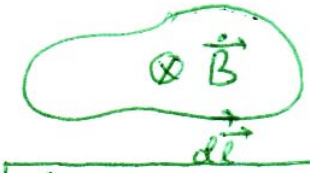
Lecture 41

③ Magnetic coupling (electric hum in audio equip. noise becomes audible, similar to transformer's hum)

Faraday law



$$\oint \vec{E}\cdot d\vec{\ell} = -\frac{d}{dt}\int \vec{B}\cdot d\vec{A} = -\frac{d\Phi_B}{dt}$$

Ex. $\dot{B} \sim mV/m^2$ due to 60Hz (in most buildings due to power lines, light fixtures)

with $R \sim 0.1\,\Omega$ wire, $i_n \sim 10mA$ for $1m^2$ loop

- time varying B-field induces voltage around any closed loop
- low freq. B-field is not easily shielded by metals

$$\delta = \frac{1}{\sqrt{\pi f \mu \sigma}}$$ ← skin depth

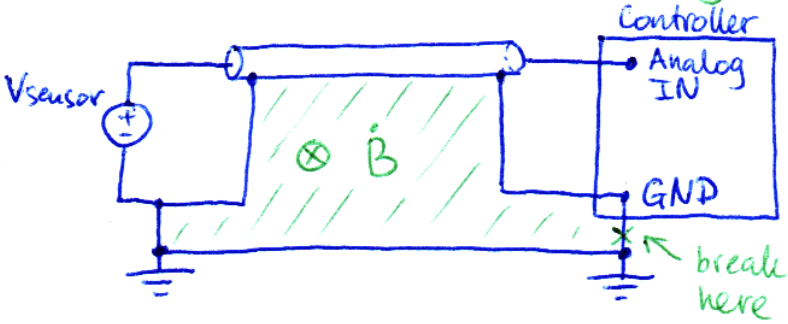
$\frac{1}{e}$ atten. of B in material; μ ← magn. permeability; σ ← conductivity

E.g. need 0.43" Al for $\frac{1}{e}$ atten. of 60Hz fields

To reduce

- avoid large enclosed conducting paths (e.g. ground loops)

Ex.



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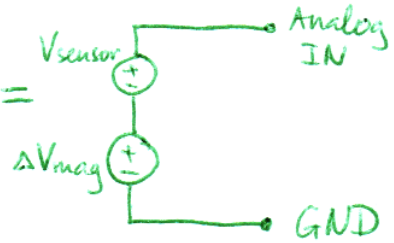
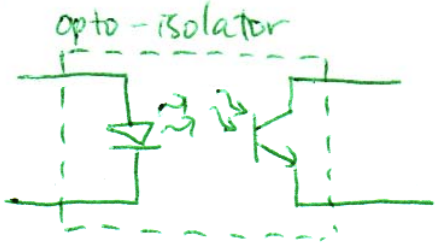


- use coax or twisted pair

  - induced fields cancel in successive twists
  - small enclosed area

- use magnetic shielding : mu-metal (Ni-Fe alloy $\mu \sim 10^5 \mu_0$)
  shorts out magn. flux

- use isolation transformers (1:1 transformers) } break ground loops
  opto-isolators



uses short optical transmission path

(4) RF coupling

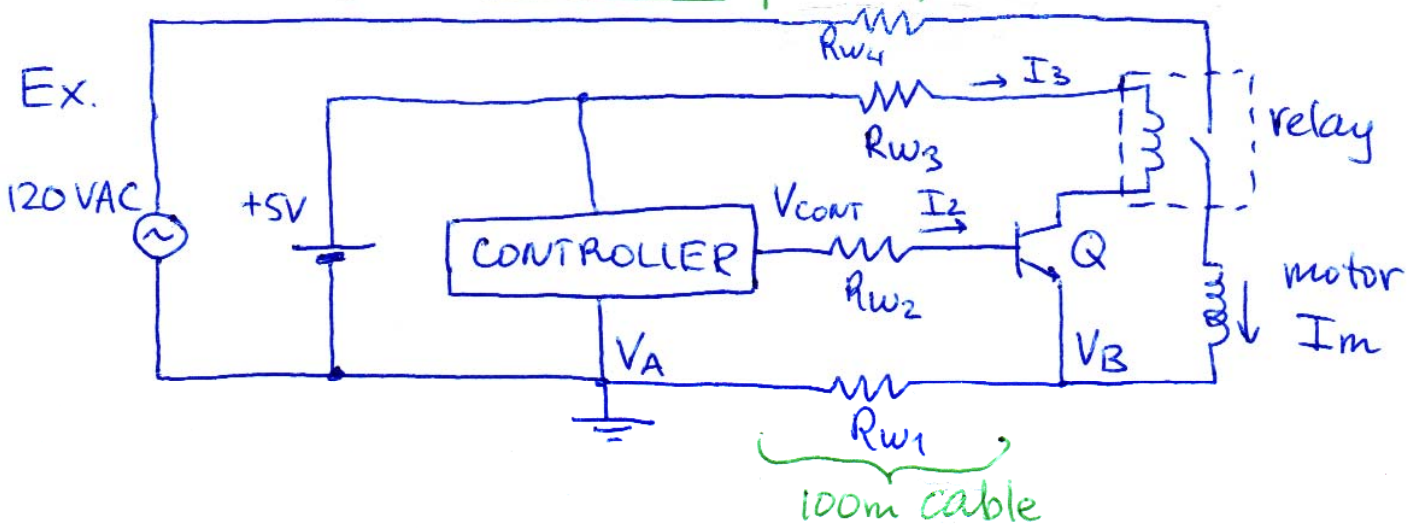
- wire leads, circuit parts can act as resonant pickups (antennas) => high freq. noise (VHF $\lambda \sim 1$-10m FM, TV
  UHF 0.1-1m TV, wireless
  SHF 0.01-0.1m cell-phones)
  $\frac{\lambda}{2}$ antenna or $\frac{\lambda}{4}$ antenna (near conducting surface)
  => very effective in picking up the RF

To reduce

- use shielding (very effective)
- keep short leads

(5) Resistive coupling

- wires ≠ equipotentials, have finite resistance
  ⇒ currents flowing thru ground lines can generate voltages in another part of the circuit



$R_W \sim 0.3\Omega$

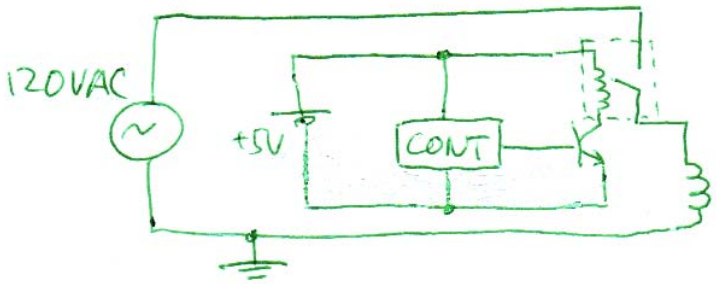
Q = ON : $I_m \sim 20A$ when starting $\gg I_2, I_3$
↖ sees low resistivity wire R_{W_1} and chooses to go there

⇒ $V_B - V_A \sim 20A \cdot 0.3\Omega \sim 6V$

since $V_{CONT} - V_A < 0.6V$, Q goes OFF when motor trying to start

To reduce

- use low resistance ground wires (copper busbars in extre cases)
- separate grounds for low and high level circuit parts


120VAC
+5V
CONT