# Designing for Availability and Reliability

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# Reliability

- From Wikipedia, the free encyclopedia
  - In general, **reliability** (systemic def.) is the ability of a person or system to perform and maintain its functions in routine circumstances, as well as hostile or unexpected circumstances.The IEEE defines it as ". . . the ability of a system or component to perform its required functions under stated conditions for a specified period of time."
- From my wife
  - How often does that damn pager go off in the middle of the night!
    - *Single largest motivation for building reliable systems*

# Why do LLRF System Fail?

Because -

- they are complex and have many single point failure possibilities
- They are produced in low volume with small teams
- They are always in a state of development

They often are put into conditions that were not foreseen by the engineers

Interface systems specifications change

Control systems for example

# What are the Main Failures?

- Misdiagnosis
  - LLRF is guilty until proven innocent
- Software
  - Interfaces
  - Upgrades
    - *side effects*
    - *Logic errors*
  - Timing relationships in multi-threaded processes
  - Configuration control
- Cables/connectors

Fig. 3 Causes of Aircraft Electronic Equipment Failures

(Aeronautical Systems Division, Wright–Patterson AFB [2])

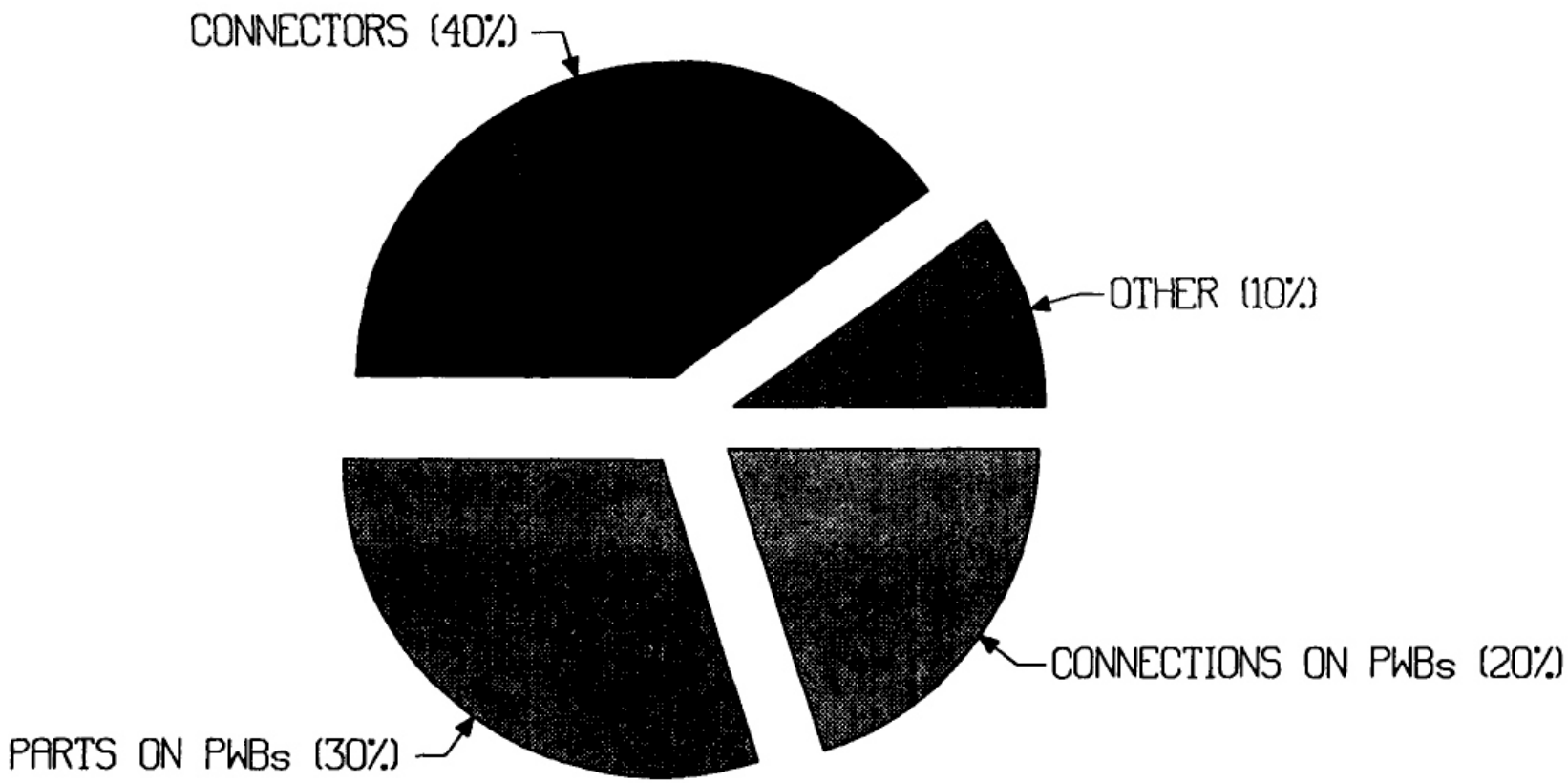


Fig. 4 Part Replacement Data for Printed Wiring Boards

(Based on Data from Hughes Aircraft [3])

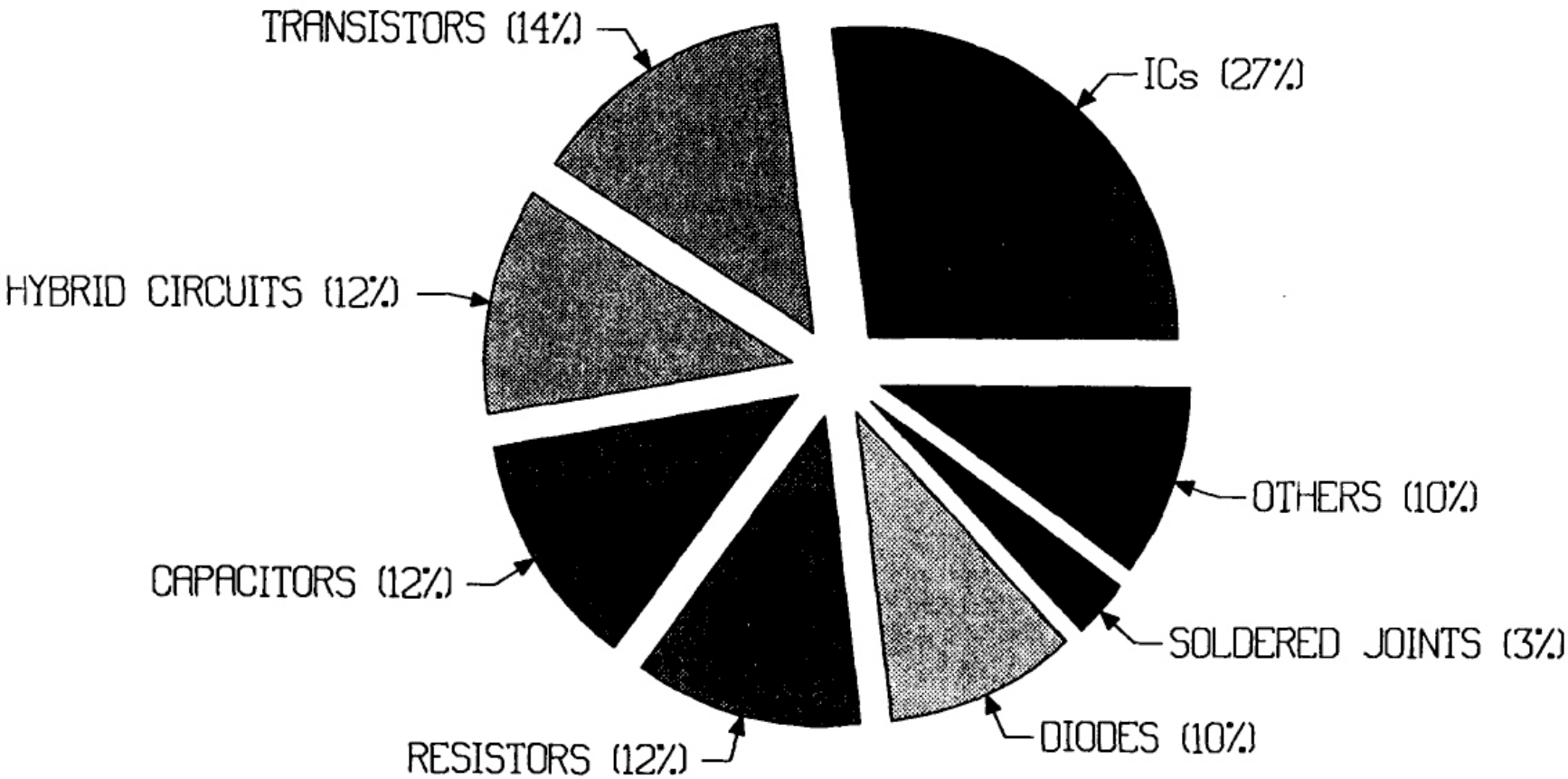
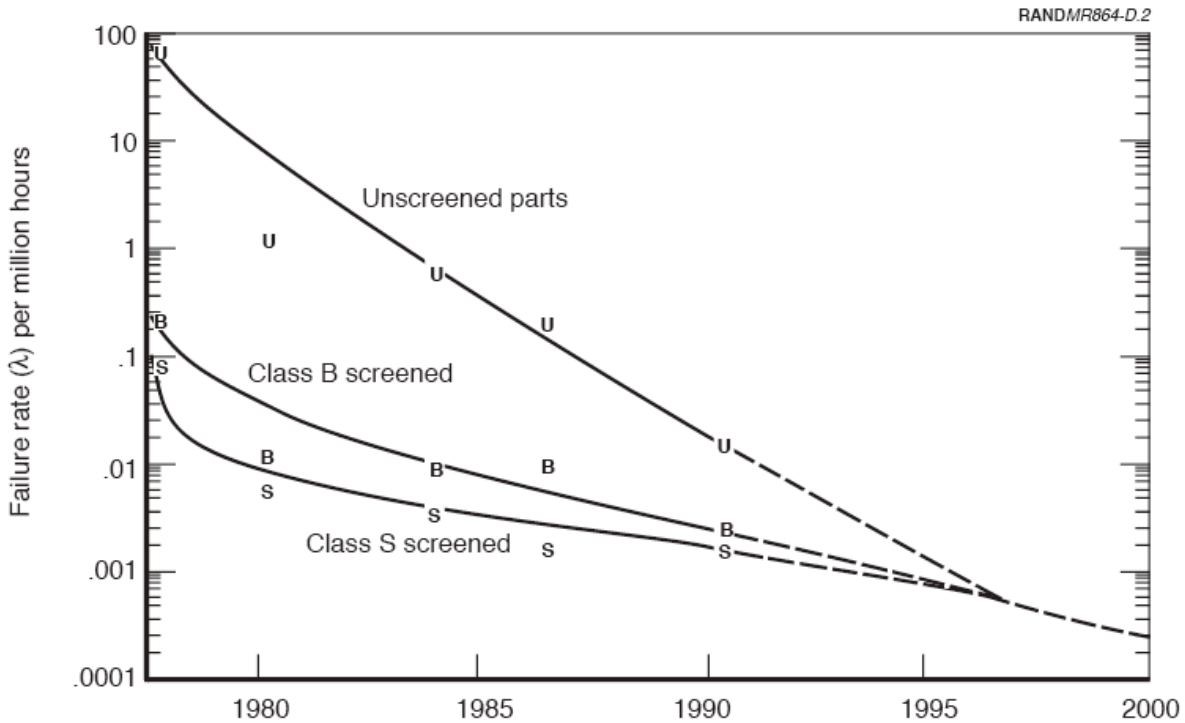


Figure D.1—Intel: Quality and Reliability Trends

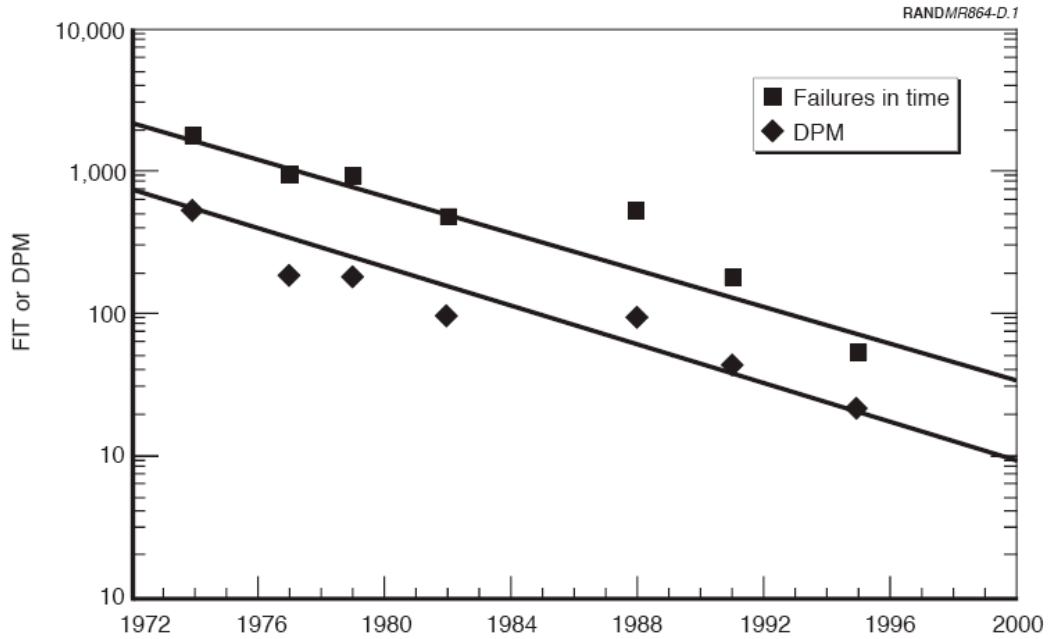



SOURCE: *Quality Magazine* (Plum, 1990, p.53).

Figure D.2—Improvements in IC Performance

# Reliability Trends

- Failure in Time (FIT) - Factor of 10 over 20 years




SOURCE: Reprinted by permission of Intel Corporation. Copyright Intel Corporation 1996.

Figure D.1—Intel: Quality and Reliability Trends

# Availability

- From Wikipedia, the free encyclopedia
- **1.** The degree to which a system, subsystem, or equipment is operable and in a committable state at the start of a mission, when the mission is called for at an unknown, *i.e.,* a random, time. Simply put, availability is the proportion of time a system is in a functioning condition.*Note 1:* The conditions determining operability and committability must be specified.*Note 2:* Expressed mathematically, **availability** is 1 minus the unavailability.**2.** The ratio of (a) the total time a functional unit is capable of being used during a given interval to (b) the length of the interval.*Note*
- The most simple representation for **availability** is as a ratio of the expected value of the uptime of a system to the aggregate of the expected values of up and down time.
- **High availability** is a system design protocol and associated implementation that ensures a certain absolute degree of operational continuity during a given measurement period.

# Design Goals for Availability

- Is there a redundant architecture for LLRF?
  - Receiver, controller, transmitter, cables
  - Vector control for a lost cavity probe by F&R power
- Would such a system be more reliable?
  - Is the higher cost and possibly double the failure rate worth it?

# Failures are Rarely Stochastic

- Random failures of parts from large manufacturers on well designed equipment is usually not the problem
- Much more likely is bad design on our part.
- Production problems
- Bad lot of parts (QA)
- Environmental issues
  - Lightning strikes

# Ultra High Reliability vs. Redundancy

- Ultra High Reliability Pros
  - Simpler design
  - Probably lower cost
  - Lower power
  - Smaller size
  - Fewer total failures
- Cons
  - When it fails it fails
  - UHR is hard to measure

- Redundancy Pros
  - Higher Availability
  - Can be better understood statistically
  - Is very good for parallel systems- large n
- Cons
  - Can double cost
  - Will double power
  - More complexity
  - May fail in new and wonderful ways

# Personal Experiences

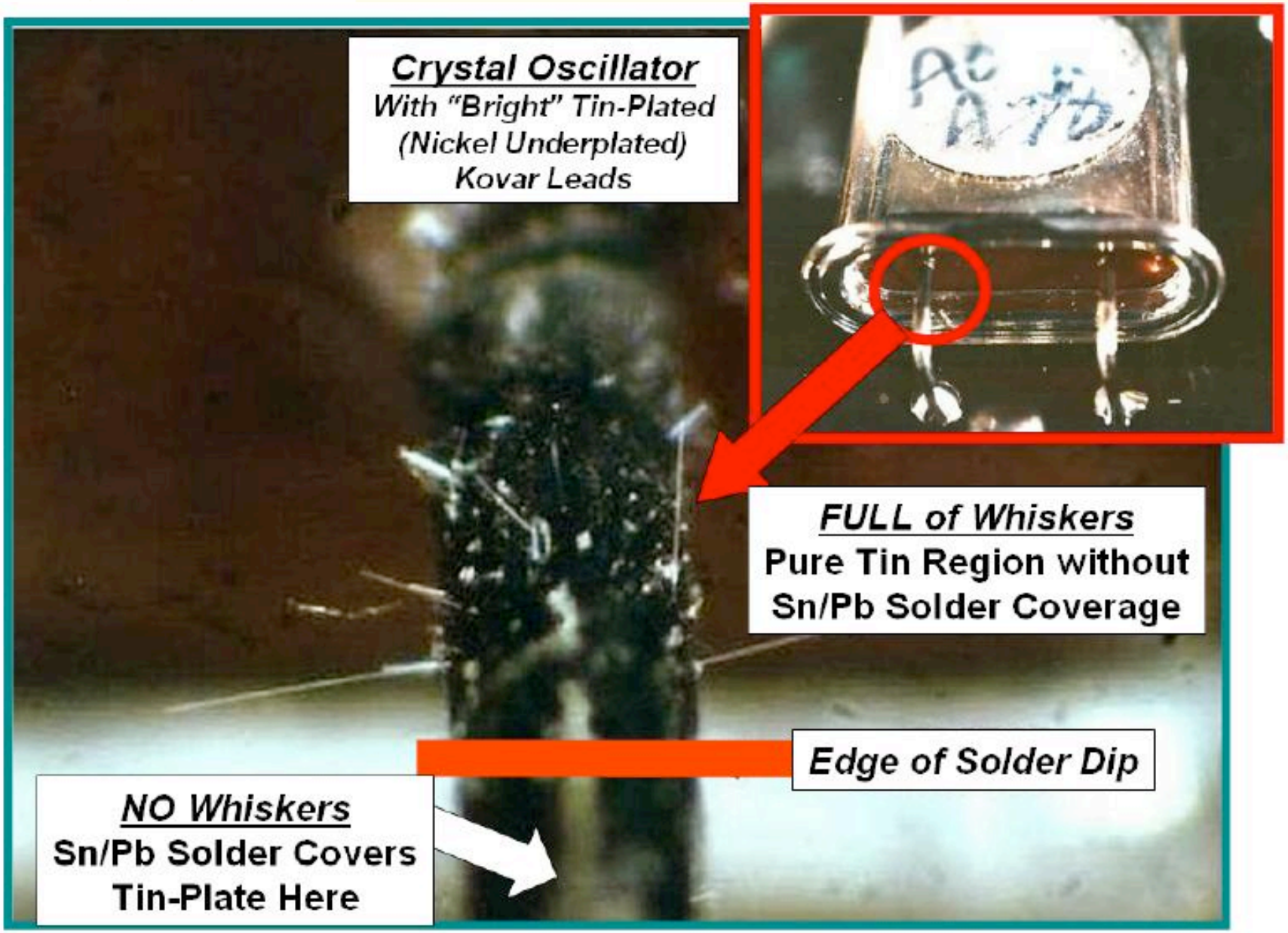
- Its usually a cable/connector
  - Broken grounds on cable or board launch
    - *Higher loss*
    - *Great antennas*
  - Oxidized contacts
    - *Resistive*
    - *Diode behavior*
  - Bad components
    - *Bad die bonding*
    - *Capacitors*
  - Poor construction
    - *SMT solder joints*

# RoHS

- Restriction of Hazardous Substances Directive From Wikipedia, the free encyclopedia · The **Directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment** 2002/95/EC[1] (commonly referred to as the **Restriction of Hazardous Substances Directive** or **RoHS**) was adopted in February 2003 by the European Union. The RoHS directive took effect on 1 July 2006, and is required to be enforced and become law in each member state. This directive restricts the use of six hazardous materials in the manufacture of various types of electronic and electrical equipment. It is closely linked with the Waste Electrical and Electronic Equipment Directive (WEEE) 2002/96/EC which sets collection, recycling and recovery targets for electrical goods and is part of a legislative initiative to solve the problem of huge amounts of toxic e-waste. In speech, it is often spelled out or pronounced [ɹɑs], [ɹɑʃ], [ɹoʊz], [ɹoʊ hɑz].

# RoHS

- From Wikipedia, the free encyclopedia
- Criticism An illustration of "bright" tin-plated Kovar (Fe-Ni-Co) leads, both above and below the level to which the leads were "hot solder dipped" in Sn63/Pb37, a typical Tin/Lead solder. The part failed 1 year after installation.Negative effects on product quality and reliability, plus high cost of compliance (especially to small business) are cited as criticisms of the directive, as well as a growing body of research indicating that the life cycle effect of lead free solder is more significant than that of traditional solder materials.Restricting lead content in solders for electronics requires expensive retooling of assembly lines and different coatings for the leads of the electronic parts. Lead-free solders have a higher melting point requiring higher process temperatures (up to 260 °C, instead of 220-235 °C), driving changes to materials for chip packagings, for some circuitboards and components containing plastics.[14] The higher temperature also precludes the use of components that cannot survive the higher temperature.Lead-free solders are significantly harder, increasing the likelihood of cracks instead of plastic deformation which is typical for Lead-containing solders.[14] Such cracks occur due to thermal or mechanical forces acting on components or the circuit board, the former being more common during manufacturing and the latter in the field.[15]The editor of Conformity Magazine wonders if the transition to lead-free solder will not affect long-term reliability of electronic devices and systems, especially in applications more mission-critical than in consumer products, citing possible breaches due to other environmental factors like oxidation.[16] This article refers to the Newark InOne "*Rohs Legislation and Technical Manual*",[17] which cites these and other "lead-free" solder issues, such as:*1.warpage or delamination of printed circuit boards,2.damage to through-holes, ICs and components on circuit boards, and3.added moisture sensitivity, all of which may compromise quality and reliability.*[edit]
- **Effect on reliability**Admission of reliability problems is found in Annex, item #7, of the RoHS directive itself, granting servers exemption from regulation until 2010.[18]Another problem that lead-free solders face is the growth of tin whiskers. These thin strands of tin can grow and make contact with an adjacent trace, developing a short circuit. Tin whiskers have already been responsible for at least one failure at a nuclear power plant.[19] Other documented failures include satellites in orbit, aircraft in flight, and implanted medical pacemakers.Reliability decay of low-lead materials may be economically desirable for some consumer product companies because it provides a mechanism to enforce planned obsolescence and replacement. Ironically, this is the opposite of the claimed intent of RoHS legislation.Some countries have exempted medical and telecommunication infrastructure products from the legislation.[20]


Crystal Oscillator
With "Bright" Tin-Plated
(Nickel Underplated)
Kovar Leads
FULL of Whiskers
Pure Tin Region without
Sn/Pb Solder Coverage
Edge of Solder Dip
NO Whiskers
Sn/Pb Solder Covers
Tin-Plate Here