# Controlling Test Plans by Information-Content-Based Redundancy Analysis

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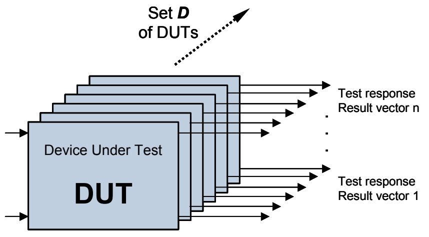
## How the theory works

### Fundamental Idea

The devices under test are seen as a black-box that provides responses (test results) to a given stimulus (test). Redundant tests are identified by calculating the information content of their test responses in relation to the rest of the test-plan. **The goal is to remove redundant tests from the test plan thereby saving test cost.**



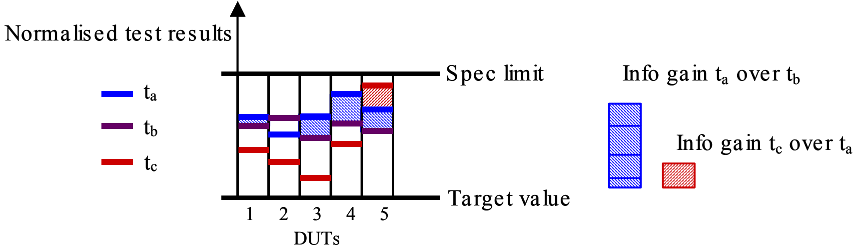
Generally, redundancy in test-plans means that test *t* can be considered for omission because there exists a set of tests $S(t)=\{t_1,t_2,...\}$ such that whenever *t* reports a failure, at least one test in $S(t)$ reports a failure, too. For high-yield products, the amount of data from faulty devices is very low, and the analysis must focus on the data collected from the good parts.

### The Definition of Information Gain

The information gain on a set *D* of devices under test (DUTs) of a test $t_x$ producing the results $t_x(1),t_x(2),\ldots t_x(|D|)$ over a test $t_y$ producing the results $t_y(1),t_y(2),\ldots t_y(|D|)$ is defined as:

$$\Delta I(t_x,t_y)=\sum_{d\in D}\max(t_x'(d)-t_y'(d),0)$$

I.e. does $t_x$ for any of the tested devices produce more critical results (closer to test limits) than $t_y$., and if yes, how much. Graphically this can be illustrated as follows.



### Ranking – a Virtual Test Plan

Ranking the tests in the algorithm works as follows:

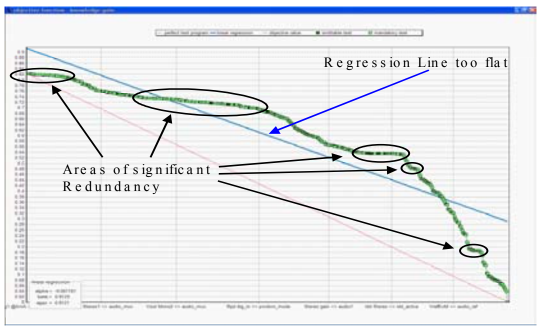
1. Choose the test with the smallest individual information content as the first one.
2. When *K* tests $t_1,t_2,..t_K$ have already been ranked, choose the next ranking test $t_z$ such that

$$z=\operatorname{argmin}_{x\in\{1..k\}}\Delta I(t_x,\{t_1,t_2,...t_k\})$$

3. Continue with step 2 until all tests have been ranked.

This approach ensures that the *k*-ranked test is the one with the smallest information gain over the set of tests ranked before *k*.

This ranking can be visualised by plotting how the ranked tests individually subtract from the total sum of information content of all tests.



### Redundancy

We define a test to be redundant, when its added information gain is less than a given threshold. Some additional properties of the test – like its $C_{pk}$ or correlation values etc. – can be considered too in a rule-based mechanism to make the final classification whether the test is to be considered redundant or not.

Note that this notion of redundancy is purely information-theoretic. Redundancy does not define "omittability". Therefore a test engineer with profound knowledge of the actual test plan must eventually approve the suggested redundant tests for omission.

## How it works in practice

### Evaluation Vehicle and Result of Redundancy Analysis

Power management and audio chips as found in mobile phones integrate most of the analog base band functionality. This usually comprises a charger, various linear and switching regulators, the audio functions like voice and HiFi CODECs and microphone and speaker amplifiers.

The test plan for such devices is made up of around 500 parametric tests. The original test plan of the chip used for the analysis was made up of 358 parametric tests.

Two studies were carried out. An initial analysis of took 13,000 devices into account; in a second step 180,000 devices were used.Not surprisingly the identified redundancy diminished the more devices were included to the analysis as, for instance, the number of defects increases in general.

| Algorithm results of test data | |
|---|---|
| | Redundancy Potential |
| 13k study | 27% |
| 180k study | 17% |

### Process of Test Classification

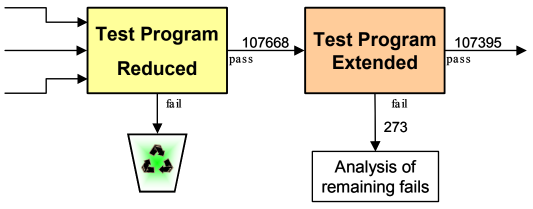
In short the process can be described as follows:

1. The method points to test(s) in a test group to be redundant.
2. Analyze whole group of tests
   a. Is test defect oriented (e.g. leakage tests)? If yes: keep.
   b. Identify root cause of redundancy
   c. Choose most appropriate test(s) to be omitted based on engineering insight on topology and test program flow.

| Results of test classifications | |
|---|---|
| Total number of tests | 358 |
| Tests classified redundant | 158 |
| Tests classified mandatory | 200 |
| Redundancy test time related | 31 % |
| **Test time reduction incl. manual improvements** | **50 %** |

### Qualification and Introduction of reduced Test Plan

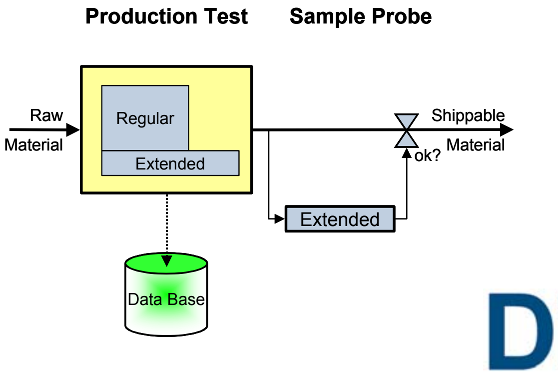
Despite a proper analysis the reduced test plan needs to be qualified for obtaining acceptance. For assuring a quality risk of below 10 ppm 100,000 pass devices of the reduced test plan from three lots were subjected to the extended (original) program. Most of the remaining fails turned out to be marginal, two general test weaknesses were found, but in fact 2 tests were found to be wrongly classified redundant.



The second step to secure acceptance of the method is to handle both test plans - the regular (reduced) and the extended (original) one - in one test program. This enables two scenarios. First the extended test plan is carried out every 50 or 100 devices. This still produces statistical data on the "removed" tests for monitoring and analysis. Secondly the extended test plan is also used for testing the sample probe drawn from each lot.

The described procedures were established at Dialog Semiconductor together with the release of the reduced test program. Results so far are very convincing:

| Production results of reduced test program | |
|---|---|
| Total number tested devices according to the reduced test plan | 3.7 M |
| Sample probe failing due to omitted test | 0 |
| Field returns due to omitted test | 0 |



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