# Skycam temperature regulation

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# 1. Problem, causes and chosen solution

## *1.1. Problem*

Dew appears in the dome when temperature gets under 10-15°C. This makes fireball tracking impossible.

## *1.2. Causes*

The appearing of due is fixed by 3 parameters
-humidity
-temperature
-air pressure

-Not much can be done about air pressure
-However humidity can be brought down by adding humidity absorbers such as silica gel or rice, and closing the system in a very dry place and making sure it is as hermetically closed as possible.
-Temperature can easily be brought up by heating resistors

## *1.3. Chosen solution*

-The chosen solution was to add resistive heating elements in the skycam, in order to bring the temperature up over the dew point.

-In order to reduce power consumption, a temperature regulation system was made so that the heating is only made when necessary, and does not require a manual operation.

-Silica gel was also added in an attempt to reduce the relative humidity.Skycam system

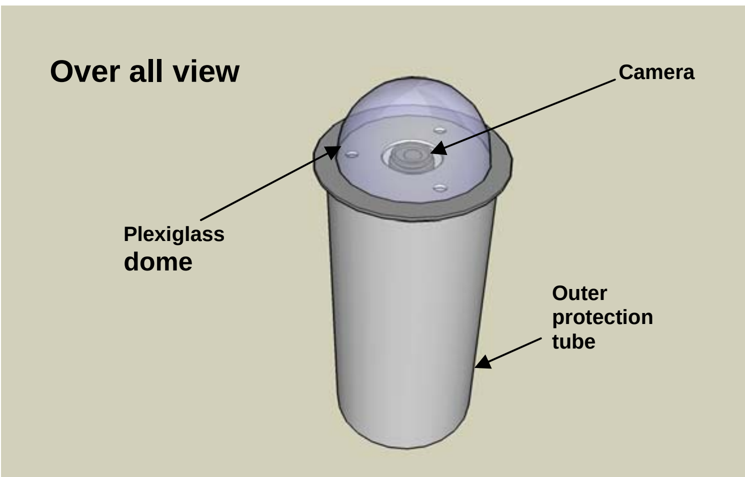
# 2. Skycam system

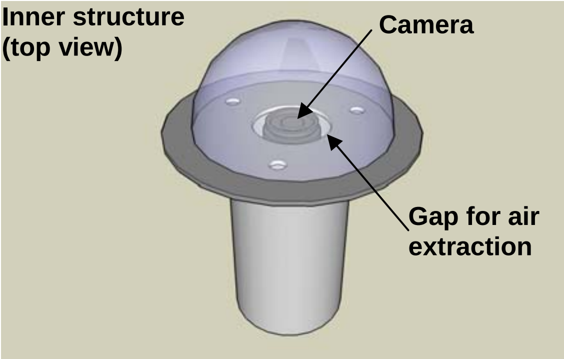
## *2.1. Quick presentation*

The skycam is a ultra sensitive camera with a fish eye objective, mounted in a mechanical structure and placed in order to look straight up at the sky and cover a maximum area.

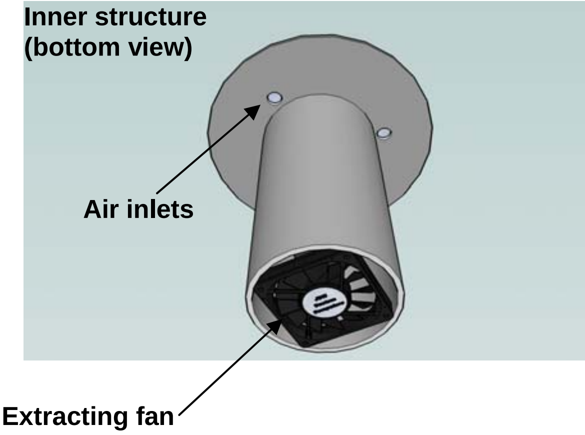
It is coupled with a computer and video analysing software which looks for traces of meteorites on the recorded video. If 3 or more cameras are coupled the trajectory can be calculated and eventually if the meteorite falls on earth the landing point can be found in order to go and fetch it.

## *2.2. Skycam structure*

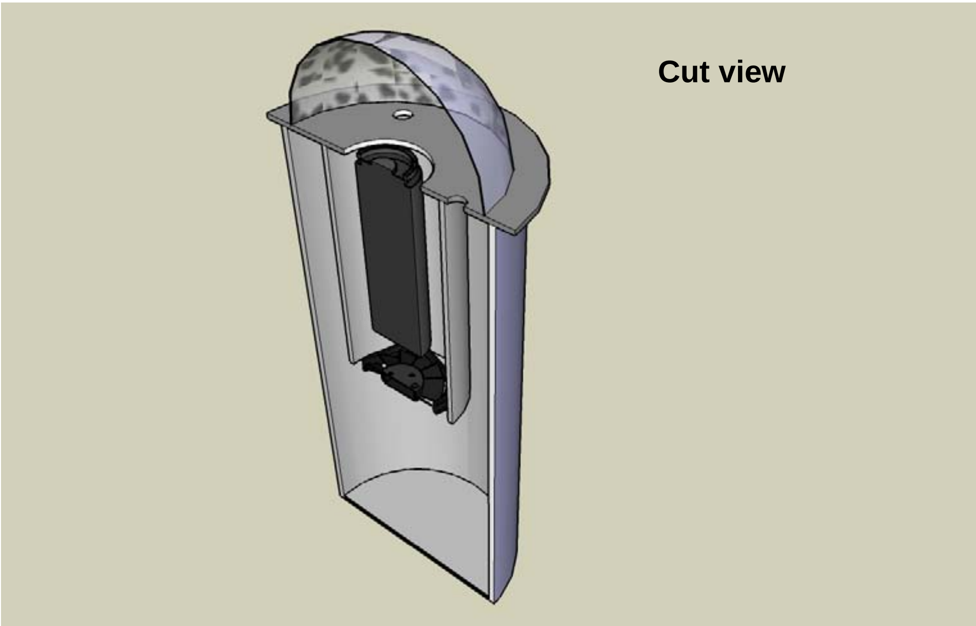




Inner structure
(top view)
Camera
Gap for air
extraction

Inner structure
(bottom view)
Air inlets
Extracting fan

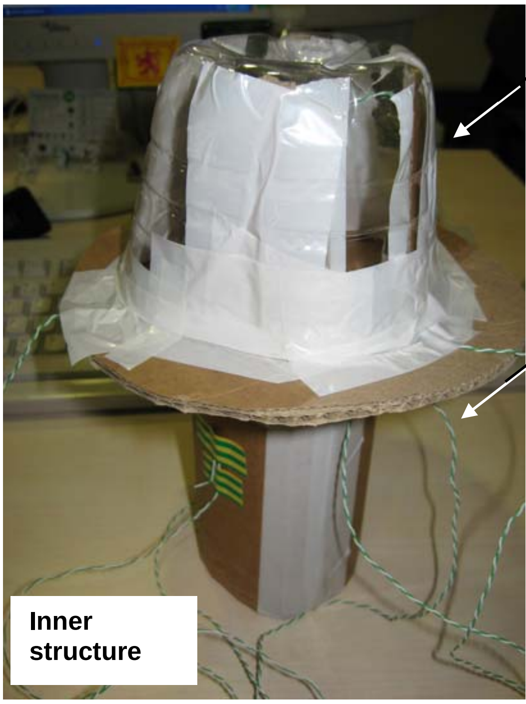



Cut view

# 3. Skycam model and thermal tuning

In order to fine tune the required power, and air flow system, a cardboard model of the Skycam was made, and measurements in a temperature controlled environment where done.

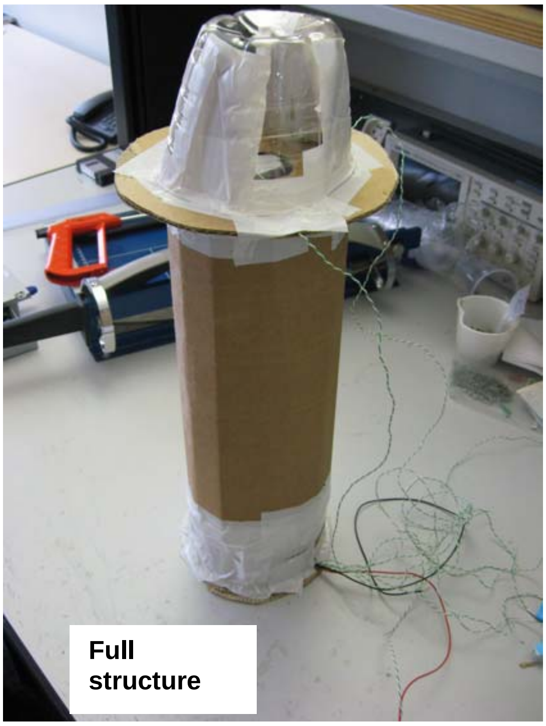
## *3.1. The model*



Dome

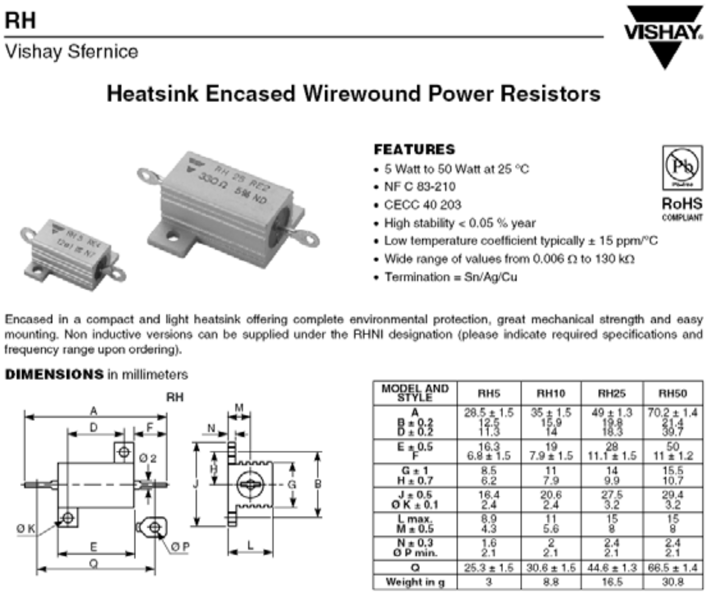
Thermocouples
For temperature
mesurements

**Inner structure**



**Full structure**

*The heating elements are two 4Ω resistors in series, supplied by the 12V supply. Vishay RH10 series, 10W.



RH

Vishay Sfernice

**Heatsink Encased Wirewound Power Resistors**

**FEATURES**

- 5 Watt to 50 Watt at 25 °C
- NF C 83-210
- CECC 40 203
- High stability < 0.05 % year
- Low temperature coefficient typically ± 15 ppm/°C
- Wide range of values from 0.006 Ω to 130 kΩ
- Termination = Sn/Ag/Cu

RoHS COMPLIANT

Encased in a compact and light heatsink offering complete environmental protection, great mechanical strength and easy mounting. Non inductive versions can be supplied under the RHNI designation (please indicate required specifications and frequency range upon ordering).

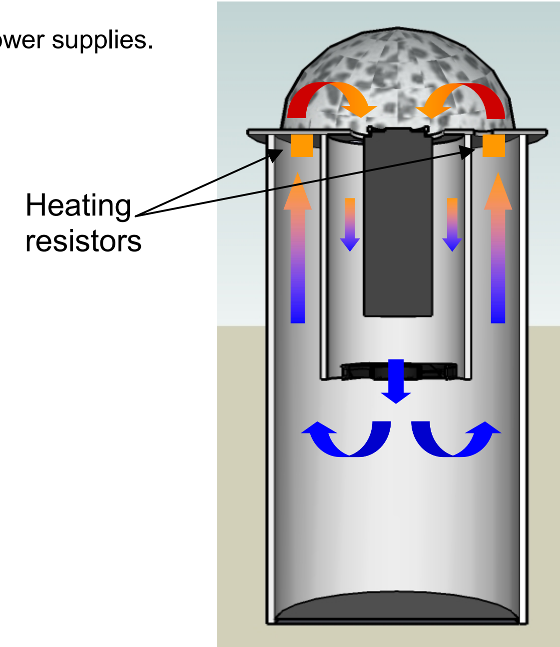
**DIMENSIONS** in millimeters



| MODEL AND STYLE | RH5 | RH10 | RH25 | RH50 |
|---|---|---|---|---|
| A | 28.5 ± 1.5 | 35 ± 1.5 | 49 ± 1.3 | 70.2 ± 1.4 |
| B ± 0.2 | 12.5 | 15.9 | 19.8 | 21.4 |
| D ± 0.2 | 11.3 | 14 | 18.3 | 39.7 |
| E ± 0.5 | 16.3 | 19 | 28 | 50 |
| F | 6.8 ± 1.5 | 7.9 ± 1.5 | 11.1 ± 1.5 | 11 ± 1.2 |
| G ± 1 | 8.5 | 11 | 14 | 15.5 |
| H ± 0.7 | 6.2 | 7.9 | 9.9 | 10.7 |
| J ± 0.5 | 16.4 | 20.6 | 27.5 | 29.4 |
| Ø K ± 0.1 | 2.4 | 2.4 | 3.2 | 3.2 |
| L max. | 8.9 | 11 | 15 | 15 |
| M ± 0.5 | 4.3 | 5.6 | 8 | 8 |
| N ± 0.3 | 1.6 | 2 | 2.4 | 2.4 |
| Ø P min. | 2.1 | 2.1 | 2.1 | 2.1 |
| Q | 25.3 ± 1.5 | 30.6 ± 1.5 | 44.6 ± 1.3 | 66.5 ± 1.4 |
| Weight in g | 3 | 8.8 | 16.5 | 30.8 |

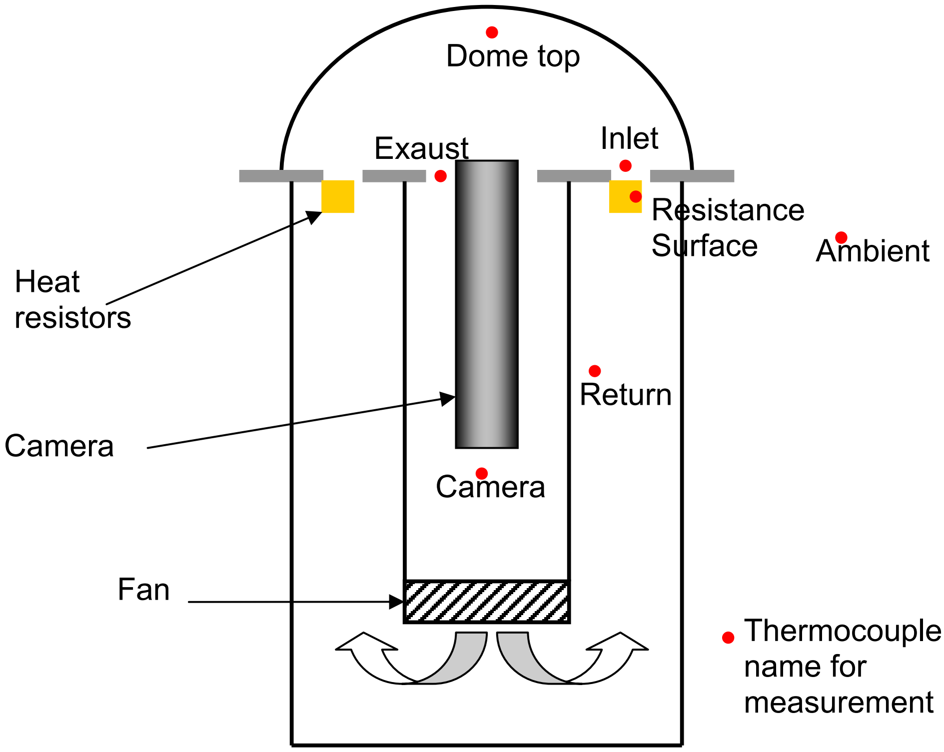
*The fan used is an 8cm fan the type you find on PC power supplies.

The air flow is shown in the following schematic




## *3.2. Thermal measurements*

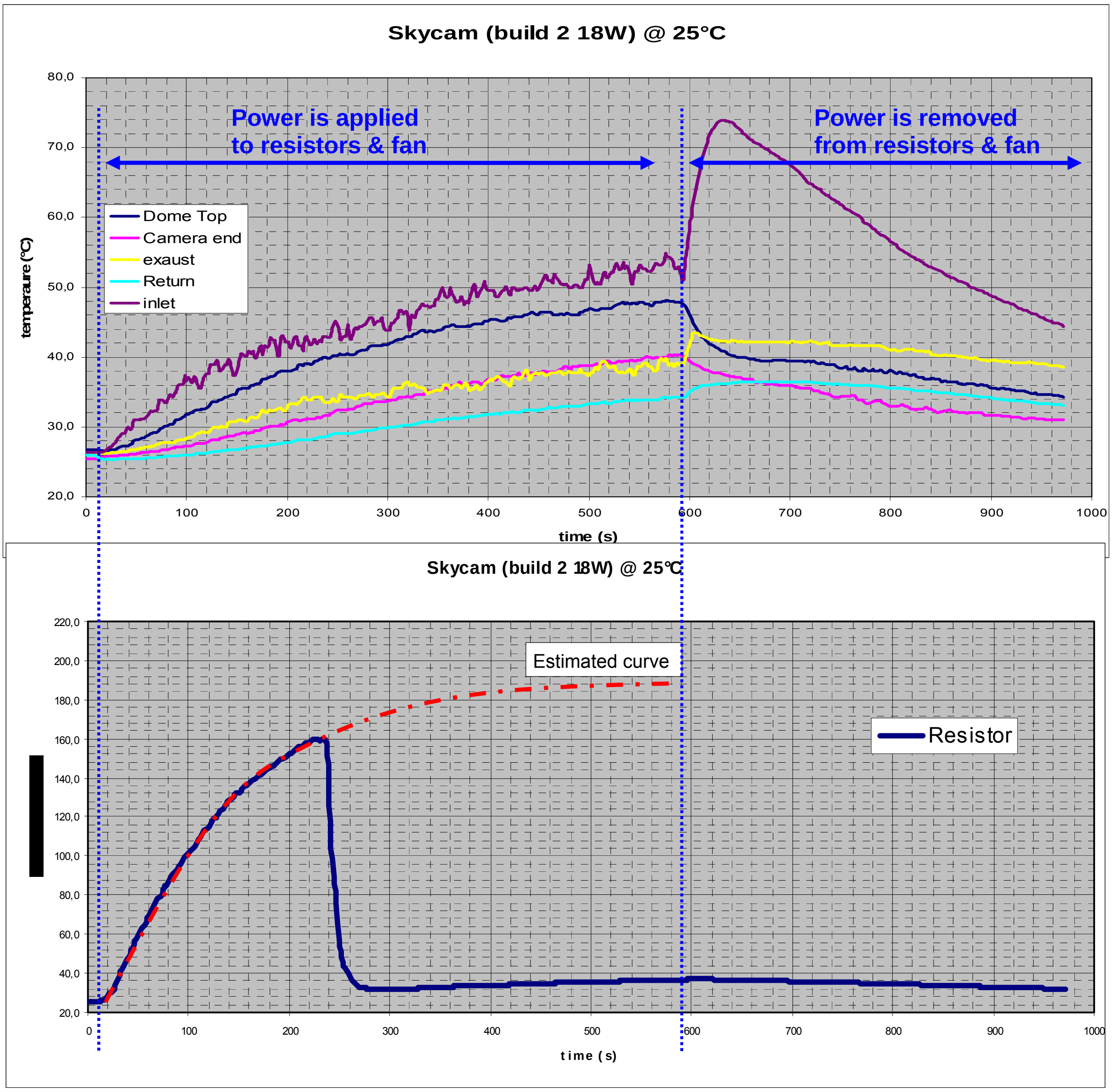
### 3.2.1. Measurement probes



### 3.2.2. Power measurement

-The first measurement was made by 26°C and was made in order to determine if the power dissipated by the elements was enough to heat up the dome from -5°C to 15°C.

-No regulation system was plugged. we only waited for the system to get to it's equilibrium, and then plugged the resistors and fan on a 12V supply to see what temperature would be reached in the dome.




* We encountered a problem during the measurement.
The probe fixed on the resistor surface which was fixed with superglue detached itself from the resistor during the test therefore causing the blue curve to drop after 250s.

We can however estimate the final surface temperature to about 190°C by following the graph's tendency. When the fan is switched off after 600s there is probably a temperature elevation due to the sop of air flow but the value of that elevation can not be determined easily.

* The temperature in the inlet is quite high (54°C after 580s) which is normal as this is the air flow that is designed to heat up the dome. The temperature increase after 600s is due to the fact that the fan and resistors are cut off and therefore the resistance's surface heat is no longer evacuated by airflow.

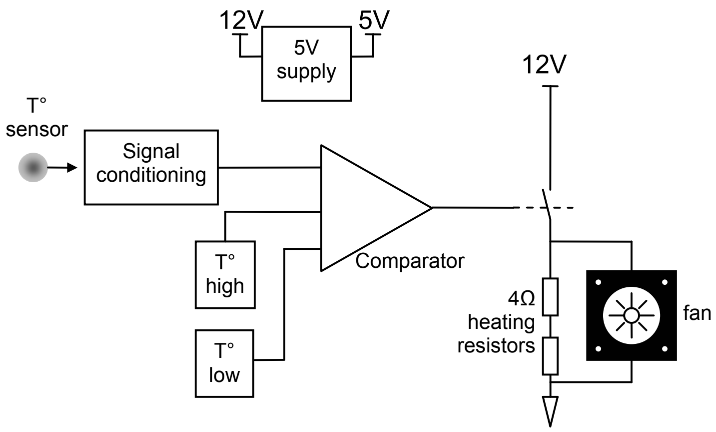
*The temperature in the dome top reaches 48°C after 580s which is 22°C above the start temperature, which means that to reach 15°C the ambient temperature can be of -7°C

*We can see the cool air leaving via the exhaust around the camera, and cooling down as it goes down (camera end temperature) and back up (return temperature).

→ Though this measurement we can see that the power is sufficient to heat up the skycam, though care should be taken around the resistive heating elements in order to prevent the melting of the plastic parts as the resistors get very hot.

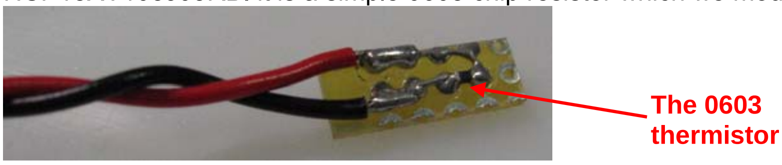
# 4. Regulation circuit

## *4.1. Block diagram*

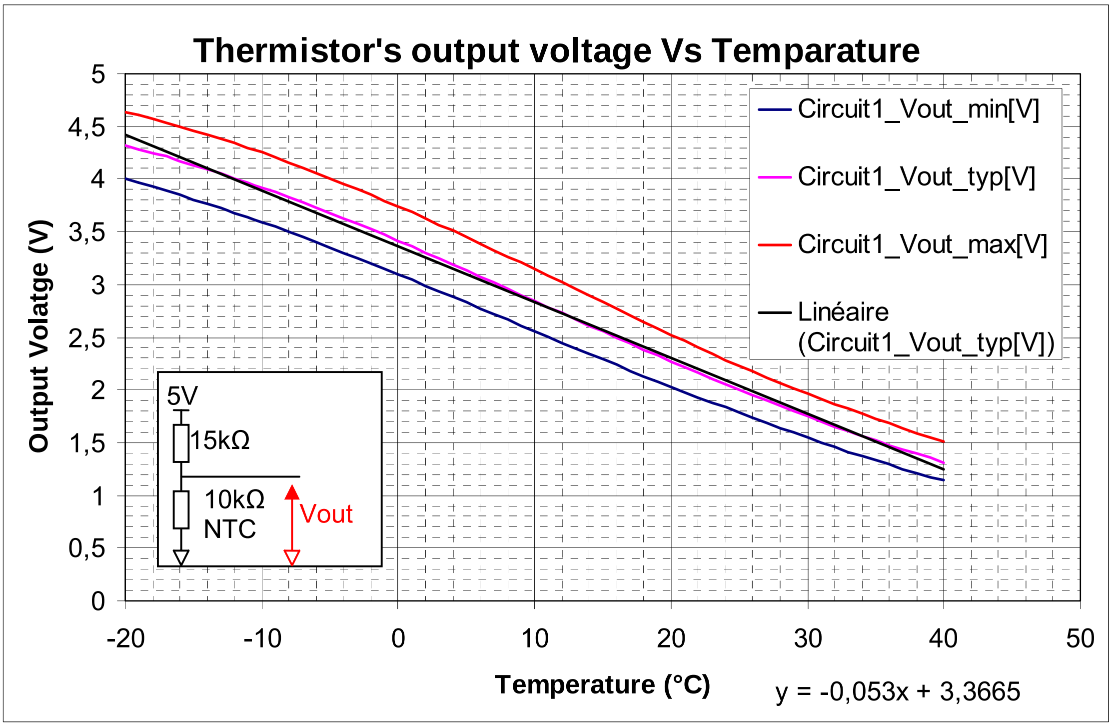


## *4.2. Temperature sensor & conditioning*

The temperature sensor used is a NTC thermitor from MUARTA, I use at work: NCP18XV103J03RB. it is a simple 0603 chip resistor which we mount on a piece of veroboard:

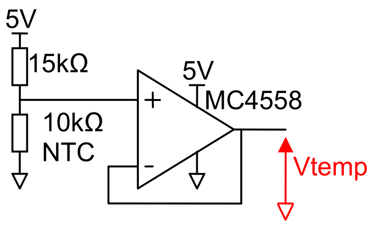



MURATA provides software which allows us to simulate the thermistor's behaviour.




The typical response curve is given on the graph. The slope is -53mV/°C.

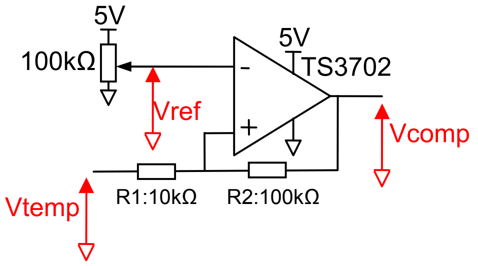
Such a circuit has very high impedance so impedance adapting is necessary in order to drive other electronic circuits. For that function we use a simple voltage follower circuit.



## 4.3. Temperature comparator

The temperature needs to be compared to a threshold in order to switch the heater on when needed. A hysteretic behaviour is also needed so that the output does not toggle on and off.

We use a simple Hysteretic comparator circuit:




The threshold is fixed around 15°C→ 2.5V

→$V_{out}$= $V_{sat+}$ if:

$$V_{temp} > V_{ref} \cdot \left(\frac{R1+R2}{R2}\right) - V_{sat+} \cdot \left(\frac{R1}{R2}\right)$$

R1=10kΩ, R2=100kΩ, $V_{sat+}$ =5V, $V_{sat-}$ =0V, $V_{ref}$=2.5V

$$V_{temp} > 2.5\left(\frac{110}{100}\right) - 5.\left(\frac{10}{100}\right) \rightarrow 2.75 - 0.5 \rightarrow 2.25V \rightarrow 20°C$$

→$V_{out}$= $V_{sat+}$ if:

$$V_{temp} > V_{ref} \cdot \left(\frac{R1+R2}{R2}\right) - V_{sat-} \cdot \left(\frac{R1}{R2}\right)$$

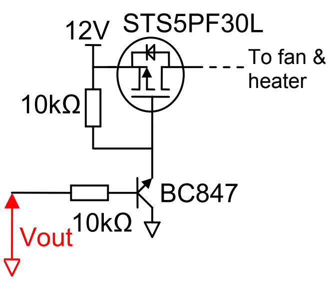
R1=10kΩ, R2=100kΩ, $V_{sat+}$ =5V, $V_{sat-}$ =0V, $V_{ref}$=2.5V

$$V_{temp} > 2.5\left(\frac{110}{100}\right) \rightarrow 2.75V \rightarrow 12°C$$

**$T_{high}$=20°C**
**$T_{low}$=12°C**

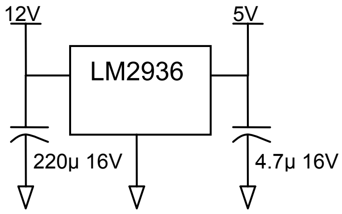
## 4.4. Power switch

The power switch is made with a P channel MOSFET transistor driven by a bipolar transistor. When the comparator outputs 5V the switch closes, and opens when the comparator outputs 0V.

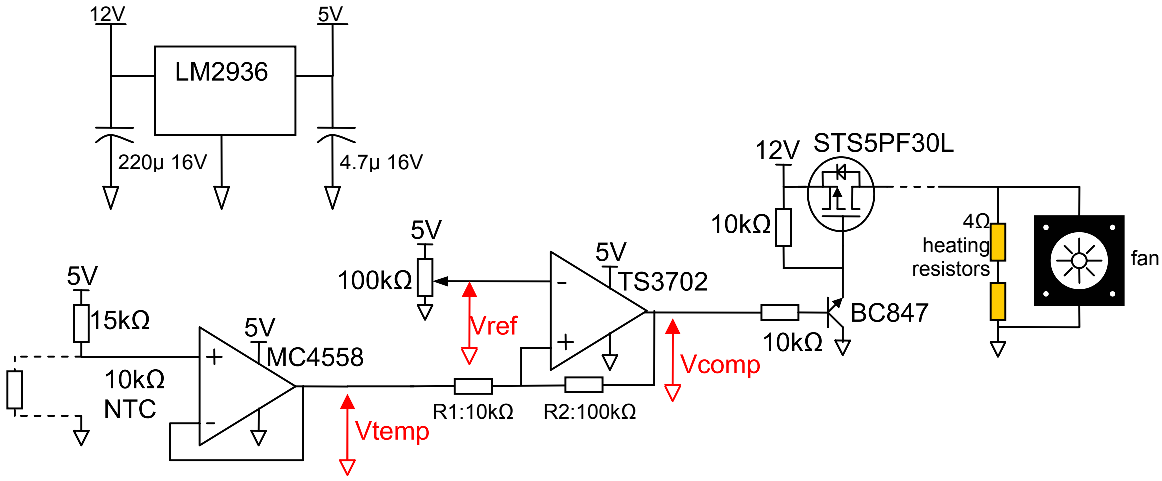


## *4.5. Power supply*

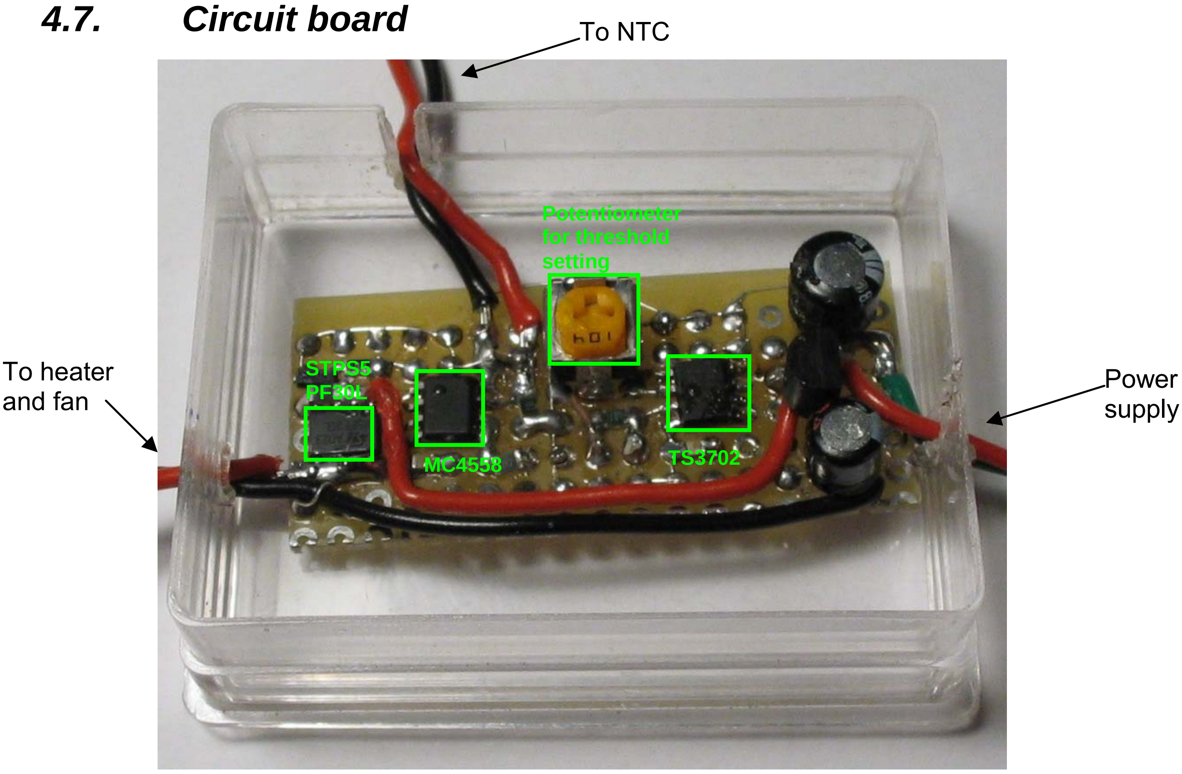
A 5V supply is made by a linear regulator from the 12V supply:




## *4.6. Complete schematics*

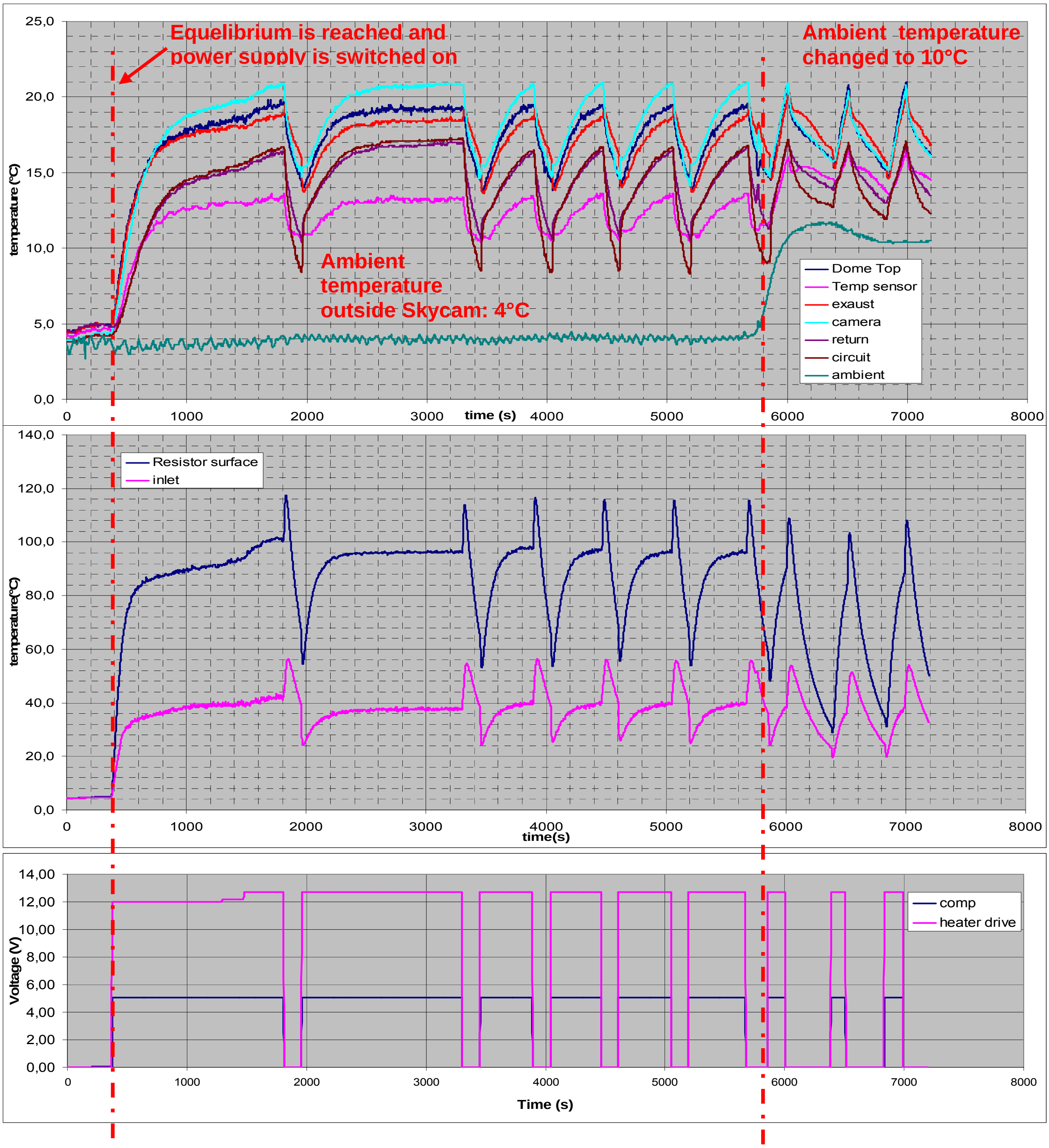



## *4.7. Circuit board*



# 5. Measurement of regulation

he regulation circuit is mounted in the cardboard model of the camera. The model is then placed in a thermally controlled area at 4°C. Once the model has reached its equilibrium the regulation circuit is powered.
After a while the ambient temperature is increased to 10°C to see the system's reactivity.



-On the above graphs we can see that the regulation switches on when the temperature is bellow 11°C, and stops when the temperature is above 13°C

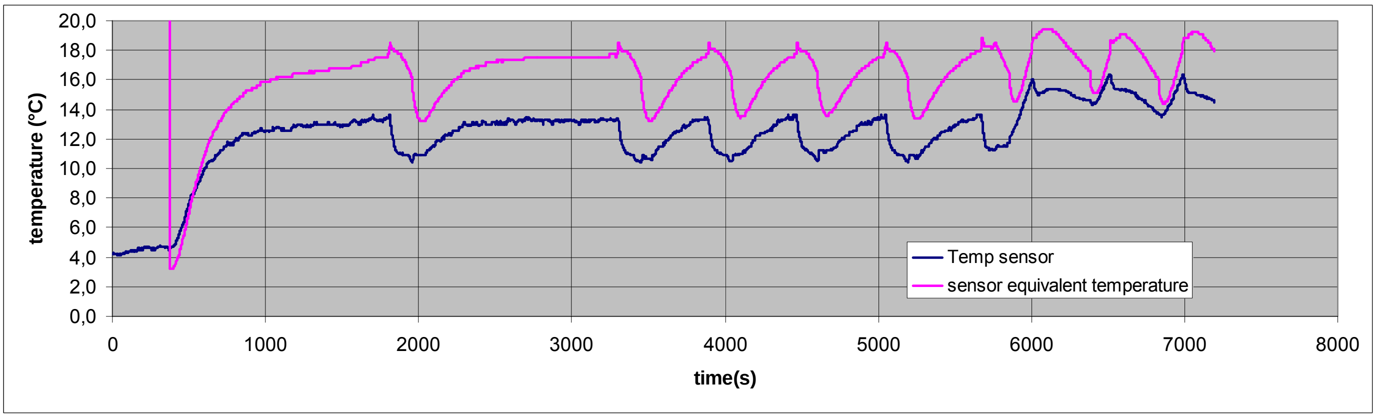
-The air blown into the dome is at about 40°C when Tamb=4°C and goes down to a mean value of 35°C when Tamb increases. The resistor surface temperature is about 90°C at 4°C ambient and 70°C at 10°C ambient.

-inside the dome: the top seems the hottest point due to hot air elevation, the air at the exaust is colder because it has been cooled down inside the dome, the temperature at the sensor level is the coldest maybe because the air on the dome size is harder to evacuate, however it shows that the sensor is correctly placed.

-we can see a difference between the temperature measured by the sensor and the temperature measured by a probe close to the sensor.
The following graph calculates the equivalent temperature that sees the sensor by using the equation found in 4.2. we find a difference of nearly 5°C. when the regulation system thinks the dome temperature is 17.5°C (at 3000s) the real temperature is 13°C.

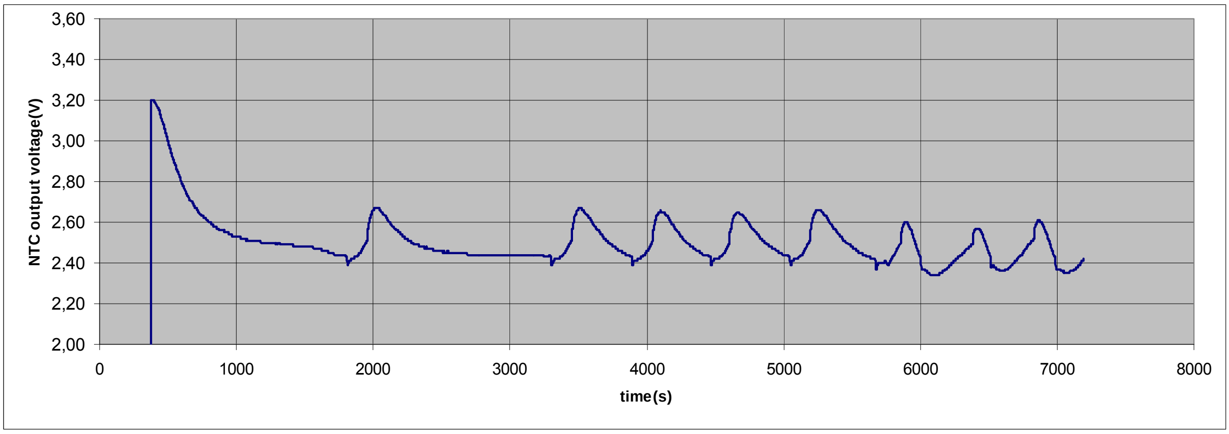
If we look at the NTC characteristics our variation is +/-4°C. with the precision of the measurement our circuit seems to fit in these limits.

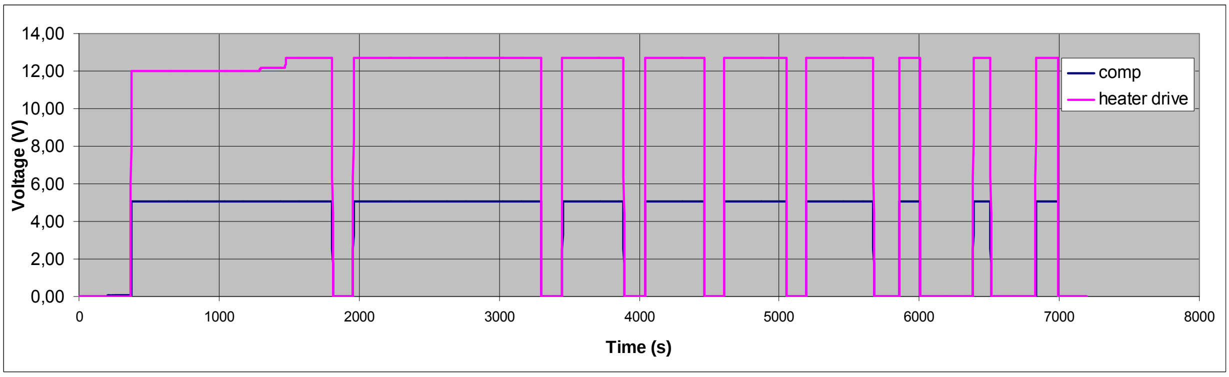
The regulation system will regulate at a lower temperature than the expected 15°C mean.



- The driving of the heating elements and the fan is done via the comparator which compares the NTC output to a reference voltage of 2.5V.

We can measure a threshold of 2.4V and 2.7V. However this threshold seems to vary a bit when the temperature is changed to 10°C (2.35 and 2.6V) but the precision pf the Yokogawa recorder is not good.



## 6. Field installation

Now correct performance is attained the system is mounted in the real Skycam: