General Safety Guidelines in the Design and Construction of Electrical Equipment

	Labels & Documents	Labels & Documents
1	**Do plan electrical safety into your design.** Leaving electrical safety aspects to latter is not a good idea. Aspects get forgotten and can be difficult to implement later. A rough drawing of the component arrangement, the wiring routes, and the earthing diagram, is recommended	**Do Not assume electrical safety is routine and requires little though.** Safety in electrical equipment is complex and should be closely considered. There are a number of Australian Standards that equipment should comply with. In the Australian research/teaching environment some of the more important standards are: AS/NZS3000 Wiring Rules, AS/NZS3100 General requirements for electrical equipment, AS61010 Safety requirements for electrical equipment for measurement, control and laboratory use, AS2243.7 Safety in Laboratories - Electrical aspects.
2	**Do document your design.** Besides being good engineering practice, accurate circuit documentation showing all modifications and additions is required for in-house constructed equipment (see AS 2243.7:1991 Clause 2.3). If special precautions are needed for installation or using the equipment they should be provided with the equipment (see AS/NZS3100 :2002 Clause 7.10)	**Do Not make documentation difficult to follow.** Plan the layout of schematics and use conventional symbols consistent with local understanding. Provide information to install and operate the equipment, as well as carry out repairs or modifications to the equipment. Highlight the safety aspects of the design so they are well understood, and not interfered with later when repairs or modifications are made.
3	**Do specify the equipment's ratings.** Documentation should include the follow: supply voltage (range), frequency (range), power (or current), description of all input and output connections, insulation ratings of accessible external circuits, environmental conditions (range), degree of protection (IEC rating) (see AS/NZS61010.1:2003 clause 5.4.2)	
4	**Do label equipment with the operating voltage and loading.** Equipment is required to be marked with the operating voltage, current rating or loading in watts or VA, ac/dc phases frequency (as applicable) (see AS/NZS3100:2002 Clause 7.1)	**Do Not use labels that fade, wear or fall off.** Check the legibility and wear resistance of any labelling. Ensure normal operation will not damage the labels. See AS/NZS 3100 clause 8.13 for details on testing of markings.
5	**Do label high current mains connections.** Equipment with a current rating above 10A (but < 20A) should have a warning notice near the cord entry point indicating the correct socket-outlet rating required. (see AS/NZS3100:2002 clause 4.4.2)	**Do Not use metallic labels that may become live if dislodged.** Adhesive metallic labels should not be used in locations where if they are detached may touch live parts or bridge insulation. (see AS/NZS3100:2002 Clause 7.2)
6	**Do label the common earth terminal.** Use the word earth, letter E or the international earth symbol ⏚	**Do Not make lettering too small to read easily.** Have pity on those who are sight

	international earth symbol ⏚ (AS/NZS3100:2002 Clause 7.4).	challenged.
	Components	**Components**
7	**Do include a fuse or circuit breaker in your design.** Mains operated equipment should include some form of over-current protection rather than rely on the building wiring for protection. External fuses should be easily accessed, clearly marked and prevent inadvertent contact with live parts when accessed or when cleaning the equipment (see AS/NZS3100:2002 Clause 3.6)	**Do Not use non- or under-rated components.** Components used in circuits should have adequate voltage and current ratings to handle maximum expected loads under sustained operating conditions. Components with unknown performance should be avoided and never used in mains circuits.
8	**Do use mains inlets with integral fuse-holders.** This guarantees the power is removed before a person can access the fuse element. Inlet/fuse-holders with a spare fuse compartment is a good investment in having the correct rating fuse available when needed.	**Do Not wire fuse-holders incorrectly.** Fuse-holders should never be wired such that power remains on the fuse element as it is withdrawn from the holder. Check that the fuse cap retains the fuse element when extracted from the holder
9	**Do choose conventional mains connector styles.** Mains inlet and outlets should be easily recognisable as such. Non-conventional plugs and sockets may not have sufficient creepage and clearance distances (see AS/NZS 3100:2002 clause 4.1.3) or may create confusion for users	**Do Not use audio/data style connectors for mains wiring.** Even if audio connectors could withstand the voltage and current, the attachment terminals, mechanical and insulation properties would most likely be inappropriate and users might assume these connectors never have dangerous voltages.
10	**Do use a switch to control equipment supplied through a flexible power cord.** Power switches should be category 1 and have their "OFF" position marked (OFF or 0). Equipment that is permanently powered and has no other means of indication is also required to have a category 1 switch. (see AS/NZS 3100:2002 clause 3.8.5)	**Do Not separately switch neutrals or other actives.** Switches are not required to control the neutral (although this is a good idea). If the neutral is switched then it must be mechanically linked to the related active(s). (see AS/NZS3000:2000 clause 2.2 (f)) A switch in a polyphase circuit must mechanically switch all related actives. A separate relay for each active in a polyphase circuit is not permitted. Never switch protective earth!
11	**Do ensure control switches and relays have the appropriate voltage and current ratings.** Choose control components that are conservatively rated for the task. AC ratings are normally higher than DC ratings because their contacts arc less.	**Do Not assume the switch will always be wired after the fuse.** There has been no rule that ensures this will be the case. The majority of equipment has the fuse wired before the control switch so that the fuse can protect the switch and its wiring. Never rely on the switch to remove the power. Unplug the equipment!
	Earthing	**Earthing**
12	**Do earth all exposed metal by suitable methods.** Exposed metal is metal that can de touched by the standard test finger and may become live with basic insulation failure (see AS/NZS 3100:2002 clause 2.1.23)	**Do Not rely on screws alone to earth panels.** Painted or anodised panels generally require the paint or anodising to be removed before connecting earth strapping. Ensure all external panels that mount or come in contact with mains wiring or components

		are adequately earthed and will stay that way with normal use (see AS/NZS 3100:2002 clause 5.3.1)
13	**Do ensure good conduction to all earthed metal.** The resistance between the common earth point and any earthed metal should be less than 0.1 ohm (1 ohm for rotating or moving metal) (see AS/NZS 3100:2002 clause 5.3.4). All earthing should be capable of carrying 1.5 times the rated current or 25 A, whichever is greater (see AS/NZS 3100:2002 clause 8.5).	**Do Not use printed circuit conductors for earthing in hand-held equipment.** PCB tracks can be used in other equipment provided at least two tracks with independent soldering points (see AS/NZS 3100:2002 clause 5.3.5). Each track should be capable of carrying 1.5 times the rated current or 25 A whichever is the greater). For 1 oz copper, the tracks would need to be >7.5 mm each.
14	**Do use tread-cutting screws** (that are not normally disturbed) to provide earth continuity for panels, provided at least two screws are used (see AS/NZS 3100:2002 clause 4.8)	**Do Not use constructional bolts/screws for earthing.** In general, fasteners for constructional purposes should not be used for making earthing terminations. There are some exceptions that relate to not disturbing the earthing connection or the mechanical rigidity (see AS/NZS 3100:2002 clause 5.3.2
15	**Do size the earthing conductor in a flexible cord at least 0.5 mm^2.** The minimum earth wire in a flexible cord is 0.5 mm^2 or the same size as the largest live conductor whichever is larger (up to 2.5 mm^2) (see AS/NZS 3100:2002 clause 4.4.1, and AS/NZS 3000:2000 clause 5.5.1.2 (g) (iii)).	**Do Not incorporate an earth conductor in double-insulated equipment.** Flexible cords for connecting double-insulated equipment should not have an earth conductor (see AS/NZS 3100:2002 clause 4.4.1 (h)
16	**Do use green/yellow colour for earthing conductors.** Make the earthing connections instantly recognisable using green/yellow with no one colour covering less than 30% of the conductor's insulation. Avoid using green or yellow for any other function (see AS/NZS 3191:1998 clause 2.2.6 and AS/NZS 3100 : 2002 clause 3.7)	**Do Not use green/yellow conductors sleeved for other tasks.** Green/Yellow, Green or Yellow conductors should never be sleeved with another colour and used as a live conductor (see AS/NZS 3000:2000 clause 3.8.2)
	Wiring	**Wiring**
17	**Do use mains-rated cable for internal mains wiring.** Mains rated cables usually have thicker insulation with a temperature rating printed on the insulation. For PVC the minimum aggregate thickness is 0.5 mm between live or exposed metal parts (see AS/NZS 3100:2002 Clause 5.2.3.2). Insulations used in mains wiring should be tested at 2 kV for 15 minutes (see AS/NZS 3100:2002 clause 5.2.3.1)	**Do Not use cables of unknown rating for mains wiring.** There is more to mains wiring than the breakdown voltage rating. Insulation thickness, temperature rating, flexibility, durability, current carrying capability all need to be taken into account. Seek cables that are identified as suitable for Low Voltage (<1000 Vac). These cables will have thicker insulation and a temperature rating visible.
18	**Do use wiring with appropriate temperature ratings for the task.** Thermoplastic insulation should normally be kept below 75°C, elastomer insulations can go as high as 150°C but check with the manufacturer. Temperature Limits are found	**Do Not allow wiring with basic insulation to protrude through openings.** Wiring should be supported (tying, lacing, clipping, etc) to prevent personal contact especially if a termination fails (see AS/NZS

	in Table 1 of AS/NZS3008.1.1:1998	3100:2002 clause 5.2.4)
19	**Do protect conductors against mechanical damage.** Openings for cables should be bushed or be shaped so as not to damage conductors or insulation. Any material immediately adjacent or touching cables must not cause abrasion. (see AS/NZS3100:2002 Clauses 4.2.2 and 4.2.3)	**Do Not locate wiring near moving parts.** Wiring in close proximity to moving parts should be guarded to prevent abrasion (see AS/NZS3100:2002 Clause 4.2.4). One should consider the likely wear and failures in moving parts in locating wiring near machinery.
20	**Do segregate extra low voltage wiring (less than or equal to 50 Vac).** Accessible internal ELV wiring should be separated from low voltage (LV) (less than or equal to 1000 Vac) wiring. Acceptable methods are rigid fixed screens/barriers, lacing, enclosure in insulation, etc. If other equipment is externally connected to ELV wiring than this would be considered as accessible internal wiring (see AS/NZS3100:2002 Clause 4.1.2).	**Do Not use mains colours for internal ELV wiring.** Brown, Blue, Green/Yellow conductors are often associated with the mains wiring. To reduce confusion choose other colours for non-mains wiring.
	Mains Cords	**Mains Cords**
21	**Do use flexible cords with the correct current rating.** Cords with 0.75 mm^2 conductors can be used for currents up to 7.5 A, 1 mm^2 for currents up to 10 A, 1.5 mm^2 for currents up to 16 A, and 2.5 mm^2 for currents up to 25 A. (see AS/NZS3100:2002 Table 4.4)	**Do Not make flexible cords too short.** In general flexible cords should be at least 1.8 metres unless it is intended for bench top or tabletop where the minimum length is 0.9 metres. (see AS/NZS3100:2002 clause 4.4.1 (b).
22	**Do use IEC inlets with the appropriate temperature ratings.** IEC plugs for hot equipment have a keyway in the plug (between line and neutral connections) to prevent normal IEC plugs being substituted on hot equipment.	**Do Not use PVC flexible cords for hot equipment.** PVC cord should not be used on equipment where external metal parts are likely to exceed 75°C and the cord is likely to touch the metal. (see AS/NZS3100:2002 4.4.1)
23	**Do use at least ordinary duty PVC flexible cords for heavy equipment.** Equipment with a mass exceeding 3 kg requires ordinary duty flexible cord. Light duty is only acceptable for equipment up to 3 kg. (see AS3100:2002 clause 4.4.1 (c).	**Do Not use beads, heat sleeving, tubing, or tape to protect flexible cords.** Flexible cords that are easy to replace (i.e. Type X attachment) should not have any of the above to protect them. (see AS/NZS3100:2002 Clause 4.5.4)
24	**Do use the recommended colours for conductors.** The international recommended colours for flexible cords are: Brown Active (Live), Blue Neutral, Green/Yellow Earth. (see AS/NZS3000:2000 clause 3.8.1 and AS/NZS3191:1996 Clause 2.2.6)	**Do Not get confused with USA mains cord colours.** The conductor colours in American are: Black Active (Live), White Neutral, Green Earth.
25	**Do provide appropriate anchorage for flexible cords.** The means of anchorage should provide effective strain relief and prevent twisting and damage to the cord. If a tortuous path is used it should be clear how the cord is to be fitted. (see AS/NZS3100:2002 clause 4.5.3)	**Do Not knot flexible cords to provide cord anchoring.** Knots in a flexible cord are not acceptable as a means of cord anchorage. Neither is floating type anchorage (eg Cable ties) unless it is independent of the cord and contained within the termination compartment. (see AS3100:2002 Clause 4.5.3)

	Joints & Connections	Joints & Connections
26	**Do consider fault conditions in using soldered connections.** One should take into account creep, mechanical stress and temperature rise under fault conditions when designing equipment with soldered connections. (See AS/NZS3000:2000 Clause 3.7.2.6). When soldering earth connections the conductor must be retained in position independent of the solder. (see AS/NZS3000:2000 Clause 3.7.2.10)	**Do Not solder strands of conductors together.** Conductors that are to be screwed, clamped, crimped or any other means that rely on pressure for contact are not to be pre soldered. Solder tends to cold flow and will loosen connections over time. Soldering the tip of a stranded conductor is acceptable. (see AS/NZS3100:2002 clause 4.6.1 and AS/NZS3000:2000 Clause 3.7.2.4)
27	**Do use appropriate crimping tools.** For solderless pressure joints use the appropriate attaching tools. (see AS/NZS3100:2002 Clause 4.6.5). A well made joint will "cold weld" metal surfaces without damaging the conductor strands.	**Do Not make joins in flexible cords except by suitable cable couplers.** Except for connections to fixed wiring, flexible cords should only be joined with suitable couplers such as plug/socket. Joins to fixed wiring should only be made using screwed or crimped terminals. (see AS/NZS3000:2000 clause 3.7.2.7)
28	**Do test crimps made with substitute crimping tools.** The recommended crimping tool is always preferred but if an equivalent is used test the connection quality first. The wire will normally break before being released from the crimp.	**Do Not solder high temperature connections.** Connections that are likely to exceed 120°C in normal operation should not be soft soldered (see AS/NZS3100:2002 clause 4.6.3). Do not use tin-plated or solder-coated crimp lugs for high temperature applications.
29	**Do strip conductor insulation carefully.** Use appropriate stripping tools and ensure that conductor strands are not marked, nicked, or broken. The wire end should be exposed only for the length required to make the connection.	**Do Not use terminals that allow conductor strands to spread.** Terminals should prevent slipping or spreading of conductor strands (see AS/NZS3100:2002 clause 4.3.6). Where connections are bolted together it's best to use crimp or solder lugs to protect the conductors.
30	**Do double the wire over when connecting flexible cord in Aussie mains plugs.** Many rewireable plugs sandwich conductor strands between screwed metal surfaces. By filling the available gap with the conductor more pressure can be exerted on the connection.	**Do Not leave loose or broken strands when making connections.** Besides weakening a connection, broken stands reduce the current carrying ability of a conductor. Loose strands also reduce current carrying ability and may bridge insulation gaps creating a hazard.
31	**Do protect stranded conductors connected by screw terminals.** Protect the stands of conductors (especially with fine stands) where screws are used to apply pressure directly to the conductors in a terminal. "Bootlace" ferrules are a good idea in this situation. A better idea is to only use terminals with in-built conductor protection.	**Do Not connect more than 4 conductors in a screwed tunnel.** There is a sensible limit to the number of conductors twisted together that can be inserted in a tunnel termination. If the insulation is thick less than 4 conductors should be connected.
	Insulation of Live Parts	**Insulation of Live Parts**
32	**Do understand creepage and clearance distances.** Creepage is the shortest path along the surface of insulation between two conductive	**Do Not ignore pollution level and the materials when deciding insulation spacing.** The microenvironment is important is

	parts. Clearance is the shortest distance through air between two conductive parts (see AS/NZS3100:2002 clauses 2.1.12 & 2.1.17).	deciding clearances and creepage distances. AS/NZS61010.1:2003 identifies 3 levels. Level 1 dry, non-conductive; Level 2 normally non-conductive, occasional condensation; Level 3 conductive pollution occurs, condensation expected.
33	**Do space tracks on PCBs to meet creepage requirements.** Coated (soldermask) PCB is considered pollution level 1. The minimum creepage and clearance for 240 V mains tracks is 1.5 mm (AS/NZS61010.1:2003 Clause 6.7.2). For high voltages a safe rule-of-thumb for creepage is to allow 200 V/mm for uncoated PCB and 250 V/mm for coated PCB (AS/NZS61010.1:2003 Table7 >2 kV)	**Do Not mount live parts too close.** The minimum clearance for 240 V mains parts is 2 mm for pollution level 1(2.5 mm for Level 2) (AS/NZS3100:2002 Table 4.1). Clearance is a complex issue. For higher (non-mains circuits) voltages a safe rule-of-thumb is to allow 600 V/mm. (see AS/NZS61010.1:2003 clause 6.7.3.2)
	Controls & Metering	**Controls & Metering**
34	**Do label On and/or Off positions of the power switch.** A lamp alone is not sufficient. The On-position and/or Off-position should be clearly marked and the switch prevented from rotation in operation. The symbols "1" and "0" are reserved as "ON" and "OFF" respectfully for power switches and should not be used for other controls (see AS/NZS61010.1:2003 clause 5.1.6)	
	Battery Operated Equipment	**Battery Operated Equipment**
35	**Do provide polarity protection for battery connection.** If the connection of the battery permits reversal, then a hazard should not be created if the battery is reversed (see AS/NZS61010.1:2003 Clause 4.3.2.4 (f) and Clause 13.2.2)	
36	**Do warn against fitting incorrect batteries.** Where the wrong battery can be fitted (eg, no rechargeable for a chargeable) and will result in a hazard, markings shall warn the user (see AS/NZS61010.1:2003 clause 13.2.2	**Do Not seal battery compartments where gas built-up is possible.** Battery compartments should be designed to prevent explosion due to flammable gas build up. (see AS/NZS61010.1:2003 clause 13.2.2). Any battery that gives off hydrogen will fall into this class.
	Rules of Thumb	**Rules of Thumb**
37	**Do consider the galvanic series when using dissimilar metals.** Most corrosive (anodic)- Zinc, Galvanised Steel, Cadmium, aluminium (17ST) Steel, Iron, Stainless Steel (active), Solder, Lead, Tin, Nickel (active), Brass, Copper, Bronze, Copper/Nickel alloy, Monel, Silver solder, Nickel (passive), Stainless Steel (passive), Silver, graphite, Gold, Platinum least corrosive (cathodic). A good source of information is Henry Otts book Noise Reduction Techniques in Electronic Systems, 2nd Edition Chapter 1	**Do Not combine metals at different ends of the galvanic series.** Corrosion is the likely result of having dissimilar metal in contact especially where moisture is present. Some bad combinations would be copper on aluminium, Brass on Galvanised Steel, Gold on Steel. Some good combinations are: Zinc on Steel, Solder on copper, Cadmium on Steel, Gold on Nickel, Nickel on Copper, Steel on Aluminium.