MŰEGYETEM 1782

VIMIA347
Embedded and Ambient Systems

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Responsible for the course:
Dr. Dabóczi, Tamás

Course outline

- Subject title: Embedded and ambient systems
- Course ID: VIMIA347
- Schedule: according to the Neptun system
- Lecturer: Krébesz, Tamás
- Course responsible: dr. Dabóczi, Tamás

Method of assessment

- In the teaching period:
  - midterm exam: can be repeated once in teaching period, and one more in the repeat period according to Code of Studies and Exams
  - Assignment: late submission until the of repeat period according to Code of Studies and Exams
- Written exams in the exam period

Embedded systems

- Definition: Embedded systems are those computer based systems
  - Whose operation is automatic (no interaction)
  - Who are in intensive information based connection with their physical/technological environment
- Examples: washing machine, mobile, GPS, telefax, aeroplane, ABS, etc.

- What is the difference between embedded systems and uC based systems?
  - Traditional uP-based systems were embedded systems but today there is a difference in
    - Technology
    - System engineering
    - Design
    - Implementation methods
  - Chip size decreased, complexity increased
  - Developments and new methods in digital signal processing and software engineering

Revolution of sensors

- An embedded system is in intensive connection with its physical environment by using sensors and actuators
- Sensors became compact
  - Signal conditioning
  - Calibration
  - Correction are integrated
- A part of signal conditioning is done by the sensor

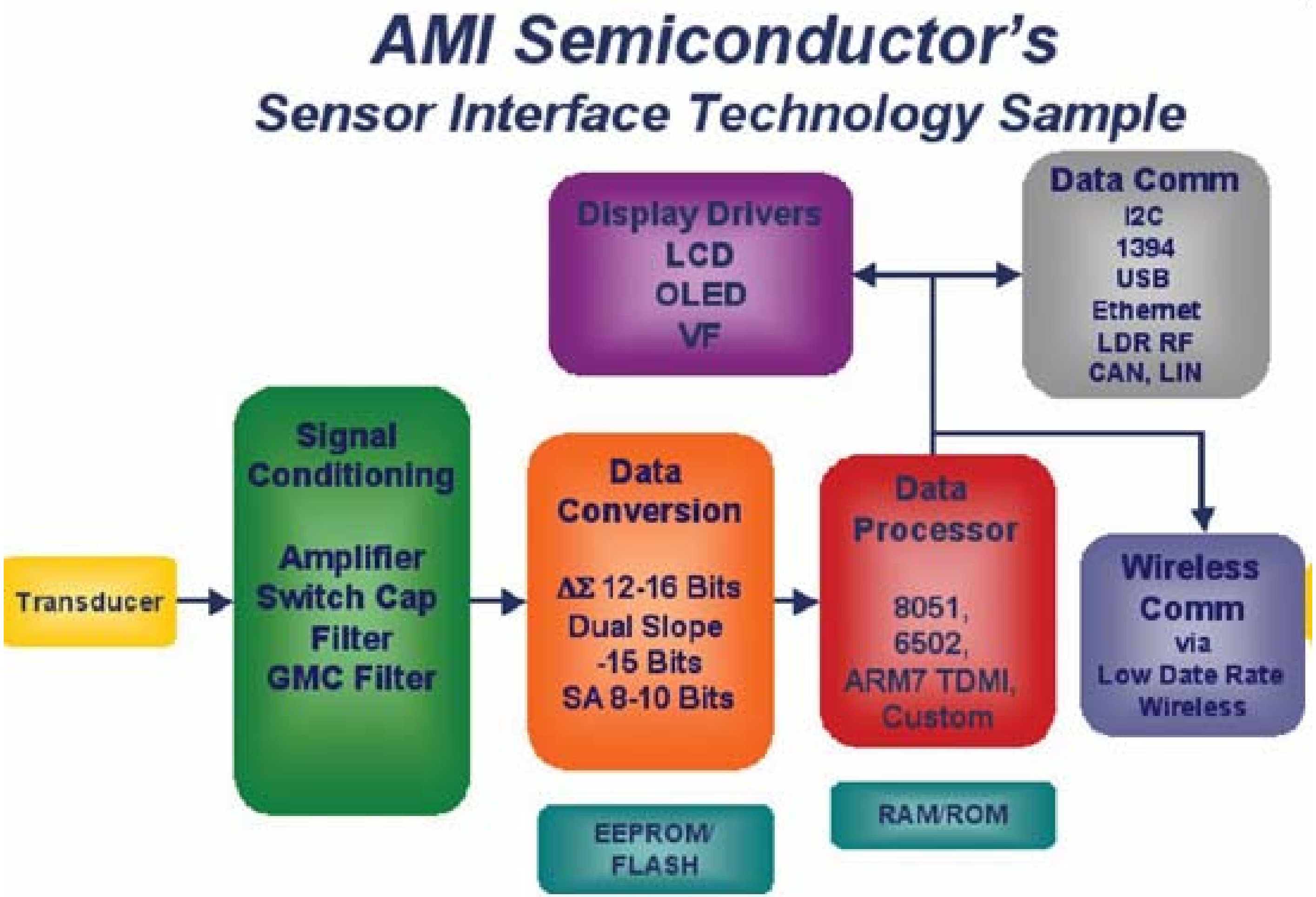
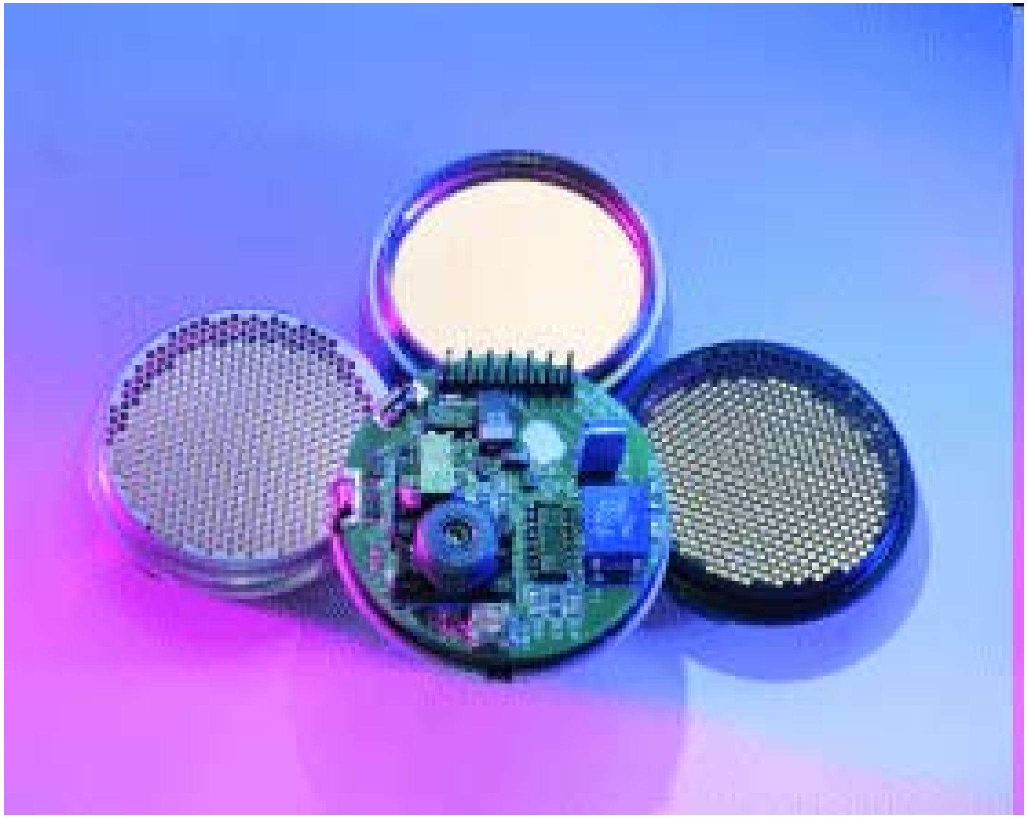


FIGURE 1 AN EXAMPLE OF SOME OF THE ELEMENTS THAT CAN BE INTEGRATED INTO A 'SMART' SENSOR INTERFACE ASIC

- Integrated smart sensor: sensor+amplifier+A/D+uC+satndardized digital output

Electrostatic Ultrasonic Transducer:



Datasheet of transducer: (SensComp Inc.)

Series MINI-A Instrument Grade, Environmental Grade, and Open Face Specifications

Distance Ranges:
0.025 - 0.3 M.........0.15 - 6.10 M ....0.3 -12.2 M
(1.0 - 12 inches)......(0.5 -20 feet)....... (1.0 - 40 feet)

Accuracy (over entire range) .... ± 0.1%
(0.025-0.3 M range = ± 1.0%)

Beam Pattern .... See Graph (Typically 15° nominal)

Repetition Rate (astable)........................ 10 Hz
May be externally triggered up to a 50 Hz rate

Output Voltage (Analog)........................ 0 to 5 VDC
(or 0 to 10 VDC)

Output Current (maximum).................... 5 ma

Output Response Time:
Analog output is filtered to the approximate formula:
$V_{OUT} = 0.9\ (V_{new\ value}) + 0.1(V_{past\ avg.\ value})$

Specifications subject to change without notice

Power Requirements ...... 8 to 24 VDC (for 5V output)
12 to 24 VDC (for 10V output)
(Maximum Current = 30 mA)

Operating Temperature .... -40 to +85° C
(-40 to 185° F)

Weight .... 17 grams (0.6 oz)

Dimensions
Thickness .... 0.950 inch
Diameter.. 1.700 inch

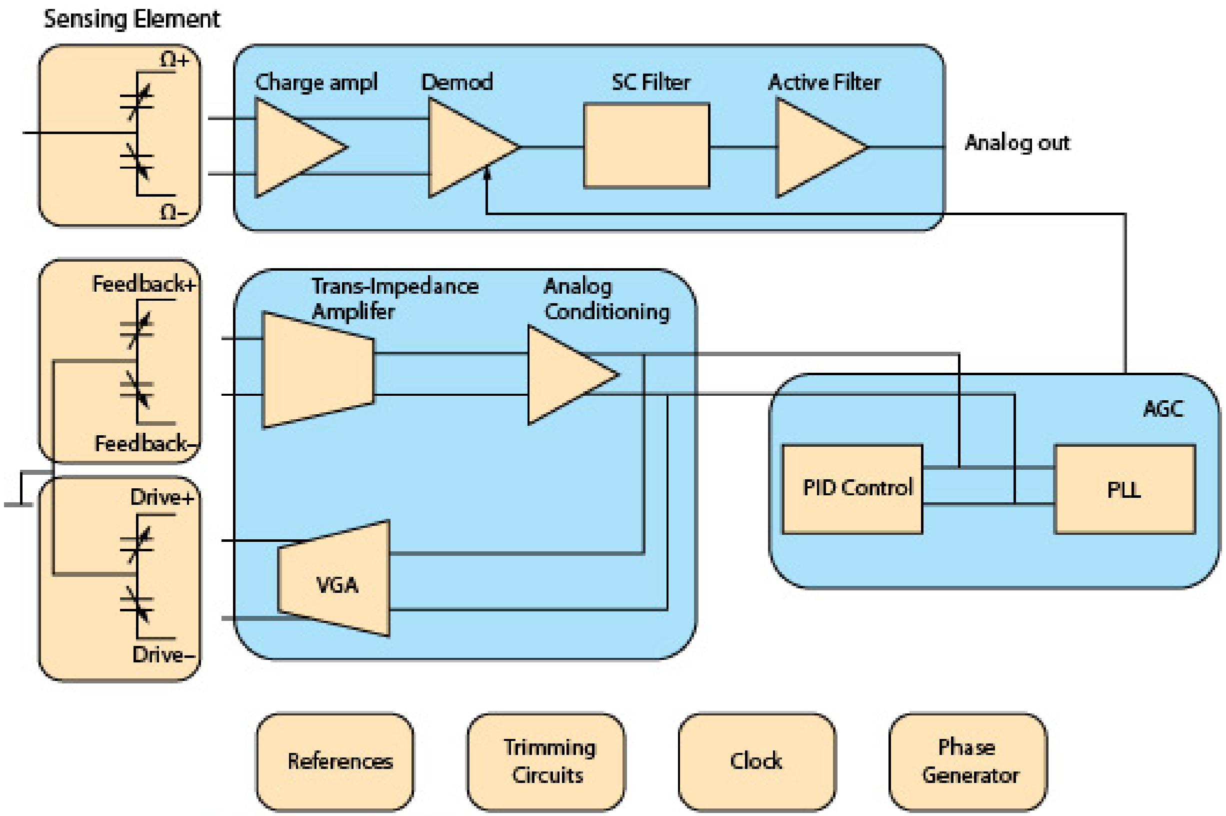
Mounting Diameter................................ 1.525 inch
Use RTV silicone or edge clips to secure in place

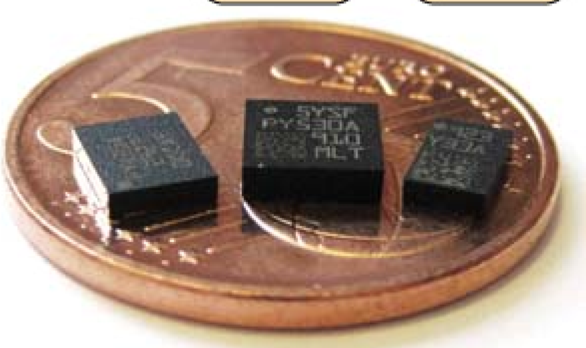
Housing, Standard Finish
Instrument Grade .... Flat Black Cold Rolled Steel
Environmental Grade...... 304 Stainless Steel
Open Face........................ Parylene Coated 304 Stainless Steel

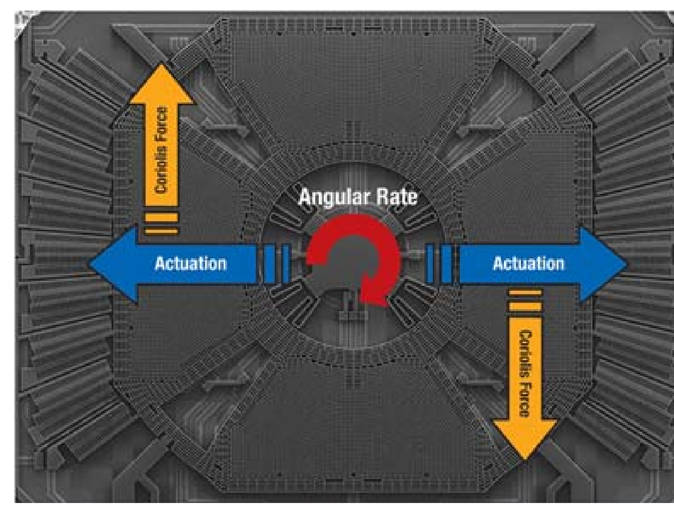
- Evaluation of actuators
  - Appearance of micro-electromechanical systmes (MEMS)
  - Integration of MEMS and semivonductor technology
    - Actuator implemented on a Si wafer
    - Micromachined integration
    - Examples:
      - relay on Si wafer
      - digital micromirror device

SENSOR SoC-MEMS

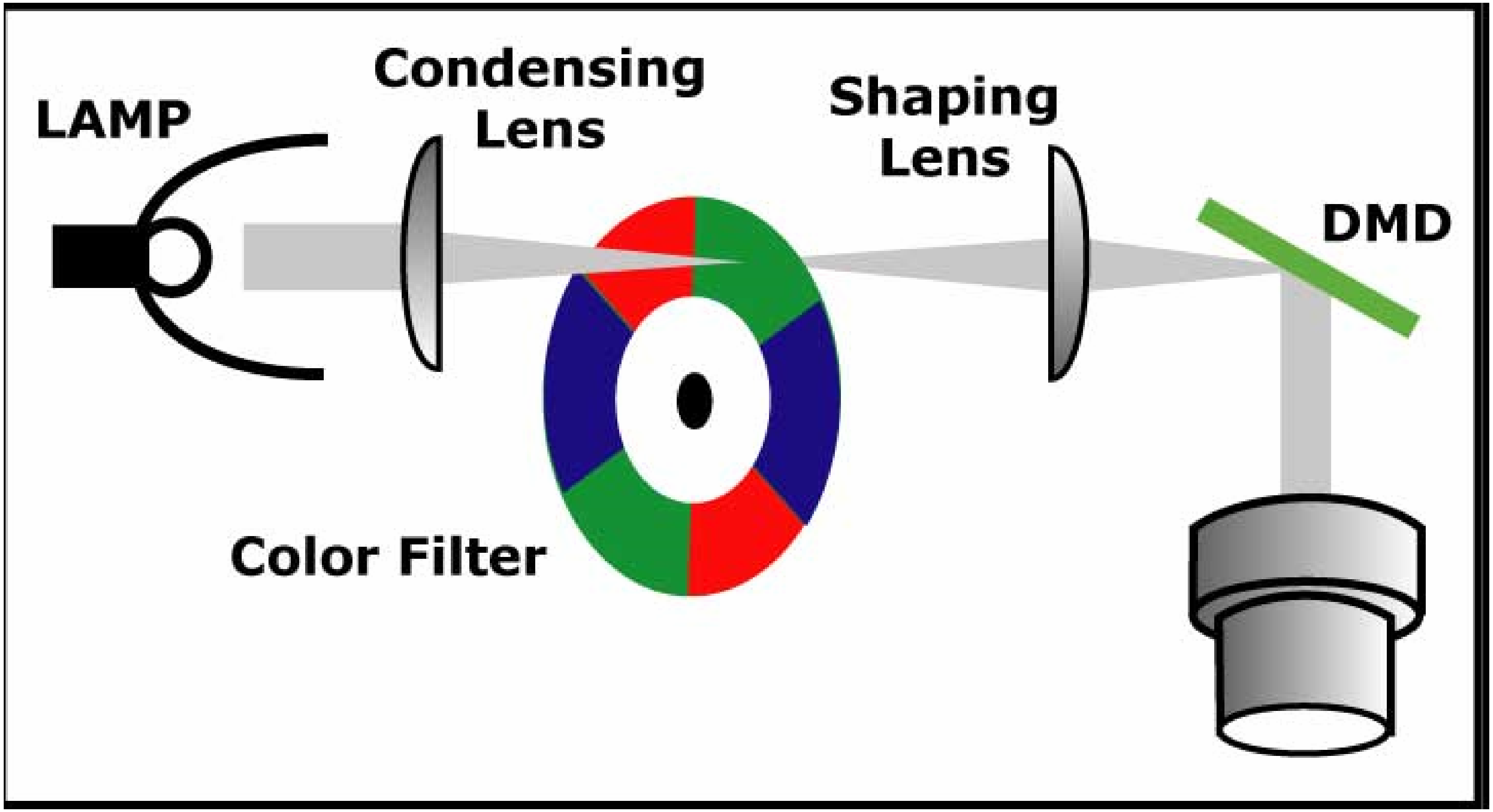
Multi-axis gyroscopes

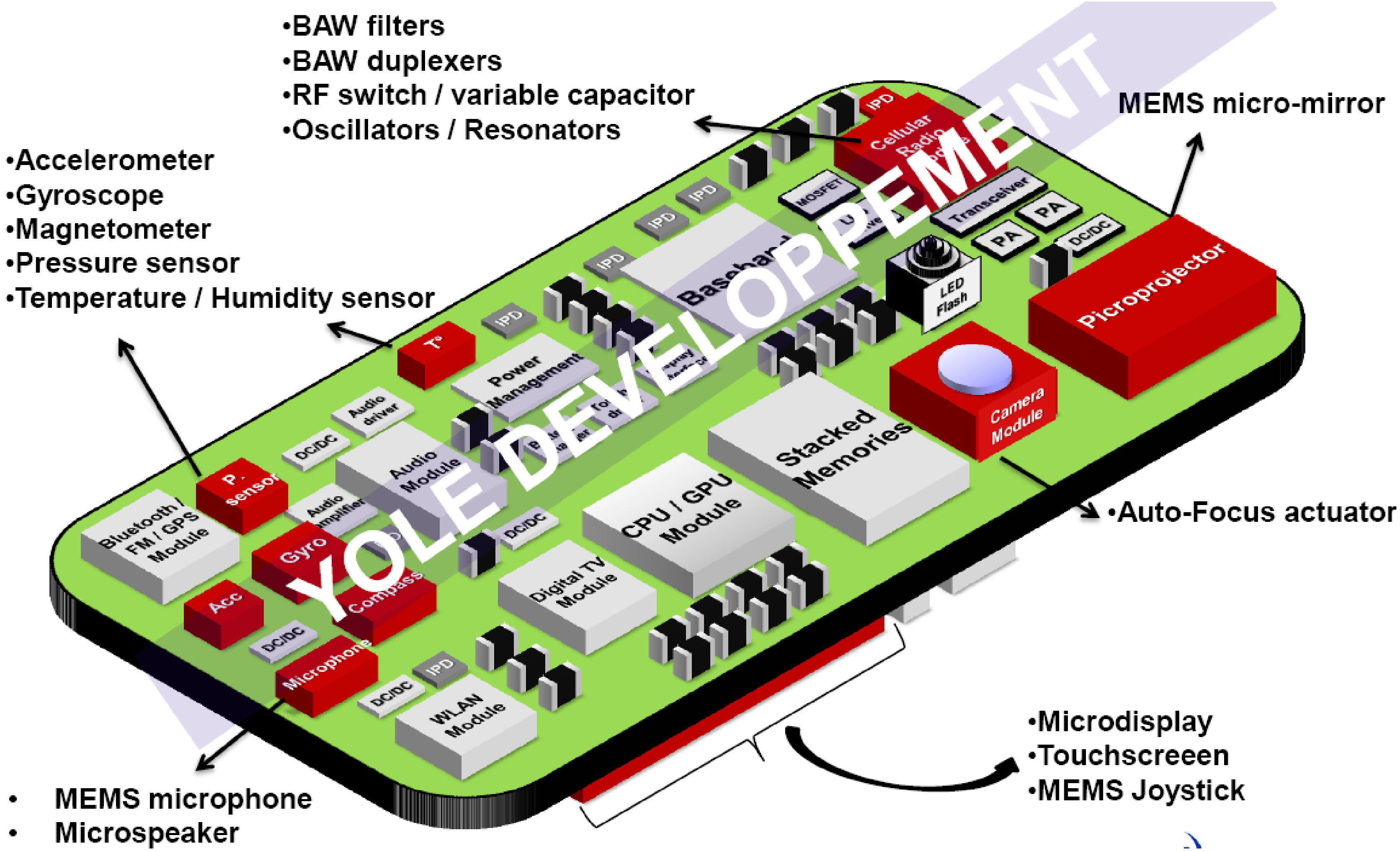




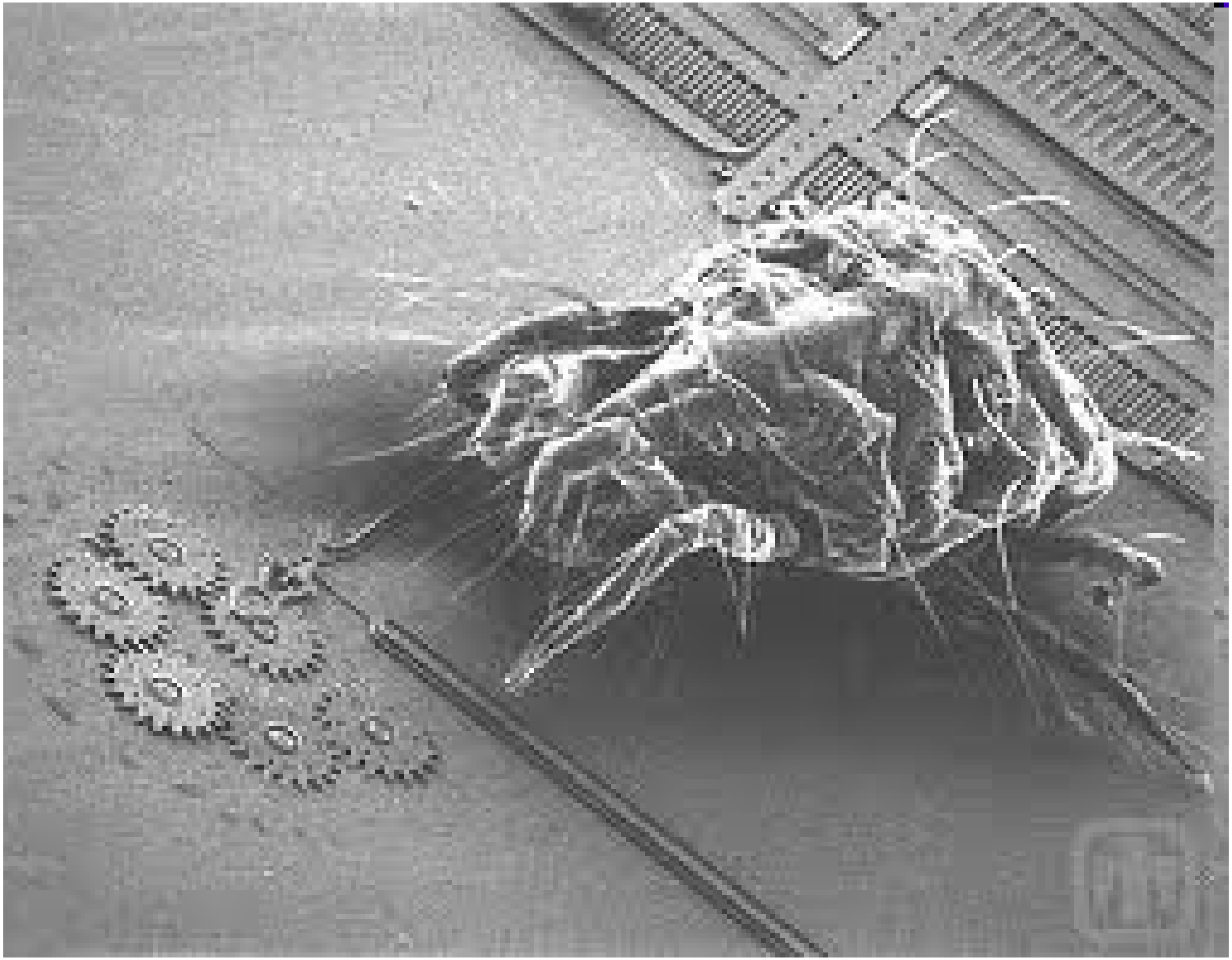


Digital Light Processing – Projector in your smart phone





Source: Yole Développement www.yole.fr

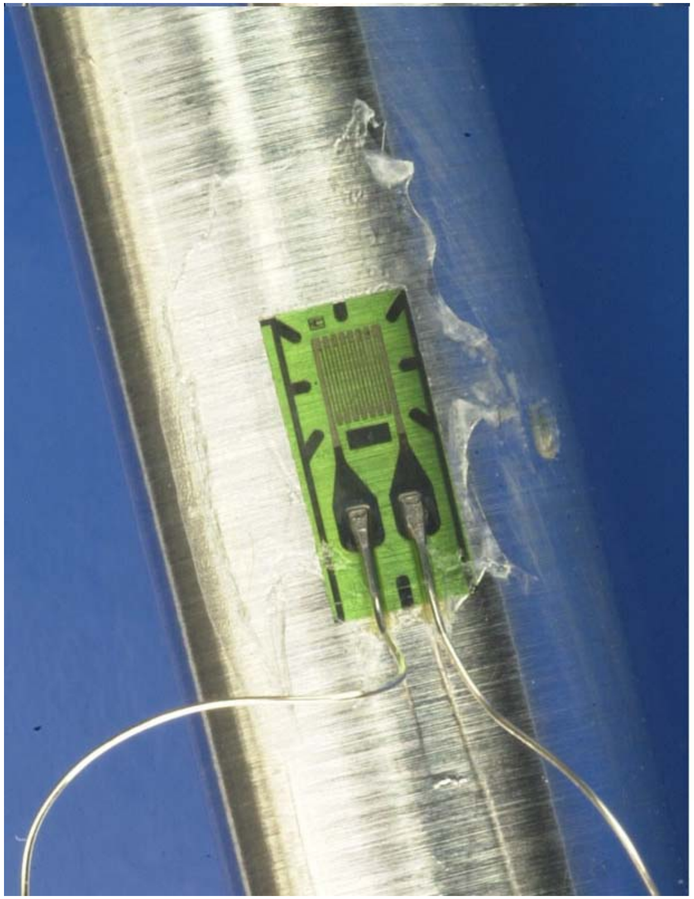


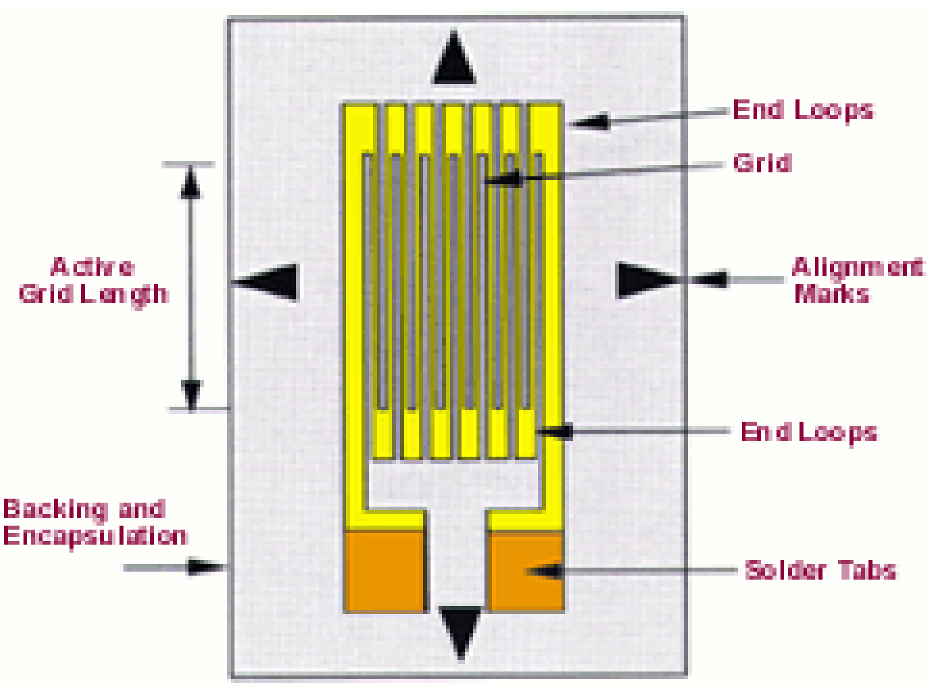
Sensors

- Difference between sensor and transducer
  - Transducer: a kind of energy is converted into an other kind of energy
  - Sensor: a kind of energy is converted into electrical signal
  - (actuator: accepts energy and produces movement)

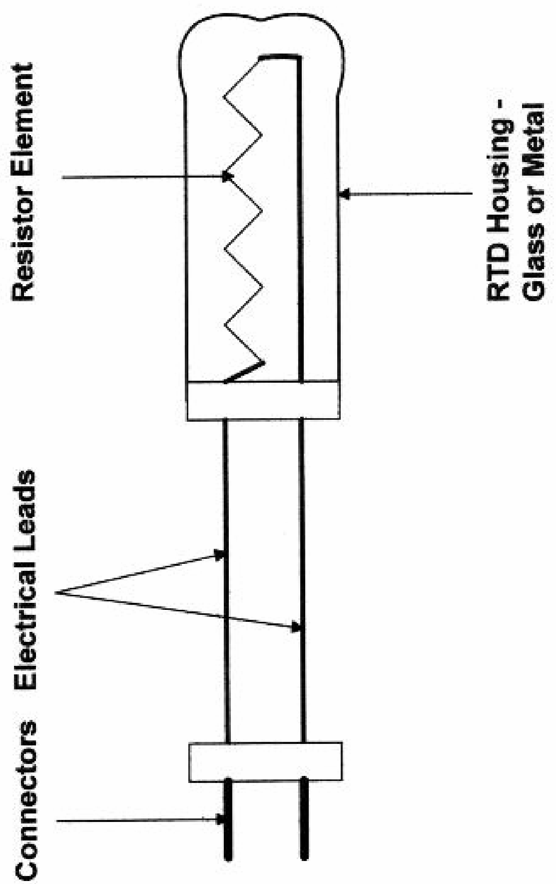
Strain gauge

- Sensors can be either active or passive
  - Active: external exitation is required
    - Strain gauge:





- Resistance temperature detector



- Thermistor

- The sensors are part of a system:
  - sensor
  - signal conditioning (amplification, level and impedance matchingm galvanic separation)
  - analog signal processing (linearization, noise or disturbance filtering)
  - AD conversion
  - digital signal processing
  - information conveying
  - action

- Examples for measuring physical characteristics by sensors [1]:

PROPERTY	SENSOR	ACTIVE/ PASSIVE	OUTPUT
Temperature	Thermocouple	Passive	Voltage
	Silicon	Active	Voltage/Current
	RTD	Active	Resistance
	Thermistor	Active	Resistance
Force / Pressure	Strain Gage	Active	Resistance
	Piezoelectric	Passive	Voltage
Acceleration	Accelerometer	Active	Capacitance
Position	LVDT	Active	AC Voltage
Light Intensity	Photodiode	Passive	Current

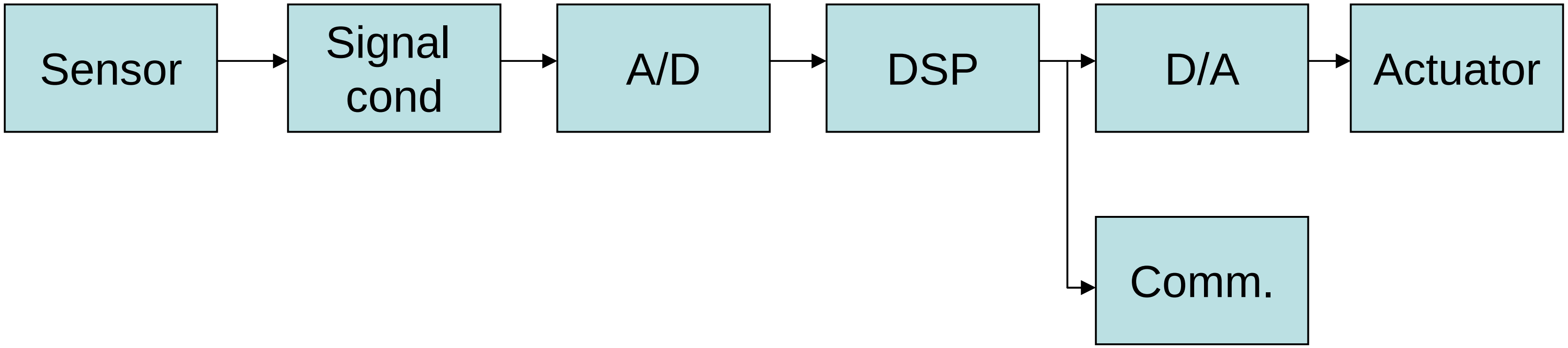
Ambient systems

- Ambient=environmental, surroundings
- Definition: ambient systems are embedded in our everyday environment to assist the activity of people
- Ambient systems continuously communicate with its environment in an autonomous way via a wireless network or channel

- Imprortant branch of ambient systems:
  - Ambient assisted living
    - Patient monitoring at home
      - Blood pressure
      - Blood sugar
      - Movement detection, etc.
    - Sport, fitness
  - Logistics
    - Monitoring of temperature of a product
    - Product localization
  - Intelligent home
    - Light, air-con, remote surveillance, alarm

- Workplace
  - RFID locks

Ambient system can be considered as a special kind of embedded system having the same architecture:

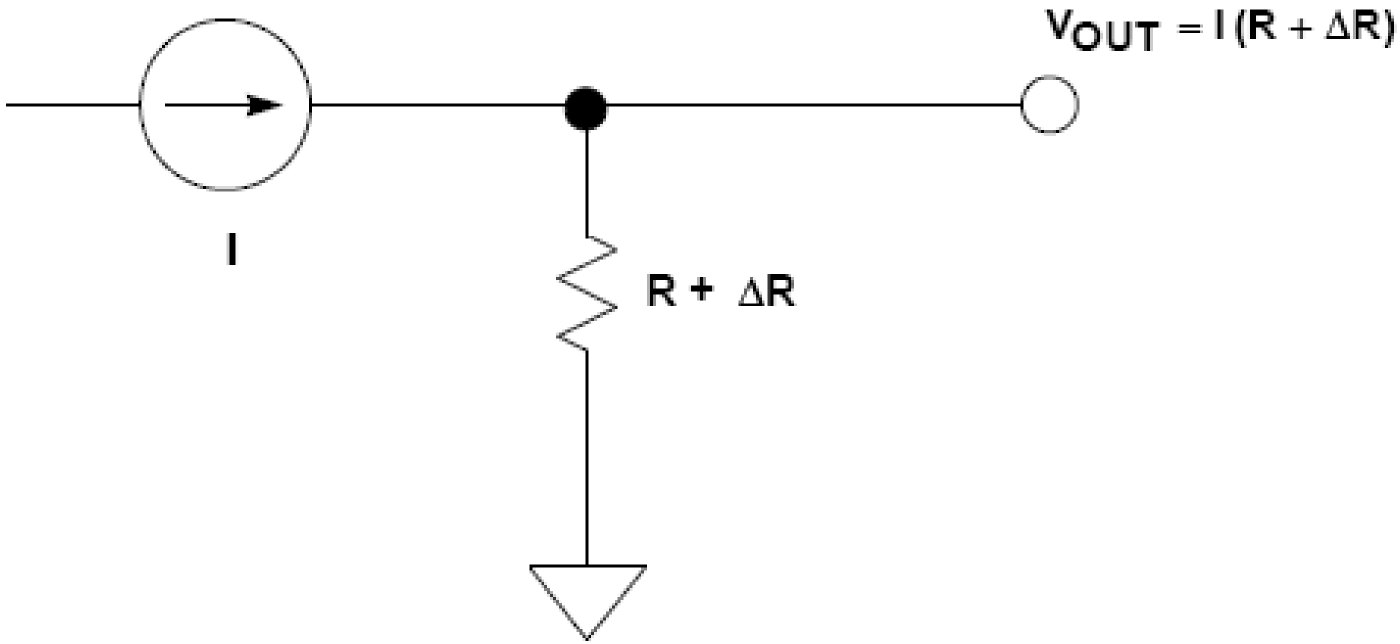


Resistive sensors

- Most common characteristics:
  - Cheap to manufacture
  - Easy to interface to signal conditioning circuits
- Typical ranges:
  - Strain gauge: 120, 350, 3500 Ohm
  - Weigh-scale load cell: 350-3500 Ohm
  - Pressure sensor: 350-3500 Ohm
  - Relative humidity: 100k-10M Ohm
  - RTD: 100-100M Ohm
  - Thermistor: 100-10M Ohm

Measuring resistance

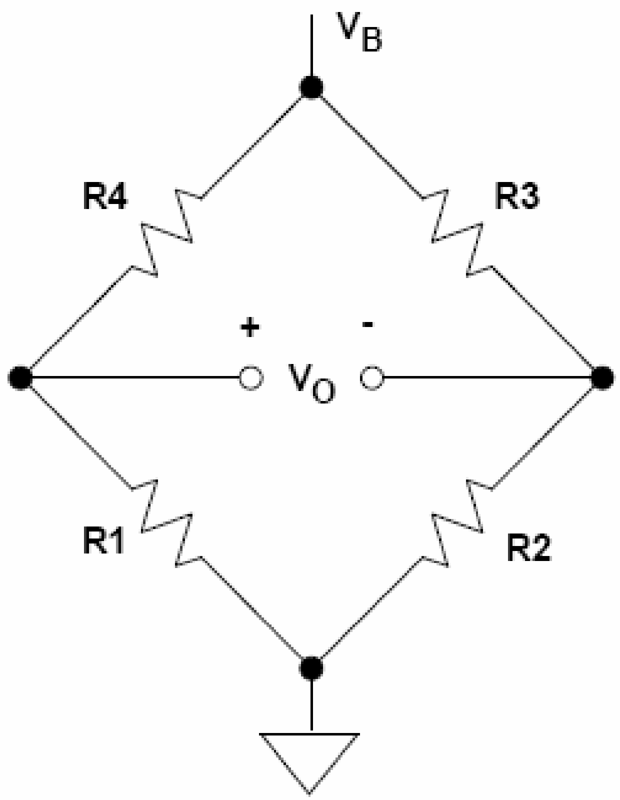
- Indirectly using a constant current source



- Requirements:
  - Accurate current source
  - Accurate voltage measurement
- Trade-off between:
  - High current
    - High output level
    - Produces errors in measurement (heating)
  - Small current
    - Small output level
    - No heating, no error caused

Bridges for measuring resistance

- Wheatstone-bridge



$$V_O = \frac{R1}{R1+R4}V_B - \frac{R2}{R2+R3}V_B$$

$$= \frac{\frac{R1}{R4} - \frac{R2}{R3}}{\left(1+\frac{R1}{R4}\right)\left(1+\frac{R2}{R3}\right)}V_B$$

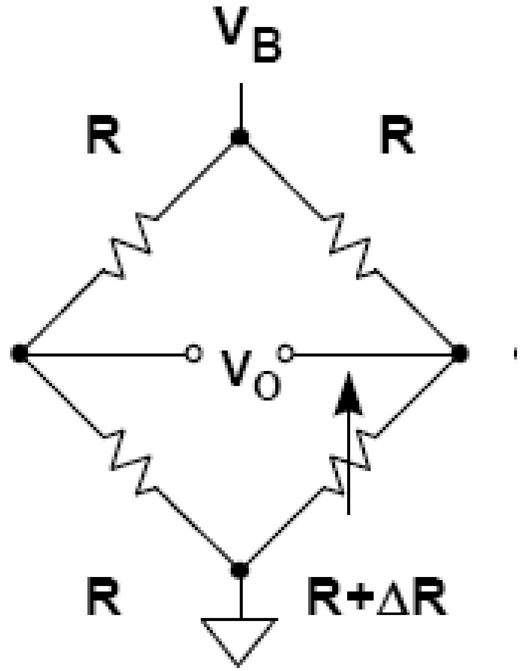
AT BALANCE,

$$V_O = 0 \quad \text{IF} \quad \frac{R1}{R4} = \frac{R2}{R3}$$

- Two ways of operation:
  - Null detector: independent of
    - Type of exitation
    - Magnitude of exitation
    - The mode of readout
    - The impedance of the detector
  - Reads a difference directly as voltage

Output voltage and linearity error

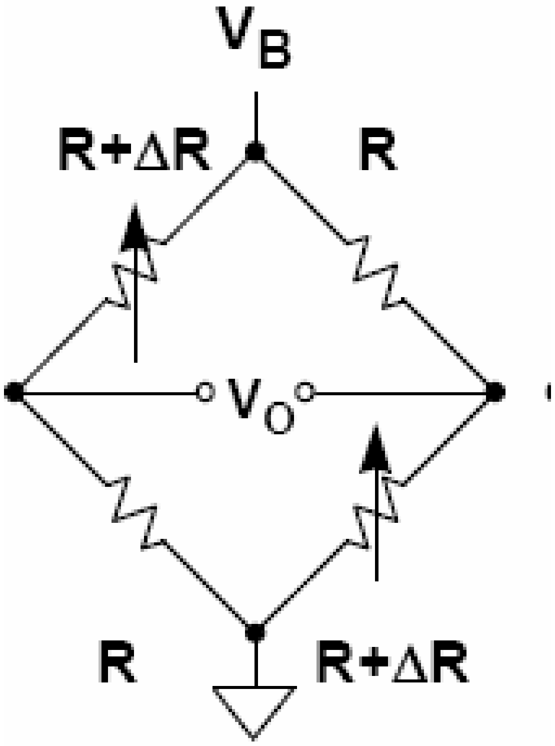
- Single element varying
- Voltage exitation



$$V_O: \quad \frac{V_B}{4}\left[\frac{\Delta R}{R + \frac{\Delta R}{2}}\right]$$

Linearity Error: 0.5%/%

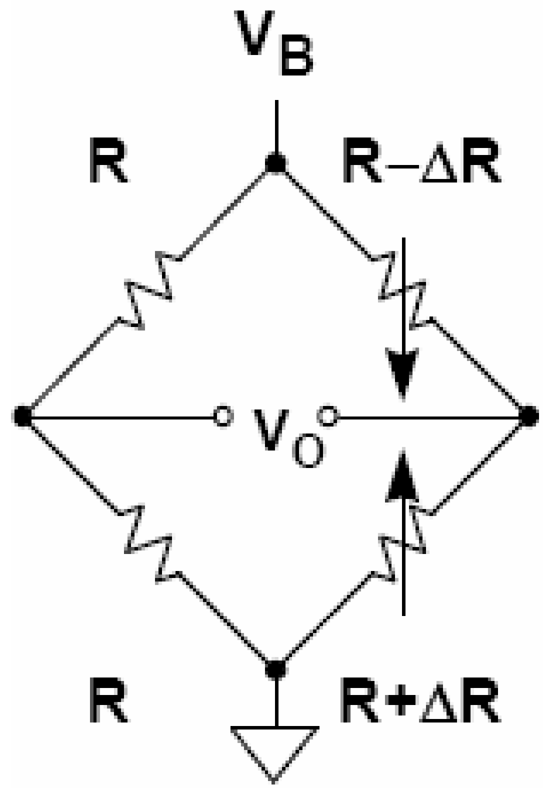
- Two-element varying (a)
- Voltage exitation



$$\frac{V_B}{2}\left[\frac{\Delta R}{R+\frac{\Delta R}{2}}\right]$$

0.5%/%

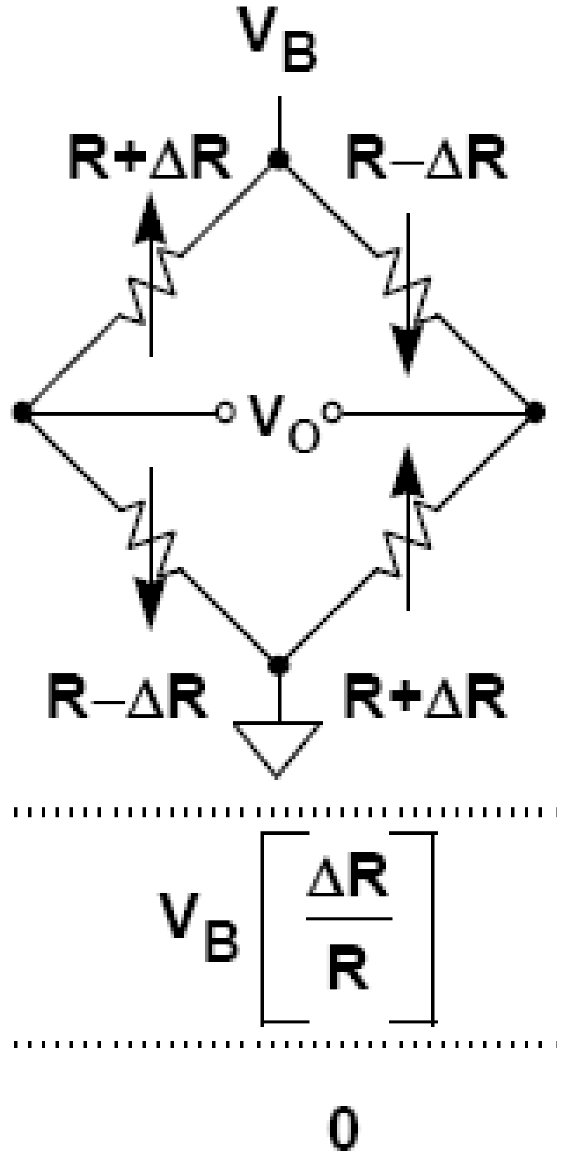
- Two-element varying (b)
- Voltage exitation



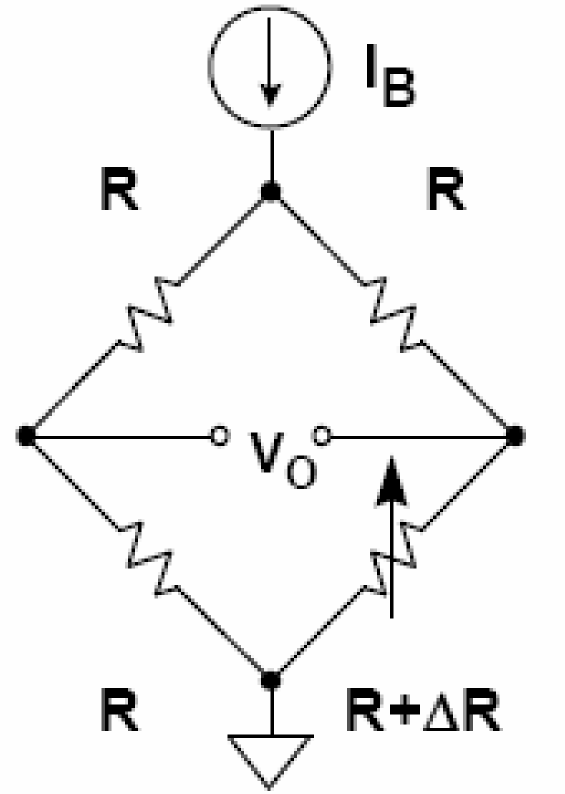
$$\frac{V_B}{2}\left[\frac{\Delta R}{R}\right]$$

0

- All-element varying
- Voltage exitation



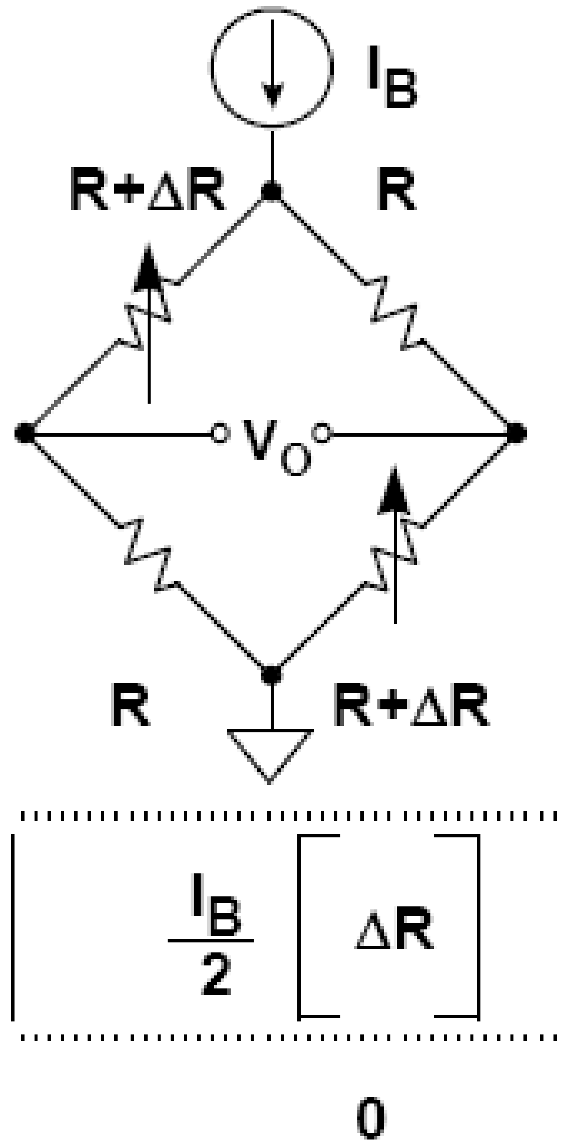
- Single-element varying
- Current exitation



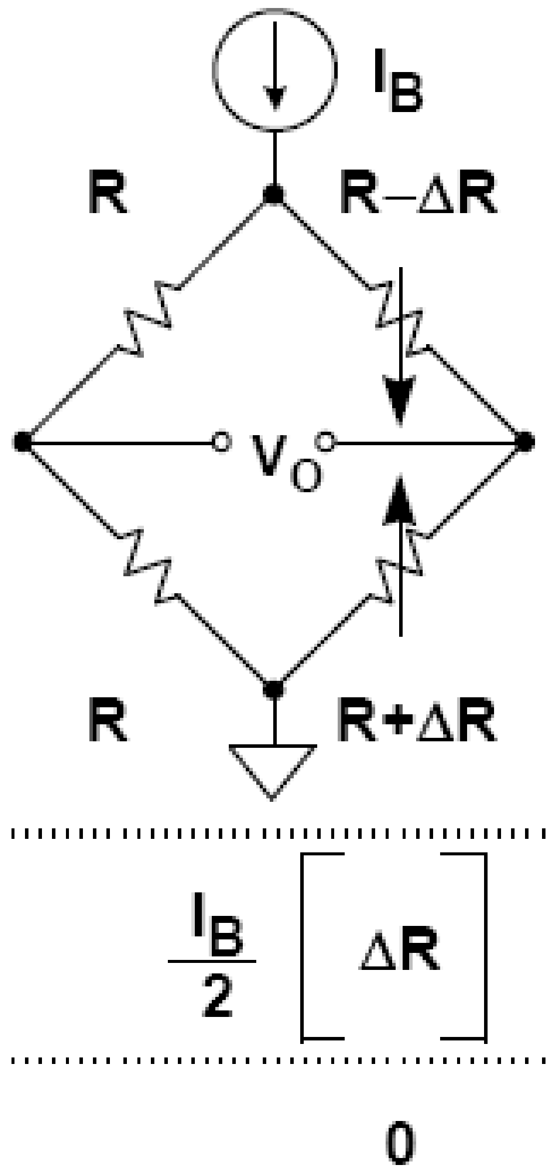
$$V_O: \frac{I_B R}{4}\left[\frac{\Delta R}{R + \frac{\Delta R}{4}}\right]$$

Linearity Error: 0.25%/%

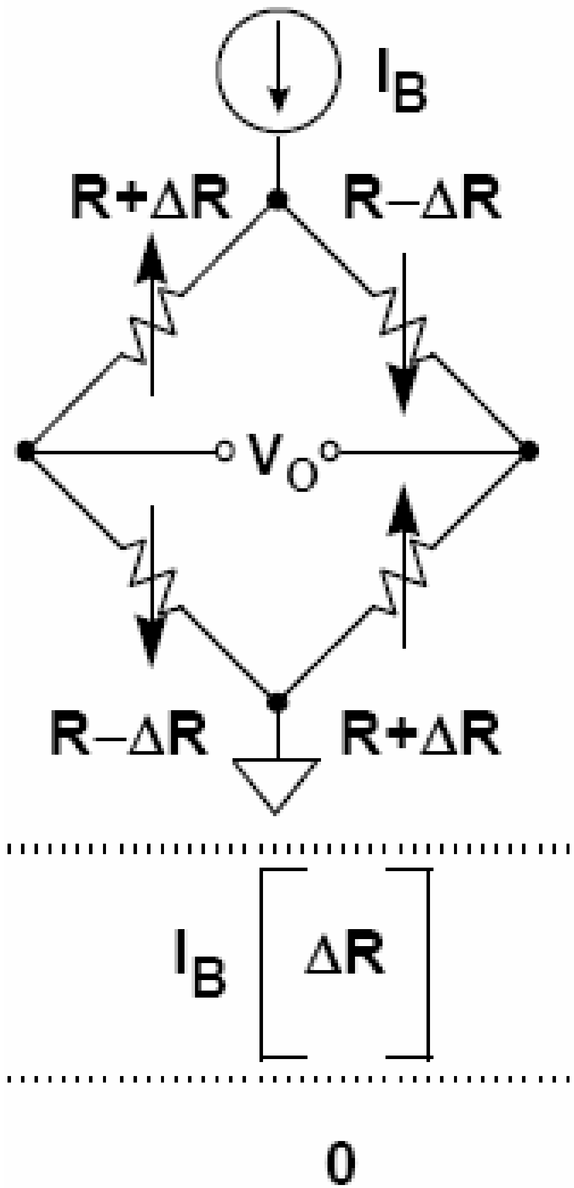
- Two-element varying (a)
- Current exitation



- Two-element varying (b)
- Current exitation

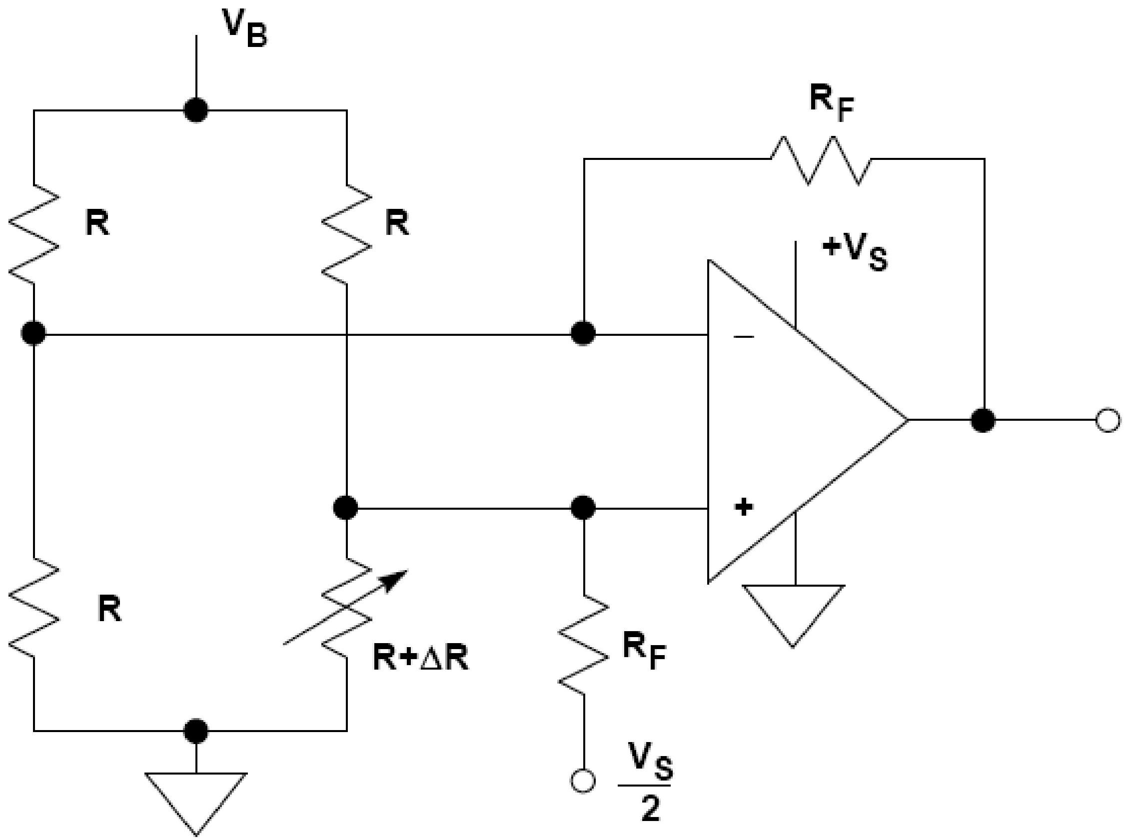


- All-element varying
- Current exitation



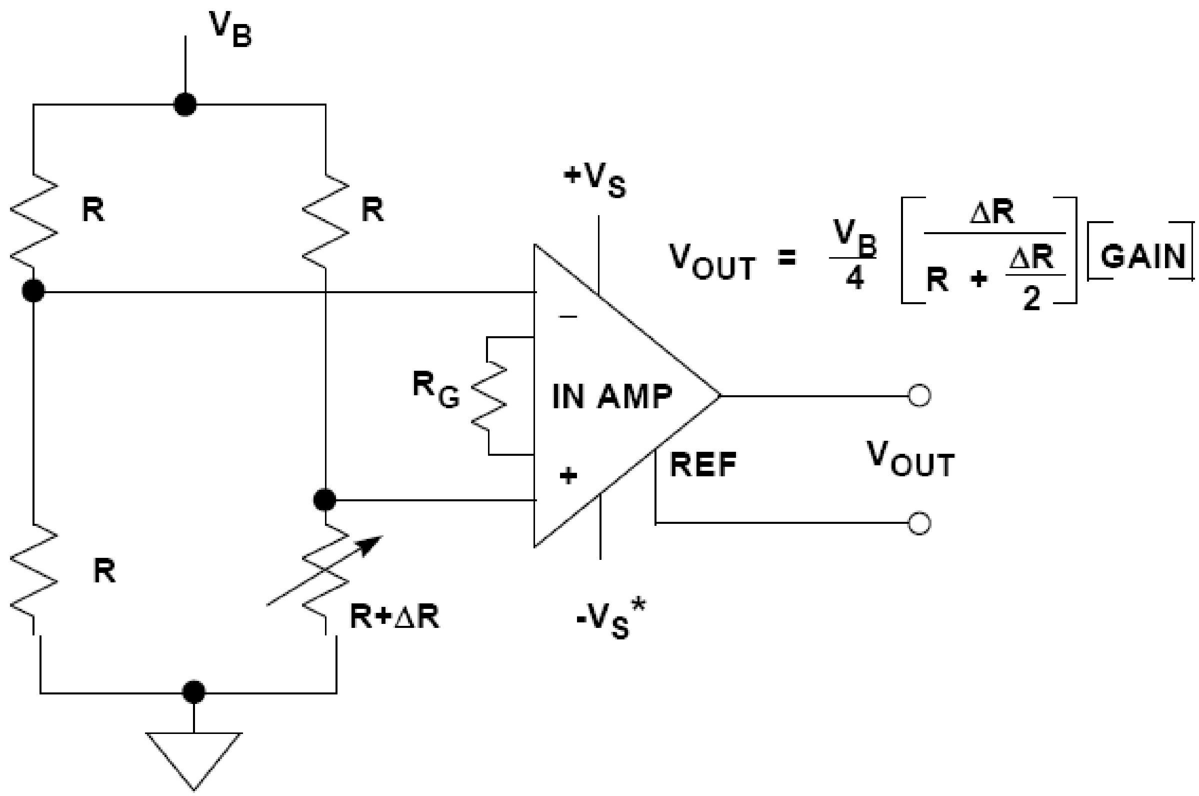
Amplifying and linearising bridge outputs

- Single-element varying bridge+operational amplifier



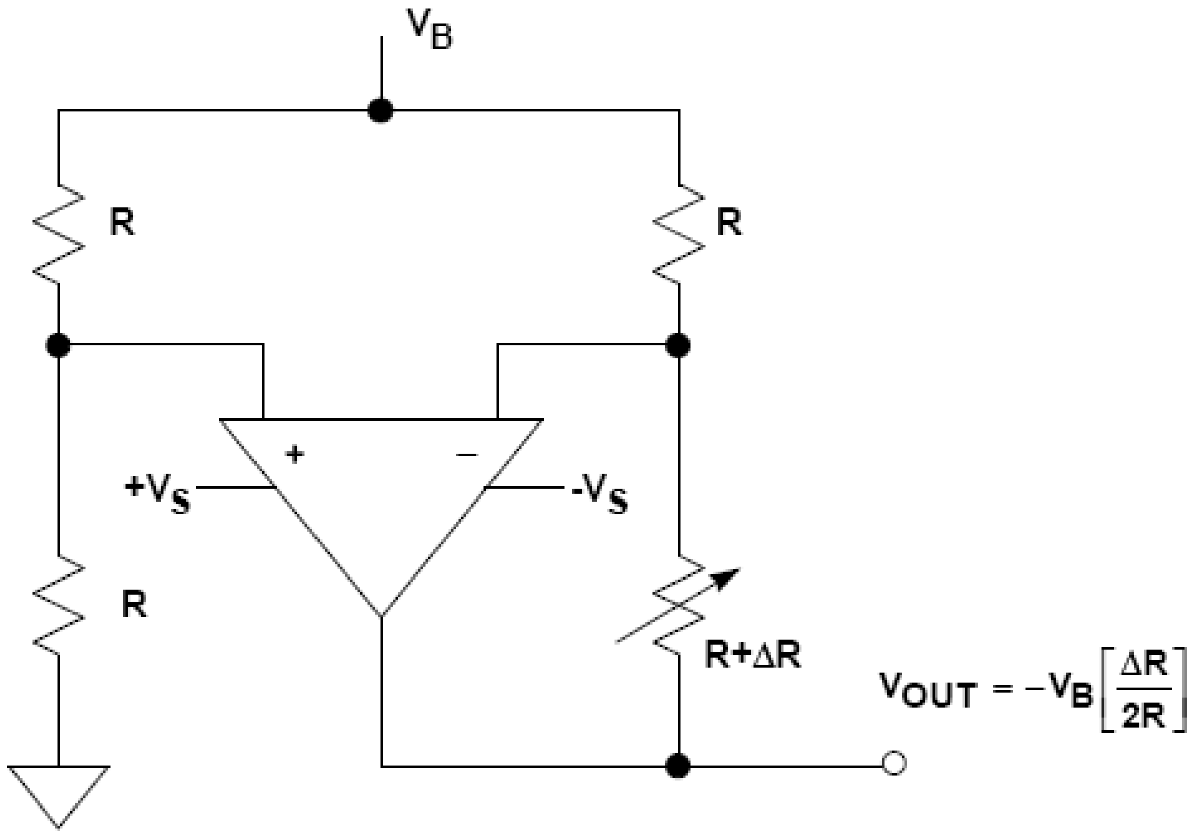
- Cons
  - Unbalances the bridge due to R_F
  - Poor gain accuracy
  - Nonlinear output
  - CMR problems
- Pro
  - Single supply operation

- Single-element varying bridge + instrumentation amplifier



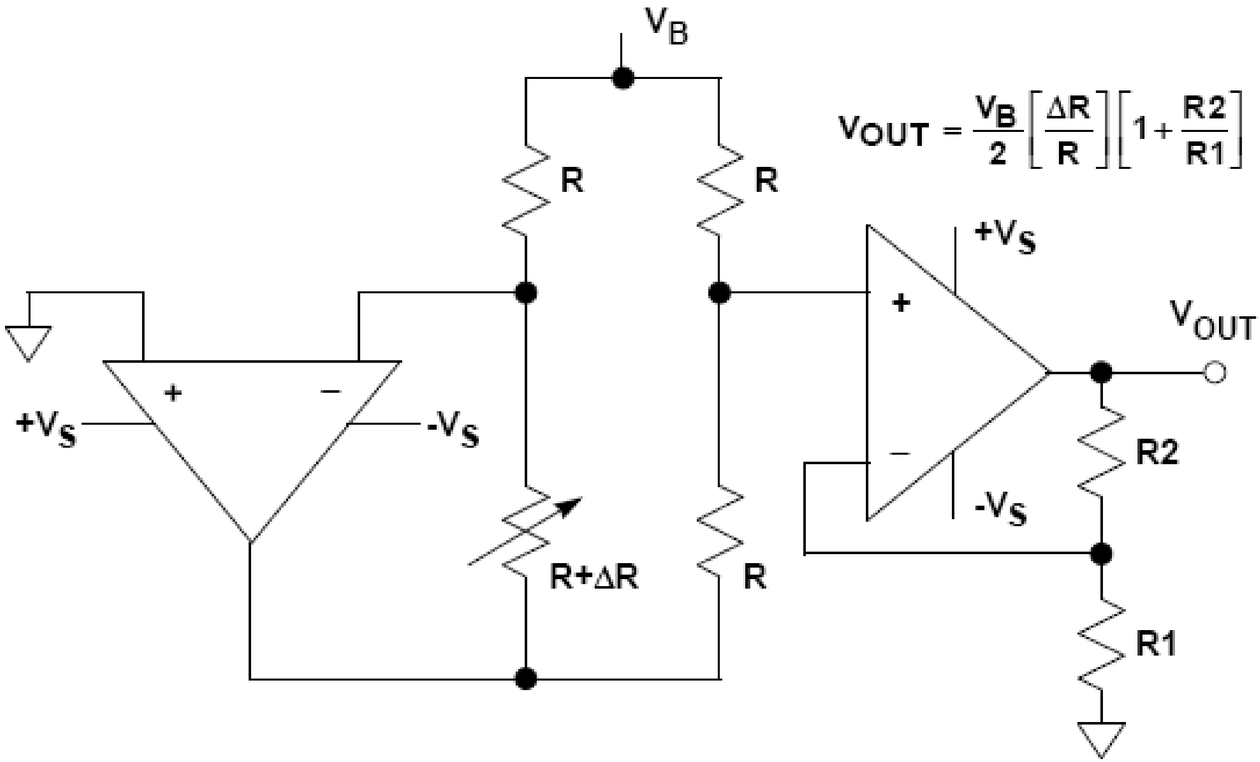
- Does not unbalance the bridge
- Excellent CMR and accuracy
- Nonlinear but SW can correct it (by uC)
- R_G ->gain setting

- Linearising single-element bridge (a)



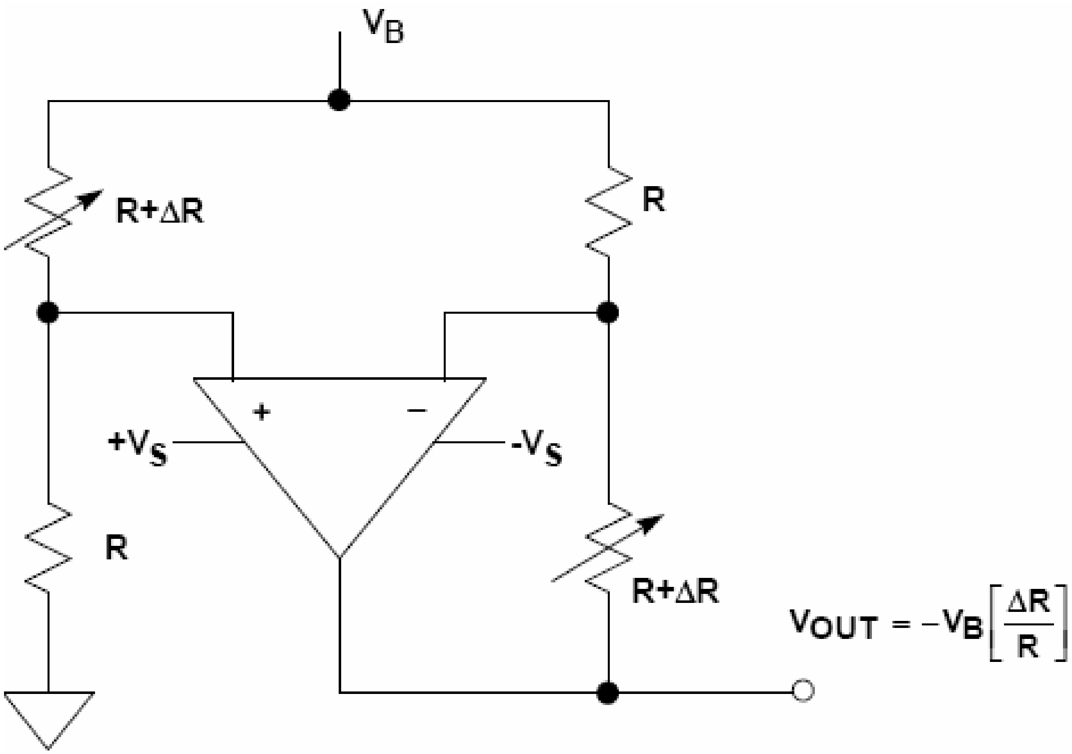
- Operational amplifier produces forced null
- Low impedance output
- 2x sensitivity
- Linear output
- Small output level -> further amplification
- Dual supply needed

- Linearising single-element bridge (b)

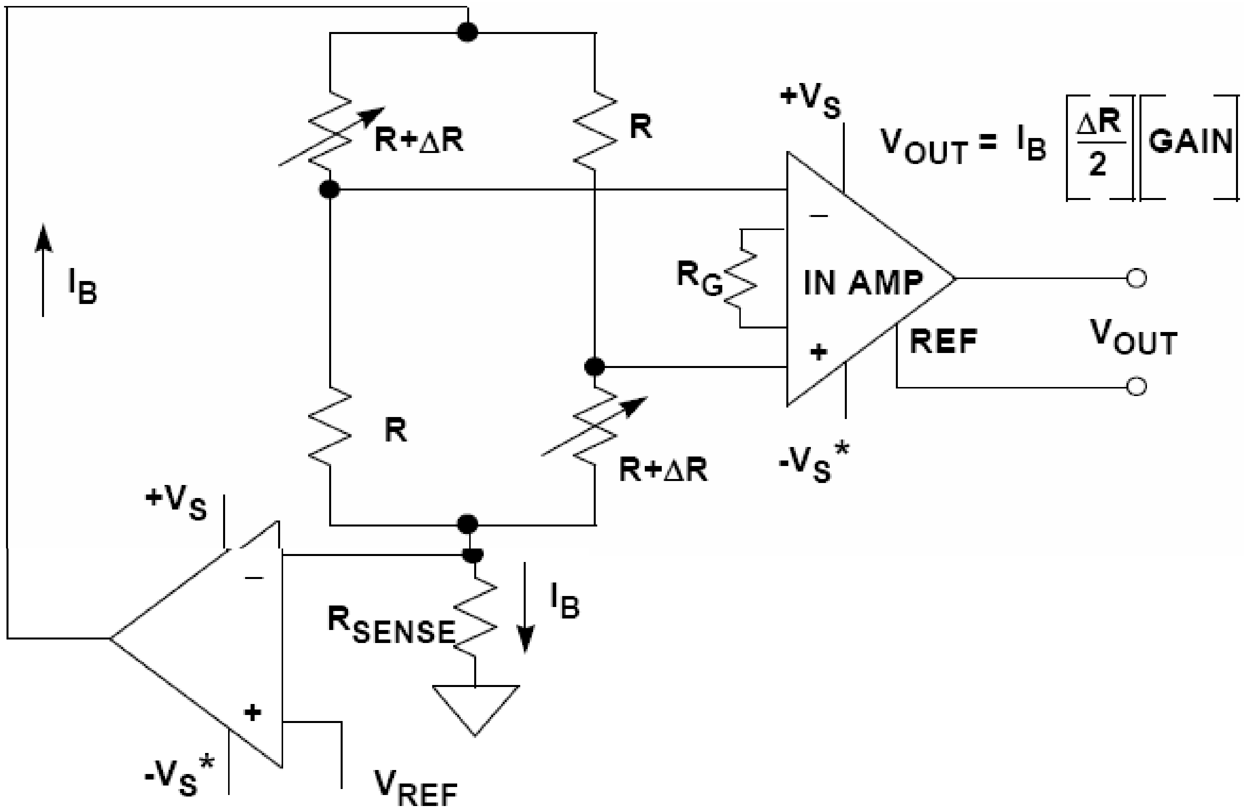


- Linear
- Temeprature dependence minimized
  - Note the ratio of resistances

- Linearising two-element bridge (a)
  - Additional gain may be required



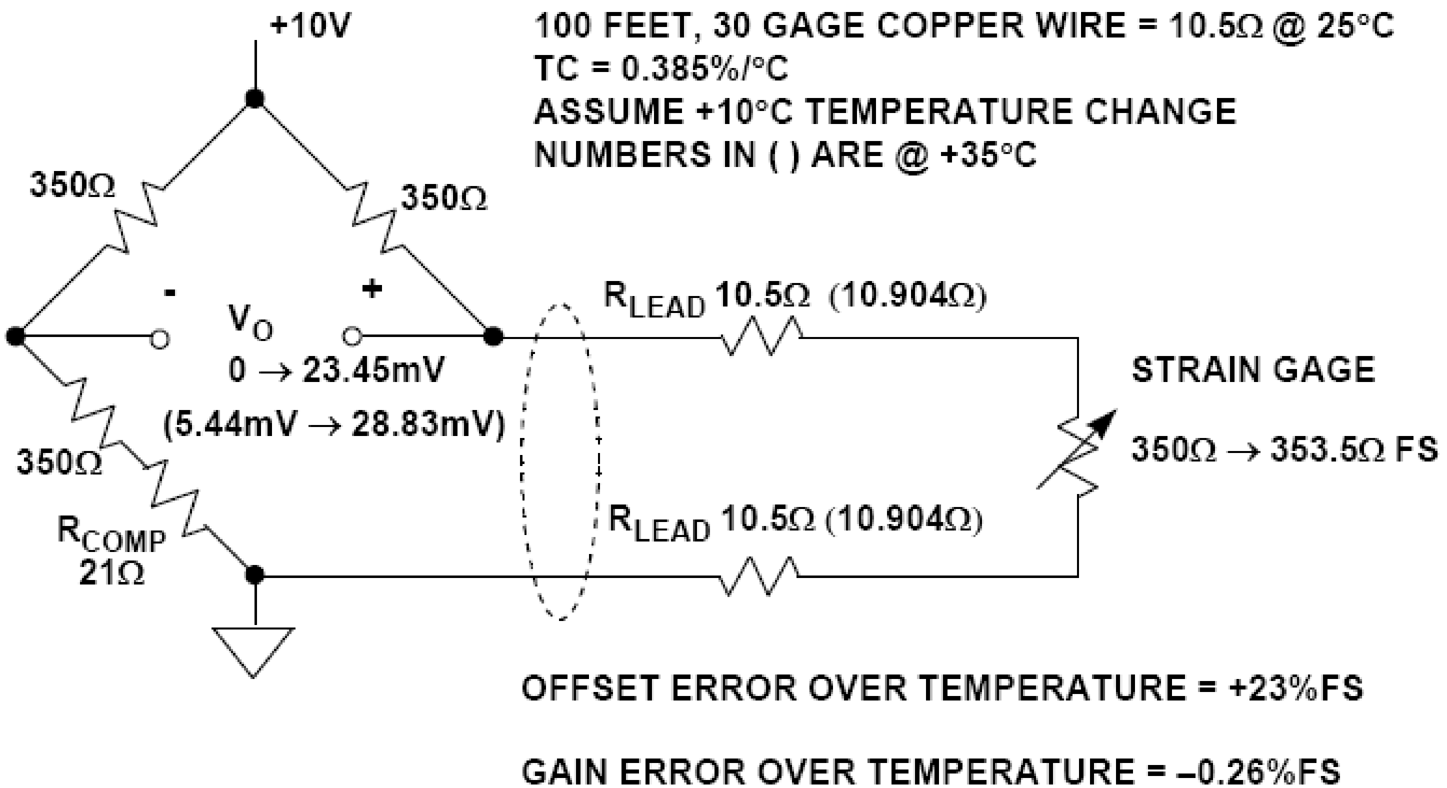
- Linearising two-element bridge (b)
  - Constant current maintained through the bridge



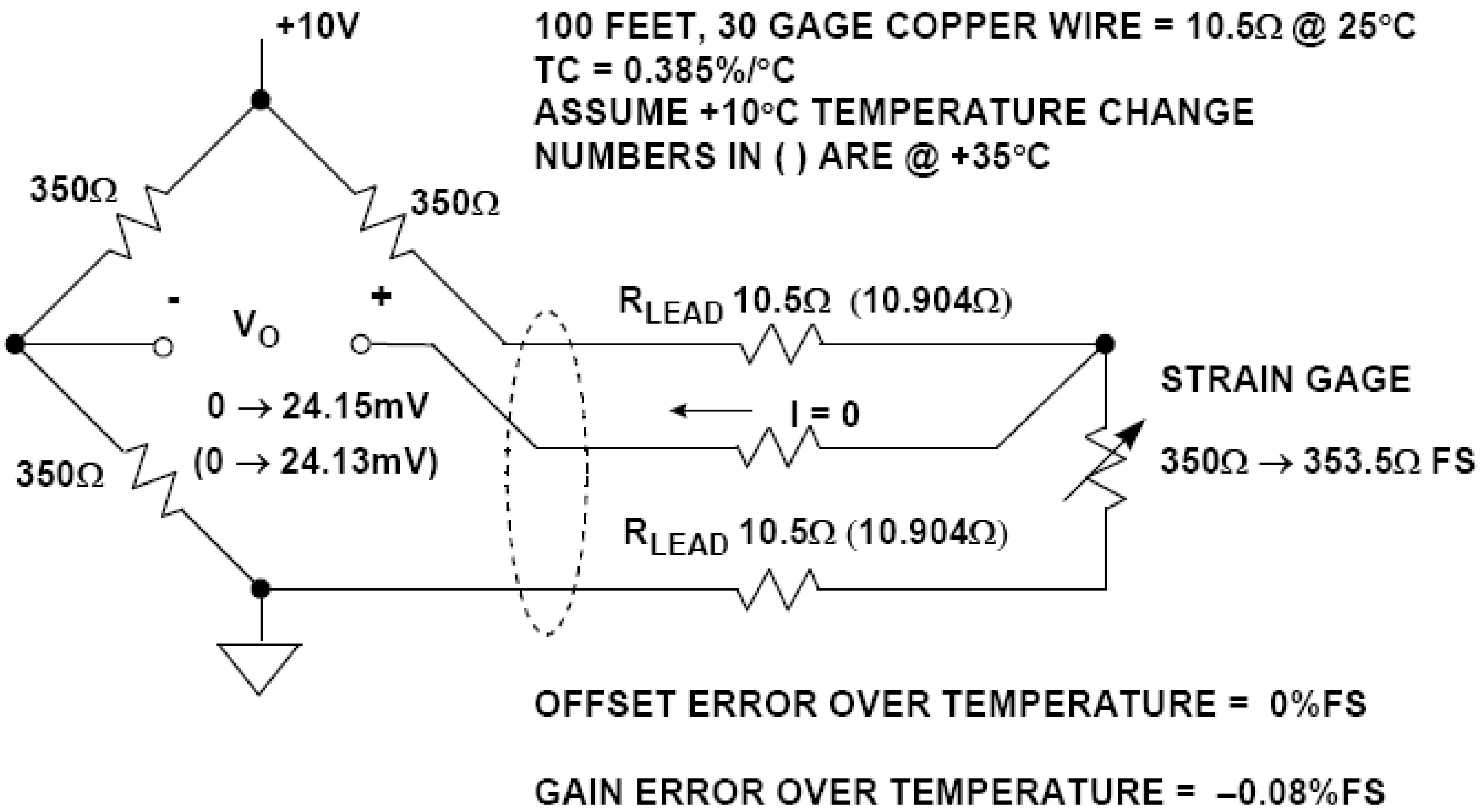
Elimination of errors in bridge measurements

- Main problems:
  - The sensor is far from the bridge
  - The lead wire has a significant resistance
  - Noise and distrurbance may be picked up on lead wire
- Goal: minimize the effect of the source of errors

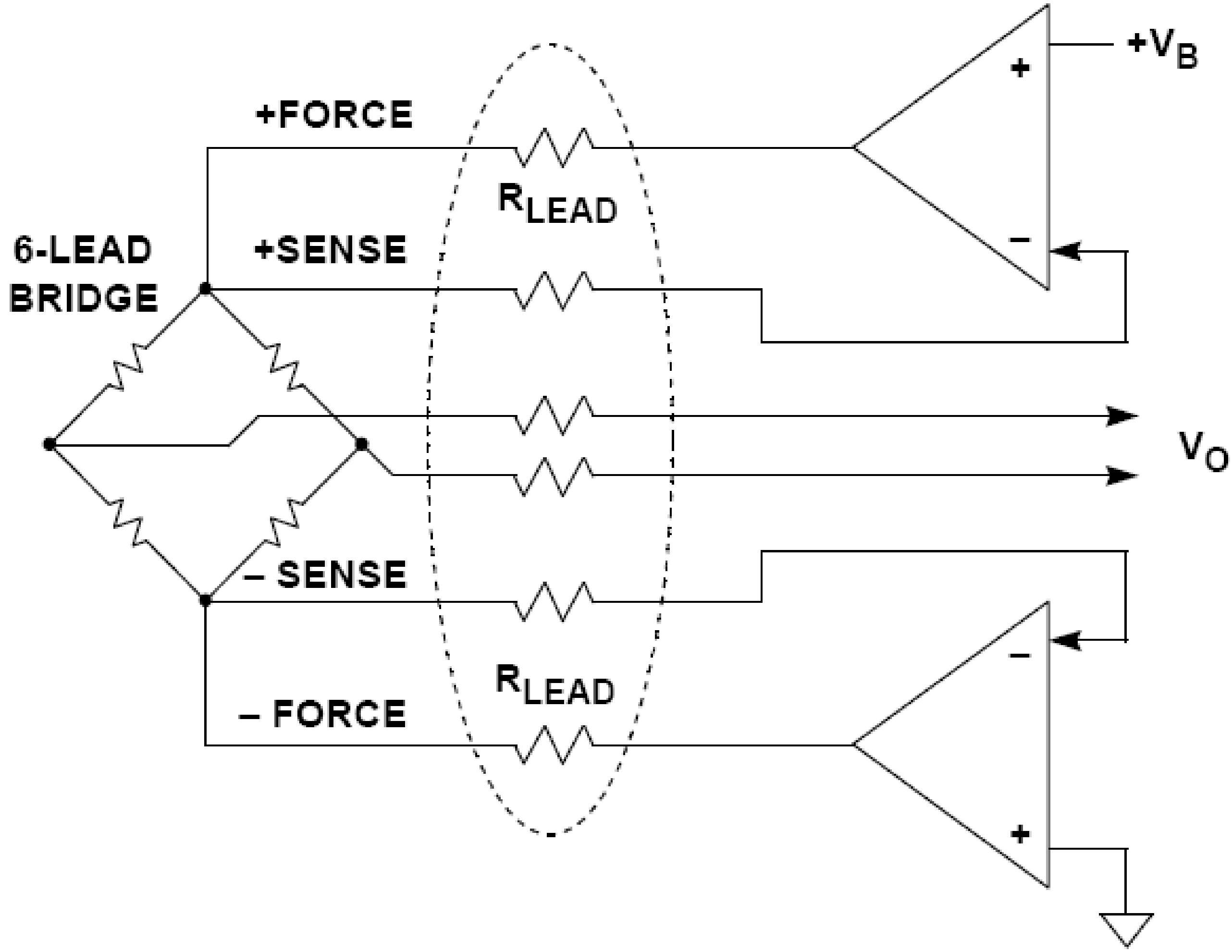
- Applying compensation resistance



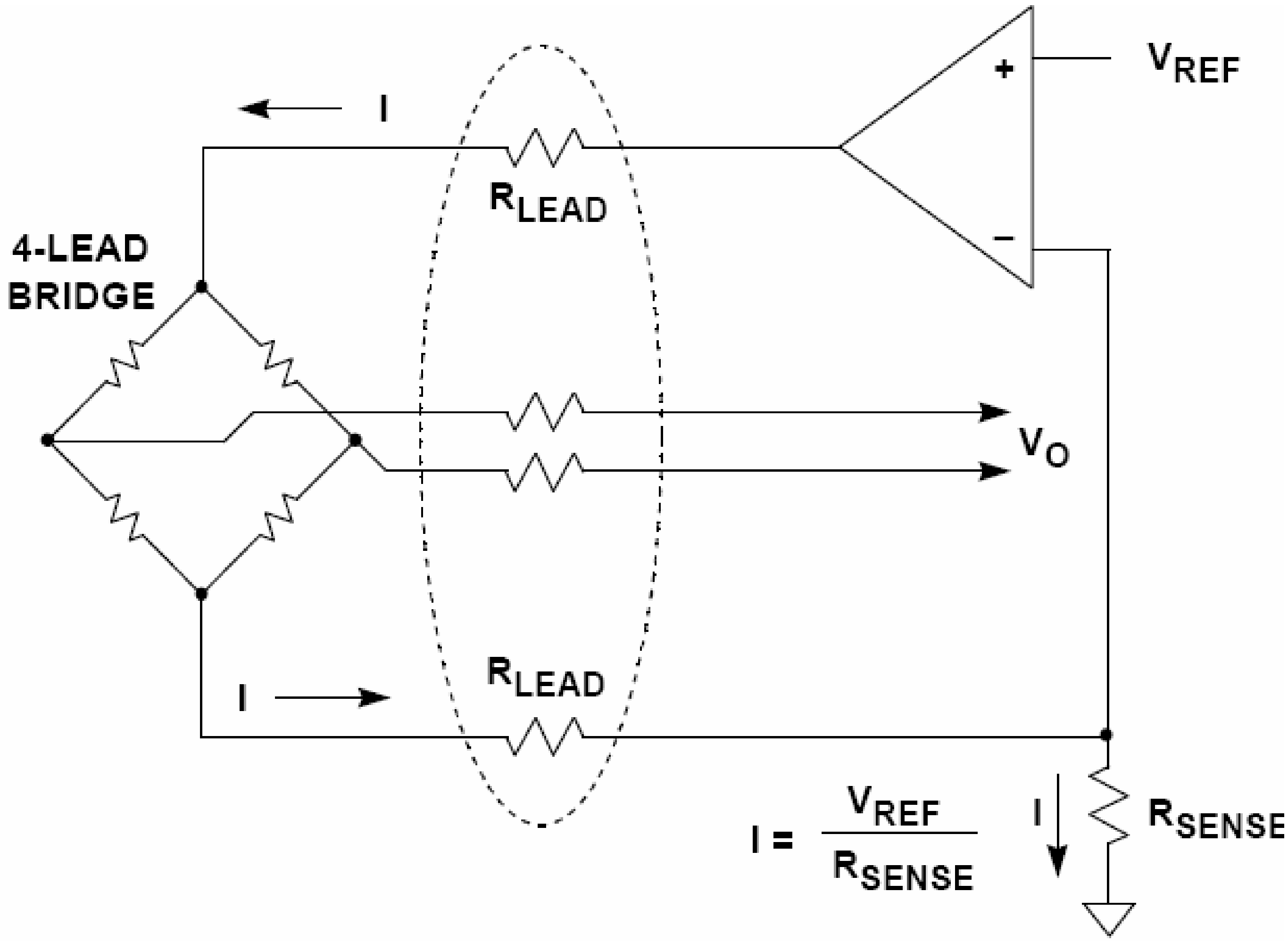
- 3-wires method



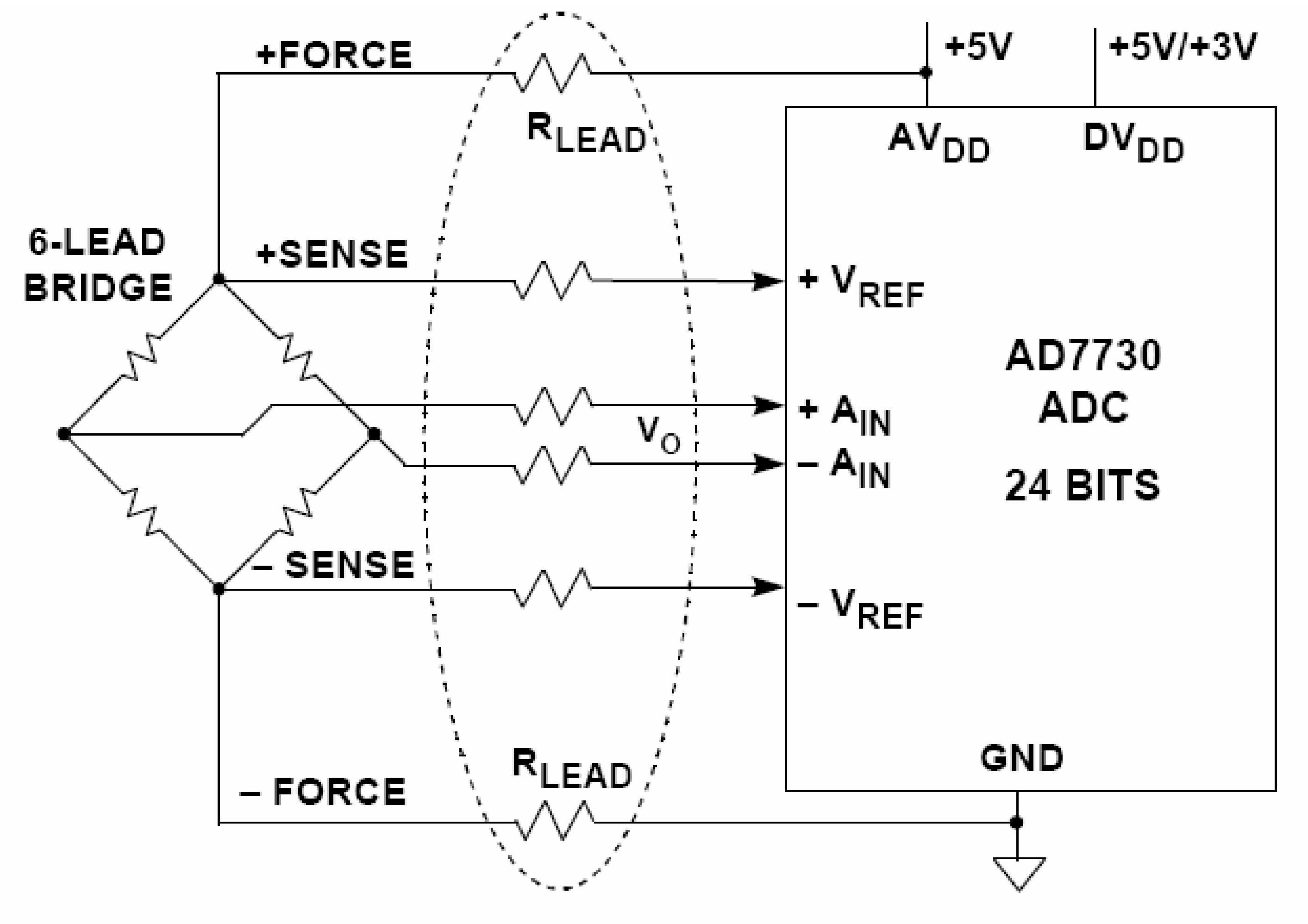
- 4-wire method (Kelvin sensing)



- Constanc current exitation



- Ratiometric method



References

[1]

Analog Devices Technical Reference Books

Practical Design Techniques for Sensor Signal Conditioning