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Massachusetts a safer
place to live and work*



Vicor's RoHS Initiative

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Introduction

Vicor Corporation, headquartered in Andover Massachusetts, designs, manufactures and markets modular power components and complete power systems used in the communications, data processing, industrial controls, test equipment, medical and defense electronic markets. Vicor is the only high-density converter manufacturer that exclusively manufactures all products in the United States. Engineers use the combined advantages of Vicor components to create compact, highly functional, economical products with streamlined development cycles that minimize time to market. The company employs 1200 people worldwide, most of them in Massachusetts.

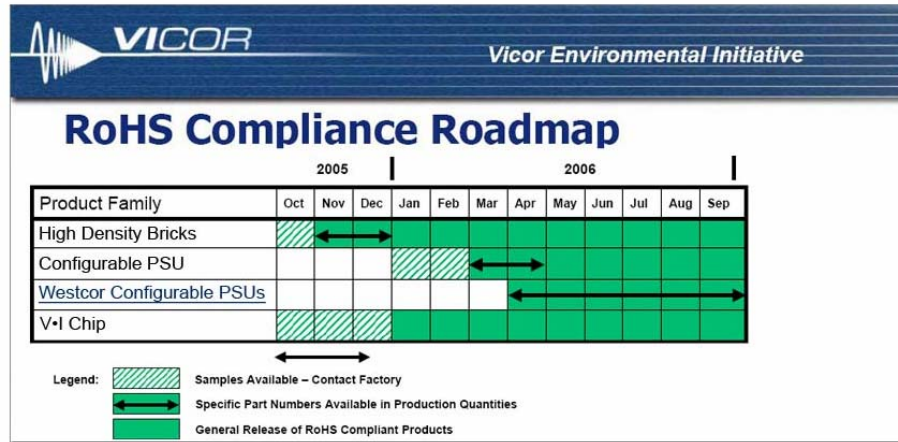
As a global leader in high-density power solutions Vicor is committed to taking an active role in protecting the environment. An ISO9001: 2000 registered company, Vicor is dedicated to developing and maintaining controlled business, design and manufacturing processes to competitively service its world-wide customer base. Vicor uses its Environmental Management Systems to assure that it meets government regulations, international standards, and its customer's requirements.

In February 2003, legislation was enacted in Europe (Directive 2002/95/EC) restricting the use of certain hazardous materials in electrical and electronic equipments placed on the market beginning July 1, 2006. This Restriction on the use of certain Hazardous Substances (RoHS) Directive limits the amount of six environmentally hazardous substances allowed in electrical and electronic equipment:

- Lead (Pb)
- Mercury (Hg)
- Cadmium (Cd)
- Hexavalent Chromium (Cr+6)
- Polybrominated Biphenyl (PBB)
- Polybrominated Diphenyl Ether (PBDE)

Vicor made a commitment early on to fulfill the requirements of the European RoHS Directive. Fundamental to its product transition strategy was a focus based upon product families rather than by product part number. Vicor's goal was to be compliant with the RoHS requirements by December 31, 2005 with individual product families achieving compliance at different times throughout 2005 through 2006, as shown on the roadmap below. It was critical to Vicor to produce

RoHS compliant products without compromising form, fit or function and that performance and reliability met or exceeded that of current products. Once a product family was deemed compliant and had completed any necessary performance and qualification testing, reliability data and samples were made available to customers on request.



Vicor’s RoHS Program Management

Vicor’s management directive was to comply with the RoHS Directive by the July 1, 2006 deadline while continuing to provide customers with legacy product and minimizing process and material waste. Additionally, Vicor wanted to ensure that this project could be achieved with no new short or long term additional personnel and with systems that would ensure long term continued compliance. Lastly, the success of this program was dependent upon the involvement and ownership of all disciplines throughout the corporation.



Five Major Engineering Achievements in Making Vicor Products RoHS Compliant

Five major engineering and sourcing achievements were realized as part of the RoHS conversion project: replacement schemes for chromate conversion coating, replacement laminate and plating finish schemes for printed circuit boards, mitigation of tin whiskers, supplier controls, and documenting purchasing requirements.

1) Conversion Coating

Vicor relies heavily on aluminum products to transfer heat out of its high operating temperature products. To ensure long term corrosion resistance, most aluminum products were finished with clear chromate conversion coatings. These coatings contain hexavalent chromium which is one of the six banned RoHS substances. RoHS allows the use of trivalent chromium but, due to anticipated future customer requirements for no chromium, Vicor chose to seek out a completely chromium free clear finish that would offer similar corrosion resistance to chromate.

Extensive research of non-chromate conversion coatings available throughout the world led Vicor to two alternative choices: MacDermid Iridite NCP and Sanchem Safeguard CC-3400. These two coatings were identified as the only non-chromate conversion coatings available in the market that meet the corrosion resistance required for Vicor products. Both coatings were evaluated and qualified to ensure that Vicor had more than one solution from which to choose. An additional consideration for Vicor was the availability of these non-chromate conversion coatings. Sanchem is available in the US but is currently very difficult to procure overseas while MacDermid Iridite NCP is available globally. Since Vicor procures some aluminum products out of Asia, they needed to ensure that their Asian suppliers had access to an approved coating so that Vicor could continue to have parts sourced in both the US and Asia.

Although the chemicals were available, Vicor could not find a supplier locally or globally that was production ready with a RoHS compliant clear chromate replacement. Vicor worked closely with a number of local plating houses to develop and qualify their processes for use on Vicor product. Once the local process development was completed, Vicor expanded its efforts with Asian suppliers as they also had no experience with RoHS compliant clear chromate replacements. Through Vicor's efforts with its suppliers, these suppliers were now able to market these chromium-free finishes to other customers as well.

As a result of changing the conversion coating, the surface preparation and appearance of Vicor's products changed from a stroked /sanded appearance to a tumbled appearance. Extensive product qualification testing and refinement were performed by Vicor to ensure that these products were equal to or better than those produced by chromate conversion coating.

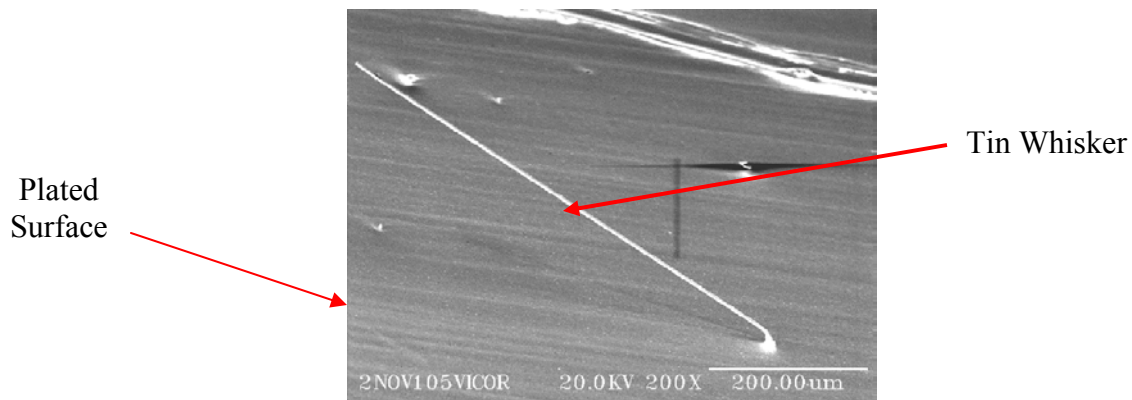
2) Printed Circuit Boards

Vicor's products are high-density electronic assemblies using high technology very thin and complex multilayer printed circuit boards with 2 ounce copper layers. Vicor printed circuit boards have very specific and exacting specifications due to their complexity and demanding requirements. These variables made it all the more difficult when searching for completely new RoHS compliant laminate selections and plating finishes for the boards. During the initial RoHS testing phases, Vicor discovered that its laminates would not survive the reflow temperatures required for lead free processing therefore they needed to find laminates and finishes that could be sourced globally while achieving strict cost requirements.

As the investigation progressed, Vicor found that laminate availability and selection were dependent on geographic location. Laminates that were available in North America were not available in Asia and vice versa which led to evaluation of numerous lots of different laminates from different suppliers. From this testing Vicor also discovered that laminate selection was design specific. A laminate that worked on one product family did not always work on another product family. As a result of six months of testing, Vicor approved one laminate and finish for North American suppliers and two laminates and two finishes (one for each product family) from Asian suppliers.

3) Mitigation of Tin Whiskers

RoHS compliance requires elimination of lead in solders. Unfortunately, the lead serves to retard the growth of tin whiskers which can grow over time and create electrical short circuits and general havoc within a product. A photograph of a tin whisker is shown below.



To combat tin whiskers while complying with RoHS, where previously tin-lead platings were specified Vicor chose whisker resistant 100% matte tin finish with a nickel under plate.

Industry data shows that 100% matte tin has been used since 2003 with no issues on semiconductor plastic molded packages, ceramic components and magnetic leads. The matte tin produces a significantly larger grain size that inhibits whisker growth, as compared to bright tin which has a comparatively very small grain size that is prone to whiskering. An additional advantage that Vicor products have to inhibit whisker growth is a conformal coat of thermally conductive encapsulant which entraps the plating and does not allow any room for whisker growth.

4) Supplier Controls

Vicor's ability to comply with the RoHS Directive was impacted by its supplier's ability to deliver compliant parts. To understand the scope of how purchased parts would be affected, Vicor sent an electronic survey to all active suppliers specific to RoHS compliance. From these responses, a master list of the status of each part was created and maintained. Each part is identified with a code from 1 to 10 with 1 being fully compliant and 10 being worst case non-compliant. Codes were then assigned to all Vicor parts including through the top level completed assembly. Parts that were identified as noncompliant were targeted for specific changes required to make them compliant or for replacement.

For standardized reporting that can be used internally or externally (customers or suppliers) an additional effort will be forthcoming to have suppliers submit their RoHS compliant material declarations on the new industry accepted IPC 1752 Materials Declarations sheet.

5) Documenting Purchasing Requirements

Vicor learned early on that there was significant confusion industry wide as to what was acceptable and what was not acceptable for RoHS. To ensure that Vicor's RoHS requirements were clear, one standard document (CST-0001) was created to cover all aspects of purchased products. This document specifically addresses each of the RoHS banned substances including identification of Vicor's approved alternatives when known, including alternatives for tin lead platings, chromium conversion coatings and printed circuit board laminates and finishes.

Use of CST-0001 across the supply base allowed Vicor to educate its current suppliers as well as to have a standard specification that could be sent out to new suppliers.

RoHS Data Infrastructure

Vicor uses PeopleSoft as its Enterprise Resource Planning software. Due to the scope of the issue, careful planning and control of this data infrastructure was required to assist in tracking the manufacture and sale of RoHS and non-RoHS compliant product. Annual sales for Vicor are \$180M and 1.65 million top level assemblies are produced annually from 74,000 work orders from complex Bills of Material (BOMs) that are up to 11 levels deep. Over 8,000 different model types are sold to over 8,000 customers.

Vicor decided to assign new part numbers for its compliant products and as product families became compliant they would be identified with a new part number. All piece parts were controlled with the RoHS code previously discussed and documented in the approved vendor listing within PeopleSoft. Nightly data processing is done to automatically identify and graduate RoHS compliant BOMs as they are completed.

In order to not strand non-compliant inventory and therefore require a financial write off for scrap, a custom “use up” functionality within PeopleSoft was created. This functionality identifies and monitors inventory levels of the non-compliant part and its compliant replacement. As inventory is reduced of the non-compliant part, demand for this part is reduced and the demand is then placed for the replacement. In this manner, a seamless inventory transition from the old to the new products can be completed with little or no financial loss associated with an inventory write off.

Major Manufacturing Initiatives to Build RoHS Compliant Products

As part of the RoHS readiness reviews, the entire manufacturing process needed to be analyzed. During this analysis, Vicor identified that solder compositions needed to be changed, alternate pins needed to be created and new reflow profiles were required for the surface mount reflow and wave soldering.

All tin lead solders were replaced with high temperature SAC305 alloy which in turn lead to complete new recipes for soldering. Through careful experimentation, specific profiles were identified and catalogued that provide proper wetting while ensuring no damage to the assembly from high temperatures during processing.

Vicor offers both the non-compliant and compliant product to meet customer needs. Eventually, all products will have the same components internally with the only difference between leaded and non-leaded customer interconnect pins. For this reason the first generation product line needed to have distinguishing characteristics added to the RoHS pins to ensure that product did not get mixed with non-compliant product. Although this would appear to be a subtle change, it actually comprises two separate manufacturing lines to ensure no mixing. As part of the RoHS effort new reflow ovens and wave solder ovens were purchased to build compliant assemblies to achieve these profiles.

As with all manufacturing process changes in accordance with ISO 9001 2000 all operators were retrained to the new procedures and appropriate manufacturing work instructions were updated. This included operator training to the new appearance of high temperature solder joints and to allow for accurate inspection of the new solder joints.

Ensuring Customer Needs Are Met

To ensure customer needs are met, Vicor completed a full product qualification on all RoHS product families. In addition, physical analysis was performed to ensure that Vicor's products are indeed RoHS compliant. Vicor's RoHS compliant products also have specific part numbers to clearly identify them as compared to the non-compliant part. Vicor has a RoHS declaration of compliance that ships with the product and is also available on our website. Lastly, a RoHS literature packet was prepared to educate Vicor's customers on all aspects of its RoHS program.

Product Qualification

Qualification of RoHS product families was looked upon as similar to new product qualification. Vicor's expectations with respect to the performance, quality and reliability of their product did not change. The testing includes electrical, mechanical, and environmental testing as summarized below:

- Thermal Shock, High/Low Temperature Test (operational)
- Accelerated Life Testing
- Vibration (operating and non operating)
- Highly Accelerated Life Testing (HALT)

All test results were documented and distributed to the engineering team members for review. Anomalies or failures were investigated and corrective action documented. Most importantly, product was not transferred to the next stage until the product met Vicor's product quality and reliability requirements.

Equally important has been a continuous process consisting of ongoing reliability and qualification testing throughout the manufacturing life of the product. This testing provides Vicor with a method to verify that the product meets or exceeds quality and reliability requirements.

Physical Analysis

To ensure that Vicor's products are RoHS compliant, independent external test laboratories have been employed to evaluate the content of product for the restricted substances. Typical analysis has involved grinding up a completed Vicor module and analyzing the resulting material. Normal reporting by the testing laboratory includes actual amounts in parts per million (PPM) of the restricted substances present in the bulk product. This information is used as a benchmark indicator for Vicor. In the event that a restricted substance is detected in significant concentrations, more rigorous testing at the homogenous material level is conducted to assure that Vicor's products meet the RoHS Directive maximum weight percentage requirements.

Vicor believes that this testing is critical to ensure that products are in compliance with the RoHS directive and validates all efforts that have been made to ensure compliance.

RoHS Product Numbering

Vicor proactively surveyed its customers early on in the RoHS program to see what preference they would have for either a completely new Vicor part number or an effectivity date for an existing part number. Universally, customers stated that they would prefer a completely new part number for the RoHS compliant part.

As a result, all Vicor saleable modules are clearly discerned from the non-compliant versus the compliant module via part number identification. For example, all VI-200 products that are non-compliant are identified by their original part number as VI-260-CU while the compliant part is identified with an “E” after the first letter V such as VE-260-CU. Similar naming conventions have been carried across all product families.

RoHS Declaration of Compliance

Vicor ships an imbedded certificate of compliance showing specific model number compliance with RoHS with every packing slip. Additionally, platform specific RoHS declarations of compliance are available on Vicor’s website. See the examples below.



400 Federal Street
Andover MA 01810
United States
978-470-2900

Packing List

Ship To: 1834-A
1-3 COMMUNICATIONS TELEMETRY-EAUF
1515 GROUNDY LANE
BRISTOL PA 19007
United States

Order Number:	Date:	Page:
V019815	01/29/2006	1
Ship Via:	Payment Terms:	
UPS	Net 30 Days	
FOB:		
FOB Factory Collect		177699
Customer PO:	Letter of Credit:	
20058		
Shipment ID:		
00012878		



00012878VICOR

Line	Sched	Product Number	Actual	Scheduled	QTY	QTY	QTY	Customer Part	
Item		Description			Ordered	Shipped	Backorder	Number	
1-1		VI-PP22-COX (Internal Item Code: #1164) VI-PP22-COX 300V/15V/15W (RoHS COMPLIANT PRODUCT)		12/23/2005	12/23/2005	EA 1	1	0	136-198-202 /FR0

CERTIFICATE OF CONFORMANCE: WE HEREBY CERTIFY THAT THE ITEMS LISTED HAVE BEEN INSPECTED AND TESTED IN ACCORDANCE WITH OUR WRITTEN PROCEDURES, MEET OR EXCEED ALL REQUIREMENTS HEREIN, AND THAT ALL ITEMS ARE IN CONFORMANCE WITH APPLICABLE CUSTOMER SPECIFICATIONS. RECORDS SUBSTANTIATING THIS ARE ON FILE AND AVAILABLE FOR REVIEW.

ALL C OF C'S ISSUED BY VICOR CORPORATION ARE VALID WITH AUTOMATED SIGNATURE.



VICOR IS COMMITTED TO FULLY COMPLY WITH THE EUROPEAN UNION'S RESTRICTION OF USE OF CERTAIN HAZARDOUS SUBSTANCES IN ELECTRICAL AND ELECTRONIC EQUIPMENT (ROHS) DIRECTIVE 2002/95/EC. VICOR CERTIFIES THAT ITS ROHS BRANDED DEVICES, ARE TO THE BEST OF IT'S KNOWLEDGE, ROHS COMPLIANT AND CONFORM TO THE ROHS DIRECTIVE 2002/95/EC. PLEASE SEE VICOR'S WEB-SITE WWW.VICORPOWER.COM FOR PRODUCT PLATFORM SPECIFIC ROHS DECLARATIONS.

Rich Paulauskas
Senior Manager, Quality



Order Comment: BUYER NAME & NUMBER:
RENEE HALBERG 267-645-7239



Declaration of EU RoHS Compliance

Vicor's VE-200 Series Platform

Compliance Certificate for Vicor's RoHS Branded Products
Vicor certifies that to its knowledge RoHS Branded products meet the Directive 2002/95/EC of the European Union's Restriction of the use of certain Hazardous substances in Electrical and Electronic Equipment (also known as the "RoHS Directive").

The certificate is applicable to the following Banned Substances and the maximum concentration values as listed in the table below:

Banned Substance (Element / Compound)	RoHS Maximum Concentration Limit (PPM)
Cadmium (Cd).....	100
Lead (Pb).....	1,000
Mercury (Hg).....	1,000
Chromium (Cr6).....	1,000
Polybrominated Biphenyls (PBBs).....	1,000
Polybrominated Diphenyl Ethers.....	1,000

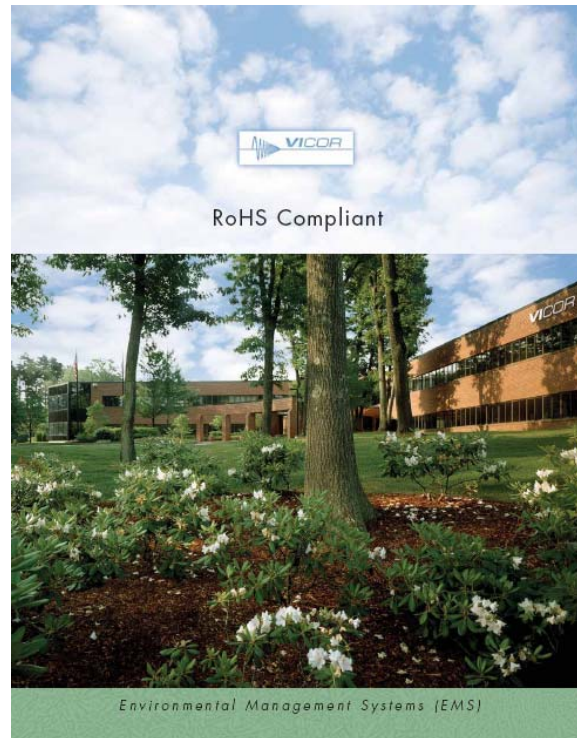
In addition, Vicor requires that its parts and material supplier require providing their company's declaration sheet that guarantee their products comply with RoHS Directive as well.



Michael McNamara
Senior Director, Quality
Vicor Corporation

RoHS Literature Packet

For those customers who may be unfamiliar with RoHS or who would like to better understand Vicor's RoHS program, Vicor prepared a RoHS literature packet that fully explains the program and the differentiation and availability of both the non-compliant and RoHS compliant product to serve all customer needs.



Community Benefits

Vicor, its stakeholders and the community as a whole will experience numerous benefits as a result of the RoHS program. The expected RoHS program benefits include:

- Elimination of 1,445 pounds of lead used in solder annually.
- Elimination of 1,337 pounds of lead used in solder paste annually.
- Elimination of 645 pounds of lead used in circuit boards annually.
- Reduction in lead air emissions by 99.96% annually.
- Reduction in the disposal of lead-based hazardous waste off site by 100% annually.

In addition, after the complete transition to RoHS compliant products, Vicor may be able to entirely eliminate regulatory reporting under the federal Community Right-to Know law (SARA Title III, Section 313) and the Massachusetts Toxics Use Reduction Act (TURA). The elimination of reporting fees and hazardous waste disposal costs should save several thousand dollars per year.