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The Economics of Automatic Testing

Chapter 8
Test strategy analysis

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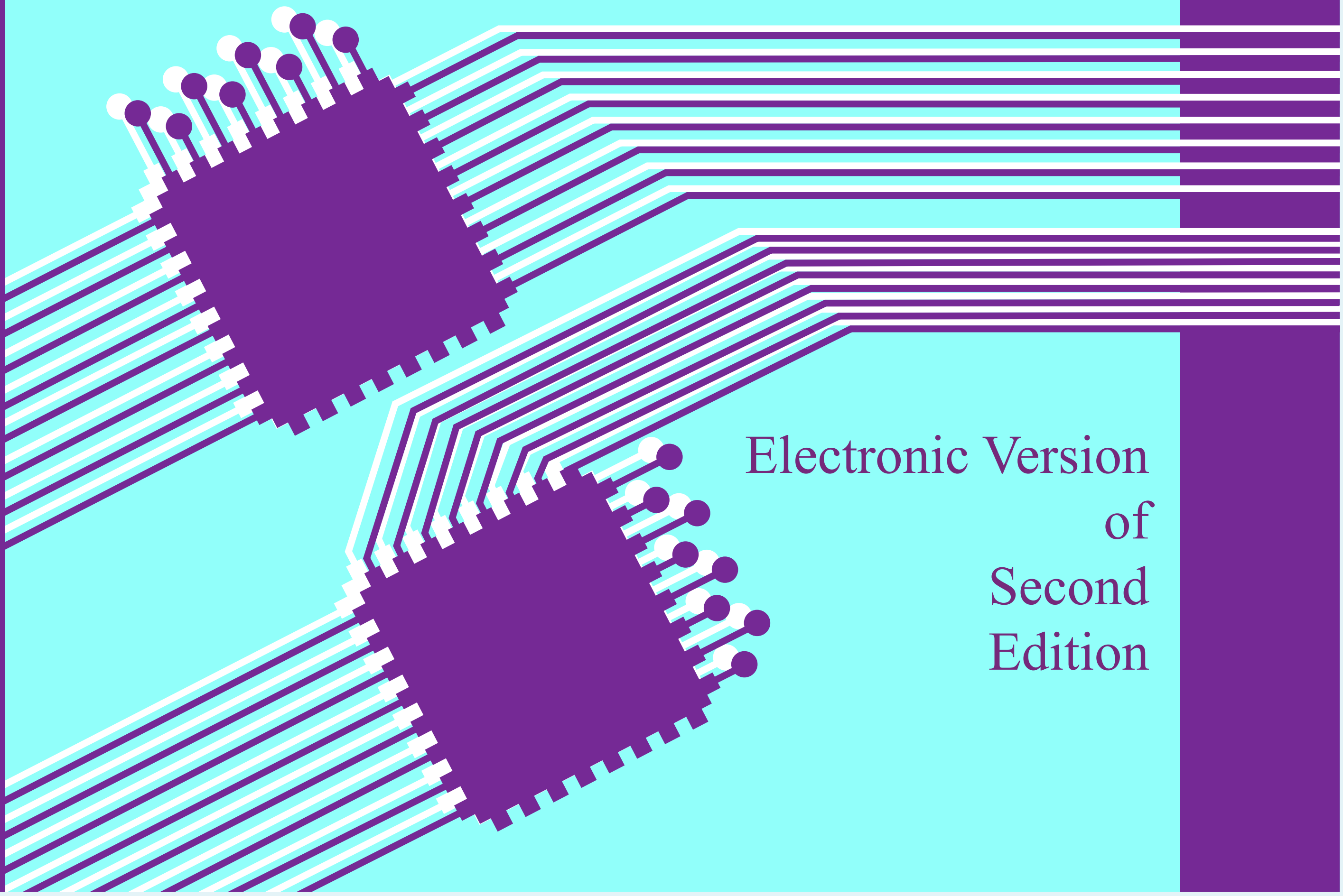

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Test stage 1 | Test stage 2 | Test stage 3

Fault Spectrum	FPB In	Detected	Escapes / FPB In	Detected	Escapes / FPB In	Detected	Escapes
Defect A	0.1	0.08	0.02	0.01	0.01	0.005	0.005
Defect B							
Defect C							
Defect D							

One per strategy

Figure 8.19 The defect detection matrix

	From Manufacturing	Test stage 1	Test stage 2	Test stage 3
FPB In	---	0.86	0.36	0.11
Yield In	---	42%	70%	90%
Detected FPB	---	0.50	0.25	0.07
Apparent Yield	---	6%	78%	93%
Fault coverage	---	58%	69%	64%
Escaping FPB	0.86	0.36	0.11	0.04
Yield Out	42%	70%	90%	96%

One per strategy

Figure 8.20 The testing result of the analysis shown as a 'yield progression'.

The next step is to define the fault coverage performance of the various test stages versus each of the fault types defined in the fault spectrum. This is usually done in the form of a ***'fault coverage matrix'***, as shown in Fig. 8.18. A section of the model is then set up to take the actual defect data from the fault spectrum and apply it to the test strategy to determine how many of each defect type are detected and how many escape, from each of the test stages. This I call the ***'defect detection matrix'*** and an example is shown in Fig. 8.19. The escaping defects from one test stage become the input defects to the next stage. Some of these are detected and some escape to become the input defects to the next stage. This continues until the ***'next test stage'*** becomes the customer. From this it is possible to determine the quality aspects of the strategy and summarize them in some manner. An example of this is shown in Fig. 8.20. This I call a ***'yield progression'*** because it shows how the yield progresses throughout the test process.

The number of defects detected at a test stage will determine the number of diagnostic operations and repair operations at that stage. From this and the input data on test, diagnosis, and repair times, as well as the labour costs of the operators, it is possible to calculate the costs for the various test stages. The TTT parameter discussed earlier also determines the throughput at each test stage. The throughput figure, the total available time, and the lost time due to program preparation and other factors will determine the capacity. This and a knowledge of the production volume will enable the model to determine how many test stages of each type, and how many repair stations, will be required. A calculation of the available capacity at each stage can also be performed.

Getting the formulae right first time, every time

In the first edition of this book, which appeared in 1982, I highlighted the fact that an inaccurate formula was being used in a number of test strategy models. Many of these were being published by ATE vendors in the form of application notes or manual worksheets. In some of these the crime was amplified by using the same formula for both functional and in-circuit test stages. Unfortunately the formula is still appearing in various forms, all of which can be reduced to the most common form, which is shown below…

$$TTT = T_t(2 - Y) + T_d(1 - Y)$$

There are two terms in the formula. One defines the time spent testing defect-free UUTs and the other defines the time spent diagnosing defects. They are both wrong for both the ICT and the FNT cases. The multiplier for the test time term (2 – Y) implies that some boards are tested twice with a passing result. This does not happen in practice. Once the board passes the test at a given stage it will migrate on to the next test stage. Each time the board visits the test stage with a failing result it will get a diagnosis. Once all of the defects have been repaired it will pass the test and then migrate on. There is no reason to test the board twice. For the diagnosis term the (1-Y) multiplier indicates that the proportion of failing boards will receive one diagnosis action. This is not correct for functional testing, which will find only one fault at a time, and it is not correct for in-circuit testing because it does not model the fact that boards with shorts will not get a full test on their first visit to the tester. A simple example will illustrate the errors…

Example

Assume a yield of 70 per cent which equates to 0.36 faults per board, of which 0.2 are shorts and 0.16 are other defects. For simplicity we will assume that the testers have a 100 per cent fault coverage. The following times have been determined…

For the functional tester…

$$T_t = 35 \text{ s} \qquad T_d = 360 \text{ s}$$

For the in-circuit tester…

$$T_t = 60 \qquad T_{ds} = 32 \qquad T_{do} = 65 \text{ s}$$

Taking the functional case first, the old formula produces the following result…

$$TTT = 35(1.3) + 360(0.3) = 153.5 \text{ s}$$ **Incorrect**

The formula defined earlier gives…

$$TTT = Tt + Td(FPB) = 35 + 360(0.36) = 164 \text{ s}$$ **Correct**

These errors for the functional case will diminish as the yield increases because, as Y tends to unity, (2 – Y) will tend to unity and (1 – Y) will tend to zero. For the in-circuit case the old formula gives…

$$TTT = 60(1.3) + 65(0.3) = 97.5 \text{ s}$$ **Incorrect**

The formula defined earlier gives…

$$TTT = T_t + T_{ds}(1 - Y_s) + T_{do}(l - Y_o)$$

where…

$$Y_s = (e^{-0.2}) = 0.82 \qquad Y_o = (e^{-0.16}) = 0.85$$

Therefore…

$$TTT = 60 + 32(0.18) + 65(0.15) = 75.51 \text{ s}$$ **Correct**

The incorrect formula was partly correct in the very early days of ATE when the testers had no diagnostics. At that time the testing operation usually involved two people. A low-skilled operator would perform a ***go/no-go test*** sorting the good boards from the bad boards. Then a skilled technician would diagnose the bad boards with a logic probe, a logic diagram and skill. The defective boards therefore had two tests. They had a test when the low-skilled operator did the sorting and they had a second test after being repaired—the so-called re-test. This makes the (2 – Y) multiplier correct for this type of operation. The (1– Y) multiplier in the diagnosis time term was still wrong because functional testers still only tested for one fault at a time. Therefore if you had an average of one fault per board (pretty good at that time) you would diagnose an average of one fault per board. The yield for the 1 FPB case is 0.37 so (1 – Y) would be 0.63. The formula would therefore understate the workload considerably. The 63 per cent of the boards that were defective would contain an average of 1.59 defects on each board, all of which would require a diagnostic action.

Using flow diagrams to check formula accuracy

Flow diagrams of the type shown in Figs 4.10, 4.11b and 4.12b can be very useful for testing the formulae used in a model. It can be a tedious process but it is worth getting right. An example is shown in Fig. 8.21 where a batch of 1000 boards with a yield of 70.5 per cent is tested. The upper part of the diagram shows how the defect distribution is calculated as per the method defined in Chapter 4. On the first visit to the tester 705 boards pass the test because they are defect-free. A further 25 also pass, even though they contain defects, due to the 85 per cent fault coverage for faults in the 'other' category. Therefore 270 boards fail the test, 139 failing the shorts test (100 per cent fault coverage for shorts) and 131 failing for other reasons. These are repaired and visit the tester for a second time. Now the 25 boards that contained both a short and some other defect fail the test and the remainder of the repaired boards pass. The 25 failing boards go to the repair station and then on to the tester for their third visit before passing and migrating on to the next stage. The number of escaping defects in the 'other' category was determined as follows…

0.20 other defects per board and an 85 per cent fault cover.

Therefore 0.17 detected faults per board.

Y_o is therefore $(e^{-0.17}) = 0.844$

$1 - Y$ is therefore 0.156

Thus 156 boards out of the batch will have 'other' defects detected but 25 of these will be on boards with a short and therefore will not be seen on the first visit to the tester. Therefore only 131 will be detected on the first visit. The flow diagram shows what will happen in practice and the numbers agree with the $(1 - Y)$ figures for the two defect types.

This example assumes that all of the diagnoses are correct, that the repair actions will be performed correctly and that no nonexistent defects will be 'detected' by the tester. In practice all of these problems can occur. The four possible outcomes of a test defined in Fig. 4.2 need to be accounted for in some manner.

This is most easily done by applying a correction factor to the number of diagnoses and the number of repair actions. The number of passing tests is not affected. This correction factor is known as the ***'loop-number multiplier'*** or simply the ***'loop number'***, since it is applied to the diagnosis/repair loop of the test process. The loop number simply adds a percentage to account for the number of unnecessary diagnosis and repair actions. For most cases this is likely to be in the 10 to 20 per cent range so the loop number will be between 1.1 and 1.2. This gives the basic functional formula…

$$TTT = Tt + Td(FPB)LN$$

Where LN is the loop number (also sometimes abbreviated to LP). The basic in-circuit