Introduction

The goal of this project is the implementation of a “digital picture box” that acts as an interface between a PC and any VGA compatible device for the display of JPEG images. Display options and image selection are implemented with the use of on-device push buttons (next, previous, function and power) as well as an IR remote control. Device status is indicated with the use of power and busy LED’s. The physical interfaces are between an RJ-45 port and a 15 pin female VGA connector.

Reliability issues pertinent to this project include component error, durability, emissions (heat and noise), speed and accuracy of image processing and image display. Safety issues were taken into account by securely casing the internal electronics and should not be a factor during normal operation. The aim of analyzing reliability and safety issues is to achieve the best performance with minimal cost and maximum customer satisfaction. This is an important aspect of any products development process as it investigates any possible dangers or unwanted effects that may be experienced by the end user.

With this in mind this document contains a reliability analysis of 5 major design components that are most likely to fail, or are critical to design operation, with calculations of failure rates for each component. In addition an FMECA (failure, mode, effects, and criticality analysis) worksheet for the entire schematic grouped into functional blocks is attached. Lastly a reference list of component data sheets and sources for calculation, analysis variables and equations is included.

Reliability Analysis

The 5 design components with the highest probability of failure due to heavy use during operation are (i) Low Drop Out Voltage Regulators: 9V – 3.3V analog and digital and 9V – 5V digital, (ii) Rabbit 3000 microprocessor, (iii) IR receiver/decoder, (iv) EPSON graphics controller, (v) DRAM memory chip.

Analysis and calculations are done with reference to the formulas and variables in the Military Handbook Reliability Prediction of Electronic Equipment [2].

Failure rate calculation variables :

MTTF: Mean time to failure $(\lambda_p)^{-1}$

λ_p : represents the predicted number of failures per 10^6 hours of operation.

λ_{BD} : die base failure rate

λ_{BP} : package base failure rate

λ_{EOS} : electrical overstress failure rate

λ_{cyc} : cycling factor

C_1 : die complexity constant

C_2: pin number constant

π_T : temperature coefficient, based on junction temperature

π_E : environmental constant, based on equipment use environment

π_Q : quality factor, military (1-2) or commercial 3 -10

π_L : learning factor, based on years device type has been in production

π_{MFG} : manufacturing process correction factor

π_{CD} : die complexity correction factor

π_{PT} : package type correction factor

(i) LDO Voltage Regulator : 9V – 3.3V analog (Texas Instruments REG103-33)

Linear MOS Device $\lambda_p = (C_1\pi_T + C_2\pi_E)\pi_Q \pi_L$

Parameter	Value	Justification
C_1	0.02	Linear, 101 – 300 transistors
π_T	7.0	Linear, MOS, T_J < 85 ^{0} C (assuming max temp.)
C_2	0.0025	SMT, 6 functional pins, non hermetic
π_E	2.0	Ground fixed environment
π_Q	10	Commercial
π_L	1.0	Years in production > 2.0

Table 1.

λ_p = (0.02*7.0 + 0.0025*2.0)10*1.0 = 1.45/10^6 hours

MTTF = 1/ λ_p = 689 655.17 hours = 78.73 years

The 9V-3.3V digital and 9V-5V digital are all in the same LDO regulator family of components from the same manufacturer and so the above calculations are applicable in determining failure rates for those components.

(ii) Rabbit 3000 microprocessor

Digital MOS Microprocessor with > 60000gates $\lambda_p = \lambda_{BD}\pi_{MFG}\pi_T\pi_{CD} + \lambda_{BP}\pi_E\pi_Q\pi_{PT} + \lambda_{EOS}$

Parameter	Value	Justification
λ_{BD}	0.16	Logic device
π_{MFG}	2.0	Non QML or Non QPL
π_T	0.88	Digital MOS, T_J < 85 ^{0} C (assuming max temp.)
π_{CD}	25	1.6 cm^2, assume 1 micron size
λ_{BP}	0.0044	128 pins
π_E	2.0	Ground fixed environment
π_Q	10	Commercial
π_{PT}	6.1	Non hermetic, surface mount
λ_{EOS}	.065	Max voltage is 5.5v , ESD Susceptibility

Table 2.

λ_p = 0.16*2.0*0.88*25 + 0.0044*2.0*10*6.1 + 0.065 = 7.6418/10^6 hours

MTTF = 1/ λ_p = 130 859.22 hours = 14.938 years

The rabbit microprocessor is being used as part of the core module which includes additional components (SRAM, Flash and Ethernet) which will affect the reliability and performance.

(iii) 14-bit IR Decoder (IR-D14 IC)

Digital Microcontroller $\lambda_p = (C_1\pi_T + C_2\pi_E)\pi_Q \pi_L$

Parameter	Value	Justification
C_1	0.02	MOS Digital, assume < 1000 gates
π_T	0.88	MOS Digital , $T_J < 85\ ^0$ C (assume same max temp)
C_2	0.0034	SMT, 8 functional pins, non hermetic
π_E	2.0	Ground fixed environment
π_Q	10	Commercial
π_L	1.0	Years in production > 2.0

Table 3.

λ_p = (0.02*0.88 + 0.0034*2.0)10*1.0 = 0.244/10^6 hours

MTTF = 1/ λ_p = 4 098 360.65 hours = 467.84 years

(iv) EPSON Graphics Controller (S1D13505)

LCD/CRT Controller $\lambda_p = (C_1\pi_T + C_2\pi_E)\pi_Q \pi_L$

Parameter	Value	Justification
C_1	0.08	MOS Digital, assume 30,001 to 60000 gates
π_T	0.88	MOS Digital , T_J = 85 ^{0} C (max operating temperature)
C_2	0.068	SMT, 128 functional pins, Non hermetic
π_E	2.0	Ground fixed environment
π_Q	10	Commercial
π_L	1.0	Years in production > 2.0

Table 4.

λ_p = (0.08*0.88 + 0.068*2.0)10*1.0 = 2.064/10^6 hours

MTTF = 1/ λ_p = 484 496.12 hours = 55.31 years

(v) 16-Bit EDO DRAM chip.

MOS Memory Device $\lambda_p = (C_1\pi_T + C_2\pi_E + \lambda_{cyc})\pi_Q \pi_L$

Parameter	Value	Justification
C_1	0.01	DRAM, Memory size > 256K
π_T	5.0	Memories , T_J < 85 ^{0} C (max operating temperature)
C_2	0.019	SMT, 40 functional pins, Non hermetic
π_E	2.0	Ground fixed environment
λ_{cyc}	0	Non EEPROM device
π_Q	10	Commercial
π_L	1.0	Years in production > 2.0

Table 5.

λ_p = (0.01*5.0 + 0.019*2.0 + 0)10*1.0 = 0.88/10^6 hours

MTTF = 1/ λ_p = 1 136 363.63 hours = 129.72 years

Summary and Conclusions

Component	Description	λ_p / 10^6 hours	MTTF years
U14	LDO voltage regulator (REG103-33)	1.45	78.73
R1*	Rabbit 3000 Microprocessor	7.64	14.94
U16	IR Decoder	0.24	467.84
U10	EPSON Graphics Controller	2.06	55.31
U9	EDO-DRAM	0.88	129.72

Table 6. Component failure rate summary (R1* Only rabbit headers are on schematic)

From the above table it can be seen that among the 5 components analyzed, the Rabbit Microprocessor is the most likely to fail by a large margin. Given that all calculations were made using a maximum operating temperature of 85^0 C as compared to the standard 25^0 C these error rates are higher than what would occur during normal operation of the circuit. It is still valuable however to reduce error rates as much as possible and this could be achieved by adding a heat sink to both the Rabbit and the EPSON extending the theoretical lifetime of the digital picture box.

FMECA (Failure, Mode, Effects and Criticality Analysis)

In conducting the FMEC Analysis, the DPB schematic is divided into its major functional blocks:

Blocks	Category	Components
A	Power Supply	9V Wall wart, Voltage regulators
B	User Interface	Push buttons, IR Decoder and Receiver
C	Physical connectors	VGA Connector, RJ-45 (on core module)
D	Graphics	EPSON, DRAM, PLDs , Crystal Oscillator
E	Microcontroller	Rabbit 3000, Reset controller

See attached worksheet for detailed analysis of all possible failure conditions for each block, the resulting effects on other parts of the design and the level of criticality for each type of failure.

There are two basic levels of criticality as pertains to this project:

LOW - meaning the overall output of the design will not be impacted and a display is still visible on the display device.

HIGH - meaning the output will be affected and the design not function as expected. Specifically a distorted image or no image at all present on the display device. For LOW criticality failures a rate of $\lambda < 10^{-4}$ will be accepted and for HIGH criticality failures a rate of $\lambda < 10^{-9}$ errors per hour of operation.

References

[1] "Designing for Reliability, Maintainability and Safety – Parts 1,2 and 3", Circuit Cellar, December 2000, January 2001, April 2001.

[2] MIL-HDBK-217F Reliability Prediction of Electronic Equipment

http://shay.ecn.purdue.edu/~dsml/ece477/Homework/Spring2004/Mil-Hdbk-217F.pdf

[3] Low-Drop Out Voltage Regulators

3.3 V : http://focus.ti.com/lit/ds/symlink.reg103-33.pdf

5 V: http://focus.ti.com/lit/ds/symlink.reg103-5.pdf

[4] Rabbit 3000 Core Module

http://www.rabbitsemiconductor.com/products/rcm3000/index.shtml

[5] IR Decoder

http://shay.ecn.purdue.edu/~477grp12/datasheets/rentron_ir_decoder.pdf

[6] EPSON Graphics Controller

http://shay.ecn.purdue.edu/~477grp12/datasheets/epson_manual.pdf

[7] EDO-DRAM

http://www.issi.com/pdf/41xx16256.pdf

[8] Crystal Oscillator

http://www.eea.epson.com/go/Prod_Admin.Categories/EEA/QD/Crystal_Oscillators/all_oscillators/go/resources/TestC2/SG8002DB

Appendix H: FMECA Worksheet

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
Block A: Power Supply						
A1	Vcc = 0V	Failure of J6 or failure of U13, U14, U15 (Any component in Block A fails or an external short)	No power to U10, therefore no image displayed at all.	Observation	HIGH	
A2	Vcc > 5V	Failure of U13, U14, U15	Unpredictable effects	Observation	HIGH	
A3	Vcc out of tolerance	C7, C20, C8	High ripple or Operation at out of spec voltage; Unpredictable	Observation	HIGH	Monitor Wall Wart
Block B: User Interface						
B1	No response to pushbuttons	SW2, SW3, SW4, SW5	No new pictures obtained	Observation	LOW	Limits the users control method to IR remote
B2	IR fluctuating or corrupted	U16, U17	Random pictures displayed for undetermined periods of time	Observation	HIGH	

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
Block B: User Interface						
B3	One of IR decoder outputs (PE0 - 4) stuck at 1.	U16,U17	Infinite cycle through images; Switching on and off continuously	Observation	HIGH	
Block C : Physical Connectors						
C1	All Outputs 0	U10, J8 R39,R40,R41, D5,D6,D7	No pixel data sent out on VGA connector	Observation	HIGH	Replace connector
C2	All Outputs 1	U10, J8 R39,R40,R41, D5,D6,D7	Wrong data on output connector; Unpredictable effects	Observation	HIGH	
C3	Random Outputs	U10, J8 R39,R40,R41, D5,D6,D7	Unpredictable effects	Observation	HIGH	
Block D: Graphics						
D1	Incorrect PLD outputs	U2, U3, U7	Pixel data sent to the wrong addresses, corrupted display	Observation	HIGH	
D2	PLDs Outputs all 0	U2, U3, U7, J5, U13	No addressing information available	Observation	HIGH	Bad Chip

D3	PLDs Outputs all 1	U2, U3, U7	Same Address is sent pixel data and is overwritten each time	Observation	LOW	
Failure No.	**Failure Mode**	**Possible Causes**	**Failure Effects**	**Method of Detection**	**Criticality**	**Remarks**
D4	EPSON all Outputs 0	U10, Q1, J20,U13	No meaningful data buffered in DRAM or sent to VGA output; Unpredictable	Observation	HIGH	User gets incorrect data from PC. Product is not useful. Easily detected.
D5	EPSON all Outputs 1	U10, Q1, J20,U13, C1 – C6, C11 – 13	No meaningful data buffered in DRAM or sent to VGA output; Unpredictable	Observation	HIGH	
D6	Clk always high (1)	U12	EPSON's communication and synchronization with rest of circuit is affected; can't interface easily	Observation	HIGH	
Block E : Microcontroller						
E1	All outputs 0	Failure in µC , U15, J6	NO functionality, interfacing, image transferring, No output at all	Observation	HIGH	Use reset controller
E2	All Outputs 1	Failure in µC	Unpredictable	Observation	HIGH	Reset µC
E3	Random outputs	S/W problem	Unpredictable effects	Observation	HIGH	Use headers to test S/W