Radiation Thermometry

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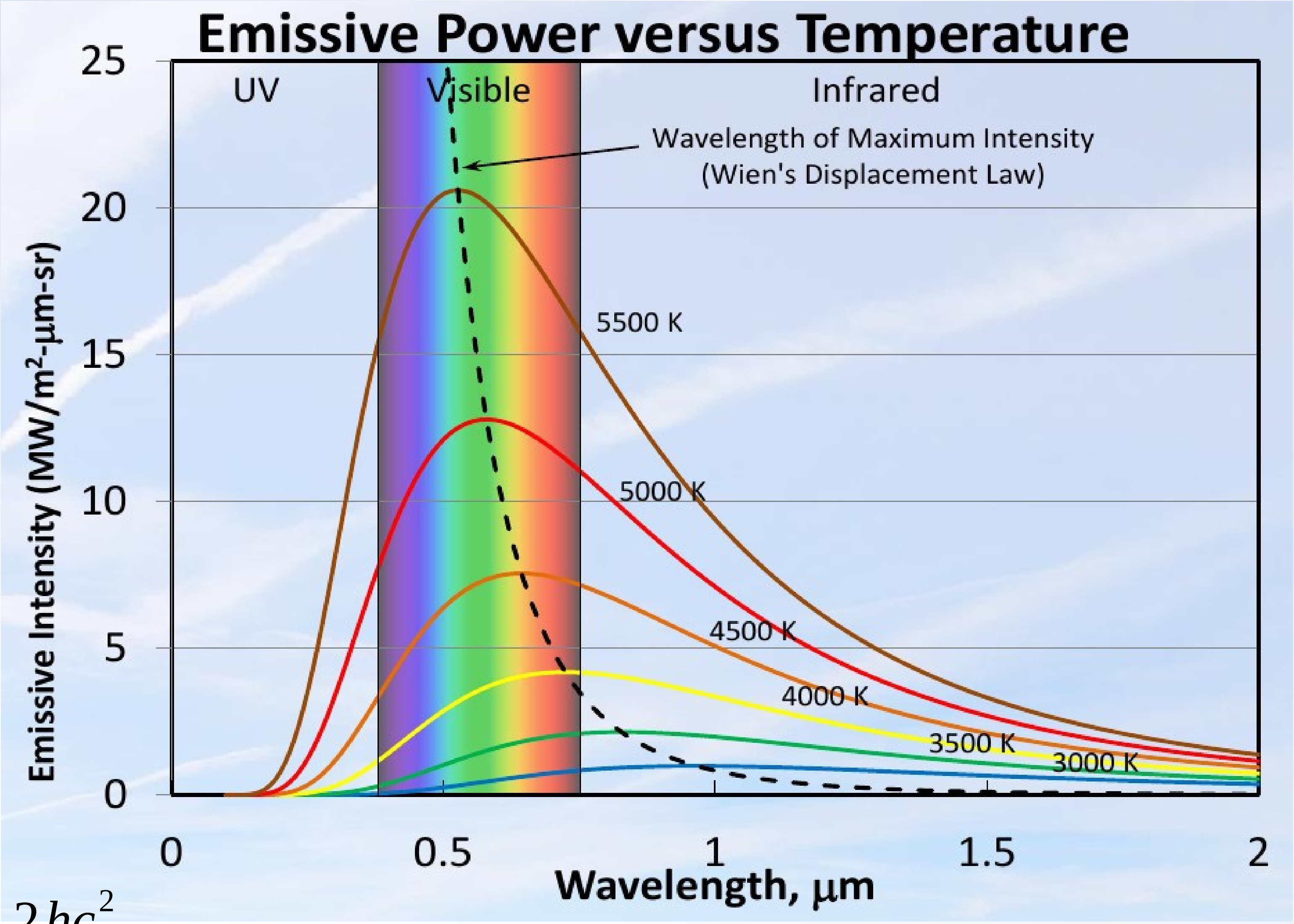
Lecture - Outline

- Radiation Thermometry
- Non-linear sensors
    - Radiation Thermometer Example
- Digitization and digital sensors

Thermometry – thermal radiation

- Non-contact measurement - necessity and advantages
- Thermal radiation and temperature (steel)
  - Bright yellow: 2000 C
  - Bright red: 1500 C
  - Red-gray: 1000 C
  - Gray: 800 C
  - Blue: 575 C
  - Purple: 520 C
  - Brown: 480 C

Thermal Emission and Temperature – Planck's Law



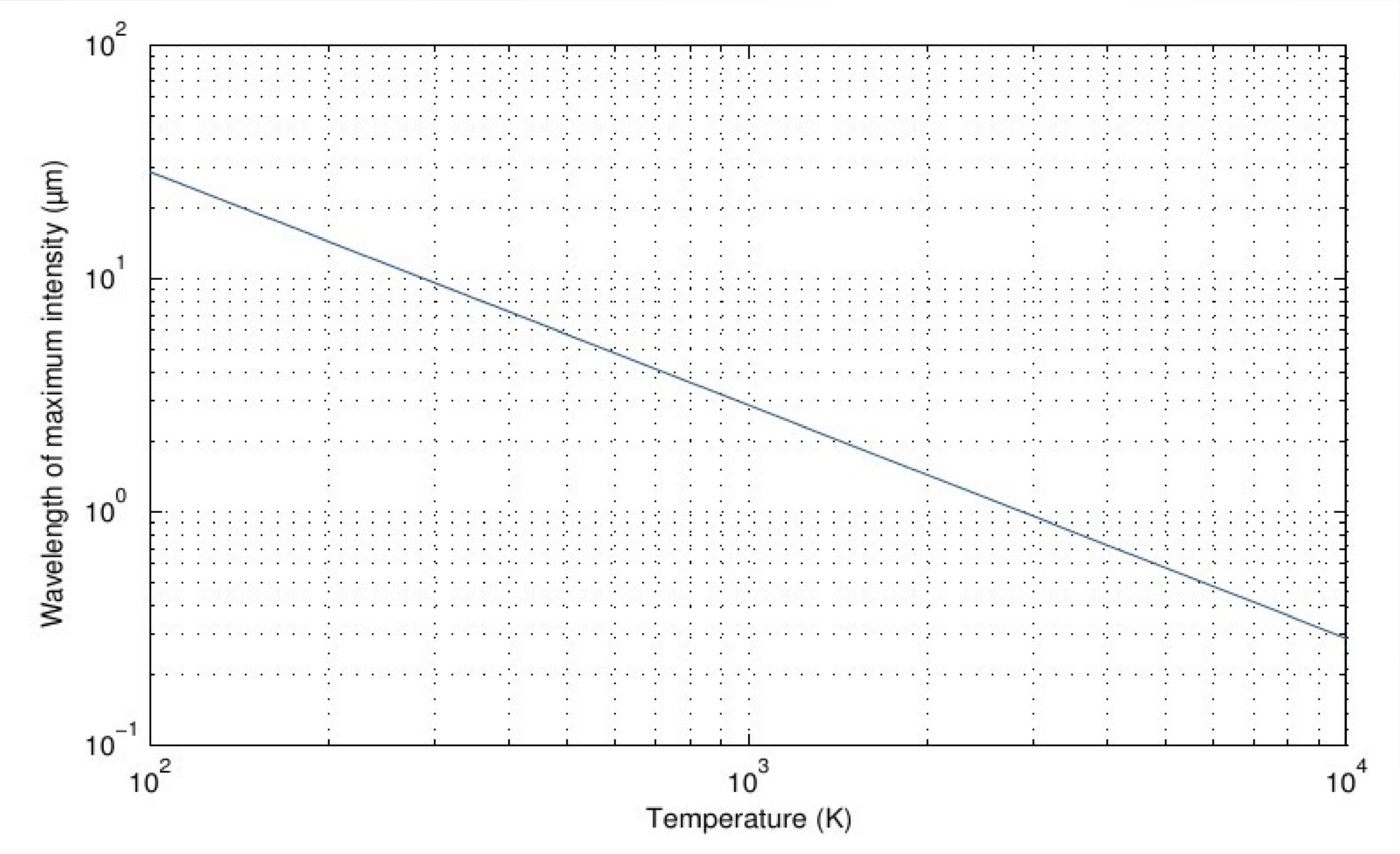
$$W(\lambda, T) = \frac{2hc^2}{\lambda^5 \left(e^{hc/(\lambda k T)}\right) - 1}$$

Ref for graphs: T.K.Risch, 2015

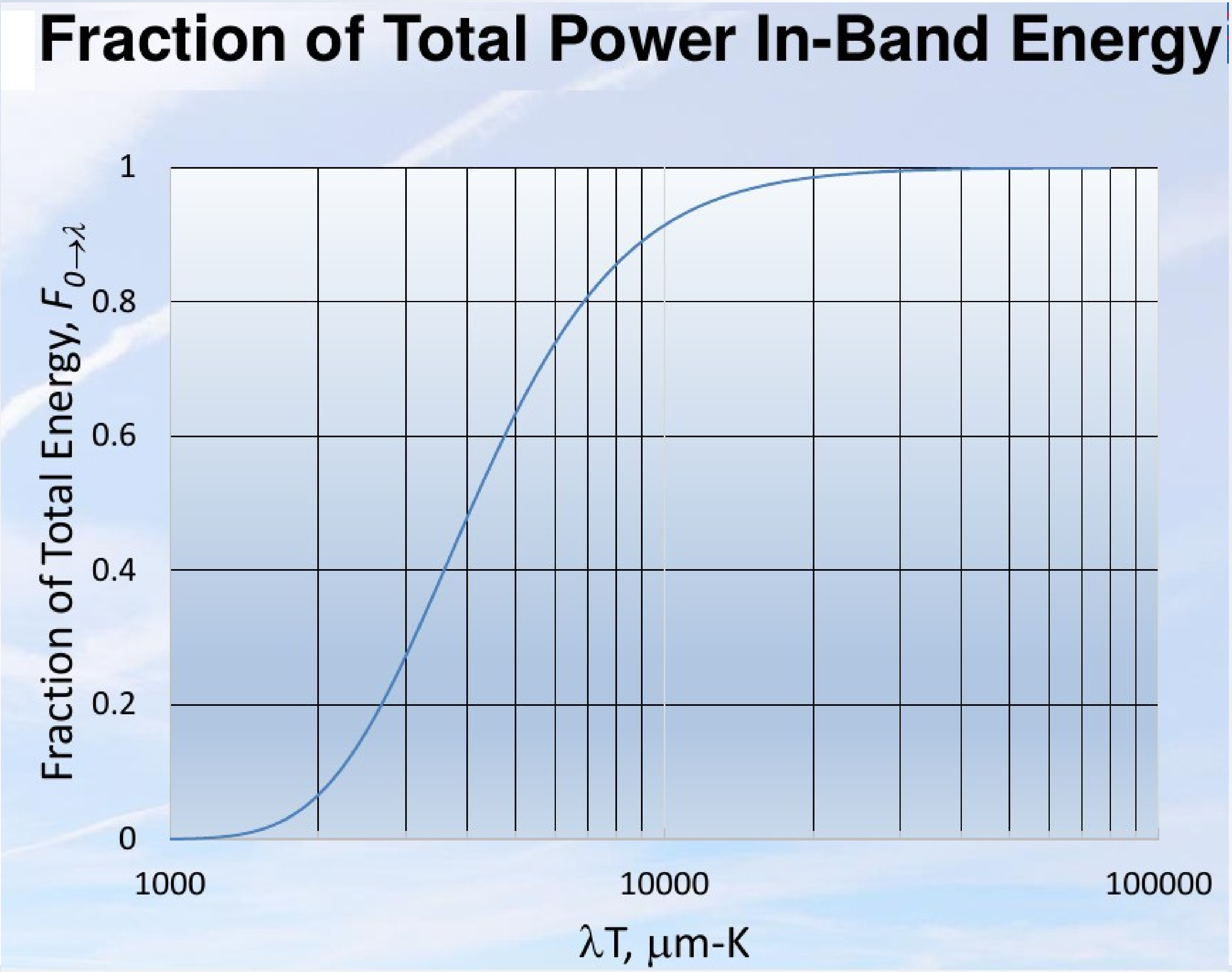
Thermal Radiation – Wien's law → peak radiation

$$W(\lambda, T) = \frac{C_1}{\lambda^5 \left(e^{C_2/(\lambda T)}\right) - 1}$$

$$\lambda_{peak} = \frac{2897}{T} \mu m$$



Fractional Thermal Power



Stefan-Boltzman Law – radiation (absorbed/emitted)

- Integrating Wien's equation can get total thermal power
  - integrate numerically
- Empirical formula by Stefan and Boltzman
- For black body, the emissivity is 1
- 'A' is a geometry factor

$$P_{tot} = A\,\epsilon\,\sigma T^4$$

$$P_{tot(blackbody)} = \sigma T^4$$

$$\sigma = 5.67037\,Wm^{-2}\,K^{-4}$$

Emissivity

- Radiated energy depends on surface properties, reflectivity
- Emissivity = Ratio of power emitted by a material to the power emitted by a perfect radiator (black body)
- Emissivity ranges from 0 to 1

Measuring thermal radiation

- Single wavelength measurement
- Two point measurement
- Multi-point spectrum measurement
  - Can estimate emissivity
- Measure Temperature rise due to absorbed energy
  - Thermocouple (thermopile)

Thermal Energy Measurement – PN jn voltage PTAT

$$V_{BE} = V_{G0}\left(1 - \frac{T}{T_0}\right) + V_{BE0}\left(\frac{T}{T_0}\right) - \left(\frac{nkT}{q}\right)\ln\left(\frac{T}{T_0}\right) + \frac{kT}{q}\ln\left(\frac{I_C}{I_{C0}}\right)$$

$$\Delta V_{BE} = \frac{kT}{q}\left(\frac{I_{C1}}{I_{C2}}\right)$$

Thermal Energy Measurement – PN jn voltage PTAT

(Proportional To Absolute Temperature)

$$V_{BE}=V_{G0}\left(1-\frac{T}{T_0}\right)+V_{BE0}\left(\frac{T}{T_0}\right)-\left(\frac{nkT}{q}\right)\ln\left(\frac{T}{T_0}\right)+\frac{kT}{q}\ln\left(\frac{I_C}{I_{C0}}\right)$$

$$\Delta V_{BE}=\frac{kT}{q}\left(\frac{I_{C1}}{I_{C2}}\right)$$

- Semiconductor PN junction voltage depends on temperature (*T*) and current (*I*)
- Using a transistor with controlled collector current, and measuring the Base-Emitter voltage, we can calculate the junction temperature
- Sometimes, two transistors with I_c in a fixed ratio is used. The difference in V_{BE} can be used.

Example of radiation thermometer

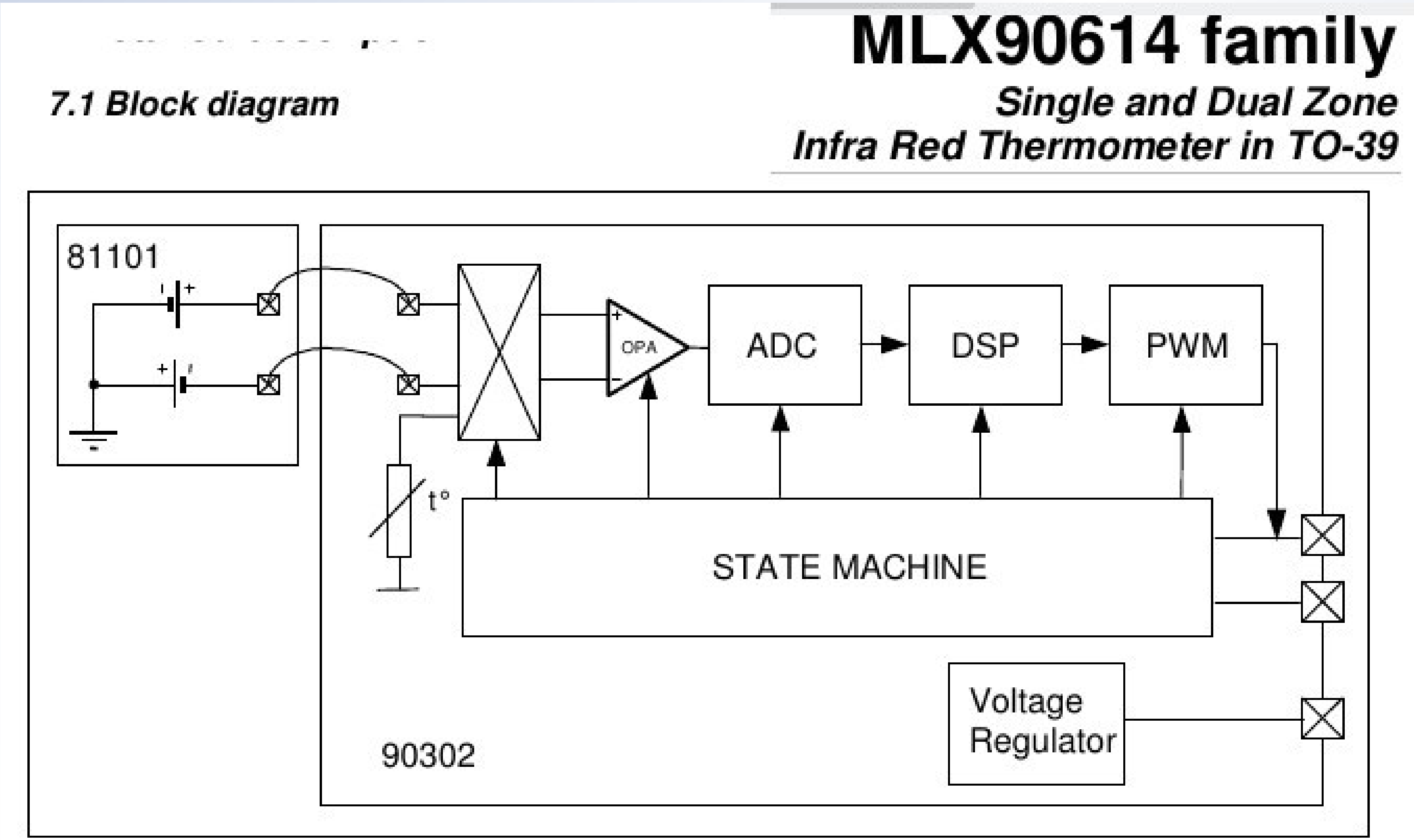


Figure 3: block diagram

Calibration of temperature sensors

- Calibrate against a known sensor
- Calibration of conductive and radiative sensors
- Standard Black-body - cavity

Applications of radiation thermal sensors

- Single point measurement
- Infrared arrays/scanners for thermal photography
- Superimposition of thermal and visible light images
- Insulation testing of thermal vessels in power plants
- Insulation testing of buildings
- Mapping Heating and Energy loss in electronic and mechanical systems
- Human body temperature measurement
    - Use laser beam to show area of measurement

Measuring Human temperature

- Thermoregulation in animals and humans
  - Maintenance of core temperature
  - controlled by the hypothalamus
- Alteration in thermoregulation – fever
- Estimation of core body temperature
  - Sub-lingual, axillary fossa
  - Forehead – convenience
- Mass screening for individuals with fever

End of Lecture