Computer Aided Fault Diagnosis in Analog Circuit

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Abstract- In this paper, a fault diagnosis system is presented for analog circuit testing based on the Simulation before Test approach. The circuit under test is subjected to a frequency response analysis, from which parameters are extracted such that they give unique values for every configuration of the circuit. This uniqueness makes them ideally suitable to characterize the state of the circuit. Software implementation has been done using MATLAB. Due to manufacturing tolerances, component failures, temperature drifts and ageing, the actual values of network parameters can be different from the nominal ones and these variations may have significant effect on the circuit performances. To overcome this problem testing of the components of the circuit has been done before implementation. This work consists of analyzing the Butterworth fourth order low pass filter at different test frequencies of 89, 142 and 272 radians/second using Sheshu Waxman algorithm. to identify the fault. Further the filter parameters CDF, PDF, Normalized function are observed to analyze filter behavior using Monte Carlo Algorithm. The efficient testing and an initial fault dictionary are also developed using MATLAB software.

Index Terms- Analog Circuit, Fault, Fault Dictionary, Monte Carlo, Seshu Waxman.

I. Introduction

Analog devices widely exist in military, communication, automatic control, instrumentation, mixed signal circuit, and chip system. The essence of the objective world determines the universality and irreplaceability of the signal analog circuit. With the development of large-scale integrated circuits, analog circuit complexity and the intensity increasing, the reliability requirements of the analog circuit are also stricter [1]. Therefore, analog circuit testing and fault diagnosis problem cannot be avoided, thus it is important to carry out research on related theories and methods.

With the development of the electronics industry, electronic equipment becomes more and more complex, the analog devices and circuit of it are indispensable. The theoretical analysis and practical application indicates that analog circuits of these devices are more prone to fault than digital circuits [2]. For this kind of equipment maintenance is very complex, but it is indispensable to guarantee the normal operation of the system [3]. In addition, with the development of VLSI development and the increasing complexity of electronic devices, artificial traditional fault diagnosis methods are unable to meet the requirements, which forced the researchers' further exploration about the testing of new theory and method, in order to adapt to the social demand for the development of new test device.

There exist a number of various techniques for analog circuit testing, convenient for testing specific types of circuits. Since no universal method exists .further improvements are possible [4]. The presented method in this paper includes proposal for fault diagnosis using Monte Carlo and Seshu Waxman algorithm approach and reason for why sehu and Waxman approach comes out to be more efficient.

The characteristics of an analog circuit can be described in several domains, e.g. DC, time and frequency. In the time domain the circuit description is based on a set of differential equations, whose order depends on the number of independent energy storage components in the circuit. The equations are solved by numerical integration and the solution can be very computationally complex, potentially unstable or non convergent for high order equations [5]. The robustness of the whole process of the multi-frequency parametric fault diagnosis with respect to manufacturing tolerances, faults of circuit components and measurement errors can be modeled using statistical techniques [6]. The procedure is based on the Monte-Carlo method. The principle of network parameter generation in accordance with statistical distribution functions is based on the inverse sampling theorem.

Authors of [7] described that the fault location technique for testing analog filters using a fault dictionary. The single hard faults of the filter passive elements can be located and identified. To enable the efficient testing an initial fault dictionary is optimized in order to get the minimal size of the dictionary with maximum number of uniquely recognized faults. After a simulation, the procedure tests the circuit and locates the failed element using adequate fault isolation criterion.

Authors of [8] proposed that at the time of testing, the magnitude of the failed analog filter is measured in the same test frequencies as in the dictionary. The fault isolation criterion is applied to the measured magnitudes and to the simulated magnitudes from the dictionary in order to locate the fault. One fault isolation criterion has been proposed by authors [8] is called "the nearest neighbor rule".

In the present work of this paper first of all fault analysis technique is implemented using Seshu Waxman algorithm and then the behavior of fourth order Butterworth low pass filter is examined using Monte Carlo algorithm. The results of two algorithms are compared and it is found that the Monte Carlo algorithm is giving better results than Seshu Waxman results, which can be used for wide range of frequencies.

In this paper script programming and graphics concept of MATLAB is used. Script language involves the command window as an interactive space for mathematical or executive text. MATLAB is a multi-paradigm numeric computing environment and 4^{th} generation programming language. It allows matrix manipulation, plotting of function and data, implementation of algorithm. The MATLAB applications are increasing day by day.

II. FAULT DIAGNOSIS METHODOLOGY

The complete system is developed using simulation and coding techniques, mentioned below..

Step 1 : The circuit is designed using the simulation technique.

Step 2 : The circuit is designed using coding. Coding for the circuit performance of Fourth order Butterworth filter is done using two different algorithms Seshu Waxman algorithm and Monte Carlo algorithms which are explained below.

Seshu Waxman algorithm -

1. Coding to obtain the Bode plot for the normalized condition.
2. Identification of fault ie. Checking for tolerance bound.
3. Applying open and short circuit condition (ie. +50% in case of open circuit and -50% for short circuit)
4. Obtaining the nominal and faulty characteristics.
5. Obtained the error characteristic.

Monte Carlo algorithm -

6. Probability function is obtained using equation No. 1.

$$(\ \tilde{p}rnd) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left\{ \frac{-(\ \tilde{p}rnd - \mu)^2}{2\sigma^2} \right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where $f(\tilde{p}rnd)$ *is the probability density function,* $\tilde{p}rnd$ *is the actual value of the* normalized network parameter, μ *and* σ *are the distribution parameters, i.e. mean* and standard deviation.

$\tilde{p}rnd = F{-1}(r)$

7. Cumulative distribution function (CDF) plot is obtained using equation No. 2.
8.

$$r = 1/\ 2[-1/\tau\ (\ 1/\tilde{p}rnd - 1) + 1] = F(\ \tilde{p}rnd) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

9. Probability Distribution Function (PDF) plot is obtained using equation No. 3.

$$(\ \tilde{p}rnd) = F'(\ \tilde{p}rnd) = 1/\ 2\ \tau\ \tilde{p}^2rnd \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3)$$

III. IMPLEMENTATION AND RESULT

The fourth order Butterworth low pass filter is designed using simulation as shown in figure 1.-

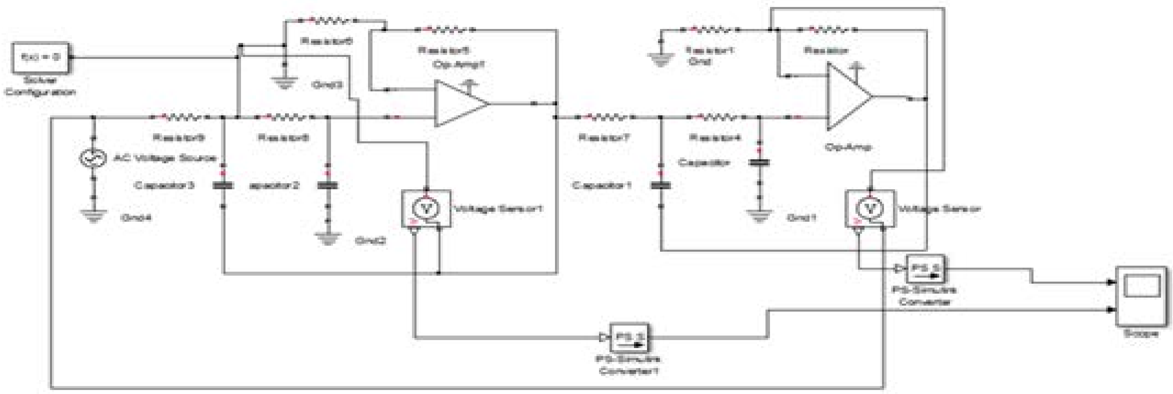

Figure .1: Butterworth fourth order low pass filter simulated circuit

Using Seshu Waxman algorithm Normalized characteristic is shown in figure 2, Fault characteristic is shown in figure 3 and Error characteristic is shown in figure 4. The magnitude values in dBs at three different test frequencies are shown in table 1. M is the standard magnitude corresponding to 3 test frequencies 89, 142 and 272 radians / second. M1 to M14 are magnitudes corresponding to 3 test frequencies when values of resistances of filter are varied in a range of values.

TABLE 1 Magnitude Table

M	12.3635	9.3957	2.2664
M1	11.1269	7.3658	-0.6608
M2	13.3198	11.3170	6.0058
M3	10.5955	7.6278	0.4985
M4	16.1840	13.2163	6.0870
M5	6.8553	3.8876	-3.2417

M6	9.5553	6.5876	-0.5417
M7	13.3198	11.3170	6.0058
M8	11.1269	7.3658	-0.6608
M9	13.3198	11.3170	6.0058
M10	11.1269	7.3658	-0.6608
M11	32.5229	29.5551	22.4258
M12	23.6316	20.6638	13.5345
M13	4.9643	1.9966	-5.1327
M14	6.1136	3.1459	-3.9834

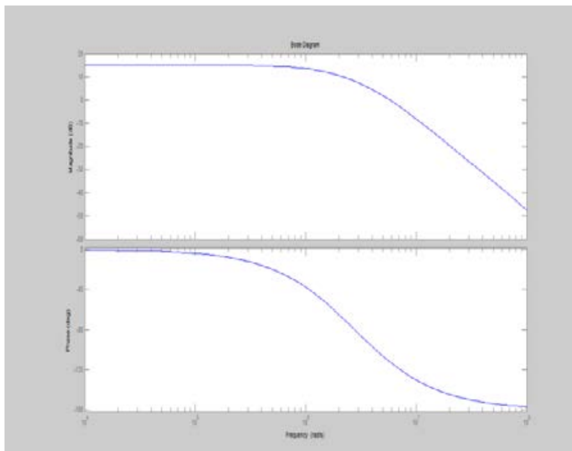

Figure. 2 Normalized Characteristic

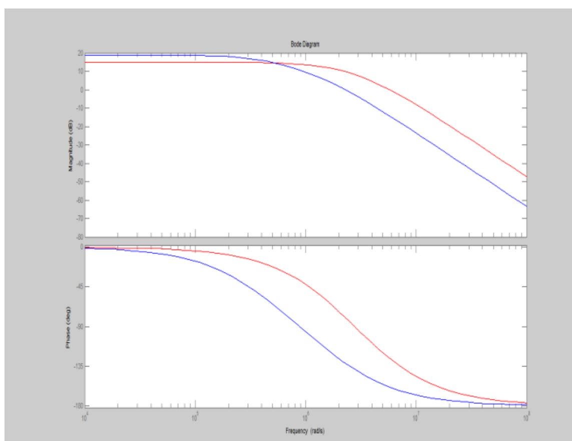

Figure. 3
Fault characteristic

Output

H3 = 8.751

1.304e-12 s^2 + 2.884e-06 s + 1

Continuous-time transfer function.

Fig 5.1
Nominal Bode plot (4^{th} order butterworth filter
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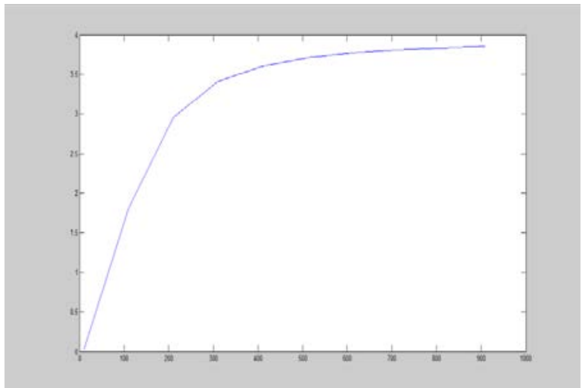

Figure. 4
Error Characteristic

At the time of testing the magnitude of the failed analog circuit is measured in the same test frequency as in dictionary, shown in TABLE 2. The table contains fault values for 3 test frequencies for the components (resistors and capacitors, different from standard values) used in 4th order Butterworth Filter considered for the present work. R_{1A+} means resistance value above the standard value (R_{1A}) and R_{1A-} means, resistance value below the standard value (R_{1A}).

TABLE 2 Fault Dictionary Table

Test Frequency		**89(rad/sec)**	**142(rad/sec)**	**272(rad/sec)**
Number	Fault	Magnitude (db)		
0	R_{1A+}	1.094E+01	7.09E+00	-1.01E+00
1	R_{1A-}	1.31E+01	1.13E+01	6.00E+00
2	R_{2A+}	1.094E+01	7.09E+00	-1.01E+00
3	R_{2A-}	1.31E+01	1.13E+01	6.00E+00
4	R_{3A+}	10.59E+00	7.62E+00	4.98E-01
5	R_{3A-}	1.61E+01	13.21E+00	6.08E+00
6	R_{4A+}	1.448E+01	11.51E+00	4.38E+00
7	R_{4A-}	9.55E+00	6.58E+00	-0.57E+00
8	R_{1B+}	1.094E+01	7.09E+00	-1.01E+00
9	R_{1B-}	1.31E+01	1.13E+00	6.00E+00
10	R_{2B+}	1.094E+01	7.09E+00	-1.01E+00
11	R_{2B-}	1.31E+01	1.13E+00	6.00E+00
12	R_{3B+}	2.36E+01	2.06E+01	1.35E+01
13	R_{3B-}	3.25E+01	2.95E+01	2.24E+01
14	R_{4B+}	6.11E+01	3.145E+00	-3.98E+00
15	R_{4B-}	4.96E+00	1.99E+00	-5.12E+00
16	C_{1A+}	1.11E+00	7.36E+00	-0.66E+01
17	C_{1A-}	13.31E+00	1.13E+01	0.6E+01
18	C_{2A+}	1.11E+00	7.36E+00	-0.66E+01
19	C_{2A-}	13.31E+00	1.13E+01	0.6E+01
20	C_{1B+}	11.12E+00	7.36E+00	-6.6E+01
21	C_{1B-}	13.31E+00	11.31E+00	6.01E-00
22	C_{2B+}	11.12E+00	7.36E+00	6.6E-01
23	C_{2B-}	13.31E+00	11.31E+00	6.01E+00

Using Monte Carlo algorithm CDF, PDF and probability function are plotted for the analysis of different components. The instance at which the density is high shows the high probability for fault condition. Nominal Bode plot is shown in figure 5, analysis of R1A is shown in figure 6, analysis of R2A is shown in figure 7, analysis of R3A is shown in figure 8, analysis of R4A is shown in figure 9 and analysis of C1A/C2A is shown in figure 10.

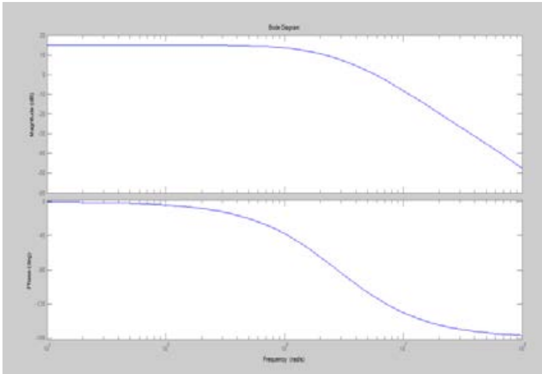

Figure. 5
Nominal Bode plot

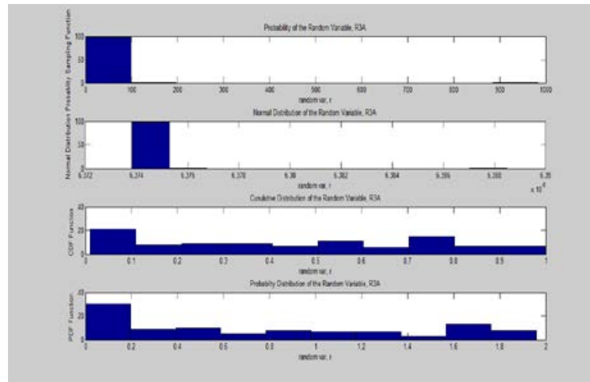

Figure. 6
Analysis of $R1_A$

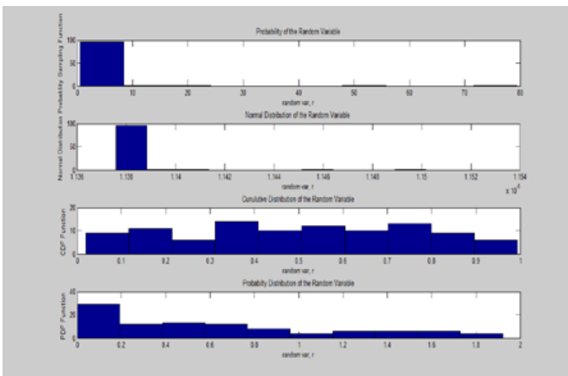

Figure. 7
Analysis for $R2_A$

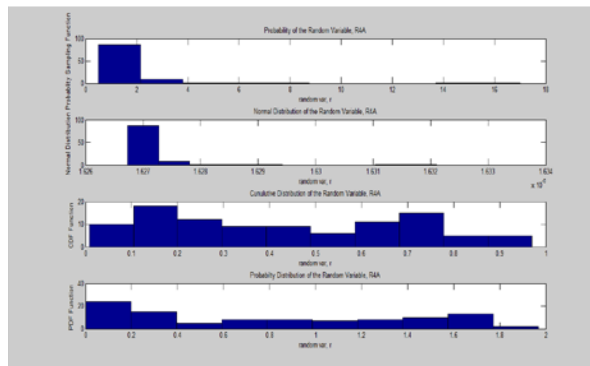

Figure. 8
Analysis for $R3_A$

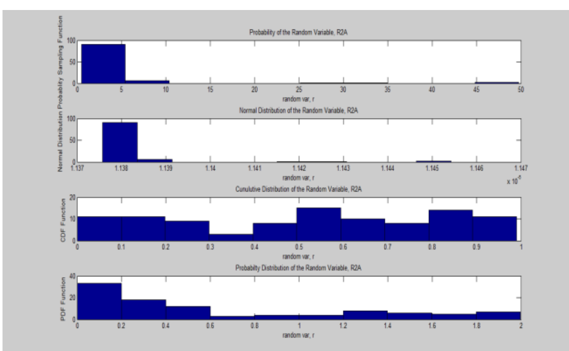

Figure. 9
Analysis for $R4_A$

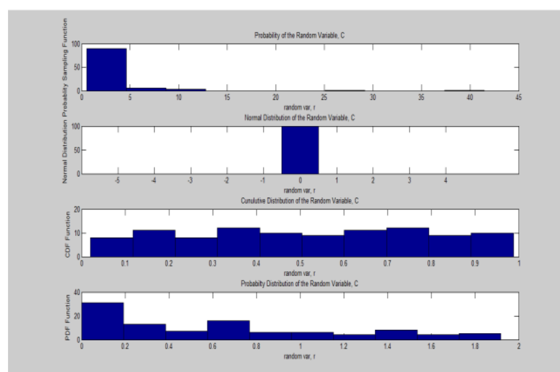

Figure. 10
Analysis for $C1_A$ /$C2_A$

IV. CONCLUSION

In this paper, fault dictionary technique are used which is a completely based on quantitative calculations. Fault dictionaries are very simple to apply, but they have certain limitation that need to be solved. One of the earliest techniques for fault definition is the seshu and Waxmann approach which varies the element +50% from its nominal. Seshu and Waxmann method is used for frequency selection process.

Dealing with statistical modeling of fault diagnosis, the whole multi frequency parametric fault was implemented in the MATLAB program. The random process is simulated by the Monte Carlo method and the results are statistically evaluated. For generating random network parameters, the inverse sampling theorem can be used. The method can generate random data sets in accordance with their cumulative distribution functions and probability distribution function.

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