BY RICHARD A QUINNELL • CONTRIBUTING TECHNICAL EDITOR

ROHS compliance: IT'S NOT EASY BEING GREEN

EUROPEAN ENVIRONMENTAL DIRECTIVES TAKE EFFECT SOON, LEAVING MANY US COMPANIES STRUGGLING TO OVERCOME THE CHALLENGES OF IMPLEMENTING COMPLIANT DESIGNS.

On July 1, 2006, electronic equipment sold in the European Union will have to comply with the ROHS (reduction-of-hazardous-substances) directive or face both removal from the market and assessment of substantial fines. However, some exemptions to this act are causing component suppliers to offer both ROHS-compliant and -noncompliant stock. This situation leaves design engineers with the sometimes-frustrating task of finding and qualifying the right components to ensure a compliant product.

The ROHS directive seeks to prevent environmental damage by eliminating dangerous materials from electronic equipment that may eventually find their way into landfills where they can contaminate ground water (see **sidebar** "ROHS in brief"). To enforce compliance, the directive allows member states to ban the sale of noncompliant products and to levy substantial fines on the product manufacturers. Manufacturers that fail to adhere to the ROHS directive thus risk losing out on participation in a multibillion-dollar market with some 400 million potential customers.

One of the restricted materials is lead, which manufacturers have widely used for more than 50 years as a prime component of solder and connection plating. Unfortunately, lead-free solder alternatives, which use high concentrations of tin, have some drawbacks that make them more difficult and costly to use than traditional solder formulas. These drawbacks include higher melting temperatures, greater rigidity, and lower surface tension when liquid, which affects the solder's ability to pull surface-mount components into alignment. One major concern regarding tin-based plating is its tendency to generate microscopic extrusions, or whiskers, from surfaces after manufacturing. These whiskers can grow long enough to form short circuits in fine-pitch packaging and can break off to contaminate pc boards.

With all these drawbacks, it is no wonder that the electronics industry did not willingly switch to lead-free solder; it took regulatory pressure to force the changeover. The problem is that the regulatory pressure is not the same across all industries. The ROHS directive's prime focus is consumer electronics. As a result, the directive temporarily or permanently exempts several product classes, including networking equipment and industrial products for installation in manufacturing facilities (see **sidebar** "Out from under ROHS").

This uneven regulatory pressure combines with the drawbacks of lead-free solders to create a market full of a mixture of leaded and lead-free components. The ROHS restrictions on materials such as cadmium, mercury, hexavalent chromium, and flame retardants produce a similarly mixed market for wires and cables, chassis platings, and packaging materials.

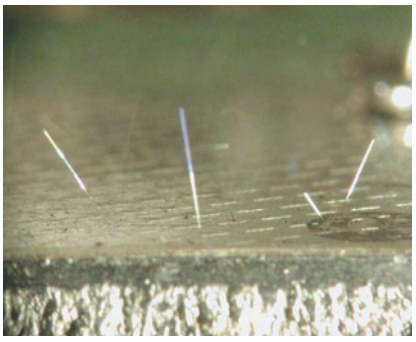
AT A GLANCE

- The ROHS (reduction-of-hazardous-substances) initiative goes into effect July 1, 2006, and restricts the use of six hazardous materials in electronic equipment, including lead in solder.
- Inconsistent parts availability and ambiguous parts-identification schemes create significant challenges for developers trying to qualify their designs as ROHS-compliant.
- Designers need to look beyond the parts to assess the impact of process changes on their design rules.
- Accounting for environmental regulations is becoming a permanent part of the design task.

The existence of a mixed market generates two of the greatest challenges facing design engineers seeking to develop ROHS-compliant products: finding parts and ensuring their compliance. Design teams are discovering that the time and effort necessary for qualifying parts for new, ROHS-compliant designs are significantly greater than they expected. That unexpected effort, along with confusion regarding exemptions, leaves some design teams scrambling to implement the ROHS directive.

Machine-vision developer Cognex represents a typical case. "When we first looked at ROHS we thought we were exempt," says Cognex hardware engineer Reza Vahedi, "but we were not convinced, so we started converting to compliant designs about 18 months ago. Later, we started getting a lot of inquiries from our customers saying that their systems needed to be compliant because their end users needed to be compliant." Vahedi reports that, when Cognex began trying to qualify components, it found no consistency among vendors in part-numbering or order-identification schemes for indicating that a component was ROHS compliant. Documentation from vendors for validating component compliance was also inconsistent.

Many design teams report similar difficulties. Michael Allen, director of engineering at Bear Power Supplies, says, "Sourcing has been a real challenge. Some companies list a ROHS part number, but it turns out they haven't started making it yet, so there are none in captivity." Allen notes that many fundamental components for use in both exempt and nonexempt applications are only now becoming available in ROHS-compliant versions and that manufacturers are making other noncompliant components. "You may have parts you have used for 16 years, such as a favorite fuse, that are just coming out in a ROHS version. But production lines have to be compliant now to meet the July 1 deadline, so design engineers are scrambling to identify and design in alternatives."



Plating materials containing high concentrations of tin can form whiskers that can cause short circuits and compromise system reliability, so many manufacturers will keep using lead for components in designs not subject to the ROHS directive (courtesy NASA Goddard Space Flight Center).

The result is a significant level of effort on the part of design teams to requalify all of their bills of material or to find alternatives when ROHS versions are unavailable. "It's a laborious process," says Allen. In some cases, he notes, a ROHS version may be available but not in a particular package style, forcing redesign of pc boards.

Allen also points out that the parts on distributors' shelves and elsewhere in the supply pipeline might be a mix of compliant and noncompliant versions and

ROHS IN BRIEF

The ROHS (reduction-of-hazardous-substances) Directive 2002/95/EC of the European Parliament imposes a restriction on the use of hazardous substances for electrical and electronic equipment within the European Union. The directive bans the use of lead, mercury, cadmium, hexavalent chromium, PBBs (polybrominated biphenyls), and PBDEs (polybrominated diphenyl ethers). Amendment 2005/618/EC clarifies the restrictions to indicate that the maximum concentration by weight in a homogeneous material for these substances is 0.01% for cadmium and 0.1% for all others.

This directive impacts the design and manufacture of electronic equipment in both obvious and subtle ways because of the widespread use of these materials. For example, lead has long been a significant component of solder and component plating. Mercury is a component of products as diverse as reed relays and fluorescent lighting. Cadmium finds use in batteries and photo sensors, as well as in wires and cables. Hexavalent chromium sees use as a plating material for electronic chassis, and manufacturers commonly use PBBs and PBDEs to make flame-retardant cloth and other materials.

Manufacturers selling products in the European Union must comply with the directive as of July 1, 2006. Member countries are free to impose their own penalties for failure to comply.

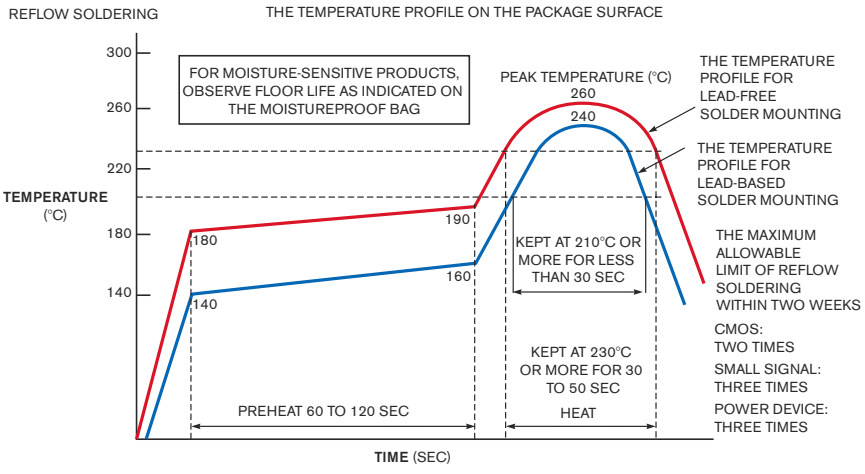


Figure 1 The surface temperature for packages soldered with lead-free materials can be as much as 40°C greater than those packages using leaded solder. This temperature difference can impact board layout and materials handling (courtesy Toshiba America Electronic Components).

that telling them apart can be challenging. "Some companies make ROHS parts, but they do not have new part numbers for them. Manufacturers may be making these ROHS parts at one plant or only after a certain date, so you have to interpret sometimes-cryptic markings to ensure compliance."

The marking issue is equally frustrating for vendors. "Our initial strategy was to not change the part numbers," says Kirk Olund, quality manager at Fairchild Semiconductor. "Making the parts ROHS-compliant had no impact on their electrical or functional performance, so we viewed it as simply being a change to the finish on the lead frame and handled it with a materials-specification-change notice. Because of pushback from our customers, however, we have now created new part numbers."

PROBLEM TEMPERATURES

Although the electrical performance of lead-free components does not differ from the performance of those with lead, designers still have other differences to consider once they find a ROHS-compliant alternative to use in their designs, Olund notes. Designers must also account for manufacturing-process changes. One of the most significant, Olund says, is the higher temperatures necessary to melt lead-free solders.

Typical soldering profiles for lead-free solder are 20 to 40°C greater than the profiles for lead-based solder. This additional heat during manufacturing can damage

OUT FROM UNDER ROHS

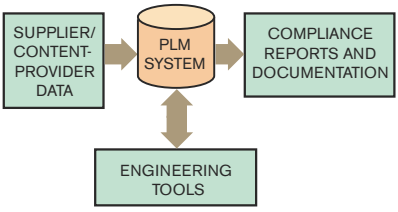
The ROHS (reduction-of-hazardous-substances) directive allows for numerous exceptions and specifies several categories of equipment that need not comply. These exceptions include mercury in several types of fluorescent lamps; lead in CRT and fluorescent-lamp-tube glass; lead in solder for servers, storage, and storage-array systems (until 2010); and lead in solder for network-infrastructure equipment. In addition, the legislation does not apply to large-scale stationary industrial tools; spare parts for equipment in service; and electronic equipment that is a component of equipment in a different category, such as a radio in a car. Batteries fall under their own regulations (see sidebar "Green batteries"). An exemption for military equipment is under debate.

components that are too close to each other. Further, the MLS (moisture-level sensitivity) of packages may be greater at the higher temperatures, requiring special handling of components while in inventory and during manufacturing to prevent moisture absorption that can result in subsequent fracturing during the soldering stage. Design engineers are typically responsible for specifying the manufacturing conditions, so they need to investigate such details when qualifying parts.

More subtle design changes also exist. Lead-free solders are more rigid than leaded solders, so designers must re-evaluate a design's resistance to vibration and shock when making a ROHS-compliant design. The wicking of liquid solder, which board fabricators use to ensure self-alignment of surface-mount components, has less effect on lead-free alternatives. As a result, the placement of components must include increased error tolerance to avoid mechanical interference and short circuits. Designers must even re-examine pc-board materials. Lead-free manufacturing's higher soldering temperatures can delaminate boards designed to use lead-based soldering.

At first glance, much of the design effort in ensuring ROHS compliance seems to be short-term. Once designers make the effort to alter their design rules and approved component lists, it appears, these new guidelines can become as second nature to them as the original ones and not permanently alter the design effort. The problem with such appearances, however, is that they do not reflect the increasing reach of environmental regulations.

The ROHS directive is only the beginning. Nations such as China and Japan are drafting their own environmental initiatives using ROHS as a template. These initiatives may have different—even



Product-life-cycle-management tools can help designers keep pace with parts-compliance issues by warehousing relevant documents and linking supplier databases to engineering tools (courtesy Omnify Software).

GREEN BATTERIES

The materials restrictions of the ROHS (reduction-of-hazardous-substances) directive do not apply to batteries and accumulators. The European Union battery directive 91/157/EEC covers these devices. This directive provides for the collection and recycling of batteries containing lead, mercury, or cadmium and requires that batteries built into equipment be removable for recycling.

However, battery packs are not totally immune to the ROHS restrictions. According to Todd Sweetland, engineering manager at MicroPower, the pc boards and charging circuits in battery packs must still meet ROHS guidelines. The battery directive covers only the batteries themselves.

The directive is also changing. The EU technical committees are updating the directive and will impose more stringent restrictions. The emerging directive will effectively ban batteries containing mercury and cadmium in most products, although medical, military, and space equipment will be exempt. The cadmium ban also allows an exemption for emergency and alarm systems as well as a four-year exemption for power tools.

Some topics under negotiation include a requirement that users can readily remove batteries from equipment and a provision that producers finance public-awareness campaigns to support recycling efforts. Recycling guidelines are also unsettled; proposals range from a goal of successfully recycling 25 to 45% by weight of batteries sold.

The EU technical committees expect to finalize the new directive by June 2006 and for member states to implement it within two years of finalization.

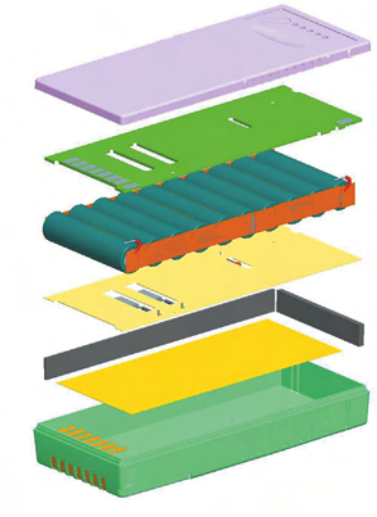
harsher—restrictions. In addition, standards bodies may eventually phase out the exemptions that ROHS currently allows. Some exemptions now have expiration deadlines. As a result, the issue of parts compliance will arise repeatedly, and designers will need to continually re-evaluate design rules and approved vendor lists to keep pace.

According to Blair Davies, director of global-design services at contract manufacturer Celestica, design engineers will need to work to keep their approved parts lists up to date. "Designers have to know a lot more than they did before," says Davies. "They have to be more involved in the selection of components. They can no longer just design-in parts and leave the rest to manufacturing. If they do, they risk designing in obsolescence as regulations and parts availability change."

One way of handling this ongoing need is to use a PLM (product-life-cycle-management) tool for tracking parts compliance as regulations change. Tools such as PLM from Omnify Software can provide a repository for documentation and data for requalifying parts when necessary. "Designers have to be cognizant of these initiatives," says Chuck Cimalore, Omnify's chief technical officer. "They also need product data and the tools to handle that data to protect themselves by keeping their qualified parts lists current."

Unfortunately, the information designers need to determine compliance as rules change may not be readily available. Cimalore notes that, although his company's tool can store compliance reports and other documentation, as well as automatically compare component data with design guidelines as regulations evolve, vendors are inconsistent in the type and format of the information they provide. Some simply provide certificates of compliance rather than full materials specifications, and others provide only partial information. "Design teams need to get their vendors to provide them the information they need," says Cimalore.

Over time, the practices and standards within the electronics industry for handling environmental concerns may finally resolve themselves. Most design teams, however, expect that this resolution will take at least several years. Meanwhile, designers will have to adapt by becoming more involved in parts qualification and in assessing the impact of process changes. Because, whether they like it or not, green design is becoming the way of the world in electronics. EDN



The batteries in battery packs are exempt from the ROHS directive, but the charging circuits and other elements of the pack may not be (courtesy MicroPower).

AUTHOR'S BIOGRAPHY

Contributing Technical Editor Richard Quinnell has been covering technology for more than 15 years. He has been a practicing engineer in embedded systems and has degrees in engineering and applied physics.

FOR MORE INFORMATION

Bear Power Supplies
www.bearpwr.com

Celestica
www.celestica.com

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MORE ROHS COVERAGE

The March issue of *EDN*'s sister publication, *Electronic Business*, includes a ROHS feature that addresses the cost to the OEM, implications in the supply chain, exemptions from compliance, and how some companies hope to offset the cost of ROHS through premium customer services. Read the article at www.eb-mag.com/ROHScosts.