N R Malotaux
Consultancy

Design for Reliability (DfR)

or how reliable is your electronic product design?

Recently we got a request whether we could calculate the MTBF (Mean Time Before Failure) of a certain electronic design. My reply was that of course we could do that, but that we won't, as we'd rather spend our time on useful things. Reliability prediction based on MTBF calculations based on data unrelated to your product is an exercise in futility and provides a false sense of knowledge. The real causes of product failure are different from the causes that are assumed in the MTBF exercise, so what's the point in wasting time on a number that doesn't help us in practice?
In order to reliably predict reliability, we have to understand the cause of all failures that can happen. If we know the cause of failures, we can prevent them. Murphy's Law is not about fate. It's about prevention.

One of the potential causes of failure of an electronic product is the limited lifetime of wet aluminium capacitors (elcos), as this is much shorter than most of the other components on your board, and much shorter than the mathematical MTBF exercise would suggest. Fortunately, their useful life is quite predictable and hence should always be taken into account by the designers.

> The popular version of Murphy's Law is:
> *If anything can go wrong, it will*
> However, the real (and original) version of Murphy's Law is:
> *if anything can go wrong, it will*
> therefore
> *we should investigate all possible ways it can go wrong,*
> *and make sure that these cannot happen*
> (see www.malotaux.nl/murphy)

Lifetime prediction of these elcos is quite straightforward. Even a manager can do it.
Some crucial warning signals that it may not have been properly done, and that your product may not survive the expected lifetime are:

- The operational lifetime is not clearly specified
- The ambient temperature in which the product is supposed to survive is not clearly specified
- The parts-list only shows the capacitance and the voltage (like: 10µF/16V)
- In general: There is no DesignLog[1] properly documenting all the design considerations and decisions

If we assume a required lifetime of our product of for example 12 year at 50°C we need the product to survive 12yr x 8760hr = 105120hr. These elcos have a specified max temperature of 85°C, 105°C or 125°C, with useful lifespans of between 1000 and some 7000hr at those temperatures, which is between 1.4 and 9.6 months.
Fortunately, the useful life of such elcos is doubled for every 10°C lower than the specified max temperature, or:

$$t_{life} = t_{spec} \times 2^{\Delta T/10}, \text{ where } \Delta T = T_{spec} - T_{use}$$

Now we can calculate which type of elco we should specify:

spec	ΔT at 50°C	lifetime multiplier	required for 105120 hr	minimum spec
85°C	35°C	$2^{35/10} = 11.3$	105120 / 11.3 = 9300hr	does not exist
105°C	55°C	$2^{55/10} = 45.3$	105120 / 45.3 = 2320hr	use 105°C / 3000hr
125°C	75°C	$2^{75/10} = 181$	105120 / 181 = 580hr	use 125°C / 1000hr

As for the value of the capacitance, the initial tolerance of elcos typically is ±20%, while at the end of useful life the capacitance is decreased by another 20%, resulting in a capacitance of only 60% of its original value. This means that we should specify a capacitance 66% higher than the minimum required for proper operation. There are a lot more properties to consider of elcos (for example self-heating), as well as of any other component, and that's why a designer must always study the full datasheet and other background documentation in order to make the right component selection, to make sure that all copies of the product keep working reliably during the required lifetime.

Now we can look in the manufacturers catalogues, check the availability and cost, and choose the appropriate exact type number. If the procurement department has a reason to deviate from our choice, e.g. because of availability or price issues, they have to get the designer's approval for any alternative.

You may ask your designers whether they did all these things and ask them to show their DesignLog[1].

This was just an example of one of the many things we can and should do to ensure that the products we design comply with all the required qualities, including reliability. Once the designer has done these exercises properly, it will be even more clear why the calculation of an MTBF is a waste of time.

Other qualities we have to design to are for example: availability, maintainability, manufacturability, security, integrity, safety, survivability, performability.
That's a lot more than just functionality.

Niels Malotaux is Quality On Time coach and expert in helping projects and organizations to deliver better quality in less time. Better requirements, design, review and implementation techniques, how to move towards Zero Defects, better planning, better scheduling, better portfolio, program and resource management. A lot of experience, based on over 40 years in electronic product design, firmware, and software development, and since 1998 teaching and coaching over 300 projects in 40+ organizations in 13 countries around the world.
More information: niels@malotaux.nl

[1] See for an explanation of DesignLog: www.malotaux.nl/designlog