

RoHS

YOUR GUIDE TO THE LEGISLATION AND ACHIEVING COMPLIANCE >>



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INTRODUCTION TO RoHS

The forthcoming RoHS Directive (2002/95/EC) has significant implications for the electronics industry. It is important that all participants in the electronics industry understand their responsibilities and the impact this Directive may have on them. In recent customer research RS has discovered that many companies are unaware of the full implications of the Directive and are not taking the necessary steps to address them. It is important to realise that RoHS isn't solely a technical manufacturing problem, it also has major implications for many aspects of business including customer and supplier relations, logistics and supply chain management etc.

RS is committed to supporting its customers through the implementation of RoHS with relevant information, products and technical support. Consequently as a service to our customers we have produced this step by step guide to the Directive and its requirements in association with industry experts Soldertec Global.

This guide will help companies who haven't yet started work on RoHS to understand the likely consequences and the need for prompt action and for those at the early stages of change to confirm that they have considered all aspects. It is intended to provide an overview of the key issues arising from the Directive; it is not intended to be a comprehensive technical guide to lead-free manufacturing. Individual situations may require expert technical advice from component suppliers and equipment manufacturers.

RS would like to express its thanks to industry experts Soldertec Global and Bob Willis, an independent consultant for their expertise and input to the content of this Guide and the images used.

What is RS doing?

RS is using its relationships with manufacturers built up over many years to establish the status of the products supplied to you. To date we have contacted over 700 suppliers and are individually reviewing approximately 150,000 products.

Due to the dynamic nature of information regarding RoHS the web is the focal point for all RoHS knowledge.

To ensure you keep up to date with all of the latest developments, check it regularly by visiting www.rs-components.com and select your local site

OUR CUSTOMER PLEDGE

- We will use all of our experience and know-how to support your RoHS needs
- Your RoHS questions answered by trained technical experts
- Fast and reliable source of compliant products
- Clear product compliance information you can trust, before you buy
- We will speak in clear language, that is relevant to your needs
- We will deliver what we promise

We have taken the time to develop a range of information and technical solutions to meet your needs.

ROHS DIRECTIVE

THE ROHS DIRECTIVE (2002/95/EC)

What is RoHS?

RoHS ("Restriction of use of certain Hazardous Substances in Electrical and Electronic Equipment") is an EU Directive that restricts the use of 6 hazardous materials in the manufacture of various types of electronic & electrical equipment. It is one of a series of EU environmental Directives and is closely linked with the WEEE (Waste Electrical and Electronic Equipment) Directive.

Which substances are restricted?

Electrical and electronic equipment must not contain more than the permitted concentrations of the following substances:

- Lead (Pb)
- Mercury (Hg)
- Cadmium (Cd)
- Hexavalent Chromium (Cr(VI))
- Polybrominated Biphenyls (PBB) and Polybrominated Diphenyl Ethers (PBDE) (flame retardants used in some plastics)

What are the maximum concentrations?

The maximum concentrations are 0.1% by weight of the **homogenous material** for all substances, with the exception of Cadmium where the limit is 0.01%.

N.B. These limits do not apply to the weight of the finished product, sub-assembly, or even a component. The EU has stated that the definition of a homogenous material is a single substance that could (theoretically) be mechanically separated from other substances (e.g. tinning on a component lead, sheath on a cable etc). A component would therefore typically contain a number of different homogenous materials.

N.B. Batteries are not included within the scope of RoHS, therefore a NiCd battery is permitted in finished goods even though the use of Cadmium is restricted.

What types of products are affected?

The RoHS Directive takes its scope from the associated WEEE (Waste Electronic & Electrical Equipment) Directive. It applies to 8 of the categories specified within the WEEE Directive:

- Large household appliances
- Small household appliances
- IT and telecommunications equipment
- Consumer equipment
- Lighting equipment (including light bulbs and household luminaires)
- Electronic and electrical tools
- Toys, leisure and sports equipment
- Automatic dispensers

RoHS legally only applies to finished goods in the above categories. It does not apply to fixed industrial plant and tools. Similarly it does not apply to the components and sub-assemblies which are used to build the finished product, or to the repair and maintenance of existing products. In practical terms however, manufacturers of the products noted previously will require "compliant" components.

When does it take effect?

From 1st July 2006 any new products "put onto the market" in Europe must be compliant i.e. products that are:

- imported into EU member states, or
- manufactured in EU members states and available for sale

RoHS does not apply to any products that are already "on the market" (already in the supply chain) in the EU prior to this date; they can continue to be sold.

ROHS DIRECTIVE

Where does RoHS apply?

Legally RoHS only affects the European Union, however it is becoming a defacto world standard because of the size of the European market. Similar legislation is currently being developed in a number of other countries. RoHS is a "single market" Directive, which means that it should be implemented uniformly throughout the EU.

Are there any exemptions?

There are various exemptions listed in the RoHS Directive, and the EU is considering further requests for exemption. The main justification for an exemption is the lack of a technically viable alternative. These exemptions may not be permanent and some are scheduled for review at a future date. The main exemptions include:

Lead

- in high melting point solders (> 85% lead content)
- in ceramic devices
- in specified alloys in limited concentrations
- in the glass of CRT's, electronic components and fluorescent tubes

Mercury

- in various types of lamps

For further information on the latest exemptions please consult www.rs-components.com and choose your local website.

How will the Directive be enforced?

An enforcement authority may request evidence that a producer has used due diligence and taken reasonable steps to comply with the requirements of the RoHS Directive and national legislation. Failure to comply could result in the eventual withdrawal of a product from the market.

In reality manufacturers and importers are likely to be the "first line of enforcement". As part of their compliance programmes many manufacturers are asking their suppliers to confirm component compliance to ensure that the finished product is in turn compliant.

How can I identify compliant components - is there a RoHS compliance mark?

Unless they are marked in some way it is usually impossible to visually distinguish between compliant and non-compliant components. Unfortunately the Directive doesn't specify a means of indicating RoHS compliance, however a number of manufacturers have introduced their own "RoHS symbol".

A variety of different approaches have been taken by manufacturers to RoHS and part numbering:

- some manufacturers identify the RoHS compliant product with a new part number
- some add a suffix to the existing part number (e.g. the compliant version of part number 1234 becomes 1234-G, or 1234PBF etc.)
- others are not planning to change part numbers at all.

This all adds to the complexity of managing RoHS compliance.

ROHS DIRECTIVE

My supplier has told me that their products are “green” or “lead-free”. Does this mean that they are RoHS compliant?

Not necessarily, from a manufacturer’s perspective there are two key aspects to component compliance:

- Restricted substances; does the product contain any of the restricted substances in concentrations above the permitted limits?
- Temperature tolerance; lead-free solder is required to manufacture RoHS compliant equipment. The most common lead-free solders have melting points that are significantly higher than that of leaded solder and consequently the manufacturing process will require higher temperatures. To be viable, the component must therefore be able to withstand the higher temperatures.

When discussing RoHS compliance it is essential to be clear what terms like “green” and “lead-free” mean, it may not mean compliance with the restricted substances and temperature tolerance described above. Some component manufacturers have implemented a 2-stage approach, initially removing the restricted materials (and stating their products are “lead-free” or “green”), and at a later date upgrading (or confirming) the temperature tolerance to withstand the higher temperatures required for lead-free soldering.

BUSINESS IMPACT OF RoHS

Who will be affected by RoHS?

The affects of this Directive are widespread. RoHS doesn't just affect those companies involved in the supply chain of the specified categories of electronic equipment; it also has wider implications for the manufacture, distribution and use of components. There are potential implications for manufacturing processes, product design, inventory management, quality control, supplier relationships, purchasing, customer relationships etc.

I manufacture products that aren't affected by RoHS, why should I be interested?

Many components used today are generic and can be found in a wide variety of applications. Component manufacturers typically do not plan to produce compliant and non-compliant versions of their products – eventually only the compliant version will be available. Consequently the companies who do not wish to make the transition to the new components should contact their suppliers urgently to understand their plans. Possible consequences may include “last time purchases” of non-compliant components to ensure availability, or identifying alternative suppliers.

What will my customers expect?

If you supply components or sub-assemblies you may be required to provide compliance declarations to your customers. Enquiries may range from simple Yes or No questionnaires to full material composition requests. Prompt and comprehensive answers to these questions will provide your customers with the reassurance they need and prevent disruption to normal business.

Customers may also require compliance information / marking on delivery notes, packaging etc.

Where are these substances found?

The restricted substances may be found in a wide variety of applications, including:

Substance	Potential usage
Lead (Pb)	Solders, Termination coatings, Paint (pigment or drier), PVC (stabiliser)
Cadmium (Cd)	Pigment, PVC (stabiliser), Contacts
Mercury (Hg)	Fluorescent lamps, Sensors, Relays
Hexavalent Chromium (Cr(VI))	Anti corrosion coating (on zinc or aluminium), Corrosion resistant paints
PBB & PBDE	Flame retardants used in plastics (PBB no longer manufactured)

COMPLIANCE

ACHIEVING & DEMONSTRATING COMPLIANCE

What will I need to do to demonstrate compliance?

The RoHS Directive restricts the use of the six substances but does not specify how producers can comply or the requirements for market surveillance; this will be specified in national law.

Two key principles of the Directive are:

- Products “placed on the market” after 1st July 2006 will be presumed to comply with RoHS. This “self declaration” is consistent with a number of other EU Directives (e.g. those requiring the CE mark). The authorities in each member state will introduce their own surveillance regime and conduct checks where appropriate.
- Producers will be expected to be able to demonstrate that they have shown “due diligence” in ensuring that their products are RoHS compliant. This principle has been used for other legislation, but it is unclear what “due diligence” actually means.

The requirements of “due diligence” may vary between countries and also between products. There are a number of potential methods of demonstrating due diligence; the following steps may be helpful in defining a suitable method:

1. Does my product need to comply?
 - If so, contact component / material suppliers to obtain compliance declarations (unfortunately there is no agreed standard for these)
 - Identify any part number changes and update purchasing systems
 - Retain compliance declarations in a “technical file”
2. Am I confident in the information provided?
 - Undertake a risk analysis to determine the level of confidence
 - How likely is the product to contain any of the restricted substances?
 - Is compliance indicated on paperwork and / or product packaging?

- Has the manufacturer or another party in the supply chain provided the compliance information?
 - Has previous information been reliable?
 - Is this product part of a range / family which is already compliant?
3. If changing suppliers review compliance implications
 4. If compliance is in doubt consider testing and / or other methods of confirming compliance
 - Testing can be difficult and costly, target its use on high risk components / suppliers
 - Request a test report from the supplier
 - Consider sharing compliance information with business partners
 5. Maintain “technical files” for at least 4 years as evidence of “due diligence”

Is there a central database of compliance information?

No, although a number of organisations have tried to set one up. When obtaining compliance information from suppliers, particularly when their part number does not change, be careful of the timing of changes and lead times within the supply chain. Non-compliant product may still be delivered many months after the manufacturer has started to make the compliant version.

How can I test for compliance?

There is no simple and cheap test for RoHS compliance; because the Directive specifies maximum concentrations in homogeneous materials, testing has to be conducted on each of these materials individually. It is not as simple as crushing the component and analysing it. Various testing techniques are available, probably the most cost-effective is ED-XRF (Energy Dispersive X-ray Fluorescence). This method is very effective at measuring the concentration of lead, mercury and cadmium. It can only detect the presence of chromium and bromine and so further testing may be required to determine whether Hexavalent Chromium, PBB or PBDE is present .

LEAD-FREE MANUFACTURING

LEAD-FREE MANUFACTURING, REPAIR & REWORK

What is the impact of RoHS on manufacturers and repairers of electronic equipment?

Lead is no longer permitted to be used in solder for most applications covered by RoHS legislation (there are a very small number of exemptions). A review of soldering techniques will be necessary.

Some electronic parts will no longer be available due to rationalisation by the component manufacturers. This will therefore also affect applications outside of the scope of RoHS.



Why are there concerns?

New solder alloys will have to be used, and they behave differently. Materials and processes will have to change. Finished products will need to be re-tested and re-qualified. There will have to be investment in new design and probably in new process equipment. Inspectors and customers will need to be re-educated.

Are there any alternatives to the new solders?

ECAs (Electrically Conducting Adhesives) are an alternative but are currently only being used in niche applications.

So the restriction on lead will only affect solders?

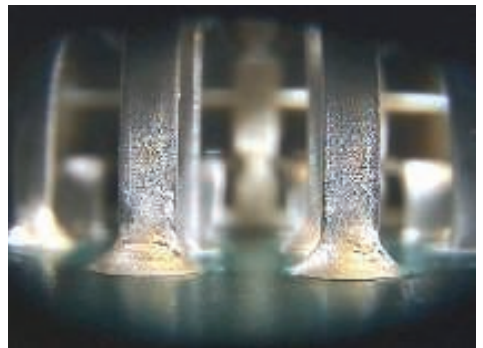
No, it also affects the solderable coatings on PCBs and electronic components.

What is the new solder alloy and why is it different?

Over 100 possible alloy candidates have been proposed and evaluated but none are "drop in" alternatives. The most popular lead-free alloys melt at about 40°C higher than tin/lead solders. The most widely used are based on tin, silver and copper and are often referred to as SAC alloys - SAC comes from the Latin names for tin (Sn), silver (Ag) and copper (Cu). They have wide process capability without a large performance detractor and have good thermal fatigue resistance. However there are other alloys available that claim specific advantages.

Some of the key differences between a SAC alloy and tin/lead solder are:

- Higher melting point
- Inferior wetting
- Forms a harder joint
- Appearance is dull / matte (may resemble a poor tin/lead solder joint)
- May require different / more active flux



Is this more expensive?

The alloys contain more expensive metals. It is therefore important to optimise the soldering processes to reduce rework and waste. SAC alloys have 12.5% more volume for the same weight so a reel of solder will be 12.5% longer.

LEAD-FREE MANUFACTURING

Will the 40°C higher melting point mean higher soldering temperatures?

Generally yes, or longer soldering times.

How will this affect my bare boards?

Higher manufacturing temperatures could delaminate the boards, cause warping or produce failure of interconnects in multilayer plated through boards. Talk to the supplier and evaluate the alternatives. If you use HASL PCBs (hot air solder levelled) then this is the time to evaluate new non lead containing finishes such as tin, gold over nickel, silver & OSP. These finishes also offer flatter pads which improves defect levels on reflowed assemblies. Lead-free HASL is also available.

What about my supply of components?

The components will need to be both RoHS compliant and lead-free process compatible. There has been a shortage of such components but this situation is improving rapidly. Again it is very important to speak with your suppliers. The higher process temperatures when using lead-free solders may cause damage to components not rated to be used at these temperatures.

What is the effect upon hand soldering of using lead-free solders?



The first thing everyone will notice is that the solder seems "slower" and the solder joints look dull. It is very important to understand that lead-free solder joints look different thereby stopping unnecessary rework of acceptable solder joints.

Soldering iron tips will be eroded much more quickly; follow the manufacturer's instructions for replacement tips (tips are now available specifically for use with lead-free solder).

Repair and rework requires high skill levels to avoid damage to the assembled PCB; consider getting operators retrained, and be aware that older irons may not have sufficiently good temperature control to avoid damage to components and boards.

The IPC610D soldering standard now incorporates the use of lead-free solders.

Do I need fume extraction?

There is a common misconception that lead-free solders are safer to use than tin/lead. The harmful fumes are generated by the flux used. If fume extraction is not currently being used, then undertake a risk assessment.



Is wave-soldering still possible in my current machine?

This depends upon the equipment manufacturer; you need to ask them. If you just change the solder and take no advice it is possible that the new solder will cause a leak in the bath.

You should also analyse the contents of the bath more regularly.

It is usual to increase the preheat temperature and increase the solder temperature slightly when using the new alloys.

LEAD-FREE MANUFACTURING

New wave-soldering machines will have a number of lead-free friendly modifications incorporated into them.

How much hotter will my reflow oven need to be set?

Although the solders melt at 40°C higher the reflow temperatures typically need only be 20°C higher. Your operating window on the machine will reduce. Experiment and take advice on the need for a new machine.

Should I use nitrogen in my wave-solder machine and reflow oven?

Nitrogen has the effect of widening the process window, reducing oxidation, lowering drossing levels, improving solderability and reducing soldering temperatures. It is not mandatory but should be considered.

Who has been soldering with lead-free solders longest?

Lead-free solders have been used for 20+ years in specialist applications. Some Japanese consumer products have used lead-free solders for the last few years, and many of the products in your home will already be lead-free.

Will I still be able to purchase leaded solder after 1st July 2006?

Yes, solder manufacturers still intend to provide leaded solder for customers who require it (e.g. repair and rework, medical instruments etc.).

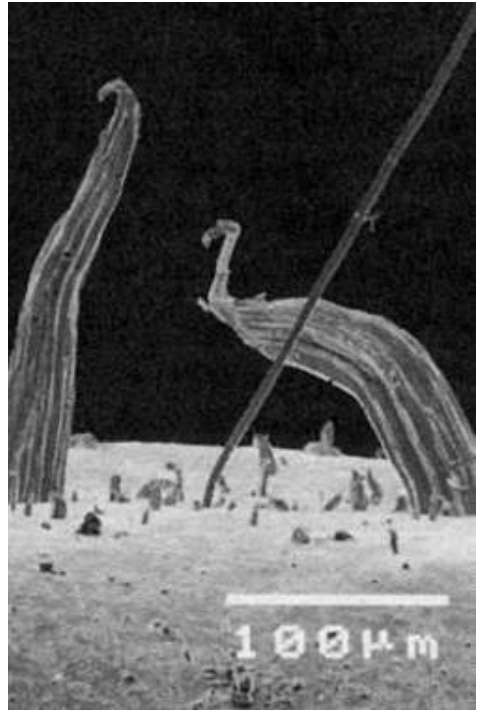
Can I use "lead-free" components with tin-lead solder?

Yes, it is possible to make a good solder joint. During the transition to RoHS compliance it will be normal for both types of components to be used on a PCB. The important point is not to implement lead-free soldering until all of the components are compliant, otherwise there is a risk of damage.

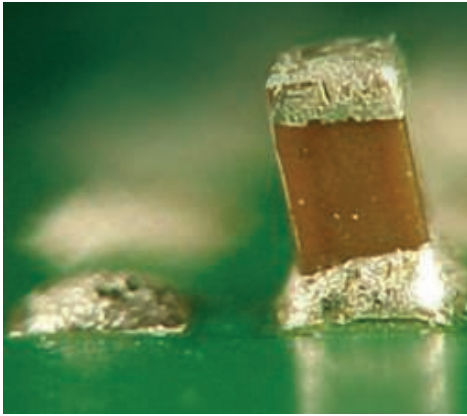
What other problems might there be?

Various other problems are mentioned in relation to lead-free manufacturing, including:

- **Tin whiskers.** These are very thin hair-like crystals of tin, which have been observed to occasionally grow from coatings of pure tin. Ordinarily they would not cause a problem, but if broken off they have the potential to cause shorting on small pitch components. Component manufacturers believe that the latest manufacturing processes have significantly reduced this problem.



LEAD-FREE MANUFACTURING



- **Tomb-stoning.** This is caused when a component is placed across pads of solder at different temperatures. As the solder solidifies the difference in surface tension causes the component to be pulled sideways or upwards away from one of the pads. In extreme cases it will no longer be in contact with the solder and the component may be seen to be standing up (hence the name “tomb-stoning”). This phenomenon occurs with tin/lead solders, but is more common with lead-free.
- **Popcorning.** Many components naturally contain some moisture. When heated rapidly the moisture turns to steam. If it cannot escape quickly enough the pressure may damage the component (popping the moulding).

CATEGORIES OF EQUIPMENT

Large household appliances

- Large cooling appliances
- Refrigerators & Freezers
- Other large appliances used for refrigeration, conservation and storage of food
- Washing machines
- Clothes dryers
- Dish washing machines
- Cooking
- Electric stoves
- Electric hot plates
- Microwaves
- Other large appliances used for cooking and other processing of food
- Electric heating appliances & electric radiators
- Other large appliances for heating rooms, beds, seating furniture
- Electric fans & air conditioner appliances
- Other fanning, exhaust ventilation and conditioning equipment

Small household appliances

- Vacuum cleaners
- Carpet sweepers
- Other appliances for cleaning
- Appliances used for sewing, knitting, weaving and other processing for textiles
- Irons and other appliances for ironing, mangling and other care of clothing
- Toasters
- Fryers
- Grinders, coffee machines and equipment for opening or sealing containers or packages
- Electric knives
- Appliances for hair-cutting, hair drying, tooth brushing, shaving, massage and other body care appliances
- Clocks, watches and equipment for the purpose of measuring, indicating or registering time
- Scales

CATEGORIES OF EQUIPMENT

IT and telecommunications equipment

- Centralised data processing:
 - Mainframes
 - Minicomputers
 - Printer units
- Personal computing:
 - Personal computers (CPU, mouse, screen and keyboard included)
 - Laptop computers (CPU, mouse, screen and keyboard included)
 - Notebook and Notepad computers
- Printers
- Copying equipment
- Electrical and electronic typewriters
- Pocket and desk calculators and other products and equipment for the collection, storage, processing, presentation or communication of information by electronic means
- User terminals and systems
- Facsimile
- Telex
- Telephones, pay telephones, cordless telephones, cellular telephones, answering systems and other products or equipment of transmitting sound, images or other information by telecommunications

Electrical and electronic tools

(with the exception of large-scale stationary industrial tools)

- Drills
- Saws
- Sewing machines
- Equipment for turning, milling, sanding, grinding, sawing, cutting, shearing, drilling, making holes, punching, folding, bending or similar processing of wood, metal and other materials
- Tools for riveting, nailing or screwing or removing rivets, nails, screws or similar uses
- Tools for welding, soldering or similar use
- Equipment for spraying, spreading, dispersing or other treatment of liquid or gaseous substances by other means
- Tools for mowing or other gardening activities

Lighting equipment (including household luminaires and light bulbs)

- Luminaires for fluorescent lamps
- Straight fluorescent lamps
- Compact fluorescent lamps
- High intensity discharge lamps, including pressure sodium lamps and metal halide lamps
- Low pressure sodium lamps
- Other lighting or equipment for the purpose of spreading or controlling light with the exception of filament bulbs

Consumer equipment

- Radio sets
- Television sets
- Videocameras
- Video recorders
- Hi-fi recorders
- Audio amplifiers
- Musical instruments
- And other products or equipment for the purpose of recording or reproducing sound or images, including signals or other technologies for the distribution of sound and image than by telecommunications

Toys, leisure and sports equipment

- Electric trains or car racing sets
- Hand-held video game consoles
- Video games
- Computers for biking, diving, running, rowing, etc.
- Sports equipment with electric or electronic components
- Coin slot machines

Automatic dispensers

- Automatic dispensers for hot drinks
- Automatic dispensers for hot or cold bottles or cans
- Automatic dispensers for solid products
- Automatic dispensers for money
- All appliances which deliver automatically all kind of products

SEARCHING FOR COMPLIANCE

RS is committed to helping you in understanding and achieving RoHS compliance. To this end the website now has added functionality. Components which are RoHS compliant are displayed with the symbol

 **RoHS Compliant**

Additional functionality is provided in that the website will also display those products that do not comply and which are exempt to remove confusion as to the compliance status of products.

In short the new website will display the following icons:

RoHS COMPLIANT 

This flag will only be displayed when manufacturers have confirmed the RoHS compliant status and we are confident that stock held in our stores is RoHS compliant.

RoHS NON COMPLIANT 

The non compliant status will only be used where the manufacturer has indicated that this product is currently non compliant and will not in the future be made compliant.

RoHS EXEMPT 

Exempt status will only be shown where the manufacturer has indicated that their component is not intended for use in a product affected by RoHS.

Where a flag is not displayed its product compliance status is still being confirmed with the supplier and a flag will be attributed to it only when it meets one of the 3 conditions detailed above.

The RoHS compliance search functionality is available at different levels within the website to make your search for these products as simple as possible.

1. Compliance information is available at product level. The compliance flag is prominently positioned next to the product information to avoid ambiguity and confusion.



SEARCHING FOR COMPLIANCE

4. To assist you in managing your BOM's (Bills of Materials) the parts list will also provide product compliance status information.

Parts List: Parts list

Quote Form | Quote History | **Parts List** | New Parts List

About this Parts List

Name: Parts list
Description: Parts list 1
Products: There are 3 products on this list
Created: 07/07/2005
Last Modified: 07/07/2005

Products on this List

Select	RS Stock No	Qty	Description (click to product info)	Units	Gross Unit Price	Order Value	Add to BOM	Remove Product
<input type="checkbox"/>	477-8230	50	Resistor, Thin Film, Axial, 0.6W, 1%, 2K53 View Product Compliance	50 (1 STK)	P.O.A.	P.O.A.	<input type="checkbox"/>	Remove
<input type="checkbox"/>	477-8224	50	Resistor, Thin Film, Axial, 0.6W, 1%, 2K02 View Product Compliance	50 (1 STK)	P.O.A.	P.O.A.	<input type="checkbox"/>	Remove

5. For your convenience RoHS compliance is also shown in the search results.

Search Results

Quick Search for:

Your search by Quick Search for: mb range returned 112 item(s).

Search only within these results:

Back to: [Previous Search Terms](#)

Results by category

Electronic (112)

Results by manufacturer

VISHAY

Best product matches found

RS Stock No	Description	Manufacturer	View Results as Images	Quote	Part Info
477-7806	Resistor, Thin Film, Axial, 0.6W, 1%, 270R	VISHAY 221291512741	View Results as Images	Quote	Part Info
477-7861	Resistor, Thin Film, Axial, 0.6W, 1%, 470R	VISHAY 221291514761	View Results as Images	Quote	Part Info
477-7940	Resistor, Thin Film, Axial, 0.6W, 1%, 400R	VISHAY 221291514001	View Results as Images	Quote	Part Info
477-7807	Resistor, Thin Film, Axial, 0.6W, 1%, 301R	VISHAY 221291513011	View Results as Images	Quote	Part Info
477-7805	Resistor, Thin Film, Axial, 0.6W, 1%, 300R	VISHAY	View Results as Images	Quote	Part Info

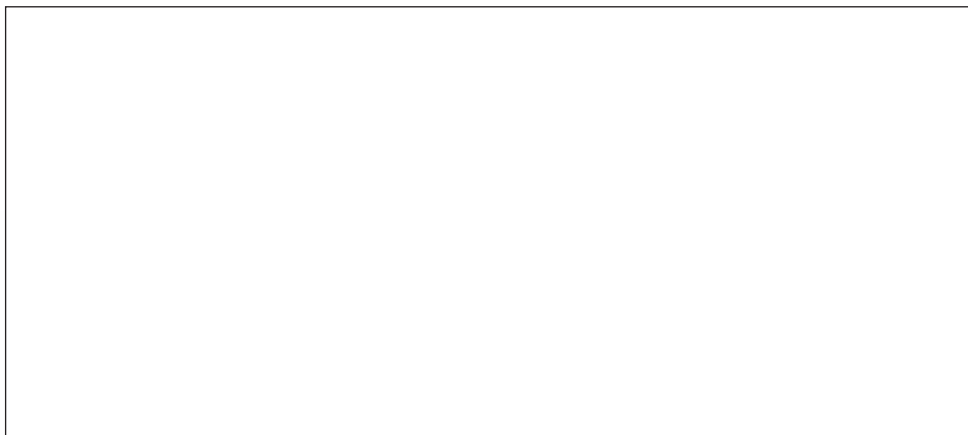
The improvements we have made to the website will help you in achieving compliance and keep up to date with legislation changes and current events.

A dedicated RoHS section has also been created on your local RS website at www.rs-components.com which details all of the latest legislation, updates from leading industry experts and case studies. You can also contact us with any question you may have and talk to one of our technical experts.

FURTHER INFORMATION

The RS website is constantly being updated with new information as it becomes available. To ensure you keep up with developments visit www.rs-components.com.

You can also call your local distributor:



Web links for industry leading organisations who can provide additional information are detailed below:

Soldertec	www.soldertec.com
Soldertec Global	www.tintechnology.biz/soldertec/soldertec.aspx
European Lead Free network	www.europeanleadfree.net
The EU Online	www.europa.eu.int http://europa.eu.int/comm/environment/waste/weee_index.htm
Bob Willis	www.leadfreesoldering.com
SMART Group	www.smartgroup.org
AFDEC	www.afdec.org.uk/RoHS.htm
National Physical Laboratory	www.npl.co.uk/ei/research/leadfree.html