Outline

- Options for on-board shields
- Electric or magnetic shield?
  - Choice of shielding material
- Connection of the shield
  - Interfaces
  - Apertures
- Application examples
  - On-board wireless
  - Heatsinks
Options for on-board shields

- Formed metal can
  - Typically tin-plated cold rolled steel, but also: plated copper, beryllium copper, brass, nickel-silver, tin plated aluminium
  - Photo-chemically machined or die-cut and pressed
- Conductively coated injection moulded plastic
  - Typically conductive paint or electroless plated nickel/copper
- Multi-compartment construction
  - Labyrinths or conductive elastomer internal walls
- Foil laminates
- Microwave absorber/shield combination

Formed metal PCB shields

- custom parts
- standard parts
- kits
- separate wall and clip-on lid
- single-piece (beware re-work!)
- surface mount or through-hole

Pictures courtesy Tecan
Electric versus magnetic field

- There are three field types: electric, magnetic and electromagnetic
- Reflection from a conductive surface of any thickness is good for electric (E-field) and electromagnetic but poor for magnetic
- Good magnetic (H-field) shielding needs either a permeable material (LF) or a thicker conductive material (HF) for absorption

The effect of skin depth

- Skin depth: \( \delta = \frac{66.1}{\sqrt{\mu_r \cdot \sigma_r \cdot F}} \) mm (F in Hz)
- Above 30MHz, many materials have \( \delta < 20\mu m \)
- RF current falls 8.6dB for every \( \delta \) penetration into material
Choice of material for the shield

- For high frequency and low frequency E-field applications any metal will do, although higher conductivity is better
  - because of $\delta$, thickness is hardly important
  - choice determined by mechanical, assembly and environmental considerations

- For low frequency H-field applications a permeable metal is needed
  - greater thickness and $\mu$, gives greater absorption
  - although, some magnetic field cancellation occurs through current flow in a "shorted turn" conductive shield

On-board E-field shielding

Capacitive coupling from noisy parts ... is eliminated by shield
**Where and how to connect?**

- An on-board shield will normally be used in conjunction with a circuit 0V plane
  - an inadequate plane will limit the effectiveness of the shield
- The shield should be connected to this plane with the lowest possible inductance, to prevent it becoming "live"
  - implies multi-point or continuous connection all around the shield base

![Diagram showing the connection of a shield to a 0V plane](image)

**Apertures**

- Apertures in the connection to the 0V plane will increase the inductance of this connection
  - keep spacing between connections to a minimum
- Apertures in the lid will cause capacitive leakage through the shield
  - don't put apertures near to devices with a high dv/dt noise voltage

![Diagram showing capacitive coupling through apertures](image)
Filtering interfaces through the shield

- 3-terminal SM filter e.g. Murata type NFM, NFL
- 2-line CM choke e.g. Murata type DLM, DLW
- PCB shield bonded to ground plane
- Filter components straddle shield wall
- Mousehole aperture for components

- Low impedance filter
- High impedance filter

Partitioning the housing

- An outer enclosure doesn’t always have to be shielded
  - partitioning sections into “clean box” and “dirty box” is effective and can be done with an on-board shield
  - but filter or isolation barriers between the sections are essential

- Main circuit in shielded “clean” section
- “dirty” section
- External terminals
- Isolators
- Partition
- Filters
- Display
- Keyboard
- “Dirty” section
- On-board shield
- Plastic enclosure
Wireless on-board

Near field capacitive coupling – control by separation distance of the noisiest parts (attenuation $\propto d^2$ in near field), but may not be adequate

Equivalent circuit of shielding can, neglecting structural resonances

Shielding can arrangement

Inductance of ground plane connection $L_G$

Most critical component

Heatsinks: the problem

Circulating currents developed in enclosure via C1 and C2

Radiated emissions from weak points in enclosure

Noise voltage $V_N$ developed on processor w.r.t circuit 0V

Cure is to connect heatsink to circuit 0V (not to case) via multipoint links – but this might be difficult
Heatsinks: on-board shield solution

- C1' is referenced to shield, which returns noise currents to circuit 0V; minimum voltage appears on heatsink
- device dissipation is conducted to heatsink through shield, which may act as a heat spreader

Summary

- Know what frequency range is to be shielded
  - calculate skin depth and choose shield type/material accordingly
- lay out PCBs expecting that noisy/sensitive circuits will benefit from on-board shields
  - apply strict segmentation rules
  - allow land areas on the surface of the PCB where a shield might fit
  - it's much easier to omit a shield that was designed in, than vice versa
- design the shield in conjunction with a circuit 0V plane
  - create as many connections through to the plane as possible - the higher the frequency range, the closer together must be the connection points
  - ensure that interfaces through the shield are adequately filtered
- keep the shield box design as simple as possible
  - less complexity makes for a cheaper unit cost
  - fewer apertures make for better shielding performance
The End
Thank you for your attention!

Consultancy and training in electromagnetic compatibility

E-mail timw@elmac.co.uk  web www.elmac.co.uk  phone +44 1929 558279