Infrared Temperature Sensor

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Traceable® Infrared Thermometer Gun

Extech IR270

How does IR thermometry work?

- All objects emit infrared radiation
- Thermal energy is emitted in the 6μm to 12μm range of the IR spectrum
- IR thermometers have:
  - a **sensing element** that takes incoming IR and converts it to an electrical signal
  - a **signal conditioning** circuit processes that signal and converts it into a more usable form

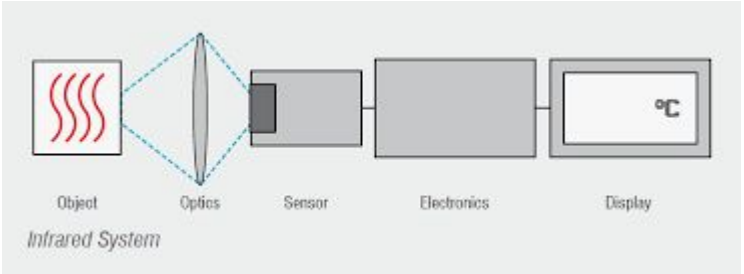


Image from Automation Forum user sivaranjith

Block Diagram

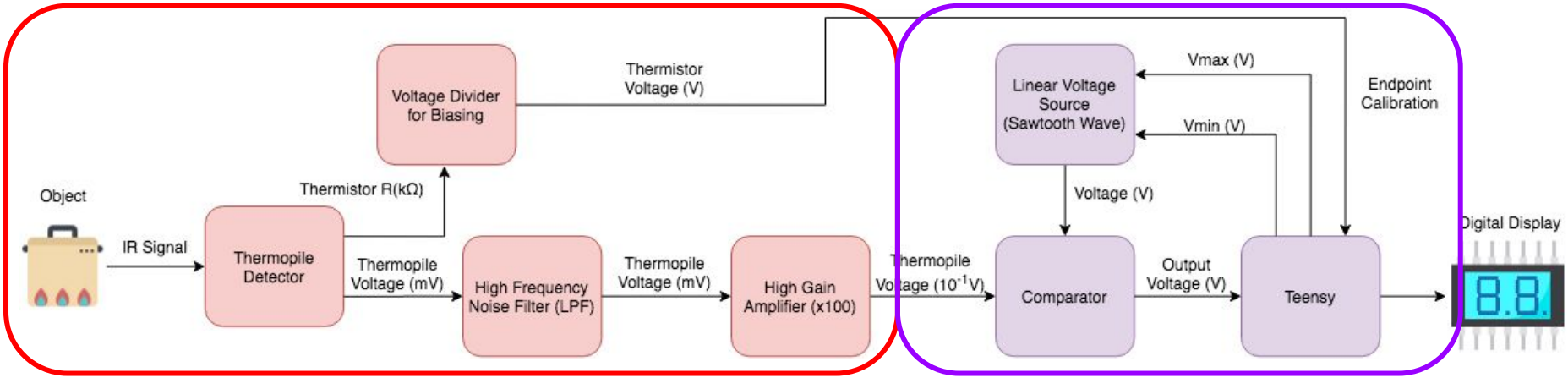


Diagram made w/ draw.io
Display icon made by Payungkead from flaticon.com

Sensing Element: the Thermopile

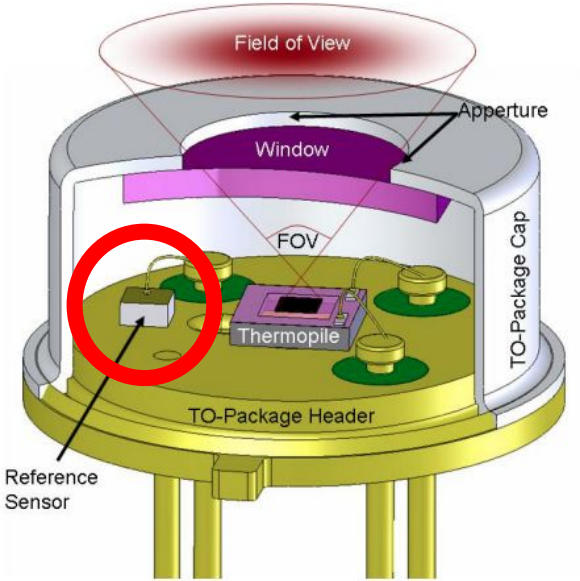
- A **thermopile** generates a voltage proportional to the temperature difference between its conductors
- Most sensor packages come with signal conditioning
- We opted for a minimalistic sensor

ZTP-148SR

Image taken from Digi-Key

Reference Sensor

- Thermopile voltage is a **differential** temperature measurement
- To isolate object's temperature, we need the reference temperature (temperature of the sensor package)
- For the ZTP-148SR, the reference sensor is a **thermistor**



Cross section through thermopile sensor from "Thermopile Sensor for Contactless Temperature"

The Thermistor

- A **thermistor**'s resistance is dependent on the temperature of the sensor package
- Use Teensy to calculate reference temperature from thermistor resistance

$$R = R_{25}e^{\beta(\frac{1}{T}-\frac{1}{T_{25}})}$$

Tambient (kΩ)	Rmin (kΩ)	Rcent (kΩ)	Rmax (kΩ)
-20	893.8	942.3	992.6
-15	677.7	712.5	748.4
-10	518.2	543.3	569.2
-5	399.4	417.6	436.4
0	310.1	323.5	337.1
5	242.6	252.4	262.4
10	191.1	198.3	205.7
15	151.5	156.9	162.3
20	120.9	124.9	128.9
25	97.00	100.0	103.0
30	77.97	80.55	83.15
35	63.03	65.25	67.50
40	51.22	53.14	55.09
45	41.85	43.50	45.18
50	34.36	35.79	37.24
55	28.35	29.58	30.84
60	23.49	24.56	25.66
65	19.56	20.49	21.44
70	16.35	17.16	17.99
75	13.73	14.43	15.15
80	11.57	12.18	12.81
85	9.79	10.32	10.88
90	8.313	8.781	9.267
95	7.085	7.495	7.923
100	6.058	6.420	6.796

Thermistor resistance chart from ZTP-148SR datasheet

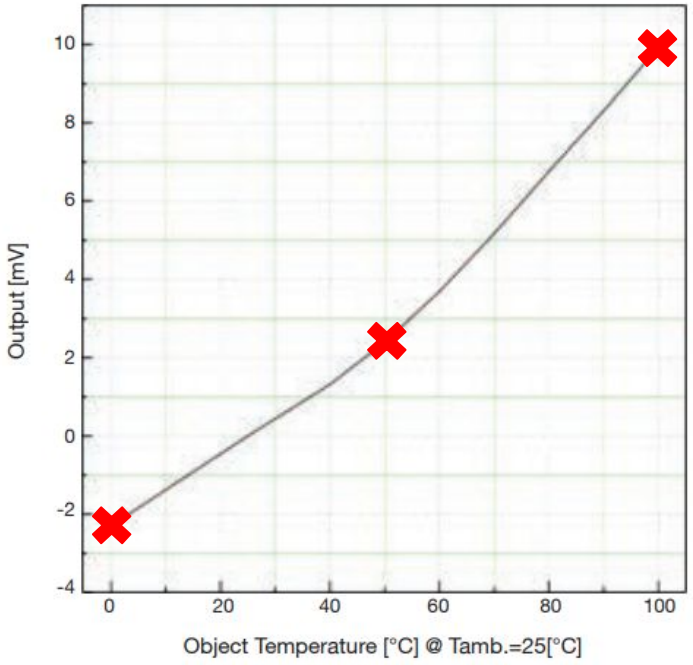
Signal Conditioning

Problems with output thermopile voltage		Solutions
1. It is **noisy**	→	1. Low pass filter
2. It is **small** (on the order of millivolts)	→	2. High gain amplifier
3. It is a **nonlinear** function of temperature	→	3. Linearization circuit

Linearization: Piecewise Linear Voltage Source

- For limited ranges, thermopile voltage vs. object temperature is approximately linear
- Generate a piecewise linear voltage waveform based on the sawtooth circuit for temperatures [0℃, 50℃] and [50℃, 100℃]
- Use Teensy to calculate the voltages for the endpoints of the ranges

$$V_{endpoint} = A(T^4_{endpoint} - T^4_{ref})$$

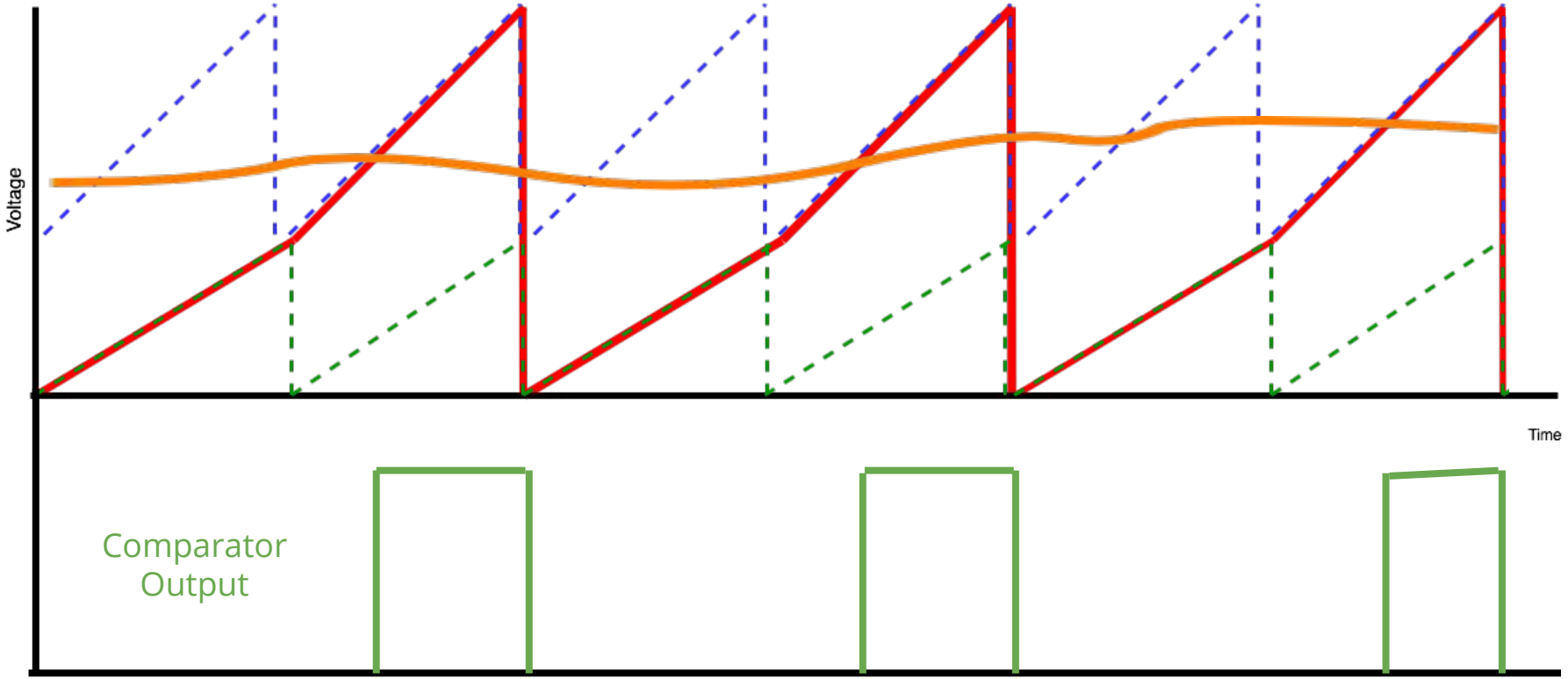


Thermistor characteristic from ZTP-148SR datasheet

Linearization: Comparator

PWLVS

Thermopile Voltage



Timeline

Week 1 (4/20): Thermopile and Reference Sensor, Filtering, Amplification simulation

Week 2 (4/27): Linear Voltage Source, Comparator, and Display simulation

Deadline 5/1: PCB Layout

Week 3 (5/4): Assembly and Testing (Breadboard)

Week 4 (5/11):