Reliability and Safety Analysis

Year: 2015 **Semester:** Spring **Team:** 13 **Project:** CoDDeLo
Creation Date: 04/03/2015 **Last Modified:** October 7, 2015
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Assignment Evaluation:

Item	Score (0-5)	Weight	Points	Notes
Assignment-Specific Items				
Reliability Analysis				
MTTF Tables				
FMECA Analysis				
Schematic of Functional Blocks (Appendix A)				
FMECA Worksheet (Appendix B)				
Writing-Specific Items				
Spelling and Grammar				
Formatting and Citations				
Figures and Graphs				
Technical Writing Style				
Total Score				

5: Excellent 4: Good 3: Acceptable 2: Poor 1: Very Poor 0: Not attempted

Comments:

1.0 Reliability Analysis

dsPIC33FJ256GP710A

The dsPIC33FJ256GP710A [1] is used to control the entire system. It was chosen for reliability analysis because of its complexity. The failure per 10^6 hours ($\boldsymbol{\lambda_P}$) and mean time to failure (MTTF) was calculated based on the formulas outlined in MIL-HDBK-217F [2]. I used the model of digital CMOS IC microprocessor model for this microcontroller. $\boldsymbol{\lambda_P} = (C_1 \cdot \pi_t + C_2 \cdot \pi_e) \cdot \pi_l \cdot \pi_q$. The MTTF and $\boldsymbol{\lambda_P}$ is in the expected range. A failure of this microcontroller would not directly cause harm to the users.

Table 1, microcontroller analysis.

Parameter name	**Description**	**Value**	***Comments***
C1	Die complexity	0.14	PIC controller
π_t	Temperature coeff.	1.5	PIC controller
C_2	Pin/Package Constant	0.052	Nonhermetic SMT with 100 pins
π_e	Environmental Constant	0.5	$\boldsymbol{G_B}$
π_l	Learning Factor	1	The IC is more than two years in production.
π_q	Quality Factor	10	Commercial components
Entire design:			
$\boldsymbol{\lambda_P}$		2.36	
MTTF		0.424	

MCP1700

The MCP1700 [3] voltage regulator is used to provide power to the digital circuits. If this voltage regulator fails to operate normally, there will be insufficient or excessive amount of power deliver to other digital components in our system, which would cause mistakes in logic computations. Incorrect logic computation would make some component, such as keypad, LCD, Xbee and motor, operate in an unexpected way, which would damage the entire system and users.
The failure per 10^6 hours is calculated by $\lambda_P = (C_1 \cdot \pi_t + C_2 \cdot \pi_e) \cdot \pi_l \cdot \pi_q$. The model of CMOS Switch-Mode Regulator is used. The MTTF and λ_P is in the expected range. A failure of this microcontroller would not directly cause harm to the users.

Table 2, voltage regulator analysis.

Parameter name	**Description**	**Value**	***Comments***
C1	Die complexity	0.01	1 to 100 bipolar transistors is used
π_t	Temperature coeff.	0.1	CMOS, T_j= 25 ° C
C_2	Pin/Package Constant	0.0012	3 pin SMT
π_e	Environmental Constant	0.5	G_B
π_l	Learning Factor	1	The IC is more than two years in production.
π_q	Quality Factor	10	Commercial components
Entire design:			
λ_P		0.016	
MTTF		62.5	

<u>Xbee Module</u>

The Xbee S1 wifi module contains MC 13213 HS08 microcontroller which dominate the complexity of this module. Also, the Xbee module is a key component to let our system to communicate with a database and quadcopters. Given this, it is important to analyze the reliability of the Xbee. The following data is obtained from the MIL_HDBK_217F [2] and the MC13213 datasheet[4]. The failure per 10^6 hours is calculated by λ_P = (C1 · πt + C2· πe) · πl · πq. The model of digital CMOS IC microprocessor is used. The MTTF and λ_P is in the expected range. A failure of this microcontroller would not directly cause harm to the users.

Table 3, Xbee module analysis.

Parameter name	**Description**	**Value**	***Comments***
C1	Die complexity	0.14	8-bit microcontroller
π_t	Temperature coeff.	0.98	maximum operating temperature is 85° C
C_2	Pin/Package Constant	0.036	Nonhermetic SMT with 71 pins
π_e	Environmental Constant	0.5	$\boldsymbol{G_B}$
π_l	Learning Factor	1	The IC is more than two years in production.
π_q	Quality Factor	10	Commercial components
Entire design:			
$\boldsymbol{\lambda_P}$		1.552	
MTTF		0.64	

<u>SUMMARY</u>

The MTTF of all three components all more than half million hours which are long enough for our machine. The possible methods to improve the reliability of our design is to use microcontroller and other ICs as simple as possible. We can also design a cooling system to reduce the temperature coefficient.

2.0 Failure Mode, Effects, and Criticality Analysis (FMECA)

There were three criticality levels for this project, low medium and high. High refers to failures which cause injury to users in a catastrophic way, such as burning and toxic gas releasing. Medium refers to failures which has a small probability to cause injury to users by mechanical collision. Low refers to negligible failure which only cause the system to shut down and does not do any damage to users. The acceptable failure rate for high level failure is $\mathbf{10^{-10}}$. For medium and low level failure, the failure rate is $\mathbf{10^{-6}}$. I assume the users read the user manual thoroughly before using our machine. We also assume the electrical system of our design will not be exposed in raining, snowing or other catastrophic weather.

3.0 Sources Cited:

[1] dsPIC33FJXXXGPX06A/X08A/X10A Data Sheet, Microchip Technology Inc., 2011.

[2] "Military Handbook Reliability Prediction of Electronic Equipment" Department of Defense. Washington DC. MIL-HDBK-217F, Dec. 2, 1991.

[3] MCP1700 Low Quiescent Current LDO, Microchip Technology Inc., 2013

[4] MC13211/212/213 ZigBee™- Compliant Platform - 2.4 GHz Low Power Transceiver for the IEEE® 802.15.4 Standard plus Microcontroller, Rev 1.8, Freescale Semiconductor, 20

Appendix A: Schematic Functional Blocks

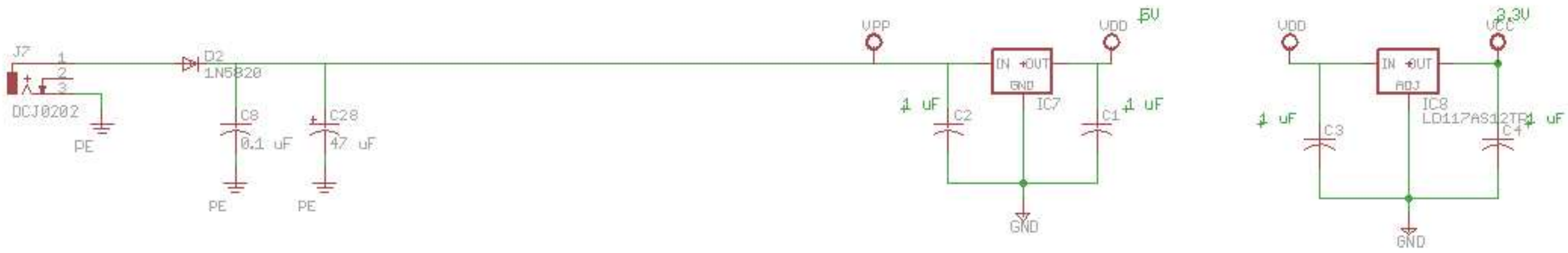

Figure 1, power supply circuit.

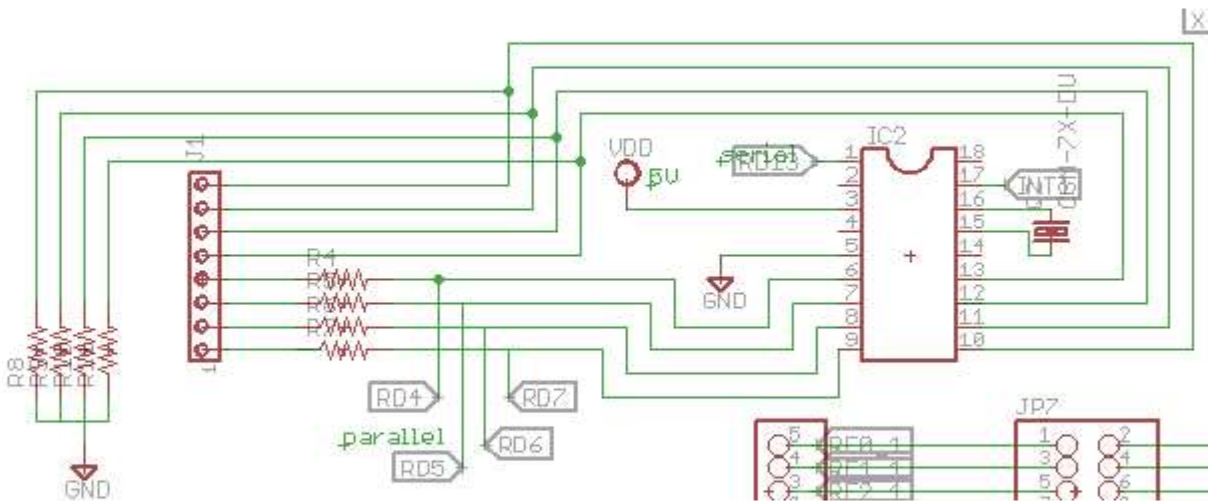

Figure 2, keypad circuit.

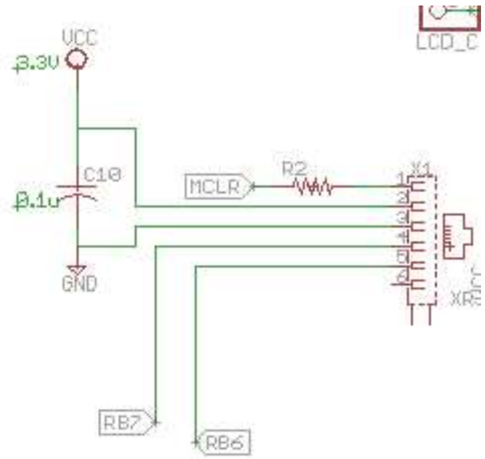

Figure 3, in-circuit programmer circuit.

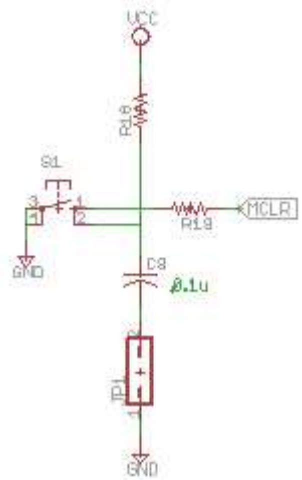

Figure 4, reset circuit.

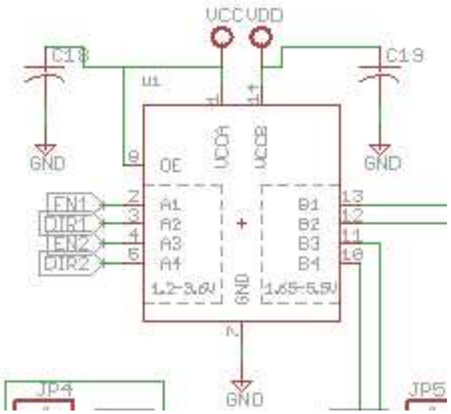

Figure 5, logic level converter circuit.

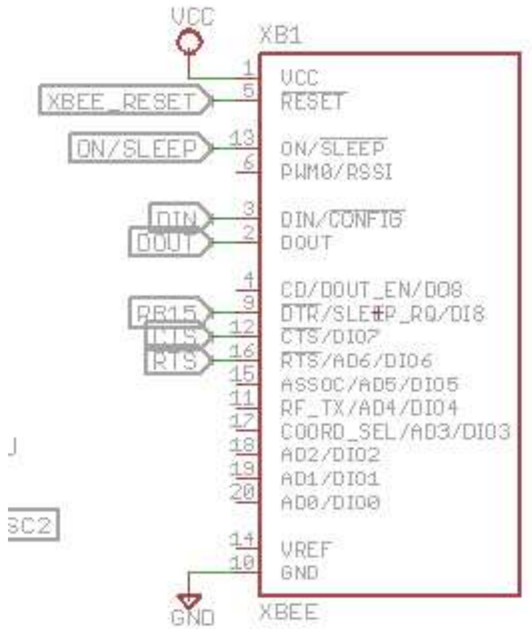

Figure 6, Xbee module circuit.

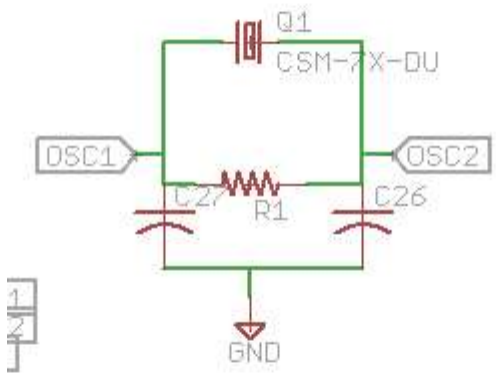

Figure 7, crystal oscillator circuit.

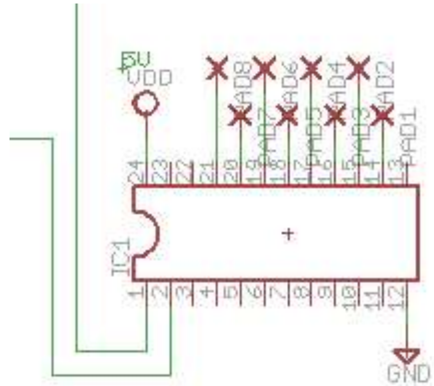

Figure 8, shift register circuit.

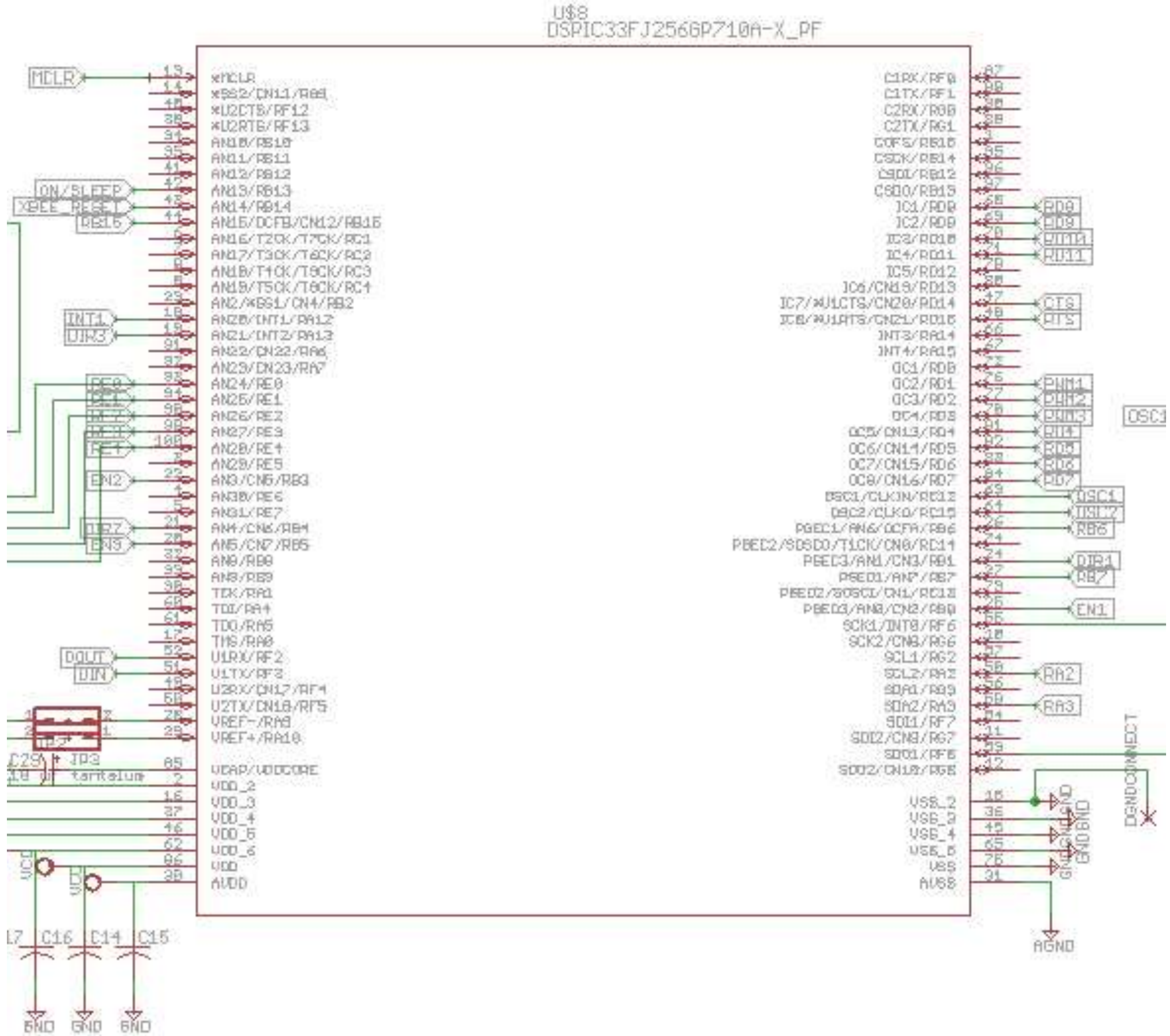

Figure 9, microcontroller circuit.

Appendix B: FMECA Worksheet

Table 4, power supply circuit FEMCA.

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
1	Voltage drop	C8, C28, C1, C2, C3, C4	Errors appear in logic computation. Some components may turns off.	Observation, Display and transmitting errors on LCD and Xbee.	Low	
2	Voltage regulator fails short	2 voltage regulators	Damage all ICs and overheat the system.	Observation, smoke/burning, excessive heat	High	The overheat on the electrical components would cause burning and toxic gas releasing from PCB

Table 5, keypad circuit FEMCA.

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
3	No input received from keypad	EDE 1144 encoder (IC2), Crystal oscillator	User cannot enter their username and password	Observation, Measure the output voltage from the keypad encoder	Low	Assuming the resistors are not open-circuited and supply voltage is normal.

Table 6, in-circuit programmer circuit FEMCA.

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
4	No voltage supply to in-circuit programmer	C10	Cannot program the microcontroller	Observation, errors appear when program the microcontroller	Low	Assuming supply voltage is normal.
5	No data received from in-circuit programmer	Damaged programming cable, damaged RJ11 connector	Cannot program the microcontroller	Observation, errors appear when program the microcontroller	Low	Assuming supply voltage is normal.
6	Large noise appears on the output of the in-circuit programmer	Opened bypass capacitor	Unpredictable	Observation, wrong software program might be performed	Low	

Table 7, reset circuit FEMCA.

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
7	Reset signal is always high	Damaged pushbutton	Cannot reset the system	Observation	Low	
8	Reset signal is always low	Shorted bypass capacitor C9	The system is always resetting. The system cannot function.	Observation	Low	Assuming pushbutton is in good status.

Table 8, logic level converter circuit FEMCA.

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
9	Output cannot reach 5V	Damaged logic converter IC	Cannot control the component that connect to the logic converters (LCD and motor drivers).	Observation, Measure the output voltage from logic converter.	Medium	Assuming supply voltage is normal.
10	Large noise appears on the output of the logic converter	Opened bypass capacitor	Unpredictable	Malfunction may appears on some components	Medium	

Table 9, Xbee module circuit FEMCA.

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
11	Failure to send data	IC on Xbee module,	No communication between our system and a database	Observation	Low	Assuming supply voltage is normal.

Table 10, crystal oscillator circuit FEMCA.

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
12	No signal received from OSC1 & OSC2 of the microcontroller	Damaged crystal (Q1)	Real time application will not accurate	Observation	Low	

Table 11, shift register circuit FEMCA.

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
13	Wrong parallel data output from the shift register	Microcontroller SPI data output and clock, Damaged shift register IC	Errors appear on LCD	Observation	Low	
14	No parallel data output from the shift register	Damaged shift register IC	No display on LCD	Observation	Low	Assuming supply voltage is normal.

Table 12, microcontroller circuit FEMCA.

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
15	No signal come out of the microcontroller	Damaged capacitor on VDD/VCORE pin	Unpredictable	Every component does not function.	Low	Assuming supply voltage is normal.
16	No supply voltage goes into VCC pin	Shorted bypass capacitors	Unpredictable	Every component does not function	Low	Assuming supply voltage is normal.
17	Large noise appears on the output of the microcontroller	Opened bypass capacitor	Unpredictable	Malfunction may appears on some components	Medium	