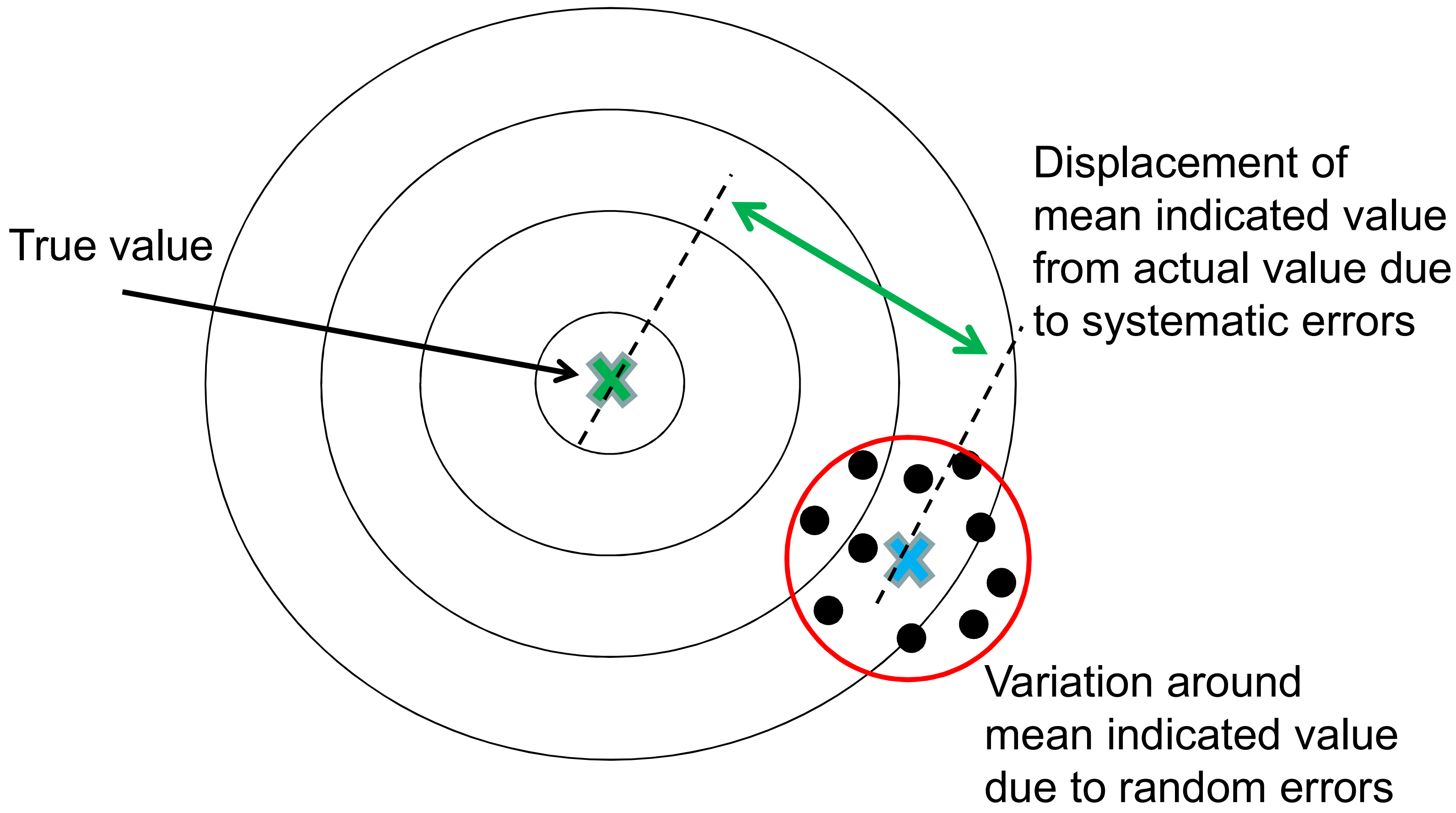
B1.6 Quantities, Decibels, Connections and Interreference

Recap - Target Analogy – random / systematic



Field and Power Quantities

- ‘Field ’ is a term used to describe a quantity whose square is proportional to power in linear system
  - Velocity
  - Force
  - Current
  - Voltage
  - *pressure*

- ‘Power ’ is a used to describe just that, quantities that are power (i.e. SI units of Watts) or proportional to power

  - power per unit area e.g. Luminous intensity or sound intensity are proportional quantities.

The decibel

- The decibel – 1/10th of a ‘bel’, named after Alexander Graham Bell

- It is logarithmic unit that expresses the ratio of two quantities - logarithmic scales are good at displaying quantities that vary over a large range.

  - It can be used in an absolute sense by making one of the quantities a prescribed level, e.g. 1 mW, 1V. The unit is suffixed: dBm or dBv
  - or it can be used relatively in which case it expresses gain.

- It is 10 times the log to the base 10 of the ratio of two power quantities

  or

- Or 10 times the log to the base 10 of the ratio of the square of two field quantities – which is 20 times the log to the base 10 of the field quantities

The decibel

Power: $$\text{dB} = 10log_{10}\frac{P_1}{P_2}$$

Field: $$\text{dB} = 10log_{10}\frac{F_1^2}{F_2^2} = 20log_{10}\frac{F_1}{F_2}$$

dB mW: $$\text{dBm} = 10log_{10}\frac{P}{0.001}$$

dB V: $$\text{dB}v = 20log_{10}\frac{V}{1}$$

Useful dB's

- Half power is -3dB
- Doubling of power is 3dB
- 10dB is ten fold increase in power
- -10dB is a ten fold reduction in power

- -6dB is half amplitude for field quantities
- 6dB is a doubling in amplitude for field quantities
- -20dB is a ten fold reduction for field quantities
- 20dB is a ten fold increase for field quantities

Scales of hearing

- Sound is useful as an example to illustrate the usefulness of dB
- The nature of our ears is highly non-linear hence the quantities measurable vary widely over what to us might appear as relatively small changes in sound.

- The threshold of hearing is often taken to be a pressure variation (SPL) of:

  20×10^{-6} Pa, We use dBA (acoustic) to describe levels relative to this.

- The pressure variation at 40 dBA (a quiet room) is;

$$40 = 20log_{10}\frac{SPL_{40}}{0.00002} \qquad SPL_{40} = 0.002\ Pa$$

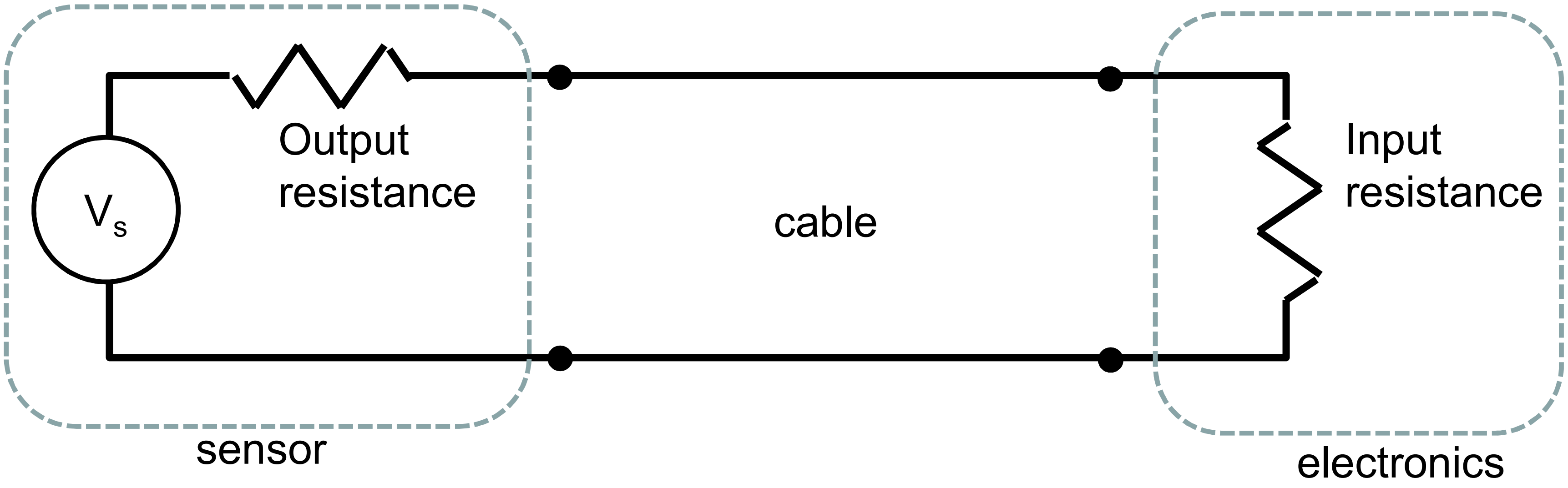
- ~100 times greater

- The pressure variation at 130 dBA (jet engine at 100m) is;

$$130 = 20log_{10}\frac{SPL_{130}}{0.00002} \qquad SPL_{130} = 63\ Pa$$

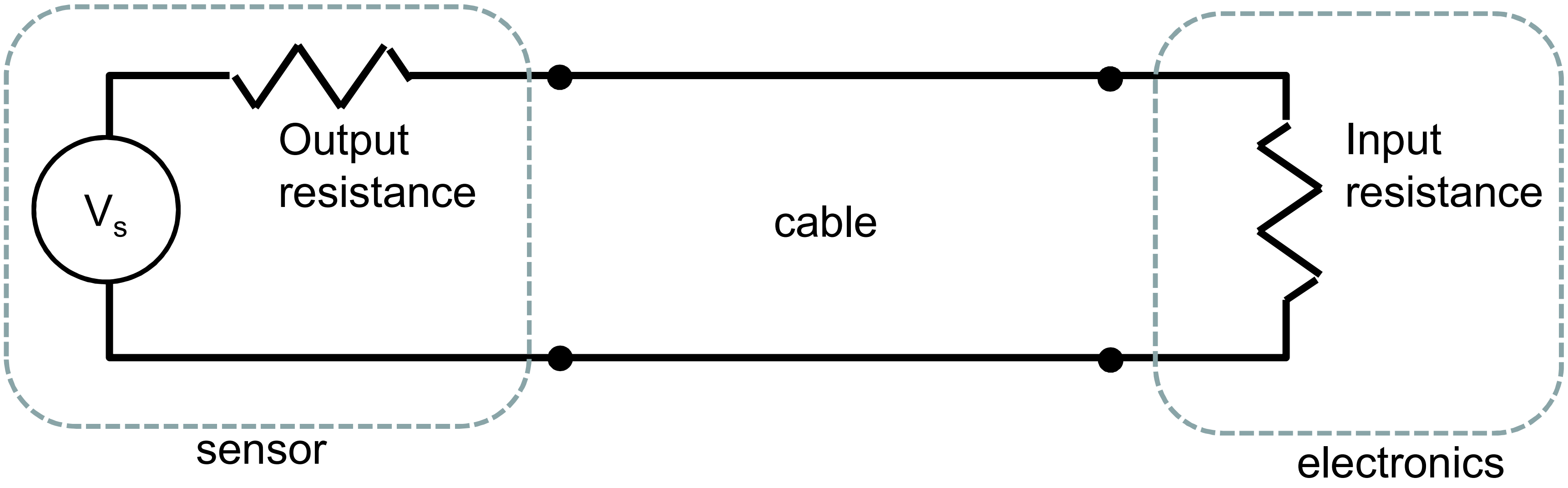
- ~3,000,000 times greater

Sensor outputs: noise



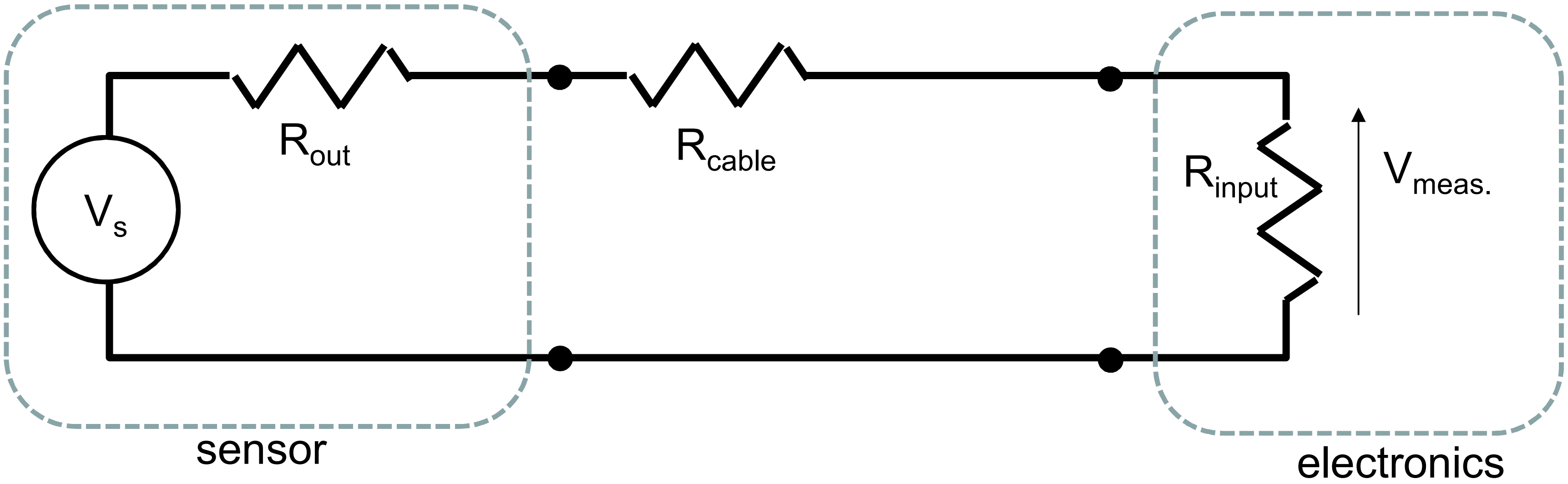
- Most sensors will have a voltage output i.e. a voltage signal will represent the measured value.
- Electrical circuits or measuring equipment connected to the sensor will place a load on the sensor. To maximise accuracy the load should be small i.e. the input resistance of the electronics should be large.

Sensor outputs: noise



- So that all of the sensor output, v_s is developed across the input of the electronics the input resistance of the electronics must be very much larger than the output resistance of the sensor, or cable resistance.
- This is why oscilloscope probes ‘divide by 10’ – it increases their input resistance.

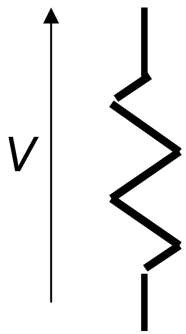
Sensor outputs: noise



- We want: $V_{meas.} = V_s$

- We get: $V_{meas.} = V_s \dfrac{R_{input}}{R_{out} + R_{cable} + R_{input}}$

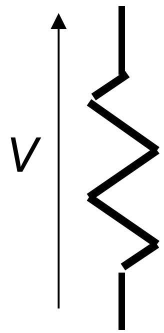
Sensor outputs: noise



1000 Ω

$$\Delta V = 100mV$$

$$\Delta P = \frac{\Delta V^2}{R} = \frac{0.1^2}{1000} = 0.01mW$$



1,000000 Ω

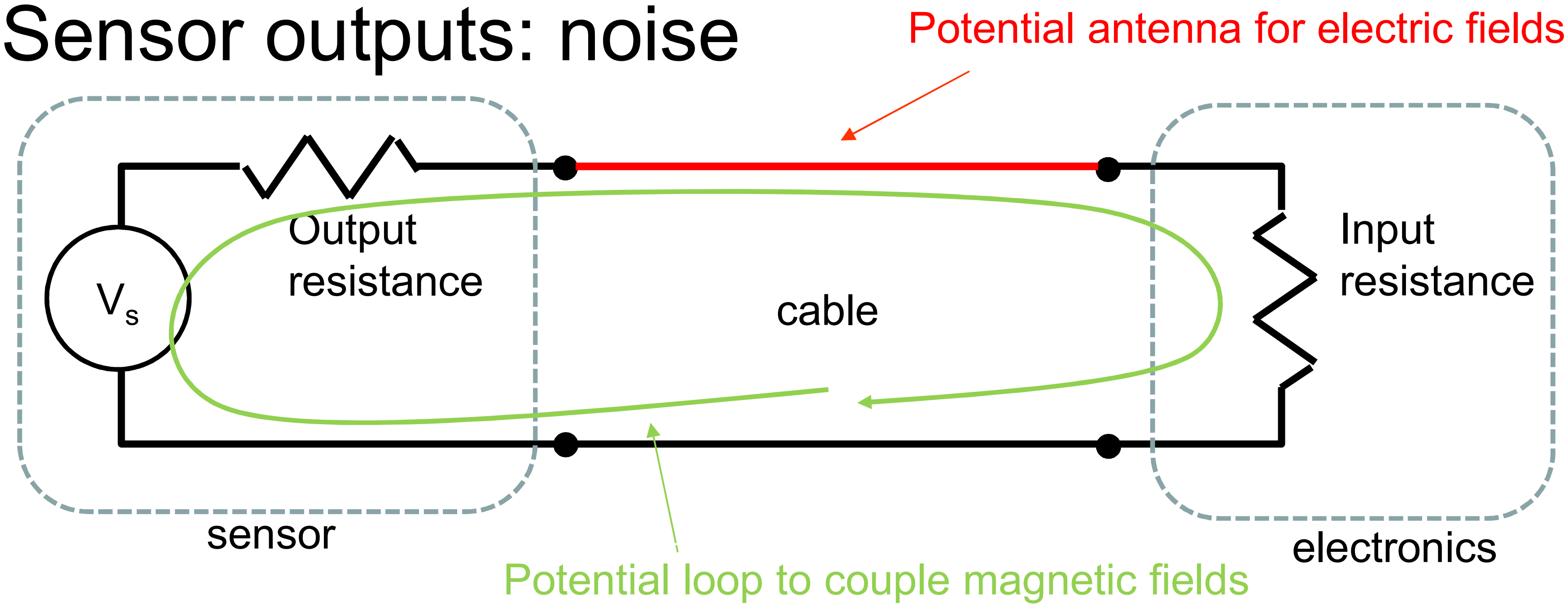
$$\Delta V = 100mV$$

$$\Delta P = \frac{\Delta V^2}{R} = \frac{0.1^2}{1000000} = 0.01\mu W$$

- The consequence of a very high input resistance is that relatively small amounts of energy can influence the voltage across an input.
- This makes the sensor system susceptible to interference.

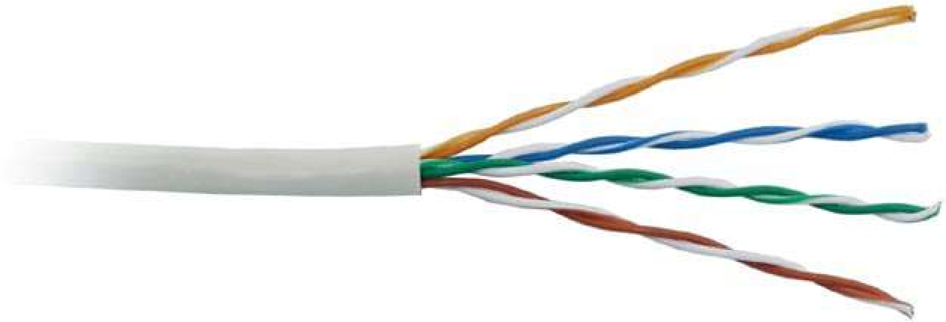
❖ *You might note that if the sensor is a 'stiff' voltage source then it should have zero (very low) output impedance, but this cannot be guaranteed over all frequencies, and we may still have cable resistances etc.*

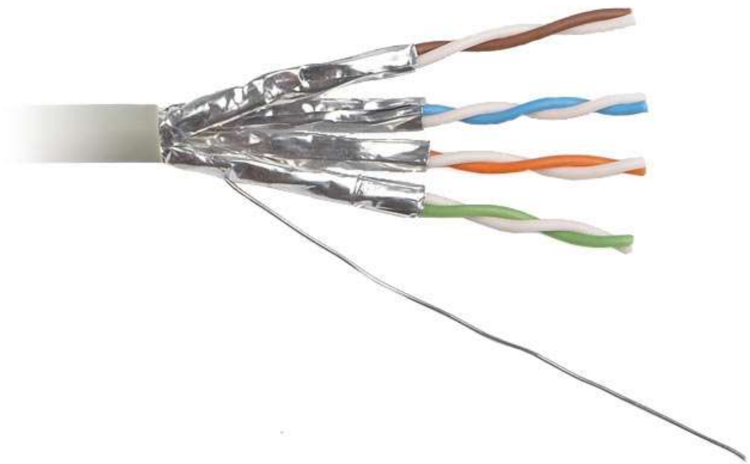
Sensor outputs: noise



- Stray electromagnetic fields from cables, mobile phones, radio broadcasts – almost any modern electrical equipment can link with the cable and create interference.
- Long cables can act as unintended aerials and loops form air-cored transformers

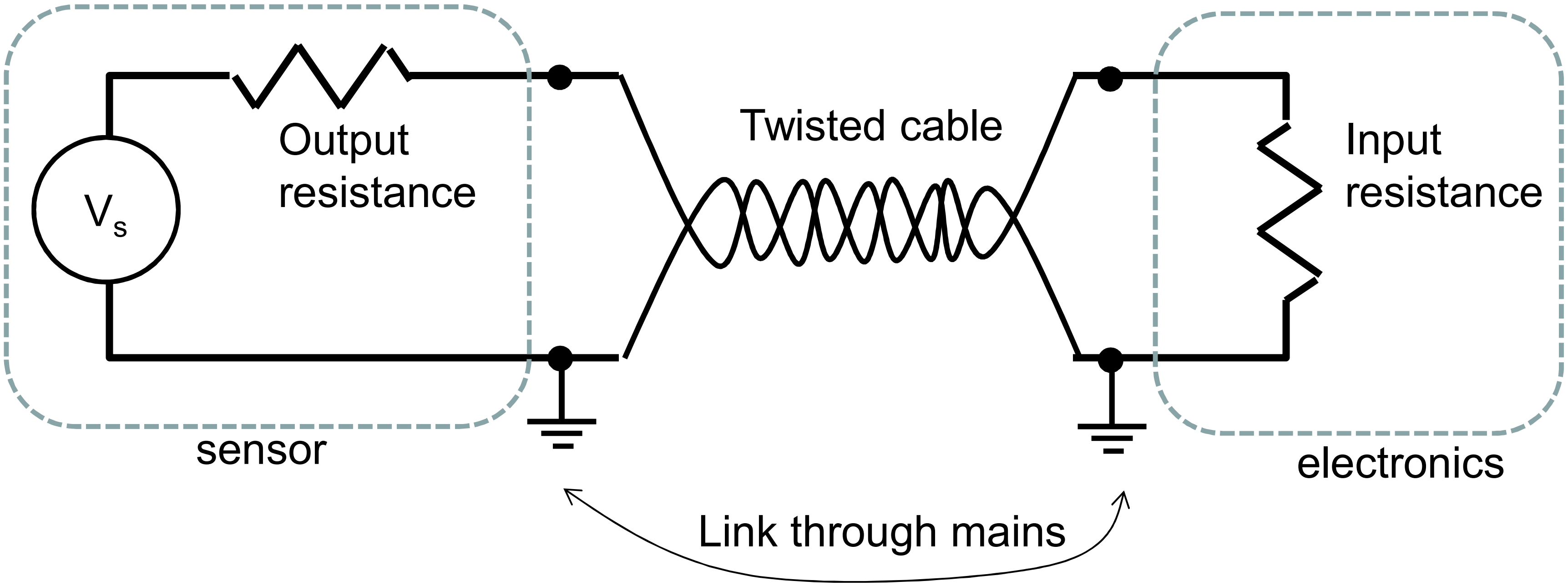
Sensor outputs: noise





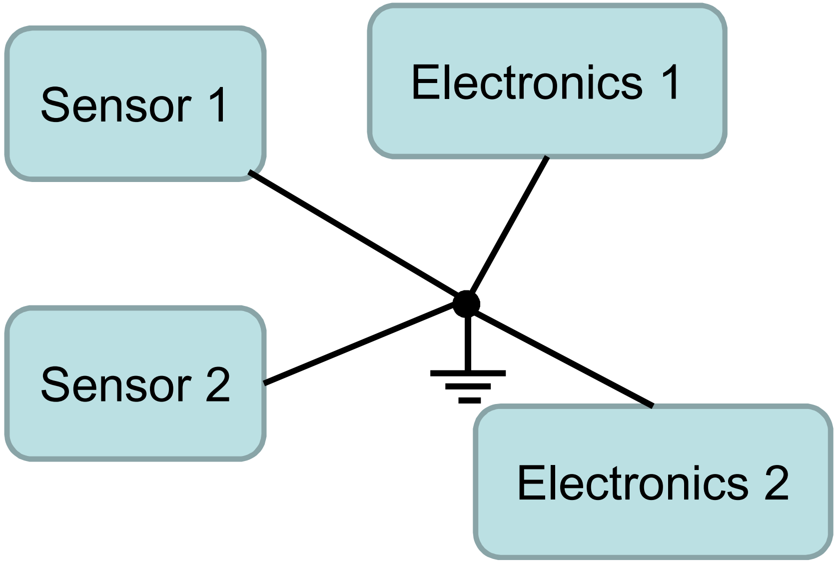
- To minimise Electro-Magnetic (EM) interference cables are twisted and or encased in a conductive shield.
- Twisting works by reducing any loops to a small area, with any residual linkage cancelled out by the next loop.
- The conductive screen acts like a ‘boundary condition’ forcing the electric filed (and any alternating magnetic field) to zero.

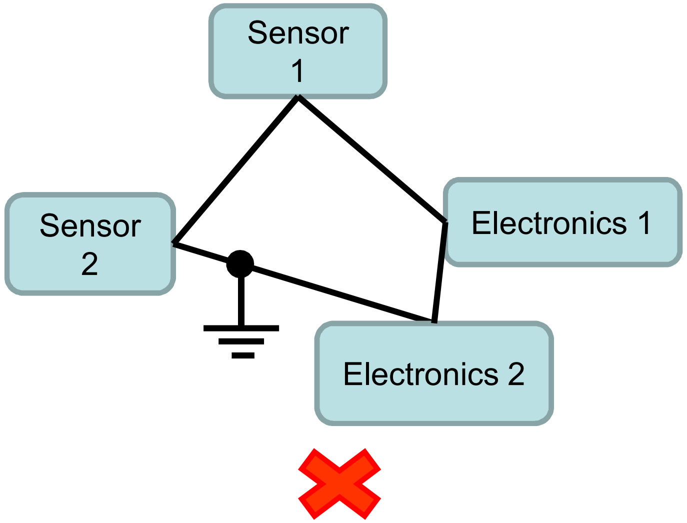
Sensor outputs: noise



- One aspect often overlooked when setting up sensors is the possibility of earth-loops – conductive loops created by multiple earth points and completed through the mains distribution system. Only earth at one end!

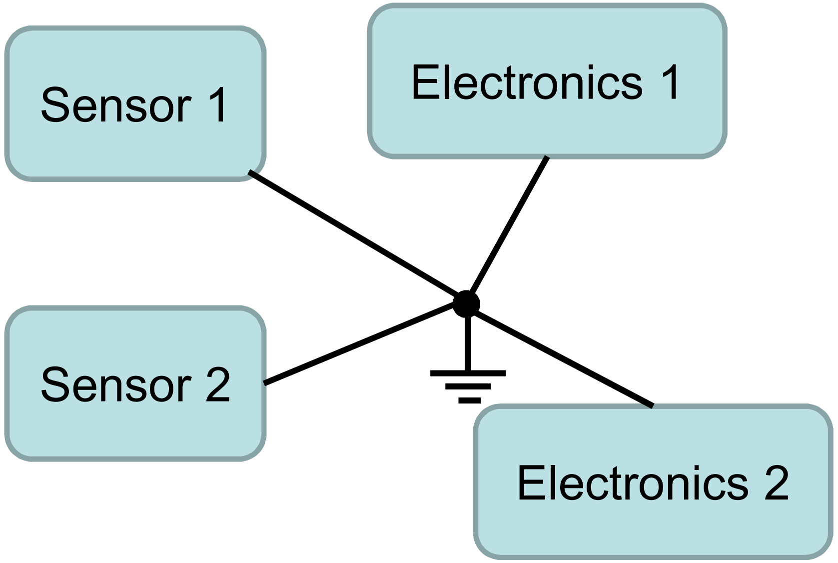
Sensor outputs: noise

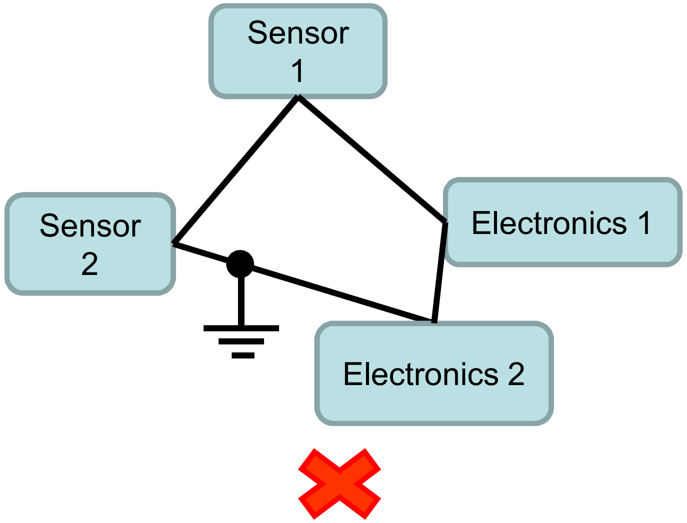




- Similarly good practice is to use ‘star’ earthing / ground referencing arrangements, taking all earth connections to single point.

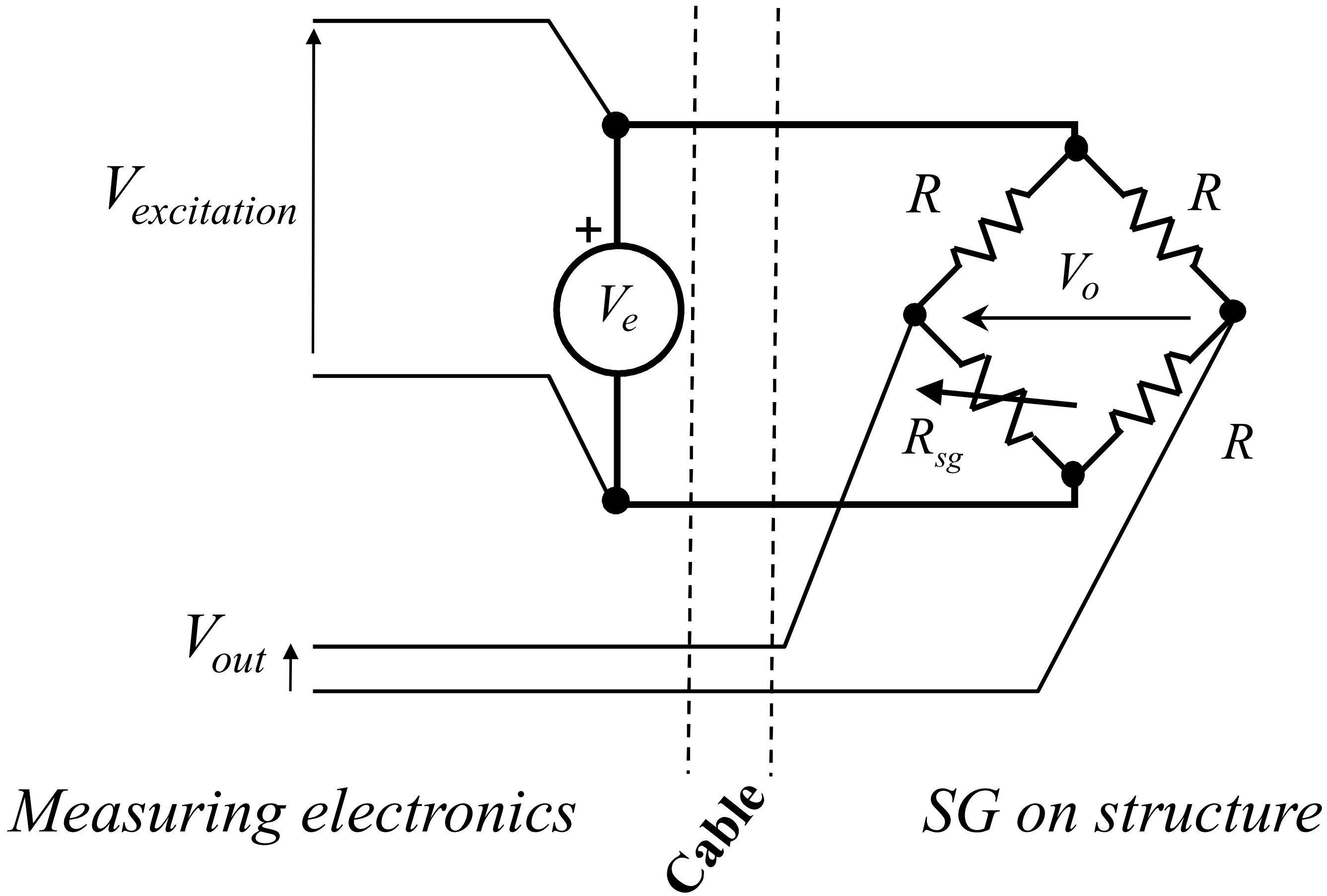
Sensor outputs: noise



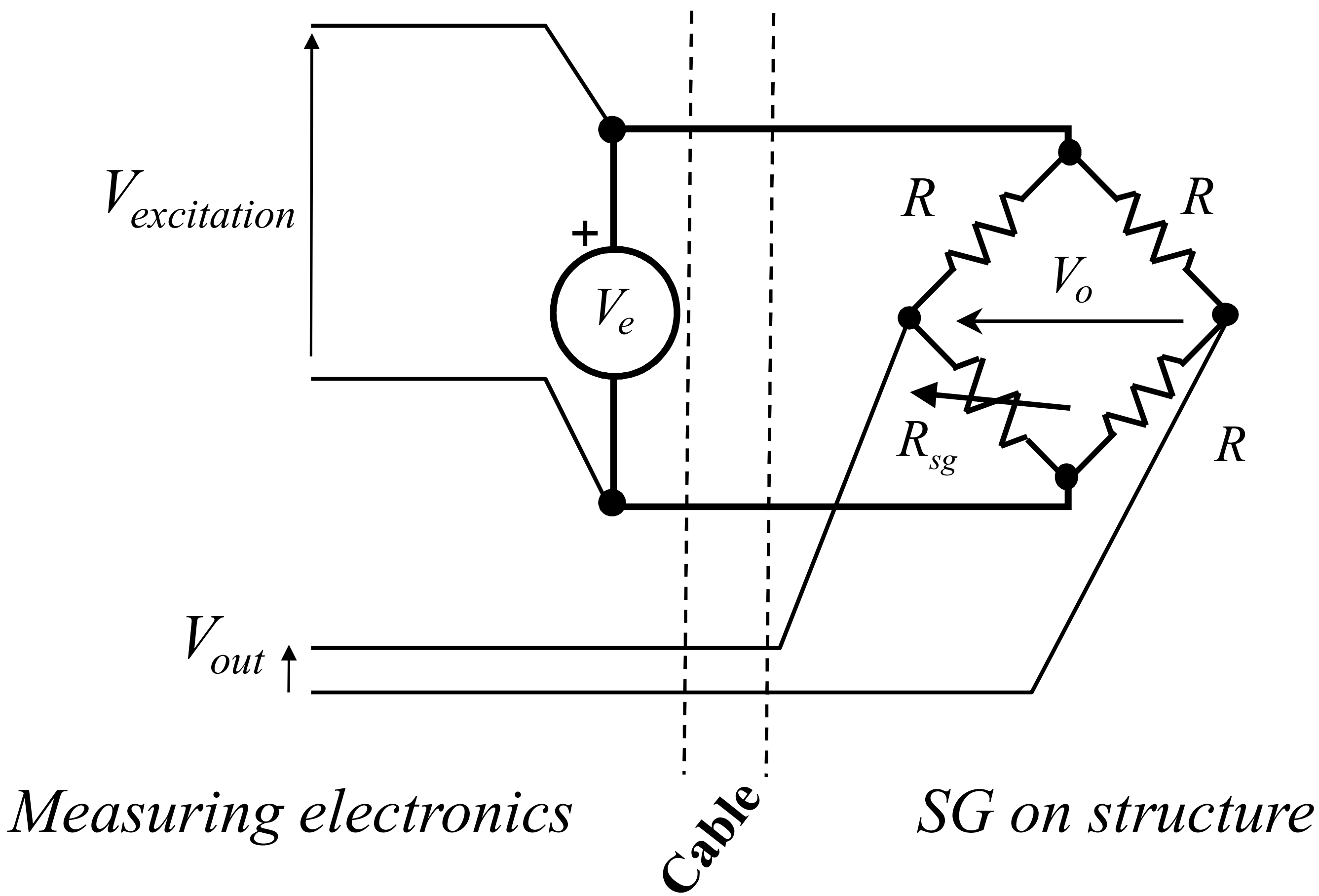


- As well as eliminating loops, this prevents the voltage drops caused by currents flowing to earth interfering with other parts of the system – conducted interference

Sensor outputs: voltage drops

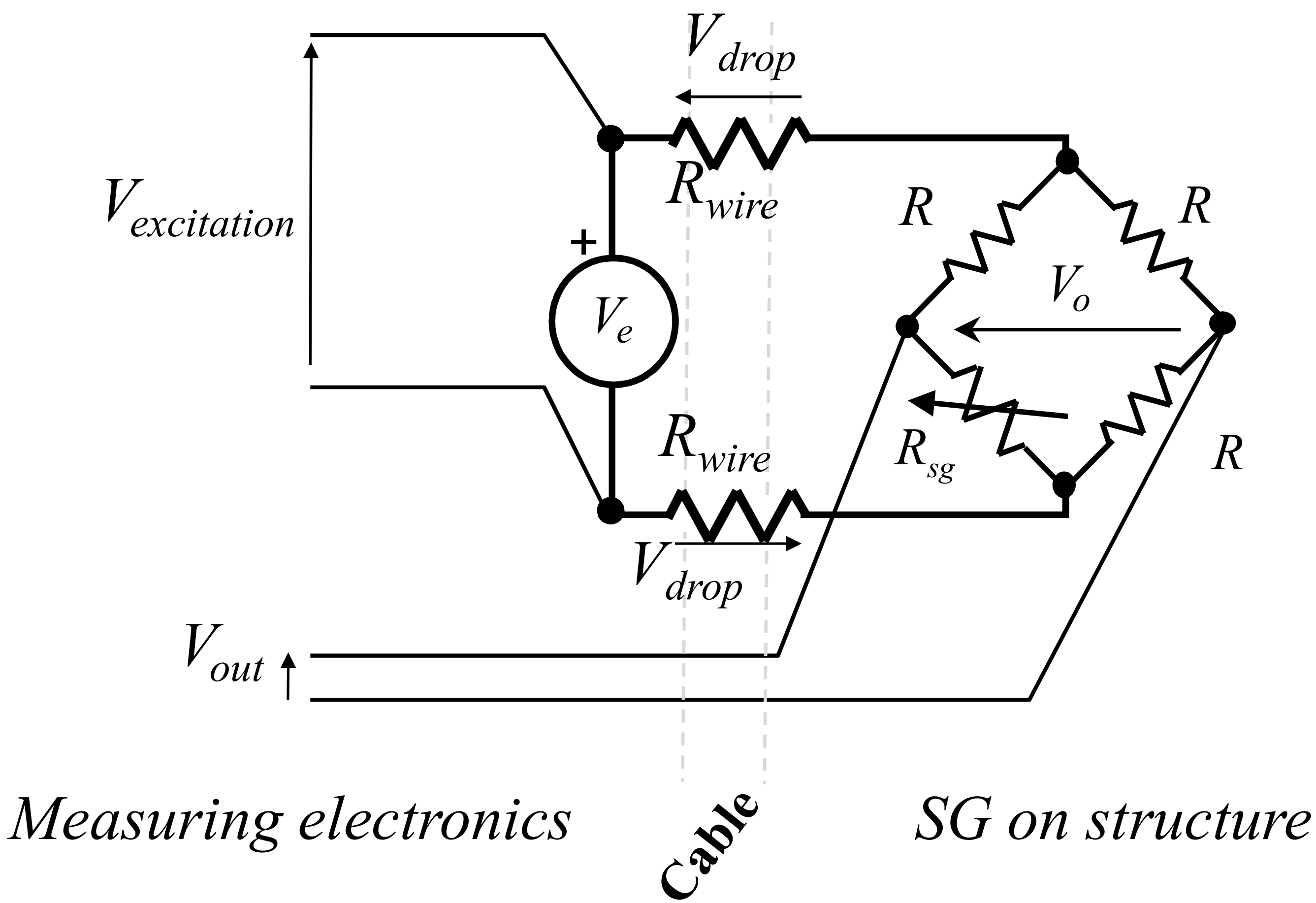


Sensor outputs: voltage drops



A strain gauge is normally connected to the electronics by a cable of not insignificant length.

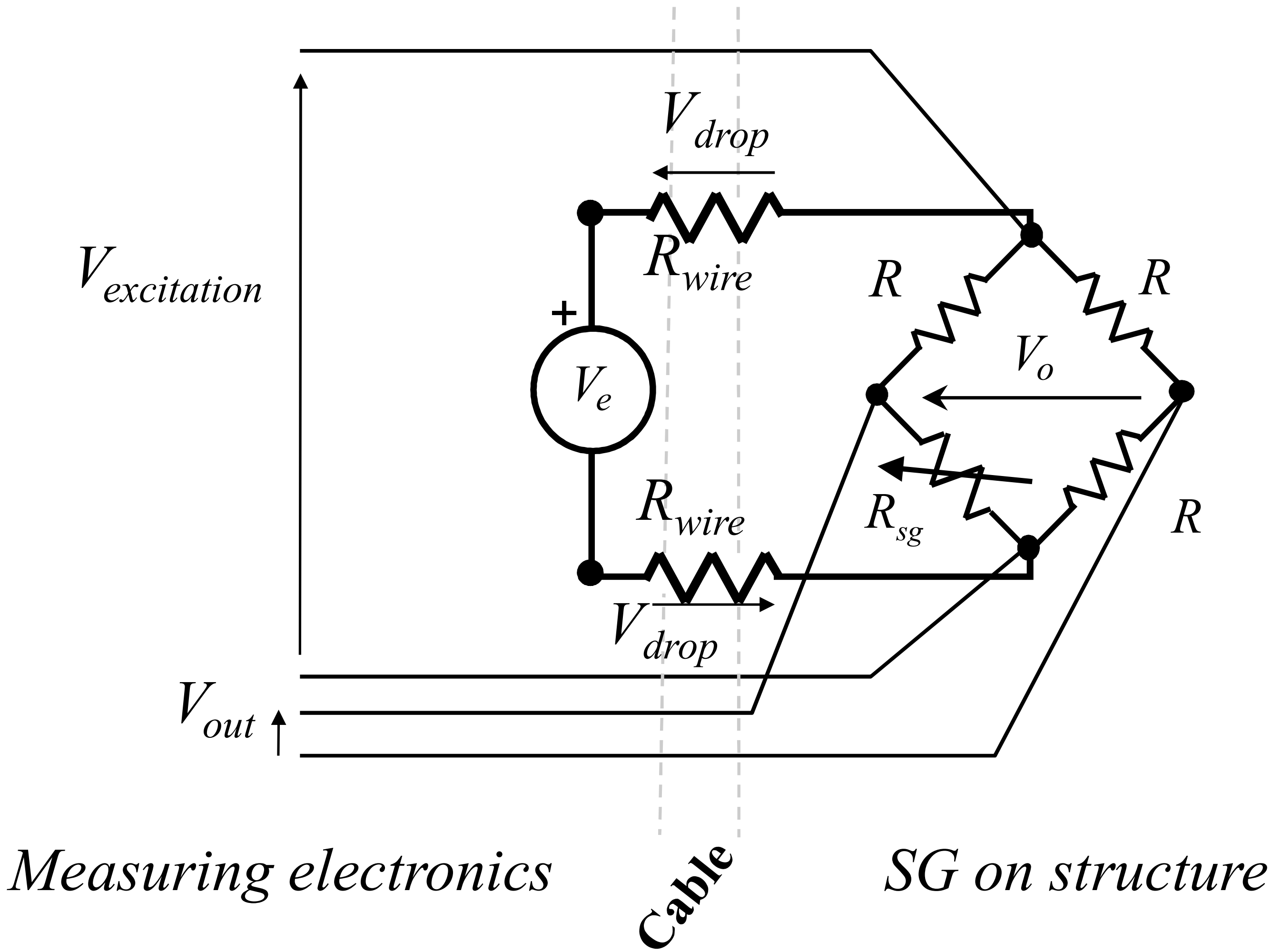
Sensor outputs: voltage drops



A strain gauge is normally connected to the electronics by a cable of not insignificant length.

The resistance of the cable can produce errors due to voltage dropped along it.

Sensor outputs: voltage drops

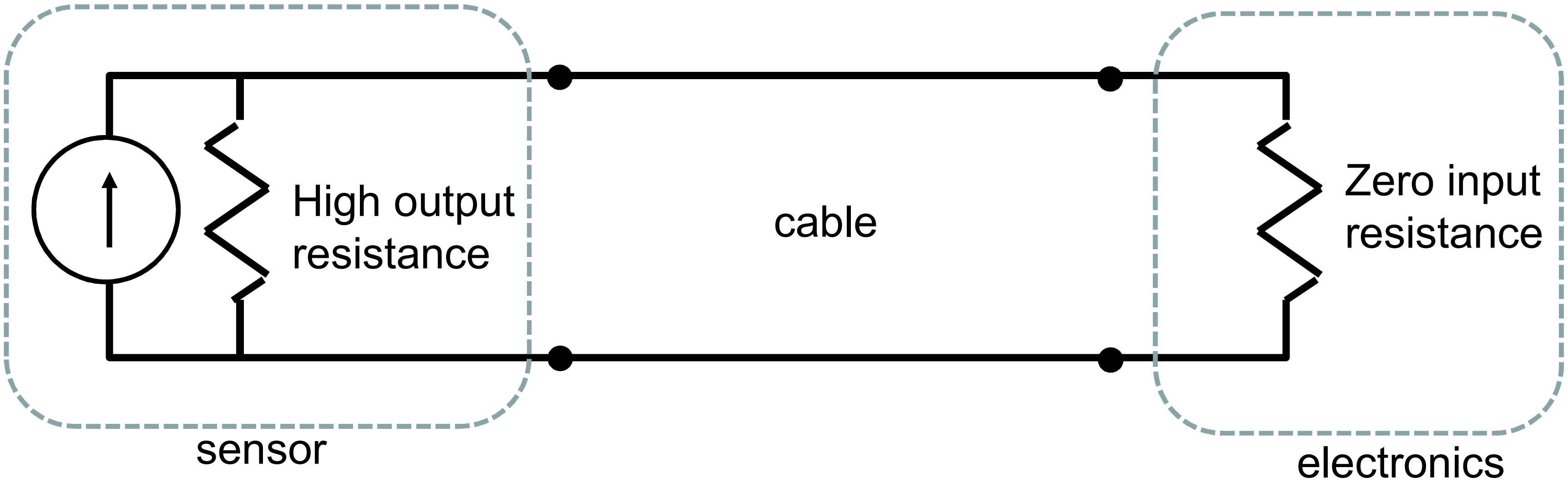


A strain gauge is normally connected to the electronics by a cable of not insignificant length.

The resistance of the cable can produce errors due to voltage dropped along it.

Using additional measuring cables avoids this.

Sensor outputs: current source



- Where cable runs are very long and high immunity to interference is desired, sometimes a current is used to encode the signal.
- The load in a current source system has low resistance and so it has greater immunity to interference.

What about TV / radio antenna / ethernet ?

- RF (radio frequency) cabling is a special case as the wavelength of the signal is much shorter than the cable.
- The cable acts as a transmission line which will cause signal energy to ‘bounce back’ if the cable end was connected to zero or infinite resistance.
  - Think of a length of rope pulled tight and one end displaced so that a wave travels along its length - some is reflected back

- A reflection will occur everywhere an RF encounters a change in ‘characteristic impedance’, so all cables/connectors are designed to have the same value.
- If we are matching an antenna, the ‘resistance’ of free space turns out to be 75Ω; 50Ω is often used as it gives better power transfer.

Aerospace Cables

The cables used on aircraft can be made up of copper, copper alloys or aluminium and are often plated to improve corrosion resistance. Aluminium cables are lighter (although physically larger) than copper for a given resistance. Aluminium hardens with work and age and so cables are formed from many small individual strands.

The body of the aircraft is generally tied to the zero volt rail of the power system but often it will not form the return path for load currents, dedicated cables are provided for this purpose. The body can have an unreliable impedance and sharing a return path may cause equipment to interfere. The whole distribution system is designed to minimise the possibility of loads affecting each other.

Aerospace Connectors

Aerospace connectors are designed and manufactured to high tolerances to provide the reliability required in the harsh environment. Temperature, humidity and pressure are all subject to large changes between the runway and the conditions experienced during flight.

The more extreme the range operating conditions the more thought must go into the design of connectors and there is a whole industry dedicated to producing them for aerospace applications. ‘Mil’ standard connectors are instantly recognisable as an aerospace connector and can be configured to handle power and data.

Operating conditions - Paschen curve

Paschen conducted the classic experiments to determine the dielectric breakdown of air at differing air pressures. Radar and counter-measure electronics on board aircraft feature high voltages and have to be rated to operate up to 70,000ft, missile systems increase this to the worst case 150,000ft. To avoid excessively large conductor separation special connectors must be used to avoid the possibility of breakdown.