

## Reliability of PhotoMOS Relays

Reliability has come to rank right along side cost and efficiency when evaluating the design and application of a system. An electrical system is composed of a collection of electronic components, materials and manufacturing processes. None of these elements are perfect and each can fail in some fashion that could influence the system's functionality.

Reliability predicts how often failures will occur. In electronic reliability analysis, it is assumed that failures are independent and random and are statistically distributed with a constant failure rate versus time.

Stress prediction methods attempt to predict the reliability of components in a detailed manner. These methods assign a specific baseline failure rate for each component used in electronic design. This baseline failure rate is then modified by multiplying certain factors relating to specific components and stresses applied in the actual application. A commonly used parts stress prediction method has been developed by the US Military Agencies (MIL HDBK-217F).

However, there is an inherent problem in using part stress methods for reliability prediction. Each of the sometimes hundreds of components in a design must be assessed in terms of its specific operating conditions. In addition, the reliability prediction method is rather theoretical and ignores vendor-specific differences, e.g. in construction or quality. The only true measure of reliability is derived from reliability testing.

Relay manufacturers who offer both electromechanical and semiconductor relays are compelled to provide two different kinds of reliability data. For electromechanical relays, which suffer wear during their lifetime, reliability data is best obtained from Weibull diagrams. All three parts of a bathtub life curve (early failures, random failures and failures due to wear) can be demonstrated via Weibull distribution. By performing suitable tests under appropriate conditions, results can be entered into a Weibull chart, leading to a failure probability for a certain number of switching operations. However, since semiconductor relays do not suffer wear over the course of their lifetime, Weibull testing is irrelevant for them.

For semiconductor relays, accelerated tests, which reduce time and testing costs, are used to predict reliability. Such tests involve applying temperature cycling and other stress factors, e.g. humidity (85°C and 85%RH is often used as a standard combination).

The failure rate,  $\lambda$ , is the fundamental variable used to define reliability.  $\lambda$  is expressed in terms of failures per unit of time. Typically the failure rate of a component is between  $10^{-8}$  and  $10^{-7}$  failures per hour and is a function of the applied stress levels.

Of these factors, operating temperature is especially important since it has a major influence on the overall reliability. The relative change in failure rate, i.e. the acceleration factor (AF), for when the operating temperature of a component is changed is given by the Arrhenius equation:

$$AF = e^{\left[ \frac{E_a}{k} \left( \frac{1}{T_1} - \frac{1}{T_2} \right) \right]}$$

AF = Acceleration Factor

$E_a$  = Activation Energy in Electron Volts =  
= 0.8V (possible range 0.3V to 1.5V)

$k$  = Boltzmann's constant =  $8.617 \cdot 10^{-5}$  eV/K

$T_1$  = New Temperature in degrees Kelvin

$T_2$  = Test Temperature in degrees Kelvin

The activation energy  $E_a$  is a factor that models the temperature versus failure rate characteristics of a component. It will vary somewhat from one component type to another. Failure rates for "use conditions" are calculated from the acceleration factor and the equivalent device hours using stress time and number of samples tested. These estimates of equivalent use hours are well beyond the end-of-life hours associated with most applications when assuming an exponential distribution. The relationship between failure rate (expressed in FIT, 1 FIT = 1 failure per billion device hours) and the Chi-squared distribution is shown in the following equation.

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$$\lambda = \frac{\chi^2}{2 \cdot EDH} = \frac{\chi^2}{2 \cdot AF \cdot CDH}$$

$\chi^2$  = Chi-squared distribution for a given confidence level

EDH = Equivalent device hours

AF = Acceleration Factor

CDH = Cumulative device hours

Chi-squared distribution		
Number of failures	$\chi^2$ at 60% confidence level	$\chi^2$ at 90% confidence level
0	1.833	4.605
1	4.045	7.779
2	6.211	10.645

Based on these equations, the failure rate for a PhotoMOS relay can be calculated as follows. Recent cyclic production line quality testing proved the functionality of 960 pieces of PhotoMOS relays in a Temperature Humidity Bias Test (THB) test with 85°C and 85%RH. During the 1000 hours of test time, no failure was observed. Therefore the FIT value with a confidence level of 90% for a field condition of 35°C and 75%RH can be calculated as follows:

$$AF = e^{\left[ \frac{E_a}{k} \left( \frac{1}{T_1} - \frac{1}{T_2} \right) \right]} = e^{\left[ \frac{0.8V}{8.617 \cdot 10^{-5} \frac{eV}{K}} \left( \frac{1}{308K} - \frac{1}{358K} \right) \right]} = 67.4$$

and

$$\lambda = \frac{\chi^2}{2 \cdot EDH} = \frac{\chi^2}{2 \cdot AF \cdot CDH} = \frac{\chi^2}{2 \cdot AF \cdot CDH} = \frac{4.605}{2 \cdot 67.4 \cdot (960hrs \cdot 1000)} = 35.6 \cdot 10^{-9} = 35.6FIT$$

Another model that has proven successful for predicting reliability of a component is the Peck model. In addition to temperature, this model takes humidity into account in order to calculate the acceleration factor.

$$AF = \left( \frac{RH_1}{RH_2} \right)^{-N} \cdot e^{\left[ \frac{E_a}{k} \left( \frac{1}{T_1} - \frac{1}{T_2} \right) \right]}$$

AF = Acceleration Factor

$E_a$  = Activation Energy in Electron Volts =

= 0.8V (possible range 0.3V to 1.5V)

k = Boltzmann's constant =  $8.617 \cdot 10^{-5}$  eV/K

$T_1$  = New Temperature in degrees Kelvin

$T_2$  = Test Temperature in degrees Kelvin

$RH_1$  = New relative humidity in percent

$RH_2$  = Test relative humidity in percent

N = experimental determined constant =

= 4.5 (possible range 2 to 12)

Using the values from our example, this equation yields a different acceleration factor and therefore a different FIT value.

$$AF = \left( \frac{RH_1}{RH_2} \right)^{-N} \cdot e^{\left[ \frac{E_a}{k} \left( \frac{1}{T_1} - \frac{1}{T_2} \right) \right]} = \left( \frac{75}{85} \right)^{-4.5} \cdot e^{\left[ \frac{0.8V}{8.617 \cdot 10^{-5} \frac{eV}{K}} \left( \frac{1}{308K} - \frac{1}{358K} \right) \right]} = 118.1$$

and

$$\lambda = \frac{\chi^2}{2 \cdot EDH} = \frac{\chi^2}{2 \cdot AF \cdot CDH} = \frac{\chi^2}{2 \cdot AF \cdot CDH} = \frac{4.605}{2 \cdot 118.1 \cdot (960hrs \cdot 1000)} = 20.3 \cdot 10^{-9} = 20.3FIT$$

As we have seen, there are many differences between semiconductor relays and electromechanical relays, and reliability testing must take these differences into account. Where electromechanical relays suffer wear over their lifetime, PhotoMOS relays pass accelerated tests without failure, which offers yet additional proof of their high reliability and long lifetime.

These and other advantages, including the enormous variety of PhotoMOS relays, make them suitable for numerous applications, such as telecommunications, measurement, security engineering, sensor technology and the automation sector. Please contact us ([info-eu@eu.pewg.panasonic.com](mailto:info-eu@eu.pewg.panasonic.com)) to learn more about our products.