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RELIABILITY AND QUALITY ASSURANCE OF ELECTRONIC COMPONENT

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ABSTRACT

An electronic component is an entity in a system which can not be further sub-dived in the course of a given reliability. However a component can made up of parts which is regarded as a self-contained unit. Thus while the reliability of a system can be influenced by altering its structure, the reliability of what is considered a component cannot be changed in such a manner, and if different characteristics are desired, the component must be replaced by another with different reliability parameters. Electronic components can be classified into two groups. The first group are those that are observed only until they fail, because either they cannot repaired, or the repair is uneconomical, or the problem is such that only the life history up to the first failure is of interest. These called non-reparable (or non-repaired) and their failures are catastrophic. The second group are those components that are repaired upon failure, hence their life histories consist of alternating operating and repair periods. They are called repairable components. This paper presents the basic concept of electronic component reliability and quality assurance. A brief historical perspective is presented along with operational definitions. The factors affecting reliability as well as the costs to provide reliability re also described. Failure modes are depicted as well as the environmental effects that affects reliability.

Keywords: Reliability, Quality assurance, Failure rate, Degree of failure, Catastrophic failure. Degradation Failure.

INTRODUCTION

Prior to World War II between 1939 and 1945, little attention was given to electrical/electronic equipment reliability. Electrical and electronic devices are usually attacked by desert heat, extreme cold of high altitudes and the high humidity of tropics. The devices also become more advanced and complicated as new communication systems, navigational systems, and transportation systems for the military came into being. These developments all improved the chance for failure of any device, instrument or system. An American survey was conducted with respect to usage of electrical/electronic equipment, what was found was staggering. Equipment was only operative for about one third of the time. It was also discovered that an average span cost was about ten times the original purchase price. Vacuum tubes, and thermionic valves, were of course, the most prone to failure. An American advisory group was set up to deal with reliability which set standards that was later adopted by civilian airlines. As the technology changed, transitory and integrated circuits were added to reliability clauses in military and civilian specifications.

At this time, a few definitions are in order.

(1) **Quality: -** Determined by the fraction effective in a given population, a low value of the fraction defective characterizes a population which would be classified as high quality.

(2) **Reliability: -** Given a population of initially operative components, which are deployed in some ways, the fraction surviving at some later point in time is their true reliability.

(3) **Failure: -** The termination of the ability of an item to perform its required function:
  (a) Degree of failure-out of specification, or completely broken down.
  (b) Cause of failure-misuse or inherent weakness.
  (c) Time of failure-sudden or gradual

(4) **Failure Rate: -** The probability of a component failing in a given interval of time (usually one hour). Mostly, in the course of a components life, this failure rate is considered as independent of time. The constant failure rate with respect to time is not appropriate for mechanical components.

A general failure pattern which was first observed for vacuum tubes (valve) that is often referred to as the bath tube valve. This curve has a steep downward sloe at the beginning, a leveling off and then a steep upward slope. This curve represents failure rate (Y-axis). The steep downward slope represents infantry mortality or the failure of a component within the first hundred or so hours of usage [1]. These early failure rates are usually found during the time the manufacturers operate devices, sometimes at elevated operating levels to weed out those less desirable components. During a components normal working life, almost a constant failure rate versus time is displayed. In this period, few devices fail. Lastly, wear out stage is reached when the curve points upward steeply. Here, components failure increases as the devices reach their wear outs and are due to design problems or conditions for use. Semiconductors also exhibit the bathtubs curve characteristics as well. However, after the infant mortality stage, semiconductor instruments are more reliable than tube instruments. Semiconductor devices and integrated circuits especially aid reliable operation by isolating itself from shock, temperature, humidity and other environmental concerns and by guarding many interconnection made inside the device [4].

FACTORS AFFECTING THE RELIABILITY OF AN ELECTRONIC DEVICE

A four part life cycle has been identified for components utilized within an electronic device. They are:

(1) ***Design and Development***

Obtained from reputable source components that meet the proper specifications. Test each device, or sample, to be sure they are what were ordered. Be aware of any self life of exposure to environmental conditions.

(2) ***Production***

The skill, training and involvement of production personnel are the most important. Good communication, proper tools and manufacturing equipment along with a well designed work area is essential for quality production.

(3) ***Storage/ Transport***

Package and store in environments protected from corrosion and mechanical damage, vibration, temperature, humidity and pressure.

(4) ***Operation***

Reduces operator error (operability) with a well written manual or in-house training. (Allan et al., 2002, Billinton and Li 2005)

THE COST OF RELIABILITY

Consumers when they purchase items consider two things. First, the purchase price is considered. This is typically referred to as capital cost. However, consumers and their organizations are becoming more and more cost conscious. Industries that wish to sell more items should address all costs in their sales literature. On the other hand, for manufacturers, as reliability is improved, design and production costs do indeed increase. However, the cost involved for repairs and free replacements under guarantee decreases significantly. The best design for the minimum total life cost includes, purchasing, initial spare components, routine maintenance and the cost of being able to operate if the equipment thus indeed fail.

Ideally, at the "optimum reliability" point, there is:

(a) High Equipment Reliability
(b) Long Equipment life

Other concerns includes systems that may influence the safety of individuals such as aircraft or nuclear power plants. Another concern could be how expensive the repair cost is or the loose revenue that may follow, such as a communication system [3].

FAILURE MODES

Equipment that is well cooled, operated without vibration or shock (mechanical) and components stressed well below their maximum rating exhibit failure rates that are so low that manufacturers cannot afford to test hundreds of thousands of components for such a long period of time to obtain precise data as to failure rate. Most component equipment failure information comes from users of large equipment (computers, telephone exchanges and other communications systems) which are operated for long periods of time. With this statistics, failure rate is either constant with time or slowly decreasing. With regards to the "bathtubs" curve for failure rates, the constant failure rate (exhibited during the components main working life) is valid or, if incorrect only slightly pessimistic [2], [5]. The wear out phase is largely irrelevant for transistorized or integrated circuit equipment. Usually, the equipment is scrapped because of technical obsolescence before wear out is encountered. The early failure stage (infant mortality) is still encountered for semiconductors (transistors, integrated circuits). However, this phase can be disregarded for reliability prediction because most of these failures are discovered during "born-in" i.e. the stage where components or equipment is operated before delivery to ensure early failure are detected and repaired. Concerning the types of failures that can be encountered, there are several possible failure modes available. Characteristics of a component or system that change to such a degree that the component or system cannot operate to its specified level or performance is one type. This may be based upon the magnitude of the change and the rate it occurs. Why should components and/or system fail? All man-made items have finite life span. As far as electronic components, stresses are caused by:

(A) **Design operating conditions:**
Applied voltage, current, power dissipation and mechanical stress.

(B) **Environmental Conditions:**
High/low temperature, temperature cycling, humidity, mechanical vibrations and shocks, high/low pressure, corrosive atmosphere, radiation, disc, insects, fungi.

The life of a component is gradually improved if operated well within full rated values of voltage, current and power. The technique is called derating. For example, one watt resistor, if operated at a wattage rating of one quarter watt dissipation, will have its operational life greatly extended. The method is especially helpful during the normal operating life of the component (not early or born in phase or wear out phase). These random failures during normal working life can be greatly reduced by departing.

Catastrophic Failure: - A large and very rapid change. Generally, an open circuit/short circuit failure which is irreversible. This type of failure is usually permanent and complete. The device must be replaced.

Open Circuits – Capacitors (especially electrolytic)

Degradation Failure: - These failures are observed as changes that occur slowly, over period of time. This will ultimately cause the circuit to operate incorrectly. Depending upon the function of the device, this may or may not be a significant problem. For example, a very stable and precise oscillator change is a problem, but a decamping capacitor may not pose any difficulty. Environmental effects on equipment occurs whether the equipment is operating (active) or switched off (static), or stored when switched off. In fact the environmental effects may be more damaging in the stored condition because there is no self-heating to counteract moisture. This is why computer systems are left on. Computer systems are also typically left operating because the best reliability is obtained at a fairly constant, median temperature range, such as 20 degrees centigrade, plus/minus 5 percent [6], [3]. Military communications, receivers/transmitters may be exposed to the most rigorous temperature ranges. Excluding outer space activities, the following listing will document temperature variations:

Deserts - 115^{0}C to 60^{0}C
Tropics - 20^{0}C to 45^{0}C
Polar Regions - 40^{0}C to 30^{0}C
Deep Sea - 10^{0}C to 30$_{0}$C

Whereas self-heating effects may at times be helpful (dissipate moisture), at other time, this effect may cause a device's internal temperature to rise above the maximum of its power rating at 25^{0}C. Additionally, heat will cause expansion and contradictions stresses in materials. A general guideline is that failure rate will typically be durable for every 10^{0}C rise in temperature. Conversely, at low temperature, materials became harden and brittle. This makes components more likely to break. Electrolytic capacitors are almost ineffective due to internal freezing of the electrolyte. Among the most damaging environmental effects is that of rapid temperature cycling. This continual expansion and contraction of materials and components accelerate failures. This is not only possible due to on/off cycling but also day/night cycles. The following listing will assist to design around some of these problems:

High Temperature:
Problems: - Exceed power ratings, expansion/contraction, increase chemical actions, rapid ageing.
Solution: - Added heat sinks, fans, ventilation devices.

Low Temperature:
Problems: - Contractions, hardening/freezing, brittle, loss of gain and efficiency.
Solution: - Heat controlled environment, use of correct materials for constructional problems.

Temperature Cycling:
Problems: - Severe stressing fatigue failure.
Solution: - Thermal delays to prevent rapid changes to effect internal components (refrigerating. freezer compressor).

Humidity

The level of moisture content in the air is called humidity. Deserts and arid regions have about 3 per cent relative humidity while tropics may contain 100 per cent relative humidity.

Relative humidity: - Relative humidity is the ratio of the amount of water vapour present in the air to the amount that will saturate the air at the same temperature.

The effects of humidity can be described as:

(1) Reduced values of insulation resistance leading to possible breakdown of the dielectric (voltage potential causing arcing)
(2) Corrosion resulting from moisture forming an electrolyte between dissimilar metals.
(3) Promotion of fungi growth which also reduce insulation resistance.

Worst Condition: - High Temperature, High Humidity.

To establish the effect of high humidity use four insulating material that do not absorb moisture or support water film and if possible resist the growth of fungi (silicons). The best solution is to hermetically seal (totally encapsulate) sensitive components or even entire assemblies in plastic resins or use sealing rings and gaskets. Additionally, desiccants (dragging agents) should be included in sealed areas to absorb any moisture that gets inside. Silica gel, for example is one such desiccants that turns pink when it has absorbed water moisture.

MECHANICAL VIBRATIONS AND SHOCKS

All instruments when transported or handled will experience some degree of mechanical shock and vibration. Vibrations may be in the range of DC to several kilohertz depending upon transport by road,, rail, sea, air (space also). Should an instrument be dropped, it may suffer from a shock (mechanical) that is 20 times the force of gravity (20g's). This could weaken the supports, loosen connections, bend and possibly fracture components and set up stresses that lead to fatigue failure. Careful design techniques can minimize mechanical vibration and shocks on equipment. For example, anti-vibration mounting, shake-proof washers and locking nuts can be used. Varnishes and the encapsulating of sensitive components in protective materials will help silicon rubber caused by vibration and shocks. Do not neglect to consider the physical situation and its electrical and electromagnetic surroundings. Variations in power supply (voltage levels, frequency and noise) has its effects. Radiation is also a problem be it electromagnetic (radio frequencies, audio frequencies) or even ionizing radiation (X-rays or nuclear reactors). Many of these environmental factors occur simultaneously. This will complicate any testing procedure and may give false and usually optimistic results.

CONCLUSION

The reliability and quality assurance of electronic components have been extensively discussed. The factors affecting the reliability of an electronic device, the cost of reliability and the failure modes were extensively emphasized.

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