

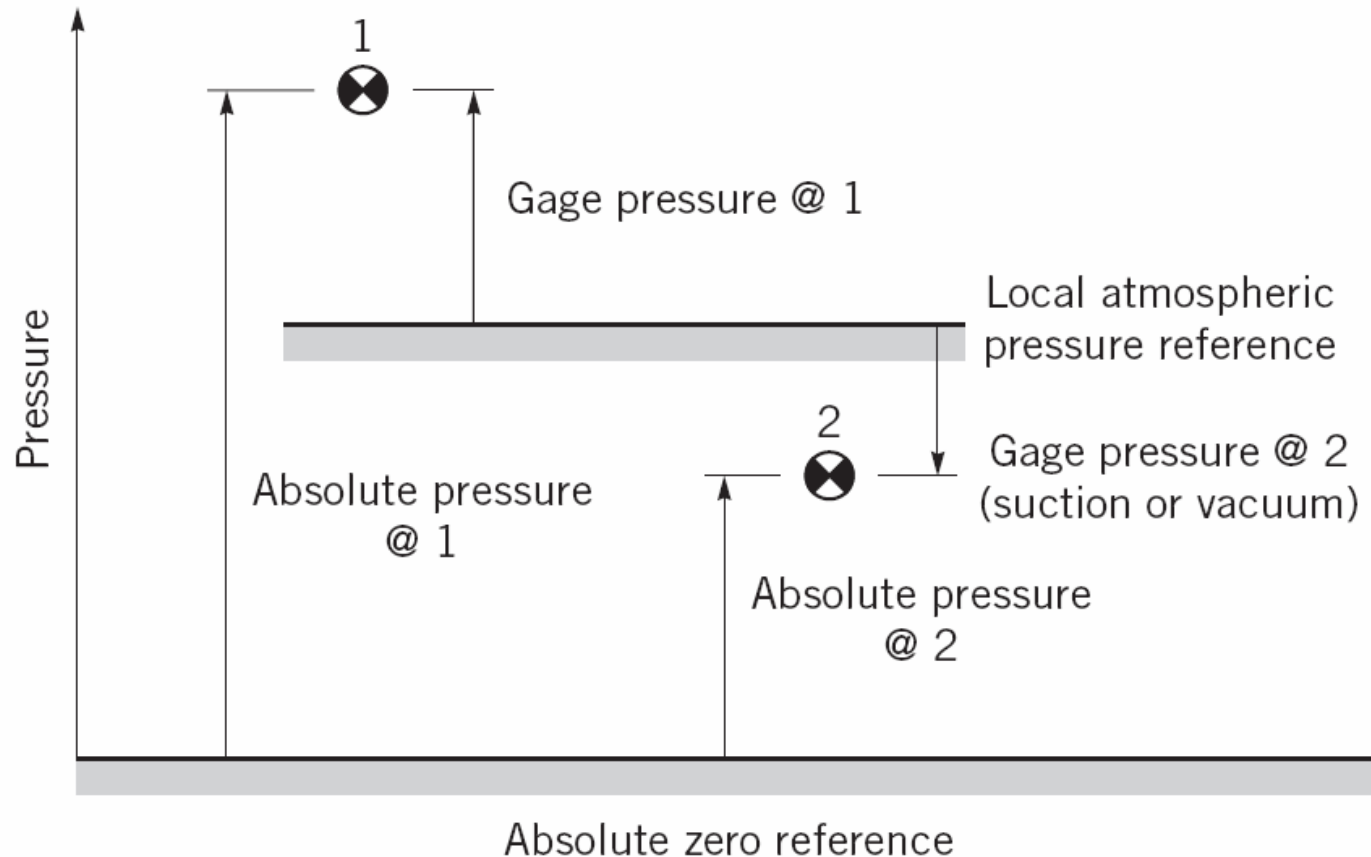
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# **ME120 Experimental Methods**

## **Pressure**

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SJSU

# Absolute Pressure, Gage Pressure, and Vacuum



Then what is “differential pressure” ?

$$P_{\text{abs}} = P_{\text{gage}} + P_{\text{ambient}}$$

- **Absolute Pressure**
- **Gage Pressure**
- **Differential Pressure**

# Pressure and Vacuum Units

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- ❑ The SI unit of pressure is pascal (Pa), which is equivalent to a newton per square meter ( $\text{N/m}^2$ ), and as a point of reference one atmosphere (atm) is 101,325 Pa.
- ❑ In the United States, pounds per square inch (psi) is still extremely popular, and 1 atm is 14.7 psi.
- ❑ In some European countries, “bar” is still popular, and 1 bar = 100,000 Pa.
- ❑ For vacuum systems, “torr” is still very popular, and 1 torr =  $1/760$  atm = 1 mmHg  $\approx$  133 Pa.

# Manometers

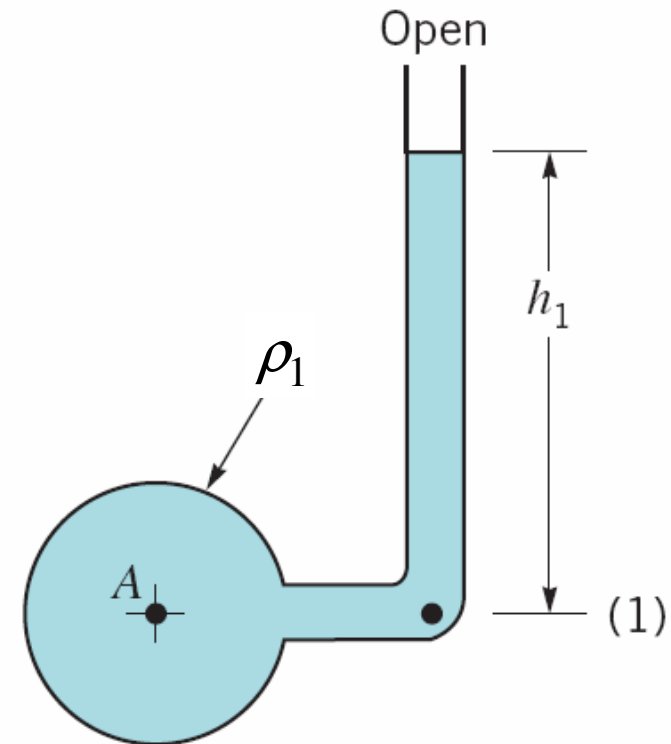
- Manometers measure pressure based on the pressure differences in liquid columns.

$$\frac{dp}{dz} = -\rho g$$

$$\int_{p_1}^{p_2} dp = -\rho g \int_{z_1}^{z_2} dz$$

$$p_2 - p_1 = -\rho g (z_2 - z_1)$$

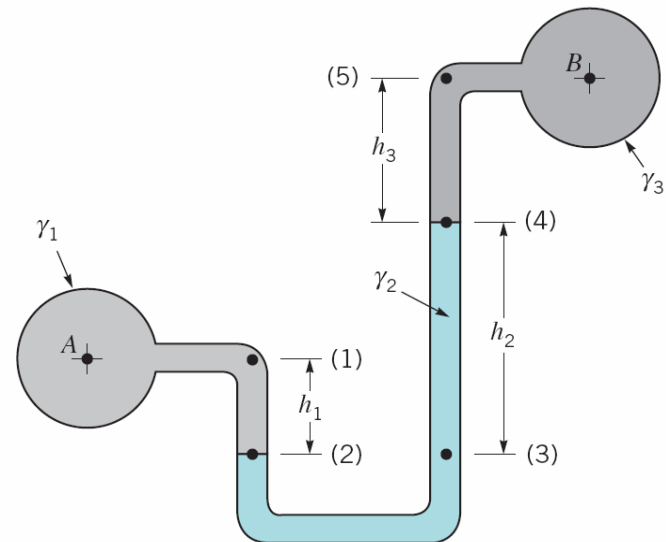
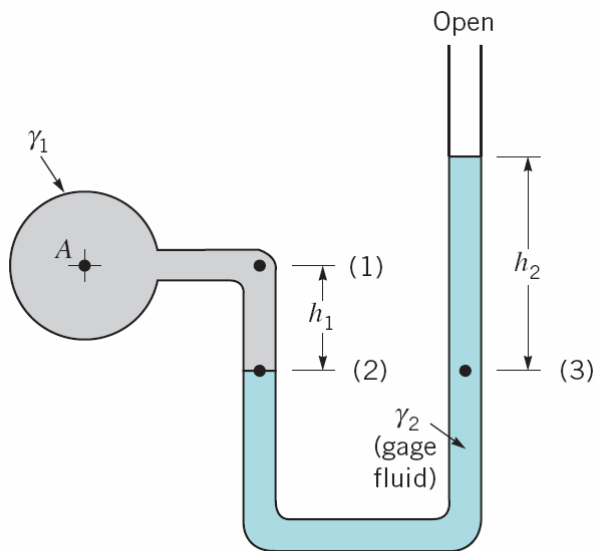
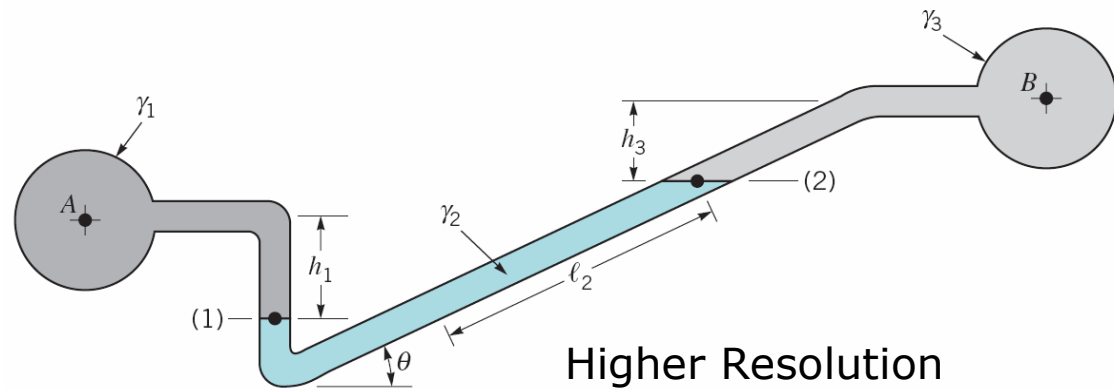
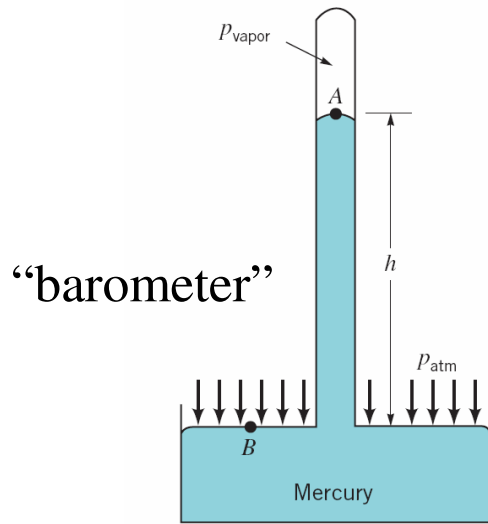
$$p_A = \rho g h_1$$



Factors affecting the accuracy:

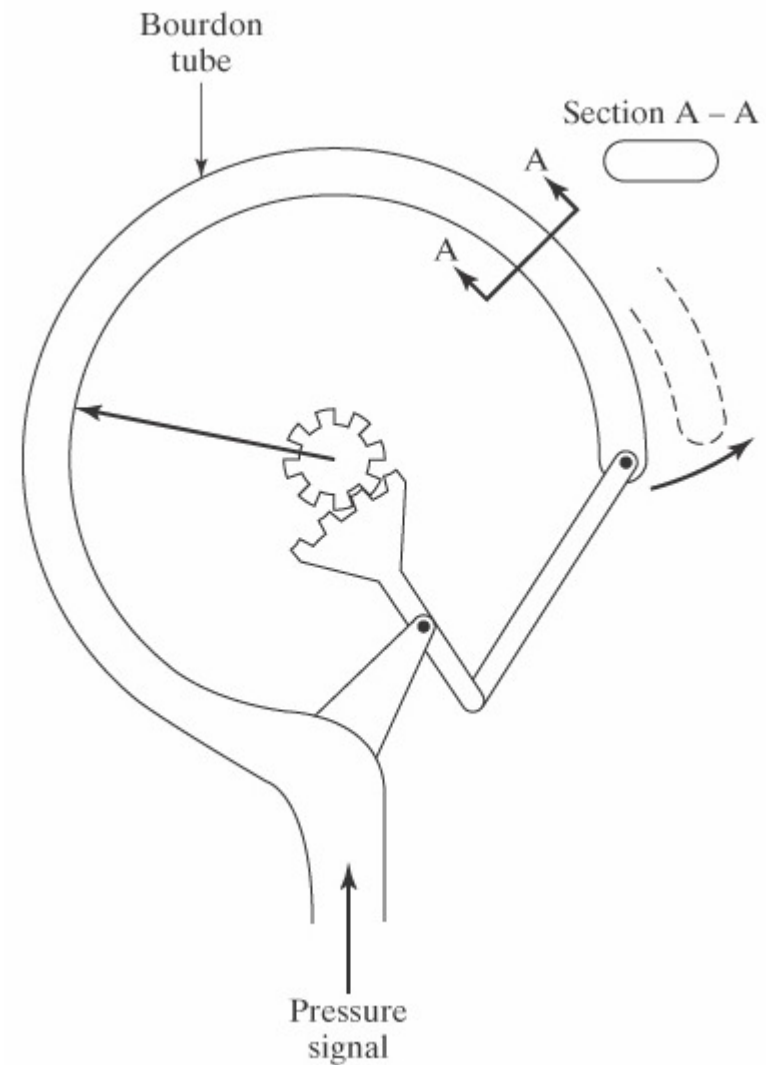
- Scale
- Density of the liquid

# Manometer Variants

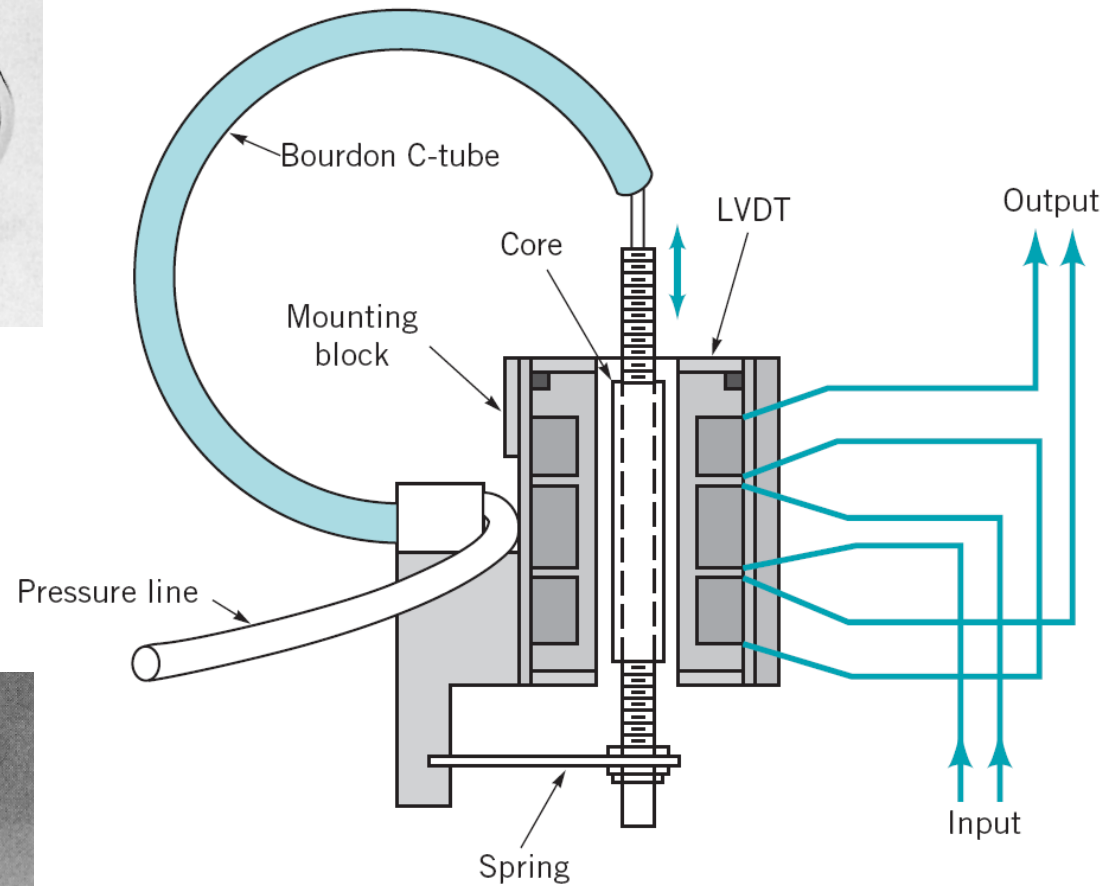
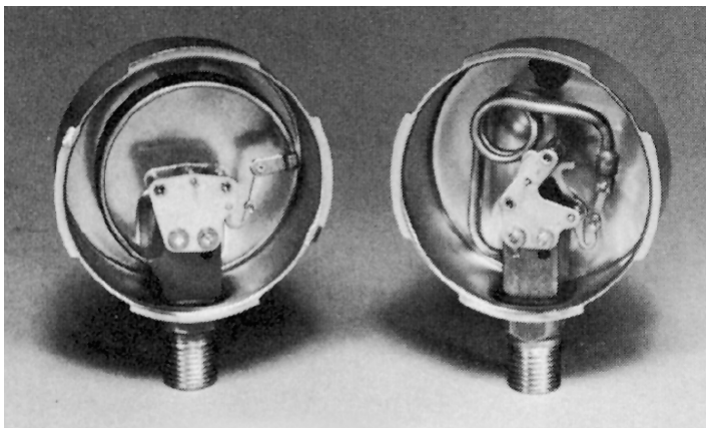
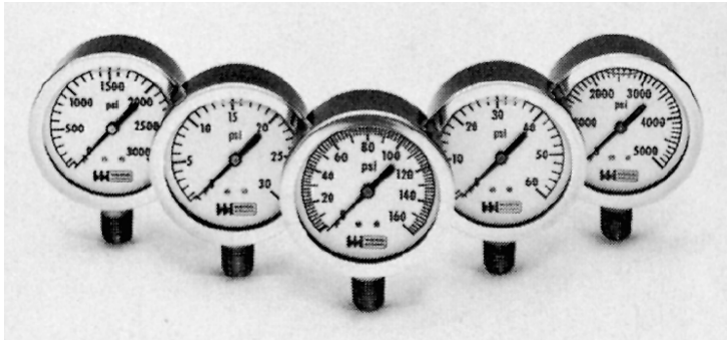


# Bourdon Gage

- ❑ A Bourdon gage uses the fact that an imbalance of pressure forces will tend to straighten a curved tube.
- ❑ Purely mechanical versions are inexpensive but relatively coarse.
- ❑ Improved resolution and accuracy can be attained by combining with displacement sensing.



# Bourdon Gage Variants

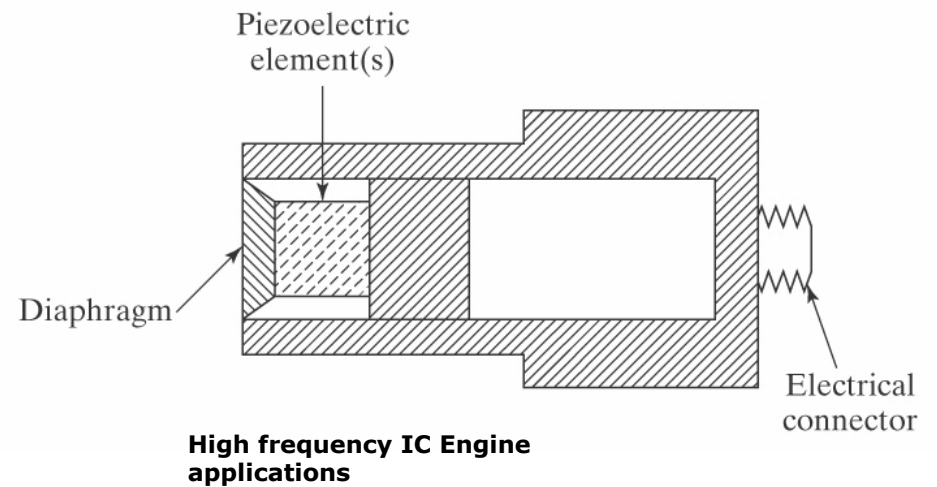
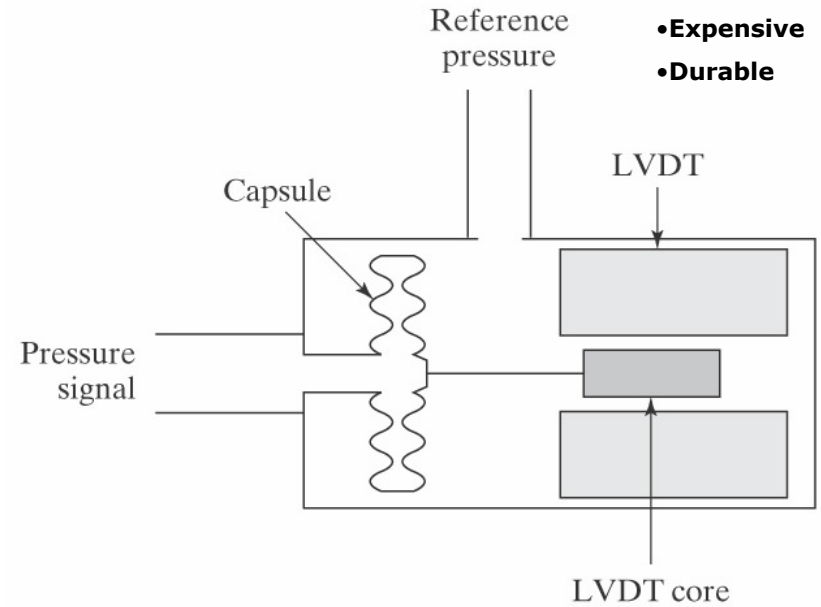
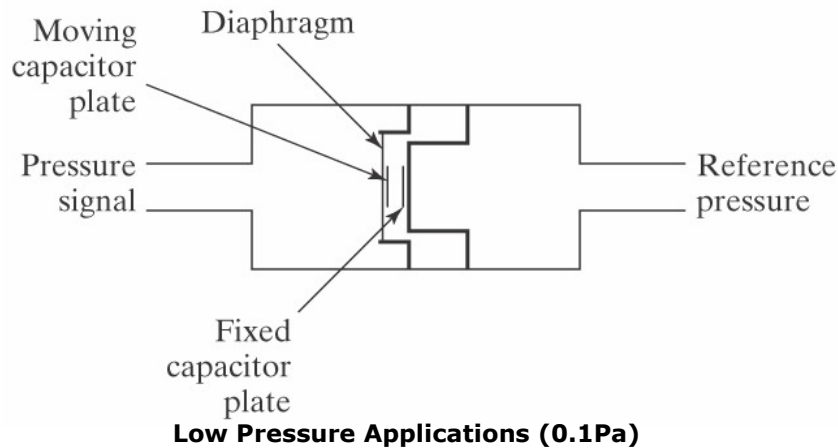
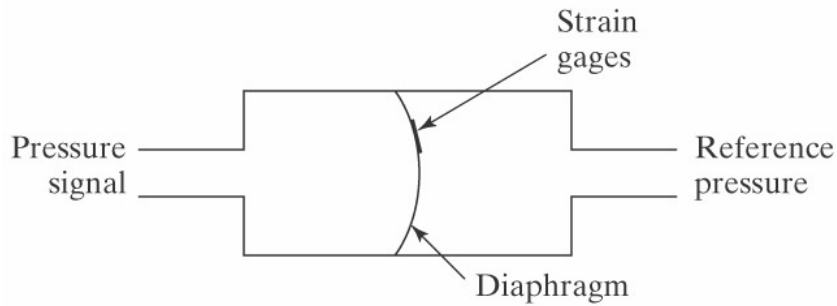


# Pressure Transducers

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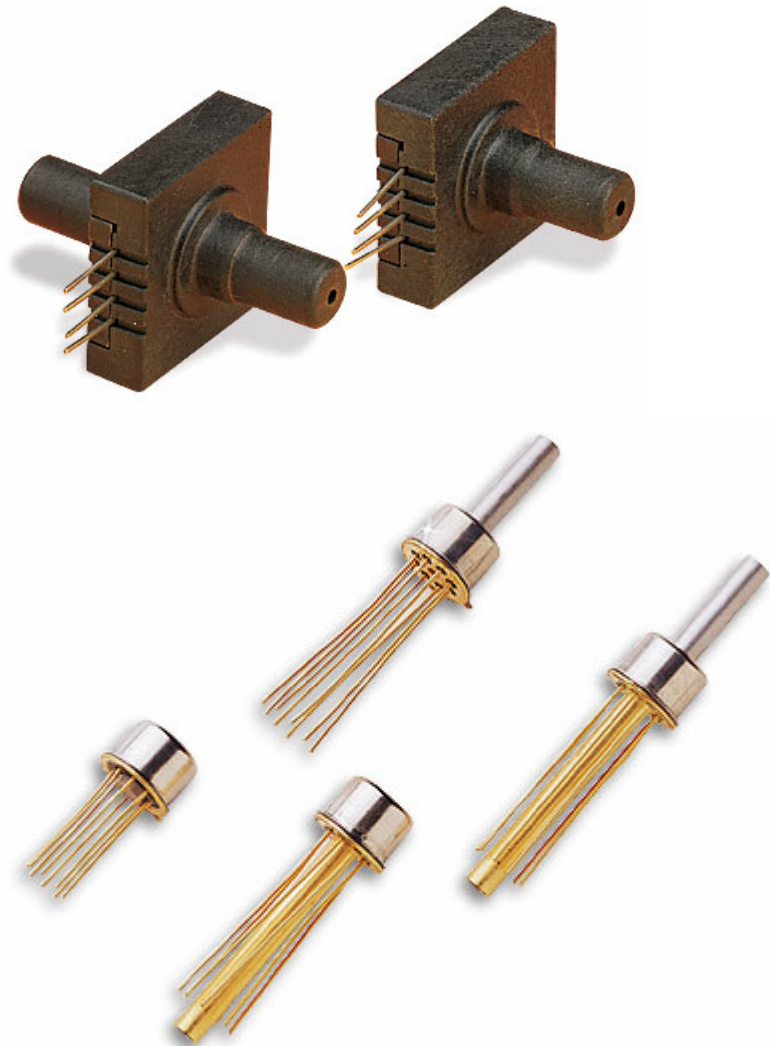
- Pressure transducers commonly use mechanical structures that exhibit significant displacement when subject to applied pressure, and convert the displacement into an electrical signal.
- Examples of common position/strain sensing elements include:
  - Strain gages
  - Linear variable differential transducers
  - Capacitive sensors in “capacitance manometers”
  - Piezoelectric elements
  - Fiber optic reflection

# Pressure Transducer Variants

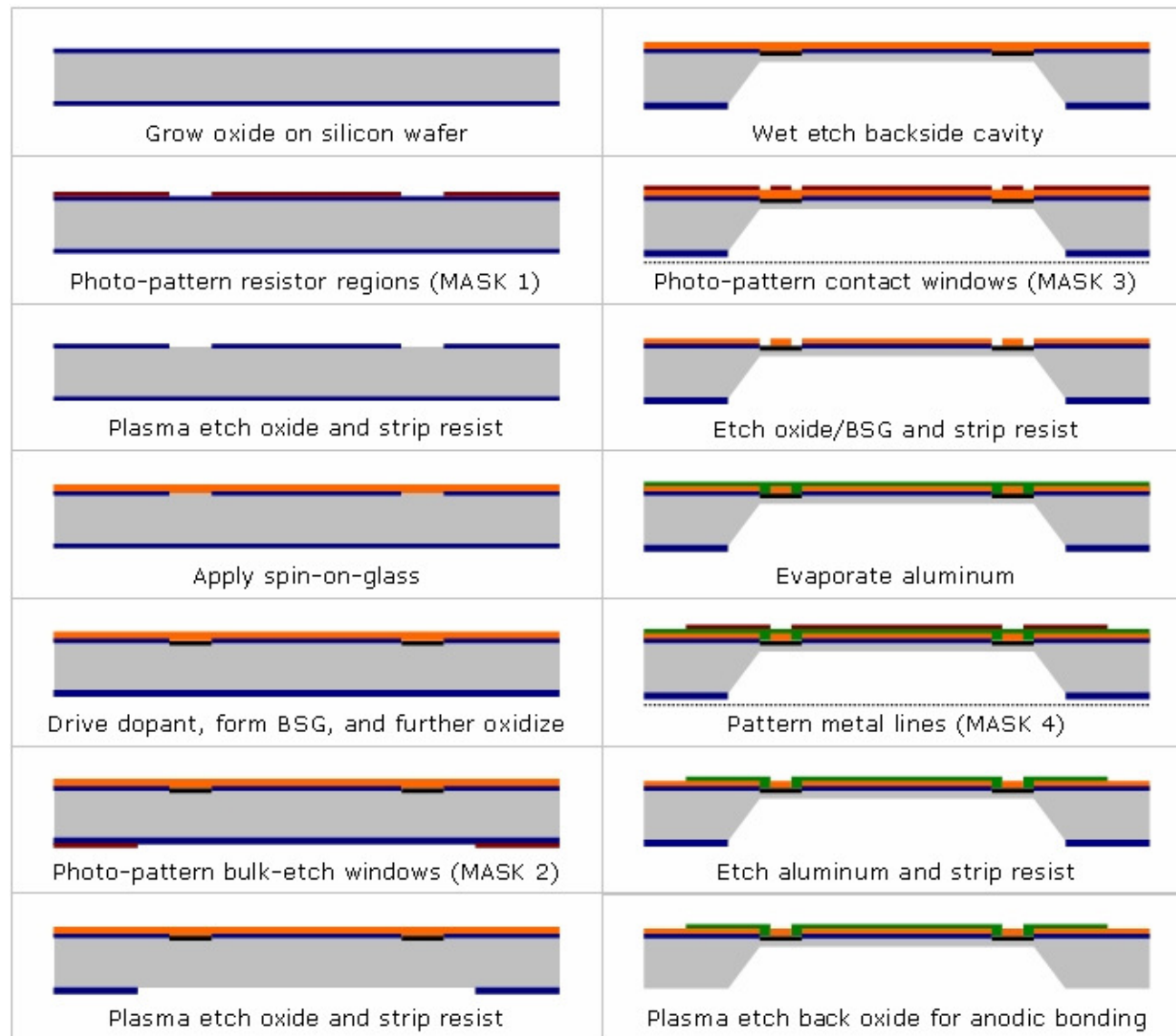


# Silicon Pressure Sensor Examples

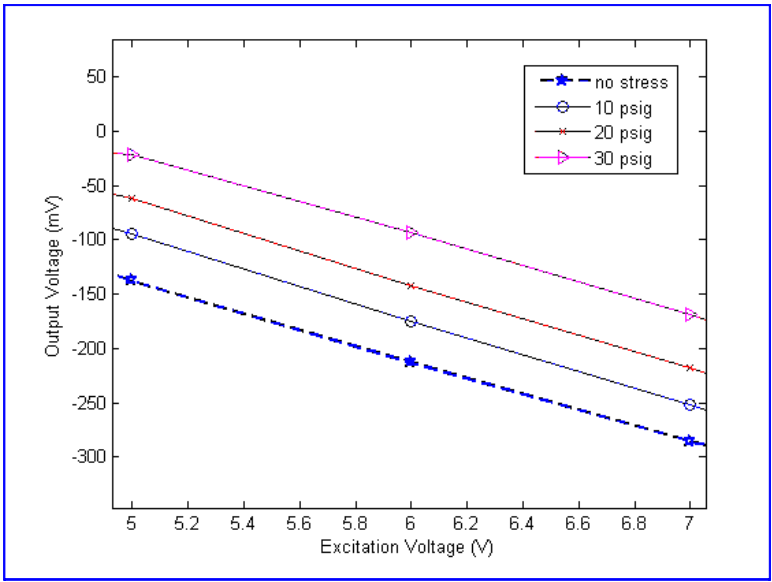
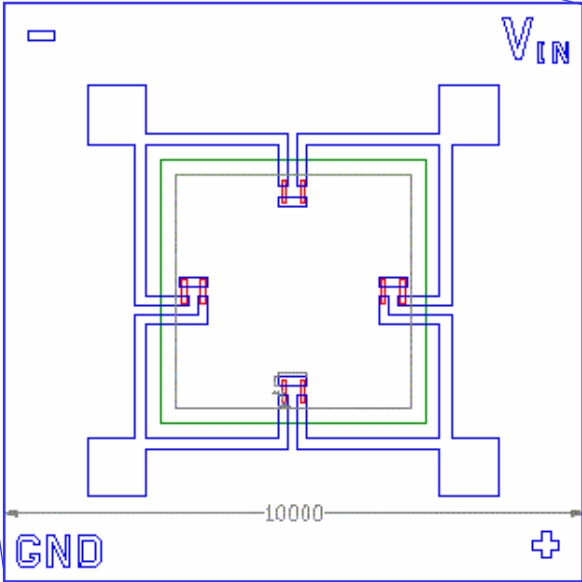
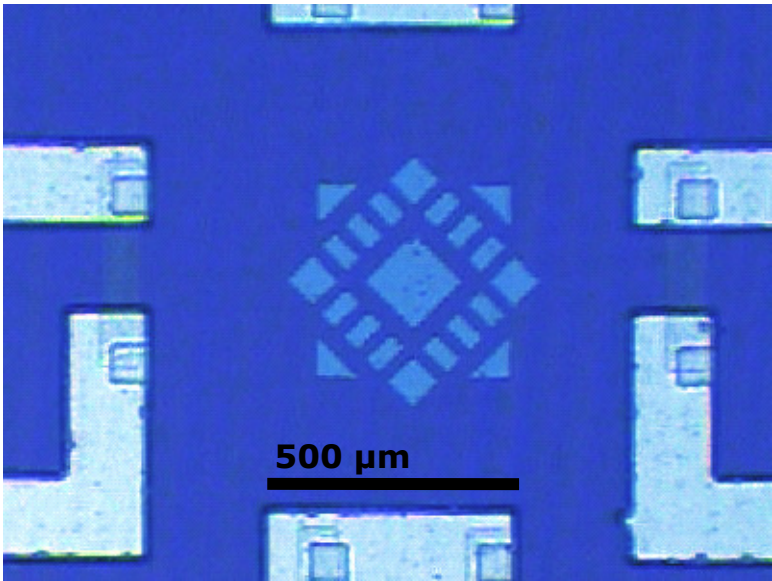
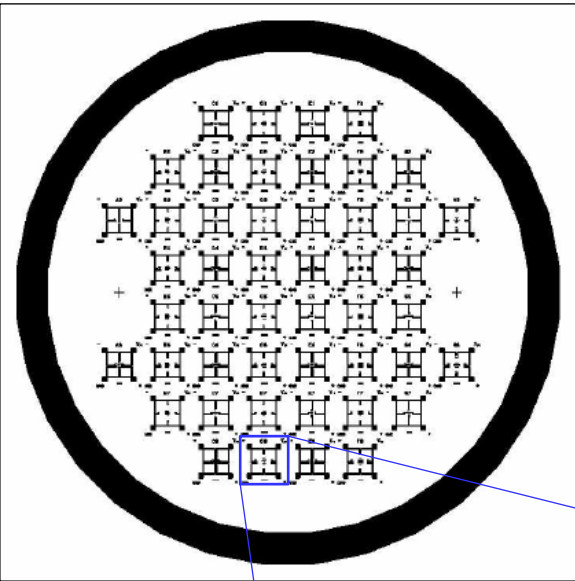
- ❑ Silicon pressure sensors are extremely practical because of manufacturing integration and great variety of packaging configurations for applications spanning automotive, aerospace, biomedical, etc.
- ❑ Manifestations vary, but almost all use a thinned silicon membrane that deforms with applied pressure.
- ❑ Many designs use diffusion to pattern piezoresistive elements, then interconnect in a (Wheatstone) bridge circuit.



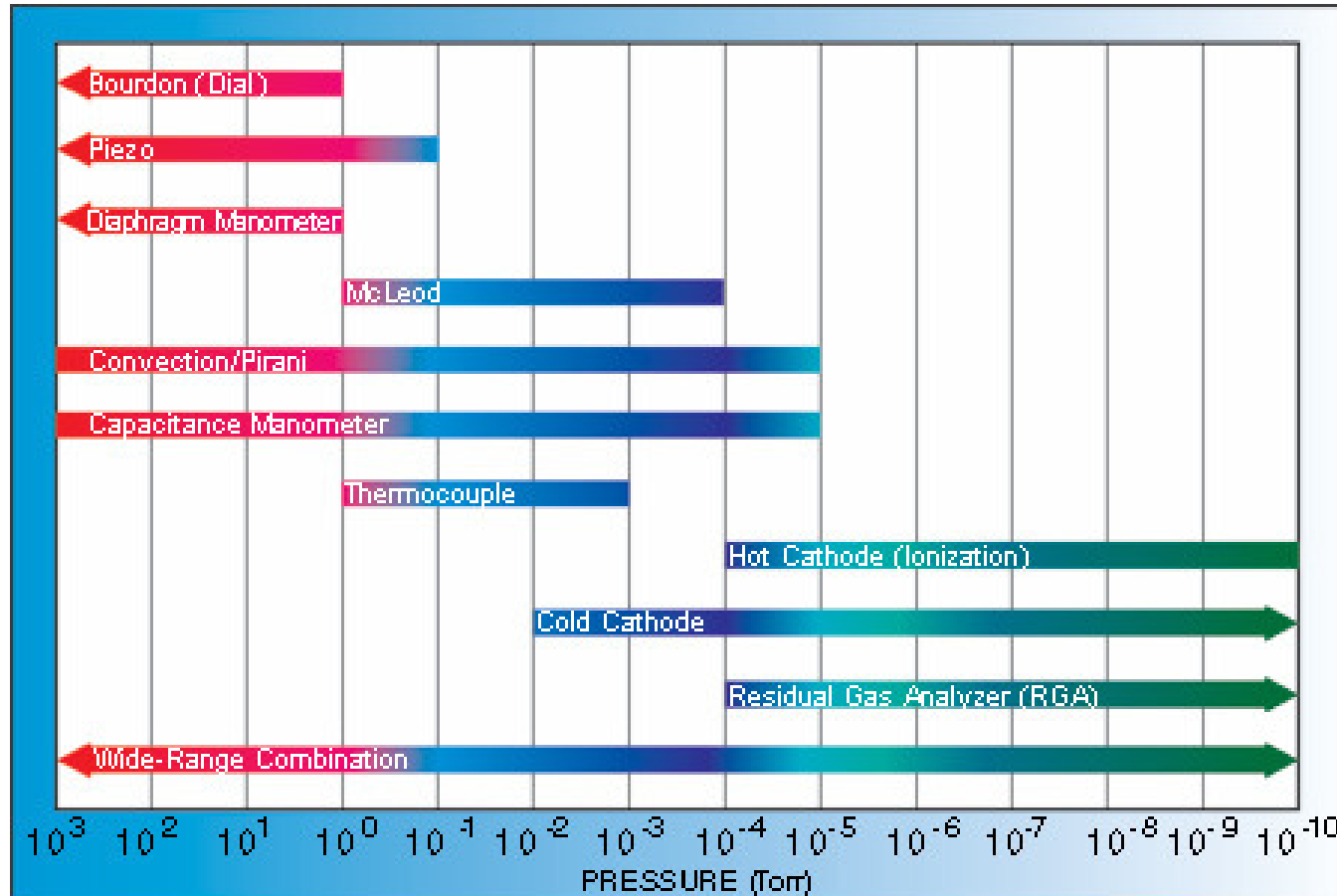
# SJSU MEMS Pressure Sensor Process Sequence



# SJSU Microelectromechanical Systems (MEMS)



# Vacuum Ranges

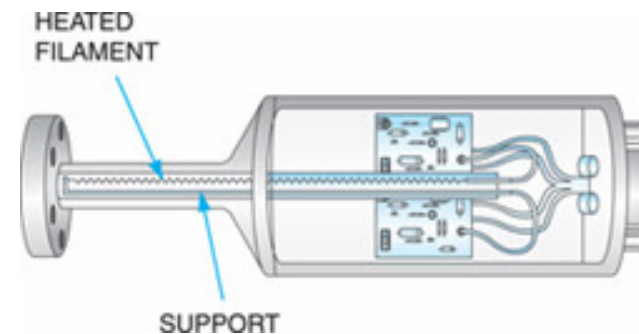
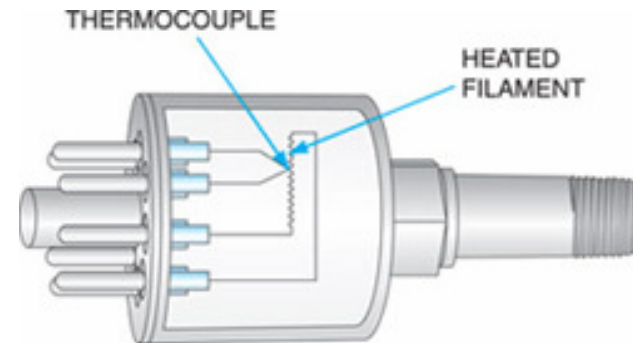


- ❑ “High vacuum” is considered to be in the range of  $10^{-3}$  to  $10^{-6}$  torr.
- ❑ “Low vacuum” actually corresponds to higher absolute pressure, greater than 1 torr.
- ❑ “Ultrahigh vacuum” (UHV) represents the extreme below  $10^{-9}$  torr.

# Thermal Vacuum Gages

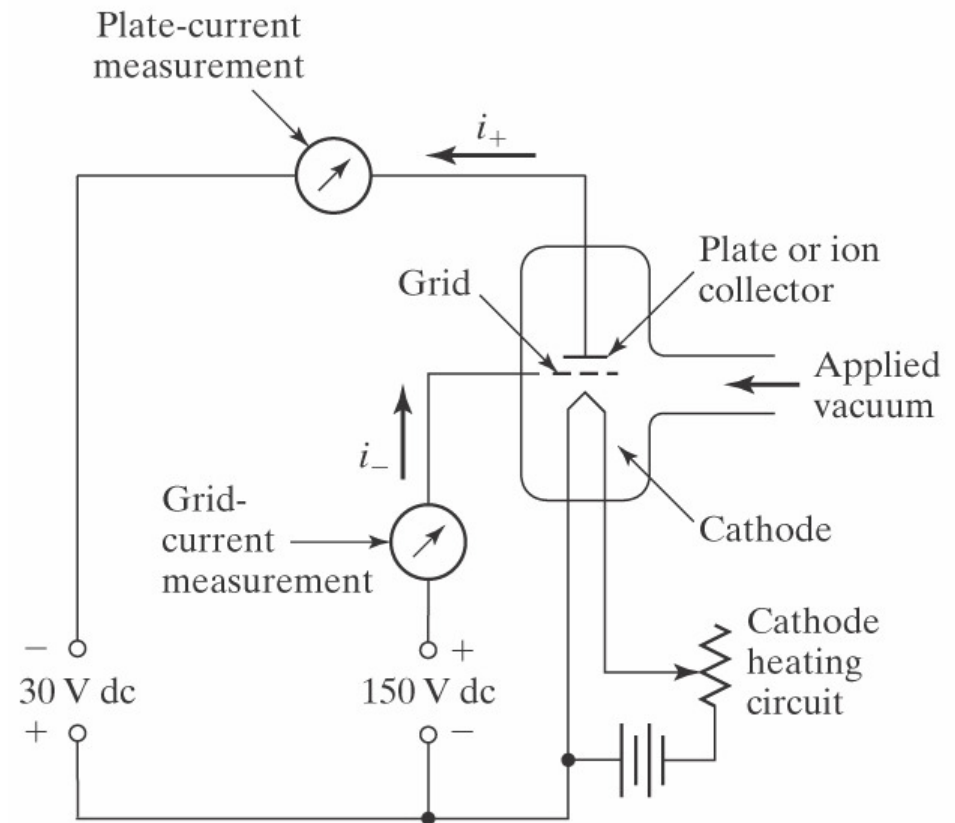
- ❑ Thermal vacuum gages use the fact that heat transfer between a gas and heated filament is dependent on molecule density...i.e. pressure.
- ❑ Thermocouple (T/C) gages place a thermocouple in contact with a heated filament to measure effectiveness of heat transfer.
- ❑ Pirani gages measure how the resistance of a filament changes with temperature in a Wheatstone bridge circuit.

$$q = C (T_f - T_w) P_{vac}$$

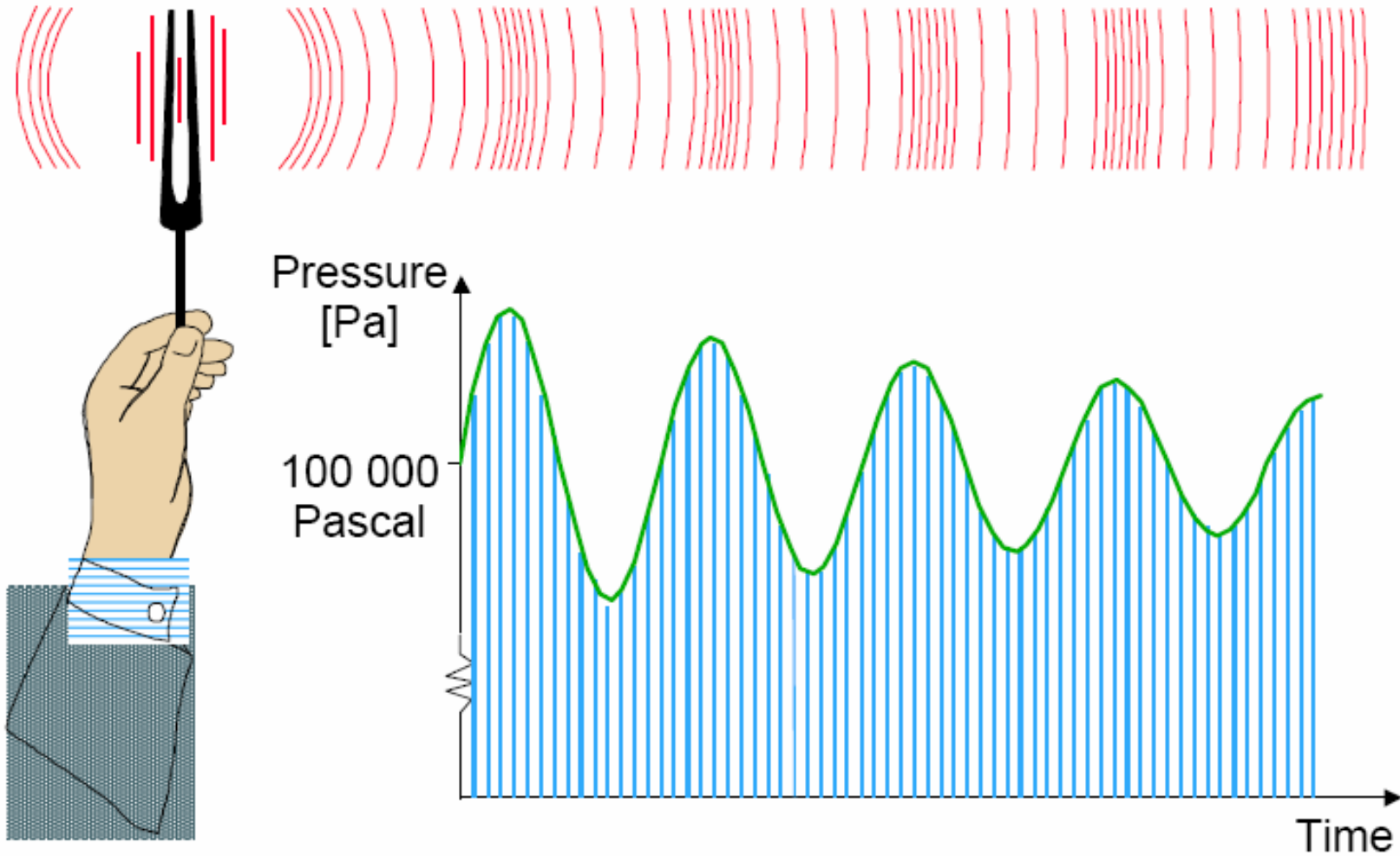


# Ionization Gages

- ❑ More extreme vacuum levels depend on monitoring ion flux.
- ❑ Ionized gases naturally depend on gas pressure and composition, so the current resulting from collection of positive ions at an electrode, for example, can be used to indicate pressure.



# Sound and Pressure

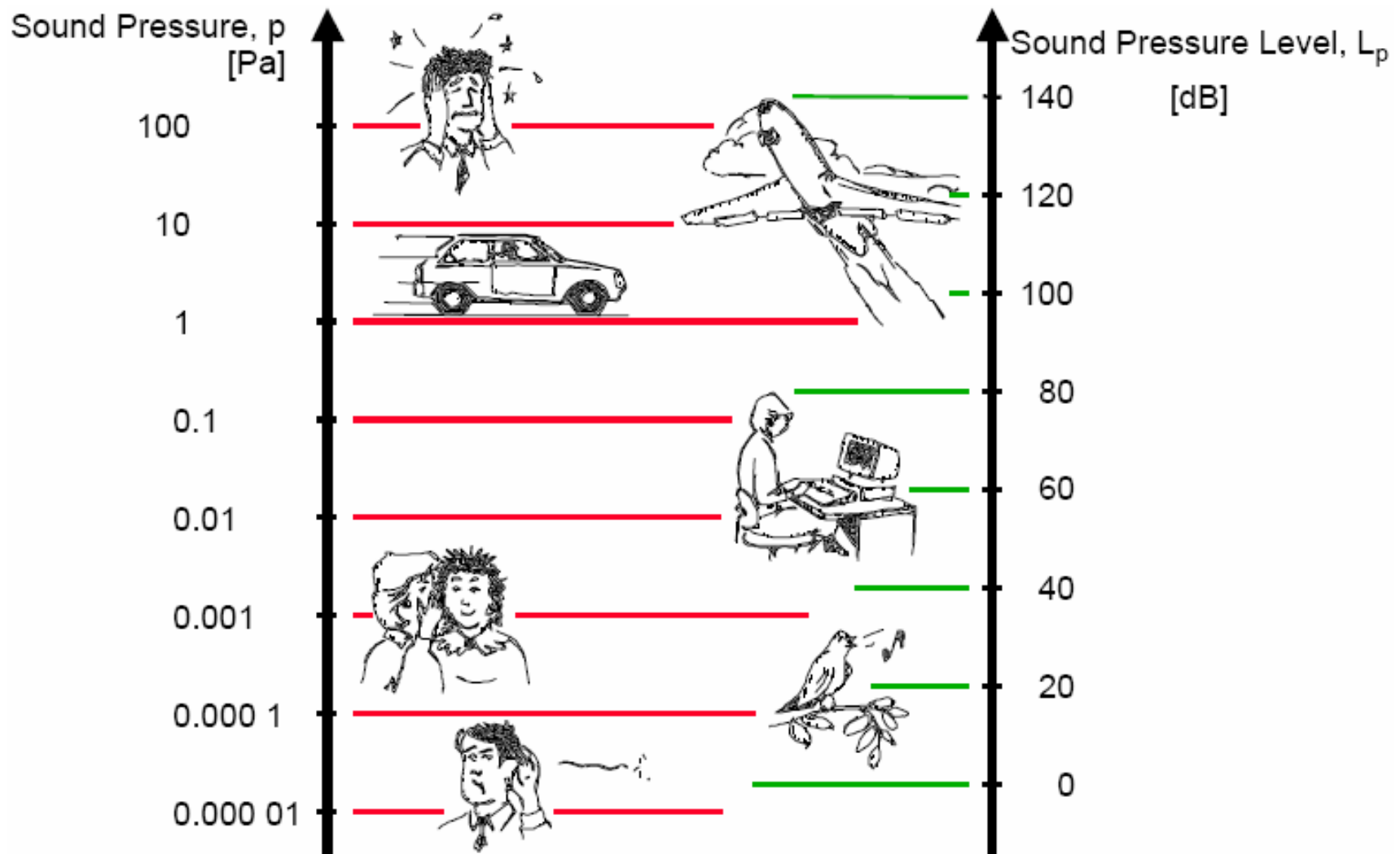


# Sound

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- ❑ Sound is ultimately a pressure variation, so the underlying principles of sound measurement are similar to pressure measurement, although more inherently concerned with dynamics.
- ❑ For example, common condenser microphones use a membrane with capacitive displacement sensing.
- ❑ “Sound pressure” is the pressure above static pressure, but pressure itself is not very convenient for communicating with respect to common audible sounds.
- ❑ “Sound pressure level” on a logarithmic decibel scale is therefore more typically used.

# Sound Pressure Level (SPL or $L_p$ )



# Sound Pressure Measurement

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- ❑ @ 20deg C Vel of sound = 344m/sec
- ❑ Audible frequencies - 20 to 20000Hz
- ❑ Bruel &Kjaer 2236 Precision Integrating sound level meter
  - Condenser Microphone
    - » Thin metal foil stretched like drumhead over a frame. Pressure changes > diaphragm movement > changes in capacitance > milli-volt signal > pre amplifier > other amplifier stages > A/D converter
    - Free-field response Microphone > one direction only
    - Random-incidence Microphone > Equally from all directions

# Basics

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- ❑ SPL is a measurement of sound strength on a logarithmic scale
- ❑  $L = \text{SPL} = 10 \log(\text{Signal Power}/\text{Ref Power})$
- ❑  $L = 10 \log (\text{Prms}/\text{Pref})^2$
- ❑  $L = 20 \log(\text{Prms}/\text{Pref})$
- ❑ Pref = Ref value for sound pressure in air = 20 micro pascals
- ❑ Sound level meter computes Prms in db based on sound pressure over a period of time

# Decibel (dB)

$$L_p = 20 \log \frac{p}{p_0} \text{ dB re } 20 \mu\text{Pa}$$

$$(p_0 = 20 \mu\text{Pa} = 20 \times 10^{-6} \text{ Pa})$$

Fixed reference pressure

Ex. 1:  $p = 1 \text{ Pa}$

$$L_p = 20 \log \frac{1}{20 \times 10^{-6}}$$

$$= 20 \log 50\,000$$

$$= 94 \text{ dB}$$

Ex. 2:  $p = 31.7 \text{ Pa}$

$$L_p = 20 \log \frac{31.7}{20 \times 10^{-6}}$$

$$= 20 \log 1.58 \times 10^{-6}$$

$$= 124 \text{ dB}$$