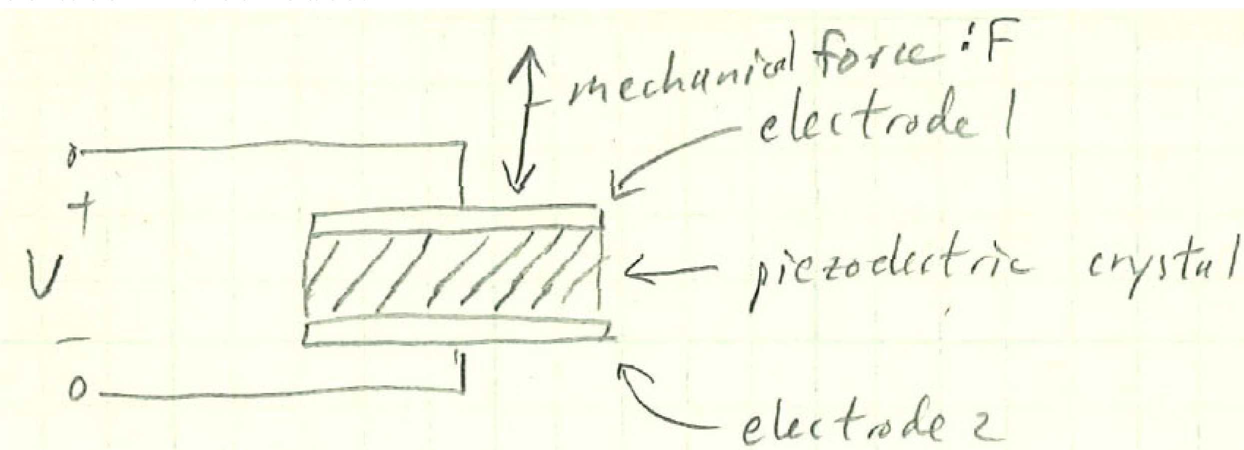
Sensing Methods: Voltage Sensing

Some sensors directly produce a voltage that is a function of the measurand.

1. Piezoelectric Crystals

Some crystals produce an electric charge when they are subjected to mechanical force (or rather the stress from that force). These crystals are called piezoelectric crystals. The crystal structure has many electrical dipoles, and they may be randomly oriented or aligned. Every dipole is a vector and all the dipole vectors in the crystal make up a vector field, **P**. Application of a mechanical stress changes **P**, which results in a change in the surface charge density, which results in the development of a voltage across the crystal. This effect is crystal plane orientation dependent. The opposite effect happens too: applying a sufficiently large voltage across the crystal results in a dimensional change.

Consider placing an "orientation appropriate" piezoelectric crystal between 2 electrodes:



A is the electrode surface area.

t is the separation distance between the two electrodes.

ε_r is the relative permittivity of the piezoelectric crystal.

Therefore, $C = \frac{\varepsilon_o \varepsilon_r A}{t}$

Also, $q = dF$

where d is an orientation dependent charge coefficient

Since also $q = CV$, then $V = \frac{q}{C} = \frac{dFt}{\varepsilon_o \varepsilon_r A}$

This equation can be rewritten to determine the force, F, resulting from applying a voltage, V. Therefore, piezoelectric crystals can be used as a sensor or as an actuator.

2. Seebeck Effect

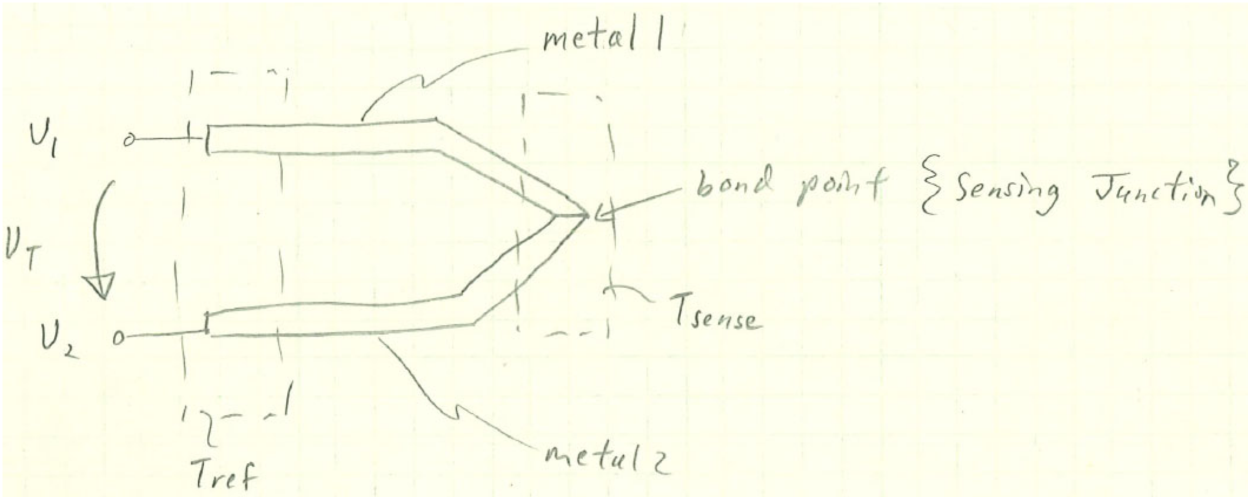
Dissimilar metals require different amounts of energy to liberate electrons from their surfaces.

This amount of energy, or "work", is quantified by the Work Function of the metal.

When two dissimilar metals are joined together to form a junction, electrons possess a tendency to move from the lower work function metal to the higher work function metal.

This results in the formation of a small voltage across the junction, and this junction potential is temperature dependent. This phenomenon is called the Seebeck effect.

Based on the Seebeck effect, a thermocouple consists of two dissimilar metals bonded at a point, the sensing junction, and brought to the temperature to be measured. The other end of the two metals is kept at a reference temperature:



T_{sense} is the temperature being sensed, and T_{ref} is a reference temperature.

V_T is the open circuit voltage appearing on the left end.

$$V_T = V_2 - V_1 = (P_2 - P_1)(T_{sense} - T_{ref}) = (P_2 - P_1)\Delta T$$

P_1 and P_2 are the Seebeck coefficients for the two metals. This temperature measurement sensor is called a thermocouple.

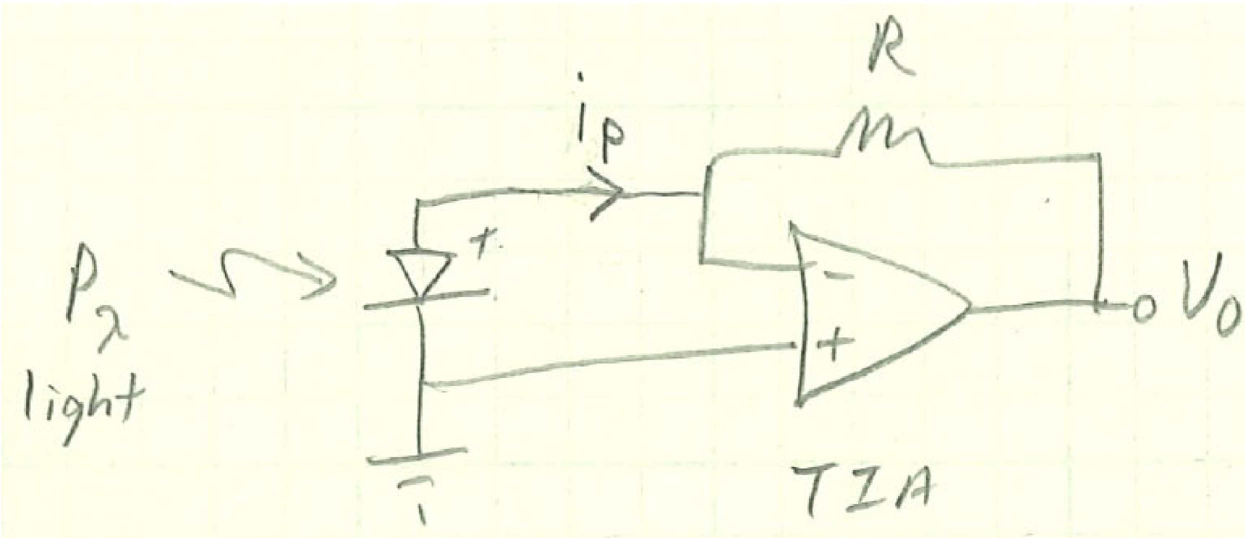
The theromocouple only produces a small current before the output voltage drops. So, a high impedance voltage meter is needed to accurately read it.

Thermocouples can be made in macroscale or in microscale (on chip) technologies.

Sensor Methods: Current Sensing

Some sensors directly produce a current that is a function of the measurand. One example is a photodiode.

This photodiode is interfaced with a TIA to produce an output voltage:



i_p is the diode photocurrent and i_p is proportional to light intensity, P_λ.

$$V_o = -Ri_p$$

A photodiode can be a pn junction diode structure or a Schottky diode structure (a p- or n-type semiconductor material in contact with a conductor) with exposure to light. Observe that positive current (the photocurrent) flows out of the anode.

Note: on a MEMS device where doped Si is in contact with a metal layer, exposure to light can generate a light-induced current into the device, which may or may not be problematic.

A photovoltaic cell (i.e. a solar cell) is a very large area pn junction diode.