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Life Analysis of 0.22µf Electrolytic Capacitor Using Artificial Neural Networks

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Abstract
Semiconductor industry is rising on an accelerating pace. The reliability and speed become a challenging issue, while providing the component at low cost and small size. Almost all the electronic equipment and gadgets use the passive components such as capacitor, resistor, inductor etc., which has the reliability issue. The chances of failure increase as the thousands of components are integrated on a single chip. The residual lifetime of an electrolytic capacitor is targeted in this research article. using artificial neural network, the future failure can be predicted. Accuracy of the artificial neural network,

Keywords– ANN, Reliability, Residual life, Artificial Intelligence (AI), Electrolytic Capacitor.

1. Introduction

In the modern technological age, the components are integrated in series or parallel connection to reduce the problem of size. As more and more components are aligned on a small space, there is more chances of failure[1]. If in the series or parallel connection, one component fails, it may accelerate failure chain, results in the system failure. To prevent the system failure, predictive analysis of the electronic components is necessary. During manufacturing, the electronic components are tested under various electrical parameters and environmental conditions, after passing the quality test, data sheet is created which has the minimum and maximum operating levels of the electronic components[2].
When the electronic component is launched in the real market, the level of environmental conditions and electrical parameters vary due to other affecting elements. This results in the lifetime variation, as compared to the life claimed by the datasheet. If the failure can be predicted well before its actual existence, it can save the repairing cost and market reputation of the manufacturer[3]. This research article targets the electrolytic capacitor's behavior under extreme environmental conditions and electrical parameters such as humidity, voltage, current, vibration and shock. The residual life is predicted using statistical technique such as regression analysis, intelligence prognostics methods such as artificial neural network, fuzzy inference system, adaptive neuro-fuzzy inference system[4]. A comparison is made in between the results of all the techniques to declare the most accurate system and technique.

2. Electrolytic Capacitor

The structure of an electrolytic capacitor structure is shown in Figure (1). The electrolytic capacitor consists of a anode foil covered by a dielectric layer, a cathode and the electrolyte liquid. Temperature rise decreases the viscosity of dielectric substrate and decrease the equivalent series resistance (ESR)[5].

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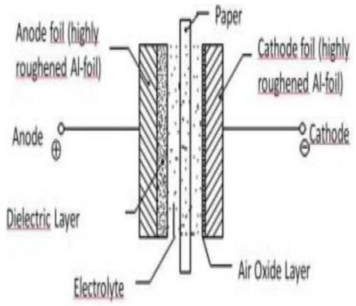

Fig.1 Construction of Aluminium Electrolytic Capacitor

The electrolyte's boiling point restricts the self-heating caused by the internal oscillating current and applied temperature[6]. The self-heating increase electrolyte losses and degrades the lifetime of electrolytic capacitors. The frequent approaches of failure for electrolytic capacitors are shown in figure. 2 and the analogy between main causes and failure approaches of capacitor is identified[7].

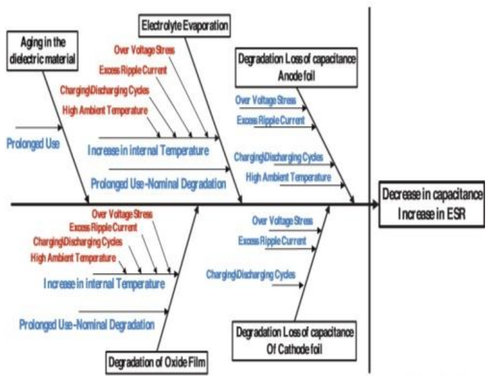

Fig.2 Failure approaches in aluminum electrolytic capacitor

The ESR of electrolytic capacitor is defined as sum of resistances due to aluminum oxide, electrodes and capacitance, so the life of electrolytic capacitor steadily reckons on applied temperature and ESR. As per specification under normal working mode, capacitors are not able to work properly in the circuit when its ESR is more than initial ESR value due to this capacitance declines to 20% of the initial value[7].

3. Research Methodology

The life of electrolytic capacitor is estimated by the formula given below:

$$Lp = Lx*2y \qquad (1)$$

Where, $y = (Tm-Ta-\Delta T)/10$

$\Delta T = I\hat{}2*ESR/(B*A)$

Lp = Predicted life of electrolytic capacitor

Lx = Load life of electrolytic capacitor

Tm = Maximum temperature rating

Ta = Ambient temperature

ΔT = Temperature rise due to ripple current
I = Ripple current applied to capacitor
B = Thermal constant of capacitor
A = Surface area of capacitor

For Electrolytic capacitor 224SML050MD4, If I = 2mA, Tm = 85°C, Ta = 4, applied voltage = 14v, Load Life = 2000 hours then, the predicted life, Lp = 250378 hours. In the same way, a life is predicted for all the possible inputs. After that, to determine the Remaining useful life the steps to be followed according to the work methodology are:

1. Firstly, several factors to be selected for estimation
2. Then the factors assigned to columns
3. Select the levels for process variable
4. Artificial Neural Networks for life estimation

3.1 Selection of factors for estimation

Residual life will be estimated by selecting the independent variable that affects the performance of electrolytic capacitor[8]. Specifications of electrolytic capacitor 224SML050MD4 used for the experiment are given in Table 1. In this voltage, Temperature, Ripple current, Frequency and Dissipation factor are the selected factors for progress of a mathematical model[9].

Table 1. Specifications of Electrolytic capacitor 224SML050MD4

Parameters	**Value**
Load Life	2000 Hours
Rated Voltage	50V
D*L	4*5.4
Capacitance	0.22µF

3.2 Selection of Levels for Process Variables

For life estimation model, five aspects are elected. The elected parameters are used for the experiment with their limits, units and notations are inclined in Table 2.

Table 2 Variables and their levels

Parameter	**Unit**	**Notion**	**Limit A**	**Limit B**	**Limit C**
Voltage	Volts	V	1	26	52
Temperature	°C	T	2	43	85

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Ripple Current	µA	RC	0.2	9	17
Frequency	Hz	F	50	120	400

3.3 Actual form of data

The factors such as voltage, current, dissipation factor and frequency in actual form are presented in the fig.3 The experiments are conducted for all the input parameters. [10]

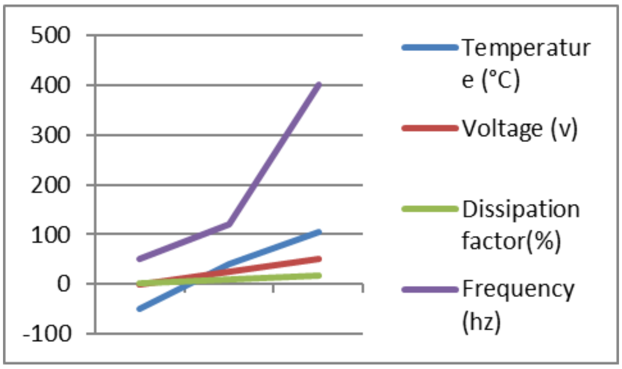

Fig.3 Actual form of data

3. 4. Artificial Intelligence Techniques for expert system for Life Prediction

The artificial intelligence techniques are employed to predict the residual lifetime of the electrolytic capacitor

3.4.1. Artificial Neural Network

The Artificial neural network uses simulated behaviour of biological neuron of brain. The number of factors in the input layer are voltage, ripple current, frequency, temperature and dissipation factor which are used to obtain the life of electronic component such as Capacitor. Feed forward three layered BPNN, The number of neurons in the hidden layer is determined by trials and error rate. There is only one output node that indicates the value of predicted life. The estimated life model is trained using MATLAB SIMULINK software. Parameter selected of Neural Network:

S.No	Parameters	Value
1	Input layer variables	5
2	Hidden layer variables	5
3	Output node	1
4	Learning	Supervised
5	Algorithm	Back Propagation Neural Networks
6	Number of Epochs	100

By simulating and performing analysis using artificial neural network with given parameters, The Remaining Useful Life (RUL) can be estimated. Figure 4. gives the structure of artificial neural networks having 5 input layers.

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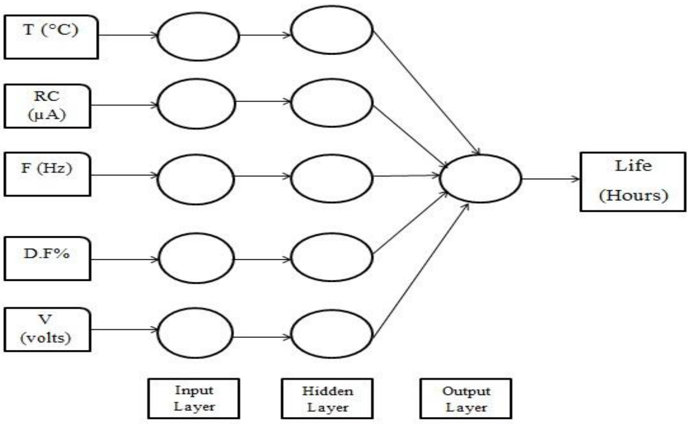

Fig. 4 Structure of Artificial Neural Network

5. Results and Discussion

The estimated residual life is perdicted using artificial neural networks, for electrolytic capacitor[10].

5.1 Estimated Life using ANN

The structure of ANN model is shown in figure. 4 and the life is estimated using ANN model that is formed in MATLAB simulink. The network model for life estimation is trained using MATLAB SIMULINK . Out of complete data, 70 % is used as experimental data. The ANN performance is shown in figure 5, given below.

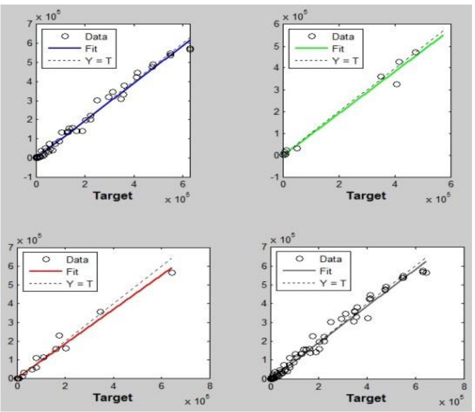

Fig.5 Target outputs of ANN model

Results are obtained in form of predicted life and error rate is obtained for every input from low to high values.

For V=28v, I = 5A, T= 34°C , F = 120 Hz and D.F.% = 5%
The output estimated life is 73619.9 hours whereas measured life using formula is 79611hours. The error rate is 7.525468%.

7. Conclusion.

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The conclusion drawn from this work is that temperature can be considered as one of the most prominent factors which can cause device failure but for more accuracy, more physical, environmental or electrical parameters can be taken. In developing ANN expert model, an efficient accuracy of 92.48% is achieved and hence it can be selected as a technique to develop Intelligent Model. Further, more parameters can be added, number of samples can be increased and more efficient technique can be applied.

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