Systems Engineering

Grounding and Wires

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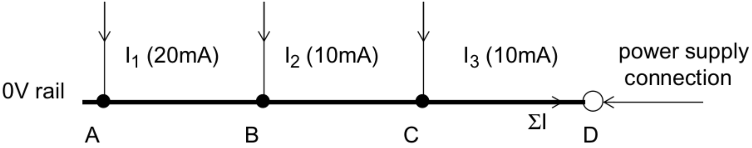
iTIC http://itic.cat

v1.0 March 2021

Reference Node

- Consider imperfect conductor: 10 mΩ/cm



- Resulting voltages

$$V_C = (i_1 + i_2 + i_3) 10\,\mathrm{m}\Omega = 400\,\mu\mathrm{V}$$

$$V_B = 400\,\mu\mathrm{V} + (i_1 + i_2) 10\,\mathrm{m}\Omega = 700\,\mu\mathrm{V}$$

$$V_A = 700\,\mu\mathrm{V} + (i_1) 10\,\mathrm{m}\Omega = 900\,\mu\mathrm{V}$$

Reference Node

- Is this a problem?
- Amps instead of milli- or microamps
- Resistance in ohms instead of milliohms
- Depending on the SNR!

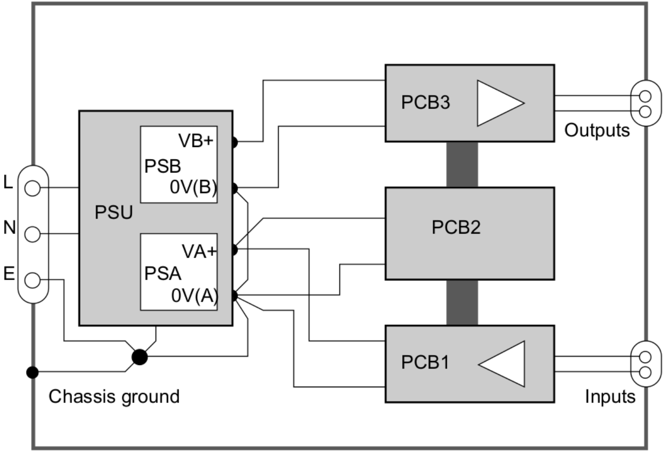
The order of blocks *may* be important!

Grounding inside one unit

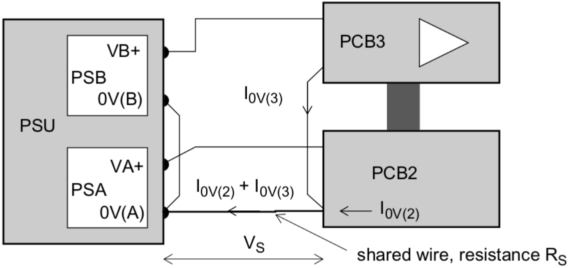
PCB1 Input signal conditioning

PCB2 Microcontroller board

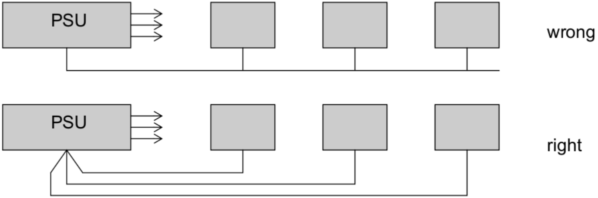
PCB3 High-current output drivers



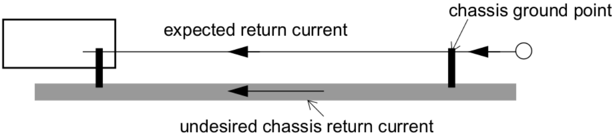
Power return



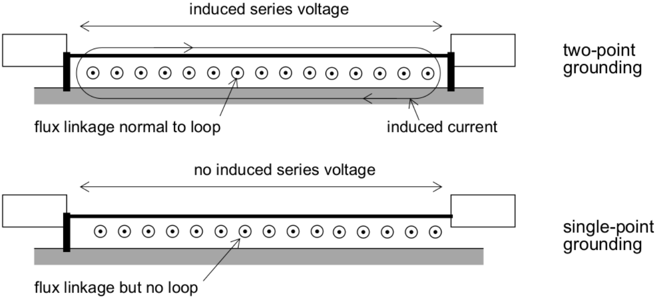
Star vs bus returns



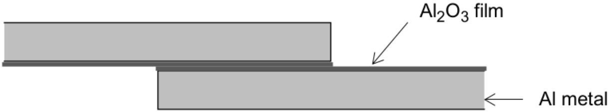
Single-Point Chassis Ground



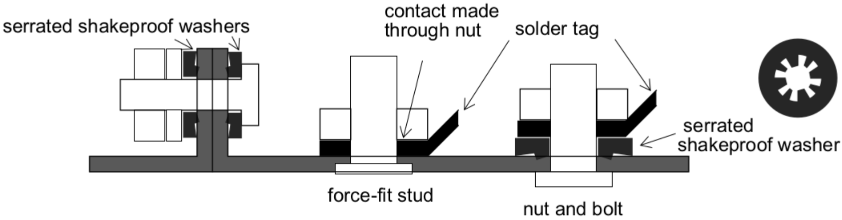
- Impedances depend on frequency
- Joints in chassis affecte by corrosion
- Ground loop:



Aluminium and aluminium joints

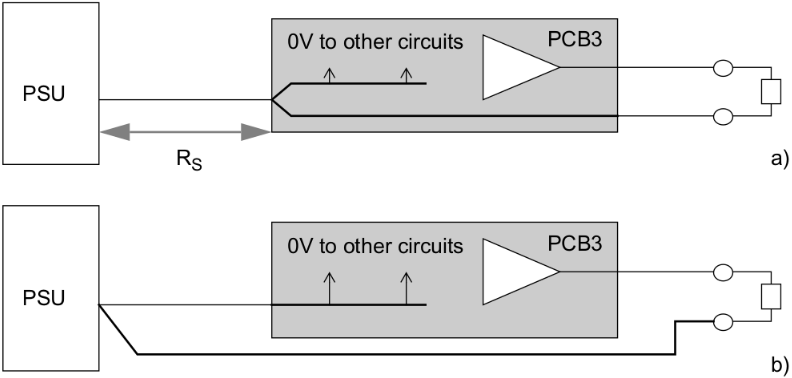


The insulating aluminium joint



Output Signal Ground

- Avoid common impedances

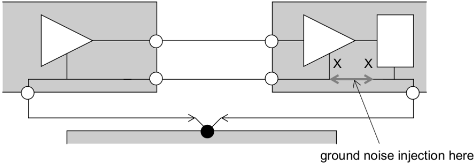


Inter-Board Signals

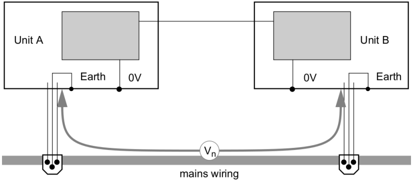
- First possibility: do nothing. Ground returns through PS
- Insert inter-board ground connection
  - High-speed digital communications
  - Precision analogue signals

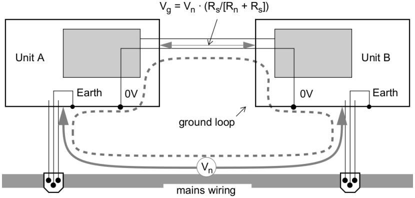
  - Drawbacks
  - There is alternative path for power return
  - Ground loops

  - Solutions
  - Separate returns
  - Differential connections / optoucouplers / 1:1 trafo



Ground Between Units





- Float (!)
- Differential link
- Galvanic isolation
  - transformer
  - optocouplers
  - fibre optic link

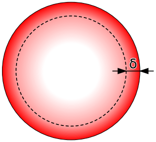
Cables

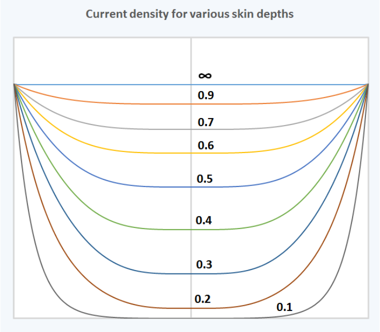
Type	Dia (mm)	I Nom	I Melt	R	L	f max (kHz)
AWG 32	0.2	0.33	~ 5	0.54	1.8	430
AWG 26	0.4	1.2	~ 20	0.11	1.7	107

- Meaning of maximum frequency?

Skin Effect

- AC current tends to concentrate near the surface of the conductor
- Skin depth δ: equivalent thickness
- Equivalent tubular conductor at DC





Skin Effect/ 2

$$\delta = \sqrt{\frac{\rho}{\pi \mu f}} = \frac{6.10 \times 10^{-2}}{\sqrt{f[\mathrm{Hz}]}}$$

- At 10 MHz, $\delta = 0.02$ mm
- Equivalent area for AWG32 (diameter 0.2 mm)

$$A_{eq} = \pi \times 0.2^2 - \pi \times (0.2 - 0.02)^2 = \pi \times 0.0076$$

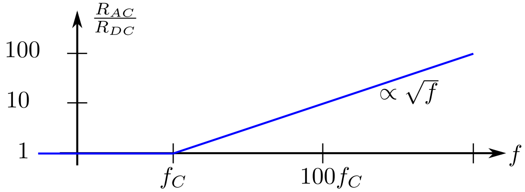
- Area at DC

$$A_{f=0} = \pi \times 0.2^2 = \pi \times 0.04$$

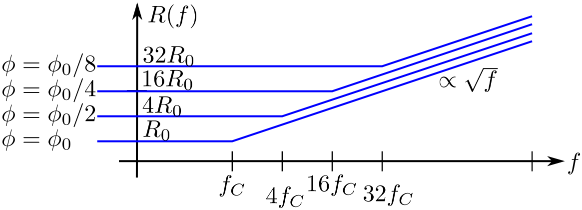
The resistance at 10 MHz is $\frac{0.04}{0.076} = 5.3$ times higher than at DC.

Frequency Response

- AC current tends to concentrate near the surface of the conductor
- Skin depth δ: equivalent thickness
- Equivalent tubular conductor at DC



One thick or several thin cables /1



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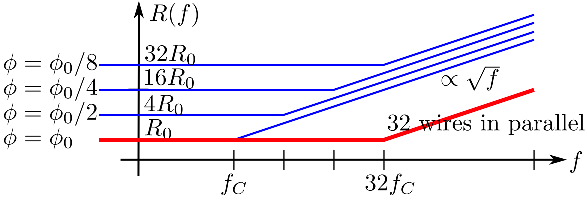

- Litz Wire
- From the german: Litzendraht. Expensive. Weaving pattern
- Used for coils in the MHz range: Required values of L mean significant wire length
- AM radio
- Induction coils