Test & Measurement Coalition

Sector Description

RoHS Scope Review of Category 9 Products

18 January 2006

The monitoring and control instrumentation category sector is not currently in the scope of the RoHS Directive 2002/95/EC restrictions. This category will be reviewed by the Commission to assess feasibility of bringing this type of equipment within the scope of the Directive.

We are pleased to provide ERA with this background paper describing the specificity of our sector as a subset of Category 9 and pointing out key issues to be taken into account in the recommendations to the Commission regarding the scope of RoHS, exemptions and transitional periods. Our coalition members have endorsed the contents of this background paper and associated papers on substitution possibilities of RoHS substances in our products.

The Monitoring and Control category sector may be divided into three sub-sectors:

1. Test & Measurement Equipment – applications of measurement products are for accurate measurement and analysis (testing), accurate signal sources or continuous monitoring. A few products have control functions. This sector provides equipment for many industrial applications including electrical and electronic product for testing electronic assemblies, industrial plant maintenance, and chemical analysis.

2. Industrial Automation – equipment for monitoring and control of manufacturing processes based on measurement and feedback on physical parameters.

3. Office and Domestic Monitoring – metering and control of temperature, electric power, gas, smoke detectors etc.

The Test & Measurement Coalition

The Test & Measurement (T&M) coalition members represent more than 60% of products by volume in the first sub-sector. We recognize that all sub-sectors have overlapping products. The T&M products provide the capabilities to make accurate and reliable measurement for industry and standards laboratories. Data on the product types we make, their applications, and the use of RoHS substances in our current products is detailed in Annex I; it represents the portfolio of five major T&M producers. It is self evident these five major producers have a wide variety of

specialized products sold in relatively small volumes compared to producers of electronic consumer products.

Bringing Category 9 into scope will require significant substitution and redesign of the large number of products due to extensive use of lead solder. Assuming that drop-in replacement, compliant components were available, compliance will require re-qualification of virtually all products after new designs are assembled with lead-free solder. **Qualification testing alone on the large number of products we make will have a major impact on our industry and on our customers even without additional practical issues to solve.**

Investigations and trials by member companies have uncovered many other compliance problems. The practical issues are:

- Redesign often presents significant technical challenges that take time to resolve – it can be 1-2 years before a new product can be released and 0.5-1 year for an enhancement. A significant amount of the time is required for environmental and safety testing of new designs.
- 15 - 20% of the components used in Test & Measurement products are custom designed for our instruments. As many of our members use around 100,000 different parts today this means redesign and testing of several thousand custom parts for each company.
- Where RoHS compliant components are available, they require extensive testing to verify their long-term reliability when used in Test & Measurements products.
- Test & Measurement products have a long product life (≈10 years on average) and frequent redesign is not common for the sector, further emphasizing the need for extended transition periods to achieve compliance with existing resources.
- Test & Measurement products are extremely complex and there are a limited number of highly qualified engineers available to work on redesign. This will divert significant resources from the development of new, innovative products.
- Material substitutes meeting our customers' reliability criteria are limited in some instances. For example a domestic household product with expected life of five years has more material options for anti-corrosion coating than a Test & Measurement product for outdoor use which customers expect to work reliably for ten years or more.
- Historically, material or component substitutions have been validated through a number of tests under extreme conditions. Testing programmes can last one or two years.
- Preliminary evaluation of several RoHS compliant substitutes in our critical applications has so far yielded less than satisfactory results. [*Member's work on RoHS compliance to date is described in section 4]*

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1. Products and Services in Test & Measurement

A. Products

Test & Measurement products include a wide range of electronic instruments including electronic counters, signal generators, logic analyzers, oscilloscopes, network analyzers, spectrum analyzers, power meters, multimeters, audio analyzers, medical test equipment and communications test equipment. Advances in science and technology require that measurement devices must continue to evolve with respect to measurement capabilities and accuracy. "It is thus axiomatic that sophisticated science and technology are associated with sophisticated measurements, while simple-minded science is associated with only elementary measuring techniques." (Electronic Instrument Handbook, 3rd edition, McGraw Hill, 2000, page xxiii) Over the past 30 years, the number of available instruments has greatly increased along with their speed, accuracy, and precision. All engineers and scientists must utilize measurements to develop, produce, test and qualify products. In order to support the advancements of science and technology, the T&M industry must continue to invest and innovate to advance measurement science. As an industry we invest heavily in research and development. Our companies invest on average 10% of revenue in R&D.

The members of the T&M Coalition offer a very broad range of products (see Product types table in Annex I). These products are widely used in a vast array of different contexts: used by public or private economic operators as well as public authorities, for monitoring or controlling virtually any conceivable parameter, in applications as diverse as industrial processes, environmental compliance testing, health care, scientific and medical research, and many more.

We have a large range of different products (each company is producing 1,600 product types on average), which have a high market value (product prices range from 100Euros to 1,000,000Euros, the average price is 5,400Euros) and a large degree of customisation to meet the specific performance and reliability requirements of our customers. This is in contrast to consumer electronics producers, who typically have smaller product ranges, lower unit prices and a decreased expectation of reliability.

Test & Measurement products account for less than1% by weight of the EU market for electrical and electronic equipment[1].

The members of the T&M Coalition estimate that they have a combined market share of over 60% by value of the Test and Measurement market in the EU.

[1] http://www.el-kretsen.se/Index-e.htm

B. Services

Since the products we sell are highly complex, and can be customized into customer specific systems, and, on average, command high prices, service contracts are often sold at the time of purchase or after the warranty has expired. On average 16.5% of our products are sold with service contracts. Our companies provide the following services to their customers: maintenance, replacement parts sales, repair, calibration, refurbishment, trade–in programs, etc. Onsite service is offered to customers where required. This service strategy supports our customers' expectation to maintain continuous uptime and long-term reliable performance. Customers requiring long-term service support include metrology centres, universities, government agencies, military, aerospace, and private and public R&D centres.

2. Nature of Operations

A. Quantities (see Annex I)

Unlike consumer goods, Test & Measurement equipment is not subject to fast-paced changes in market patterns. The market is slow moving. EU customers buy small quantities of our products (350 units on average per product per year in the EU total). Some systems are sold in very small quantities (2-10) whereas our highest volume products may reach 5,000-10,000 per year. They are primarily sold to laboratories, universities, government and industry rather than to private consumers.

B. Lifetimes

The products we place on the market typically last for many years - between 5-30 years and 10 years on average. The lifetime of any given unit can often be extended through regular maintenance and servicing.

C. Design cycles

The quantities and long lifetimes of Test & Measurement equipment are closely related to the design cycle. Our products do not undergo frequent re-design, because there is little market demand for such changes. Whereas a television or mobile telephone's existence on the market may last for two or three years, we typically offer our products for much longer periods. Products are redesigned every 5 to 15 years with an average of 7 years.

D. Human resources

Our companies make very different use of human resources from consumer goods producers. While fast-paced market changes require frequent re-design of consumer electronics, the slower market evolution our sector sees, and the fact that a broader range of products is on offer at any given time, means that we employ a comparatively smaller number of people to look after a broader range of products. Test & Measurement instruments are so complex that it takes a substantial amount of time to train skilled engineers to the necessary level of sector-specific expertise to allow them to redesign products. The redesign process therefore poses a practical execution problem for the T&M industry.

We employ 820 engineers on average per company. However these include service engineers, support engineers, hardware designers and software writers so only a limited number have the necessary skills to evaluate components and redesign products for RoHS compliance. A typical situation is one where, on average, one design engineer is responsible for 8 different product lines.

Redesign is not common for our sector. The majority of our engineers are dedicated to new product development and new technological innovation. This is important in our business sector in order to meet the technology needs of our customers and meet our growth objectives.

Without a reasonable phase-in process for the use of hazardous substances, assuming we will come into the scope of the RoHS Directive, the majority of available resources would need to be applied to the redesign of current products. The process to redesign the products to RoHS requirements is almost as long as the new products design process requiring the utilisation of all available engineering resources.

Increasing engineering capacity would not solve the problem as design engineers are highly specialised in this field and require several years of sector-specific training. This would put our companies in the position of sacrificing forward technology needs of the Test & Measurement industry or sacrificing sales into the European Union. Further, European Union customers would be adversely affected as they would not have access to the technological advances that these products bring to the manufacturing industry, educational institutions, health care, laboratories, and research and development facilities.

E. Product Obsolescence

Without a reasonable transition period for RoHS compliance, our companies will be forced to obsolete many older products. In many cases we will not be able to get a return on investment from redesigning older products because of the resources involved. Forced obsolescence will have a significant impact on companies who have invested in modular T&M systems. A modular T&M system consists of individual products residing in a rack/chassis to create a modular system. A modular system can be continually upgraded as application needs change or as individual parts fail and need to be replaced. Because many older products will become obsolete a customer will no longer be able to replace only the portion of his system that fails to meet new requirements. The entire system will need to be scrapped and a new system purchased causing two effects. First, more equipment than necessary will become waste having an environmental impact. Second, the customer will have a significant financial burden due to:

- The cost to replace an entire system which could easily exceed the cost of a single product by many times
- The additional testing time required to qualify an entirely new system, and

- The impact of system downtime on research, development or production

3. Reliability requirements of Test & Measurement Customers

A. Reliability

Reliability of a product is essentially the probability that the product will perform its intended function under given operating conditions for a specified period of time without failure. Reliability is a key requirement and concern from our customers. It is imperative to our customers that we verify any product changes made for environmental compliance reasons do not reduce product reliability.

Our products command comparatively high prices. They are used for monitoring and control of parameters and processes that are often critical to the continued and effective functioning of the economy and to the protection of the environment from the risk of disasters. Although our products do not always control mission critical processes, they are often used to calibrate and test equipment that is used in mission critical applications. For instance, conformance testing ensures public safety by monitoring performance of products to limit radiation and signal interference, thus ensuring critical communication and meeting general public and private infrastructure needs.

Our products are used by laboratories (for technological research), universities (for technical training and education), manufacturers (for product development and manufacturing of their products), government agencies (for conformance testing and R&D), military customers (for defence research), etc. They are essential to the good functioning of electronic communications networks, heavy industrial processes such as steel manufacturing, the testing of vehicles for compliance with emissions standards, and the monitoring of complex systems such as in-flight diagnostics for aircraft. The list is long and pervasive.

Our customers require that our products have greater bandwidth, accuracy, and precision than the products they themselves are producing. Reliability and accuracy of Test & Measurement equipment are important in applications such as screening for cancers, where quality and integrity of data is important for correct trustworthy decisions; similarly in standards laboratories for electrical calibration, and for chemical tests in environmental or drug analysis.

Examples of critical applications with reliability needs of our products are given in Annex II.

B. Reliability constraints imposed by our customers

Our customers are intolerant of system failures that interrupt their research and manufacturing processes. Test & Measurement products must meet

their requirements to ensure their operational and uptime expectations. Customers expect more than 10 years of product life, and many products purchased 20 years ago are still in use. One of the biggest differences between Test & Measurement equipment and other electronic products is the expected useful life of our products.

Our customers require that our products meet pan-European ISO 61010 safety standards. In addition, many are certified to CE, UL, CSA, CUL, VDE, TÜV, and multi-national safety and reliability standards. Additional standards may be applied to products in some specific customer sectors including military/aerospace, pharmaceutical and food safety.

Reliability constraints may be imposed or negotiated in customer contracts:

- Some aerospace customers impose conditions (solder composition, component termination finishes) to minimise tin whisker growth because lead-free solder combined with poor material finishes are known to cause premature failure.

Some customers with critical applications impose financial warranty replacement conditions to enforce overall reliability including clauses such as:

- Warranting against design defects in addition to normal warranty for material and workmanship
- Turnaround repair-time limits to get units working after callout – over 95% of call outs are fixed within two working days
- Epidemic failure clauses – Epidemic failure occurs when a specified percentage of products purchased contain the same defect or originating cause of defect in a consecutive period, typically of 24 months. If so, the producer is required to provide a remedy plan within a few working days to correct the units. Furthermore and to the extent that such epidemic failures affect customer production or service launch dates, liquidated damages may apply.

Accuracy and speed of measurement are equally important to our EU customers; in many manufacturing test applications the customer can get added value if increased throughput of tested product can be achieved by faster measurements. To this end our customers look for products or upgrades to make existing equipment measure faster with the same accuracy and reliability. Faster speed of testing is also a competitive advantage in development of new medicines based on DNA or RNA analysis using Bio-chemical analysers, where the EU is at the forefront of research.

T&M equipment is used by the Pharmaceutical Industry and Food Industry to confirm that specifications/standards defined by Agencies like the Food and Drug Administration are met. Users can be R&D departments and production departments of large pharmaceutical companies. They can also be quality control labs acting as a third party,

providing certification for agencies. Users have to follow strict requirements defined by audit rules. They can't use a new T&M Product if the one they are using becomes defective. To deal with this issue they use service contracts to get their equipment repaired on site in a defined time window like 4 hours. On the other hand measurement precision must be stable and confirmed. This is another audit requirement. In order to confirm the precision of the measurement, customers require that a Service test called operational qualification is done on a yearly basis. This type of test confirms that testing specifications of the T&M product have not changed.

The reliability requirement is one of the most fundamental drivers of our design and service activities. The market, in effect, requires much more in-depth testing of our technology in order to ensure reliability.

We demonstrate product reliability through component and material testing:

- Highly Accelerated Life Testing (HALT), shake, shock (1 meter drop, all corners), vibration (3-axis), temperature (-40°C to +50°C) and humidity (0 to 90% RHT) testing is commonplace. A product will be stressed until some part fails, then the part is replaced and the unit stressed more. When many parts have failed and are replaced with more reliable alternatives, we stop. In this way we make the most robust design possible. In addition some companies perform other proprietary tests for handheld products used in industrial environments that go well beyond the European norm EN61010.

- We monitor our product reliability in the field by researching every failure as to its failure mode and root cause. Our customers generally require a written corrective action. We set up yearly WRR (warranty return rate) reduction goals. Our average failure rates are significantly less than 1%.

- Customers want reliable products and prompt service. These factors are addressed through product design, quality of manufacture and support models tailored to customer needs. This uniqueness of our market is demonstrated by:
    - Design features to improve uptime – diagnostic software to log hours of use and prompt when key components need servicing, auto cleaning by sprays of chemical sampler trays and optics, slide out and self-aligning components.
    - Support after sales obsolescence - After a product is withdrawn from sale we support Test & Measurement customers with repair service, calibration and spare parts for 5 years on average. Standard support for Bio-chemical analysis products is 7 years as required by government environmental laboratories, hospitals and pharmaceutical customers.

How does this relate to RoHS? A new design in our industry frequently borrows heavily from core technology developed and proven over a long period of time. The redesign work that will be done on the T&M equipment to be made RoHS compliant will require retesting and re-qualification under the large number of conditions outlined above and to satisfy our customers' confidence in terms of reliability of the redesigned products. Many components (see below Product Development and Design) to be redesigned are not "off the shelf" and thus these components are not normally validated by a component manufacturer with a very large client base. The implementation of RoHS, therefore, causes tremendous practical problems that need to be taken into account in the deadlines for implementation.

C. Qualification

One of the consequences of the reliability requirement of the market is that we take great care in ensuring the quality of the parts we buy from our suppliers. The whole supply chain is subject to a degree of scrutiny and quality control that is on a scale that dwarfs similar processes in the consumer goods market.

Our companies have put in place quality control measures and have developed specific quality requirements for the suppliers.

Some companies include these quality requirements in their contracts with their suppliers. In some cases[2], third party audits of strategic suppliers have been introduced to gain assurance that the environmental and social responsibility expectations of them, including material restrictions, are being met.

Information has been provided to suppliers, giving termination finish guidelines and information on testing to the JEDEC 22A121 procedure.

Other companies require that suppliers have a quality system in place and that they conform to their corporate environmental policy. To enforce this, most T&M coalition members have a quarterly scorecard, which includes a quality component.

Similarly our customers impose qualification requirements on our products. Chemical analysis users employ the definitions for Qualification by the Analytical Instrument Association, Sept. 1996:

Installation Qualification (IQ)
"Establishes that the instrument is received as designed and specified, that it is properly installed in the selected environment, and that this environment is suitable for the operation of the instrument."

[2] http://www.agilent.com/environment/env_expectations.shtml

Operational Qualification (OQ)
"The process of demonstrating that an instrument will function according to its operational specifications in the selected environment."

Performance Qualification (PQ)
"The process of demonstrating that an instrument consistently performs according to a specification appropriate for its routine use."

4. The T&M industry and transition to RoHS compliance

A. Research and Development

T&M Coalition members are among the most active members of the NEMI Pb-free Task Group[3], as well as other organisations such as HDP-UG, IPC, JEDEC, iNEMI, IEEE, that support the technology design demands of the Test & Measurement industry. It is important to note that T&M Coalition members have significant knowledge and experience in this area.

B. Product Development and Design

On average 15 – 20% of the components in our products are custom, they do not have drop-in replacements and are specifically designed for our products. This includes sheet metal parts, microwave modules, transformers, plastic moulded parts, etc.

It must be pointed out, however, that because of the nature of our products we push many off the shelf components to the limits of their capabilities. It is erroneous to assume because they are off the shelf that it is easy to make products RoHS compliant. Higher lead-free processing temperatures alone will reduce component lifetimes as well as cause drift in specifications making the design of precision instrumentation needing PPM (Parts per Million) performance difficult to achieve.

It is to be noted as well that the some of the off the shelf parts are difficult to find in a RoHS compliant version. This would require a complete redesign of the part, if possible. The parts that are not available include some of the most critical Integrated Circuits. Many instruments are designed around these components, so to use alternates would in essence mean redesigning the product from the beginning.

Even if all the parts are RoHS compliant, there is still a big question about the long-term reliability of non-lead solder assemblies. There have been no substantiated studies that allow us to predict product reliability 8-12 years into the future, while there are studies that show the possibility of tin whisker growth well within that time.

Many producers have 100,000 or more different parts used in their products.

[3] http://www.inemi.org/cms/projects/ese/High_Rel_RoHS.html

There are three categories of difficulty with regard to replacing non-compliant components:

1. 60%-80% of purchased components are off the shelf, and most suppliers are introducing RoHS compliant replacement versions. Some board mountable components are not backwards compatible with lead solder and must be assembled with lead-free solder to make reliable joints to printed circuit boards. Finished, off the shelf metal parts (nuts, bolts, etc.) with non-compliant coatings now have off the shelf compliant versions to meet a single property requirement such as anti-corrosion. Suppliers usually specify that the part meets a standard test; in this case a producer does not have to retest those parts. Where two or more properties are required to meet different standards, the possible choices narrow.

2. 10%-20% are specialized custom parts where alternative compliant materials are known to be available for similar uses. Sample compliant prototypes will have to be purchased and tested either by the producer or a qualified test company under contract. Cost and resources are involved to completely evaluate a new design before taking it to production.

3. A final 10%-20% are custom parts where no alternatives are known with all the required properties. For example, we have a large number of chromate conversion coated fabricated custom parts containing small amounts of hexavalent chromium. No substitute has yet been identified that meets the unique challenges of Test & Measurement products in controlling emitted and absorbed electromagnetic energy while offering the same high level of corrosion protection. In this situation a producer has to investigate and test potential candidate materials often employing consultants and fabrication companies with specialized knowledge to create, assemble and test prototypes.

C. Investigation of Substitutes

A considerable time is needed to evaluate **available** substitutes against the demanding requirements (reliability, speed and accuracy) of our products as compared to consumer products. Over the past five years our member companies have been investing significant amounts in testing programmes on the feasibility of removal of RoHS-banned substances from some assemblies as well as the required manufacturing processes. This has been limited by the non-availability of RoHS compliant critical components, and material processes.

The testing results showed that redesigning and re-qualifying Test & Measurement products to meet the RoHS directive will be difficult with no certainty they will continue to meet expected performance and reliability characteristics.

- Some companies have built trial assemblies and are now studying their performance. Not all the parts for those assemblies are RoHS compliant, only "Lead-free" soldering compatible, meaning in some cases that they can withstand higher soldering temperatures. Some companies have tried to obtain RoHS compliant components for over a year and finally had to start trials with mixed components.

- A member company has completed the prototype evaluation phase in a project to replace refractory ceramic fibre material used for insulation in the oven assembly of a gas chromatograph instrument. There were five potential candidate alternative materials. It took one year to find the two candidates that could meet technical and manufacturing requirements. Both suitable alternatives involve a 10% increase in cost to make the replacement oven assembly. Engineering resources required during the one-year evaluation project were:

  1 Project Leader & Mechanical Engineer (Full Time Engineer)
  1 Chemical Engineer (0.5 FTE)
  1 Quality Engineer (0.5 FTE)
  1 Procurement Engineer (0.2 FTE)
  3 Project Consultants (0.3 FTE)
  3 Support R&D Managers (0.3 FTE)

- A member company started testing programmes 5 years ago focused on substitution of lead free components into leaded solder processes, the removal of restricted fire retardants in plastics, and the use of mercury in switches and relays. $150K has been invested so far in this project. The results showed that alternative fire retardants in plastics are providing adequate performance. However, very few satisfactory results have been shown so far when using lead free components in leaded solder processes.

- Another member has been working for 3 years on testing hexavalent chromium substitutes. They are currently evaluating lead free substitute solders. The likely end date with the current resources would be about 2010. A total of 2.2 million dollars have been invested so far.

- Another member formed a cross-functional team in December 2004 which has begun to address all areas of the business affected by releasing RoHS compliant products including production, procurement, materials, equipment, and engineering.

  They first developed lead-free manufacturing capabilities and chose three existing products to prototype on the lead-free manufacturing line. The prototypes were inspected for solder joint quality by a third-party lab after production and have undergone extensive functional and reliability testing by the company's own engineering staff. While the testing results are still being analysed, there are failures, which are directly related to the higher manufacturing temperatures for lead-free manufacturing and the mechanical properties of the solder. The

company is investigating solutions to the defects found on the initial prototypes.

In addition, prototypes of additional products, which cover a wider range of product lines, are planned including high speed and high precision products. In procuring components for these additional products, significant end-of-life component issues have been found which would force a major product redesign.

- Another member is developing a number of "discovery experiment programs"; some have been completed and many are still under way to look at the feasibility of the removal of RoHS banned substances or determine where specific exemptions are required.

  The first round of discovery experiments was started in February 2004. The end date for most of these programs is estimated to be the end of October 2006. However, much of the testing that has been completed reveals data that suggests more testing will be required. Due to the precision and performance expectations of the products the company considers that the results are not "good enough" and is concerned about the degradation of performance.

  There are currently 12 discovery programs under way and actively managed by a Program Manager. These include: RoHS-compliant laminate exploration, RoHS-compliant BGA and ASIC development, testing and validation, RoHS conversion of a low cost instrument, RoHS conversion of a mid-range instrument to prove production processing, EMC validation for the replacement of cadmium plated hardware with stainless steel, last time buy supply stream continuity evaluation, conversion and evaluation of a semi-custom processor board, evaluation of highly sensitive hand-added components such as relays, oscillators, and launches, hexavalent chromate conversion coating replacement feasibility, Pb-free wave solder testing experiments, off-the-shelf and custom power supply/peripheral modules for evaluation to RoHS-compliance, and tin whisker research and experimentation.

  In addition to the 12 discovery programs there are several more product programs being evaluated by the Design for Environment team. Each program has a team of individuals representing engineering, quality, manufacturing, safety, finance, and marketing. Each program has a defined schedule and is tracked per accounting period by the Program Manager.

5. Collection, Recycling & Limited Impact on Environment and Health

The environmental impact of Test & Measurement products is very small due to the low volume of products placed on the market and the nature of our customer base. Review of the waste stream has shown that all of monitoring

and control equipment comprises less than 1% of the WEEE stream[4]. Additionally, there are high recovery and refurbishment rates for Test & Measurement equipment driven by the resale and material value contained in our products.

- All Coalition members have invested in creating take back or trade-in programs, some in operation for decades, which further limit the environmental and health impacts of our products.

- We have high recovery and reuse rates of our products. For some member companies, the remarketed value of reused products is a significant portion of their business.

- Member companies have pursued a strategy of creating end-of-life management programs specifically for their products. This approach allows them to exercise greater control of the management process and enables them to more easily recover valuable parts for re-use where practical. Additionally, it gives members an infrastructure that helps their sales organisations offer trade-in opportunities to customers.

- Following the WEEE Directive, coalition members have joined collection and recycling systems such as Recupel (Belgium national collection), RTA (The Netherlands), Gambica (UK), etc. In some cases – e.g. in Germany and Austria, companies initiated their own scheme.

- Some interesting data that becomes evident: the age of end-of-life products returned through our take back program ranges from 8-30+ years. The products have an average life of 10 years.

[4] http://www.el-kretsen.se/Index-e.htm

Annex I

1. Description of the types of products produced by our member companies

Application sector	Product Types
Automotive	Automotive Testers
	CAN Communication Modules
Bio chemical	DNA Micro-arrays and scanners
Chemical	Capillary Electrophoresis Products
	GC and GC/MS Products
	ICP-MS Products
	Lab-on-a-Chip
	LC and LC/MS Products
	UV-VIS Products
Design	Semiconductor Parameter Analyzers
Environmental Test	Air Quality Testers
	Area Monitors
	Survey Meters
Manufacturing test	Flat Panel Array Testers
	In-Circuit (Board) Testers
	Memory Testers
	Optical Inspection (Board) Testers
	Parametric Testers
	RF IC Testers
	System On a Chip (SOC) testers
	X-Ray Inspection (Board) Testers
Medical	Blood Pressure Simulators
	Defibrillator/Pacemaker Calibrators

Application sector	Product Types
General Purpose	Bench Power supplies
	Counter/Timers
	Current Clamp Meters
	Current Detectors
	Capacitance Systems
	Light, current, voltage Test
	Data Acquisition Units
	Digital Multi-meters
	Digital Thermometers
	Digital Waveform Generators/Analyzers
	Dynamic Signal Analyzers
	Electrometers
	Fast Transient Response Power Supplies
	Function/Arbitrary Waveform Generators
	GPIB Instrument Control Modules
	Hall Effect Systems
	High Power/High Voltage Sources
	High-Speed Digitizers
	Image Acquisition Modules
	Impedance Analyzers
	Infrared Thermometers
	Analog & digital I/O Boards
	Laser Diode Mounts

	Diagnostic X-Ray QA	Inductance capacitance resistance Meters
	Dosimeters	Logic Analyzers
	Electro-surgery Calibrators	Loop Calibrators
	External Pacemaker Calibrators	Source meters
	Gas Flow Calibrators	Modular Test System
	Gas Measurement Testers	Motion Control Modules
	Incubator Calibrators	Multifunction Calibrators
	IV Pump Calibrators	Oscilloscopes
	Multi-parameter Patient Simulators	Pattern / Pulse Generators
	Nuclear Medicine	PCI Boards
	Oncology QA	PCMCIA Boards
	Pulse Oximeter Simulators	Pico Ampmeters
	Radiation Safety	Power Meters
	Ultrasound Wattmeter Calibrator	Pressure Calibrators
Optical	High Speed Laser Driver	Pressure Meters
	Light-wave Component Analyzers	Process Calibration Tools
	Optical Dispersion Analyzers	Programmable Voltage Sources
	Optical Power Measurement	Pulse Generators
	Optical Spectrum Analyzers	PXI Chassis & modules
	Optical Switching	RCL Meters
	Optical Time Domain Reflectometers	Scope Calibrators
	Photonic Measuring Instruments	Serial Instrument Control Modules
	Optical Temperature Control	Signal Conditioning Modules
	Pulsed Laser Tester	Signal Generators
Plant Monitors	Industrial Control and Distributed I/O	Source Measure Units
Safety test	Earth Ground Testers	Spectrum analyzers
	Electrical Safety Analyzers	Switches
	Electrical Testers	Switching and Control

	Portable Appliance Testers
Standards	Infrared Black Bodies Standards
	Primary Standards
	Resistor Standards
	Temperature Standards
	Voltage Standards
Telecomms Test	Base Station Testers
	Bit Error Rate testers
	Bluetooth testers
	Cable Testers
	Digital Comms. Analyzers (DCAs)
	Distributed Network Analysis Products
	Mobile or Wireless Communications. Test sets
	Network Analyzers
	Noise Figure Analyzers
	Protocol Analyzers
	RF Microwave Measuring Systems
	RF Signal Analyzer
	Router Testers
	SONET/SDH/OTN Test sets
	Telecom Testers
	Voice Quality Analyzers

	TV Pattern Generators
	USB Modules
	VCO/PLL Signal analyzers
	Voltage/Current Sources & detectors
	VXI Chassis & modules
Temperature Measurement	Dry-Well Calibrators
	Temperature and Humidity Calibrators
	Temperature Probes
	Temperature Readouts
	Temperature/Humidity Loggers
	Thermography Cameras
	Thermometer Readouts

2. Example Products

Example Products from Agilent Technologies – more details at www.agilent.com

PSA Spectrum Analyzer

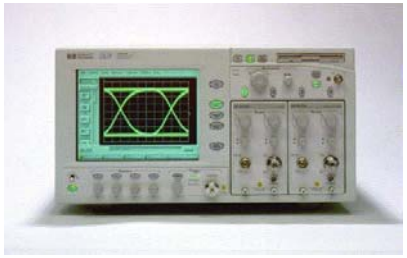
Network Analyzers

Signal Analyzer

Logic Analyzer

Tuneable Laser

Power Meters



Oscilloscope

Waveform Generator

Bench Power Supply

Lightwave Analyzer

LCD Flat Panel Tester

X-Ray Board Tester

Gas Chromatograph

Mass Spectrometer

DNA Bio-analyzer

Example Products from Fluke Corporation –more details at www.fluke.com

Digital Multimeters

Current Clamp Meters

Process Calibrators

Counter Timers

DMM & Insulations Testers

Multi-phase Power Quality Standards

Power Quality Monitor/Analyzers

Electrical Testers

Digital Thermometers

Infrared Cameras & Thermometers

Temperature, DC LF & Scope Calibrators

Network Cable Testers (Copper & Fiber)

Telecom Test Sets

Network Health Analyzers

Biomedical Calibration Products

Example Products from Keithley Instruments – more details at http://www.keithley.com/

CV System

Picoammeter

Parametric Test System

Opto Test System

Scanner Card

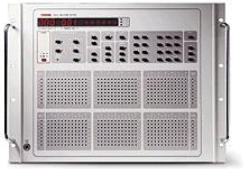
Digital Multi-Meter

Switch Card

Power Supply

Opto Electronics Test

Switch System



Switching and Control

High Resistivity
Measurement System

Simultaneous CV System

Data Acquisition Card

Low Level Source Meter

Example Products from National Instruments – more details at www.ni.com

PXI GPIB Device

USB GPIB Device

PCI Data Acquisition Device

USB Data Acquisition Device

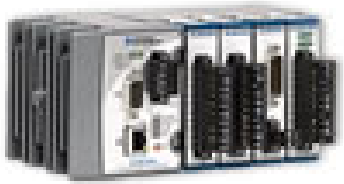
PXI Measurement System

PXI Controller

PXI RF Vector Signal Generator

VXI Controller

FieldPoint Programmable Automation Controller



CompactRIO Programmable Automation Controller

Compact Vision System

Signal Conditioning System

Example Products from Tektronix– more details at http://www.tek.com/home/products.html

Oscilloscopes

Logic Analyzers

Logic Analyzer Modules

Protocol Analyzers

Digital Access System

Wireless Field Tester

Digital Audio Monitor

Video Waveform Monitor

Handheld Waveform Monitor

Picture Quality Analyzer

Automatic Video Measurement Set

Data Timing Generators

Curve Tracers

Arbitrary Waveform Generator

Spectrum Analyzers

Example of Products from Anritsu – more details at http://www.anritsu.com

Millimeter Wave Test System

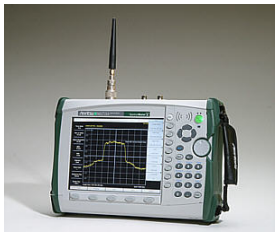
Vector Network Analyzer(VNA)

Node B Analyzer

Spectrum Analyzer (SPA)

18 Port Measurement System

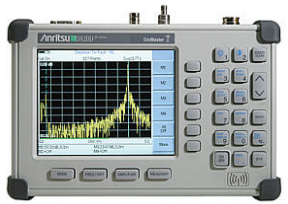
Microwave Synthesizer



7.1Ghz SPA

Sensors

Amplifier Test System



1 Handheld VNA

Signal Analyzer

3. Summary use of RoHS Substances from five member companies

Units and estimated weights (in kg) of products and RoHS-restricted substances sold in the EU in 2004

EU Product Shipments		Cadmium			Hexavalent Chromium			Mercury			Lead				BFRs	
Total Units Sold	Total Product Weight	Plating	Switch Contacts	Other Uses*	Aluminium Chromate Coating	Steel Chromate Coating	Other Uses	LCD Back-Lights	Relays & Switches	Other Uses*	Solder	Ball Grid Arrays	Radiation Shields	Other Uses*	PBDE	PBB
840,319	1,358,875	0.001	0.001	0	6.7	0.011	0	0.34	0.014	0	15,726	32	2010	91	0	0

** These figures exclude the use of the specified material in batteries and accumulators, which is governed by Directive 91/157/EEC (as amended).*

Applications and product types where RoHS substances are used

	Cadmium			Hexavalent Chromium			Mercury			Lead				BFRs	
	Plating	Switch Contacts	Other Uses*	Aluminium Chromate Coating	Steel Chromate Coating	Other Uses	LCD Back-Lights	Relays & Switches	Other Uses*	Solder	Ball Grid Arrays	Radiation Shields	Other Uses*	PBDE	PBB
Automotive	None	None	None	None	None	None	None	None	None	Yes	Yes	None	Yes	None	None
Bio chemical	None	None	None	Yes	Yes	None	None	None	None	Yes	Yes	None	Yes	None	None
Chemical	Yes	None	None	Yes	Yes	None	None	None	None	Yes	Yes	None	Yes	None	None
Design Testers	Yes	None	None	Yes	Yes	None	Yes	None	None	Yes	Yes	None	Yes	None	None
Environmental Test	None	None	None	None	None	None	None	None	None	Yes	None	Yes	Yes	None	None
Manufacturing test	Yes	Yes	None	Yes	Yes	None	Yes	Yes	None	Yes	Yes	Yes	Yes	None	None
Medical	None	None	None	Yes	Yes	None	Yes	Yes	None	Yes	Yes	Yes	Yes	None	None
Optical	Yes	None	Yes	Yes	Yes	None	Yes	None	None	Yes	Yes	None	Yes	None	None
Plant Monitoring	None	None	None	Yes	None	None	None	None	None	Yes	Yes	None	Yes	None	None
Safety test	None	None	None	Yes	Yes	None	None	None	None	Yes	None	None	Yes	None	None
Standards	None	None	None	Yes	None	None	None	None	Yes	Yes	None	None	Yes	None	None
Telecomms	Yes	None	None	Yes	Yes	None	Yes	None	None	Yes	Yes	None	Yes	None	None
Design Testers	Yes	None	None	Yes	Yes	None	Yes	None	None	Yes	Yes	None	Yes	None	None
Temperature	None	None	None	Yes	None	None	None	None	None	Yes	None	None	Yes	None	None
General Purpose	Yes	None	None	Yes	Yes	None	Yes	Yes	None	Yes	Yes	Yes	Yes	None	None

Annex II

1. Examples of critical applications of our products

- **Semiconductor industry**: Our applications include design engineers using our products to debug and evaluate new designs and technologies, an example being the semiconductor industry. They include manufacturing applications for products like cell phones, pacemakers, circuit board assemblies, etc. In the video and telecommunications protocol markets we have products that are used in monitoring applications requiring 24X7 operations.

- **Outdoor industrial settings**: Many products are designed for heavy-duty use in industrial settings and often out of doors. Digital multimeters, current meters and power quality analyzers are known for their safety, reliability, and ease of use. They are used to measure and monitor often-lethal voltages and currents in environmentally challenging locations through the world. Failure could have catastrophic results including significant property damage, loss of production, personal injury or death.

- **Calibration and Maintenance Applications:** Calibrators, network monitors and testers, medical testers and other calibration products are depended upon to provide reliable and accurate measurements over extended periods of time. Erroneous measurements can have catastrophic results as already mentioned.

- **Power generators: (utilities)** quote the cost of downtime as the loss / non-availability of electricity generating capacity per hour. The associated lost revenue depends on the capacity of the generating unit and demand at the time of failure. Generator output ranges from 50 to 600 Megawatts for many gas and steam turbines. If plant monitoring or control equipment forces a shutdown due to failure or erroneous operation the cost can be substantial.

- **Nuclear Power Plant**: Maintenance and Inspection System[5]
One customer designed a single, flexible system to control many different inspection and maintenance tools for nuclear power plants. The limited space and harsh environment of nuclear reactors requires highly reliable T&M equipment along with modularity and a wide range of I/O. The customer has deployed the system in four U.S. nuclear reactors so far in 2004. Because of the flexibility of the modular system, engineers can design new tools reusing the same control system, which minimizes training and setup time.

- **Production Monitoring**[6]
The GE Medical Systems plant located in Bangalore, India, manufactures many critical components used to build sophisticated, high-value medical equipment. Some of these components are processed in ovens where both the

[5] http://sine.ni.com/csol/cds/item/vw/p/id/570/nid/124100
[6] http://sine.ni.com/csol/cds/item/vw/p/id/103/nid/124400

temperature and vacuum are cycled according to predetermined recipes for up to 72 hours. A reliable supervisory control system was implemented to monitor 20 manufacturing process ovens that operate around the clock. These ovens are unattended at night, and the system must provide a safety shutdown on any ovens that malfunction.

- **Telecommunications provider:** monitoring equipment is employed to control signals to examine the duration of calls (from destination voice pickup until call termination), delays in making connections from switching node to node and to provide billing data. Downtime of monitoring equipment means that call routing efficiency cannot be measured or optimised.

- Military application: [7]
The Royal Australian Airforce (RAAF) developed an Airborne Data Acquisition and Recording System (ADARS) to assist in flight test and data gathering exercises for the Australian Army's Black Hawk helicopters. The ADARS was designed with a modular construction so the RAAF could reconfigure and upgrade the system in the future. Important design criteria included survivability in extreme environmental conditions, such as temperature, pressure, humidity, shock, and vibration. The ADARS system also needed to meet aerospace crash loading safety requirements and satisfy the strict electromagnetic compatibility requirements of military aircraft.

Examples of manufacturing applications:
- Automating a Cold Steel Rolling Process[8]
The ferrous and nonferrous metal industry uses a cold rolling mill to obtain metal strips (in the form of coils) with uniform thickness. These mills require a high-precision monitoring and control system. One customer implemented a compact, closed-loop control system for online gauge monitoring and control in cold rolling mills to deliver high-precision monitoring combined with fast response times and ensure continuous operation, 24 hours a day, seven days a week, with minimal human intervention.

- Production Test System for Xbox 360 Controllers[9]
Microsoft used modular instruments to develop a production test system for Xbox 360 controllers. The Xbox 360 controller-functional test system tests device communication and monitors data packets at the bit level to verify that all controller-functional messages are within specification. The system also monitors signals at the chip level to analyze the electrical signals for parameters such as rise/fall times, minimum/maximum voltage levels, and current draw. The system demands high-performance signal capture to qualify the signal integrity of the new controller and ensure a high-quality user experience.

[7] http://sine.ni.com/csol/cds/item/vw/p/id/91/nid/124100
[8] http://sine.ni.com/csol/cds/item/vw/p/id/569/nid/124100
[9] http://sine.ni.com/csol/cds/item/vw/p/id/662/nid/124400