crydom Solid Statements

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The Life Expectancy of Solid State Relays

In our previous edition (SSRs vs. EMRs) we discussed the many advantages of solid state relays over electromechanical relays. To summarise, these are:

- ***Long Life Expectancy***
- ***Quiet Operation (no acoustic noise)***
- ***Fast Switching***
- ***Zero-Crossing***
- ***Shock & Vibration Resistant***
- ***No Contact Arcing or Bouncing***
- ***Phase-Angle Controllable***
- ***Low Input Power (coil) Consumption***

In this edition we are going to focus exclusively on life expectancy, which is arguably the most significant advantage to using solid state relays. We say "arguably" simply because there are some applications where life expectancy has been relegated to a mere #2 or #3 on the priority list. However, in most applications, especially ones where the relay must switch power to the load multiple times over a relatively short duration and the warranty runs longer than a few months, life expectancy remains #1 on the list. Therefore, and as one would expect, engineers frequently ask us to specify the life expectancy of the solid state relays they are considering for their designs.

Unfortunately, it's not the easiest of questions to answer...

Mean Time Before Failure (MTBF)

Life expectancy is often expressed in terms of MTBF / MTTF (mean time before failure or mean time to failure) and/or "number of operations". These specifications are often conditional and subjective, depending upon the product and application. Furthermore, as we will see, MTBF and # of Operations are both nearly impossible to spec for solid state relays. However, such information provides engineers with the data necessary to improve upon "weak links" in their design, so therefore they ask…

Of the two, MTBF is the most commonly requested specification for life expectancy we receive from design engineers. This is probably because it is a widely used specification for common electronic items such as hard drives, printer, power supplies, etc. Or it could be that it is a statistical approximation, which just makes whoever uses the term feel smart. Ironically, it is possibly the most irrelevant measure of life expectancy for solid state relays. This is due to the fact that it is the manner in which the SSR is used, not the duration for which it is used, that determines how long it will "live" in a given application. Solid state relays dissipate heat when conducting load current so the components within will expand slightly as the SSR temperature increases. When the SSR is turned off it begins to cool and the internal components contract accordingly. The greater the

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thermal fluctuations, the greater the stress placed on internal components. If the stress on these components becomes too extreme (more than ~10ºC to ~20ºC per minute continuously at die level) then the life of the SSR will decrease.

On the other hand, if you operate a solid state relay at or near its maximum die temperature without any fluctuations (just turn it on and let it go…) then theoretically it will last forever. This is because there is no expansion or contraction of critical components. Therefore, no thermal fatigue.

Of course we all know that nothing lasts forever, so we're back to "square one" with calculating MTBF. If we know that a SSR will last forever (or a few days shy of forever) when operating continuously, and much less than forever when turning on and off continuously, then the MTBF has to be somewhere in between. The rest is just guesswork. Fortunately, having more experience with solid state relays than any other manufacturer in the world, our estimates tend to be more accurate than most.

Crydom's approach to MTBF, as explained in the FAQ section of our website, is to calculate an estimated MTBF based on total in-service hours in reference to the number of returns received from the field over the same duration. Assumptions as to the actual hours in service must be made, as well as to the percentage of failed products returned to us for analysis, but in general we can reach a relatively accurate conclusion. When all is said and done, the final result is an estimated MTBF of between 2 million hours and 40 million hours.

Yes, that's "millions" of hours, and for those of you who are wondering, 40 million hours equates to 4,566 years, excluding any adjustments for leap year every four years. But to be more reasonable we simply state that our estimated MTBF is >2 million hours, which is an easier-to-swallow 228 years.

Number of Operations

The less frequently requested, but more (again, arguably…) realistic measure of life expectancy is the relays rated "number of operations" (also referred to as mechanical / electrical endurance). As the name implies, this specification basically tells you how many times you can reliably expect the relay to switch power to and from a resistive load. In other words, how many times will the relay do what you want it to do before someone has to go out and replace it with a new one.

Calculating number of operations for electromechanical relays is relatively straight forward. Manufacturers of EMRs typically specify endurance for mechanical operations (no voltage connected to the relay) and electrical operations (fixed voltage and current through the EMR into a resistive load). The most common mechanical endurance rating for EMRs is usually in the range of 10 million operations. Somewhat impressive, until you actually consider that there is no load attached to the contacts, which means they're not really doing anything other than bouncing back and forth. However, once you attach a load to the contacts the electrical endurance rating drops dramatically to as low as 100K operations.

Now, some might think that 100k operations at rated load voltage / current is still impressive – possibly even overkill, depending upon the application. But just to put things into perspective, let's consider a typical resistive heating application such as an electric oven or griddle. In order to maintain set temperature levels the relay must turn on and off as much as five to six times per minute. If we consider a short eight hour work day / five day work week for the restaurant using the oven, then at five times per minute the number of operations reaches – 300 per hour, 2,400 per day, ~50,000 per month, ~600,000 per year….

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Suddenly a maximum endurance rating of 100K operations doesn't look so impressive. Under these conditions the manufacturer can reasonably expect their ovens to begin failing after only two months in the field; more than likely a less-than-desirable service rate unless the warranty period is extremely short.

Alternatively, solid state relays have no moving parts, which mean there are no contacts to arc and bounce with each actuation. Therefore, the only limitation to the life expectancy of a SSR is **A)** whether or not it is used within its specifications, and **B)** how well the heat dissipation is managed to minimise thermal gradients. If both "A" and "B" are managed well then we're back to "best estimates" for specifying the maximum number of operations for solid state relays. However, as we stated before, our estimates tend to be far more accurate than most. As a result, our calculations show that in such cases a Crydom solid state relay could reasonably be expected to function normally for 50 million to 500 million operations. Using the daily number of operations from our previous example, this means using an SSR instead of an EMR could extend the life of the switching component in the oven from 2 months (with the EMR) to 833 years (or 83 years at the lower end of the calculation, just to be prudent) – a much more appealing warranty period!

Conclusions?

Given the information herein it should be fairly obvious why SSRs are highly preferable to EMRs in many applications, especially where the relay is expected to switch power to the load many times in a (relatively) short duration. However, as opposed to EMRs it is extremely difficult to actually specify a "fixed" MTBF / Endurance rating for a SSR as this is subject to the conditions of each and every application (ambient temperature, heat sink, duty cycle, surge currents, etc.). What we *can* say, with a very high level of confidence, is that a Crydom SSR will far outlast any EMR on the market when utilised within its specifications. But for those engineers that still require a number, and most will, the rule of thumb is >2 million hours for "observed MTBF", and >50 million operations under normal operating conditions.

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