Optimal Operating Temperature of a Solar Thermal Stirling Engine

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Introduction

Goal: *Explore the relationship between the operating temperature and energy production of a simple heat engine powered by the sun.*

Stirling engines

- Simple external combustion heat engine
- Alpha-type Stirling engines (Fig. 1) – used in experiment
  - Two cylinders attached to (e) flywheels with (d) 90 degrees phase difference and connected by a (c) tube which allows air to flow between the (a) cold cylinder and (b) hot cylinder.

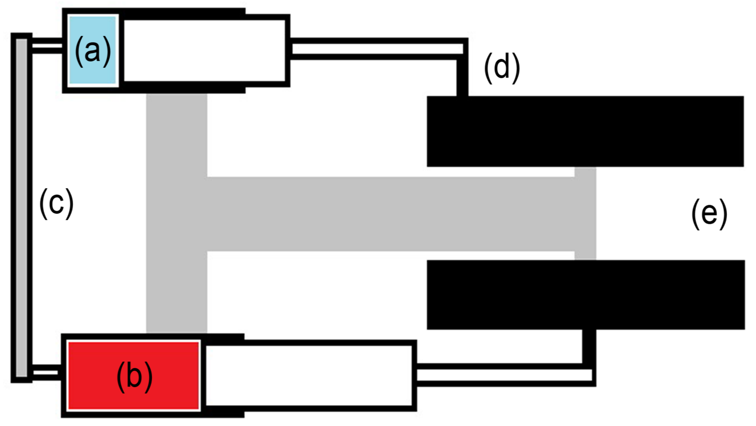


Figure 1. Alpha-type Stirling engine.

Figure 2. Ivanpah Solar Power Facility, CA.[2]

Solar thermal electricity

- Temperature differential created by solar thermal energy
- Current power plants:
  - Small scale: Parabolic mirrors heat a liquid salt solution which flows to a boiler, produces steam, runs a turbine, and generates energy.[3]
  - Large scale: Ivanpah Solar Power Facility in California (Fig. 2) uses arrays of thousands of mirrors to focus sunlight to a single tower which houses the pipes where the liquid solution flows to produce energy.[1]

Significance:

It is essential that alternatives for electricity production are researched and tested in order to improve efficiencies, reduce the cost of renewable energy, and be more environmentally friendly.

Materials

a) Alpha-type Stirling engine (made by Sunnytech)
b) Fresnel lens – solar collector (not pictured)
c) Arduino UNO microcontroller board
d) K-type thermocouple & Arduino MAX6675 module
e) Brushless DC motor
f) Adafruit ADA254 MicroSD card breakout board
g) Arduino LCM1602C 16x2 LCD screen
h) IC74HC595N 8-bit shift register

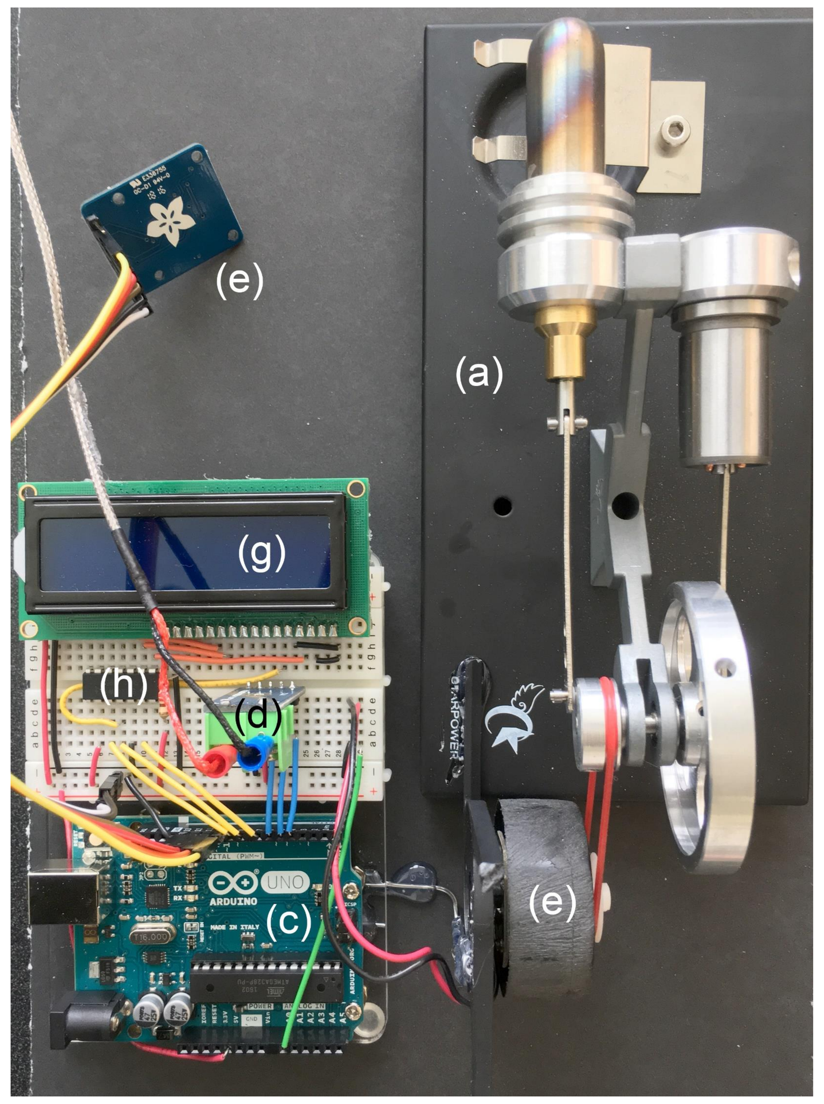


Figure 3. Stirling engine and data collection setup with labels as described above. Fresnel lens not shown.

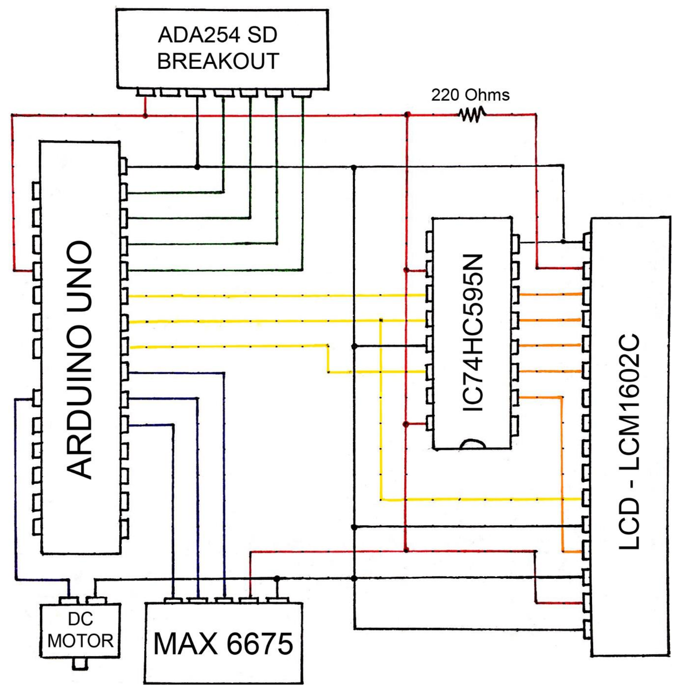


Figure 4. Circuit diagram of electronics involved with collecting data.

Methods

Arduino UNO
Data processing

Modified PC fan
Alternator

Thermocouple
High temp. data

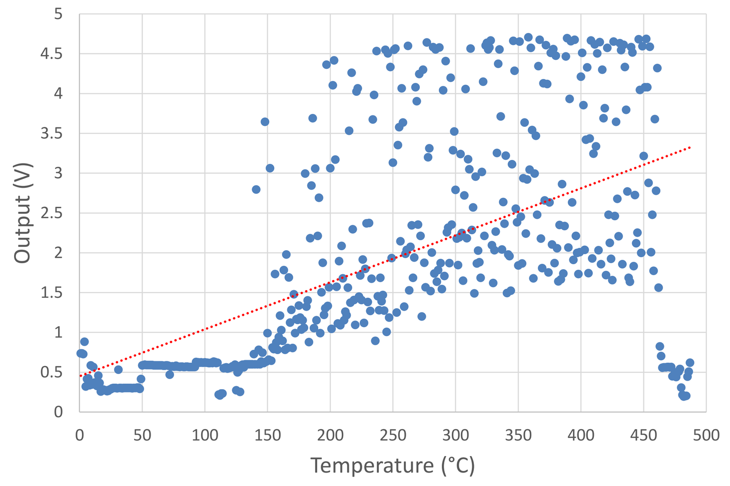
Fresnel lens + apertures
Solar collector which allows for change in the amount of light to manipulate temperature

ADA254 MicroSD board
Data recording

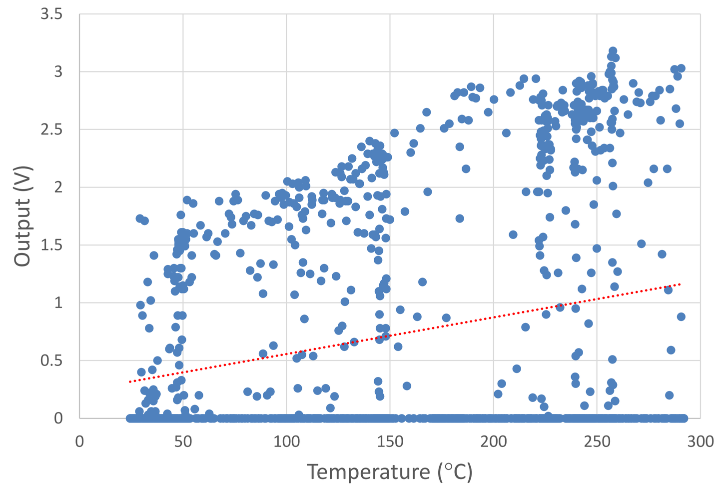
LCD + shift register
Live data readout

Results

- Graph 1 – First data set
  - Spike in engine output can be seen around 175°C
  - Output decreases exponentially to a rough plateau
  - T > 475°C: data lacks real output due to disconnecting motor from flywheel
- Graph 2 – Second data set
  - Odd zero-output data



Graph 1. Initial data with linear best-fit line with slope = 0.0059 V/°C.



Graph 2. Second data set with linear best-fit line with slope = 0.0032 V/°C.

Discussion

Uneven alternator output	⇨	Varying rotational speed or Belt slippage
Graph 1: Sharp rise in output	⇨	Greater thermal energy gives exponentially more output
Graph 2: Fairly linear output increase	⇨	• Disregarding zero-output data for now • Lower minimum operating temperature to run engine • Groupings of data points

Future Work

- Wire DC motor in series with capacitor to avoid large drops in output
- Measure angular velocity of the flywheel without a load (i.e., the alternator assembly)

Contact

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References

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