2.996/6.971 Biomedical Devices Design Laboratory

Lecture 10: Sensors

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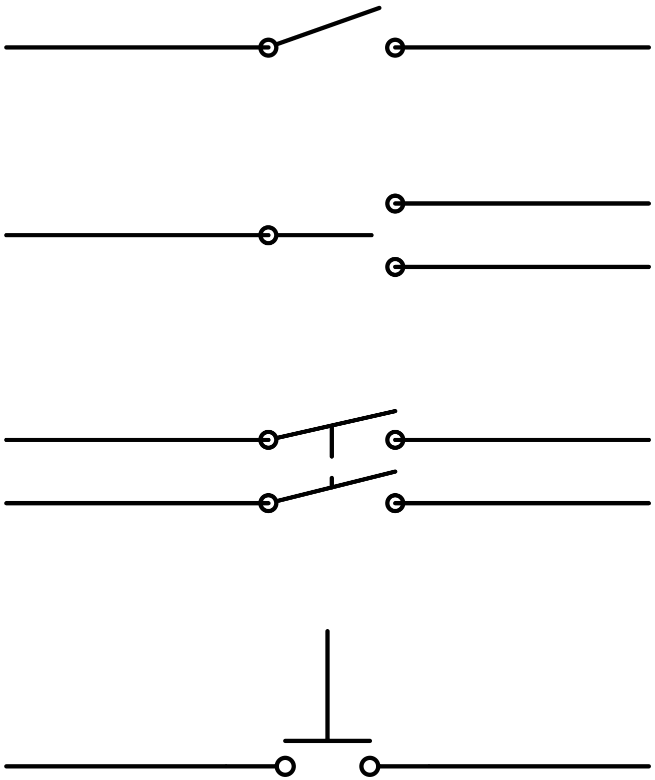
Switches



Single-pole,
(SPST)

- Pull-ups and pull-down
- De-bouncing

Reed Switches

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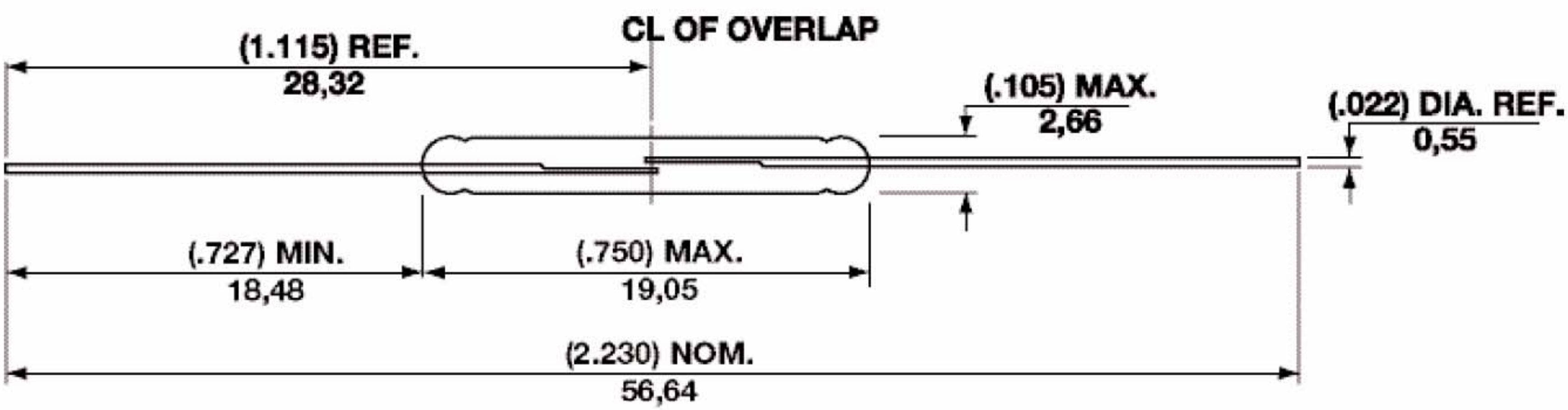
- Magnetically operated
- Non-contact operation
- Door open/close detection



Piezoresistive Strain Gages

$$\frac{dR}{R} = \frac{dl}{l}\left(1 + 2\upsilon + C(1 - 2\upsilon)\right) = G\frac{dl}{l} = G\varepsilon$$

- Gage factor
  - Common metals G~2-3
  - Platinum G=6
  - Semiconductors G~40-200
- Metals have greater elongation limits
  - Constantan foil:
    - Up to 3-5% elongation
    - G=2
  - Higher strains are limited by bonding

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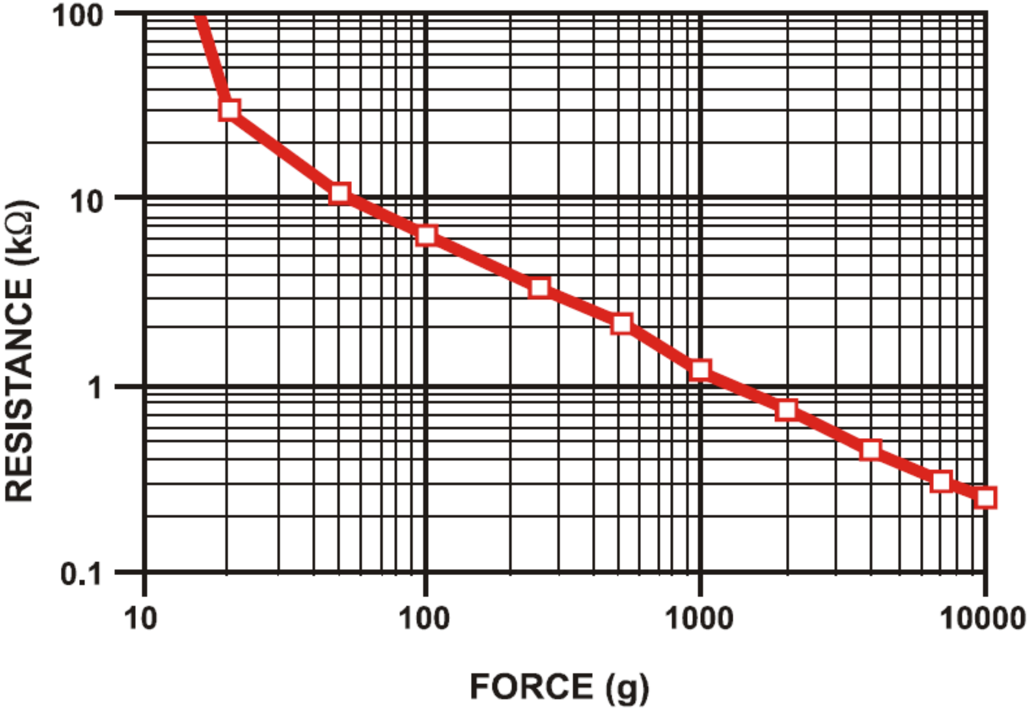
Force Sensitive Resistors (FSR)

- Pressure sensitive polymer
  - Decrease in resistance with applied pressure
- Not suitable for precision measurements!
  - Force accurace range from ±5 to ±25%
- Repeatable mechanics is key!



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Photoresistor
(Light-Dependent Resistor)

- Very slow (response time ~100ms)
- Hysteresis behavior
- CdS ~ 480nm
- ZnS ~ 320nm
- CdSe ~ 720nm
- PbS ~ 2000nm

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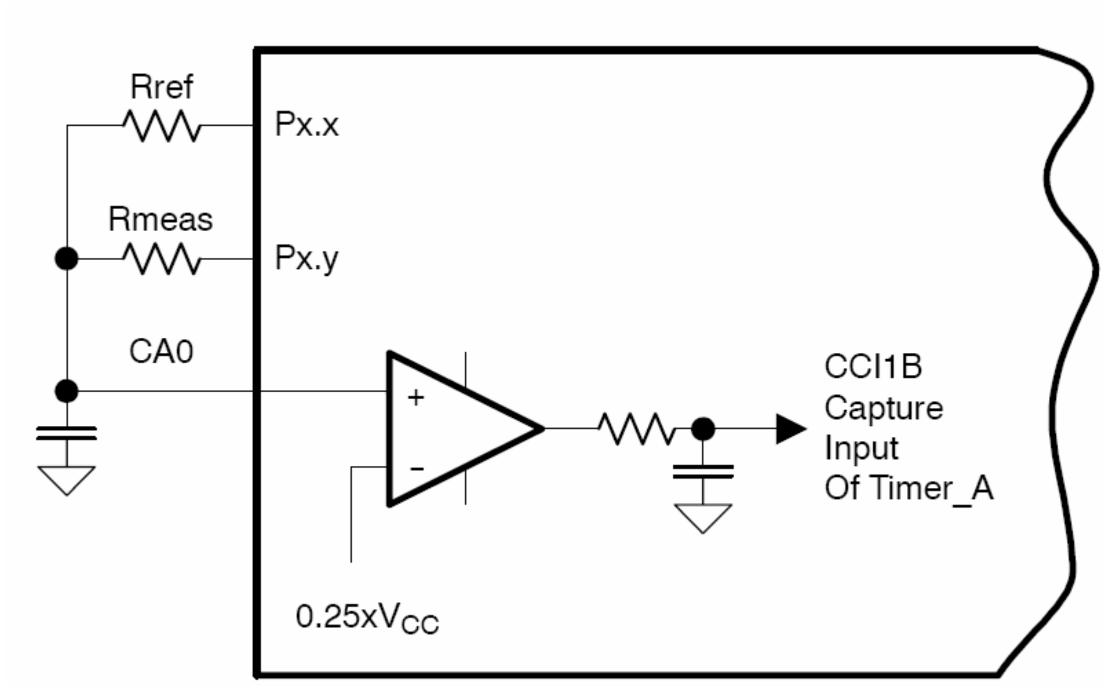
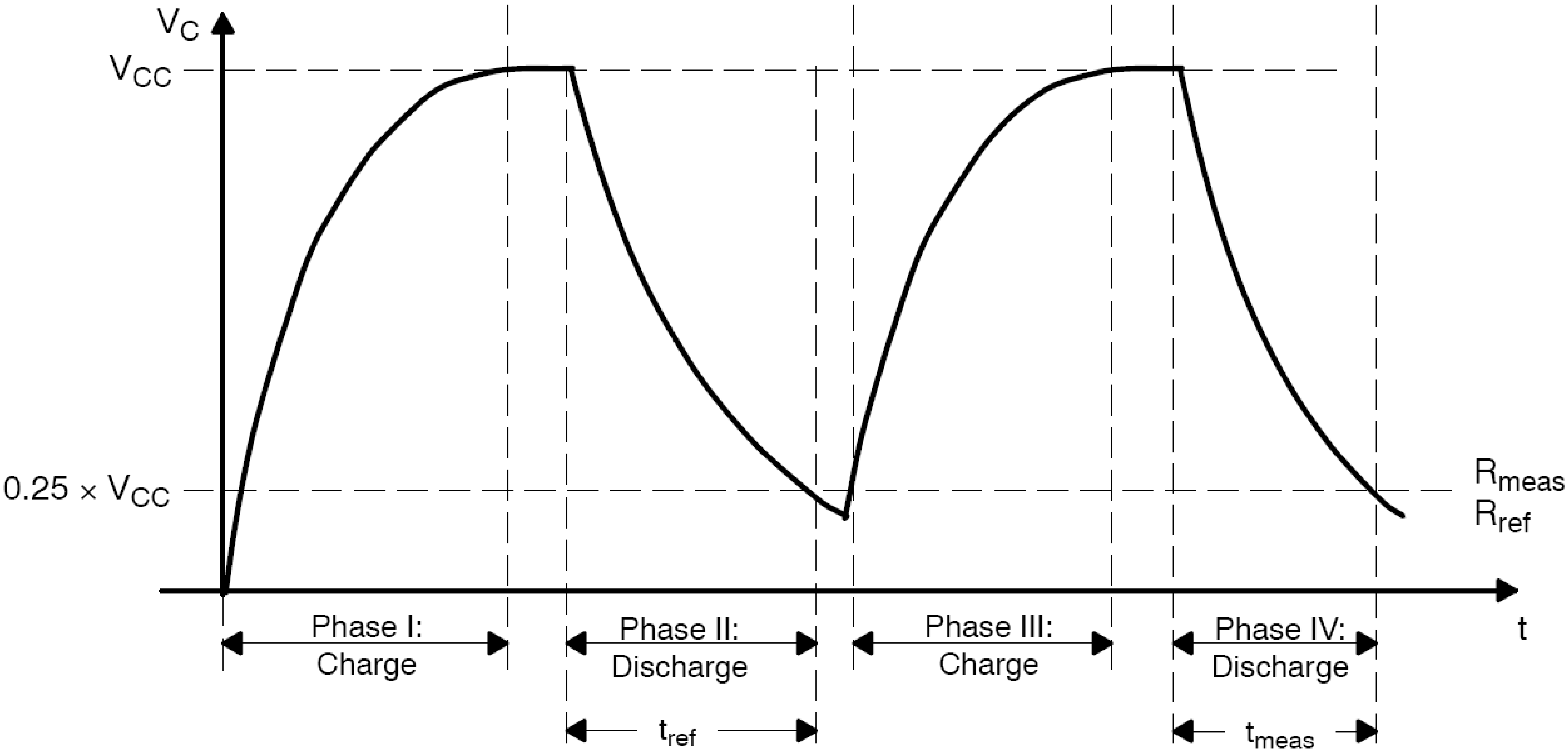
Resistance Measurement Circuits

- Quick-and-dirty techniques:
  - Trans-impedance amplifier
  - Resistive divider
  - Timer-comparator

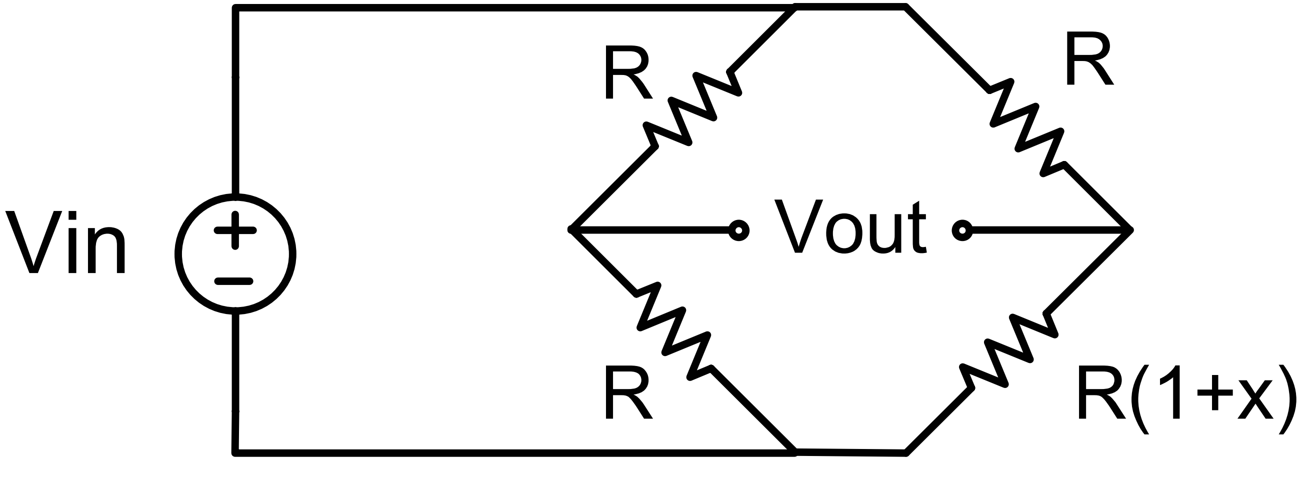


Result only dependent on the ratios of the test and reference resistors

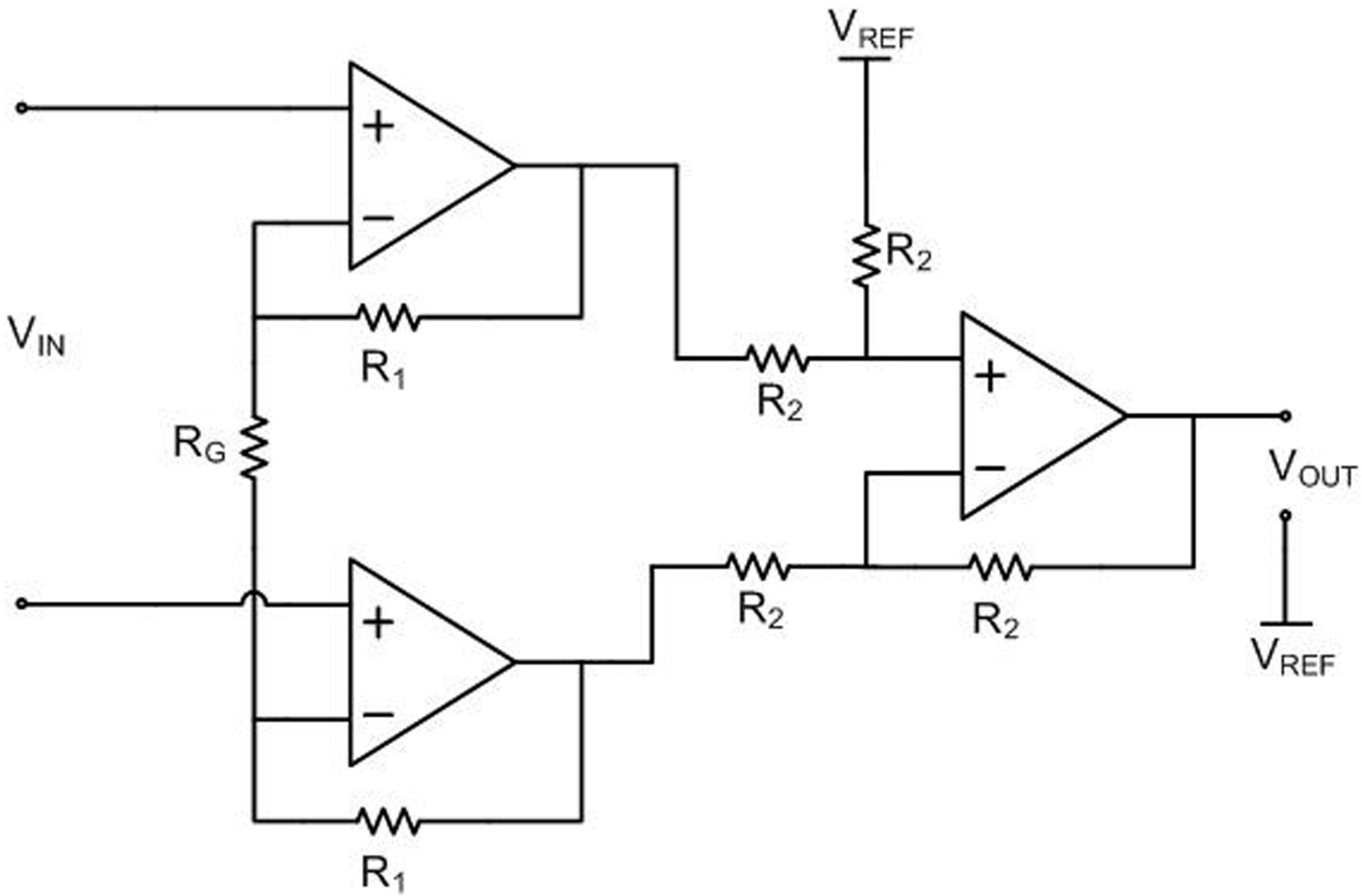


Wheatstone Bridge

- Match resistors to remove common-mode interference
- Not linear
- Linearize using multiple sensors

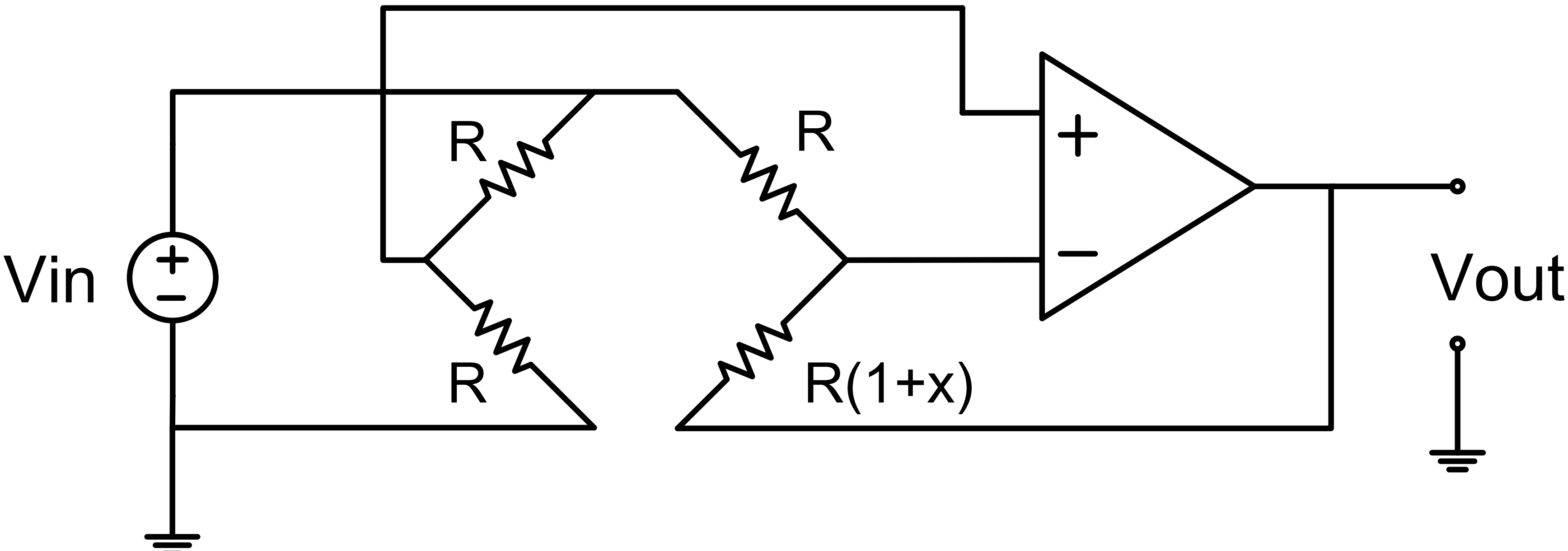


Instrumentation Amplifier



- Available as a packaged amplifier, e.g. INA118
- R_G and V_{REF} accessible externally

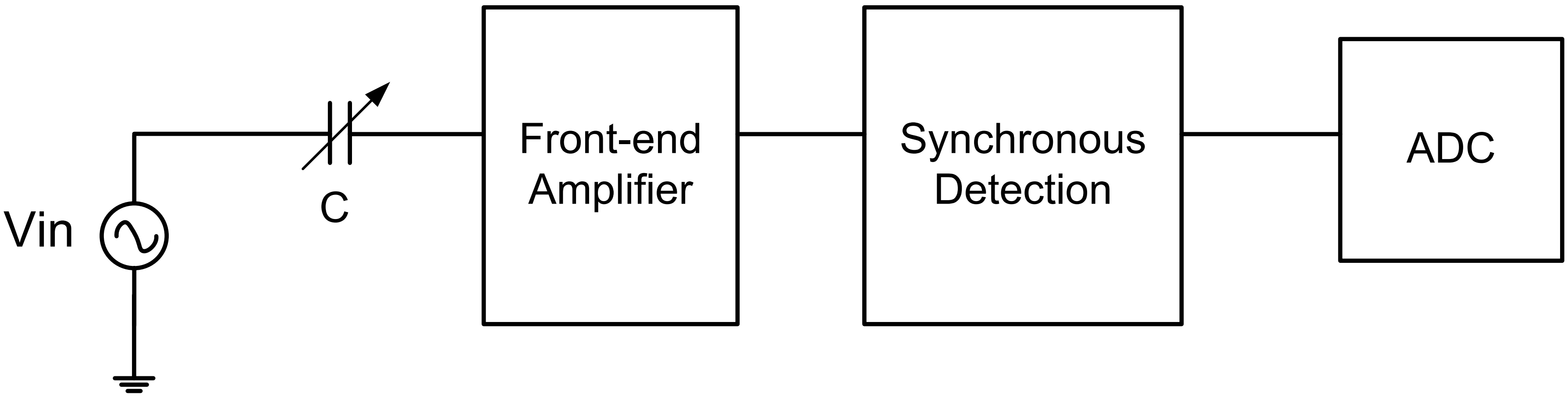
Servo'ed Split Bridge



- Vout = -x*Vin/2
- Require dual supplies if x>0

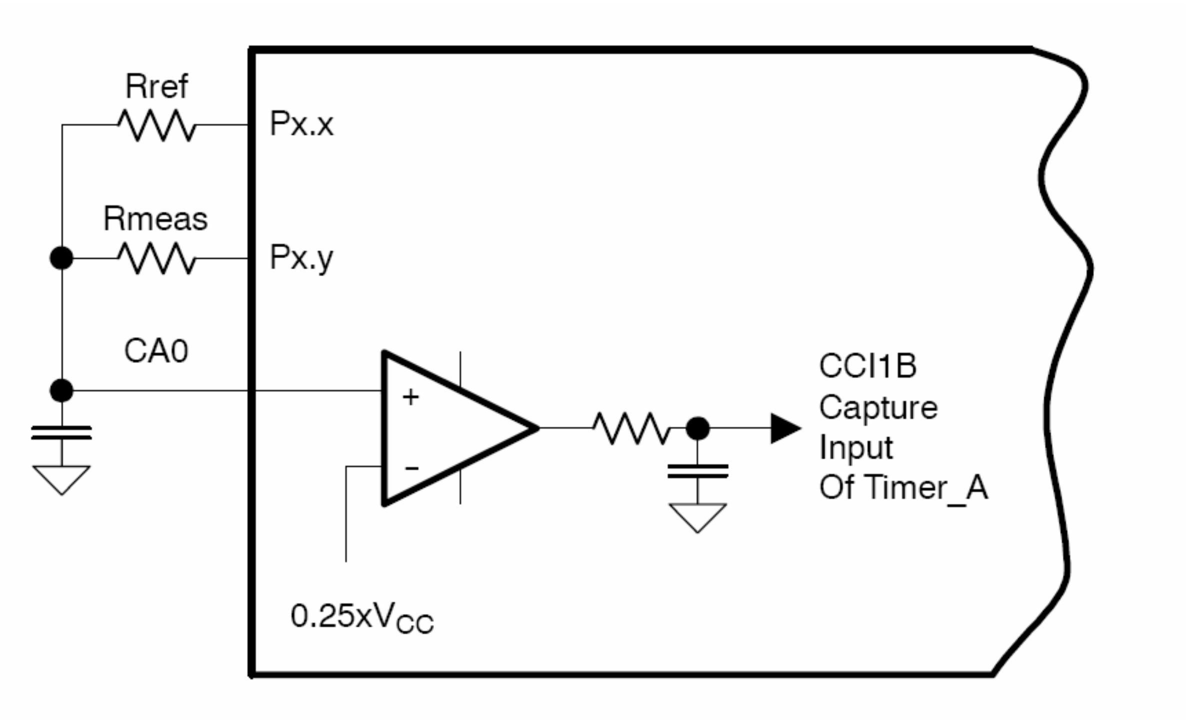
Capacitance (E-field) Sensing

- Cost effective
- Infinite resolution
- Require transient excitation signal

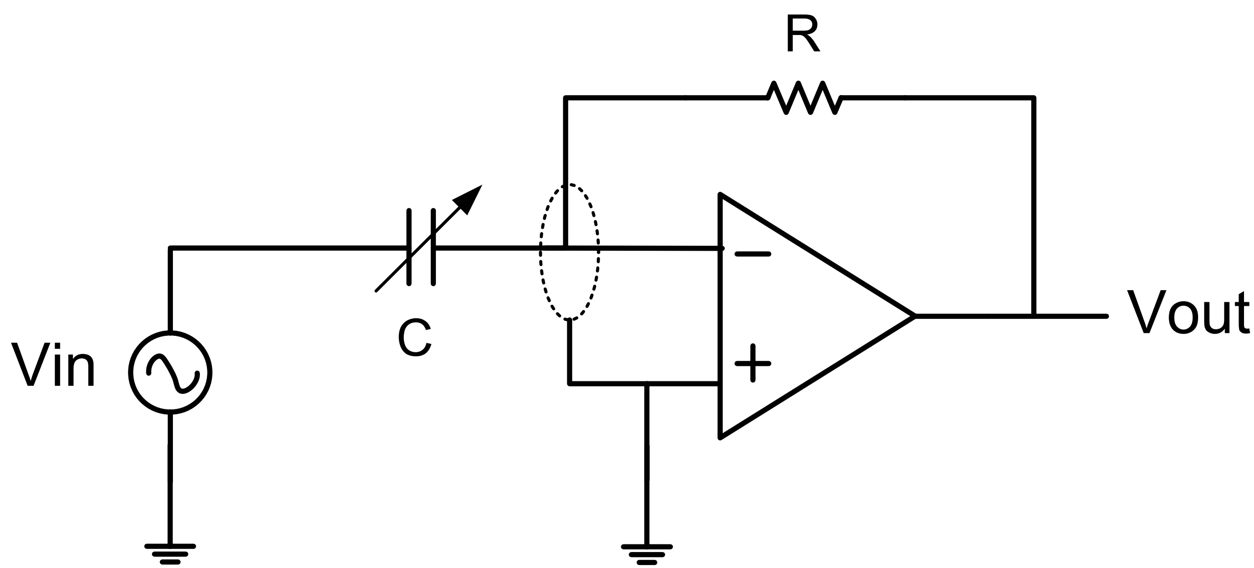


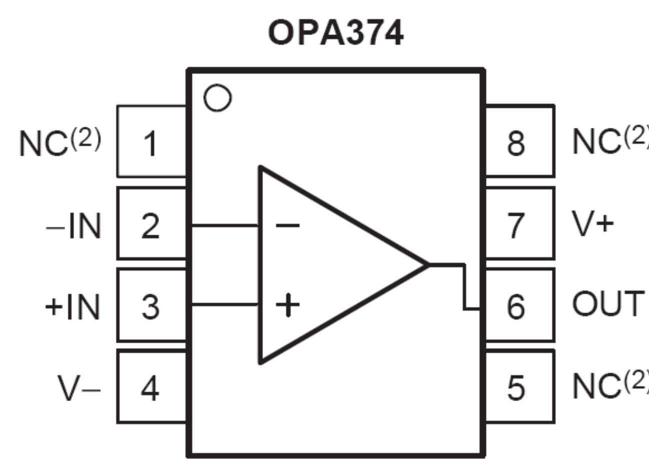
Cap Sensing – The quick and dirty way

- Exchange the resistor and capacitor
- Measure capacitor discharge time

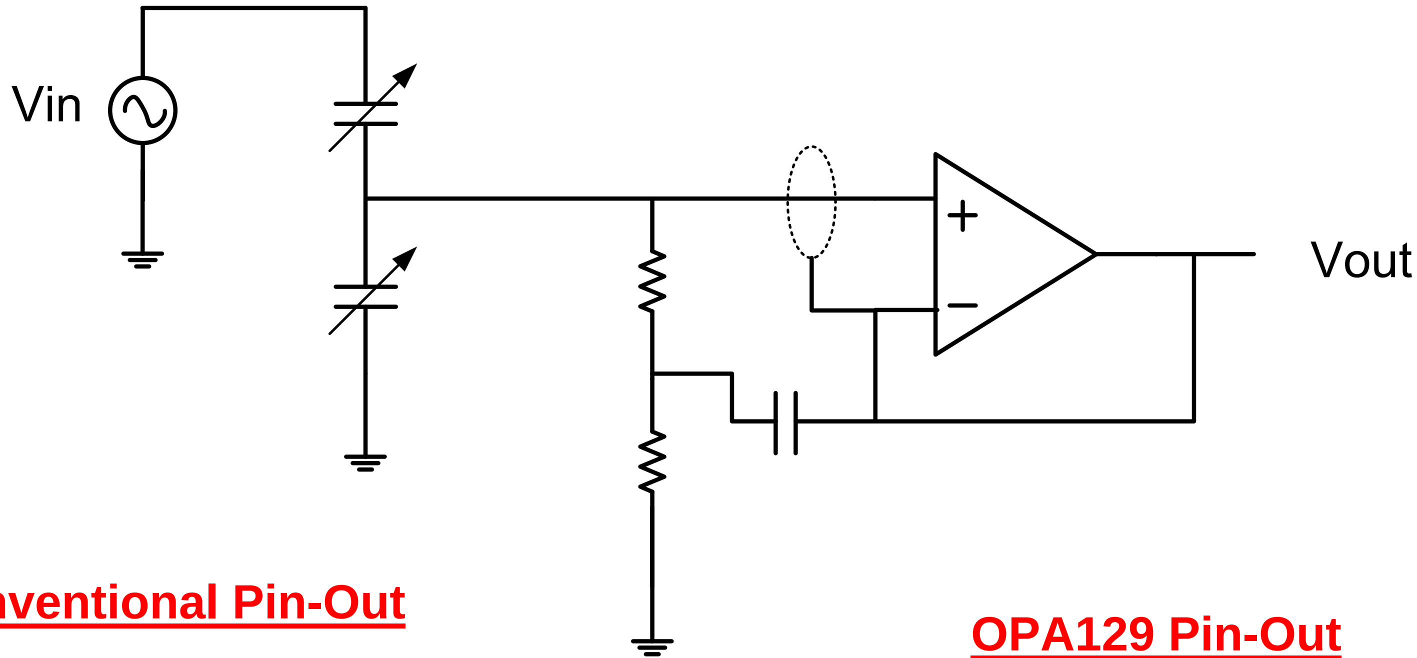


Low-Impedance Method

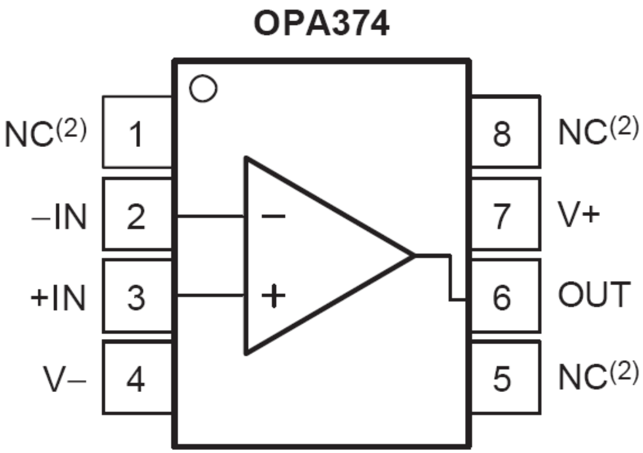




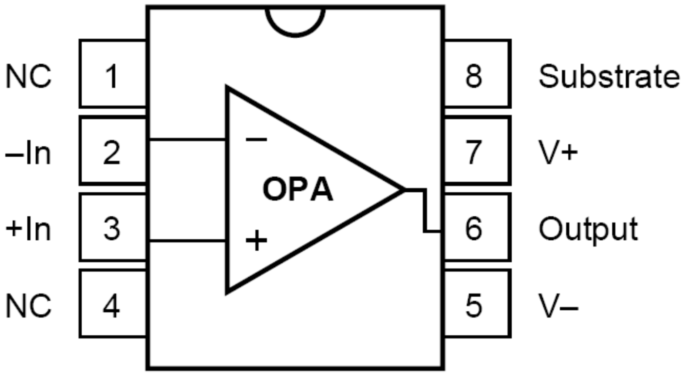
High-Impedance Method



Conventional Pin-Out



OPA129 Pin-Out



Magnetic Field Sensing

- H-field
  - Applied field
  - Units (CGS): Oe (Oersted)
  - Units (SI): Ampere Turns / Meter
- B-field
  - Applied + induced field
  - $B = \mu(H + M)$
  - Units (CGS): Gauss
  - Units (SI): Tesla (1 Tesla = 10^4 Gauss)
- In air (in CGS units): 1 Oe = 1 Gauss
- Earth’s magnetic field: 0.3 – 0.6 Gauss
- Sensitivities:
  - Hall-effect: >50 Oe
  - GMR: 0.1 to 0.5 Oe

Hall-effect Sensors

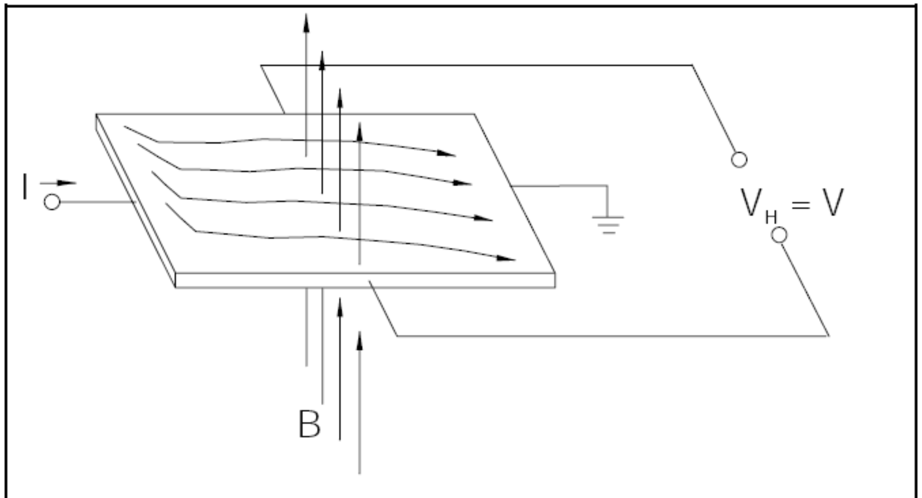
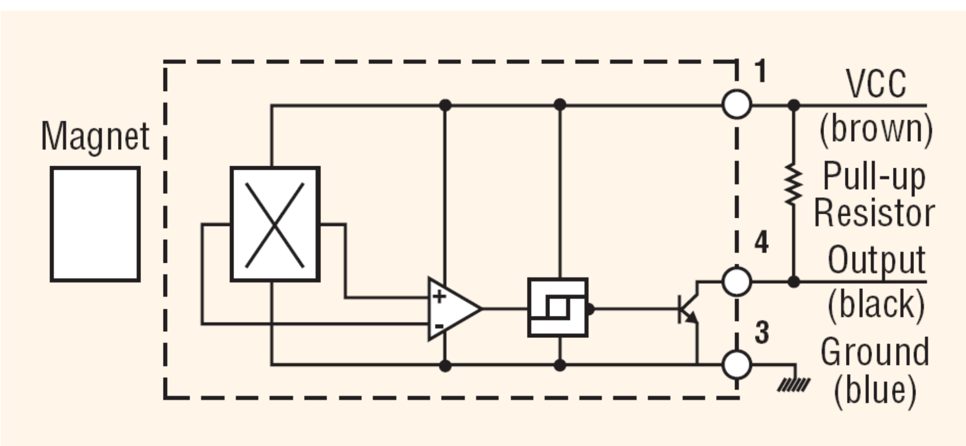


Figure 2-2 Hall effect principle, magnetic field present



- Ubiquitous
- Low cost
- Non-contact
- Line-of-sight not required
- Poor accuracy
  - >50 Oe magnetic field required
- Generally used in switch mode

Applications of Magnetic Sensors

Figure 5A

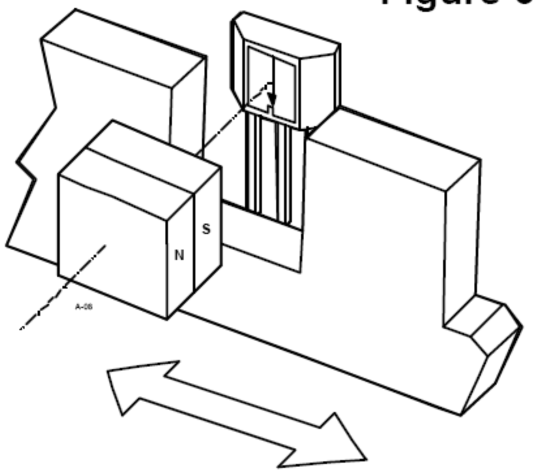
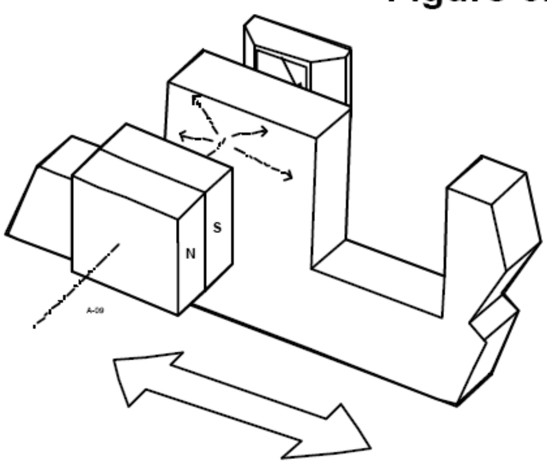
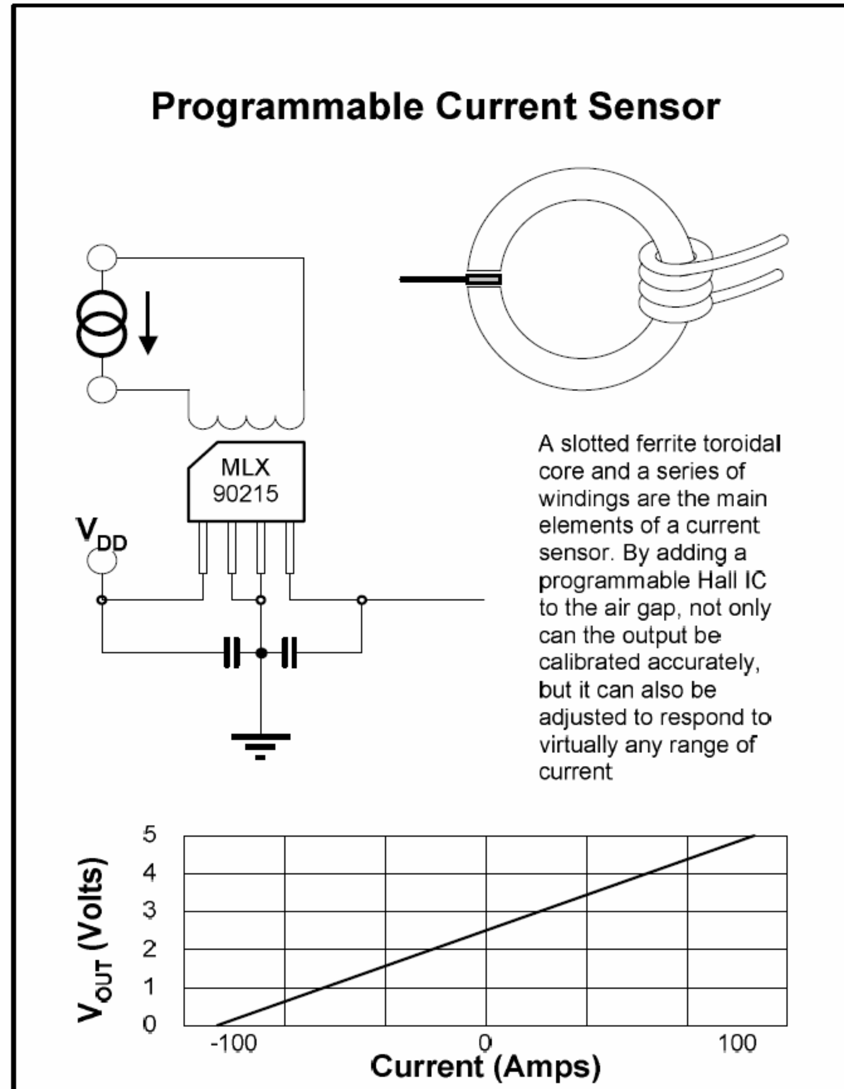


Figure 5B





Giant Magnetoresistance (GMR)

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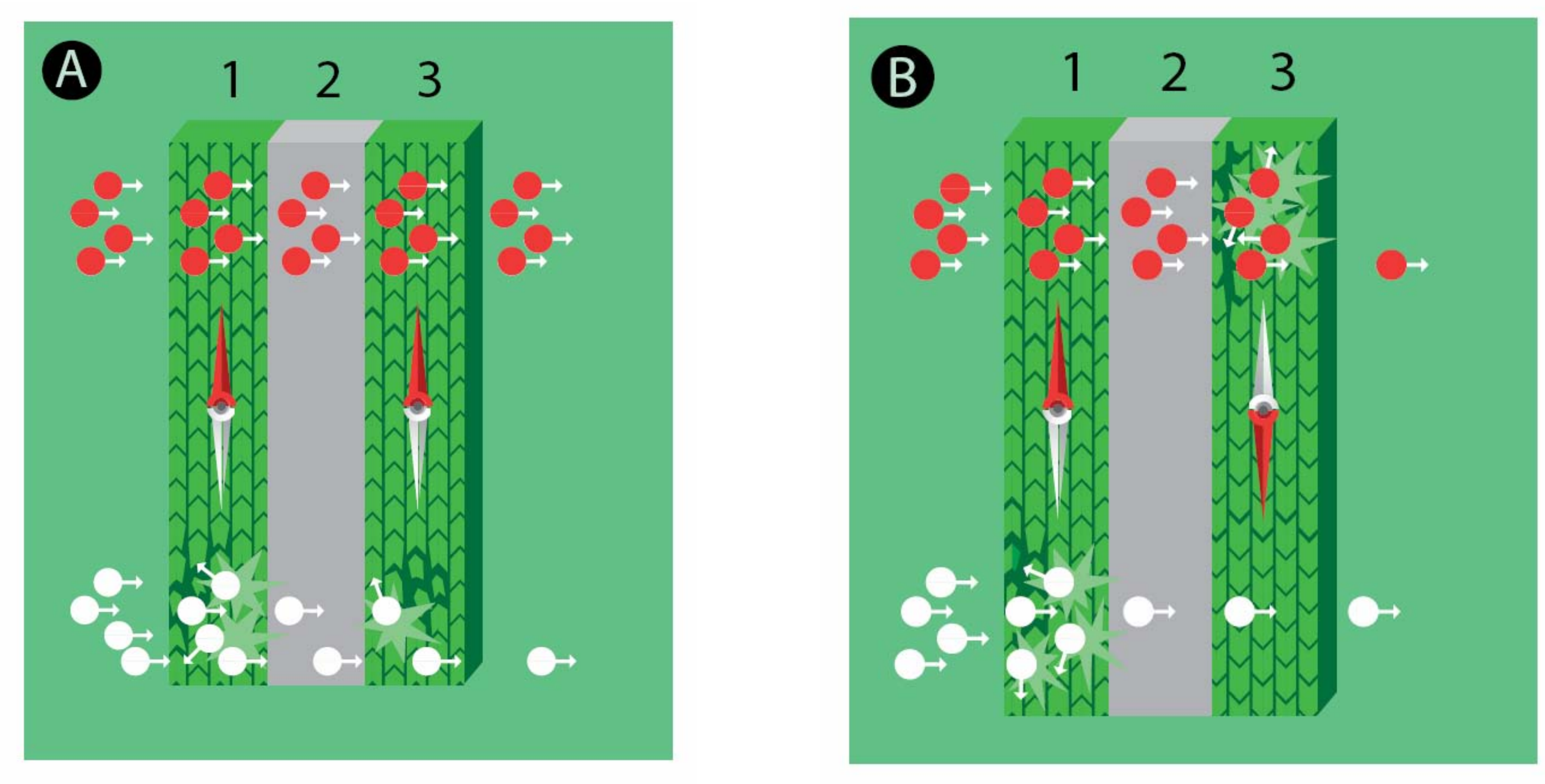
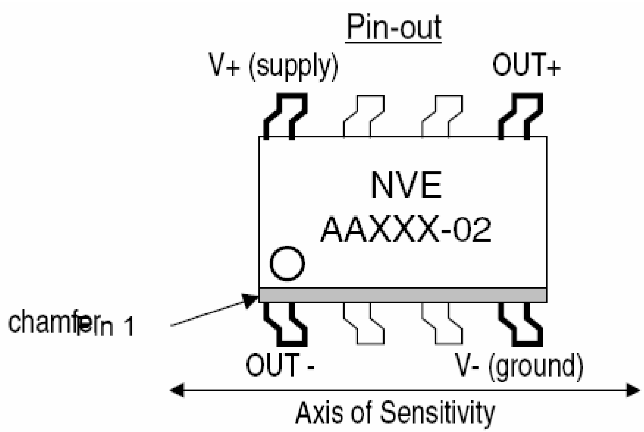
- Nobel Prize in Physics 2007
- Discovered in 1988, brought to market in 1997
- Albert Fert (France) and Peter Grünberg (Germany)

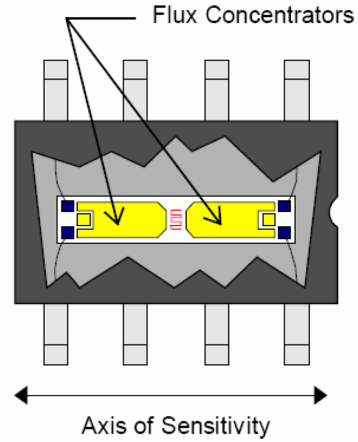
Spin-Dependent Conduction

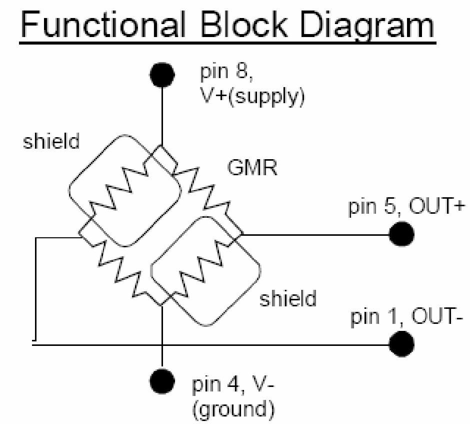


- ~5nm layers
- Section 2 could be a conductor or insulator
- Practically 8 - 12% conductivity change

GMR Sensors from NVE







Magnetic Characteristics:

Part Number	Saturation Field (Oe[1])	Linear Range (|Oe[1]|)		Sensitivity (mV/V-Oe[1])		Resistance (Ohms)	Package[2]	Die Size[3] (µm)
		Min	Max	Min	Max			
AA002-02	15	1.5	10.5	3.0	4.2	5K ±20%	SOIC8	436x3370
AA003-02	20	2.0	14	2	3.2	5K ±20%	SOIC8	436x3370
AA004-00	50	5	35	0.9	1.3	5K ±20%	MSOP8	411x1458
AA004-02	50	5	35	0.9	1.3	5K ±20%	SOIC8	411x1458
AA005-02	100	10	70	0.45	0.65	5K ±20%	SOIC8	411x1458
AA006-00	50	5	35	0.9	1.3	30K ±20%	MSOP8	836x1986
AA006-02	50	5	35	0.9	1.3	30K ±20%	SOIC8	836x1986

Hysteresis and Biasing

- All magnetic materials exhibit hysteresis behavior