Extrinsic noise

- or Why Things Don't Always Work

    even though you thought you'd done everything right

    Practical instrument systems composed of electrical components
      define geometry of potentials and electric fields in system
    measurement of charge <==> rearrangement of potentials in system
      ie current flows

- we can't take the current paths for granted - why?

    already know that electrostatic (capacitive) and magnetic (inductive) connections are present between components - as well as simple conductive connections

    so usually there are several routes along which current can flow, especially depending on frequency range covered by instrument

- we need to plan them

Simple example

- Thunderstorm

  dramatic movement of charges with obvious consequences

  but even at some distance from lightning strike, observe induced and conductive current flows

  frequent source of damage to electronics

  fax machines, modems, telephones,..

Sources of pickup

- **Lights**

    typically ~50Hz but...

- **Power supplies - in almost all apparatus!**

    50Hz "hum" - often transformers

    Switched mode: AC rectified -> DC -> DC chopped -> square wave (~kHz)

    uses capacitors and diodes to generate high(er) voltages - eg kV for TV

- **RF pickup**

    capacitive coupling of high frequencies from...

    ... computers, radio or TV, mobile phones,...

    ... digital logic inside system

- **Microphonics**

    surface vibrations of metal surface, cause capacitance variations

        motors, vacuum pumps, transformers, ...

How to find noise sources

- Lights

    Do I need to say?

- 50Hz mains and higher frequencies

    analogue oscilloscope, varying time base and trigger

- RF

    analogue scope

    spectrum analysis

    can sometimes be misleading without experience

- Varying conditions, eg ground connections

    sometimes hard to avoid in practice

    but not the best way of improving things, especially if hit-or-miss

- How to avoid or eliminate extrinsic noise?

Shielding

• **place sensitive amplifier- detector in metal enclosure**
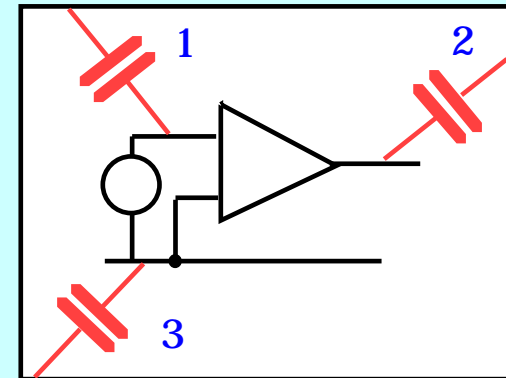
- external E field lines terminate on surface

Incident EM waves reflected

$$E_{ref}/E_{inc} \quad (1-Z/Z_0) \quad Z_0 = (\mu_0/\epsilon_0)^{1/2} = 377$$

Absorbed wave limited to skin depth

$$\sim e^{-x/\delta} \quad \delta = (2/\mu\sigma\omega)^{1/2}$$

Al: $\delta \sim 100\mu m$ at 1MHz
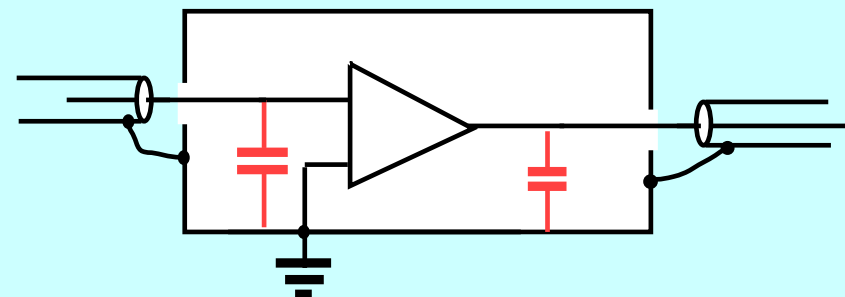
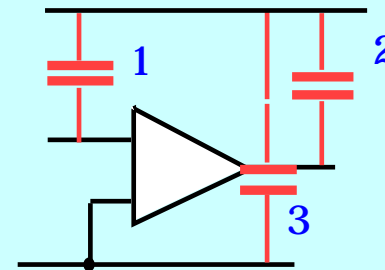• **Potential problems**

capacitances to shield - feedback

shield connection

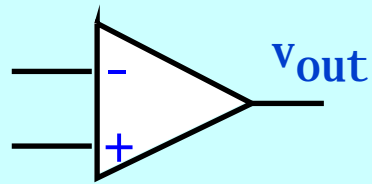how to get signals in and out?

try to make tight connections

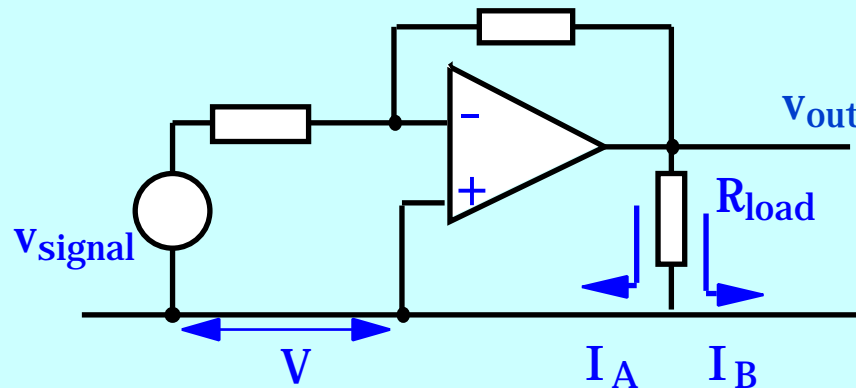with low resistance

E field can penetrate gaps <<

Ground loops

- **Real amplifiers have more than 3 terminals**

v_{out}

Inputs draw no current but output provides current
- where does it go?

- **Route for output current**

does it flow where it should?

$v_{out} >> v_{signal}$

v_{out}

R_{load}

v_{signal}

V

I_A I_B

I large

R in line -> V

- **If current flows in reference line (usually ground) expect voltage drops**

ie ground is not 0V everywhere - even if circuit diagram assumes so

ensure large currents, especially later amplifier stages, provided separately
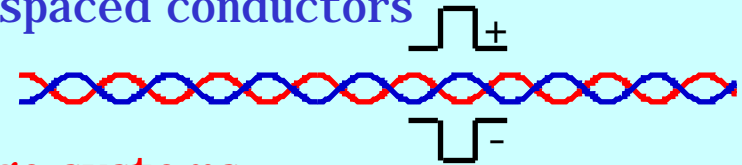
Inductive and conductive paths

- **Inductive paths**

  Long paths can form loops in which other currents flow

  currents => changing magnetic field

  B induces current noise

  Avoid with balanced signals, flowing in closely spaced conductors

- **May still be difficult to implement in remote, large systems**

  optical data transmission can remove a large part of loop

- **Routing noise out of sensitive locations**

  large capacitors to ground, or DC point

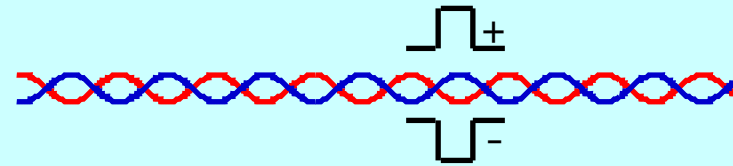 at frequencies where   C >> 1, noise sees low impedance path to ground

Other solutions

•Differential transmission and receivers

> same noise appears on both lines
>
> can subtract common mode signals
>
>> at expense of loss of some dynamic range, eg...

•Battery power

> eliminate AC from supply

•Filter

> if signal is limited to a freqency range, eg by bandpass noise filter
>
> should be protected against noise outside range of interest
>
> if insufficient, add more filtering