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Discuss on the MTBF Evaluation and Improvement Methods of Power Adapter

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Abstract: *The MTBF evaluation methods and reliability improvement technologies of typical power adapter is discussed in this paper. Firstly, the basic structure of a typical power adapter is introduced; secondly, the reliability model is built and the reliability parameter is evaluated at the same time; thirdly, some reliability improving technologies are proposed to improve the reliability and reduce the manufacturing cost; lastly, the specific reliability data is compared between improvement and before. These reliability improvement technologies are effective, it can be applied to design and manufacture high reliability electric products.*
Keywords: *MTBF, Evaluation, Improvement method, Power adapter*

I. Introduction

With the development of science and technology, high performance and security power adapters have been used in almost all common electronic products [1-5]. Since the products are designed by different manufacturers with different level,the reliability indexes of power adapters produced by different factories are various especially at the mean time between failures (MTBF), which ranged from nearly one hundred thousand hours to a few thousand hours [6-8]. This would influence on the further development of power adapter [9]. Therefore, The methods to assess the reliability index MTBF and improve the design faultiness, has become the research focus of numerous power adapter manufacturers and research institutions.

II. Basic Structure Of Typical Power Adapter

A typical power adapter mainly consisted of the transformer module, rectifier module, filter module, and regulator module, combined with protection module, feedback modules and other components. A typical circuit structure of a power adapter is shown in Fig. 1.

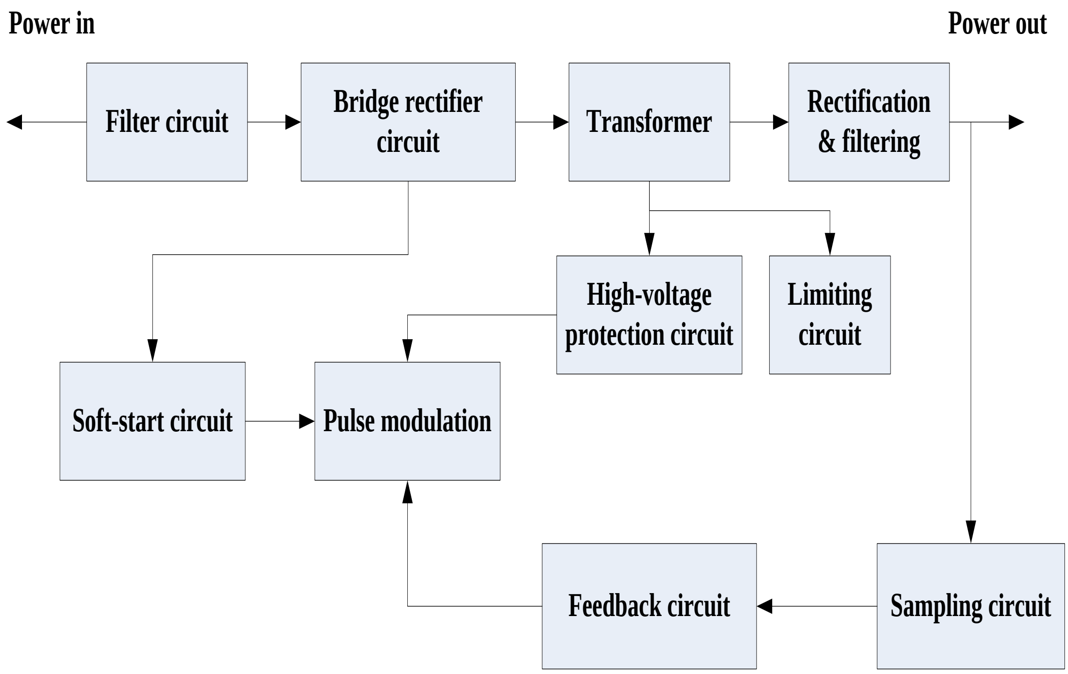

Fig.1: A typical circuit structure of a power adapter

According to the typical circuit structure of a power adapter, a typical design schematics is shown as Fig. 2.

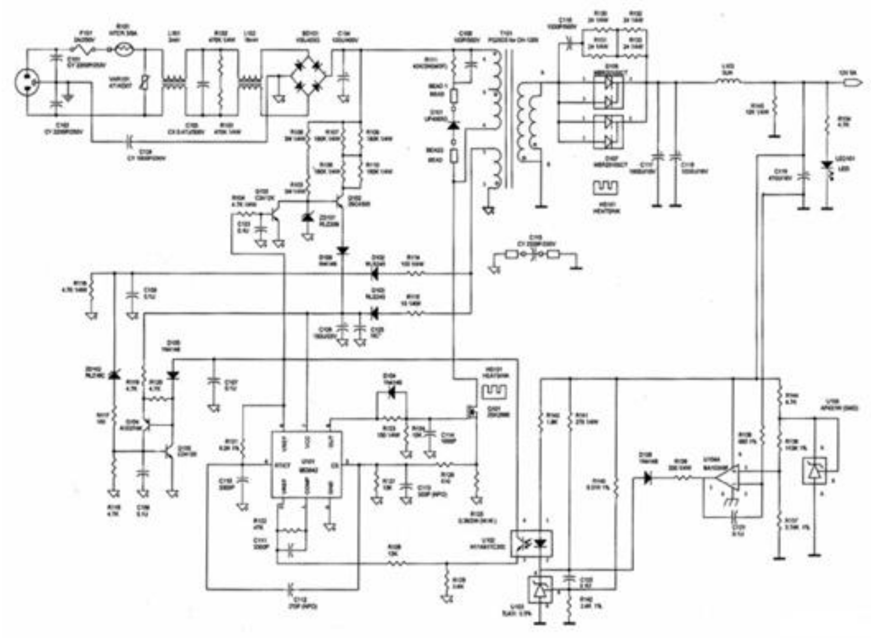

Fig. 2: A typical design schematics of a power adapter

III. The Assessment Method Of MTBF Of Power Adapter

3.1 MTBF Concept

The reliability is an important performance of product. Reliability is the probability of a product which can complete a predetermined function under the given conditions and time. The average life expectancy is the main gauge to measure the reliability of a product. For repairable products, the average life expectancy is an average time between failures of two adjacent, i.e. MTBF. The MTBF is calculated by

$$MTBF = \int_{0}^{\infty} tf(t)dt \qquad (1)$$

Where *f (t)* is the instantaneous product failure rate.

The product life distribution is exponential distribution, MTBF = 1 / λ, where, λ is the total failure rate of the products. The life distribution of electronic products is exponential distribution usually. Based on this, we found that if we wanted to evaluate the MTBF of power adapter, the total failure rate λ should be calculated first.

3.2 Reliability model of Power Adapter

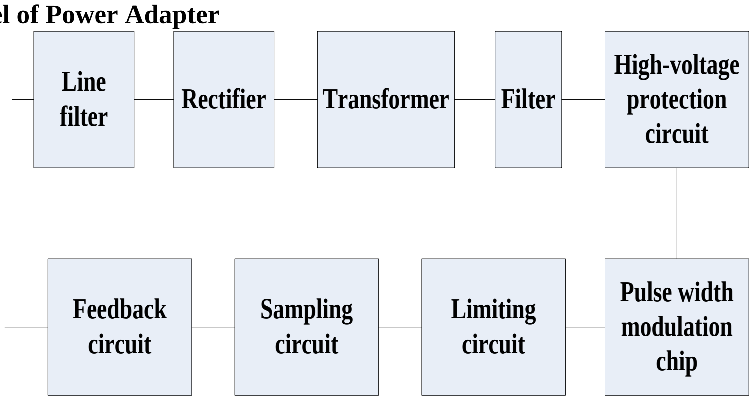

Fig 3: The reliability model of power adapter

Expected failure rate of the power adapter is based on the establishment of its reliability models. Referring the functional principle of the device and system, divided the device into several parts which are relatively independent in circuit and whose internal units are tandem structure. And then made sure the logic and mathematical relationships between each divided parts, namely established reliability models of the products. The typical power adapter consisted of line filter, rectifier, transformer, filter, high-voltage protection circuit, pulse width modulation chip, limiting circuit, sampling circuit, the feedback circuit. The relationship between these various modules is series model.

3.3 Stress analysis method

According to the unit belonged, used ways, work temperature, electric stress and other environment parameters, connected with the failure model of electronic components and the reliability model of the product, the total failure rate of power adapter λ can be obtained:

$$\lambda = \sum_{i=1}^{n} \lambda_i = \sum_{i=1}^{n} f_i(\lambda_b, \pi_Q, \pi_T, \pi_V, \pi_C, \pi_E, \pi_L, \pi_A) \qquad (2)$$

For the products whose reliability model is parallel structure, the λ is:

$$\lambda = \lambda' \left(\frac{1}{1 + \frac{1}{2} + \frac{1}{3} + \dots + \frac{1}{n}} \right) \qquad (3)$$

IV. The Improved Technologies For MTBF

4.1 Increase the backup unit.

The failure rate is 2/3 of the original failure rate when add a backup unit usually. If necessary, 1-2 units can be used as backup redundancy units.

The work principle of increasing the redundancy to improve the reliability of the unit is as follows:

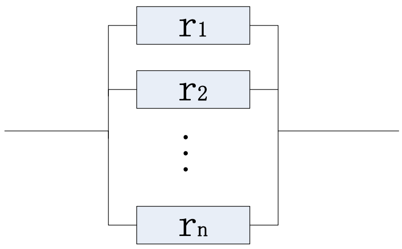

Fig 4: The principle diagram of increasing the redundancy

The reliability of system is:

$$R_s = 1 - F_s = 1 - \prod_{i=1}^{n} f_i = 1 - \prod_{i=1}^{n} (1 - r_i) \qquad (4)$$

For the products whose life distribution is exponential distribution, MTBF is:

$$MTBF = \int_0^\infty R_s(t)dt$$

$$MTBF = \sum_{i=1}^{n} \frac{1}{\lambda_i} - \sum_{1 \le i < j \le n} \frac{1}{\lambda_i + \lambda_j} + \dots + (-1)^{n-1} \frac{1}{\lambda_1 + \lambda_2 + \dots + \lambda_n} \qquad (5)$$

When n parts of the product are same, MTBF is:

$$MTBF = \int_0^\infty \{1 - (1 - e^{-\lambda t})^n\}dt = \frac{1}{\lambda} + \frac{1}{2\lambda} + \dots + \frac{1}{n\lambda} \qquad (6)$$

4.2 Derating stress design

Extra stress existed in some components. Thermal analysis showed that the ambient temperature of metal film resistors is 76℃, but the rated temperature is only 70℃, therefore, a higher rated temperature (100 ℃ above) needed to be considered for the metal film resistance.

Another example:

The original power load factor of one diode S is 0.4, stress analysis showed that the ambient temperature is 80 ℃, the junction temperature is:

$$T_j \approx 80℃ + 0.4 \times 150℃ = 140℃ \qquad (7)$$

Its junction temperature exceeded the maximum allowable temperature 125 ℃ as Class II derating standard , so its load factor should be considered from 0.4 down to 0.25 or less.

4.3 System reliability optimization based on Lagrange allocation method

When MTBF and λ cannot reach the requirement value, or the manufacturing cost is too high when MTBF and λ are fit, Lagrange allocation method can be used to realize the reliability allocation, and which made the manufacturing cost least.

Supposing there are n sub-system in the power adapter, the reliability of each sub-system is Ri(i=1,2,…,n), the manufacturing cost is xi, and the relationship between Ri and Xi is:

$$R_i = 1 - e^{-\alpha_i (x_i - \beta_i)}$$

The limit condition is the total reliability $R_s = \prod_{i=1}^{n} R_i$ is immovable. For solving this, Lagrange multipliers § is introduced to structure Lagrange function as follow:

$$L(X, \xi) = \sum_{i=1}^{n} x_i - \xi (R_s - \prod_{i=1}^{n} R_i) \quad (8)$$

$$x_i = \beta_i - \frac{\ln(1 - R_i)}{\alpha_i} \quad (9)$$

Step the formula (9) into equation (8), then

$$L(R, \xi) = \sum_{i=1}^{n} [\beta_i - \frac{\ln(1 - R_i)}{\alpha_i}] - \xi (R_s - \prod_{i=1}^{n} R_i) \quad (10)$$

Solving these equations:

$$\begin{cases} \frac{\partial L}{R} = 0 & i = 1, 2, \ldots, n \\ \frac{\partial L}{\xi} = 0 \end{cases} \quad (11)$$

Then the reliability value of each sub-system $R^* = [R_1^* \ R_2^* \ldots R_n^*]^T$ can be obtained when the cost is least and the reliability is best.

4.4 Test

We chose one typical power adapter for testing. The total failure Rate of the power adapter before improvement is 50×10-6/h, MTBF is 20000 h, manufacturing cost is about 135¥. And The total failure Rate of the power adapter before improvement is 35.9×10-6/h, MTBF is 27855 h, manufacturing costs is about 95¥ by using redundant backup, stress derating design, system reliability optimization and some other methods. It can be found that the MTBF of the power adapter have been greatly improved and the manufacturing cost is reduced in a certain extent after improving the reliability.

V. Conclusion

Using redundant backup and stress derating design approach can improve the reliability of electronic products. Applying optimization method for reliability system can reduce manufacturing costs. These methods can be applied to design and manufacture other electronic products.

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