Repairability Standard for Hi-tech Equipment

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Hi-tech electronic equipment is increasingly manufactured in such a way that it requires very specialised and expensive equipment to repair it – if indeed repair is even possible. Sometimes this is done for ease of manufacture, sometimes to save manufacturing costs, sometimes simply out of habit, and occasionally quite intentionally to make repair impossible.

If hi-tech is to have a place in the Developing World where supply chains are long, and if products are to have a useful life beyond the time during which the original manufacturer is prepared to repair them, and if local repair is to be economical, this must change.

There is an obvious tension between the manufacturer retaining control of his IPR, and the ability of an engineer from a third party to repair the product, or modify its behaviour if circumstances change. However, it should be an objective that products should last as long as possible, and continue to work even if the manufacturer loses interest or goes out of business.

To encourage sustainability in hi-tech manufacture, a standard is proposed against which equipment may be assessed and tested, and certified to be repairable.

Requirements or recommendations in black should be testable on Day1, and again after any significant hardware change. Those in blue endure for the life of the product, and must therefore be written into procurement contracts.

It is proposed that for certification, the following criteria **should**, or **must** be met:

1. Access for Repair

	Requirement/Recommendation	Reason
1.1	The product **must** be held together with security screws, and not ultrasonically welded together	It must be possible to get inside the unit to effect a repair.
1.2	The security of security screws **should** be finely judged, so that an ill-equipped novice cannot open the unit, but not so secure that it is impossible for a competent engineer to open it. Security screw heads **must** be such that a standard hex security screwdriver kit can open the unit.	A competent engineer must be able to get inside the unit without breaking it.
1.3	Security screws **must** not be at the bottom of a deep narrow hole, such that a universal hex screwdriver cannot reach them.	If they were, a very specific screwdriver would be required to open the unit.
1.4	Fixing screws **should** be of one sort. If this is not possible, they should be very obviously different, (e.g. significantly different length or diameter, different plating) so that during reassembly it is easy to put the correct screw in each location.	Putting screws in the wrong place will mean either that the unit is not securely closed, or that the case is damaged.
1.5	Where other screws are accessible on the	So engineer does not undo screws that do

	outer casing of the unit, cover fixing screws **should** be indicated with a special symbol, eg ➔ or ※	not need to be undone to remove the cover – especially if to do so could leave a loose nut inside the unit.
1.6	One-time fixing clips **must** not be used.	It must be possible to take a unit apart, and put it together again, without needing to replace anything simply through doing that. (Replacing cable ties is acceptable.)
1.7	Components **must** not be potted in epoxy.	If they are, they can't be repaired.
1.8	If components are glued in place, it **must** be possible to break the glue to remove a broken part, without damaging what it is glued to	For example, the glass in front of a display should not be so tightly bonded to the display that replacing a broken glass breaks the display as well, or removal of a battery bonded to a case damages the case.

2. Documentation, Circuit diagram/schematic

	Requirement/Recommendation	Reason
2.1	A service manual **must** be available. It **should** be both downloadable from the Internet and supplied in a paper form with the unit, along with the user instruction manual.	The chances of repair being successful are hugely increased by the availability of a service manual to the repair engineer.
2.2	If any preventive maintenance is recommended for the unit, this **must** be spelled out in a separate section of the user manual (if the user can do it) or the service manual (if an engineer is required).	The need for preventive maintenance in the Developing World is not widely understood, and almost always neglected.
2.3	The schematic of the unit **must** be available to the service engineer, without needing to be sent to him/her by the manufacturer. If manufacturers are concerned to protect their IPR, the schematic does not need to contain every detail – control circuitry can be shown as a box – but all power and sacrificial components **must** be identified and shown.	Diagnosis is hugely easier if a schematic is available.
2.4	The schematic **should** be on the inside of the equipment case.	So that there is no possibility of its loss.
2.5	The schematic **should** also be in the service manual.	So the engineer has it when he needs it.
2.6	If there are any adjustable components in the unit, the method of adjustment/calibration **must** be described in the service manual. Adjustment **must** not require a custom calibration jig.	Adjustment may be necessary due to drift with time, user fiddling or component replacement.

3. All electronic components

General principles: Every foreseeable fault **should** be diagnosable and repairable using standard tools, a soldering iron and a multimeter (and just possibly an oscilloscope). A surface mount workstation **must** not be required to replace any part that is considered likely to fail.

	Requirement/Recommendation	Reason
3.1	All electronic components apart from mask-programmed parts and transformers **must** be	There must be confidence that replacement parts will be available when needed.

	available from at least two manufacturers, and either manufacturer's part **must** work equally well. Semiconductor parts that are known to be near end of life **must** not be designed in.	
3.2	Any other custom parts that could possibly fail (eg transformers) **must** be available as spares for [5] years. A production run **should** include making extra quantities to be held back as spares.	There must be confidence that replacement parts will be available when needed.
3.3	Spare parts **should** be made available at a proportionate price – that is to say, a minor component **should** be available at a small percentage of the purchase price of the complete product – and any handling charge **must** be modest and reasonable.	Today, it is often cheaper to scrap the whole product and buy new, than to obtain the spare part – even if labour is a zero cost.
3.4	If construction is modular, each module **should** be considered as a custom part, and thus **should** be available as a spare for [5] years.	For example, a sealed RF module should be available as a spare, as it may be impossible to replace an active component within it.
3.5	If a chip is mounted directly on the printed circuit, the whole printed circuit **must** be considered to be a custom part.	A chip mounted under a plastic bump on a printed circuit cannot be replaced.
3.6	Parts **must** not have their identification numbers ground off	You can't replace a chip if you can't read its part number.

4. Printed circuits

	Requirement/Recommendation	Reason
4.1	Multi-layer printed circuits **must** not be used (double-sided is fine).	Without a custom-built test jig, it is impossible to detect a printed circuit fault inside a multi-layer board.
4.2	The printed circuit **should** as far as possible not be relied on to provide mechanical strength.	Flexing of printed circuits is a common cause of faults.
4.3	Unless the power plane is required to act as a heat sink, all pin-through-hole pads in ground and power planes **must** have a thermal relief design	It is very difficult to heat a ground or power plane sufficiently with a soldering iron to remove a component from a hole, without damaging other components.
4.4	All surface-mount solder pads **must** be visible. Solder-bump packages **must** not be used.	It must be possible to re-make a solder joint with a (perhaps very small) soldering iron. It is not possible if the solder joint is underneath the chip on the printed circuit.
4.5	Zebra-strip LCD display connectors **must** have a means to hold them in position	It is very common for these to get displaced, losing some elements of the LCD display.

5. Power electronic components and moving parts

This includes:

- All semiconductors exposed to high voltages or high currents, including diodes and bridge rectifiers, FETs, IGBTs, SCRs, triacs
- Large electrolytic capacitors

- High-wattage resistors
- Any other component apart from transformers that is likely to operate at more than 20'C above ambient.
- Motorised components – eg cooling fans
- All other moving parts

	Requirement/Recommendation	Reason
5.1	No power component **should** be surface-mounted if it has more than five pins, and there **must** not be copper tracks between the pads.	It is very difficult to replace SMT devices with many pins just using a soldering iron.
5.2	Any component that must not be replaced with a generic equivalent **must** be identified as such.	If there are very critical characteristics necessary for safe or reliable operation, these must be evident to the engineer replacing the part.

6. Programmable parts, firmware and apps

	Requirement/Recommendation	Reason
6.1	Boot loaders **should** be mask-programmed	So the boot loader cannot get corrupted, even during an aborted upgrade.
6.2	Flash memory firmware **must** be field-reloadable.	So that the program can be reloaded if corrupted, or an update is required.
6.3	Programmed parts **should** not require special programming equipment.	It may be necessary to email the program to the engineer, and he may not have access to a programmer.
6.4	With suitable facilities, it **should** be possible to extract the program from a programmed part, and copy it to an off-the-shelf part.	This may be necessary if a programming file is not available.
6.5	Programmed parts **must** be identified as such, and if not field-upgradeable, **must** have a revision number marked on them.	So the engineer knows that a part off-the-shelf cannot be used.
6.6	Programmable components that cannot be re-programmed in situ **must** be socketed	So they can be removed to be re-programmed.
6.7	Software and firmware **should/must** be open-source. (This is an emotive issue.)	Requirements change, and it may be necessary to change the software, to continue to use the product. Without this, the product will become useless.
6.8	Software source code that is not open-source **must** be lodged in escrow with a third party, such that if the manufacturer collapses or otherwise decides no longer to support the product, the third party will release the source code to another organisation willing to take on the responsibility of software maintenance	Ditto (also an emotive issue!) It must be assumed that software maintenance will be required throughout the useful life of the product.
6.9	Over the lifetime of a product, minor modifications to hardware and software will be implemented, for example to fix bugs. There are likely to be combinations of hardware revision level and software revision	A software change could cause old hardware to stop working.

	level that are incompatible. Software revisions **must** be tested prior to release on every earlier version of hardware that is in the field. Any unworkable combinations **must** be clearly stated.	
6.10	If there are any hardware revisions in existence that cannot tolerate a software revision, the upgrade **must** not happen automatically, and if attempted manually, **should** be prevented by the software upgrade testing the hardware revision state before executing.	What happens if the upgrade is to fix something that is discovered to be dangerous? (How would we do a product recall of a consumer product in Africa??)

7. Batteries

	Requirement/Recommendation	Reason
7.1	Batteries **must** be readily replaceable by a service engineer.	One should expect to have to replace them routinely – even rechargeable ones.
7.2	Batteries **should** not be user-accessible, unless any battery of the same physical size may be used.	Users will replace batteries with others of the same size, regardless of the battery technology (or what the manual says!).
7.3	Printed-circuit-mounted batteries that are soldered in **must** be widely available in the correct configuration	Batteries will wear out during the lifetime of the product.
7.4	Sufficient information **must** be provided to the service engineer to enable him/her to tell if a replacement battery from a different manufacturer is suitable.	The original battery may not be available.

8. Sacrificial and safety-critical components

This includes:

- One-time fuses
- Lightning arresters
- Fusible resistors
- One-time thermal fuses (but not resettable thermal cut-outs)
- Class X or Y safety-critical capacitors

	Requirement/Recommendation	Reason
8.1	At design time, where protection can be achieved without using a sacrificial component, it **should** be (for example, by designing in a resettable fuse)	This avoids a need for continual supply of replacement sacrificial components, and the danger that safety components will be circumvented.
8.2	Sacrificial components **should** be socketed	So replacement requires the minimum of tools
8.3	Sacrificial components **must** not be surface-mount	Replacement must be easy (or the repairer is liable to just jumper it out)
8.4	Sacrificial components **should** generally not be user-accessible, but only replaced by a service engineer.	The user is unlikely to have the correct replacement part. It is also desirable to have an enquiry into why it blew.

8.5	Sacrificial components **must** be easily available from many suppliers	To encourage the correct replacement
8.6	If sacrificial component is socketed, one or two cold-spares **should** be provided inside the unit, or if externally accessible, in the user pack.	To encourage the correct replacement
8.7	It **must** say in the legend on the printed circuit adjacent to safety-critical components what the rating must be.	To encourage the correct replacement

9. Connectors

	Requirement/Recommendation	Reason
9.1	All surface-mounted connectors that are accessible to the user **must** have at least two pin-through mounting holes.	Surface-mounted connectors are notorious for coming adrift from the printed circuit.
9.2	All connectors **must** be polarised	So it is not possible to put the plug in the wrong way round
9.3	Two connectors in the unit that are electrically incompatible **must** also be physically incompatible.	So there is no possibility of plugging into the wrong connector.
9.4	Internal connectors **should** be retained with a blob of silicone	To prevent connectors shaking lose in transit on bumpy roads.
9.5	External connectors (except those intended for fixed wiring) **must** be tested to survive a sideways force, such as may be applied when a user trips over a lead	Accidents happen! (Exact test TBD)
9.6	Internal leads that will be flexed during repair of the unit **must** be of stranded wire (or a flexible printed circuit)	Assume the unit will be taken apart several times in its lifetime, and wires must not fatigue and break.
9.7	Where a particular connector is already in common use for a particular purpose, it **must** only be used for the same purpose on the unit.	Users are liable to assume that if a plug physically fits a socket, it will be safe to plug it in – even if it is from something completely different.
9.8	Retaining catches on connectors **must** not catch when the connector is pulled through a hole by the lead	If they catch, they will break off. (How many RJ-45 leads have you seen with the catches broken off?)
9.9	All exposed metalwork **must** either be completely insulated or at the same voltage.	It must be assumed that the user may short any two metal items together.
9.10	If there is exposed metalwork on the roof and inside the building, the exposed metalwork **must** be connected to earth	To prevent electrocution by lightning.

10. Separable components

It must unfortunately be assumed that any separable components that come with the system will, over time, be lost or broken.

	Requirement/Recommendation	Reason
10.1	The system **must** be usable without minor components (for example a remote control, or mounting bracket)	The component may get lost or broken.
10.2	A battery cover or protective unit lid **should**	If it is, it will get lost!

	not be detachable.	
10.3	Supplied leads **must** survive a trip test.	Accidents happen! (Exact test TBD)
10.4	If a connector on the end of a lead gets damaged (for example crushed), it **should** be possible for the service engineer to replace it without replacing the whole lead.	Connectors are likely to be easier to obtain than custom leads.
10.5	It **must** be possible for an engineer with suitable tools and joining materials to cut and join a lead	It may be necessary to extend a lead, or to pass it through a hole smaller than the connector on the end.

11. The total system

	Requirement/Recommendation	Reason
11.1	If operation relies on the mobile phone network, (or even on being within the coverage of a particular operator), this **must** be clearly stated prior to sale or supply.	This may make the product unusable in its proposed application
11.2	If operation relies on communication with a remote server on the Internet, this **must** be clearly stated prior to sale or supply, and the supplier **must** commit that this will continue to be operational for [5] years	This gives the supplier (or someone who takes the supplier over) absolute control over the future of the product, even after outright purchase. If the supplier fails, in this case the future will be uncertain.
11.3	Any upgrade to the server software **must** be subject to the same backwards compatibility tests described for firmware above (§6.9,6.10).	The supplier must not force users to buy new hardware.
11.4	A process of continuous improvement requires that an effective mechanism **must** be provided, whereby a user or field service engineer can communicate issues back to the design team, to enable remediation in the next hardware revision. This facility **must** continue to function after the end of the warranty period.	The Design Team cannot fix problems that they don't know about.

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