Electronics
Analog and Digital Grounds

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May 31, 2017
Analog and Digital Grounds

Digital noise; fast, lots of current
Analog noise; slow, low current
Analog and Digital Grounds

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- digital noise; fast, lots of current
- analog noise; slow, low current
### Connection resistance

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Electronics Analog and Digital Grounds
Connection resistance

Consider a trace on a circuit board.
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Copper resistivity $\rho \approx 1.56 \times 10^{-8} \Omega \cdot m$

Trace dimensions $\approx \text{mm} \times \text{mm} / 100 \times \text{length} (\text{cm})$

Resistance $R \approx 10^{-8} \text{length} / (10^{-3} \times x \times 10^{-5}) \rightarrow 1 \Omega / \text{m}$

Voltage fluctuation on lines $\Delta V = (\Delta I) R$; thus mA fluctuation $\rightarrow$ mV/m fluctuation.

This includes fluctuations on power and ground lines. The farther you get from power and ground connections, the more noise you get on power and ground lines.
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Thus mA fluctuation $\rightarrow$ mV/m fluctuation. *This includes fluctuations on power and ground lines.* The farther you get from power and ground connections, the more noise you get on power and ground lines.
Effect of noise on power and ground lines

Analog
Consider an op amp with a gain of 1000 (inverting amp), assumes "ground" is zero; if off by few mV with an input signal of mV, effect could be very large.

Digital
May produce glitches.
Effect of noise on power and ground lines

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Solution to noise problems - analog
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Digital and analog grounds should be separated to minimize problems with analog signals due to digital noise on power and ground lines.
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Solution to noise problems - analog

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Separate grounds; MCP3008 (Microchip)
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CH0  1  16  $V_{DD}$
CH1  2  15  $V_{REF}$
CH2  3  14  AGND
CH3  4  13  CLK
CH4  5  12  $D_{OUT}$
CH5  6  11  $D_{IN}$
CH6  7  10  CS/SHDN
CH7  8  9  DGND
Separate grounds; MCP3008 (Microchip)

“If no ground plane is utilized, both grounds must be connected to $V_{SS}$ on the board.”
From MCP3008 datasheet (Microchip)

FIGURE 6-5: Separation of Analog and Digital Ground Pins.
“If a ground plane is available, both digital and analog ground pins should be connected to the analog ground plane.”
Separate grounds; ADC0804 (National Semiconductor)
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“Note: The separate A Gnd point should always be wired to the D Gnd.”
From ADC0804 datasheet (National Semiconductor)
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Can you identify which symbol is for each type of ground?
Solution to noise problems - digital

Use filter capacitors from V<sub>cc</sub> to ground near IC to smooth the fluctuations as close to the device as possible; the value is typically 0.01 → 0.1 µF.
Solution to noise problems - digital

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Solution to noise problems - digital

Use filter capacitors from $V_{cc}$ to ground near IC to smooth the fluctuations as close to the device as possible; The value is typically $0.01 \rightarrow 0.1 \mu F$
Filter capacitors
Filter capacitors

Here’s an ordinary circuit board.
Filter capacitors
Filter capacitors

Notice the filter capacitors.
Filter capacitors

Notice the filter capacitors.
Filter capacitors

Notice the filter capacitors.
Filter capacitors

Here are more.
Filter capacitors

Here are more.
Filter capacitors

Find some more.
Filter capacitors

Find some more.