Calculation of the Actual Failure Rate of a DSP Board Using the FMEDA

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1. Introduction

IEC 61508 Part 4 [1] defines a dangerous failure as a failure which "has the potential to put the safety-related system in a hazardous or fail-to-function state." The standard also defines a safe failure as a failure which "does not have the potential to put the safety-related system in a hazardous or fail-to-function state." To indicate that a dangerous failure is detectable by an on-line diagnostics, it is classified as dangerous detected or dangerous undetected. Similarly, a safe failure is classified as safe detected or safe undetected.

Most components have multiple failure modes and these failure modes are more or less important depending on how they are used within a particular design. Though a component is part of a safety function, there is a particular failure mode that has no effect on a safety function. This failure mode is called "No Effect". The purpose of some components is to support a human interface display and auxiliary functions that are not part of the circuitry providing the functionality of digital safety systems. This category of components is referred to as "Not a Part" since they are not a part of the implementation of the desired safety function. In this paper, the "Not a Part" failure rates are excluded because they are considered to be not relevant to a safe failure.

This paper presents a method to calculate a DSP (Digital Signal Processor) board failure rate and failure mode data using an FMEDA (Failure Modes Effects and Diagnostic Analysis).

2. FMEDA

An FMEDA [2] is an FMEA extension. The FMEDA added two additional pieces of information to FMEA analysis process. The first piece of information added to an FMEDA is the quantitative data (failure rates and the distribution of failure modes) for all components being analyzed. The second piece of information added to an FMEDA is the ability of a system or subsystem to detect internal failures via automatic on-line diagnostics.

The FMEDA technique considers (1) all the components of a design, (2) the functionality of each component, (3) the failure modes of each component, (4) the impact of each component failure mode on the product functionality, and (5) the ability of any automatic diagnostics to detect the failure. The results of the FMEDA are subsystem/product level failure rates, failure modes, and diagnostic capability (Fig. 1). It is a technique recommended to generate failure rates for each important category (safe detected, safe undetected, dangerous detected, dangerous undetected) in the safety models [3].

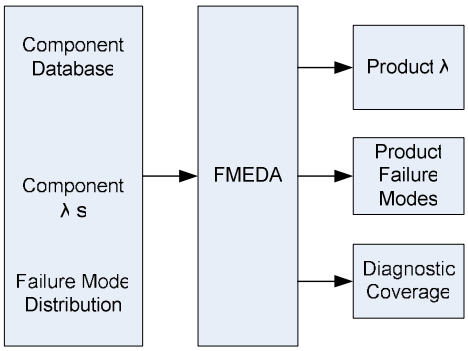

Fig. 1. FMEDA Inputs and Outputs

3. Calculation of Failure Rate for DSP Board

3.1 Component Failure Data Source

The DSP board manufactured by Samchang Enterprise Co., LTD was used for the analysis. This DSP boards are used in the bistable modules and coincidence modules, and so on in digital plant protection system of SMART (System-integrated Modular Advanced ReacTor). The components which consist of DSP board are shown in Table 1. Data sources on component failure rates and failure mode distributions are data from RELEX database and EPRD (Electronic Part Reliability Data) documents available from the Reliability Analysis Center.

Table 1. DSP Component Lists

Components	Quantity	Category	Subcategory
TMS320C40GFL60	1	Integrated Circuit	Microprocessor
EPM7128STC-100-15	1	Integrated Circuit	PAL, PLA
SCV64(CA91C078A-33-EG)	1	Integrated Circuit	VHSIC/VLSI CMOS
DS1232N	1	Integrated Circuit	Linear
74F04	1	Integrated Circuit	Logic, CGA or ASIC
74F08	2	Integrated Circuit	Logic, CGA or ASIC
74F245D	7	Integrated Circuit	Logic, CGA or ASIC
74F175	2	Integrated Circuit	Logic, CGA or ASIC
K6R4016C1D-TC10	4	Integrated Circuit	Memory
M27C256B-12F1	1	Integrated Circuit	Memory
KX0-110 (60Mhz)	1	Miscellaneous	Quartz Crystal
DC015 (32Mhz)	1	Miscellaneous	Quartz Crystal
0.1UF	87	Capacitor	Chip, Ceramic (CDR)
10K	47	Resistor	Film(RL, RLR, RN, RNR, RM)
330	2	Resistor	Film(RL, RLR, RN, RNR, RM)
120	1	Resistor	Film(RL, RLR, RN, RNR, RM)
4.7K	16	Resistor	Film(RL, RLR, RN, RNR, RM)
180	1	Resistor	Film(RL, RLR, RN, RNR, RM)
22K	2	Resistor	Film(RL, RLR, RN, RNR, RM)

3.2 Performing FMEA

The progressive use of deep submicron technologies results in a new population of faults and failure modes [2]. There are four FMEA levels in most electronic systems. They are register/transistor level, component level, board level, and system level. In fact, because a DSP board easily reaches millions of gates and several millions of transistors, a FMEA at a gate level is practically impossible. So, an FMEA is performed at a component level.

Mentioned earlier, information on failure rates and failure mode distributions at a component level is prepared from RELEX database and EPRD documents. For example, Failure modes and failure mode distributions of a specific capacitor are below: ratio of failure mode 'Short' is 0.49, 'Change in Value' is 0.29, and 'Open' is 0.22. The sum of ratios of failure modes is 1.0 (=0.49+0.29+0.22). The result of FMEA is shown in Table 2.

3.3 DSP Board Failure Rates

There are various types of failure rates for the DSP board. They include safe detected failure rate, safe undetected failure rate, dangerous detected failure rate and the dangerous undetected failure rate. As shown in Table 2, there are four types of failure modes ('No Operating', 'Wrong Operating', 'Operating Delay', 'Potential Failure') in the DSP board. The only dangerous undetected failure mode of them is 'Wrong Operating'. That is, the other three failure modes are safe failures or dangerous detected failures. The summation for the failure rates of the dangerous undetected failures in each component forms a DSP board failure rate. The dangerous undetected failure rate is defined in (1). Similarly, the equations of other three failure modes can be derived.

$$\lambda_t = \sum_{i=1}^{m} N_i \lambda_i \sum_{k=1}^{n} R_{ik} \qquad (1)$$

N_i : The number of a specific component *i*

λ_t : The total failure rate of dangerous undetected failures in DSP board

λ_i : The failure rate of component *i*

R_{ik} : The ratio of dangerous undetected failure mode *k* of a component *i*

As shown in Table 3, the total failure rate of the DSP board is $8.85*10^{-6}$. The dangerous undetected failure rate of the DSP board is $5.36*10^{-6}$ and its failure mode distribution is 60.54%. The dangerous detected failure rate is $2.84*10^{-6}$ and its failure mode distribution is 32.05%.

5. Conclusions

All the failure modes of each component of a DSP board were extracted from the RELEX database and EPRD documents. And then an FMEA was performed to identify the types of failure modes of the DSP board. As a result, four failure modes of the DSP board were classified as follows: 'No Operating', 'Wrong Operating', 'Operating Delay', and 'Potential Failure'.

From a view point of system reliability considering on-line diagnostic capability, only the 'Wrong Operating' failure mode of the DSP board directly affects a system failure and its ratio is 60.54%. This result shows that the system reliability can be improved through calculating the actual failure rate. In the near future, a validation based on a fault injection and a fault simulation will be performed to cross check the FMEA results.

Table 2. Component Failure Modes and Effects

Components	Failure Mode	Effect on DSP board
TMS320C40GFL60	Input Open	No Operating
	Output Open	Wrong Operating
	Supply Open	No Operating
	Output Stuck Low	Wrong Operating
	Output Stuck High	Wrong Operating
EPM7128STC-100-15	Output Stuck High	Wrong Operating
	Output Stuck Low	Wrong Operating
	Input Open	No Operating
	Output Open	Wrong Operating
SCV64(CA91C078A-33-EG)	Supply Open	Wrong Operating
	Output Open	Wrong Operating
	Input Open	No Operating
	Supply Open	No Operating
DS1232N	Improper Output	Wrong Operating
74F04	Output Stuck High	Wrong Operating
	Output Stuck Low	No Operating
	Input Open	Wrong Operating
	Output Open	Wrong Operating
K6R4016C1D-TC10	Data Bit Loss	Wrong Operating
	Short	Wrong Operating
	Open	No Operating
	Slow Transfer of Data	Operating Delay
KX0-110 (60Mhz)	No Output	No Operating
	Untunned Frequency	Wrong Operating
	Reduced Power	Potential Failure
0.1UF	Short	No Operating
	Change in Value	Wrong Operating
	Open	No Operating
10K	Open	No Operating
	Parameter Change	Wrong Operating
	Short	Wrong Operating

Table 3. DSP Failure Modes and Distributions

DSP board Failure Mode	Failure rate ($10^{-6}/h$)	Failure mode distribution
No Operating	2.83540005	32.05279 %
Wrong Operating	5.35548782	**60.54114 %**
Operating Delay	0.64892485	7.335774 %
Potential Failure	0.00621850	0.070297 %
Total Sum	8.84603122	100 %

REFERENCES

[1] CEI International Standard IEC 61508 Part 4, 1998-2000

[2] John C. Grebe, William M. Goble, "FMEDA – Accurate Product Failure Metrics", exida, Sellersville, PA 18960 USA, February 2007

[3] Riccardo Mariani, Gabriele Boschi, "A Systematic approach for Failure Modes and Effects Analysis of System-On-Chips", Proceeding of 13th IEEE International On-Line Testing Symposium IOLTS, 2007, Pisa, Italy