



HALL EFFECT MEASUREMENT SYSTEM

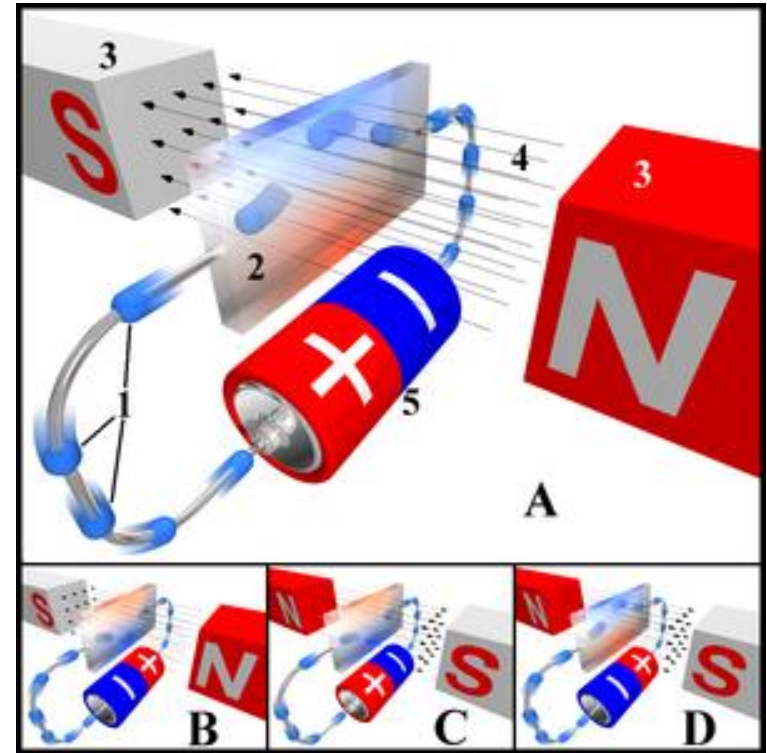
Hall and van der Pauw Measurements

The Hall Effect Measurement System



The Hall Effect

- Hall effect refers to potential difference (Hall voltage) on opposite sides of a thin sheet of conducting or semi-conducting material through which an electric current is flowing, created by a magnetic field applied perpendicular to the Hall element
- Presence of measurable transverse voltage is called the **Hall effect** after E. H. Hall who discovered it in 1879.



The Hall Effect

- Ratio of voltage created to product of the amount of current and the magnetic field divided by the element thickness is known as the Hall coefficient
 - Characteristic of the material
- Conduction phenomenon
 - Different for different charge carriers
- Hall voltage has a different polarity for positive and negative charge carriers
 - Used to study the details of conduction in semiconductors and other materials which show a combination of negative and positive charge carriers.

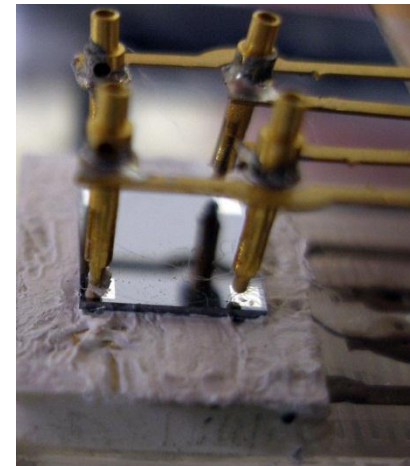
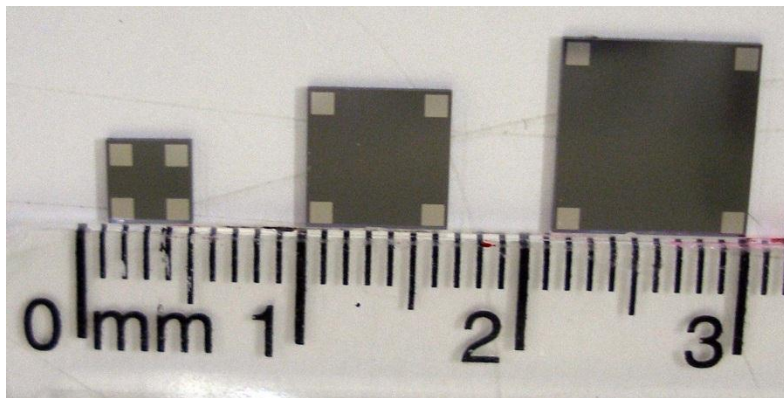
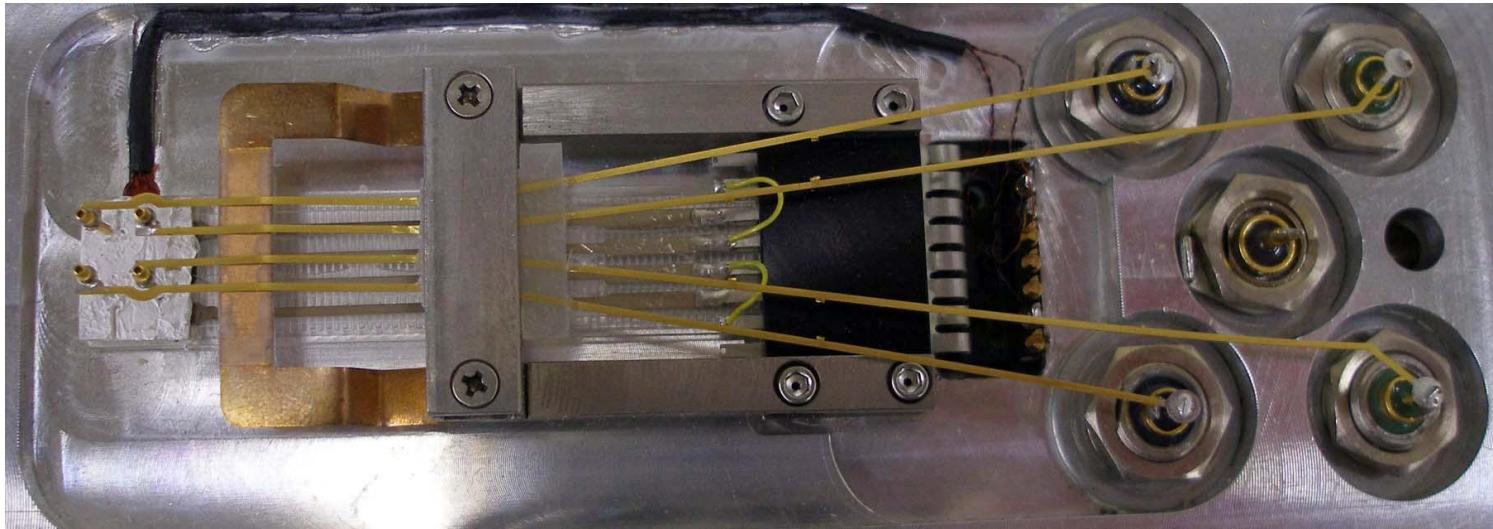
The van der Pauw Method

- Characterizes a sample of semiconductor material
 - can be successfully completed with a current source and a voltmeter.
- From the measurements made, the following properties of the material can be calculated:
 - The sheet resistance, from which the resistivity can be inferred for a sample of a given thickness.
 - The doping type (i.e. if it is a P-type or N-type) material.
 - The sheet carrier density of the majority carrier (the number of majority carriers per unit area).
 - Density of the semiconductor (doping level) can be found for a sample with a given thickness.
 - The mobility of the majority carrier.

Taking Measurements

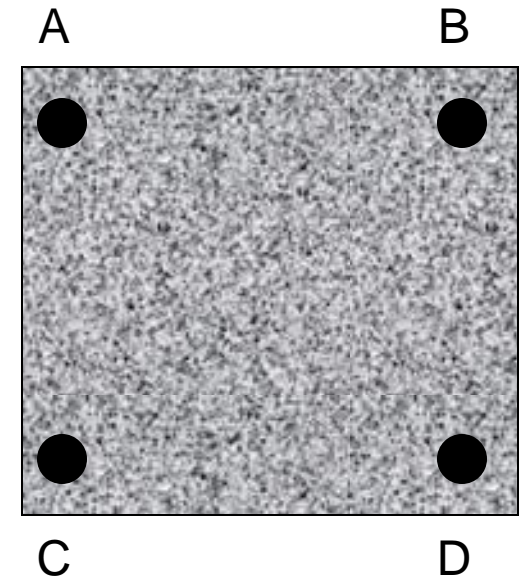
- Measurements require four ohmic contacts on the sample:
 - On or as close to sample boundary as possible
 - Infinitely small
 - Error is given by D/L
 - D = average diameter of contact
 - L = distance between contacts
 - Leads from contacts should be of the same batch of wires to minimize thermoelectric effects
 - All four contacts need to be same material

Taking Measurements



Taking Measurements

- Current I_{AB} is a positive DC current measured in amperes (A)
 - Injected into contact A
 - Take out of contact B
- Voltage V_{CD} is a DC voltage (V)
 - measured between contacts C and C with no externally applied magnetic field
- Sheet Resistance, R_S , is measured in Ohms (Ω)



Taking Measurements

➤ Ohm's Law:

$$R_{AB,CD} = V_{CD} / I_{AB}$$

➤ calculates the resistance along one edge

e.g. Vertical edge: $R_{AC,BD}$ and Horizontal edge: $R_{AB,CD}$

➤ Actual sheet resistance is related to these resistances by the van der Pauw formula:

$$e^{\left(\frac{-\pi R_{AB,CD}}{R_s}\right)} + e^{\left(\frac{-\pi R_{AC,BD}}{R_s}\right)} = 1$$

➤ Obtain a more precise measurement of R_s by taking several reciprocal measurements and averaging

Hall Measurements

- When a charged particle (e.g. electron) is placed in a magnetic field, it experiences a Lorentz force proportional to the strength of the field and the velocity at which it is traveling through the field.
 - Force is strongest when the field is perpendicular to the direction of motion.
- Applying a current results in a steady flow of electrons through the material
 - Applying an external magnetic field will result in an accumulation of electrons at one edge of the sample
 - Creates a potential difference across the material

Hall Measurements

- Magnitude of the Hall voltage (V_H):

$$V_H = \frac{IB}{qn_s}$$

- I = current (A)
- B = strength of magnetic field
- q = Elementary Charge (1.602×10^{-19} coulombs)
- n_s = sheet density of the majority carrier

Making the Hall Measurements

- Two types of measurements need to be made:
 - One in a magnetic field in the positive field direction
 - One in a magnetic field in the negative field direction
- Constants:
 - Direction of magnetic field
 - Magnitude of injected current
- Overall Hall voltage can be calculated
 - Polarity of the V_H indicated the type of material
 - Positive = P-Type
 - Negative = N-Type

Components in a Hall System

- Pure high-pressure gas (greater than 1800 psi)
 - Gas Lines, Pressure Gauge, etc
- Filter/Dryer Apparatus
- Refrigerator
- Computer (not included)
- Temperature controller
- Circuit Breakout Box
- Vacuum Pump (not included)
- Hall Vacuum Chamber
- Hall Electronics and Software
- Magnet (optional)
- Magnetic Power Supply (optional)

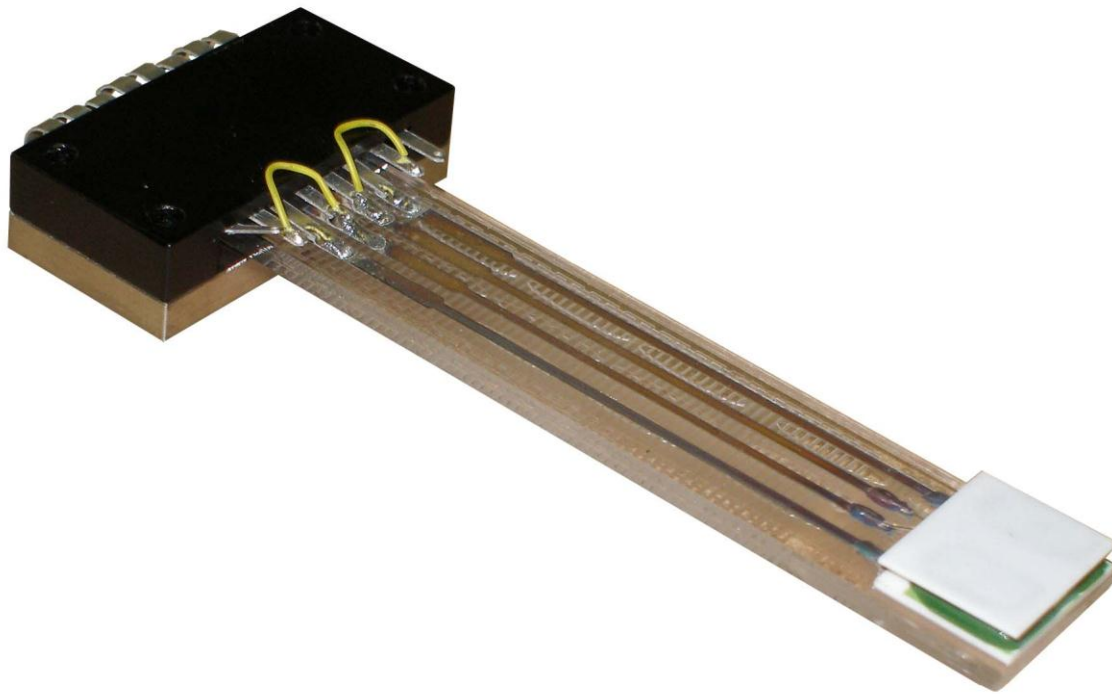
Gas, Lines, Gauges, etc

- 99.998% Prepurified Nitrogen at 2640 psi or higher
- High Pressure Nitrogen Regulator
- High Pressure Nitrogen Lines (supplied)
- Gas Flow Meter (supplied)

Filter/Dryer Systems



The Joule-Thomson Refrigerators

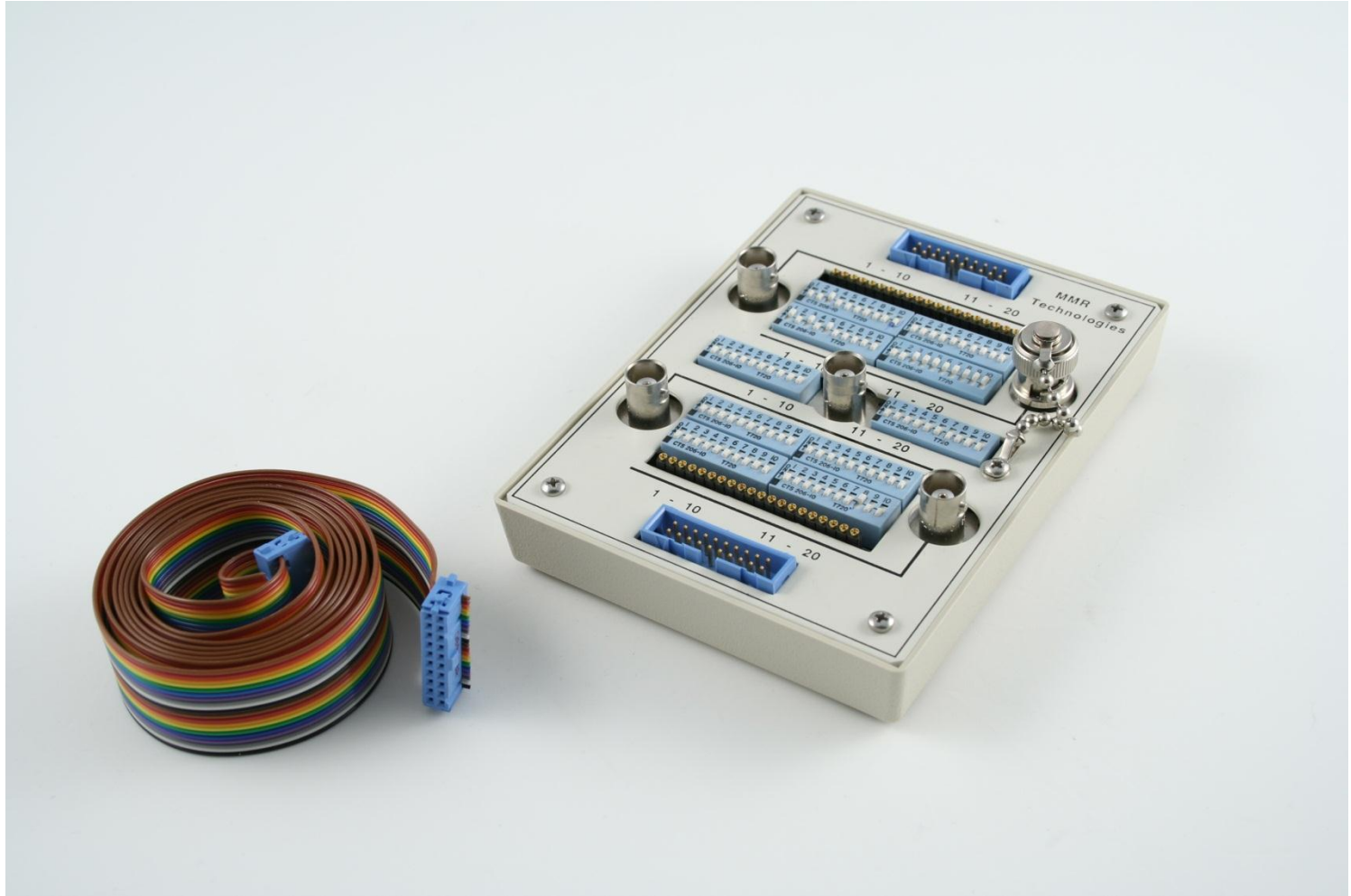


R2500-XX

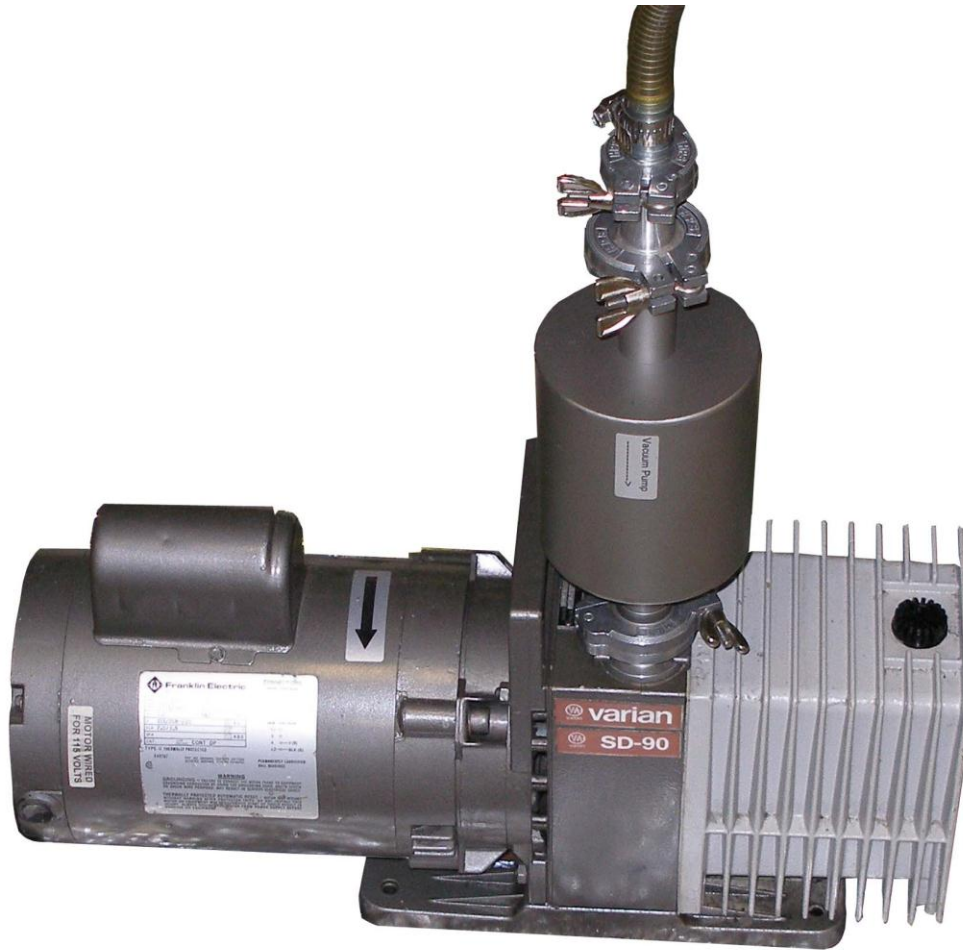
Computer System

- Pentium Processor, 1 GHz minimum
- CD-ROM Drive (4x)
- 250 MB RAM
- 50 MB free on hard drive
- 2 RS232 Serial Ports

Circuit Breakout Box



Vacuum Pump and Accessory Kit



Hall Vacuum Chamber



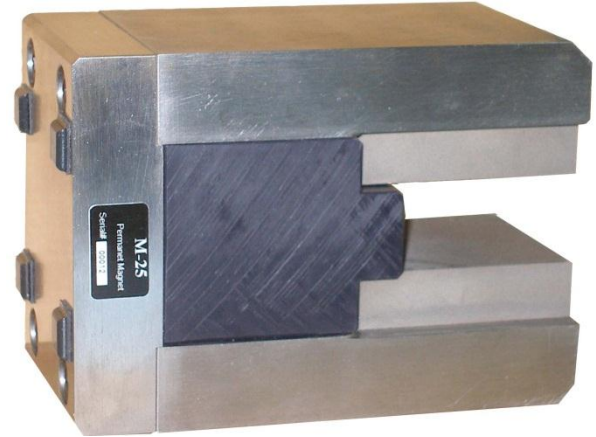
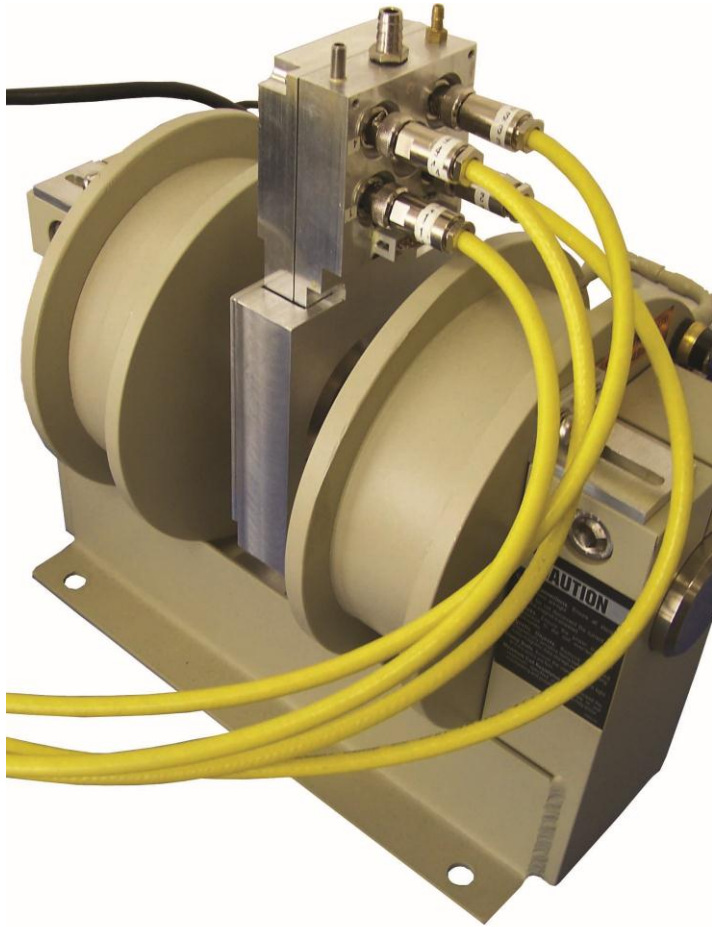
Spring-Loaded Probes



Hall Electronics



Magnets and Power Supplies



Possible Temperature Ranges

Kelvin Scale

- 70 K to 580 K
- 80 K to 580 K
- 70 K to 730 K
- 80 K to 730 K
- 300 K to 730 K

Centigrade Scale

- - 200 °C to 305 °C
- - 190 °C to 305 °C
- - 200 °C to 455 °C
- - 190 °C to 455 °C
- 25 °C to 455 °C

$$K = °C + 273$$

Why do we care about the Hall Effect?

- Hall effect devices:
 - Immune to dust, dirt, mud, water
 - Better for position sensing
- Hall sensors:
 - Can easily detect stray magnetic fields
 - Work well as electronic compasses
- Hall effect current transducers:
 - High accuracy, environmentally hardy, low power consumption
 - Ideal solution for solar energy management



THANK YOU FOR YOUR TIME AND ATTENTION

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