Common mistakes in electronic design.

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by Craig Hillman, PhD, DFR Solutions

Designing for reliability plays a critical role in the ultimate success or failure of your product and helps you avoid common design mistakes.

Most executives responsible for managing product performance or warranty returns will tell you that the most common headaches in manufacturing come from suppliers or manufacturers. For example, a new, cheaper supplier used the wrong material, or a process went haywire for a day or two. These issues, which manufacturers often describe as 'random' failures, are the primary drivers for the cost of quality. So, who cares about design? Well, you should. Designing for reliability plays a critical role in the ultimate success or failure of your product. Design plays an integral role in the manufacturability of your product. The easier the design is to manufacture, the greater its tolerance to the standard variation in all manufacturing processes. Design also plays an important role in component reliability, because designs that avoid the use of extended-value components and minimize the application of thermal and electrical stresses reduce the risk that marginal components will induce product failure.

You cannot overlook the degree of risk you incur by ignoring design-for-reliability issues. Component or manufacturing problems, as prevalent as they are, tend to affect a small percentage of products. For some manufacturers, however, a small percentage translates to costs of hundreds of millions of dollars. Design issues can kill every unit your customer uses. So, what are some of the most common mistakes in electronic design?

Flex cracking

Flex cracking is one mistake. It most commonly occurs when the PCB (printed-circuit board) under a ceramic-chip capacitor bends excessively. The brittle ceramic-chip capacitor cannot respond to the strain and cracks. These flex events can occur during depaneling, testing, connector or card insertion, or attachment or from accidental dropping of the part or mechanical shock. Your approach to this problem depends on your cost constraints, design constraints, and the degree of acceptable risk. For example, you could use a shorter capacitor if you can find a similar capacitance and voltage in a smaller case. Alternatively, you could use a narrower bond pad, rotate the capacitor 90[degrees], or move the capacitor 45 to 60 mil away from the flex point. Another approach is to use an open-mode capacitor or one with flexible terminations.

In one case study, an industrial-controls company had to maintain tight spacing between an attachment point, which the system was using as ground, and a large chip capacitor to ensure adequate electrical performance. Capacitors having flexible terminations and with similar electrical parameters were unavailable. The high density of the system prevented the designers from rotating the capacitor. The solution was to reduce the bond-pad width, measuring flexure during attachment and modifying torque limitations to ensure a low risk the capacitor's cracking.

A similar issue arises with BGAs (ball-grid arrays). These leadless devices have limited compliance, and, if you place them near a flex point, such as a press-fit connector or an attachment, for example, they can experience cracking in the laminate, solder ball, or PCB. These devices offer fewer design approaches to designers than ceramic capacitors do. These approaches primarily consist of moving the BGA, using a thicker board, or adding ribs to the board for greater rigidity. BGA flex cracking has started to eclipse ceramic-chip-capacitor failures as more companies switch to the more rigid, brittle, and lead-free SAC305 tin-silver-copper alloy.

Joint wear and custom connections

Some of the most extensive design-for-reliability efforts focus on avoiding the wearing out of solder joints. The best approach to this problem is to assess robustness during the design phase by deriving predictions based on first- and second-order models or on FEA (finite-element analysis). You can also derive accelerated life tests from models that KC Norris and AH Landzberg developed at IBM in 1969 (Reference 1). However, the product-qualification segment of the design cycle often occurs too late to catch errors. With these straightforward tools available, why do solder joints sometimes wear out? Several drivers are responsible. Some, including failure to perform reliability modeling and failure to perform accelerated life testing, are obvious. Three reasons stand out, however, as the most common: the use of adjacent heat sources, excessive power dissipation, and the use of custom solder joints.

PCB designers think in only two dimensions. However, in certain applications, heat sources separate from the electronics can be hot enough, close enough, or both to cause a serious temperature rise on localized components. A designer may forget about these heat sources during modeling and may not install them during testing only to find that they cause solder joints to wear out after months or years in the field.

Excessive power dissipation becomes a problem in two ways. First, if a designer pays too little attention to components with high power dissipation during reliability modeling or fails to exercise them during testing, then the dissipated heat can accelerate solder-joint fatigue through elevated temperature or a change in temperature effects. These problems typically arise for components off the board, such as motors, generators, or high-current bus bars. Second, a designer might choose the wrong component or mislabel a component from the bill of materials. This error can be especially deleterious for chip resistors: Substituting a 1/8W resistor for a 1/4W resistor can sufficiently elevate temperatures to induce solder joints to wear out.

JEDEC (Joint Electron Device Engineering Council, now the JEDEC Solid State Technology Association) is the primary driver of industry-standard test requirements for second-level packaging. Because of these standards, most component designs are sufficiently robust for all but the most severe environments, such as automotive-under-the-hood, satellite, and similar applications. Therefore, the most common components to wear out are custom solder interconnections. Designers often use these joints to mechanically or thermally connect components or the PCB to housing or other mechanical support structures. Just as with outside heat sources, designers sometimes fail to test these custom solder interconnections with the PCB assembly, meaning that they sometimes overlook this design issue during product qualification. A low-cost solution is to keep the solder joints at temperatures lower than 75 to 80[degrees]C, especially if the temperature of the components will vary over time. A better approach is to use physics-of-failure models to understand risks before finalizing your design.

Electrolytic capacitors

Although designers love electrolytic capacitors because of their high capacitance, they hate them because they fail over time. This love/hate relationship has led to a range of methods for derating and predicting lifetime. What are the best approaches? It all depends on whether you are derating voltage, ripple current, or temperature. With voltage derating, remember that electrolytic capacitors work best when you apply voltage to them. With no voltage, they have no dielectric and no capacitance. Although electrolytic-capacitor manufacturers have over the last five years improved these capacitors' low-voltage performance, try to avoid voltages below 25% of the rated voltage. At the other end of the spectrum, designers create capacitors by applying voltages 150 to 200% greater than the rated voltage. In addition, applied voltage tends to have minimal influence on lifetime. Because of this fact, the derating guidelines specify a maximum applied voltage of 80 to 90% of rated voltage, although some manufacturers apply 90 to 100% of rated voltage.

Once you target a desired life cycle for your design, you can decide on the appropriate temperature derating. The industry-accepted equation is a doubling of life for every 10[degrees]C drop in temperature. Although some questions exist concerning the accuracy of this model, designers must be aware of three nuances. The first is that this life equation is relatively conservative-at least for reputable capacitor manufacturers. Vendors often define 'lifetime' as 1 or 0.1% of failed parts, as opposed to the more standard MTTF (mean time to failure), which might yield a 63% failure rate. If your design lies between these extremes in desired lifetime, then it should be OK. Second, few applications experience constant temperatures. Users turn computers on and off, the sun rises and sets, and other similar temperature-affecting conditions occur. Make sure to incorporate variations in temperature into any lifetime calculation. Finally, all bets are off if there is elevated temperature due to an adjacent component, such as a resistor or a MOSFET. Some indications show that a highly localized temperature increase more quickly induces failure than the industry model predicts. Keep hot components away from electrolytics.

Ripple current on electrolytic capacitors is an odd electrical parameter. Designers tend to ignore or forget it in most bill-of-materials calculations. Remember that 'equivalent' capacitors are not equivalent when it comes to ripple-current ratings. And manufacturers can 'uprate' ripple current. Some companies allow applied ripple current to be 150 to 200% of rated ripple current. They achieve this flexibility because ripple current primarily increases capacitor temperature, and vendors often specify capacitor lifetime at rated temperature and rated ripple current. The lower the temperature at which the design can operate, the higher the uprating margin on the ripple current.

Designing for reliability plays a critical role in the ultimate success of a product and the company's bottom line. You must assess the evolving design, find potential weaknesses, and solve problems before they escalate. Recognizing and addressing potential problems will prevent manufacturing and supplier-quality issues later in the process-and will let you sleep better at night.

Craig Hillman, PhD, is chief executive officer and managing partner of DFR Solutions (www.dfrsolutions.com). He has a postdoctoral fellowship from Cambridge University, a doctorate from the University of California, and a bachelor's degree from Carnegie Mellon University (Pittsburgh).

Reference

Norris, KC, and AH Landzberg, 'Reliability of Controlled Collapse Interconnections,' Journal of Research and Development , pg 266, IBM, May 1969.