Infrared Temperature Sensor

6.101 Final Project Abstract
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Overview

The goal of our project is to build an infrared laser thermometer. Laser thermometers use infrared sensors to measure the energy emitted by the surface of an object. IR thermometers are used in medical, industrial and home settings for a wide variety of applications. We seek to deconstruct a seemingly simple commonly used object to understand the underlying mechanisms and science that allows for us to perform safe sensing from a distance. We have determined that there are five core stages that will allow us to perform temperature sensing. Our project aims to go a step beyond basic sensing and achieve a decent level of accuracy by taking into account not only the amount of energy being emitted by the object we are sensing, but also the IR energy in the ambient environment.

Underlying Science

Infrared radiation is a form of electromagnetic radiation. This form of energy is given off by all objects. Unlike visible light our eyes cannot see infrared light, however, we are able to feel it on our skin and this creates a feeling of heat. A higher intensity of IR light (the amount of energy being radiated from a source) is indicative of a higher temperature. We are using a sensing element to turn this emitted energy into an electrical signal. There are five types of infrared radiation and of those five we are interested in capturing long-wavelength and the higher portion of mid-wavelength infrared. Most common household thermometers that are used for either human temperature sensing or for culinary applications detect radiation that has a wavelength of between around 5µm to 14µm. For our project we're to detect temperatures in the range of 0℃ to 100℃ which corresponds to about a 6µm to 12µm wavelength.

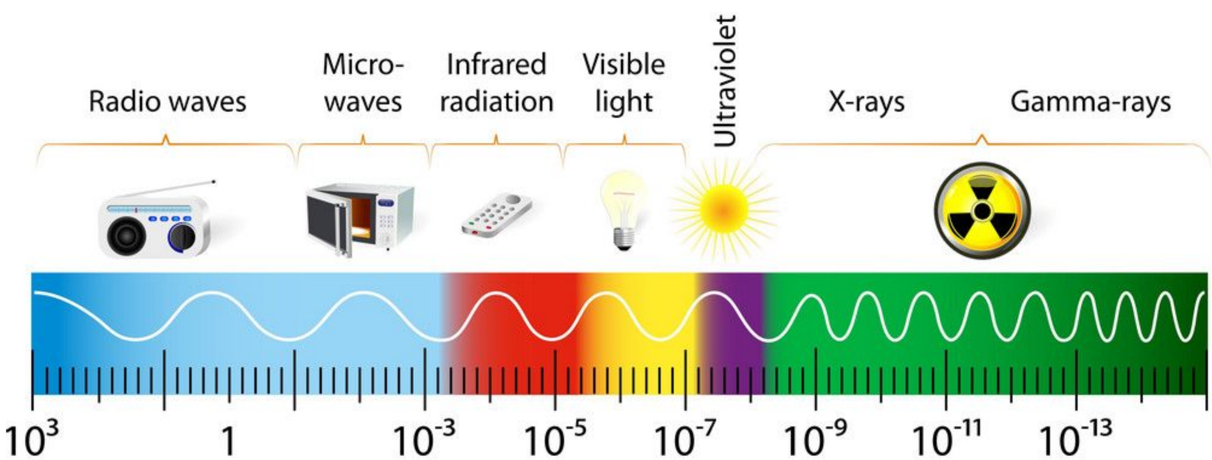

Figure 1. The electromagnetic spectrum which shows the general wavelengths of IR light

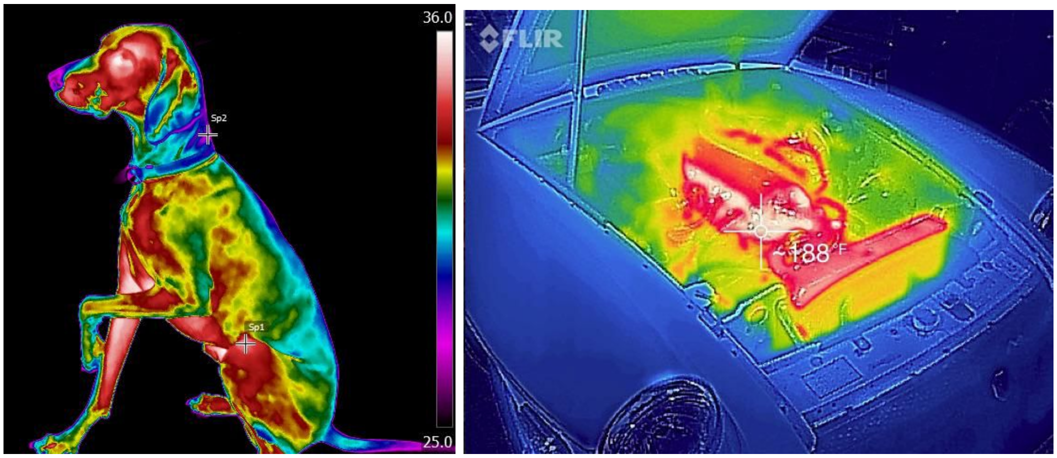

Figure 2. Thermal imaging showing the infrared radiation from a dog and a car engine

IR Detector

As mentioned in the previous section, we are looking to detect infrared signals with a wavelength in the range of roughly 6μm to 12μm. There are many different kinds of IR sensors, but in order to sense this range of energy we must use a thermopile sensor. A thermopile sensor absorbs IR energy. The detector's properties then change and the thermopile generates a thermoelectric voltage on the order of millivolts. We plan on using a ZTP-148SR thermopile IR sensor due to its 0℃ to 100℃ range and it's simple input to output. Most thermopile sensors have pre-integrated signal conditioning however we want to design our own signal conditioning circuit to optimize the output. If we cannot obtain a ZTP-148SR, we will use a ZTP-115M module since it is currently one of the cheaper and more widely available thermopile sensors. The ZTP-115M already comes with signal conditioning circuitry which we will not use if we decide to purchase this component.

Filtering & Amplification

For the ZTP-148SR there is a typical noise voltage of 37nV RMS. This noise can be modeled by a voltage source. We plan on using a simple first order RC circuit to filter out any high frequency AC noise. This will allow us to gather clean measurements that don't experience a lot of fluctuation. Depending on what kind of noise we witness, we may add additional filtering stages.

We will use a simple inverting op amp configuration in order to increase the magnitude of the voltage coming from the thermopile. Since the range of voltages that we can expect from the thermopile is in the range of -2mV to 10mV we will magnify the voltage by at most 100x and add an offset voltage before amplification so that we will be working exclusively with positive voltages. This offset voltage, although not necessary, will make the later stages of signal processing simpler.

Emissivity Calibration (Differential Input)

In order to account for the emissivity of different objects, we need to compare the voltage from the sensed object against the voltage from the surroundings. Generally this emissivity is at around 0.97. We can combine the two voltages in a ratio in order to obtain an output voltage that relates more closely to the temperature of the object we are trying to sense.

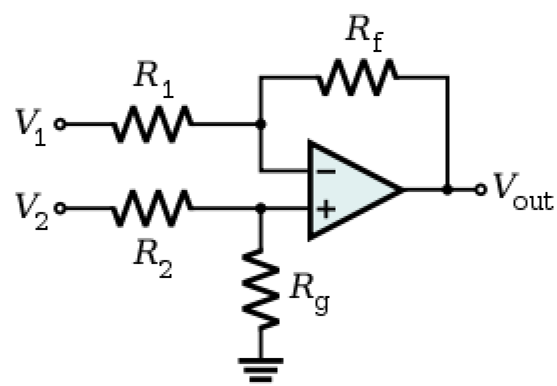

Figure 4. General differential op amp circuit layout

Calibration Loop (Comparator)

In order to identify what temperature corresponds to the output voltage, we are going to linearize the circuit by using a calibration loop. We will create a model in matlab for the thermopile's voltage to temperature response. We will use the Teensy 3.2 to provide a reference voltage and act as a linear voltage source. This voltage will be compared against the voltage output by the differential op amp circuit using a comparator. When the two voltages are equal we will see the output of the comparator change from negative to positive as we continue to step through the voltages. Once this rise is detected, we know to display the corresponding temperature on the screen.

ADC

In order to convert the voltage into a signal that can be displayed on a digital screen, we must use an analog to digital converter (ADC).

In order to sidestep this need to design and build an ADC, we plan to use the Teensy 3.2 to perform the analog to digital conversion. The Teensy has a 10 bit ADC. We can use Pedvide's ADC library in order to perform the appropriate conversions to decipher the analog signal. We will then process the digital signal and display it on either a TFT display or an OLED LCD display.

Assignments

Elaine: Filtering & Calibration Loop
Kika: Detector, Amplification, ADC, Differential Input

Timeline

Week 1 (4/20): Detector, Filtering, Amplification simulation

Week 2 (4/27): Differential Input and Calibration Loop simulation

Week 3 (5/4): PCB Design

Week 4 (5/11): Assembly and Demo!

Block Diagram