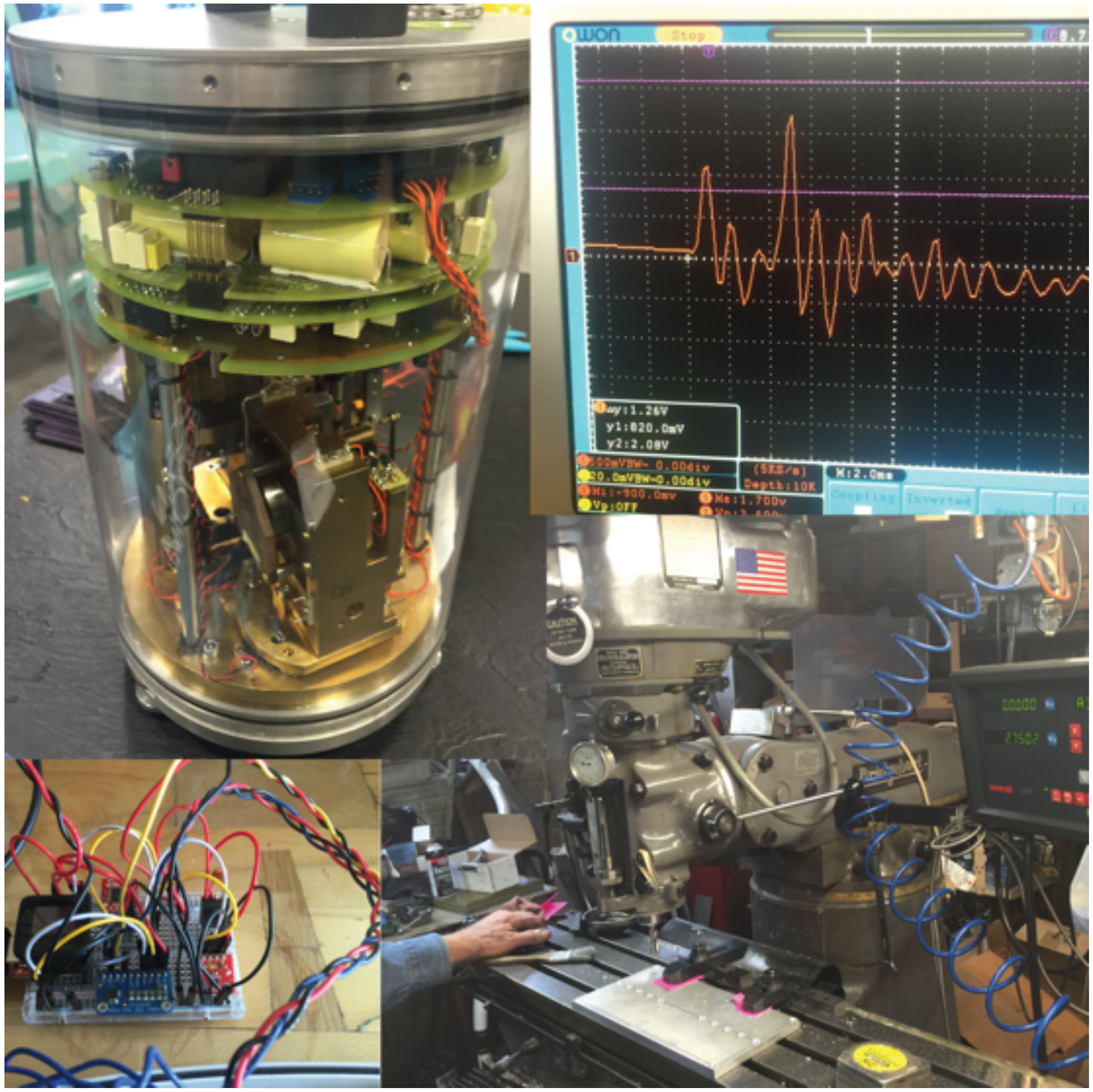
Signal Integrity and Input Impedance

J.R. Leeman and C. Marone

Techniques of Geoscientific Experimentation

November 8, 2016



A few “news” items

- Please clean up in the lab
- All project parts are in
- Be careful if you are using batteries of any kind
- Let’s talk about essential tools/instruments
- Watch the soldering videos on the website

Today we're going to talk about how to keep your signals clean and useable in noisy environments

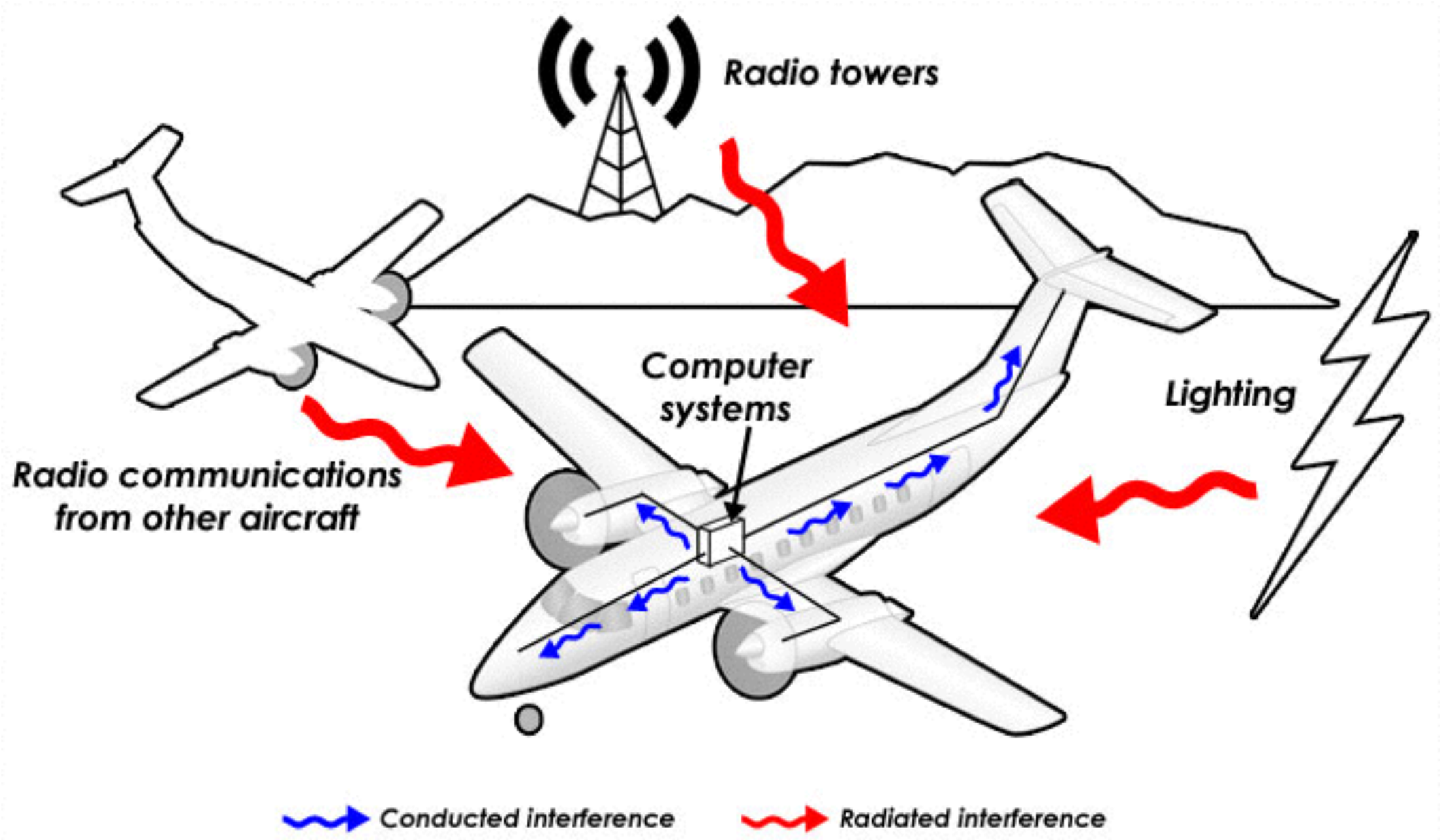
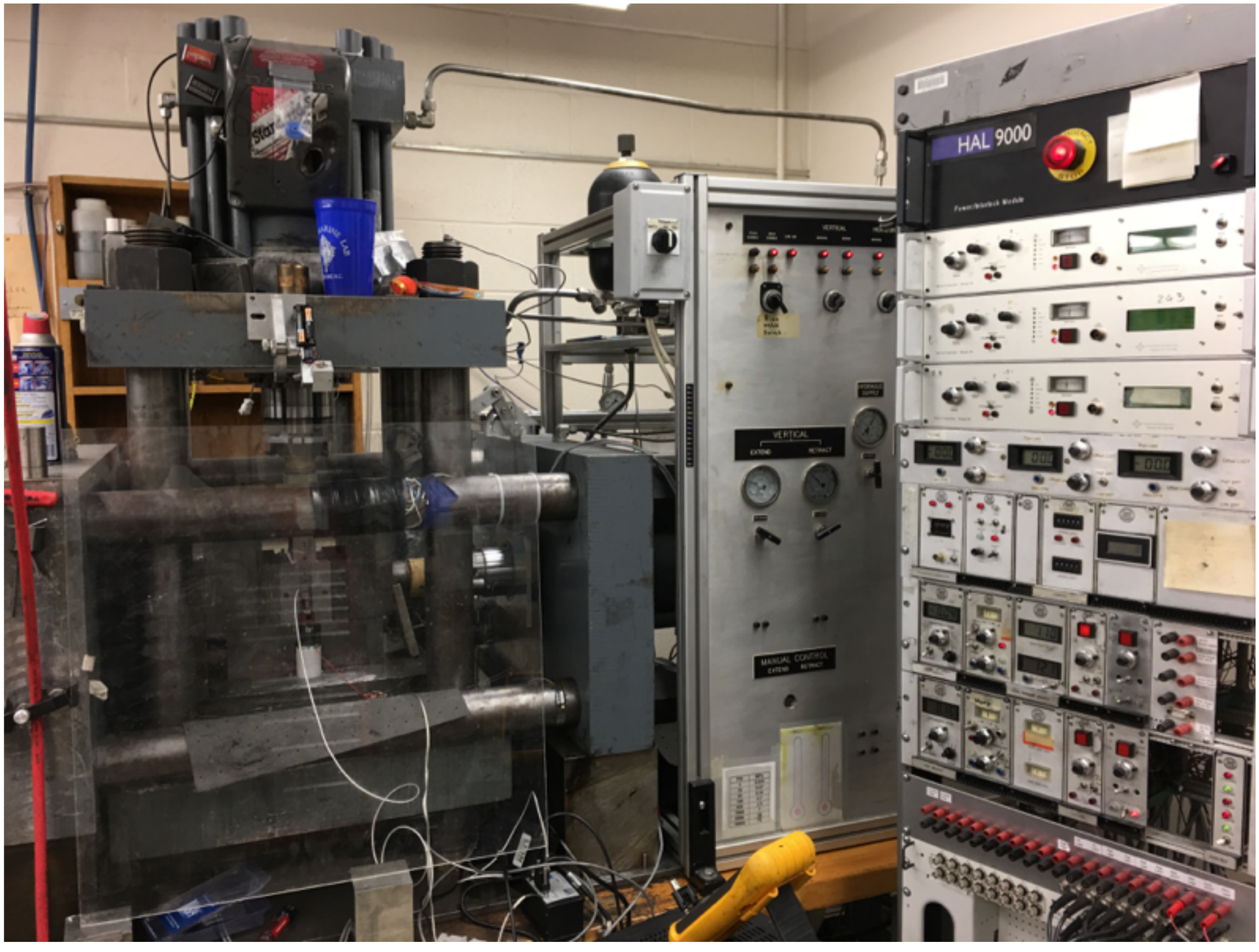


Image: faa.gov

Today we're going to talk about how to keep your signals clean and useable in noisy environments



Interference issues have caused real problems in real science

Microwave oven blamed for radio-telescope signals

Studies about mysterious signals and super-strong spider silk triggered online chatter.

Chris Woolston

08 May 2015

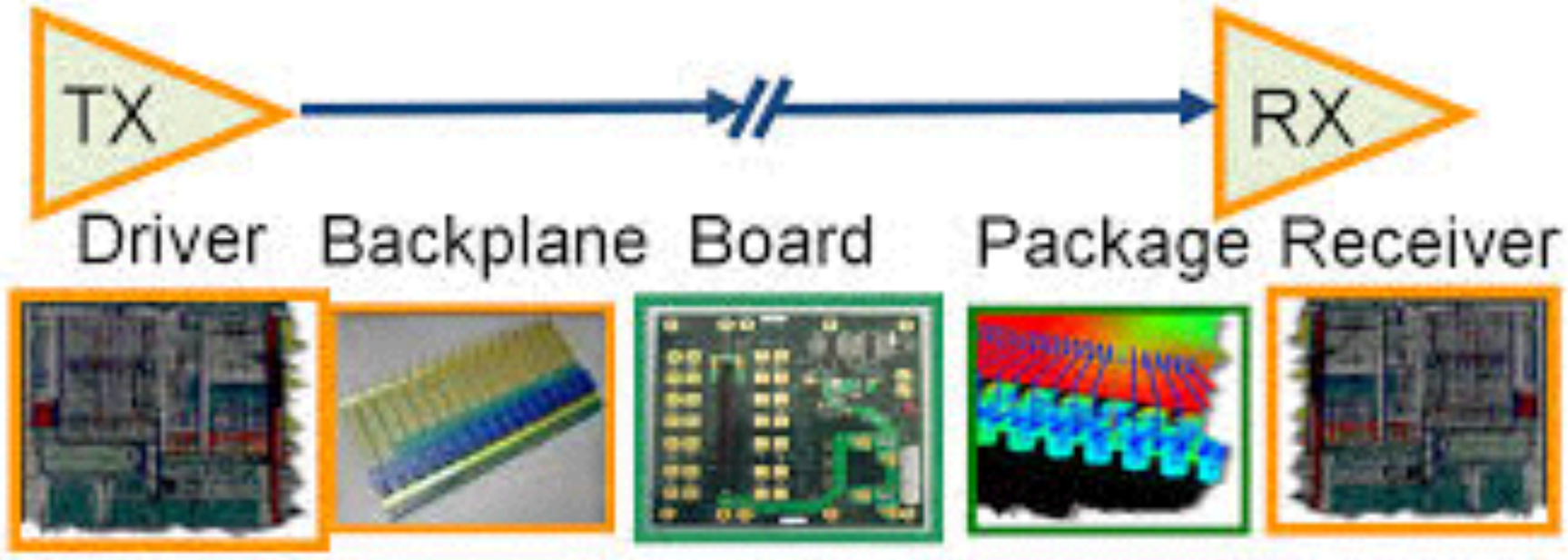
A report[1] on the surprising origins of rogue signals picked up by a radio telescope simmers on social media, while researchers on the web commented on an amazing feat of arachnid ingenuity — spinning graphene-laced silk.

After more than four years of searching, researchers using the Parkes radio telescope in New South Wales, Australia, have identified the source of some mysterious signals: a microwave oven in the facility's break room. The news quickly spread on Twitter. Karina Voggel, an astronomy PhD student at the European Southern Observatory in Garching, Germany tweeted:

John Sarkissian/CSIRO/JPL/NASA

A microwave oven at the Parkes radio telescope in Australia was nabbed as the source of elusive signals.

There are many places in every system that are susceptible to interference



What could possibly go wrong?

Image: bethesignal.com

There are two primary forms of interference we worry about

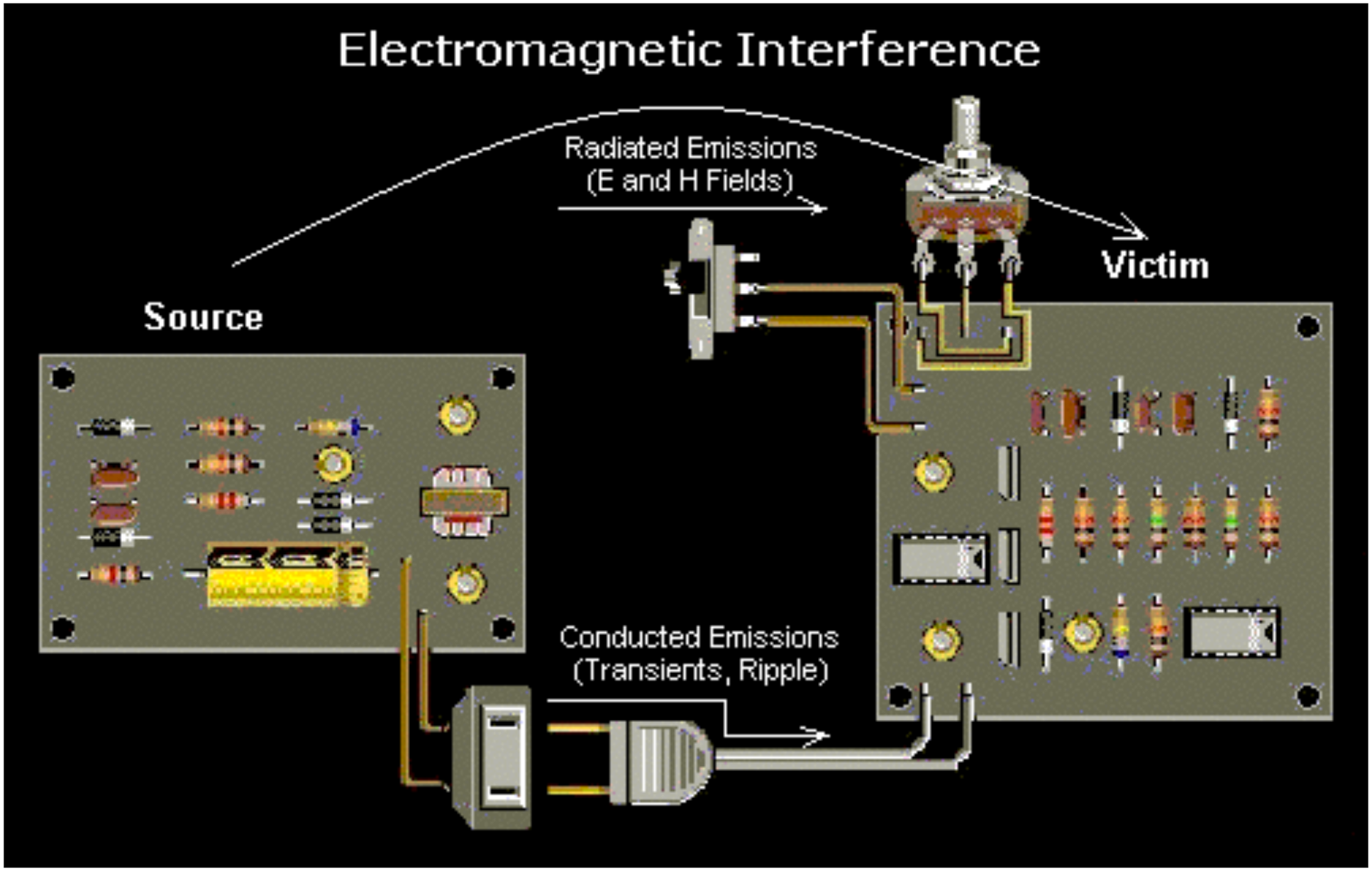


Image: radioing.com

Radiated emissions come from other devices intentionally or unintentionally

Intentional

Unintentional

Images: Fitbit/TI

Every wire, trace, and connection is a little antenna

Image: djdepot.com, macrumors.com

Every wire, trace, and connection is a little antenna

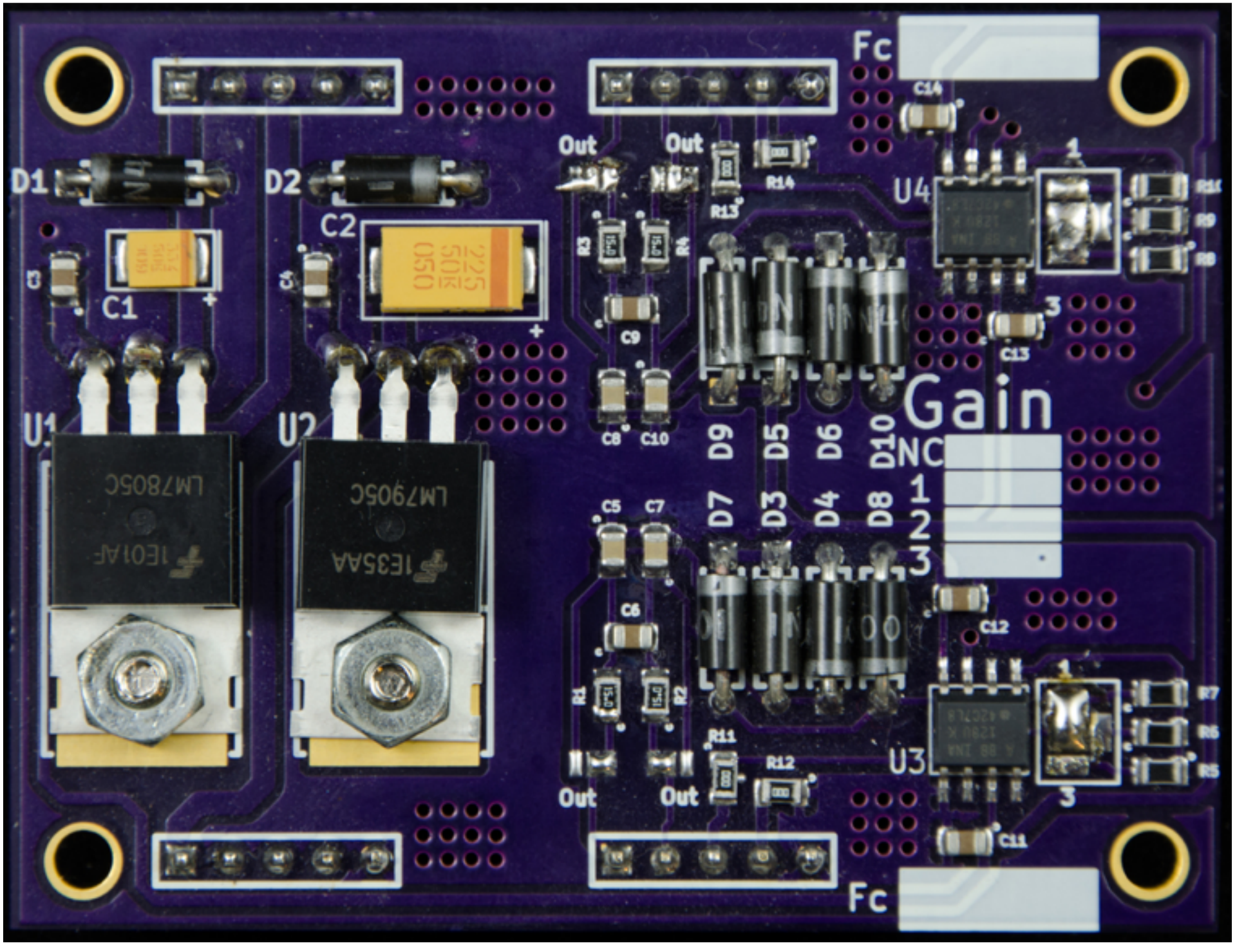


Image: leemangeophysical.com

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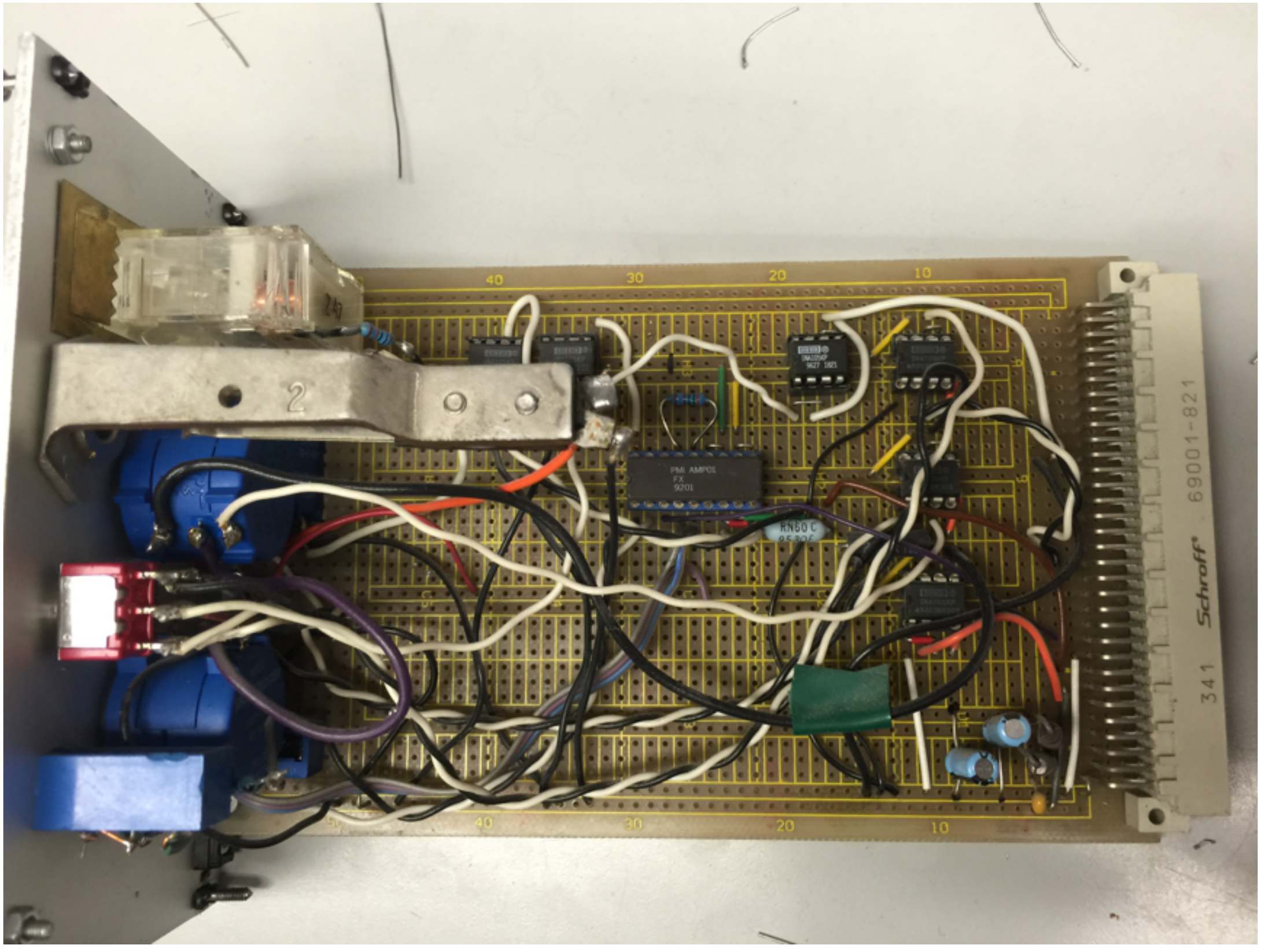

This is a big deal, for your data, and for legal reasons

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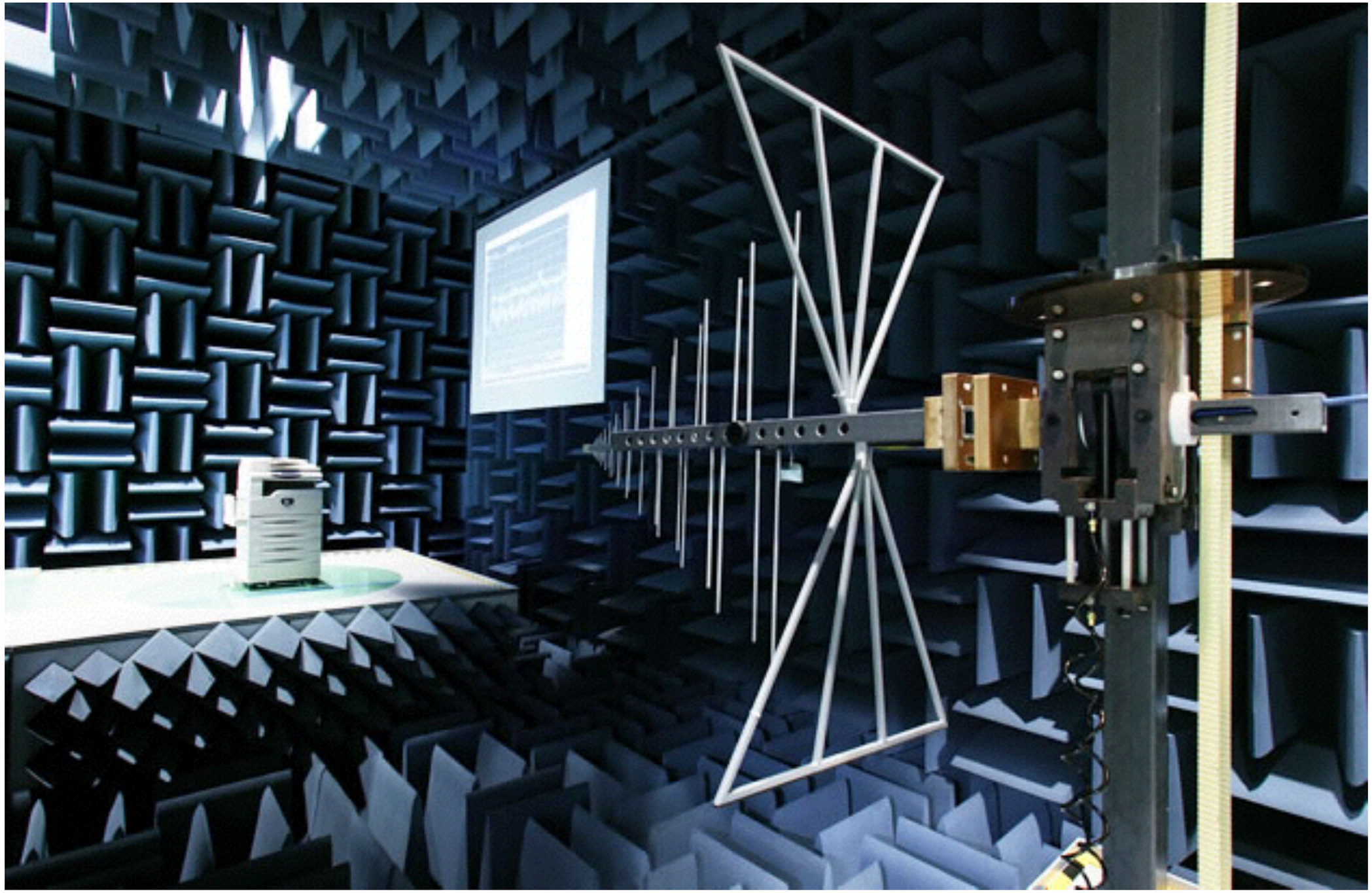
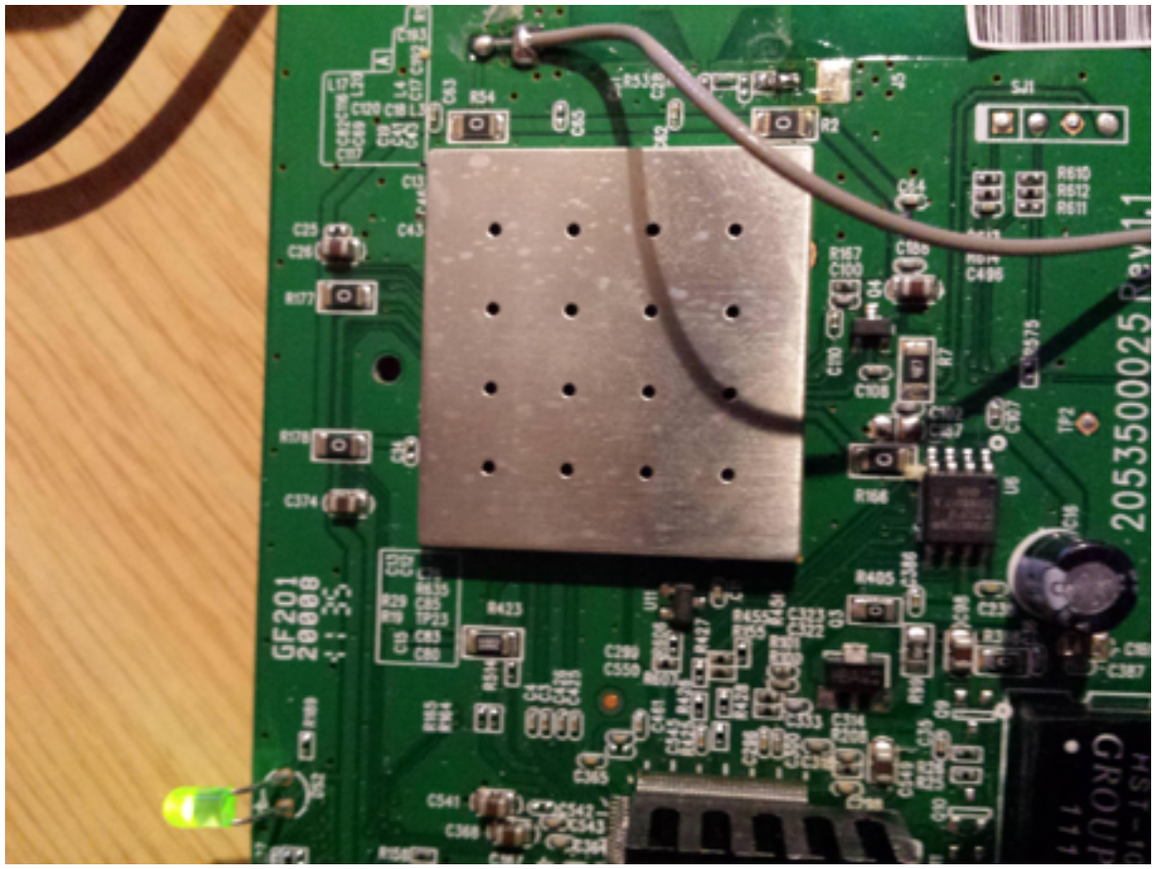
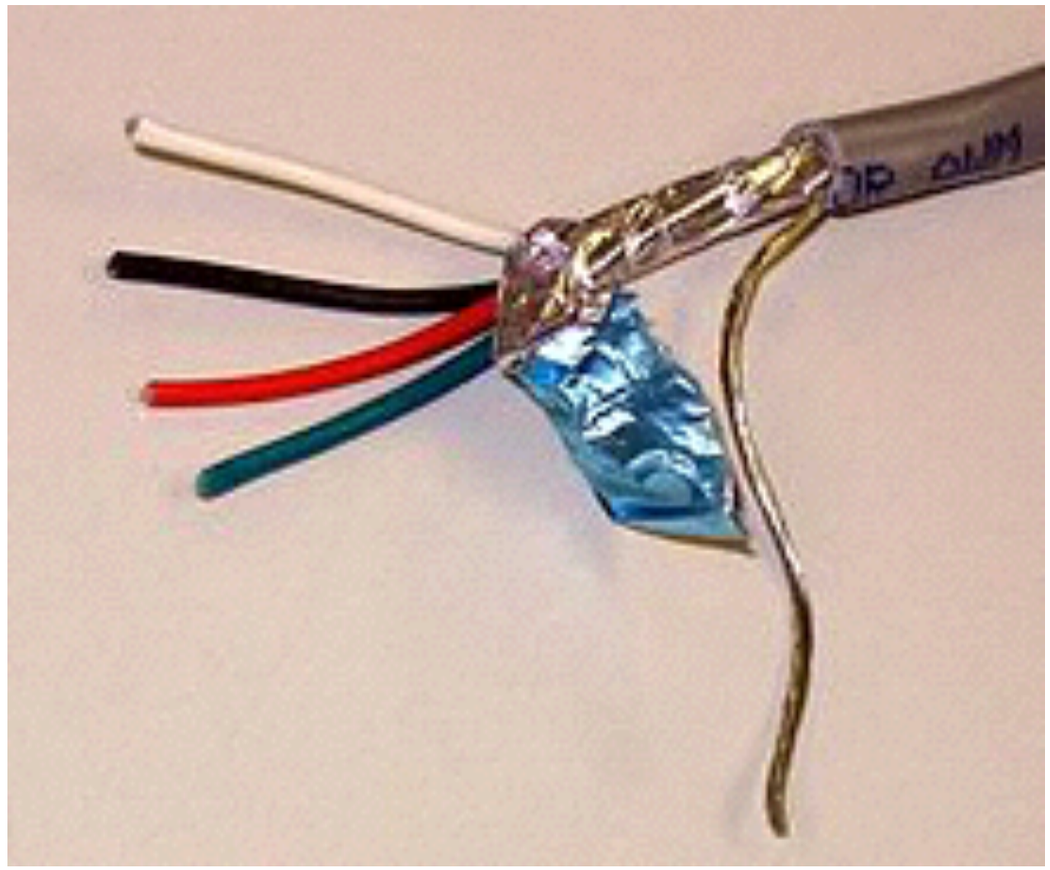


We use shielding to combat radiated interference and to prevent radiating interference





Images: stackexchange.com, smnrc.org, wikipedia.com

Shielding operates by making a Faraday cage around your equipment/wires

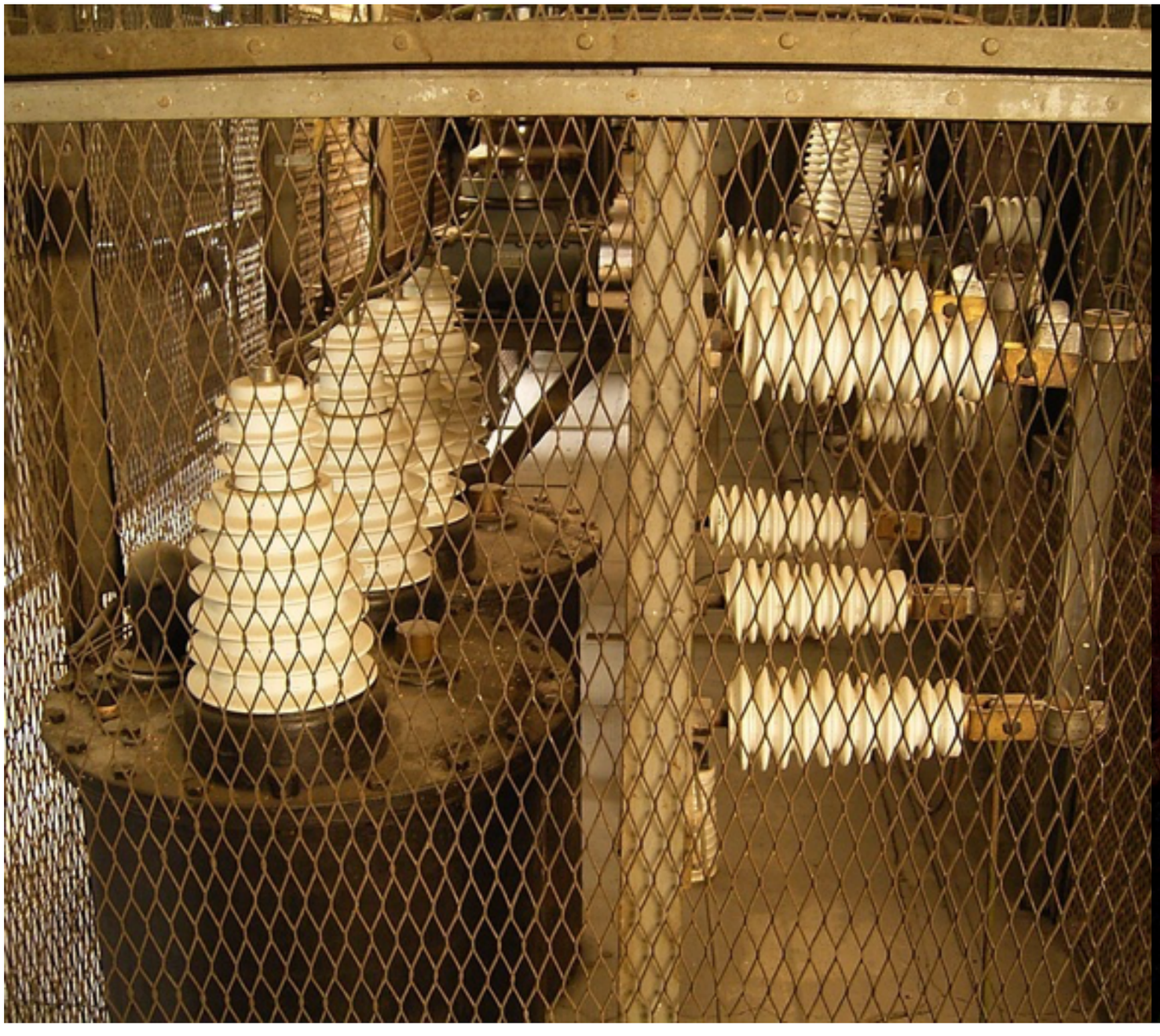


Image: wikipedia.com

Charges on one side are balanced by equal and opposite charge on the other, canceling the external field

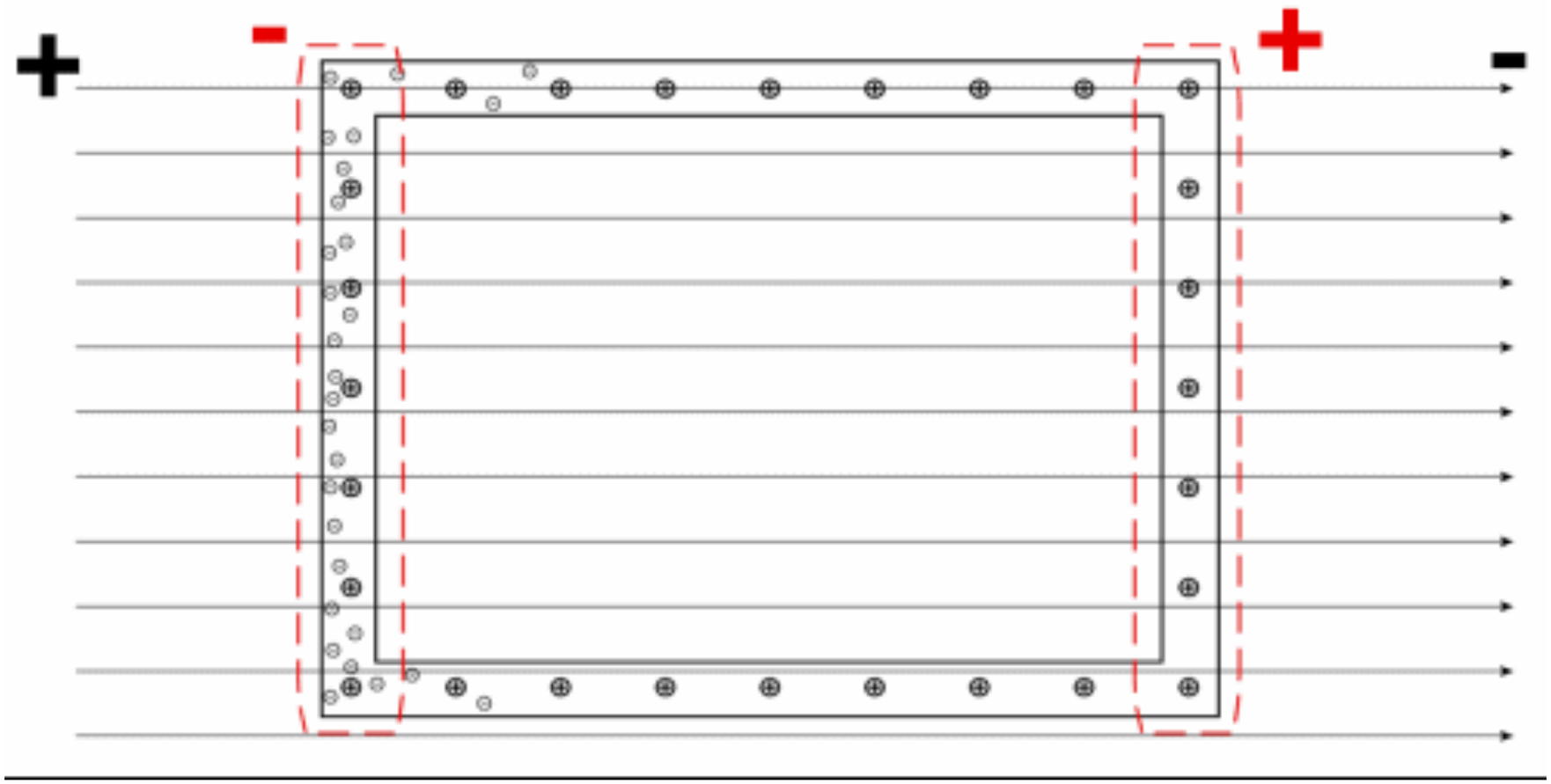


Image: Wikipedia

Note that this cannot block static or slowly varying magnetic fields

Image: Canada MEG Consortium

Solid shields are more effective than meshes, conduit being the most effective for wire shielding

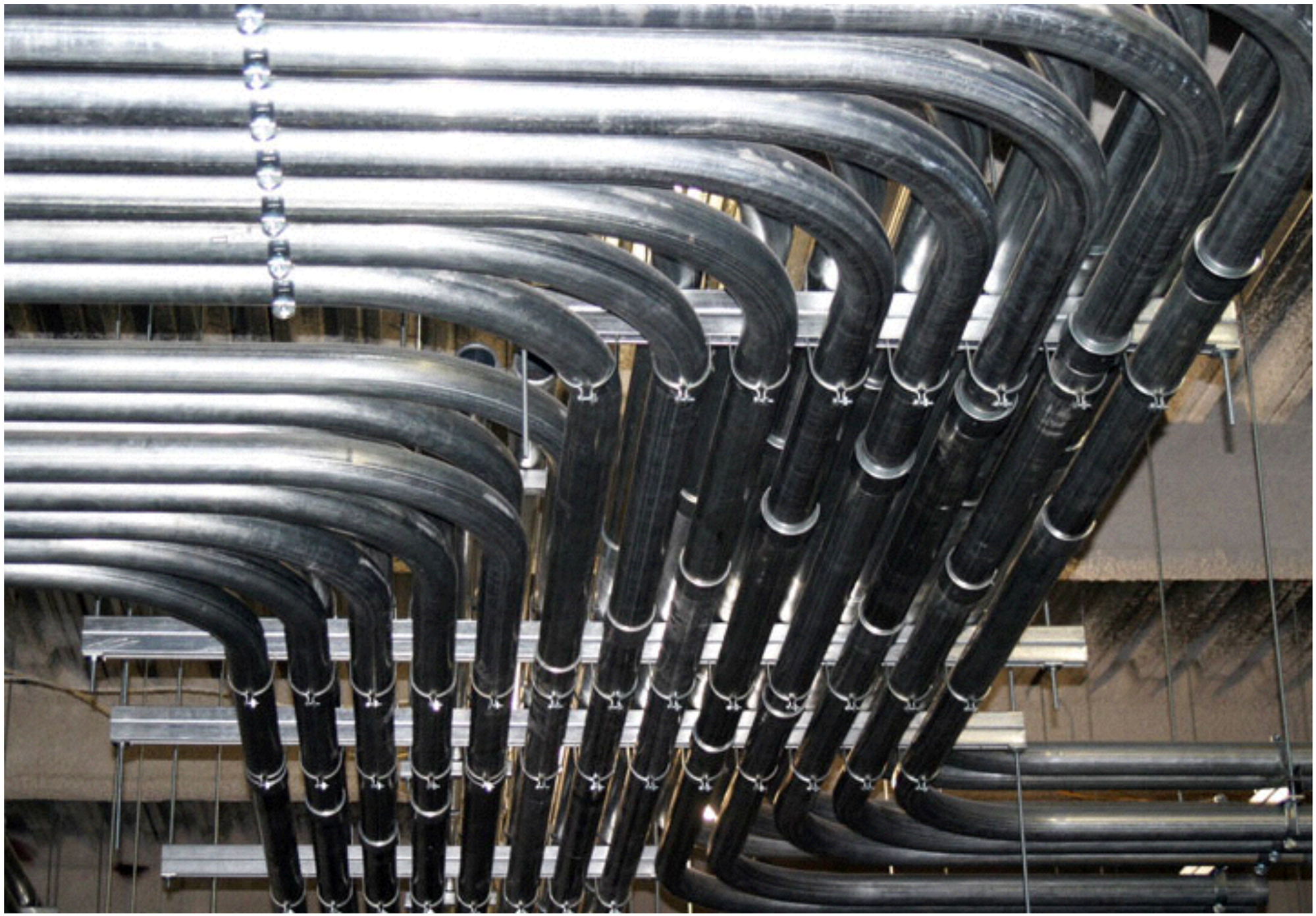
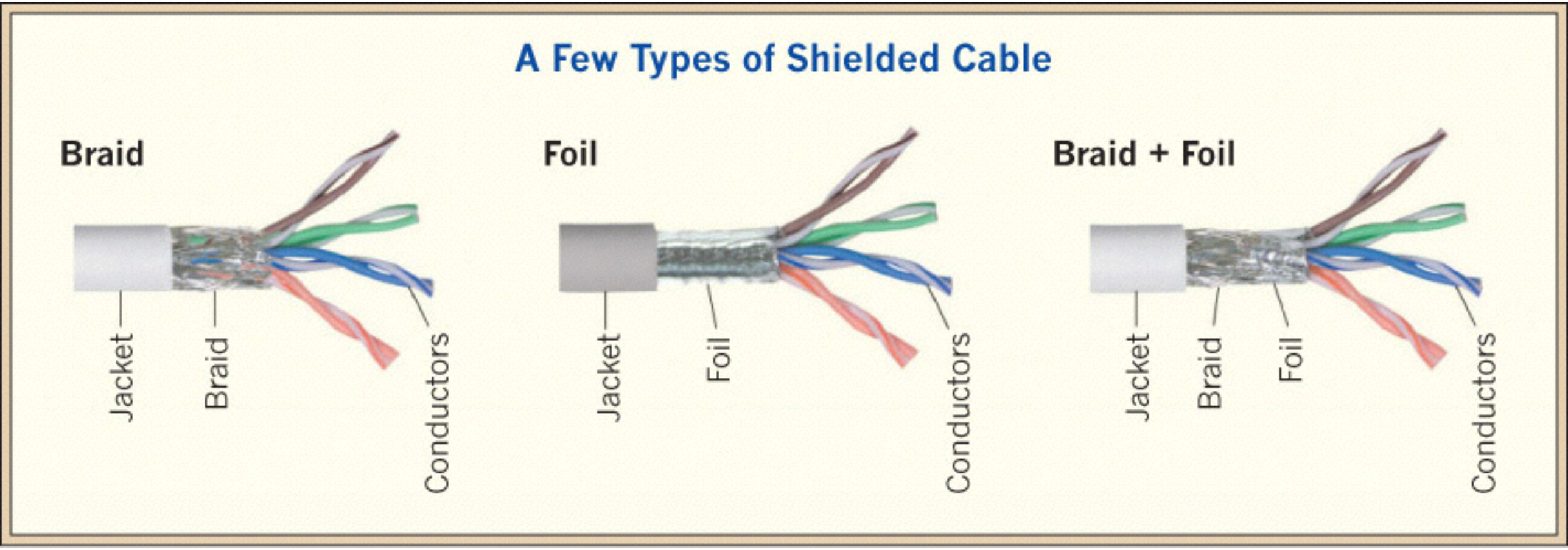


Image: alliedeg.us

Shielded cables can have foil or mesh shields, or multiple shields



Holes in braid leak
Best for EMI

Thin = High Resistance
Best for RFI

Best of both worlds

Image: ecmweb.com

Only ground one end of a shielded cable

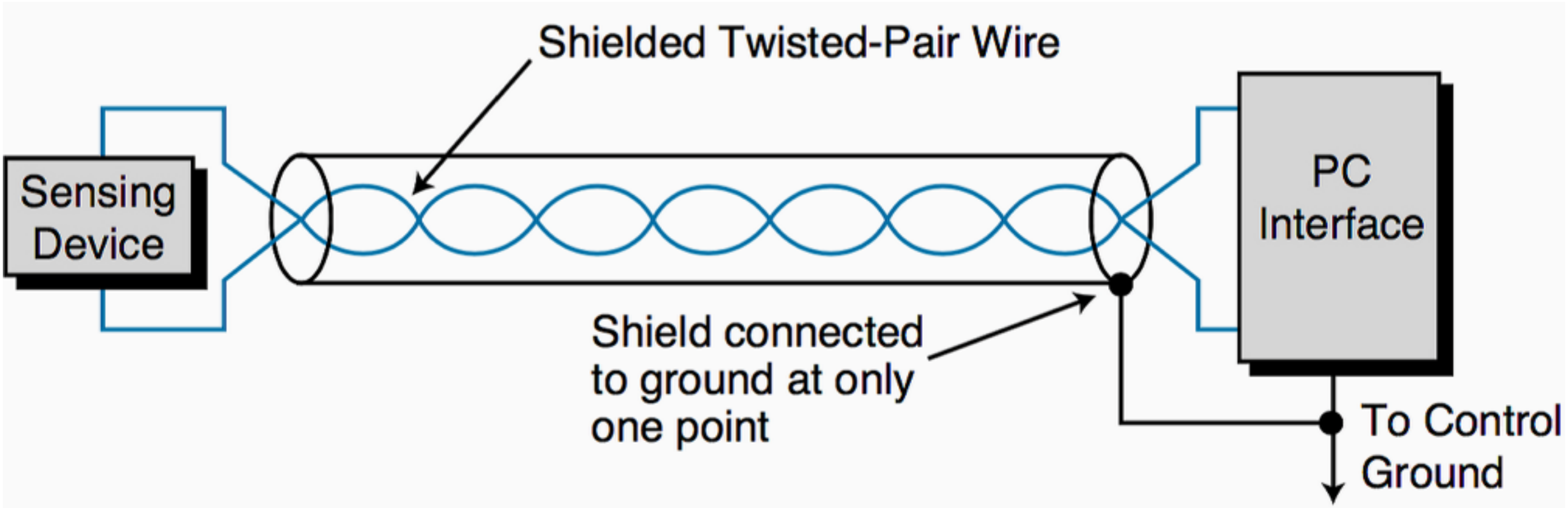


Image: electrical-engineering-portal.com

We're trying to avoid ground loops that can be dangerous

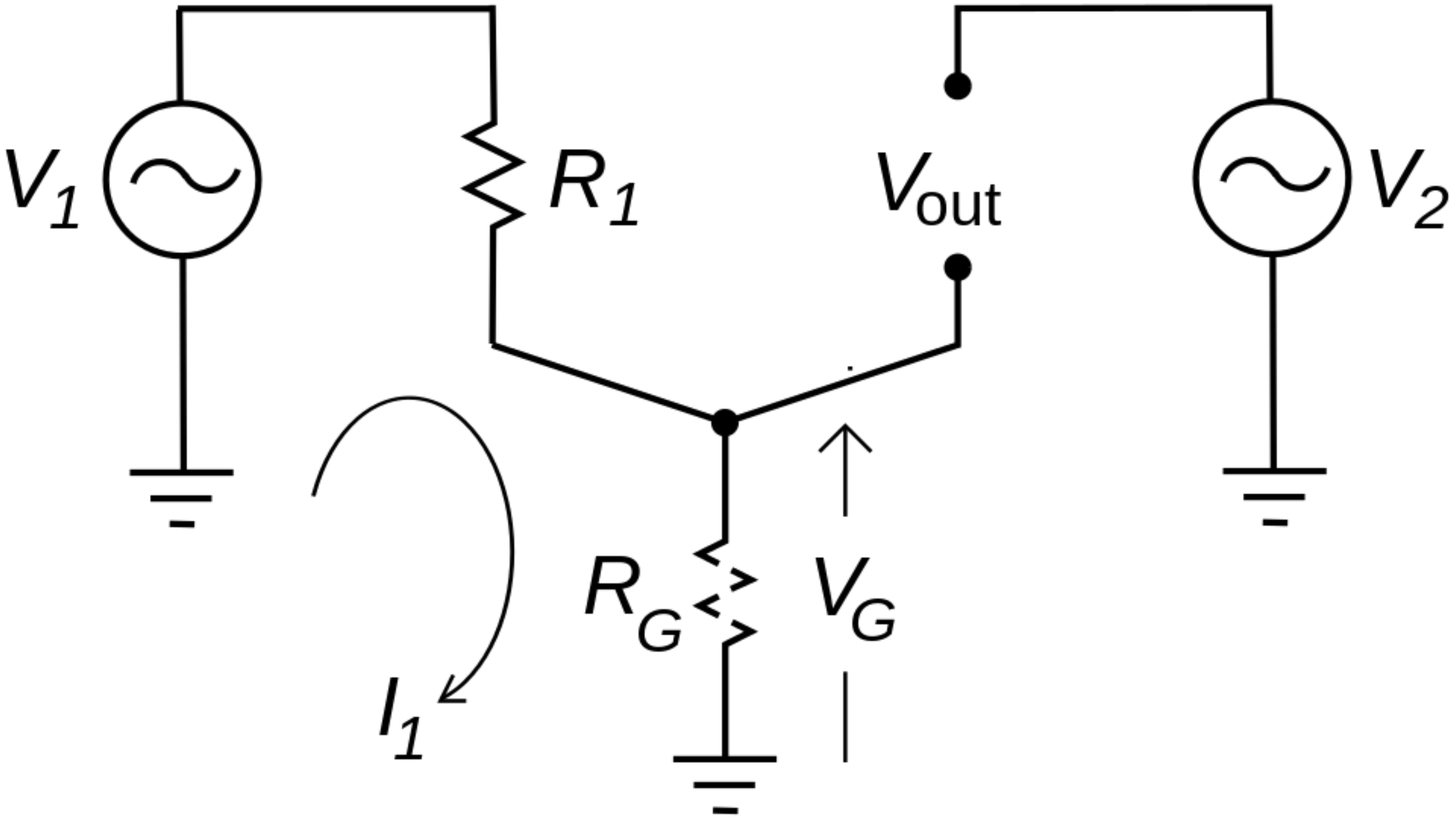


Image: wikipedia.com

Why are the wires twisted?

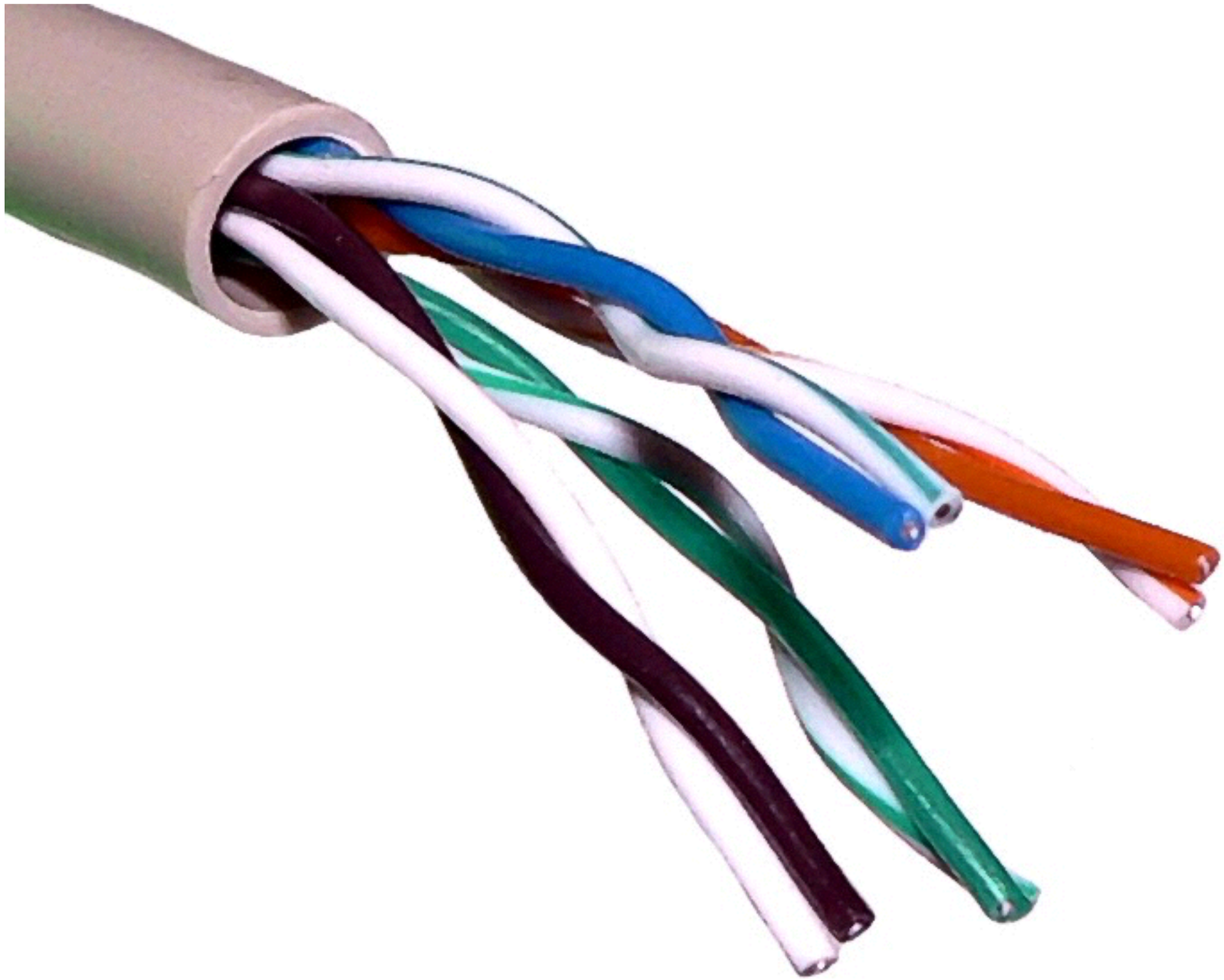


Image: wikipedia.com

Conducted emissions are the other major noise source

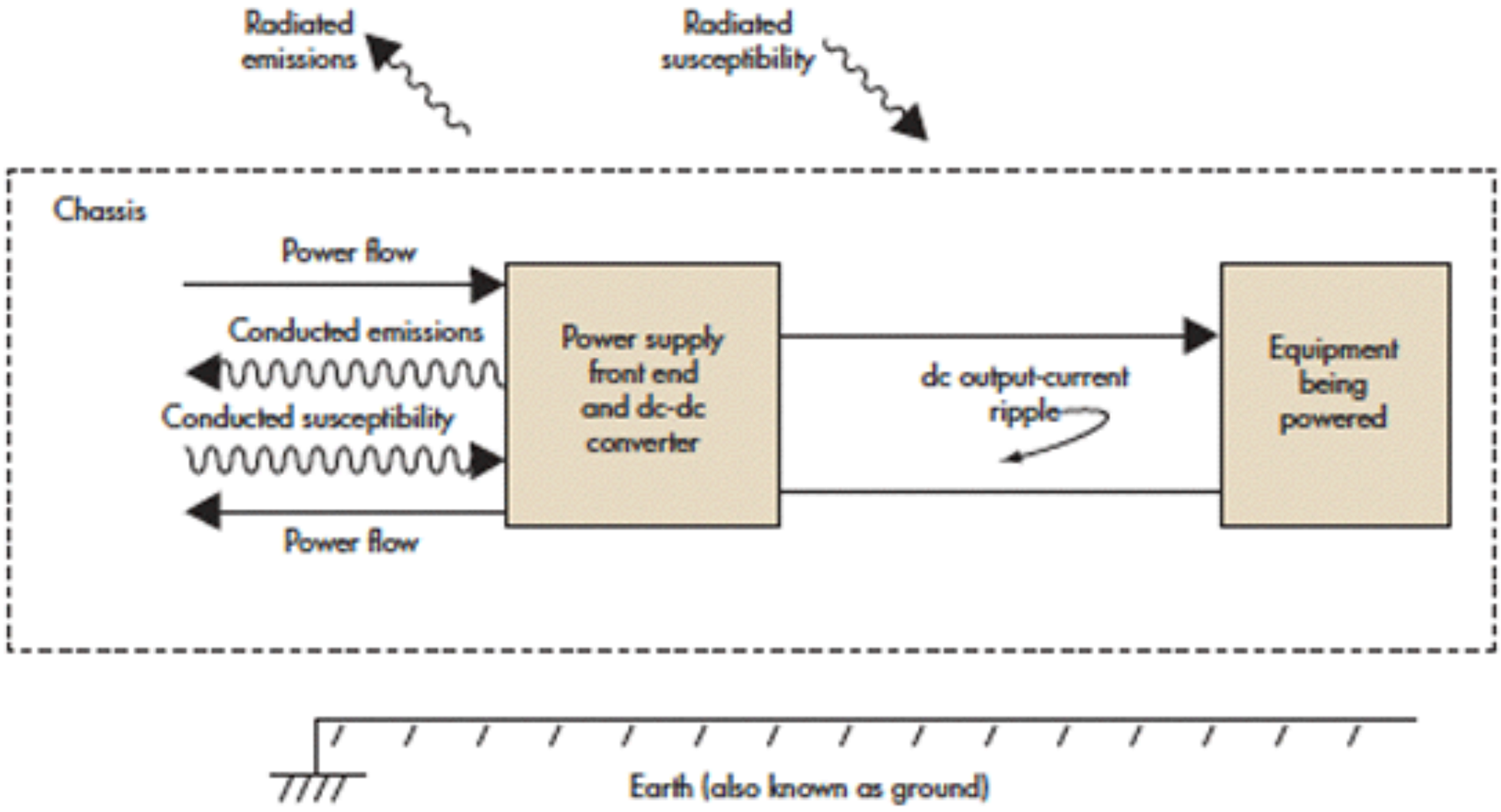


Image: electronicdesign.com

We need to add filtering to our lines

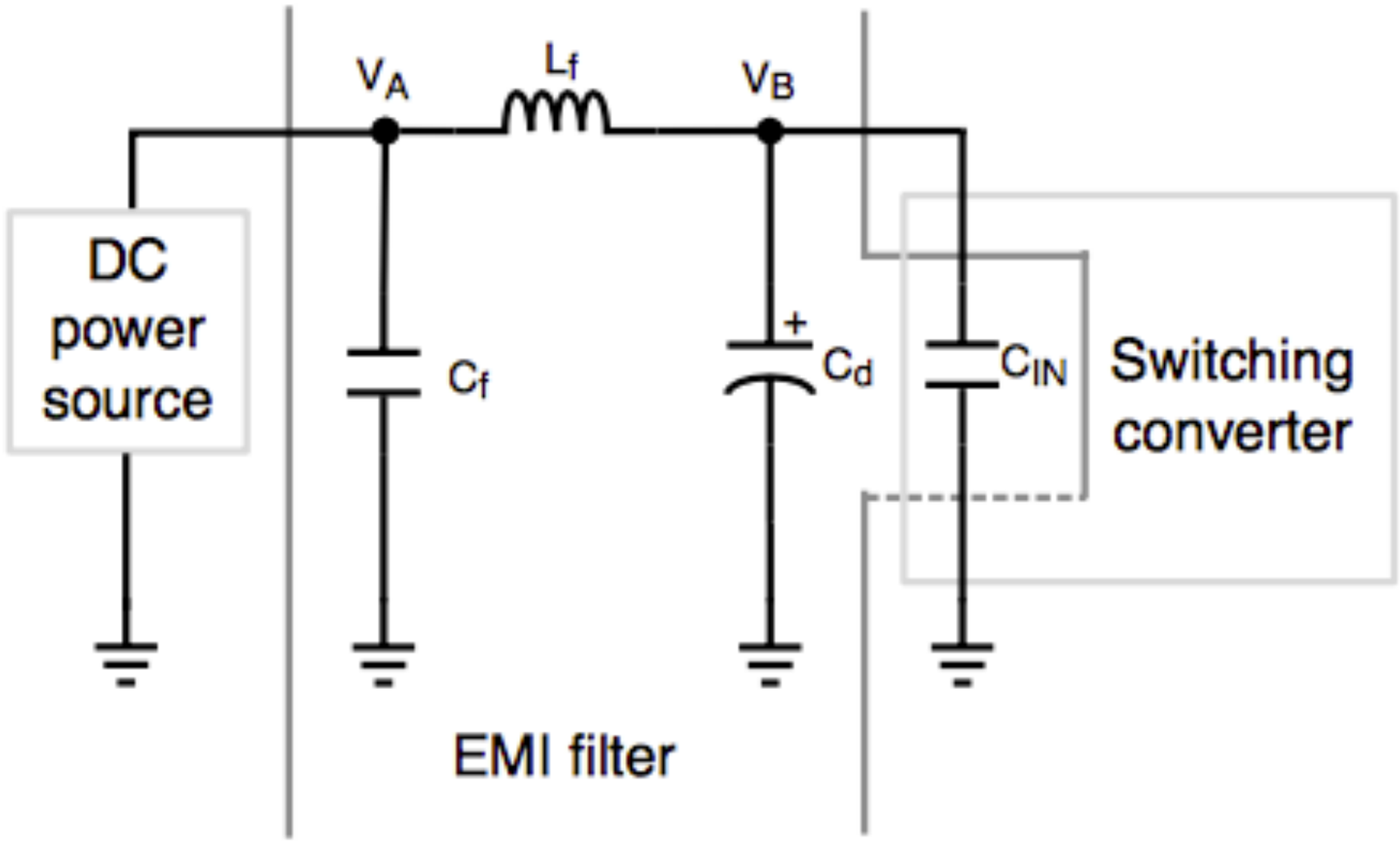
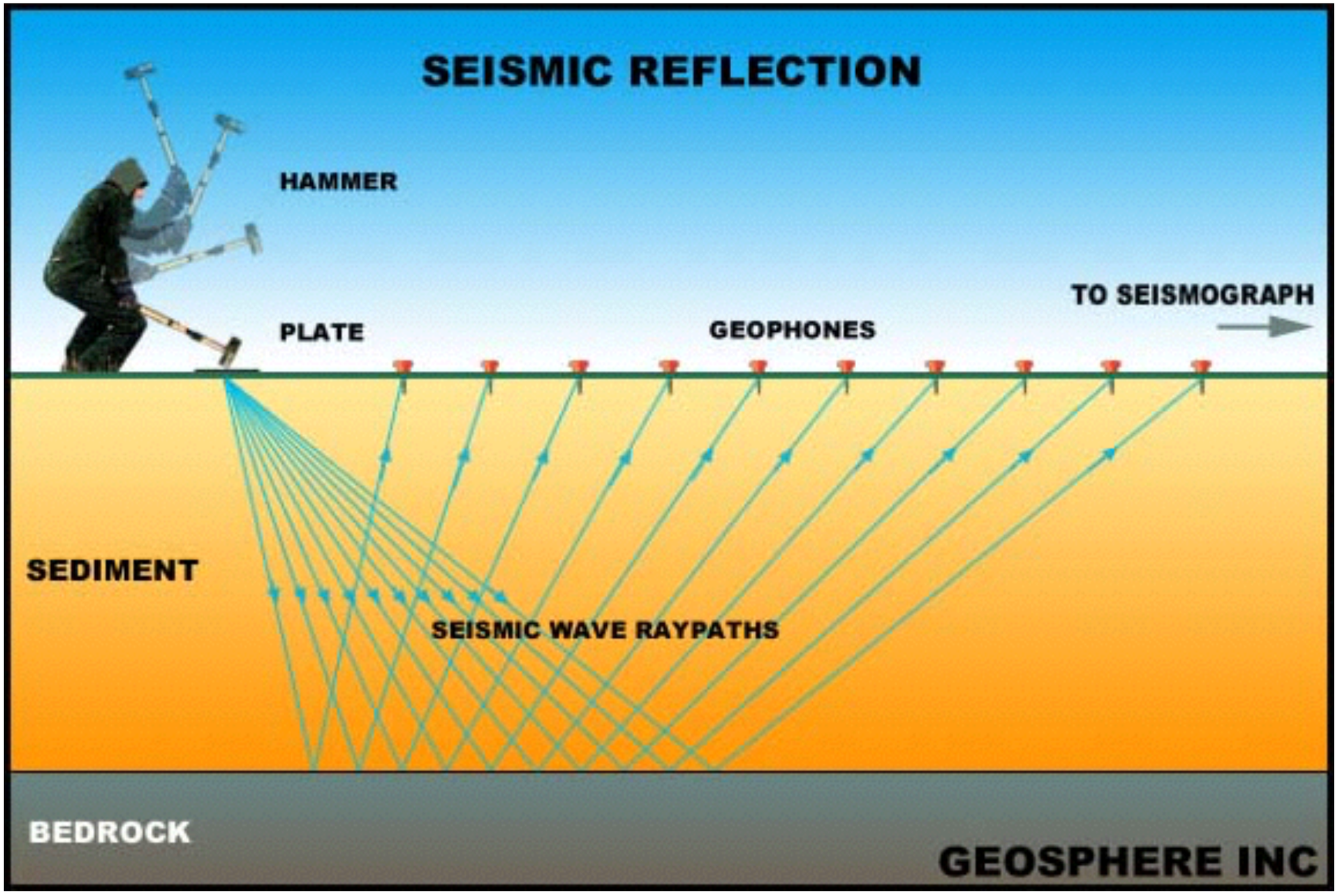


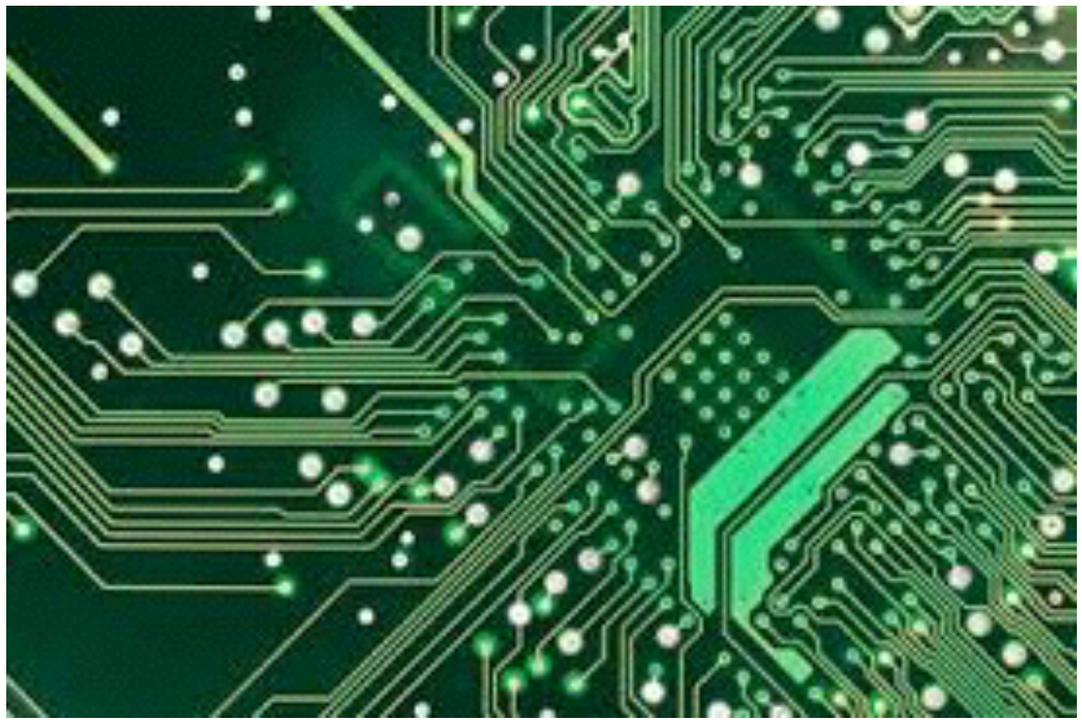
Figure 4. Simplified Schematic For EMI Filter Design

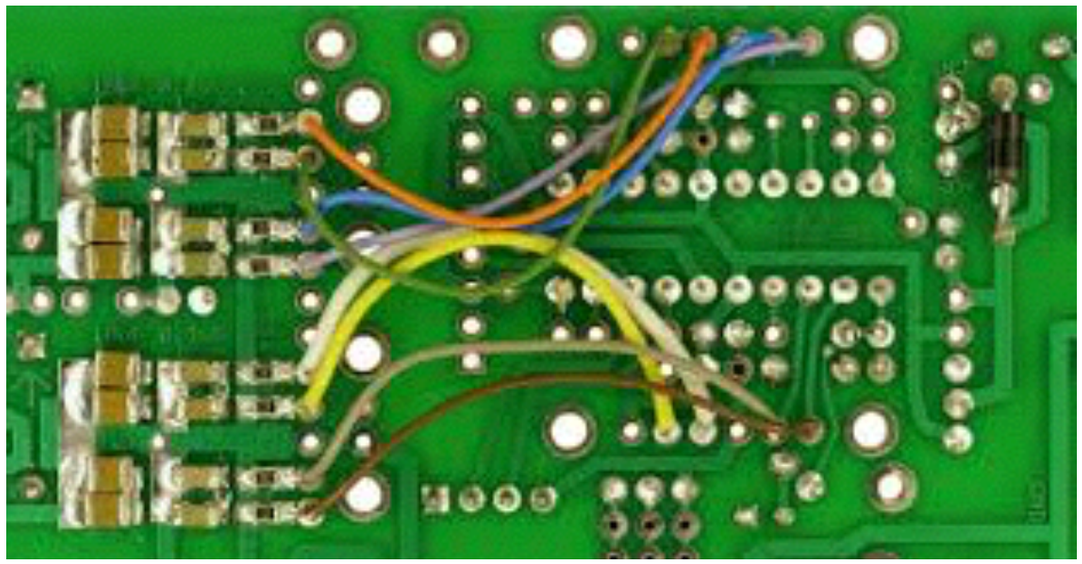
Image: TI

Reflections in transmission lines



Everything is a transmission line!





Just like in seismic/acoustic reflection, electrical reflections occur at impedance contrasts

Image: wikipedia.com

Electrical impedance is the measure of the opposition that a circuit presents to a current when a voltage is applied.

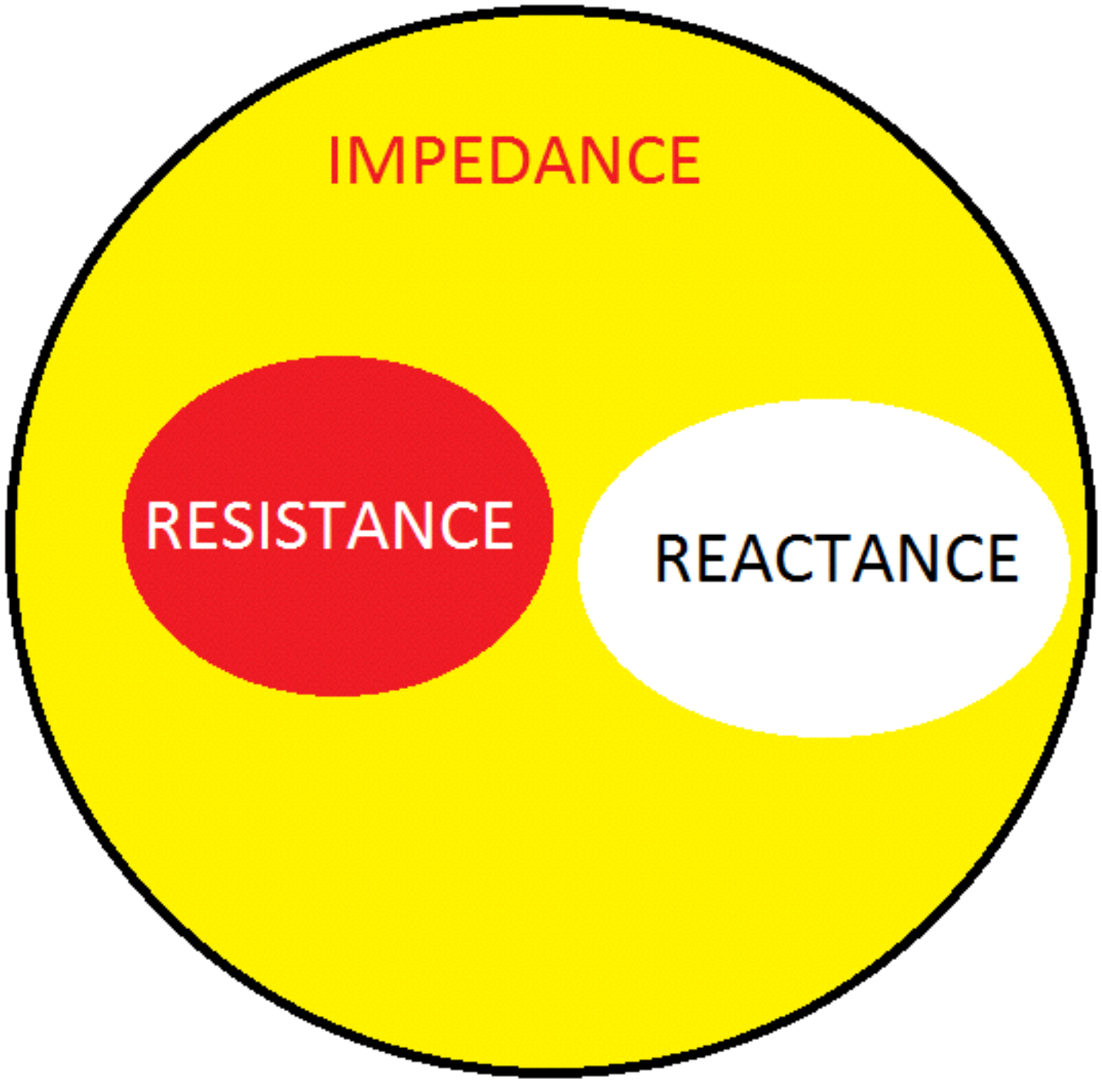


Image: stackexchange.com

Impedance is basically a frequency dependent resistance (really it's the vector sum of resistance and reactance)

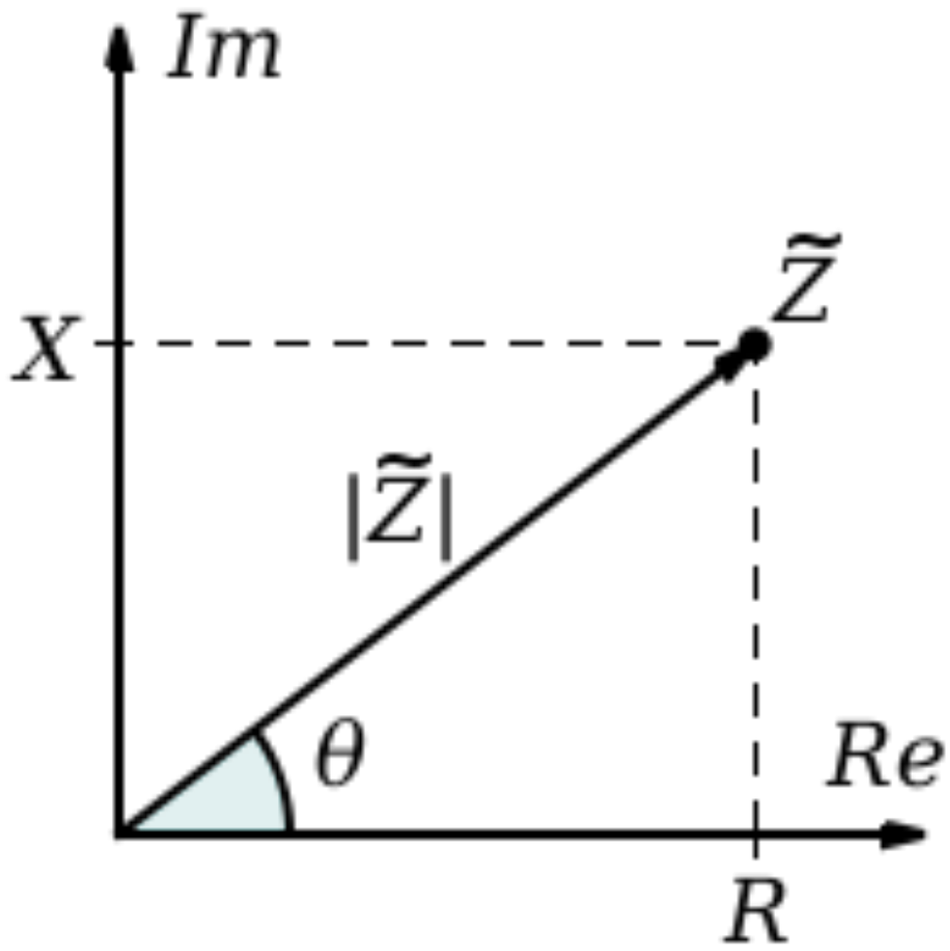
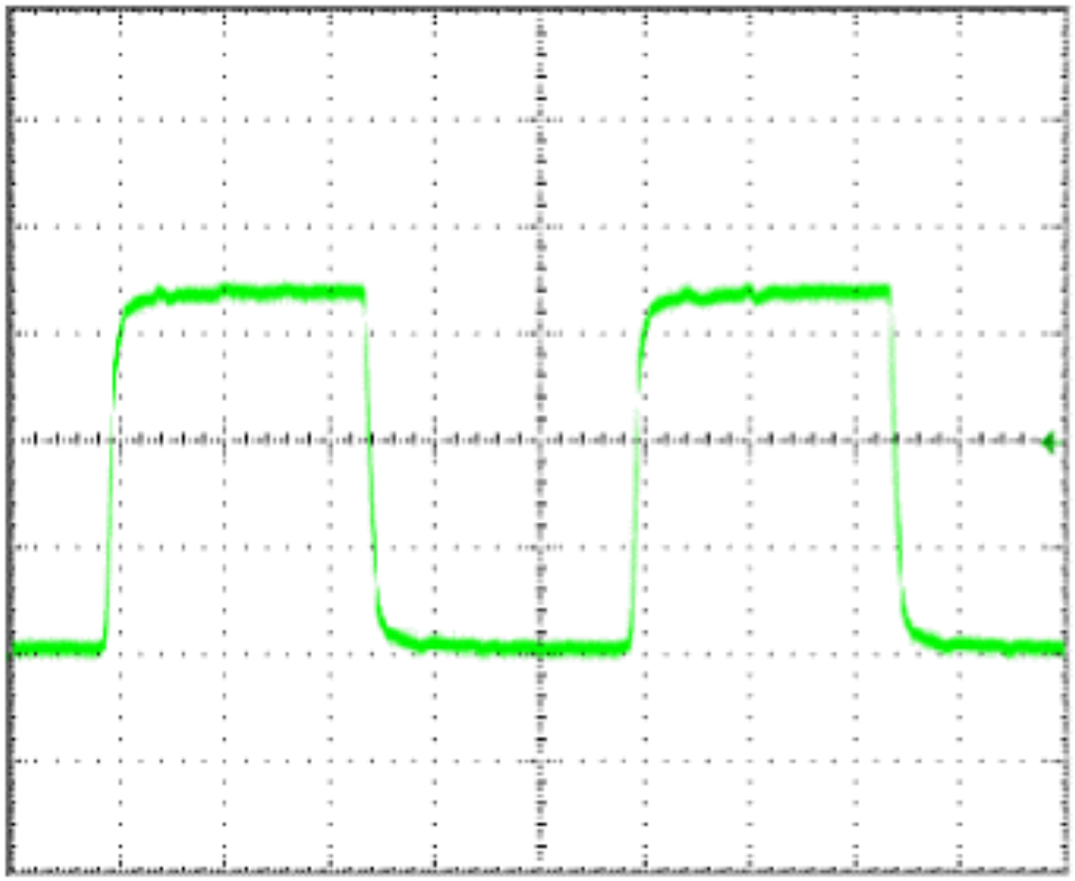
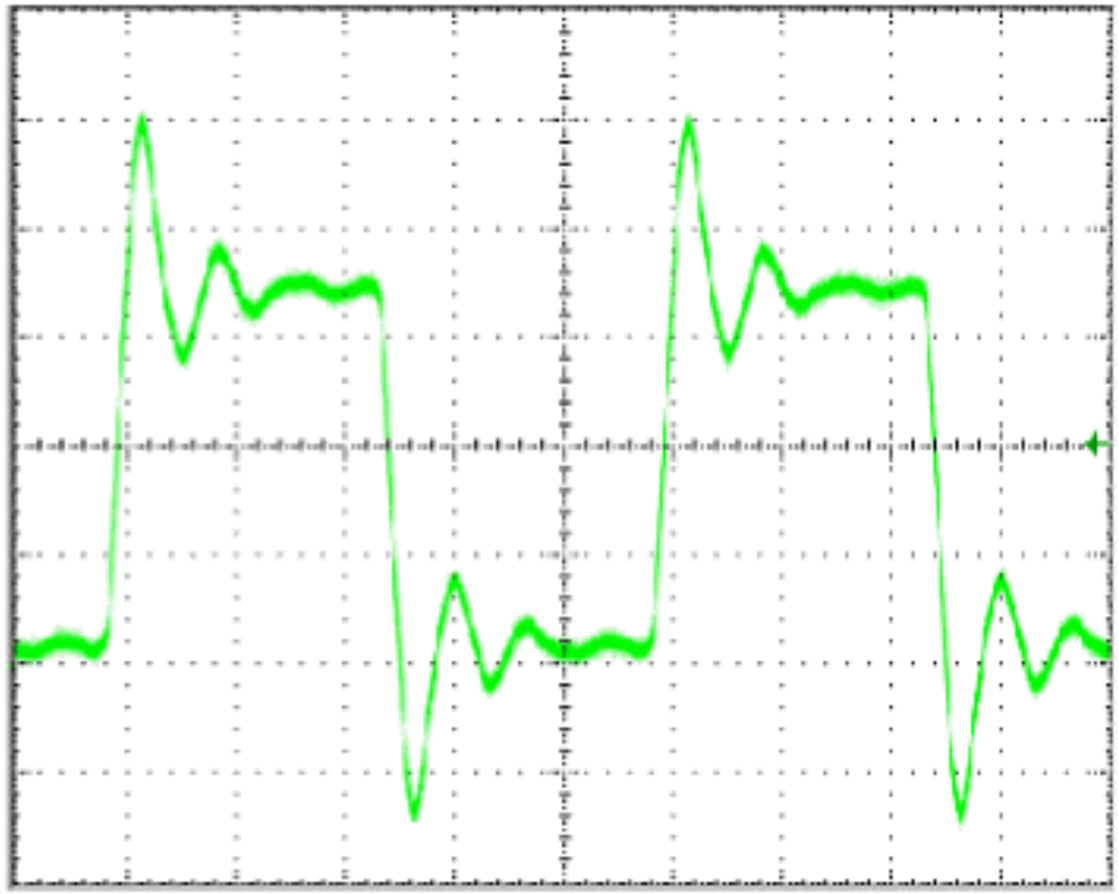


Image: wikipedia.com

Reflections cause ringing and bad signal quality



a.



b.

Image: ni.com

There are actually several problems with signals like that

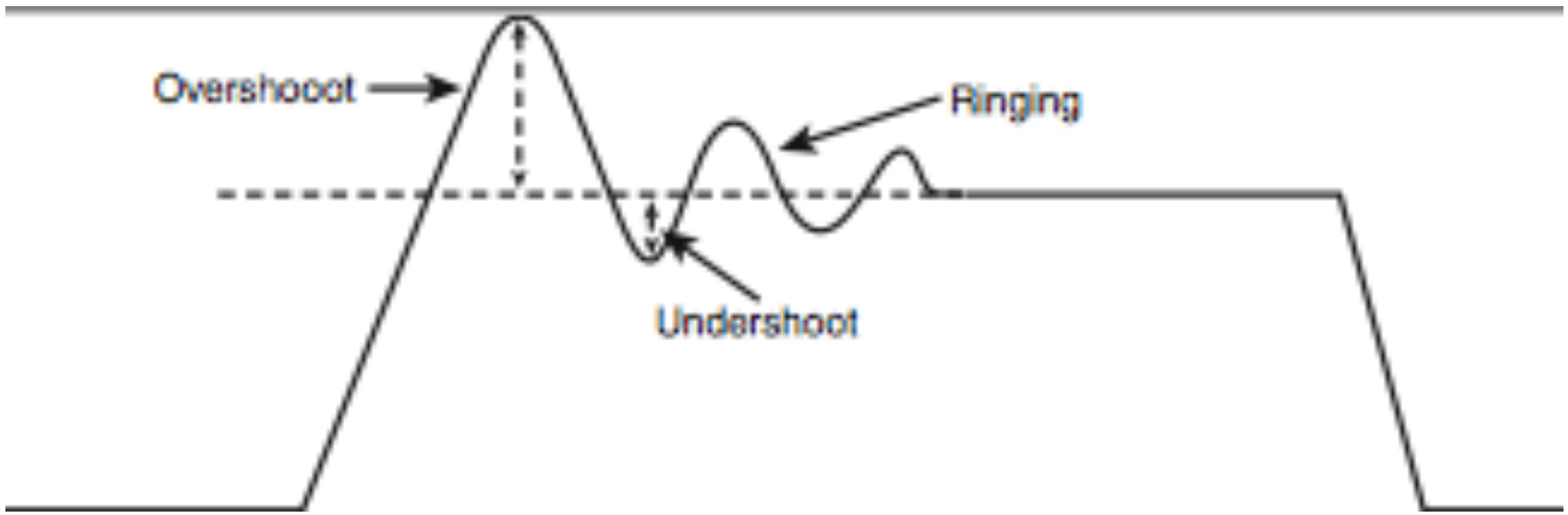


Image: eetimes.com

Let’s use this principle to calculate the length of cable I have

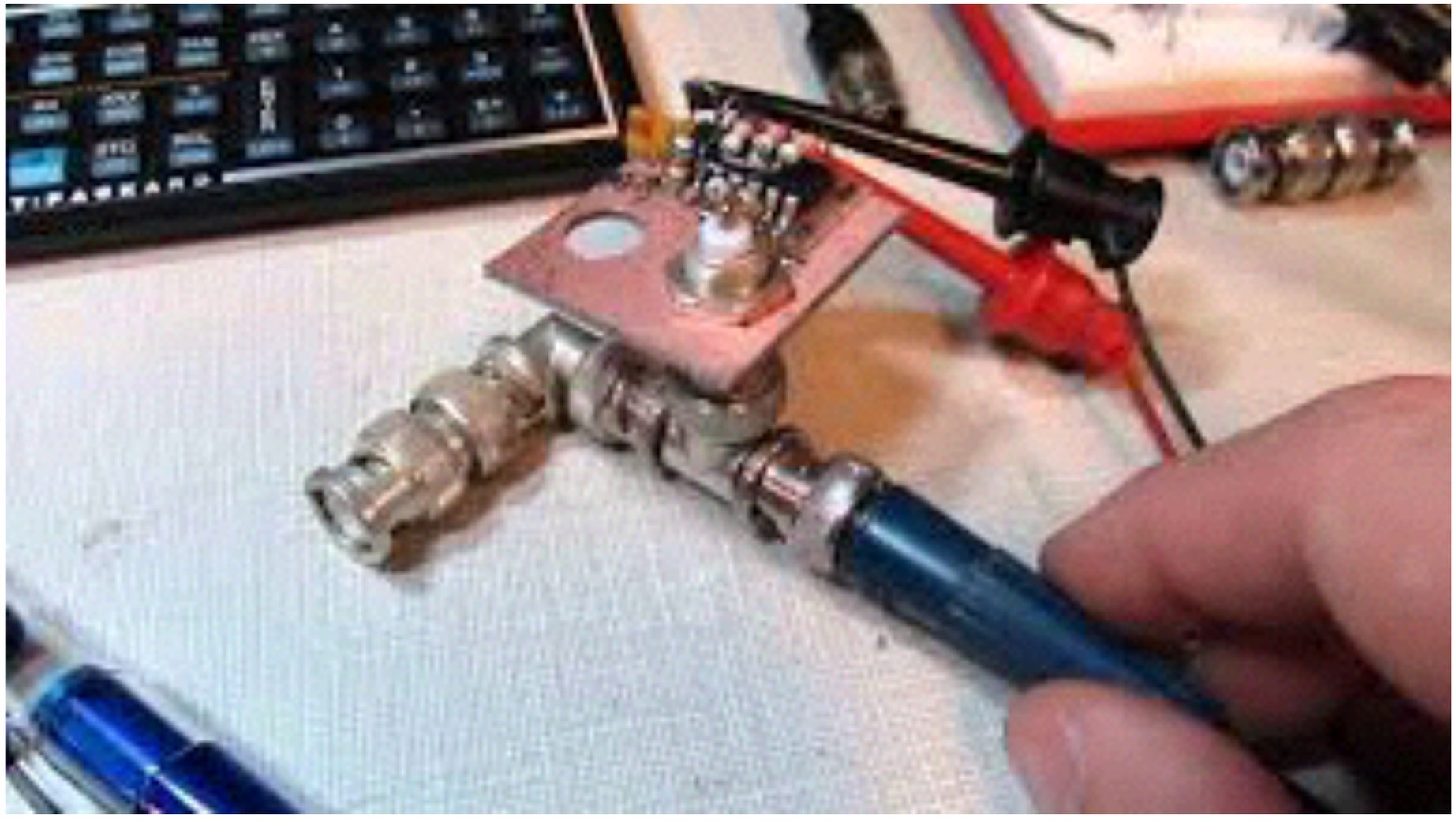


Image: Alan Wolke, W2AEW

Let’s think about a function generator and scope connected together

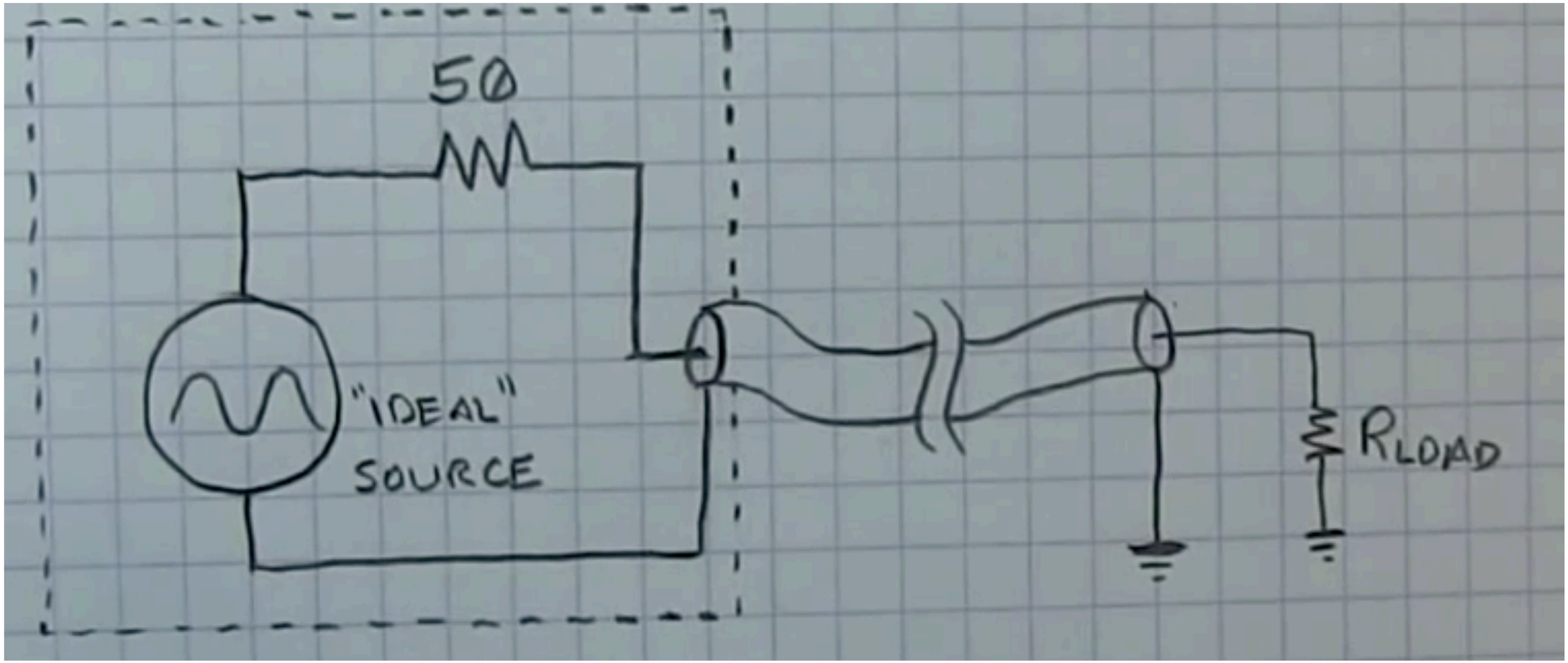


Image: Alan Wolke, W2AEW

Impedance mis-matches are a common source of sensor to ADC confusion

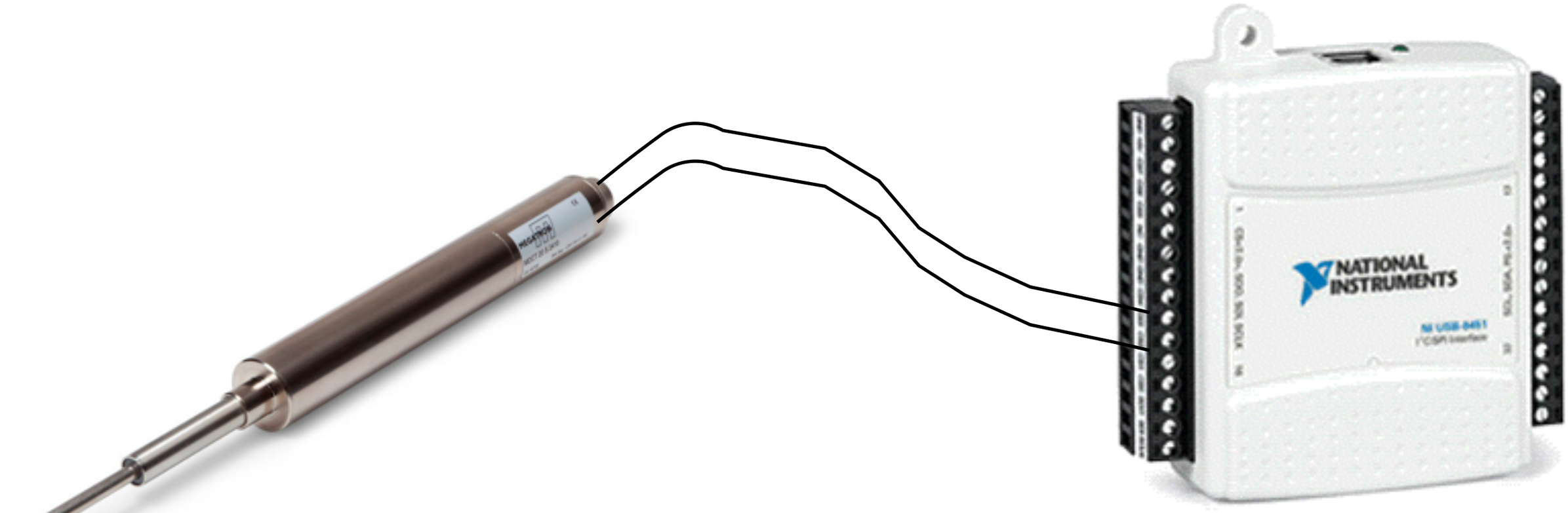


Image: allaboutcircuits.com

How can we prevent this from being an issue?

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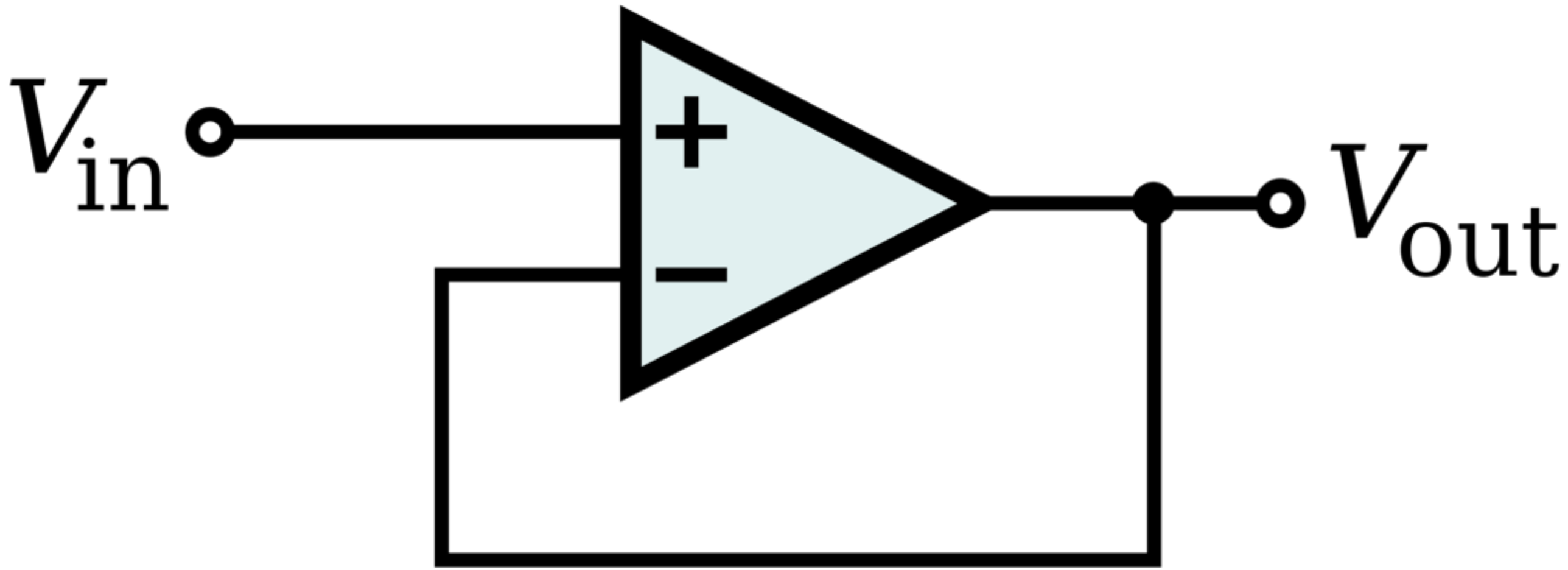

Image: stackexchange.com

Lower the source impedance, Rsource. This can be done in a variety of ways depending on the type of signal source. One good way to lower the Rsource is to use an op amp. This is an almost universal solution since you can match any impedance to any other impedance with proper op amp trickery. However, of course there is the cost, complexity, board area, etc. Sometimes a different interface circuit will help, or the sensor might be designed with a lower output impedance.

Image: TI

It is also a common cause of cross-talk in the ADC

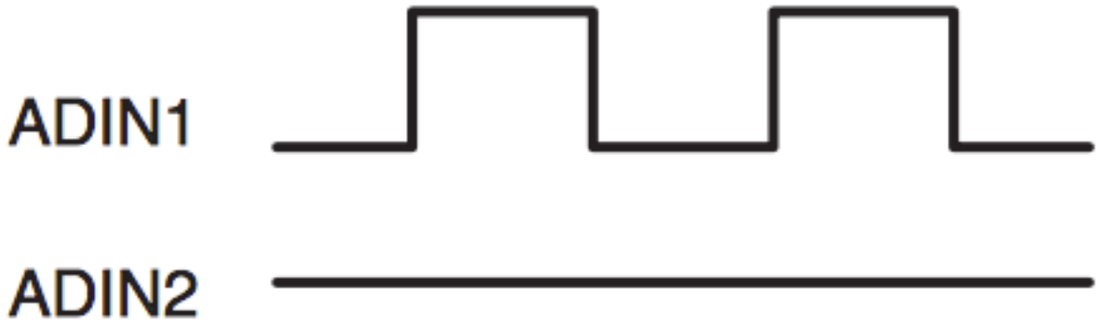

Figure 4. Adequate Impedance

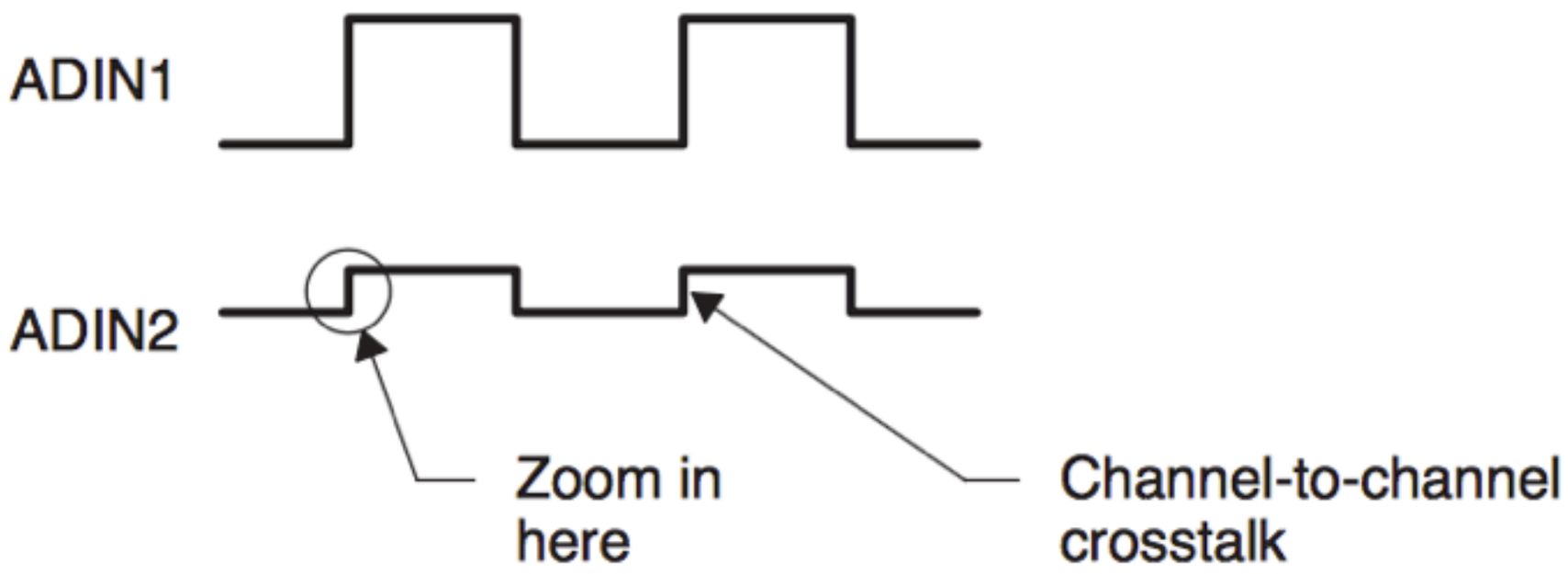

Figure 5. High Impedance

Image: TI