [3]. The microcontroller then uses the Ethernet interface to query the external databases on the serial number and locate the customer or product information.

LCD (Crystalfontz CFAG240128D-FMI-T 240 x 128 Graphical LCD)

The LCD utilizes an 8-bit parallel data bus to receive data from the microcontroller through general I/O. The LCD module [4] has a built-in controller with a 4 kB external display RAM to store data. The RFID Xpr3ss application will use the graphic mode of operation for displaying startup images and possibly product images. In this mode, each bit in RAM corresponds to a dot on the LCD which will either illuminate or not. It will also utilize the text mode of operation for displaying product information. In this mode, each byte of RAM represents a character to be displayed, with special registers that set the character width and line spacing. A Crystalfontz CFACCFL1 inverter module [8] is used to control power to the LCD backlight and requires 5 V and 450 mA. The LCD logic circuitry also requires a current source of 15 mA and an operating voltage of 5 V [4].

As valid customer key fobs or products are detected by the RFID reader and corresponding information is located within the external databases, the LCD is updated by placing the appropriate data bits onto parallel Port A (PADx) and then strobing the LCD controller in accordance with the specified timing characteristics. This will update the LCD RAM, which is polled at a high frequency, constantly refreshing the display and showing the customer his or her identification information, purchased products, running total, and other userful information.

Keypad (Storm 6000 Series PIN Entry Pad)

The 16-key keypad [5] is connected through a 7 x 2 pin header to a Fairchild MM74C922 16-key encoder operating on 5 V and 1.1 mA maximum [9]. The encoder scans input signals from the four rows and four columns of the keypad matrix at a rate of approximately 600 kHz, as determined by the C_{osc} capacitor. When the customer is not pressing any keys, internal pull-up resistors on the encoder pull the open-drain row outputs high and the open-drain column outputs to logic zero. However, when a key is pressed to input a PIN or select a receipt option, the row output goes low. The data, a binary encoding of the corresponding key press, is latched, put onto a 4-bit bus, and sent directly to the microcontroller through the Port H (PHx) general I/O pins. Finally, the data available signal goes high, triggering an interrupt and informing the microcontroller that data is ready to be handled.

Printer (Star Micronics NP-211 Thermal Kiosk Receipt Printer)

The thermal printer is used to print 58 mm wide receipts for the customer, should he or she select the printed receipt option on the keypad by selecting the appropriate option after being prompted by the LCD. For minimum power consumption, the printer receives transmissions at 9600 baud via RS232 protocol [10] using a DB9 connector. Formatting of sent data is very flexible, making it an ideal solution for development. A word consists of a single start bit, 7 or 8 data bits, odd, even, or no parity, and at least one stop bit. The printer operates in an interrupt-driven mode.

A separate wall-wart rated at 7 V regulated output and 1.6 A is provided with the printer, which supplies enough power to function properly, as it satisfies the operating voltage requirement of 7 - 14 V regulated DC. It was advised that the printer be powered individually by its own regulated wall-wart, thereby requiring the aforementioned second power supply for the RFID Xpr3ss system. The reasoning lies both in the fact that the printer was designed to run as the only load on the supply, and because the 1.6 A rating is on the low end of the total current design constraints. Another advantage to running the printer off of its own supply is that the current spikes that could occur during operation will not impact other components in the design.

When the customer selects the printed receipt option, the data log of the customer's purchases stored on SRAM is transmitted to the printer through the SCI0 port on the microcontroller. That data is stored into the printer's 5 kB receiving buffer before being printed.

3.0 Summary

The RFID Xpr3ss system attempts to revolutionize the retail self-checkout industry as it is known today. The use of RFID technology in the place of UPC labels will save customers time, and the ability to perform real-time inventory updates will save stores both time and money. The RFID Xpr3ss system is comprised of several component modules, including the power supplies, microcontroller with oscillator and Ethernet circuitry, RFID reader, LCD, keypad with encoder, and thermal printer, that all work together to transmit data efficiently and seamlessly, thereby improving the customer's self checkout-experience.

List of References

[1]   Texas Instruments MC34063A Switching Regulator
        http://focus.ti.com/lit/ds/symlink/mc34063a.pdf

[2]   Texas Instruments REG1117 LDO Voltage Regulator
        http://focus.ti.com/lit/ds/symlink/reg1117a.pdf

[3]   Intersoft Corp WM-RO-MR2 Medium Range RFID Reader
        http://www.intersoft-us.com/dnload/WMROMR2.pdf

[4]   CrystalFontz CFAG240128D Graphic LCD
        http://www.crystalfontz.com/products/240128d/CFAG240128DFMIT.pdf

[5]   Storm Interface 6000-210023 16 Key PIN entry keypad
        ftp://ftp.ambrit.co.uk/technicalspecs/6000.pdf

[6]   Freescale MC9S12NE64 Microcontroller
        http://www.freescale.com/files/microcontrollers/doc/data_sheet/MC9S12NE64V1.pdf

[7]   Maxim IC MAX220 - MAX249 Multichannel RS232 Drivers/Receivers
        http://pdfserv.maxim-ic.com/en/ds/MAX220-MAX249.pdf

[8]   CrystalFontz CFAICCFL1 Inverter for Backlit Graphic Modules
        http://www.crystalfontz.com/products/240128d/CFAICCFL1.pdf

[9]   Fairchild Semiconductor MM74C922 16 Key Encoder
        http://www.fairchildsemi.com/ds/MM%2FMM74C922.pdf

[10] Star Micronics NP-211 Thermal Kiosk Receipt Printer
        http://www.starmicronics.com/printers/printers_pages/support/manuals/NP_manuals/NP21
        1SM.pdf

Appendix A: Design Rule Check Report

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Checking Pins and Pin Connections

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Checking Schematic: SCHEMATIC1
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Checking Electrical Rules

Checking for Unconnected Nets

Checking for Invalid References

Checking for Duplicate References

Check Bus width mismatch
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Appendix B: Bill of Materials Report

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   Revised: Thursday, February 23, 2006
           Revision:


Bill Of Materials       February 23,2006       19:33:46       Page1

Item   Quantity     Reference   Part
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1      6      C1     0.22uF
              C3     0.22uF
              C4     0.22uF
              C5     0.22uF
              C6     0.22uF
              C7     0.22uF
2      1      C2     0.01uF
3      2      C8     15pF
              C9     15pF
4      1      C10    470pF
5      1      C11    4700pF
6      9      C12    0.1uF
              C13    0.1uF
              C14    0.1uF
              C15    0.1uF
              C16    0.1uF
              C17    0.1uF
              C18    0.1uF
              C19    0.1uF
              C21    0.1uF
7      1      C20    1.0uF
8      4      C23    10
              C24    10
              C25    10
              C26    10
9      2      C27    100
              C30    100
10     1      C28    330 uF
11     1      C29    1500 pF
12     1      D1     1N5819
13     1      J0     Background Debug
14     1      J2     DB9 - RFID
15     1      J3     DB9 - Printer
16     1      J4     HEADER 10X2
17     1      J5     DIPSOC-3x2
18     1      J6     7x2 Keypad Header
19     1      J7     RJ-45 Connector
20     1      J8     7V Wall Wart
21     2      J9     12 HEADER
              J10    12 HEADER
22     1      J11    HEADER 7
23     1      L1     170 uH
24     1      L2     1.0 uH
25     4      R1     49.9
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                R2    49.9
                R3    49.9
                R4    49.9
26    1         R5    12.4k
27    2         R6    220
                R7    220
28    1         R8    180
29    1         R9    0.22
30    1         R10   10M
31    2         R11   2.2k
                R15   2.2k
32    1         R12   18.92k
33    4         R13   10k
                R14   10k
                R21   10k
                R22   10k
34    1         R17   10k SIP 6
35    1         R18   RESISTOR SIP 3
36    1         R19   10k SIP 8
37    1         R20   10k SIP 7
38    1         SW1   SW PUSHBUTTON
39    1         U1    microcontroller
40    1         U3    MAX233A/SO
41    1         U4    MM74C922 Keypad Encoder
42    1         U10A  mc34063ap
43    1         U11   REG1117-5
44    1         U12   REG1117-33
45    1         U13   GAL22V10
46    1         Y1    25MHz
```