# Resistances featuring

February 14, 2019

Summary

In this documenr we present resistances featurin for the project **Solar incubator** reliazed by SIUFIM-Foristom, at Universidad Francisco de Paula Santander (UFPS). Through 2 experinents was characterized resistances and obtained its math fitting to get more resumible form. Data was gotten using Arduino Data Logger system (DLS) assembled especifically for this project. DLS currently has 3 sensors: DHT22, Voltage sensor, Current sensor. Further, is possible add more sensors in order to manege others vaeiables or compare sensors' data for the same variable. Indeed, every experiment is done over a initial conditions such as must be mentioned at the start.

The libraries required are called in next:

```
In [84]: import numpy as np
         import matplotlib.pyplot as plt
         %matplotlib inline
         import pandas as pd
         import os
         #import ClusterCV2
         from scipy.optimize import curve_fit
         from sklearn.cluster import KMeans
```

```
In [85]: def func(x, a, b, c):
             return a * np.exp(-b * x) + c
```

## 1 Experimentos

```
In [86]: os.chdir("/Users/Ghiordy F. Contreras/SIUFIM/DATA/")
```

### 1.1 Resistencia de 50W

```
In [87]: os.chdir("/Users/Ghiordy F. Contreras/SIUFIM/DATA/50W/")
```

#### 1.1.1 Experimento 1

**Prueba 1**

```
In [88]: #Din = pd.read_csv('DATALOG_20190212b.txt',
         #                  names=['t(ms)','T(řC)','RH(%)','V(V)','I(A)'])
         #Din = pd.read_csv('DATALOG_20190212b.txt',
         #                  names=['Time','Temperature','RH','Voltage','Current'])
```

```
Din = pd.read_csv('D20190212a.txt',
                  names=['Time','Temperature','RH','Voltage','Current'])
Din
```

Out[88]:

| | Time | Temperature | RH | Voltage | Current |
|---|---|---|---|---|---|
| 0 | 1199 | NaN | NaN | NaN | NaN |
| 1 | 1728 | NaN | NaN | NaN | NaN |
| 2 | 2251 | NaN | NaN | NaN | NaN |
| 3 | 2775 | NaN | NaN | NaN | NaN |
| 4 | 3567 | NaN | NaN | NaN | NaN |
| 5 | 4090 | NaN | NaN | NaN | NaN |
| 6 | 4614 | NaN | NaN | NaN | NaN |
| 7 | 5137 | NaN | NaN | NaN | NaN |
| 8 | 5931 | NaN | NaN | NaN | NaN |
| 9 | 6454 | NaN | NaN | NaN | NaN |
| 10 | 6977 | NaN | NaN | NaN | NaN |
| 11 | 7500 | NaN | NaN | NaN | NaN |
| 12 | 8294 | NaN | NaN | NaN | NaN |
| 13 | 8817 | NaN | NaN | NaN | NaN |
| 14 | 9340 | NaN | NaN | NaN | NaN |
| 15 | 9864 | NaN | NaN | NaN | NaN |
| 16 | 10657 | NaN | NaN | NaN | NaN |
| 17 | 11181 | NaN | NaN | NaN | NaN |
| 18 | 11734 | NaN | NaN | NaN | NaN |
| 19 | 12257 | NaN | NaN | NaN | NaN |
| 20 | 13050 | NaN | NaN | NaN | NaN |
| 21 | 13574 | NaN | NaN | NaN | NaN |
| 22 | 14097 | NaN | NaN | NaN | NaN |
| 23 | 14620 | NaN | NaN | NaN | NaN |
| 24 | 15414 | NaN | NaN | NaN | NaN |
| 25 | 15937 | NaN | NaN | NaN | NaN |
| 26 | 16460 | NaN | NaN | NaN | NaN |
| 27 | 16984 | NaN | NaN | NaN | NaN |
| 28 | 17777 | NaN | NaN | NaN | NaN |
| 29 | 18300 | NaN | NaN | NaN | NaN |
| .. | ... | ... | .. | ... | ... |
| 68 | 9891 | NaN | NaN | NaN | NaN |
| 69 | 10685 | NaN | NaN | NaN | NaN |
| 70 | 11208 | NaN | NaN | NaN | NaN |
| 71 | 11735 | NaN | NaN | NaN | NaN |
| 72 | 12258 | NaN | NaN | NaN | NaN |
| 73 | 13051 | NaN | NaN | NaN | NaN |
| 74 | 13575 | NaN | NaN | NaN | NaN |
| 75 | 14098 | NaN | NaN | NaN | NaN |
| 76 | 14621 | NaN | NaN | NaN | NaN |
| 77 | 15415 | NaN | NaN | NaN | NaN |
| 78 | 15938 | NaN | NaN | NaN | NaN |
| 79 | 16461 | NaN | NaN | NaN | NaN |

```
80  16985          NaN NaN      NaN      NaN
81  17778          NaN NaN      NaN      NaN
82  18301          NaN NaN      NaN      NaN
83  18825          NaN NaN      NaN      NaN
84  19348          NaN NaN      NaN      NaN
85  20142          NaN NaN      NaN      NaN
86  20665          NaN NaN      NaN      NaN
87  21188          NaN NaN      NaN      NaN
88  21711          NaN NaN      NaN      NaN
89  22535          NaN NaN      NaN      NaN
90  23058          NaN NaN      NaN      NaN
91  23581          NaN NaN      NaN      NaN
92  24104          NaN NaN      NaN      NaN
93  24898          NaN NaN      NaN      NaN
94  25421          NaN NaN      NaN      NaN
95  25945          NaN NaN      NaN      NaN
96  26468          NaN NaN      NaN      NaN
97  27261          NaN NaN      NaN      NaN

[98 rows x 5 columns]
```

**Prueba 2**

```
In [89]: Din = pd.read_csv('D20190212b.txt',
                           names=['Time','Temperature','RH','Voltage','Current'])
         Din
```

```
Out[89]:
792 NaN NaN 12.54 -4.701317 NaN NaN 9.88 -8.551843 NaN NaN 9.32 -10.332368 NaN NaN 9.1


792 NaN NaN 12.54 -4.701317 NaN NaN 9.88 -8.551843 NaN NaN 9.32 -10.332368 NaN NaN 9.1


792 NaN NaN 12.54 -4.701317 NaN NaN 9.88 -8.551843 NaN NaN 9.32 -10.332368 NaN NaN 9.1


792 NaN NaN 12.54 -4.701317 NaN NaN 9.88 -8.551843 NaN NaN 9.32 -10.332368 NaN NaN 9.1


792 NaN NaN 12.54 -4.701317 NaN NaN 9.88 -8.551843 NaN NaN 9.32 -10.332368 NaN NaN 9.1
```

**Prueba 3**

```
In [90]: Din = pd.read_csv('D20190212c.txt',
                           names=['Time','Temperature','RH','Voltage','Current'])
         Din
```

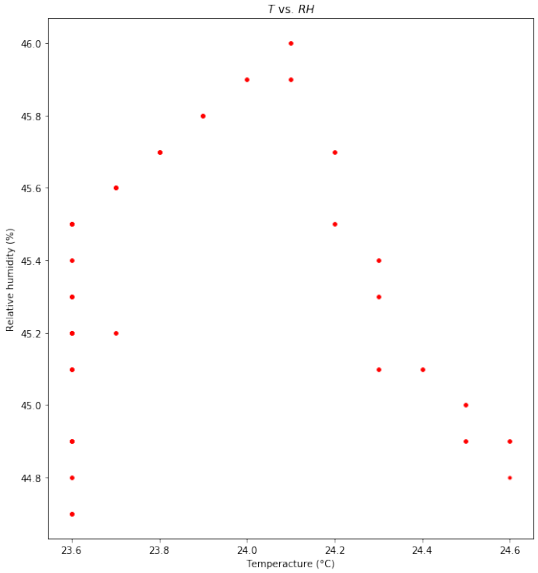
Out[90]:

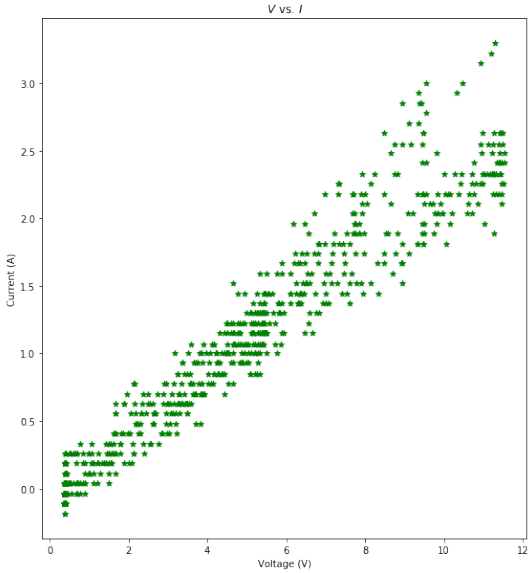
| | Time | Temperature | RH | Voltage | Current |
|---|---|---|---|---|---|
| 0 | 793 | 23.6 | 44.9 | 5.51 | 1.15 |
| 1 | 1327 | 23.6 | 44.9 | 3.78 | 0.78 |
| 2 | 1853 | 23.6 | 44.9 | 2.49 | 0.63 |
| 3 | 2380 | 23.6 | 44.9 | 4.83 | 0.93 |
| 4 | 3178 | 23.6 | 45.5 | 1.68 | 0.56 |
| 5 | 3704 | 23.6 | 45.5 | 5.32 | 1.07 |
| 6 | 4232 | 23.6 | 45.5 | 0.41 | 0.04 |
| 7 | 4758 | 23.6 | 45.5 | 5.42 | 1.07 |
| 8 | 5557 | 23.6 | 45.5 | 0.39 | 0.19 |
| 9 | 6083 | 23.6 | 45.5 | 5.32 | 1.15 |
| 10 | 6610 | 23.6 | 45.5 | 0.71 | -0.04 |
| 11 | 7166 | 23.6 | 45.5 | 0.39 | 0.04 |
| 12 | 7965 | 23.6 | 45.5 | 5.32 | 1.37 |
| 13 | 8492 | 23.6 | 45.5 | 0.41 | -0.04 |
| 14 | 9019 | 23.6 | 45.5 | 5.17 | 1.15 |
| 15 | 9545 | 23.6 | 45.5 | 1.12 | 0.11 |
| 16 | 10344 | 23.6 | 45.5 | 5.22 | 1.22 |
| 17 | 10870 | 23.6 | 45.5 | 0.88 | -0.04 |
| 18 | 11398 | 23.6 | 45.5 | 5.05 | 1.00 |
| 19 | 11927 | 23.6 | 45.5 | 3.29 | 0.63 |
| 20 | 12725 | 23.6 | 45.5 | 3.42 | 0.85 |
| 21 | 13252 | 23.6 | 45.5 | 3.56 | 0.78 |
| 22 | 13778 | 23.6 | 45.5 | 3.90 | 0.70 |
| 23 | 14306 | 23.6 | 45.5 | 3.27 | 0.70 |
| 24 | 15104 | 23.6 | 45.5 | 3.37 | 0.93 |
| 25 | 15631 | 23.6 | 45.5 | 3.59 | 0.78 |
| 26 | 16157 | 23.6 | 45.5 | 3.46 | 0.63 |
| 27 | 16685 | 23.6 | 45.5 | 3.71 | 0.70 |
| 28 | 17482 | 23.6 | 45.5 | 2.32 | 0.56 |
| 29 | 18010 | 23.6 | 45.5 | 4.54 | 1.00 |
| .. | ... | ... | ... | ... | ... |
| 703 | 419731 | 24.2 | 45.5 | 0.39 | -0.04 |
| 704 | 420529 | 24.3 | 45.4 | 0.39 | 0.19 |
| 705 | 421056 | 24.3 | 45.4 | 0.39 | -0.04 |
| 706 | 421583 | 24.3 | 45.4 | 0.39 | -0.11 |
| 707 | 422110 | 24.3 | 45.4 | 0.37 | -0.11 |
| 708 | 422908 | 24.3 | 45.3 | 0.39 | 0.19 |
| 709 | 423435 | 24.3 | 45.3 | 0.41 | -0.11 |
| 710 | 423962 | 24.3 | 45.3 | 0.39 | -0.04 |
| 711 | 424519 | 24.3 | 45.3 | 0.39 | -0.11 |
| 712 | 425317 | 24.3 | 45.1 | 0.39 | 0.26 |
| 713 | 425844 | 24.3 | 45.1 | 0.39 | -0.04 |
| 714 | 426372 | 24.3 | 45.1 | 0.39 | -0.11 |
| 715 | 426898 | 24.3 | 45.1 | 0.39 | 0.04 |
| 716 | 427697 | 24.4 | 45.1 | 0.39 | 0.19 |
| 717 | 428223 | 24.4 | 45.1 | 0.41 | -0.04 |
| 718 | 428750 | 24.4 | 45.1 | 0.39 | -0.04 |

```
719  429280          24.4  45.1     0.39    -0.11
720  430078          24.5  45.0     0.39     0.19
721  430605          24.5  45.0     0.39    -0.04
722  431132          24.5  45.0     0.39    -0.04
723  431660          24.5  45.0     0.39     0.04
724  432457          24.5  44.9     0.41     0.19
725  432985          24.5  44.9     0.39    -0.04
726  433511          24.5  44.9     0.39    -0.04
727  434038          24.5  44.9     0.39    -0.04
728  434836          24.6  44.9     0.39     0.11
729  435363          24.6  44.9     0.39    -0.04
730  435891          24.6  44.9     0.39     0.04
731  436417          24.6  44.9     0.39    -0.04
732  437216          24.6  44.8     0.41     0.11

[733 rows x 5 columns]
```

### Data graphics

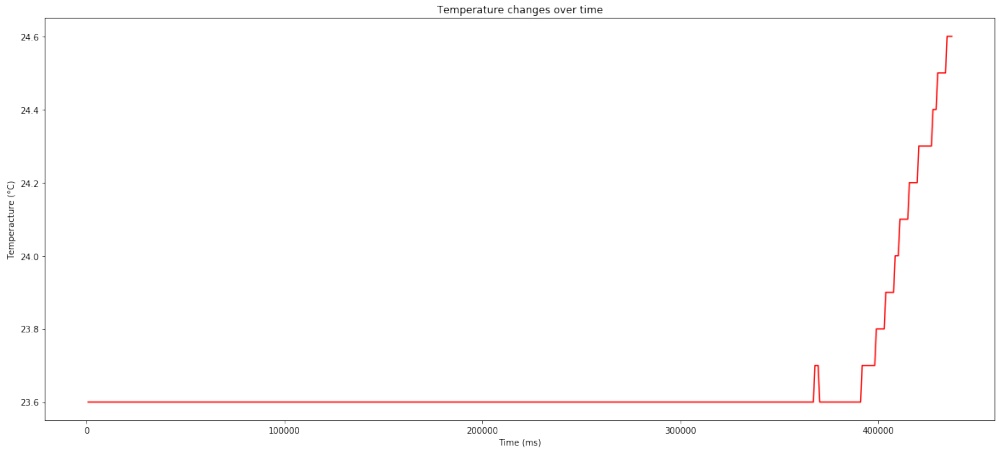
```
In [91]: plt.figure(figsize=(20,10))
         plt.subplot(121)
         plt.scatter(Din.Temperature,Din.RH,marker='.',color='red')
         plt.xlabel('Temperacture (řC)')
         plt.ylabel('Relative humidity (%)')
         plt.title('$T$ vs. $RH$')
         plt.subplot(122)
         plt.scatter(Din.Voltage,Din.Current,marker='*',color='green')
         plt.xlabel('Voltage (V)')
         plt.ylabel('Current (A)')
         plt.title('$V$ vs. $I$')
         #plt.savefig('Exp1_Pro_3')

Out[91]: Text(0.5,1,'$V$ vs. $I$')
```

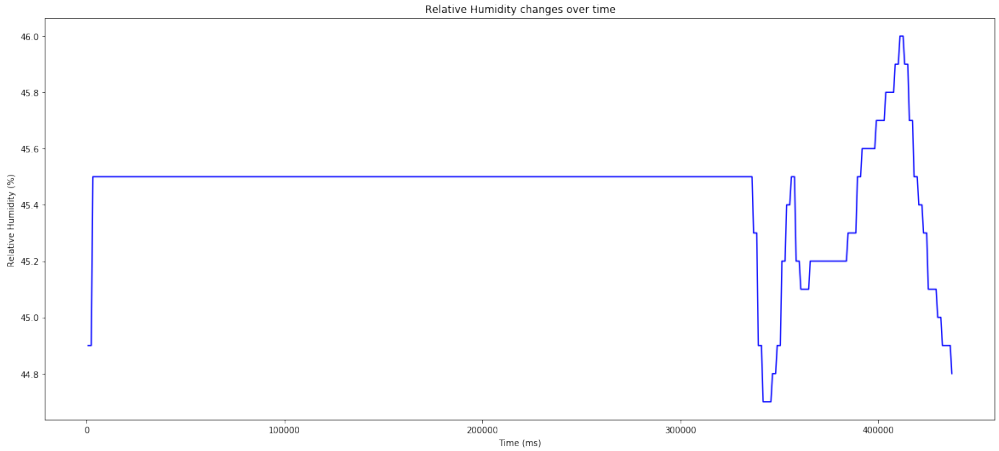


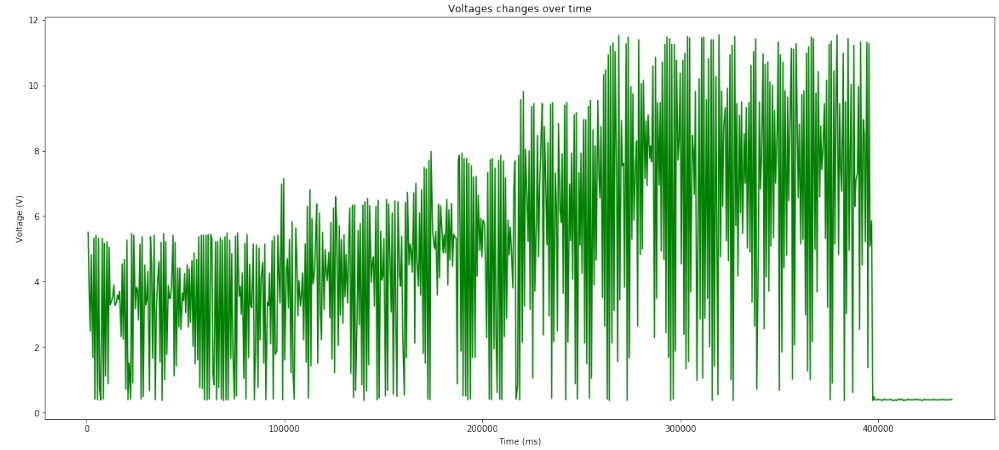



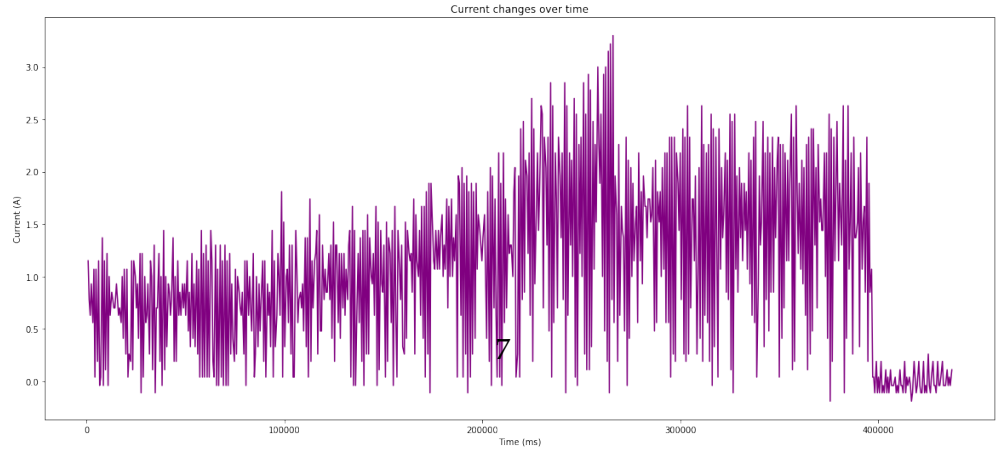

In [92]:
```
plt.figure(figsize=(20,40))
plt.subplot(411)
plt.plot(Din.Time,Din.Temperature,
         color = 'red')
plt.ylabel('Temperacture (řC)')
plt.xlabel('Time (ms)')
plt.title('Temperature changes over time')
plt.subplot(412)
plt.plot(Din.Time,Din.RH,
         color = 'blue')
plt.ylabel('Relative Humidity (%)')
plt.xlabel('Time (ms)')
plt.title('Relative Humidity changes over time')
plt.subplot(413)
plt.plot(Din.Time,Din.Voltage
         ,color = 'green')
plt.ylabel('Voltage (V)')
plt.xlabel('Time (ms)')
plt.title('Voltages changes over time')
plt.subplot(414)
plt.plot(Din.Time,Din.Current,
         color =  'purple')
plt.ylabel('Current (A)')
plt.xlabel('Time (ms)')
plt.title('Current changes over time')
```

Out[92]:
```
Text(0.5,1,'Current changes over time')
```


Temperature changes over time
Temperacture (°C)
24.6
24.4
24.2
24.0
23.8
23.6
0
100000
200000
300000
400000
Time (ms)


Relative Humidity changes over time
Relative Humidity (%)
46.0
45.8
45.6
45.4
45.2
45.0
44.8
0
100000
200000
300000
400000
Time (ms)


Voltages changes over time
Voltage (V)
12
10
8
6
4
2
0
0
100000
200000
300000
400000
Time (ms)


Current changes over time
Current (A)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
100000
200000
300000
400000
Time (ms)

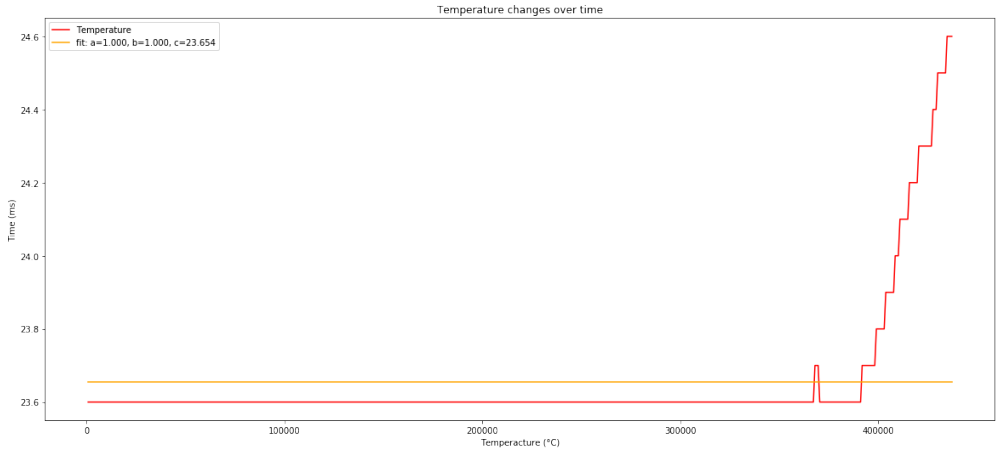
**Curve fitting into function** $f(x) = ae^{(-b*x)} + c$

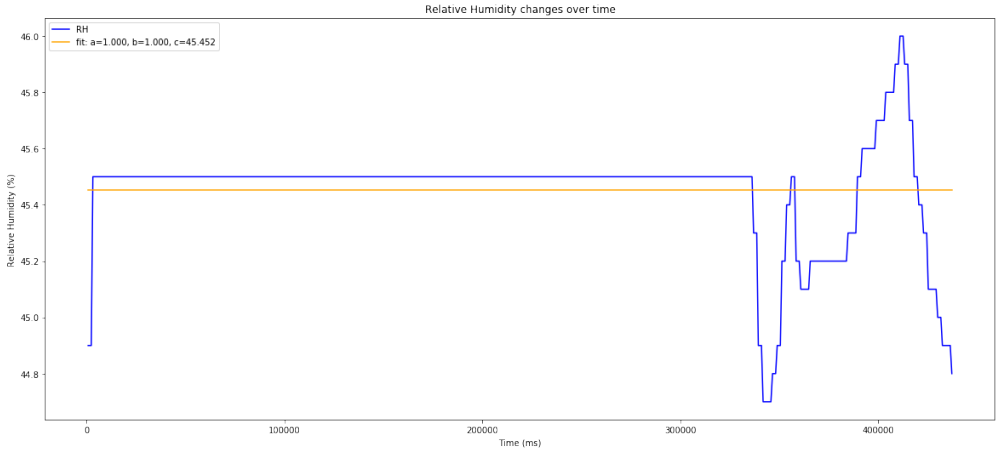
```
In [93]: plt.figure(figsize=(20,40))
         plt.subplot(411)
         plt.plot(Din.Time,Din.Temperature,
                  color = 'red')
         popt, pcov = curve_fit(func, Din.Time, Din.Temperature)
         plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                  label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
         plt.xlabel('Temperacture (řC)')
         plt.ylabel('Time (ms)')
         plt.title('Temperature changes over time')
         plt.legend()
         plt.subplot(412)
         plt.plot(Din.Time,Din.RH,
                  color = 'blue')
         popt, pcov = curve_fit(func, Din.Time, Din.RH)
         plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                  label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
         plt.ylabel('Relative Humidity (%)')
         plt.xlabel('Time (ms)')
         plt.title('Relative Humidity changes over time')
         plt.legend()
         plt.subplot(413)
         plt.plot(Din.Time,Din.Voltage
                  ,color = 'green',)
         popt, pcov = curve_fit(func, Din.Time, Din.Voltage)
         plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                  label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
         plt.ylabel('Voltage (V)')
         plt.xlabel('Time (ms)')
         plt.title('Voltages changes over time')
         plt.legend()
         plt.subplot(414)
         plt.plot(Din.Time,Din.Current,
                  color =  'purple')
         popt, pcov = curve_fit(func, Din.Time, Din.Current)
         plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                  label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
         plt.ylabel('Current (A)')
         plt.xlabel('Time (ms)')
         plt.title('Current changes over time')
         plt.legend()
```

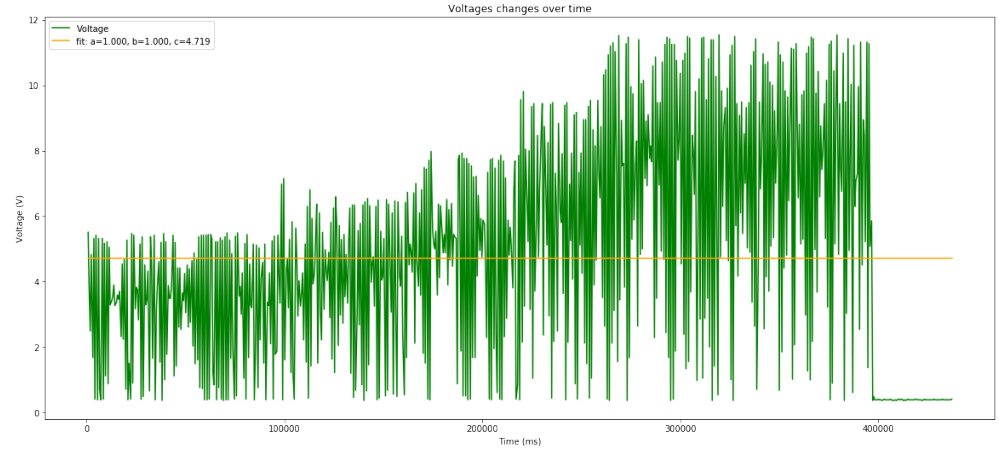
```
C:\Users\Ghiordy F. Contreras\Anaconda3\lib\site-packages\scipy\optimize\minpack.py:794: Optim
```

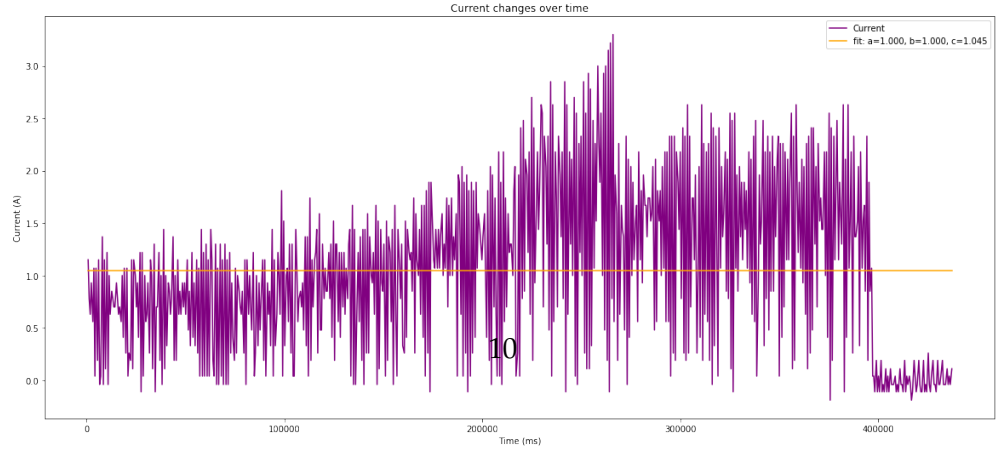
```
  category=OptimizeWarning)
```

```
Out[93]: <matplotlib.legend.Legend at 0x1f08a3b59b0>
```


Temperature changes over time
Temperature
fit: a=1.000, b=1.000, c=23.654
Time (ms)
Temperacture (°C)


Relative Humidity changes over time
RH
fit: a=1.000, b=1.000, c=45.452
Relative Humidity (%)
Time (ms)


Voltages changes over time
Voltage
fit: a=1.000, b=1.000, c=4.719
Voltage (V)
Time (ms)


Current changes over time
Current
fit: a=1.000, b=1.000, c=1.045
Current (A)
Time (ms)

**Prueba 4**

```
In [94]: Din = pd.read_csv('D20190212d.txt',
                           names=['Time','Temperature','RH','Voltage','Current'])
         Din
```

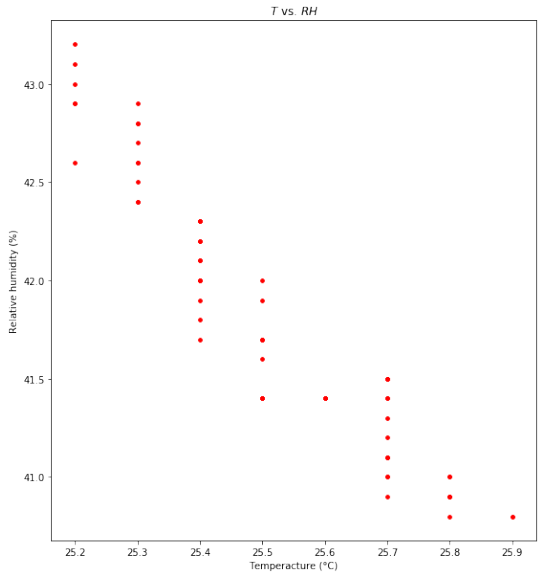
Out[94]:

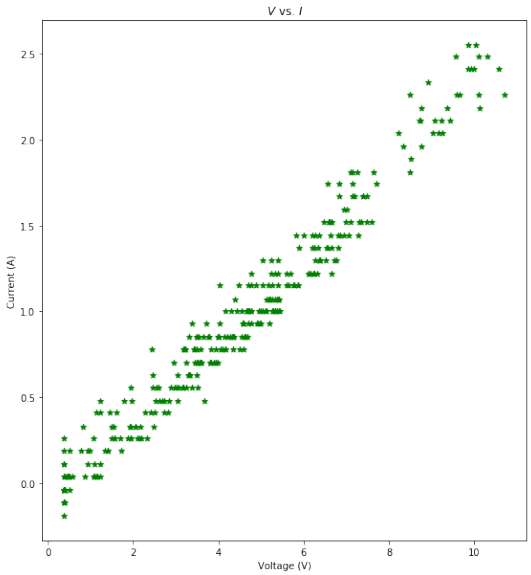
| | Time | Temperature | RH | Voltage | Current |
|---|---|---|---|---|---|
| 0 | 793 | 25.2 | 42.6 | 4.00 | 0.85 |
| 1 | 1351 | 25.2 | 42.6 | 0.39 | -0.04 |
| 2 | 1879 | 25.2 | 42.6 | 5.42 | 1.00 |
| 3 | 2408 | 25.2 | 42.6 | 5.12 | 1.07 |
| 4 | 3206 | 25.2 | 43.2 | 0.46 | 0.04 |
| 5 | 3733 | 25.2 | 43.2 | 5.22 | 1.07 |
| 6 | 4259 | 25.2 | 43.2 | 1.93 | 0.33 |
| 7 | 4787 | 25.2 | 43.2 | 4.54 | 0.85 |
| 8 | 5584 | 25.2 | 43.1 | 4.39 | 1.07 |
| 9 | 6112 | 25.2 | 43.1 | 1.71 | 0.26 |
| 10 | 6638 | 25.2 | 43.1 | 5.12 | 1.00 |
| 11 | 7164 | 25.2 | 43.1 | 0.39 | 0.04 |
| 12 | 7963 | 25.2 | 43.0 | 5.25 | 1.22 |
| 13 | 8489 | 25.2 | 43.0 | 2.07 | 0.33 |
| 14 | 9017 | 25.2 | 43.0 | 4.05 | 0.78 |
| 15 | 9543 | 25.2 | 43.0 | 3.56 | 0.70 |
| 16 | 10342 | 25.2 | 42.9 | 0.98 | 0.19 |
| 17 | 10868 | 25.2 | 42.9 | 5.29 | 1.00 |
| 18 | 11396 | 25.2 | 42.9 | 0.39 | -0.04 |
| 19 | 11922 | 25.2 | 42.9 | 5.42 | 1.07 |
| 20 | 12721 | 25.2 | 42.9 | 3.42 | 0.78 |
| 21 | 13250 | 25.2 | 42.9 | 1.42 | 0.19 |
| 22 | 13776 | 25.2 | 42.9 | 4.59 | 0.78 |
| 23 | 14304 | 25.2 | 42.9 | 3.25 | 0.70 |
| 24 | 15131 | 25.3 | 42.9 | 5.39 | 1.30 |
| 25 | 15657 | 25.3 | 42.9 | 0.41 | 0.04 |
| 26 | 16185 | 25.3 | 42.9 | 5.37 | 1.07 |
| 27 | 16711 | 25.3 | 42.9 | 1.42 | 0.19 |
| 28 | 17510 | 25.3 | 42.8 | 3.83 | 0.78 |
| 29 | 18036 | 25.3 | 42.8 | 3.49 | 0.78 |
| .. | ... | ... | ... | ... | ... |
| 284 | 170115 | 25.8 | 40.9 | 3.71 | 0.93 |
| 285 | 170641 | 25.8 | 40.9 | 9.93 | 2.41 |
| 286 | 171168 | 25.8 | 40.9 | 1.95 | 0.26 |
| 287 | 171695 | 25.8 | 40.9 | 10.30 | 2.48 |
| 288 | 172493 | 25.8 | 41.0 | 1.24 | 0.48 |
| 289 | 173020 | 25.8 | 41.0 | 10.57 | 2.41 |
| 290 | 173547 | 25.8 | 41.0 | 3.22 | 0.78 |

```
291  174073         25.8  41.0     9.44     2.11
292  174872         25.8  40.9     6.56     1.74
293  175398         25.8  40.9     7.59     1.52
294  175926         25.8  40.9     7.20     1.67
295  176452         25.8  40.9     6.81     1.37
296  177251         25.8  40.9     8.91     2.33
297  177777         25.8  40.9     4.71     0.93
298  178307         25.8  40.9     9.17     2.04
299  178834         25.8  40.9     4.54     1.00
300  179632         25.8  40.9     8.34     1.96
301  180159         25.8  40.9     6.00     1.44
302  180715         25.8  40.9     7.71     1.74
303  181242         25.8  40.9     6.66     1.37
304  182040         25.8  40.8     8.49     2.26
305  182567         25.8  40.8     5.69     1.22
306  183094         25.8  40.8     8.71     2.11
307  183621         25.8  40.8     5.27     1.00
308  184419         25.9  40.8     9.56     2.48
309  184946         25.9  40.8     3.61     0.70
310  185473         25.9  40.8     9.59     2.26
311  186000         25.9  40.8     3.93     0.78
312  186798         25.9  40.8     9.86     2.55
313  187324         25.9  40.8     3.07     0.56

[314 rows x 5 columns]
```

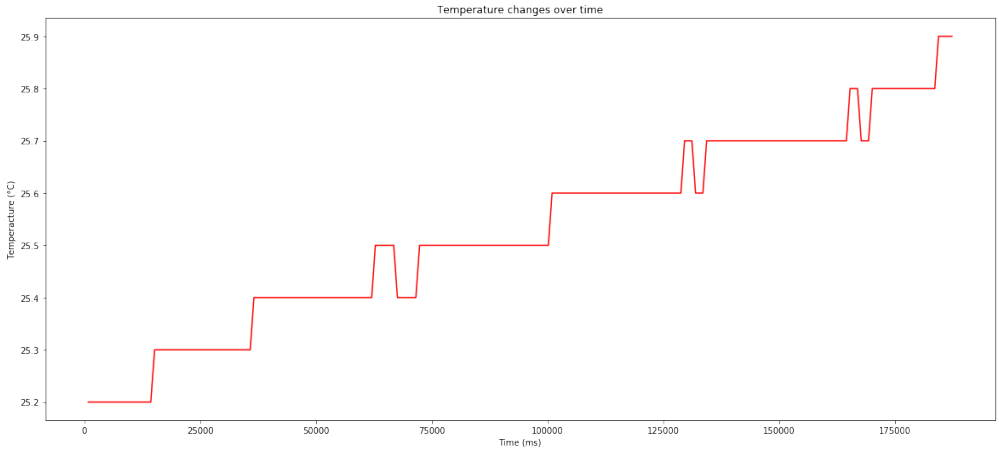
### Data graphics

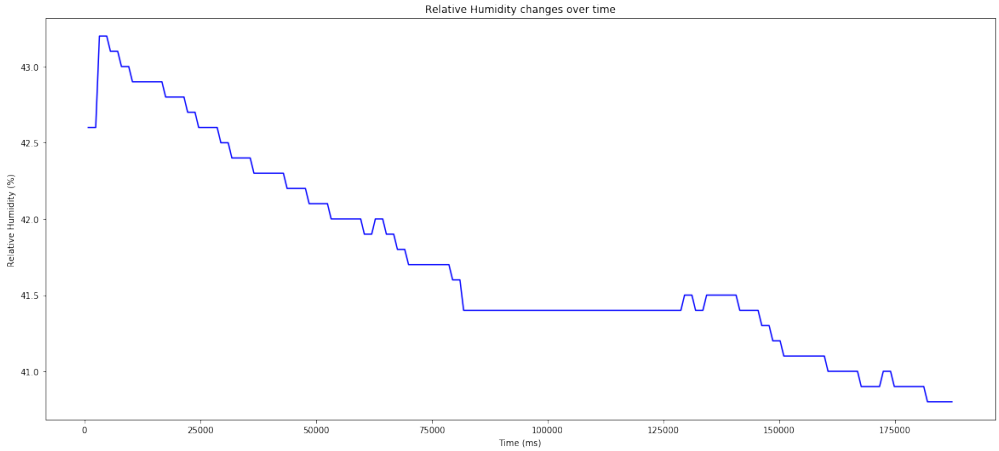
```
In [95]: plt.figure(figsize=(20,10))
         plt.subplot(121)
         plt.scatter(Din.Temperature,Din.RH,marker='.',color='red')
         plt.xlabel('Temperacture (řC)')
         plt.ylabel('Relative humidity (%)')
         plt.title('$T$ vs. $RH$')
         plt.subplot(122)
         plt.scatter(Din.Voltage,Din.Current,marker='*',color='green')
         plt.xlabel('Voltage (V)')
         plt.ylabel('Current (A)')
         plt.title('$V$ vs. $I$')
         #plt.savefig('Exp1_Pro_3')

Out[95]: Text(0.5,1,'$V$ vs. $I$')
```

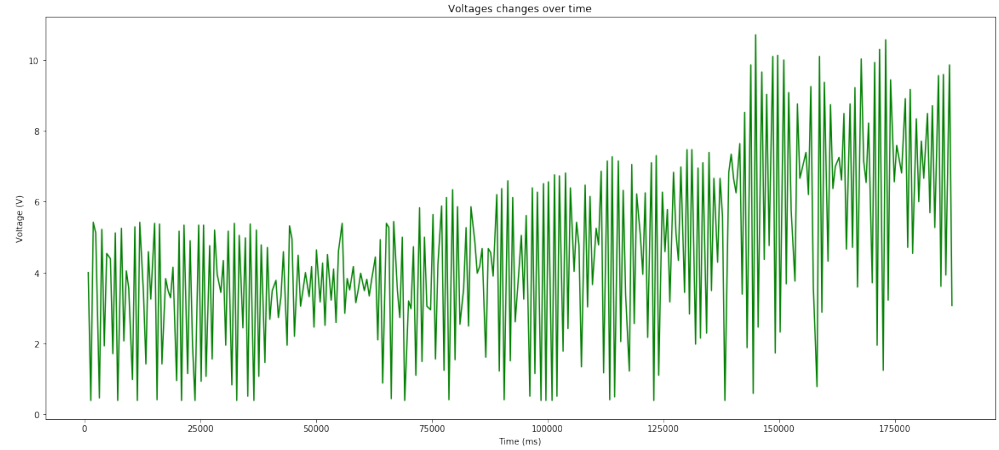


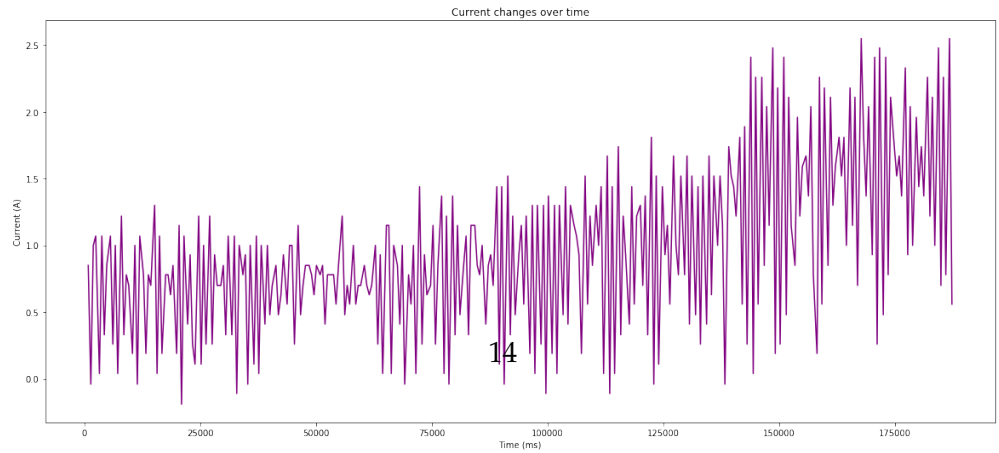




```
In [96]: plt.figure(figsize=(20,40))
         plt.subplot(411)
         plt.plot(Din.Time,Din.Temperature,
                  color = 'red')
         plt.ylabel('Temperacture (řC)')
         plt.xlabel('Time (ms)')
         plt.title('Temperature changes over time')
         plt.subplot(412)
         plt.plot(Din.Time,Din.RH,
                  color = 'blue')
         plt.ylabel('Relative Humidity (%)')
         plt.xlabel('Time (ms)')
         plt.title('Relative Humidity changes over time')
         plt.subplot(413)
         plt.plot(Din.Time,Din.Voltage
                  ,color = 'green')
         plt.ylabel('Voltage (V)')
         plt.xlabel('Time (ms)')
         plt.title('Voltages changes over time')
         plt.subplot(414)
         plt.plot(Din.Time,Din.Current,
                  color =  'purple')
         plt.ylabel('Current (A)')
         plt.xlabel('Time (ms)')
         plt.title('Current changes over time')

Out[96]: Text(0.5,1,'Current changes over time')
```


Temperature changes over time
Temperacture (°C)
Time (ms)


Relative Humidity changes over time
Relative Humidity (%)
Time (ms)


Voltages changes over time
Voltage (V)
Time (ms)

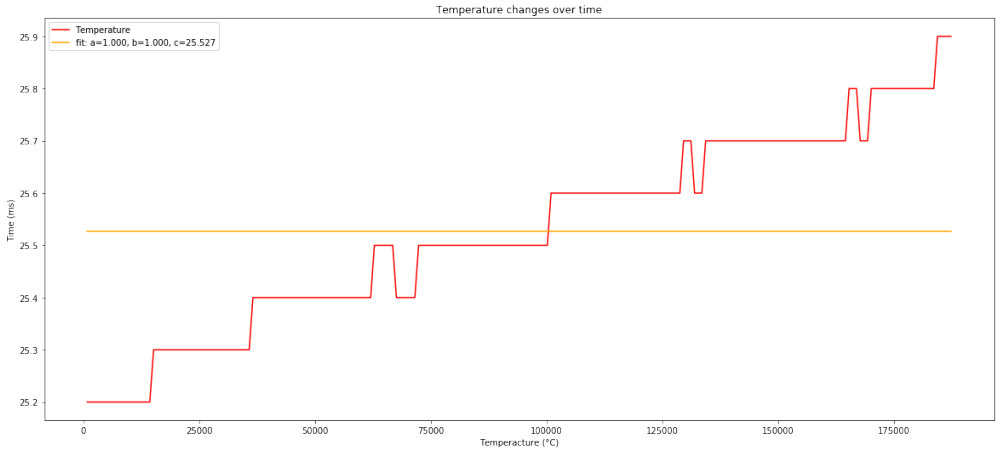

Current changes over time
Current (A)
Time (ms)

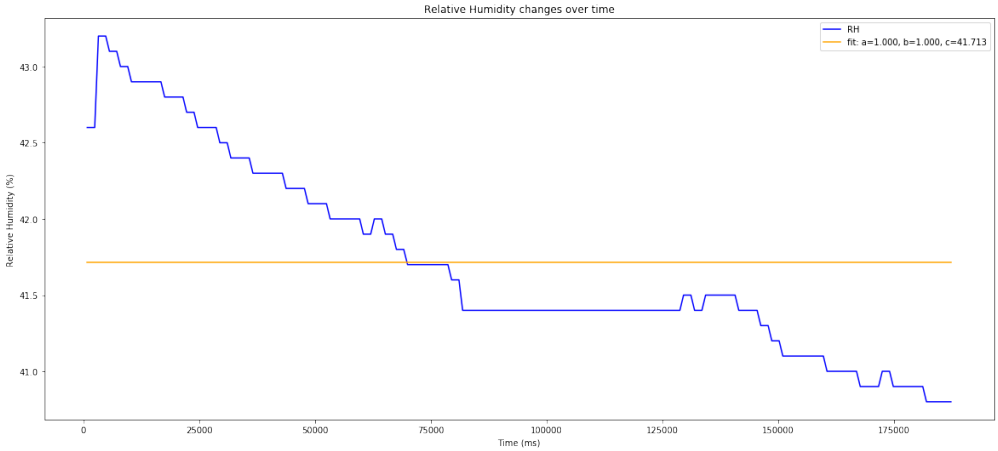
**Curve fitting into function** $f(x) = ae^{(-b*x)} + c$

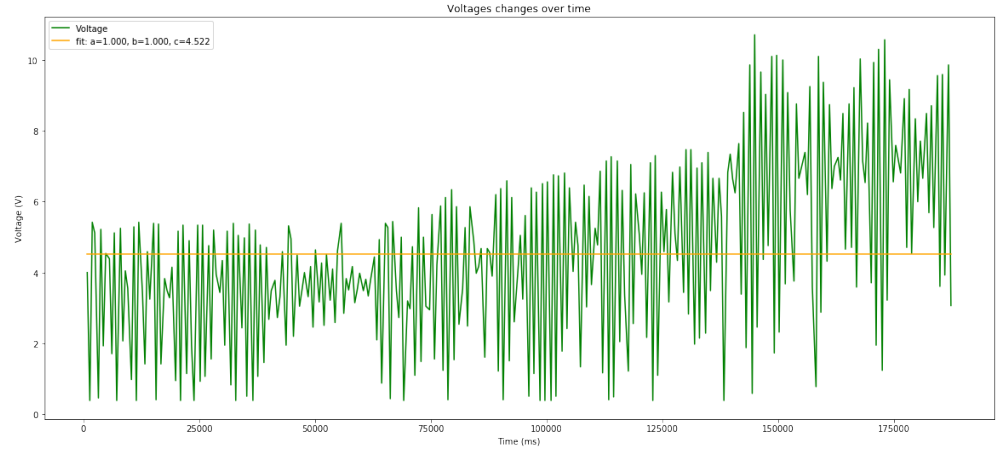
```
In [97]: plt.figure(figsize=(20,40))
         plt.subplot(411)
         plt.plot(Din.Time,Din.Temperature,
                  color = 'red')
         popt, pcov = curve_fit(func, Din.Time, Din.Temperature)
         plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                  label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
         plt.xlabel('Temperacture (řC)')
         plt.ylabel('Time (ms)')
         plt.title('Temperature changes over time')
         plt.legend()
         plt.subplot(412)
         plt.plot(Din.Time,Din.RH,
                  color = 'blue')
         popt, pcov = curve_fit(func, Din.Time, Din.RH)
         plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                  label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
         plt.ylabel('Relative Humidity (%)')
         plt.xlabel('Time (ms)')
         plt.title('Relative Humidity changes over time')
         plt.legend()
         plt.subplot(413)
         plt.plot(Din.Time,Din.Voltage
                  ,color = 'green',)
         popt, pcov = curve_fit(func, Din.Time, Din.Voltage)
         plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                  label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
         plt.ylabel('Voltage (V)')
         plt.xlabel('Time (ms)')
         plt.title('Voltages changes over time')
         plt.legend()
         plt.subplot(414)
         plt.plot(Din.Time,Din.Current,
                  color =  'purple')
         popt, pcov = curve_fit(func, Din.Time, Din.Current)
         plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                  label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
         plt.ylabel('Current (A)')
         plt.xlabel('Time (ms)')
         plt.title('Current changes over time')
         plt.legend()

C:\Users\Ghiordy F. Contreras\Anaconda3\lib\site-packages\scipy\optimize\minpack.py:794: Optim
```

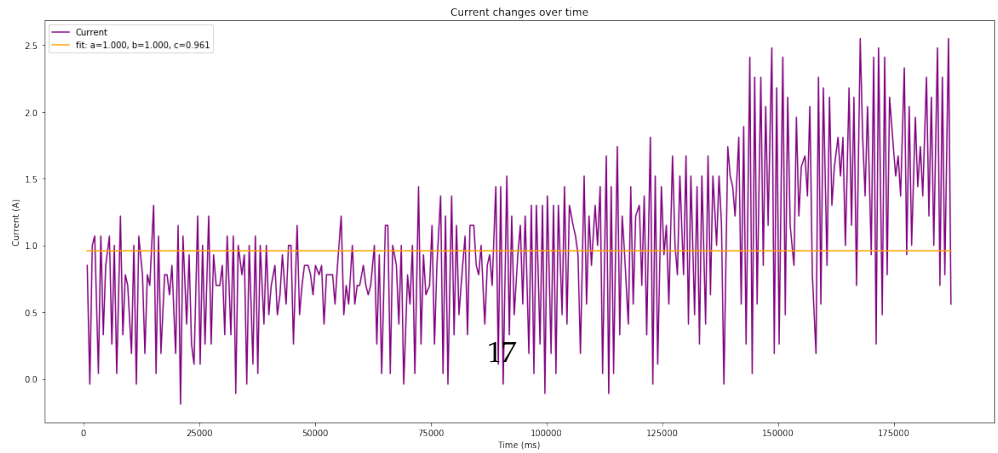
```
  category=OptimizeWarning)
```

```
Out[97]: <matplotlib.legend.Legend at 0x1f08f680e10>
```


Temperature changes over time
Temperature
fit: a=1.000, b=1.000, c=25.527
Time (ms)
Temperacture (°C)


Relative Humidity changes over time
RH
fit: a=1.000, b=1.000, c=41.713
Relative Humidity (%)
Time (ms)


Voltages changes over time
Voltage
fit: a=1.000, b=1.000, c=4.522
Voltage (V)
Time (ms)


Current changes over time
Current
fit: a=1.000, b=1.000, c=0.961
Current (A)
Time (ms)

**Prueba 5**

```
In [98]: Din = pd.read_csv('D20190212e.txt',
                           names=['Time','Temperature','RH','Voltage','Current'])
         Din
```

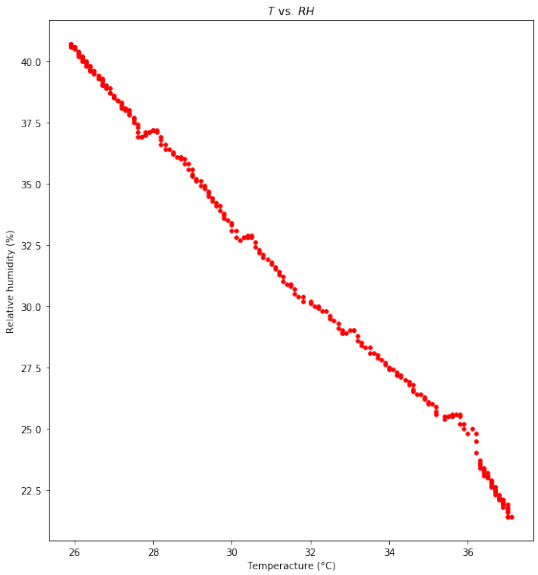
Out[98]:

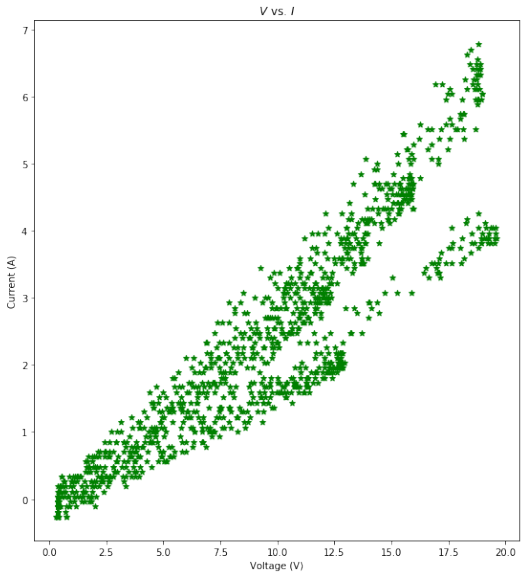
| | Time | Temperature | RH | Voltage | Current |
|---|---|---|---|---|---|
| 0 | 793 | 25.9 | 40.7 | 1.56 | 0.26 |
| 1 | 1319 | 25.9 | 40.7 | 10.52 | 2.48 |
| 2 | 1850 | 25.9 | 40.7 | 8.39 | 2.04 |
| 3 | 2376 | 25.9 | 40.7 | 7.61 | 1.52 |
| 4 | 3174 | 25.9 | 40.7 | 6.42 | 1.67 |
| 5 | 3701 | 25.9 | 40.7 | 9.32 | 2.11 |
| 6 | 4228 | 25.9 | 40.7 | 2.12 | 0.48 |
| 7 | 4754 | 25.9 | 40.7 | 10.49 | 2.48 |
| 8 | 5553 | 25.9 | 40.7 | 0.39 | 0.19 |
| 9 | 6079 | 25.9 | 40.7 | 9.96 | 2.33 |
| 10 | 6605 | 25.9 | 40.7 | 5.05 | 0.93 |
| 11 | 7162 | 25.9 | 40.7 | 3.00 | 0.41 |
| 12 | 7960 | 25.9 | 40.6 | 8.91 | 2.26 |
| 13 | 8487 | 25.9 | 40.6 | 7.25 | 1.59 |
| 14 | 9014 | 25.9 | 40.6 | 5.05 | 1.22 |
| 15 | 9541 | 25.9 | 40.6 | 10.05 | 2.26 |
| 16 | 10339 | 25.9 | 40.6 | 2.49 | 0.70 |
| 17 | 10865 | 25.9 | 40.6 | 10.59 | 2.48 |
| 18 | 11393 | 25.9 | 40.6 | 0.39 | -0.04 |
| 19 | 11919 | 25.9 | 40.6 | 10.03 | 2.33 |
| 20 | 12720 | 26.0 | 40.6 | 5.83 | 1.67 |
| 21 | 13247 | 26.0 | 40.6 | 9.86 | 2.26 |
| 22 | 13773 | 26.0 | 40.6 | 1.00 | 0.26 |
| 23 | 14301 | 26.0 | 40.6 | 10.35 | 2.41 |
| 24 | 15098 | 26.0 | 40.6 | 2.59 | 0.63 |
| 25 | 15625 | 26.0 | 40.6 | 8.91 | 1.96 |
| 26 | 16152 | 26.0 | 40.6 | 7.00 | 1.37 |
| 27 | 16678 | 26.0 | 40.6 | 4.95 | 1.22 |
| 28 | 17477 | 26.0 | 40.6 | 10.20 | 2.48 |
| 29 | 18003 | 26.0 | 40.6 | 1.27 | 0.33 |
| ... | ... | ... | ... | ... | ... |
| 1147 | 686851 | 37.0 | 21.4 | 9.37 | 1.30 |
| 1148 | 687650 | 37.0 | 21.4 | 12.88 | 2.18 |
| 1149 | 688180 | 37.0 | 21.4 | 10.13 | 1.59 |
| 1150 | 688709 | 37.0 | 21.4 | 2.00 | 0.19 |
| 1151 | 689239 | 37.0 | 21.4 | 6.30 | 0.78 |
| 1152 | 690069 | 37.0 | 21.4 | 11.27 | 1.81 |
| 1153 | 690598 | 37.0 | 21.4 | 4.27 | 0.56 |

```
1154  691128         37.0  21.4     3.59     0.33
1155  691657         37.0  21.4    10.88     1.67
1156  692457         37.0  21.4    12.79     2.11
1157  692986         37.0  21.4    10.20     1.59
1158  693516         37.0  21.4     3.17     0.48
1159  694045         37.0  21.4     4.05     0.41
1160  694847         37.0  21.4     9.47     1.52
1161  695376         37.0  21.4    12.86     1.96
1162  695905         37.0  21.4    10.71     1.67
1163  696434         37.0  21.4     4.32     0.70
1164  697238         37.0  21.4    10.03     1.81
1165  697766         37.0  21.4     2.83     0.48
1166  698296         37.0  21.4     4.76     0.56
1167  698825         37.0  21.4    11.35     1.67
1168  699626         37.1  21.4    12.64     2.18
1169  700155         37.1  21.4     9.59     1.44
1170  700685         37.1  21.4     1.17     0.11
1171  701213         37.1  21.4     7.03     1.00
1172  702014         37.1  21.4    12.27     1.96
1173  702543         37.1  21.4    11.74     1.89
1174  703073         37.1  21.4     5.00     0.70
1175  703632         37.1  21.4    12.86     1.96
1176  704433         37.1  21.4    10.76     1.96

[1177 rows x 5 columns]
```

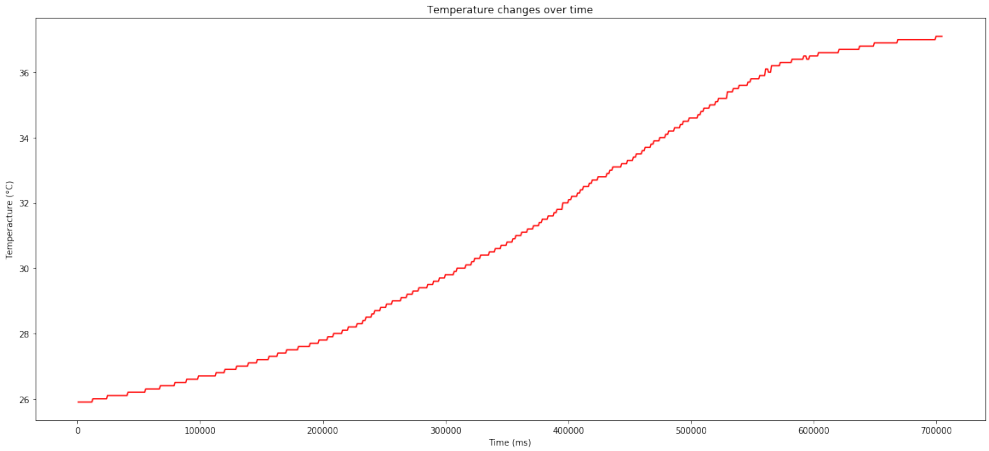
### Data graphics

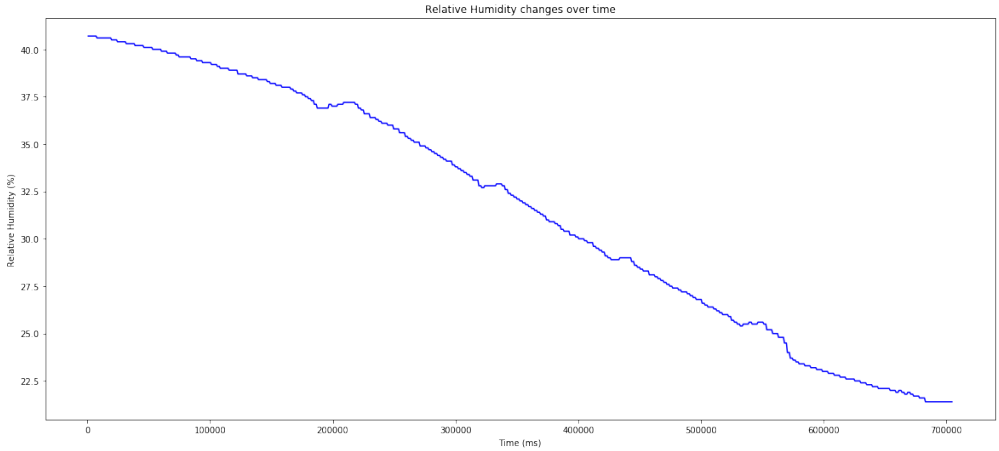
```
In [99]: plt.figure(figsize=(20,10))
         plt.subplot(121)
         plt.scatter(Din.Temperature,Din.RH,marker='.',color='red')
         plt.xlabel('Temperacture (řC)')
         plt.ylabel('Relative humidity (%)')
         plt.title('$T$ vs. $RH$')
         plt.subplot(122)
         plt.scatter(Din.Voltage,Din.Current,marker='*',color='green')
         plt.xlabel('Voltage (V)')
         plt.ylabel('Current (A)')
         plt.title('$V$ vs. $I$')
         #plt.savefig('Exp1_Pro_3')

Out[99]: Text(0.5,1,'$V$ vs. $I$')
```

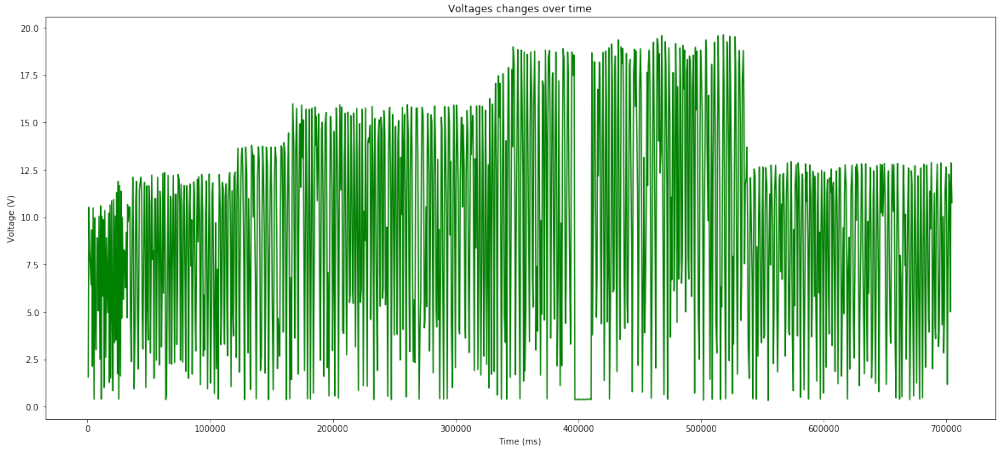


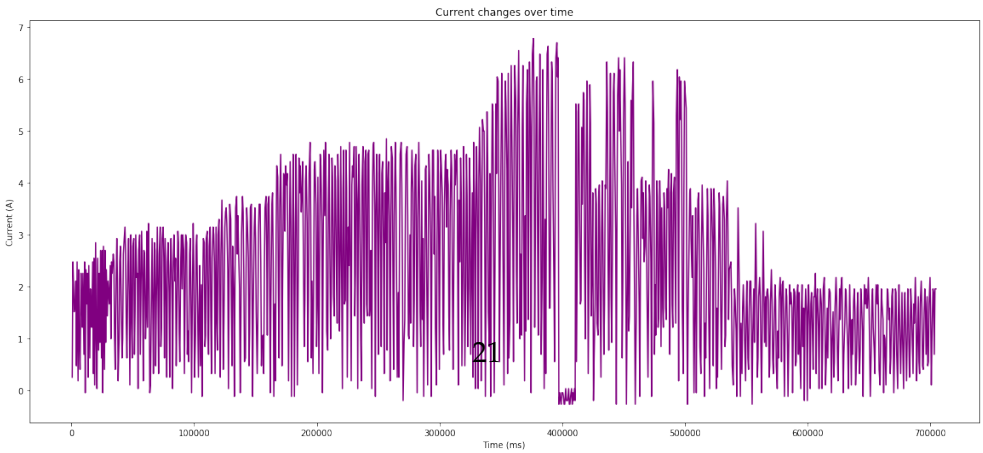




```
In [100]: plt.figure(figsize=(20,40))
          plt.subplot(411)
          plt.plot(Din.Time,Din.Temperature,
                   color = 'red')
          plt.ylabel('Temperacture (řC)')
          plt.xlabel('Time (ms)')
          plt.title('Temperature changes over time')
          plt.subplot(412)
          plt.plot(Din.Time,Din.RH,
                   color = 'blue')
          plt.ylabel('Relative Humidity (%)')
          plt.xlabel('Time (ms)')
          plt.title('Relative Humidity changes over time')
          plt.subplot(413)
          plt.plot(Din.Time,Din.Voltage
                   ,color = 'green')
          plt.ylabel('Voltage (V)')
          plt.xlabel('Time (ms)')
          plt.title('Voltages changes over time')
          plt.subplot(414)
          plt.plot(Din.Time,Din.Current,
                   color =  'purple')
          plt.ylabel('Current (A)')
          plt.xlabel('Time (ms)')
          plt.title('Current changes over time')

Out[100]: Text(0.5,1,'Current changes over time')
```


Temperature changes over time
Temperacture (°C)
Time (ms)


Relative Humidity changes over time
Relative Humidity (%)
Time (ms)


Voltages changes over time
Voltage (V)
Time (ms)

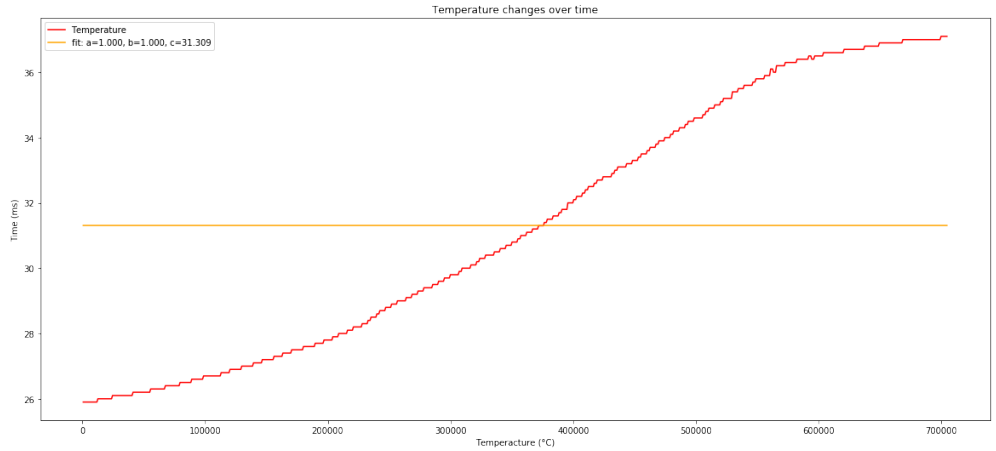

Current changes over time
Current (A)
Time (ms)

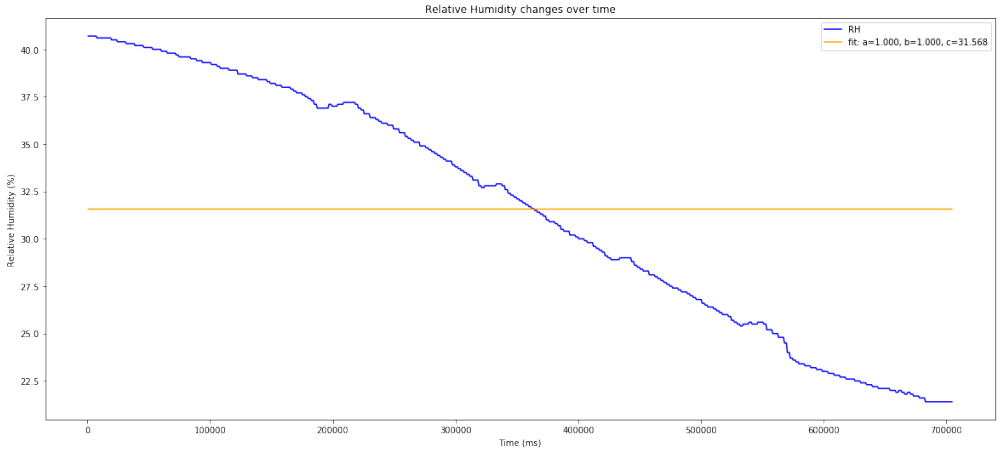
**Curve fitting into function** $f(x) = ae^{(-b*x)} + c$

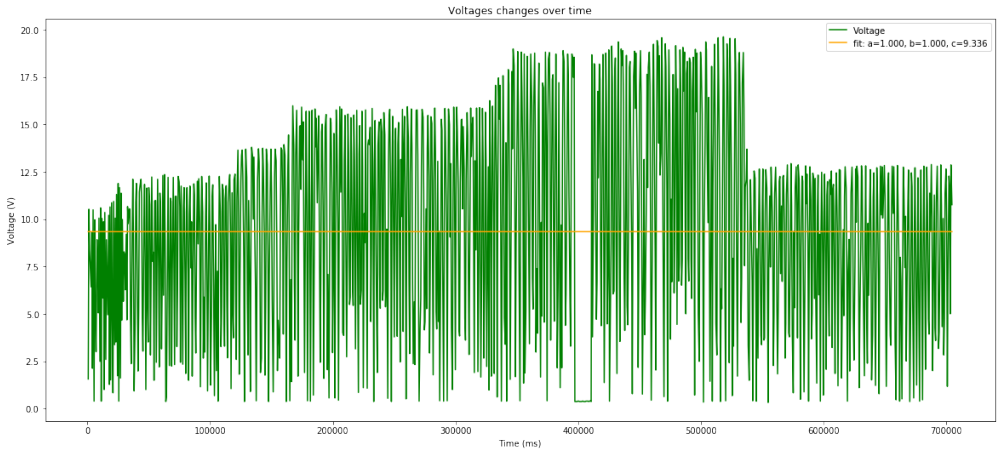
```
In [101]: plt.figure(figsize=(20,40))
          plt.subplot(411)
          plt.plot(Din.Time,Din.Temperature,
                   color = 'red')
          popt, pcov = curve_fit(func, Din.Time, Din.Temperature)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.xlabel('Temperacture (řC)')
          plt.ylabel('Time (ms)')
          plt.title('Temperature changes over time')
          plt.legend()
          plt.subplot(412)
          plt.plot(Din.Time,Din.RH,
                   color = 'blue')
          popt, pcov = curve_fit(func, Din.Time, Din.RH)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Relative Humidity (%)')
          plt.xlabel('Time (ms)')
          plt.title('Relative Humidity changes over time')
          plt.legend()
          plt.subplot(413)
          plt.plot(Din.Time,Din.Voltage
                   ,color = 'green',)
          popt, pcov = curve_fit(func, Din.Time, Din.Voltage)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Voltage (V)')
          plt.xlabel('Time (ms)')
          plt.title('Voltages changes over time')
          plt.legend()
          plt.subplot(414)
          plt.plot(Din.Time,Din.Current,
                   color =  'purple')
          popt, pcov = curve_fit(func, Din.Time, Din.Current)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Current (A)')
          plt.xlabel('Time (ms)')
          plt.title('Current changes over time')
          plt.legend()

C:\Users\Ghiordy F. Contreras\Anaconda3\lib\site-packages\scipy\optimize\minpack.py:794: Optim
```

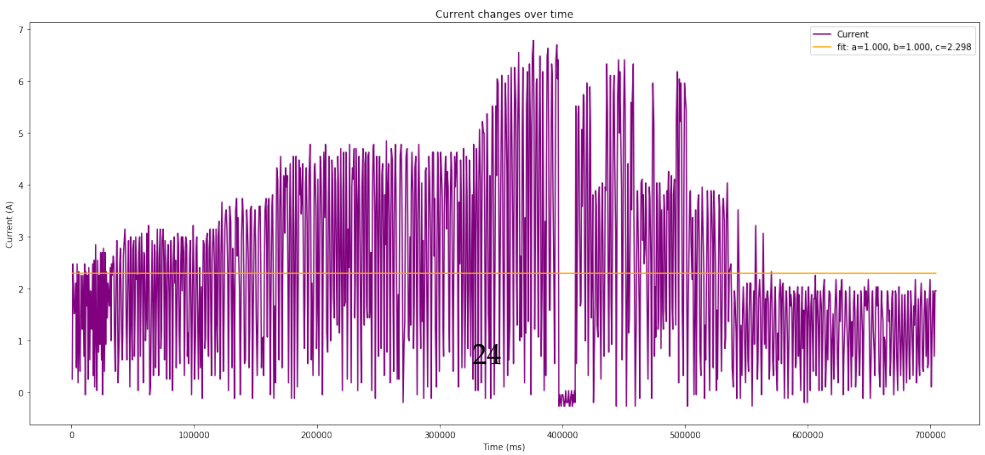
```
  category=OptimizeWarning)
```

```
Out[101]: <matplotlib.legend.Legend at 0x1f08e6d0630>
```


Temperature changes over time
Temperature
fit: a=1.000, b=1.000, c=31.309
Time (ms)
Temperacture (°C)


Relative Humidity changes over time
RH
fit: a=1.000, b=1.000, c=31.568
Relative Humidity (%)
Time (ms)


Voltages changes over time
Voltage
fit: a=1.000, b=1.000, c=9.336
Voltage (V)
Time (ms)


Current changes over time
Current
fit: a=1.000, b=1.000, c=2.298
Current (A)
Time (ms)

### 1.1.2 Experimento 2

**Prueba 1**

```
In [102]: Din = pd.read_csv('D20190213a.txt',
                            names=['Time','Temperature','RH','Voltage','Current'])
          Din
```

Out[102]:

| | Time | Temperature | RH | Voltage | Current |
|---|---|---|---|---|---|
| 0 | 900 | NaN | NaN | 0.39 | -0.04 |
| 1 | 1443 | NaN | NaN | 0.34 | 0.04 |
| 2 | 1969 | NaN | NaN | 0.34 | -0.11 |
| 3 | 2493 | NaN | NaN | 0.32 | -0.26 |
| 4 | 3290 | 22.3 | 44.4 | 0.32 | 0.19 |
| 5 | 3817 | 22.3 | 44.4 | 0.32 | -0.11 |
| 6 | 4343 | 22.3 | 44.4 | 0.29 | -0.19 |
| 7 | 4871 | 22.3 | 44.4 | 0.32 | -0.11 |
| 8 | 5668 | 22.1 | 44.9 | 0.44 | 0.48 |
| 9 | 6196 | 22.1 | 44.9 | 0.44 | 0.04 |
| 10 | 6722 | 22.1 | 44.9 | 0.44 | 0.11 |
| 11 | 7249 | 22.1 | 44.9 | 0.44 | 0.19 |
| 12 | 8047 | 22.1 | 44.8 | 0.44 | 0.33 |
| 13 | 8573 | 22.1 | 44.8 | 0.41 | 0.19 |
| 14 | 9101 | 22.1 | 44.8 | 0.44 | 0.04 |
| 15 | 9627 | 22.1 | 44.8 | 0.44 | 0.04 |
| 16 | 10426 | 22.0 | 44.8 | 0.44 | 0.33 |
| 17 | 10952 | 22.0 | 44.8 | 0.44 | 0.11 |
| 18 | 11480 | 22.0 | 44.8 | 0.44 | 0.19 |
| 19 | 12009 | 22.0 | 44.8 | 0.44 | 0.11 |
| 20 | 12807 | 22.0 | 44.7 | 0.44 | 0.33 |
| 21 | 13334 | 22.0 | 44.7 | 0.44 | 0.19 |
| 22 | 13860 | 22.0 | 44.7 | 0.44 | 0.11 |
| 23 | 14397 | 22.0 | 44.7 | 0.44 | 0.04 |
| 24 | 15195 | 22.0 | 44.7 | 0.44 | 0.26 |
| 25 | 15722 | 22.0 | 44.7 | 0.44 | 0.04 |
| 26 | 16248 | 22.0 | 44.7 | 0.44 | -0.04 |
| 27 | 16776 | 22.0 | 44.7 | 0.44 | 0.11 |
| 28 | 17573 | 22.0 | 44.7 | 0.44 | 0.26 |
| 29 | 18101 | 22.0 | 44.7 | 0.44 | 0.11 |
| .. | ... | ... | ... | ... | ... |
| 113 | 68108 | 22.0 | 44.1 | 0.41 | 0.11 |
| 114 | 68658 | 22.0 | 44.1 | 0.41 | 0.04 |
| 115 | 69184 | 22.0 | 44.1 | 0.41 | 0.04 |
| 116 | 69982 | 22.0 | 44.1 | 0.44 | 0.41 |
| 117 | 70509 | 22.0 | 44.1 | 0.41 | 0.04 |
| 118 | 71035 | 22.0 | 44.1 | 0.44 | -0.04 |

```
119  71563         22.0  44.1     0.44     0.11
120  72360         22.0  44.1     0.44     0.33
121  72888         22.0  44.1     0.44     0.11
122  73414         22.0  44.1     0.41     0.04
123  73942         22.0  44.1     0.44     0.04
124  74739         22.0  44.1     0.44     0.26
125  75269         22.0  44.1     0.44     0.04
126  75796         22.0  44.1     0.41     0.04
127  76322         22.0  44.1     0.41     0.04
128  77121         22.0  44.1     0.44     0.26
129  77647         22.0  44.1     0.44     0.04
130  78175         22.0  44.1     0.44     0.04
131  78701         22.0  44.1     0.44     0.19
132  79500         22.0  44.1     0.44     0.33
133  80026         22.0  44.1     0.41     0.04
134  80553         22.0  44.1     0.41     0.11
135  81080         22.0  44.1     0.44     0.11
136  81878         22.0  44.1     0.44     0.33
137  82405         22.0  44.1     0.44     0.19
138  82931         22.0  44.1     0.44     0.11
139  83459         22.0  44.1     0.41     0.04
140  84256         22.0  44.1     0.44     0.33
141  84784         22.0  44.1     0.44     0.04
142  85313         22.0  44.1     0.41     0.04

[143 rows x 5 columns]
```

**Prueba 2**

```
In [103]: Din = pd.read_csv('D20190213b.txt',
                            names=['Time','Temperature','RH','Voltage','Current'])
          Din
```

Out[103]:

| | Time | Temperature | RH | Voltage | Current |
|---|---|---|---|---|---|
| 0 | 901 | NaN | NaN | 0.39 | 0.04 |
| 1 | 1449 | NaN | NaN | 0.37 | 0.04 |
| 2 | 1975 | NaN | NaN | 0.37 | -0.04 |
| 3 | 2500 | NaN | NaN | 0.39 | -0.04 |
| 4 | 3296 | 22.0 | 43.4 | 0.37 | 0.26 |
| 5 | 3823 | 22.0 | 43.4 | 0.37 | 0.04 |
| 6 | 4349 | 22.0 | 43.4 | 0.37 | -0.04 |
| 7 | 4877 | 22.0 | 43.4 | 0.37 | -0.04 |
| 8 | 5675 | 22.0 | 44.1 | 0.39 | 0.26 |
| 9 | 6201 | 22.0 | 44.1 | 0.37 | -0.11 |
| 10 | 6728 | 22.0 | 44.1 | 0.37 | -0.04 |
| 11 | 7255 | 22.0 | 44.1 | 0.37 | -0.04 |
| 12 | 8053 | 22.0 | 44.1 | 0.37 | 0.26 |
| 13 | 8580 | 22.0 | 44.1 | 0.37 | 0.04 |

| | | | | | |
|---|---|---|---|---|---|
| 14 | 9107 | 22.0 | 44.1 | 0.37 | -0.04 |
| 15 | 9633 | 22.0 | 44.1 | 0.37 | -0.04 |
| 16 | 10431 | 22.0 | 44.1 | 0.37 | 0.26 |
| 17 | 10958 | 22.0 | 44.1 | 0.37 | -0.04 |
| 18 | 11488 | 22.0 | 44.1 | 0.37 | -0.04 |
| 19 | 12014 | 22.0 | 44.1 | 0.37 | -0.11 |
| 20 | 12813 | 22.0 | 44.1 | 0.37 | 0.26 |
| 21 | 13339 | 22.0 | 44.1 | 0.37 | -0.11 |
| 22 | 13867 | 22.0 | 44.1 | 0.37 | -0.04 |
| 23 | 14393 | 22.0 | 44.1 | 0.37 | -0.11 |
| 24 | 15192 | 22.0 | 44.1 | 0.37 | 0.26 |
| 25 | 15718 | 22.0 | 44.1 | 0.37 | -0.04 |
| 26 | 16245 | 22.0 | 44.1 | 0.39 | -0.04 |
| 27 | 16772 | 22.0 | 44.1 | 0.37 | -0.04 |
| 28 | 17570 | 22.0 | 44.1 | 0.37 | 0.19 |
| 29 | 18097 | 22.0 | 44.1 | 0.37 | -0.19 |
| .. | ... | ... | ... | ... | ... |
| 36 | 22353 | 22.0 | 44.1 | 0.37 | 0.19 |
| 37 | 22880 | 22.0 | 44.1 | 0.37 | -0.19 |
| 38 | 23407 | 22.0 | 44.1 | 0.37 | -0.11 |
| 39 | 23933 | 22.0 | 44.1 | 0.37 | -0.04 |
| 40 | 24732 | 22.0 | 44.1 | 0.37 | 0.26 |
| 41 | 25259 | 22.0 | 44.1 | 0.37 | -0.04 |
| 42 | 25786 | 22.0 | 44.1 | 0.37 | -0.11 |
| 43 | 26312 | 22.0 | 44.1 | 0.37 | 0.04 |
| 44 | 27110 | 22.0 | 44.1 | 0.37 | 0.26 |
| 45 | 27637 | 22.0 | 44.1 | 0.37 | -0.04 |
| 46 | 28164 | 22.0 | 44.1 | 0.37 | -0.04 |
| 47 | 28691 | 22.0 | 44.1 | 0.37 | 0.04 |
| 48 | 29489 | 22.1 | 44.2 | 0.37 | 0.26 |
| 49 | 30016 | 22.1 | 44.2 | 0.37 | -0.04 |
| 50 | 30542 | 22.1 | 44.2 | 0.34 | -0.04 |
| 51 | 31070 | 22.1 | 44.2 | 0.37 | 0.04 |
| 52 | 31870 | 22.1 | 44.2 | 0.37 | 0.11 |
| 53 | 32397 | 22.1 | 44.2 | 0.37 | -0.04 |
| 54 | 32924 | 22.1 | 44.2 | 0.34 | -0.04 |
| 55 | 33451 | 22.1 | 44.2 | 0.37 | -0.04 |
| 56 | 34249 | 22.0 | 44.1 | 0.37 | 0.11 |
| 57 | 34776 | 22.0 | 44.1 | 0.37 | -0.04 |
| 58 | 35303 | 22.0 | 44.1 | 0.37 | -0.04 |
| 59 | 35829 | 22.0 | 44.1 | 0.37 | 0.04 |
| 60 | 36628 | 22.0 | 44.1 | 0.37 | 0.19 |
| 61 | 37154 | 22.0 | 44.1 | 0.37 | -0.04 |
| 62 | 37704 | 22.0 | 44.1 | 0.37 | 0.04 |
| 63 | 38231 | 22.0 | 44.1 | 0.37 | -0.11 |
| 64 | 39029 | 22.0 | 44.1 | 0.39 | 0.26 |
| 65 | 39556 | 22.0 | 44.1 | 0.37 | -0.04 |

```
[66 rows x 5 columns]
```

**Prueba 3**

```
In [104]: Din = pd.read_csv('D20190213c.txt',
                            names=['Time','Temperature','RH','Voltage','Current'])
          Din
```

Out[104]:

| | Time | Temperature | RH | Voltage | Current |
|---|---|---|---|---|---|
| 0 | 892 | NaN | NaN | 0.29 | -0.11 |
| 1 | 1418 | NaN | NaN | 0.32 | -0.11 |
| 2 | 1943 | NaN | NaN | 0.29 | -0.11 |
| 3 | 2468 | NaN | NaN | 0.29 | -0.19 |
| 4 | 3267 | 22.1 | 43.5 | 0.27 | -0.04 |
| 5 | 3794 | 22.1 | 43.5 | 0.27 | -0.48 |
| 6 | 4321 | 22.1 | 43.5 | 0.24 | -0.48 |
| 7 | 4848 | 22.1 | 43.5 | 0.27 | -0.48 |
| 8 | 5646 | 22.1 | 44.2 | 0.29 | -0.04 |
| 9 | 6173 | 22.1 | 44.2 | 0.29 | -0.48 |
| 10 | 6700 | 22.1 | 44.2 | 0.27 | -0.48 |
| 11 | 7227 | 22.1 | 44.2 | 0.27 | -0.56 |
| 12 | 8025 | 22.1 | 44.2 | 0.29 | -0.11 |
| 13 | 8551 | 22.1 | 44.2 | 0.27 | -0.41 |
| 14 | 9078 | 22.1 | 44.2 | 0.27 | -0.56 |
| 15 | 9605 | 22.1 | 44.2 | 0.27 | -0.56 |
| 16 | 10403 | 22.1 | 44.2 | 0.29 | -0.19 |
| 17 | 10930 | 22.1 | 44.2 | 0.27 | -0.56 |
| 18 | 11457 | 22.1 | 44.2 | 0.27 | -0.41 |
| 19 | 11983 | 22.1 | 44.2 | 0.27 | -0.63 |
| 20 | 12782 | 22.1 | 44.2 | 0.29 | -0.19 |
| 21 | 13308 | 22.1 | 44.2 | 0.27 | -0.63 |
| 22 | 13838 | 22.1 | 44.2 | 0.27 | -0.56 |
| 23 | 14365 | 22.1 | 44.2 | 0.27 | -0.63 |
| 24 | 15163 | 22.1 | 44.2 | 0.29 | -0.11 |

**Prueba 4**

```
In [105]: Din = pd.read_csv('D20190213d.txt',
                            names=['Time','Temperature','RH','Voltage','Current'])
          Din
```

Out[105]:

| | Time | Temperature | RH | Voltage | Current |
|---|---|---|---|---|---|
| 0 | 902 | NaN | NaN | 0.32 | -0.26 |
| 1 | 1449 | NaN | NaN | 0.29 | -0.26 |
| 2 | 1975 | NaN | NaN | 0.29 | -0.26 |
| 3 | 2500 | NaN | NaN | 0.29 | -0.33 |
| 4 | 3297 | 22.1 | 43.5 | 0.32 | 0.04 |
| 5 | 3823 | 22.1 | 43.5 | 0.29 | -0.26 |

| | | | | | |
|---|---|---|---|---|---|
| 6 | 4350 | 22.1 | 43.5 | 0.32 | -0.33 |
| 7 | 4877 | 22.1 | 43.5 | 0.29 | -0.33 |
| 8 | 5676 | 22.1 | 44.2 | 0.32 | 0.04 |
| 9 | 6202 | 22.1 | 44.2 | 0.29 | -0.26 |
| 10 | 6728 | 22.1 | 44.2 | 0.29 | -0.33 |
| 11 | 7256 | 22.1 | 44.2 | 0.29 | -0.26 |
| 12 | 8053 | 22.1 | 44.2 | 0.32 | 0.04 |
| 13 | 8581 | 22.1 | 44.2 | 0.32 | -0.33 |
| 14 | 9107 | 22.1 | 44.2 | 0.32 | -0.33 |
| 15 | 9636 | 22.1 | 44.2 | 0.29 | -0.33 |
| 16 | 10435 | 22.1 | 44.2 | 0.32 | -0.04 |
| 17 | 10961 | 22.1 | 44.2 | 0.29 | -0.19 |
| 18 | 11489 | 22.1 | 44.2 | 0.29 | -0.33 |
| 19 | 12015 | 22.1 | 44.2 | 0.29 | -0.33 |
| 20 | 12814 | 22.1 | 44.2 | 0.32 | 0.04 |
| 21 | 13340 | 22.1 | 44.2 | 0.29 | -0.26 |
| 22 | 13868 | 22.1 | 44.2 | 0.29 | -0.33 |
| 23 | 14394 | 22.1 | 44.2 | 0.29 | -0.19 |
| 24 | 15192 | 22.1 | 44.2 | 0.29 | -0.04 |
| 25 | 15719 | 22.1 | 44.2 | 0.29 | -0.33 |
| 26 | 16246 | 22.1 | 44.2 | 0.29 | -0.41 |
| 27 | 16773 | 22.1 | 44.2 | 0.29 | -0.41 |
| 28 | 17570 | 22.1 | 44.2 | 0.29 | 0.04 |
| 29 | 18098 | 22.1 | 44.2 | 0.32 | -0.33 |
| .. | ... | ... | ... | ... | ... |
| 76 | 46169 | 22.1 | 44.2 | 0.32 | 0.04 |
| 77 | 46695 | 22.1 | 44.2 | 0.32 | -0.26 |
| 78 | 47222 | 22.1 | 44.2 | 0.32 | -0.26 |
| 79 | 47750 | 22.1 | 44.2 | 0.29 | -0.33 |
| 80 | 48547 | 22.1 | 44.2 | 0.32 | 0.04 |
| 81 | 49074 | 22.1 | 44.2 | 0.29 | -0.33 |
| 82 | 49601 | 22.1 | 44.2 | 0.32 | -0.33 |
| 83 | 50127 | 22.1 | 44.2 | 0.32 | -0.33 |
| 84 | 50928 | 22.1 | 44.2 | 0.34 | 0.11 |
| 85 | 51456 | 22.1 | 44.2 | 0.34 | -0.26 |
| 86 | 51982 | 22.1 | 44.2 | 0.32 | -0.33 |
| 87 | 52509 | 22.1 | 44.2 | 0.32 | -0.33 |
| 88 | 53307 | 22.1 | 44.2 | 0.34 | 0.11 |
| 89 | 53834 | 22.1 | 44.2 | 0.32 | -0.26 |
| 90 | 54361 | 22.1 | 44.2 | 0.32 | -0.26 |
| 91 | 54910 | 22.1 | 44.2 | 0.32 | -0.19 |
| 92 | 55708 | 22.1 | 44.2 | 0.34 | 0.11 |
| 93 | 56236 | 22.1 | 44.2 | 0.34 | -0.19 |
| 94 | 56762 | 22.1 | 44.2 | 0.32 | -0.33 |
| 95 | 57289 | 22.1 | 44.2 | 0.32 | -0.33 |
| 96 | 58087 | 22.1 | 44.2 | 0.32 | -0.04 |
| 97 | 58614 | 22.1 | 44.2 | 0.32 | -0.26 |
| 98 | 59141 | 22.1 | 44.2 | 0.32 | -0.33 |

```
99   59668         22.1  44.2     0.32    -0.26
100  60466         22.1  44.2     0.32     0.04
101  60996         22.1  44.2     0.32    -0.33
102  61522         22.1  44.2     0.32    -0.26
103  62050         22.1  44.2     0.32    -0.19
104  62848         22.1  44.2     0.34     0.11
105  63374         22.1  44.2     0.32    -0.33

[106 rows x 5 columns]
```

**Prueba 5**

```
In [106]: Din = pd.read_csv('D20190213e.txt',
                            names=['Time','Temperature','RH','Voltage','Current'])
          Din
```

Out[106]:

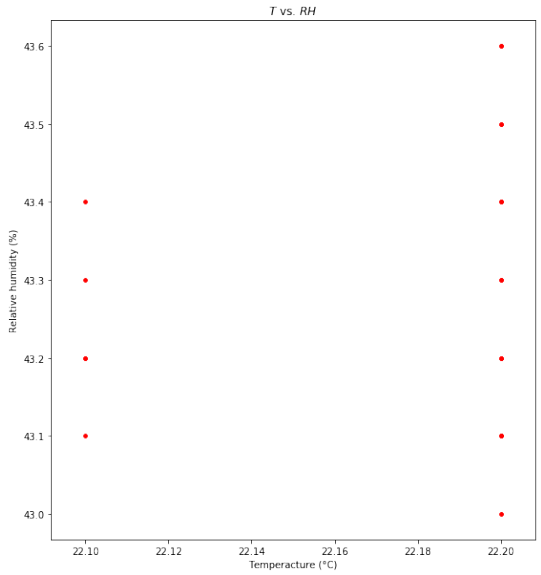
| | Time | Temperature | RH | Voltage | Current |
|---|---|---|---|---|---|
| 0 | 793 | 22.2 | 43.0 | 0.51 | 0.11 |
| 1 | 1320 | 22.2 | 43.0 | 0.56 | 0.11 |
| 2 | 1848 | 22.2 | 43.0 | 0.59 | 0.11 |
| 3 | 2374 | 22.2 | 43.0 | 0.54 | 0.04 |
| 4 | 3172 | 22.2 | 43.6 | 0.66 | 0.33 |
| 5 | 3699 | 22.2 | 43.6 | 0.73 | 0.11 |
| 6 | 4226 | 22.2 | 43.6 | 0.41 | 0.11 |
| 7 | 4752 | 22.2 | 43.6 | 0.44 | 0.11 |
| 8 | 5551 | 22.2 | 43.6 | 0.61 | 0.33 |
| 9 | 6077 | 22.2 | 43.6 | 0.73 | 0.04 |
| 10 | 6604 | 22.2 | 43.6 | 0.41 | 0.19 |
| 11 | 7131 | 22.2 | 43.6 | 0.46 | 0.04 |
| 12 | 7928 | 22.2 | 43.5 | 0.41 | 0.41 |
| 13 | 8458 | 22.2 | 43.5 | 0.56 | 0.04 |
| 14 | 8985 | 22.2 | 43.5 | 0.51 | 0.11 |
| 15 | 9534 | 22.2 | 43.5 | 0.56 | 0.04 |
| 16 | 10332 | 22.2 | 43.5 | 0.49 | 0.41 |
| 17 | 10859 | 22.2 | 43.5 | 0.49 | 0.11 |
| 18 | 11385 | 22.2 | 43.5 | 0.41 | 0.11 |
| 19 | 11913 | 22.2 | 43.5 | 0.39 | 0.11 |
| 20 | 12710 | 22.1 | 43.4 | 0.41 | 0.26 |
| 21 | 13237 | 22.1 | 43.4 | 0.41 | 0.04 |
| 22 | 13764 | 22.1 | 43.4 | 0.44 | 0.11 |
| 23 | 14290 | 22.1 | 43.4 | 0.41 | 0.11 |
| 24 | 15089 | 22.2 | 43.4 | 0.44 | 0.26 |
| 25 | 15616 | 22.2 | 43.4 | 0.41 | 0.11 |
| 26 | 16143 | 22.2 | 43.4 | 0.39 | 0.11 |
| 27 | 16669 | 22.2 | 43.4 | 0.39 | 0.04 |
| 28 | 17467 | 22.2 | 43.4 | 0.39 | 0.41 |
| 29 | 17994 | 22.2 | 43.4 | 0.39 | 0.11 |
| .. | ... | ... | ... | ... | ... |

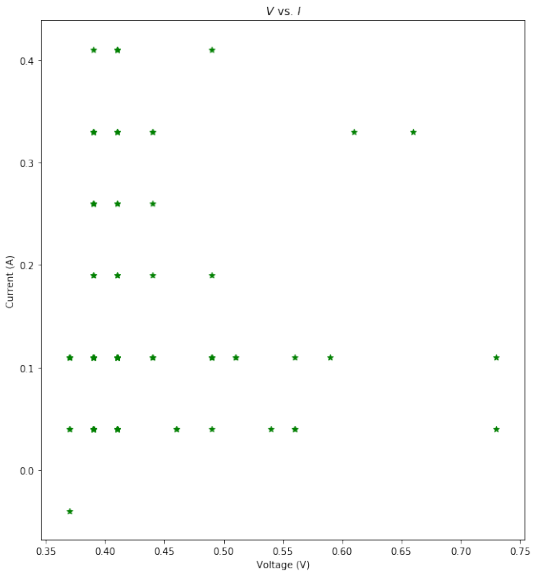
```
63  38104         22.2  43.2     0.39     0.04
64  38901         22.2  43.2     0.41     0.41
65  39428         22.2  43.2     0.46     0.04
66  39957         22.2  43.2     0.49     0.04
67  40484         22.2  43.2     0.41     0.11
68  41282         22.1  43.1     0.39     0.33
69  41809         22.1  43.1     0.39     0.11
70  42336         22.1  43.1     0.39     0.04
71  42863         22.1  43.1     0.41     0.11
72  43661         22.2  43.1     0.41     0.41
73  44188         22.2  43.1     0.39     0.04
74  44715         22.2  43.1     0.41     0.11
75  45241         22.2  43.1     0.41     0.11
76  46088         22.2  43.1     0.41     0.26
77  46615         22.2  43.1     0.39     0.04
78  47141         22.2  43.1     0.39     0.11
79  47669         22.2  43.1     0.37     0.11
80  48466         22.2  43.1     0.39     0.26
81  48994         22.2  43.1     0.37     0.11
82  49520         22.2  43.1     0.37     0.04
83  50046         22.2  43.1     0.37     0.04
84  50843         22.2  43.1     0.39     0.33
85  51369         22.2  43.1     0.41     0.11
86  51897         22.2  43.1     0.37     0.11
87  52423         22.2  43.1     0.41     0.19
88  53221         22.2  43.1     0.39     0.33
89  53747         22.2  43.1     0.41     0.04
90  54274         22.2  43.1     0.39     0.11
91  54801         22.2  43.1     0.39     0.11
92  55599         22.2  43.0     0.39     0.26

[93 rows x 5 columns]
```

**Data graphics**

In [107]:
```
plt.figure(figsize=(20,10))
plt.subplot(121)
plt.scatter(Din.Temperature,Din.RH,marker='.',color='red')
plt.xlabel('Temperacture (řC)')
plt.ylabel('Relative humidity (%)')
plt.title('$T$ vs. $RH$')
plt.subplot(122)
plt.scatter(Din.Voltage,Din.Current,marker='*',color='green')
plt.xlabel('Voltage (V)')
plt.ylabel('Current (A)')
plt.title('$V$ vs. $I$')
#plt.savefig('Exp1_Pro_3')
```

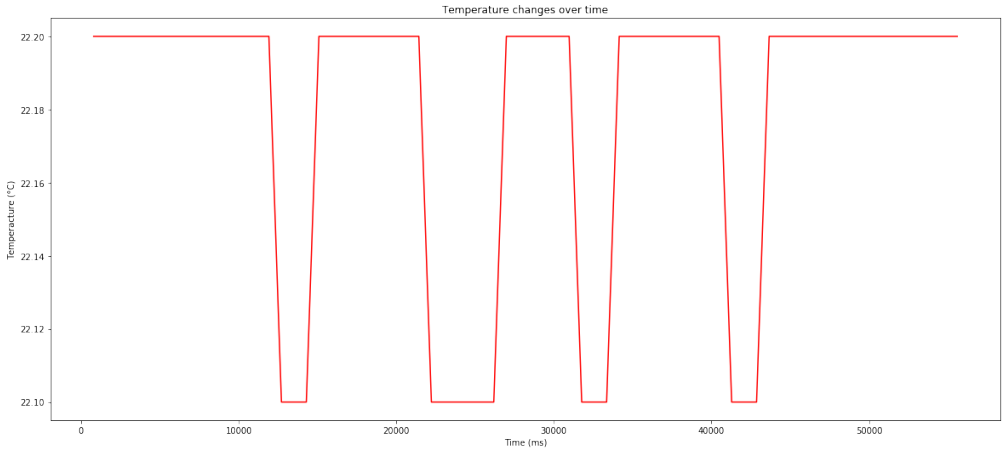
Out[107]:
```
Text(0.5,1,'$V$ vs. $I$')
```

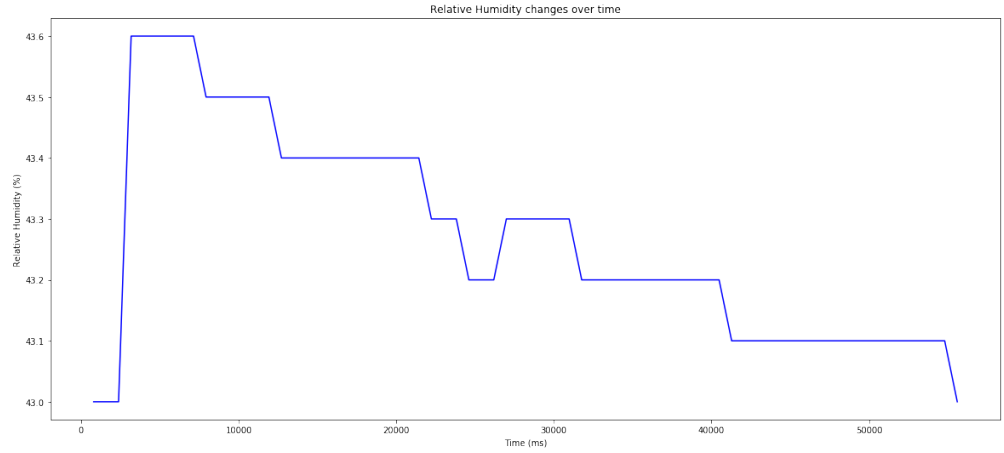


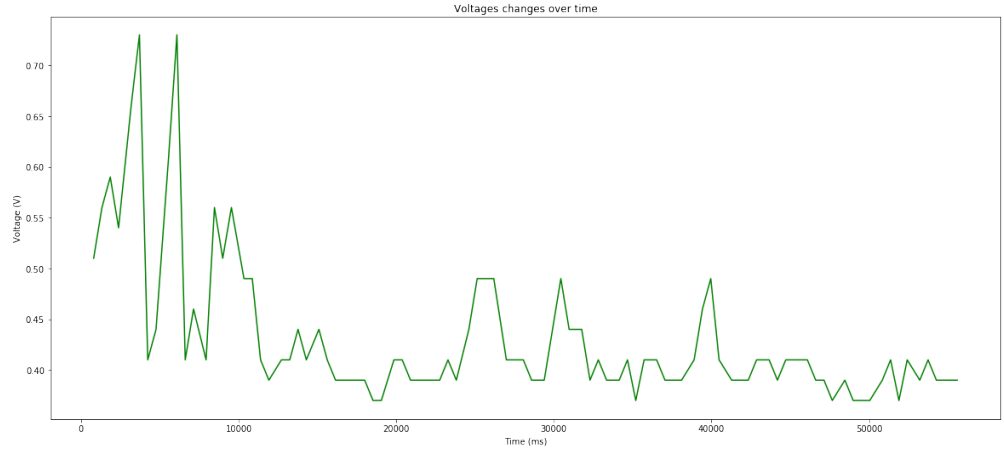



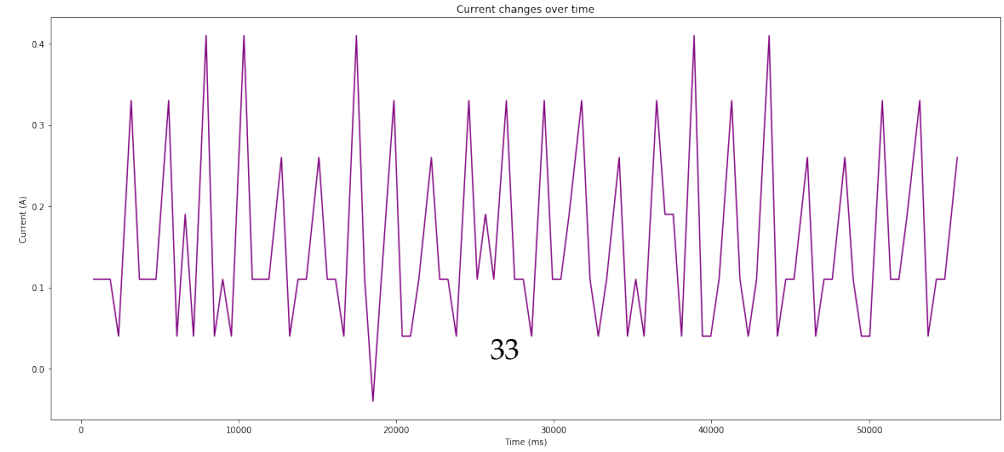

In [108]:
```
plt.figure(figsize=(20,40))
plt.subplot(411)
plt.plot(Din.Time,Din.Temperature,
         color = 'red')
plt.ylabel('Temperacture (řC)')
plt.xlabel('Time (ms)')
plt.title('Temperature changes over time')
plt.subplot(412)
plt.plot(Din.Time,Din.RH,
         color = 'blue')
plt.ylabel('Relative Humidity (%)')
plt.xlabel('Time (ms)')
plt.title('Relative Humidity changes over time')
plt.subplot(413)
plt.plot(Din.Time,Din.Voltage
         ,color = 'green')
plt.ylabel('Voltage (V)')
plt.xlabel('Time (ms)')
plt.title('Voltages changes over time')
plt.subplot(414)
plt.plot(Din.Time,Din.Current,
         color =  'purple')
plt.ylabel('Current (A)')
plt.xlabel('Time (ms)')
plt.title('Current changes over time')
```

Out[108]:
```
Text(0.5,1,'Current changes over time')
```


Temperature changes over time
Temperacture (°C)
22.20
22.18
22.16
22.14
22.12
22.10
0
10000
20000
30000
40000
50000
Time (ms)


Relative Humidity changes over time
Relative Humidity (%)
43.6
43.5
43.4
43.3
43.2
43.1
43.0
0
10000
20000
30000
40000
50000
Time (ms)


Voltages changes over time
Voltage (V)
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0
10000
20000
30000
40000
50000
Time (ms)

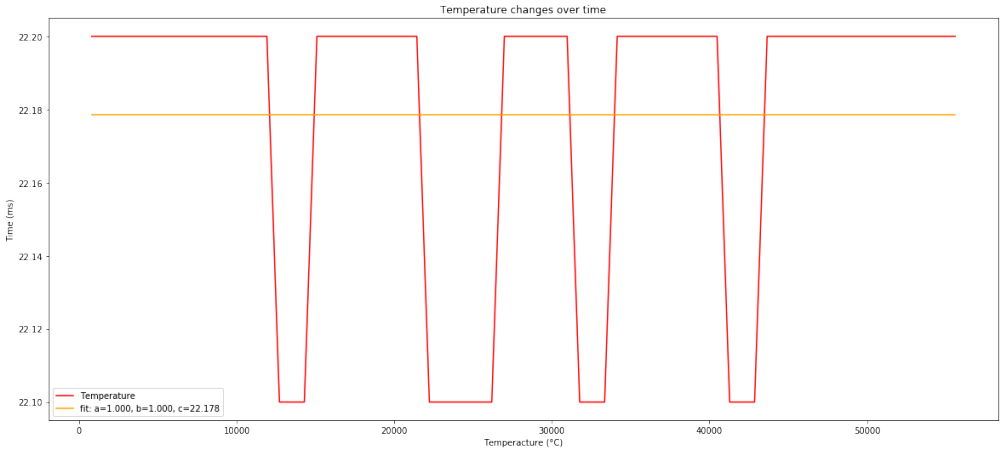

Current changes over time
Current (A)
0.4
0.3
0.2
0.1
0.0
0
10000
20000
30000
40000
50000
Time (ms)

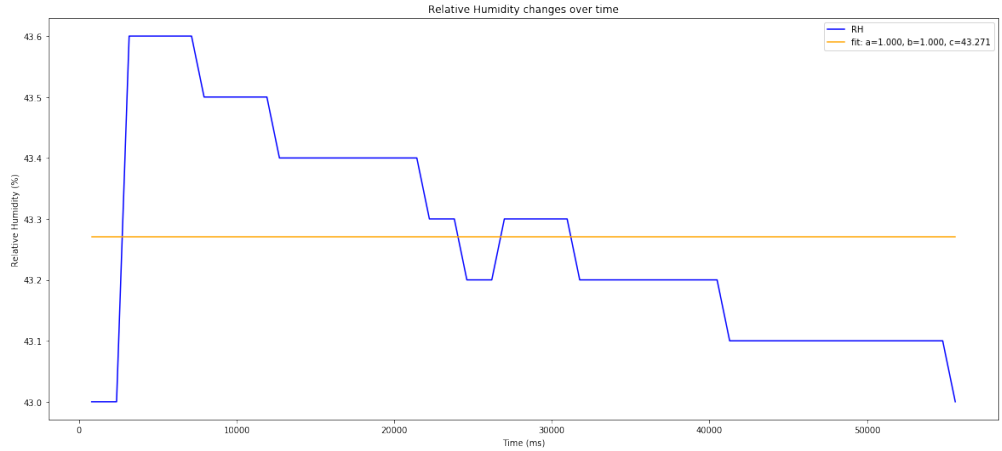
**Curve fitting into function** $f(x) = ae^{(-b*x)} + c$

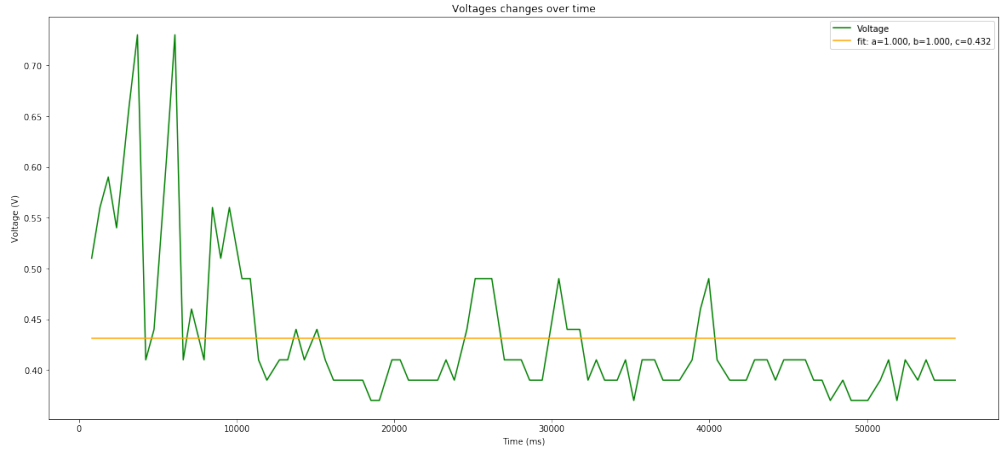
```
In [109]: plt.figure(figsize=(20,40))
          plt.subplot(411)
          plt.plot(Din.Time,Din.Temperature,
                   color = 'red')
          popt, pcov = curve_fit(func, Din.Time, Din.Temperature)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.xlabel('Temperacture (řC)')
          plt.ylabel('Time (ms)')
          plt.title('Temperature changes over time')
          plt.legend()
          plt.subplot(412)
          plt.plot(Din.Time,Din.RH,
                   color = 'blue')
          popt, pcov = curve_fit(func, Din.Time, Din.RH)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Relative Humidity (%)')
          plt.xlabel('Time (ms)')
          plt.title('Relative Humidity changes over time')
          plt.legend()
          plt.subplot(413)
          plt.plot(Din.Time,Din.Voltage
                   ,color = 'green',)
          popt, pcov = curve_fit(func, Din.Time, Din.Voltage)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Voltage (V)')
          plt.xlabel('Time (ms)')
          plt.title('Voltages changes over time')
          plt.legend()
          plt.subplot(414)
          plt.plot(Din.Time,Din.Current,
                   color =  'purple')
          popt, pcov = curve_fit(func, Din.Time, Din.Current)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Current (A)')
          plt.xlabel('Time (ms)')
          plt.title('Current changes over time')
          plt.legend()

C:\Users\Ghiordy F. Contreras\Anaconda3\lib\site-packages\scipy\optimize\minpack.py:794: Optim
```

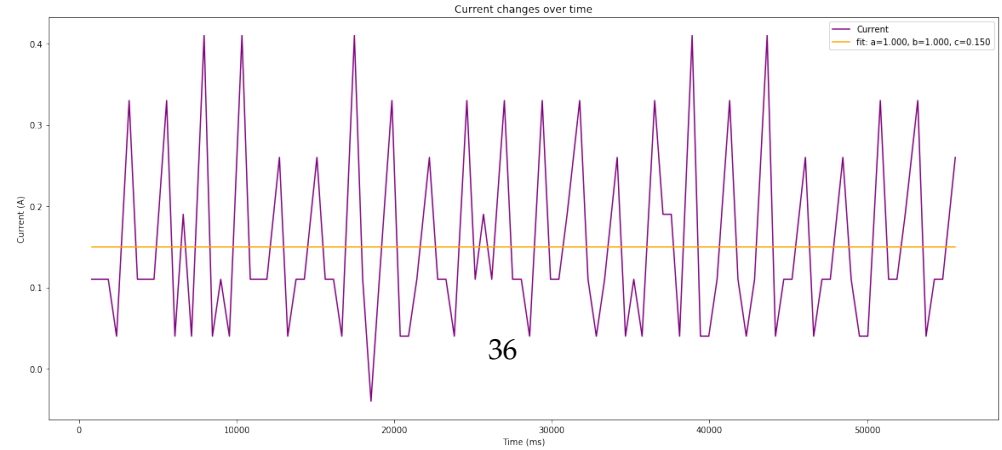
```
  category=OptimizeWarning)
```

```
Out[109]: <matplotlib.legend.Legend at 0x1f0909c5470>
```


Temperature changes over time
Time (ms)
Temperacture (°C)
Temperature
fit: a=1.000, b=1.000, c=22.178


Relative Humidity changes over time
Relative Humidity (%)
Time (ms)
RH
fit: a=1.000, b=1.000, c=43.271


Voltages changes over time
Voltage (V)
Time (ms)
Voltage
fit: a=1.000, b=1.000, c=0.432


Current changes over time
Current (A)
Time (ms)
Current
fit: a=1.000, b=1.000, c=0.150

**Prueba 6**

```
In [110]: Din = pd.read_csv('D20190213f.txt',
                            names=['Time','Temperature','RH','Voltage','Current'])
          Din
```

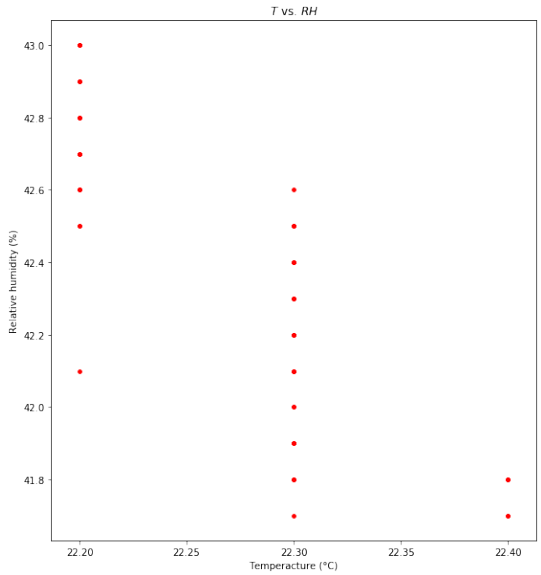
Out[110]:

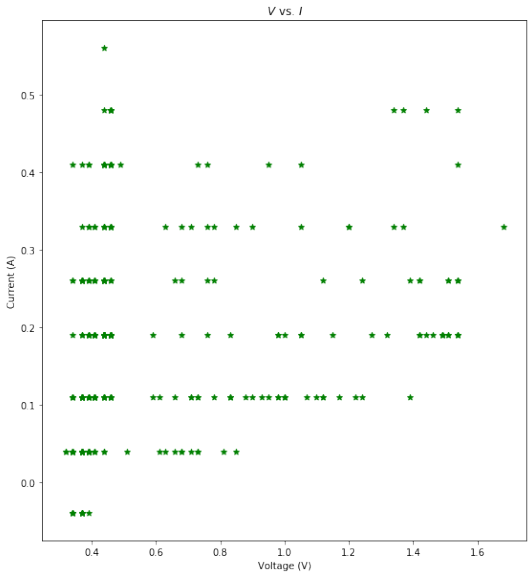
| | Time | Temperature | RH | Voltage | Current |
|---|---|---|---|---|---|
| 0 | 793 | 22.2 | 43.0 | 0.39 | 0.11 |
| 1 | 1320 | 22.2 | 43.0 | 0.41 | 0.04 |
| 2 | 1847 | 22.2 | 43.0 | 0.39 | 0.19 |
| 3 | 2373 | 22.2 | 43.0 | 0.37 | 0.11 |
| 4 | 3172 | 22.2 | 43.0 | 0.39 | 0.41 |
| 5 | 3698 | 22.2 | 43.0 | 0.41 | 0.04 |
| 6 | 4225 | 22.2 | 43.0 | 0.41 | 0.11 |
| 7 | 4752 | 22.2 | 43.0 | 0.37 | 0.04 |
| 8 | 5553 | 22.2 | 43.0 | 0.37 | 0.26 |
| 9 | 6079 | 22.2 | 43.0 | 0.37 | 0.11 |
| 10 | 6605 | 22.2 | 43.0 | 0.37 | 0.04 |
| 11 | 7133 | 22.2 | 43.0 | 0.39 | 0.19 |
| 12 | 7930 | 22.2 | 42.9 | 0.44 | 0.33 |
| 13 | 8480 | 22.2 | 42.9 | 0.39 | 0.04 |
| 14 | 9007 | 22.2 | 42.9 | 0.41 | 0.04 |
| 15 | 9534 | 22.2 | 42.9 | 0.37 | 0.11 |
| 16 | 10332 | 22.2 | 43.0 | 0.41 | 0.33 |
| 17 | 10859 | 22.2 | 43.0 | 0.39 | 0.11 |
| 18 | 11385 | 22.2 | 43.0 | 0.39 | 0.04 |
| 19 | 11912 | 22.2 | 43.0 | 0.39 | 0.04 |
| 20 | 12710 | 22.2 | 42.9 | 0.41 | 0.26 |
| 21 | 13237 | 22.2 | 42.9 | 0.39 | 0.11 |
| 22 | 13764 | 22.2 | 42.9 | 0.39 | 0.11 |
| 23 | 14290 | 22.2 | 42.9 | 0.37 | 0.11 |
| 24 | 15088 | 22.2 | 42.9 | 0.39 | 0.26 |
| 25 | 15616 | 22.2 | 42.9 | 0.37 | 0.04 |
| 26 | 16145 | 22.2 | 42.9 | 0.39 | 0.04 |
| 27 | 16671 | 22.2 | 42.9 | 0.39 | 0.19 |
| 28 | 17470 | 22.2 | 42.8 | 0.39 | 0.33 |
| 29 | 17996 | 22.2 | 42.8 | 0.37 | 0.04 |
| .. | ... | ... | ... | ... | ... |
| 330 | 197199 | 22.3 | 41.8 | 0.44 | 0.19 |
| 331 | 197727 | 22.3 | 41.8 | 0.46 | 0.26 |
| 332 | 198524 | 22.3 | 41.8 | 0.44 | 0.41 |
| 333 | 199052 | 22.3 | 41.8 | 0.44 | 0.04 |
| 334 | 199579 | 22.3 | 41.8 | 0.44 | 0.19 |
| 335 | 200105 | 22.3 | 41.8 | 0.44 | 0.26 |
| 336 | 200903 | 22.4 | 41.8 | 0.46 | 0.41 |

```
337  201431         22.4  41.8     0.41     0.19
338  201960         22.4  41.8     0.41     0.26
339  202487         22.4  41.8     0.46     0.19
340  203285         22.4  41.8     0.44     0.48
341  203811         22.4  41.8     0.46     0.19
342  204362         22.4  41.8     0.41     0.33
343  204889         22.4  41.8     0.41     0.19
344  205687         22.3  41.7     0.44     0.41
345  206214         22.3  41.7     0.44     0.19
346  206741         22.3  41.7     0.44     0.26
347  207267         22.3  41.7     0.44     0.11
348  208066         22.4  41.8     0.46     0.33
349  208593         22.4  41.8     0.46     0.11
350  209121         22.4  41.8     0.44     0.19
351  209647         22.4  41.8     0.44     0.33
352  210445         22.4  41.7     0.46     0.41
353  210972         22.4  41.7     0.44     0.26
354  211499         22.4  41.7     0.44     0.26
355  212029         22.4  41.7     0.46     0.11
356  212827         22.4  41.7     0.49     0.41
357  213353         22.4  41.7     0.41     0.11
358  213880         22.4  41.7     0.44     0.19
359  214407         22.4  41.7     0.46     0.19

[360 rows x 5 columns]
```

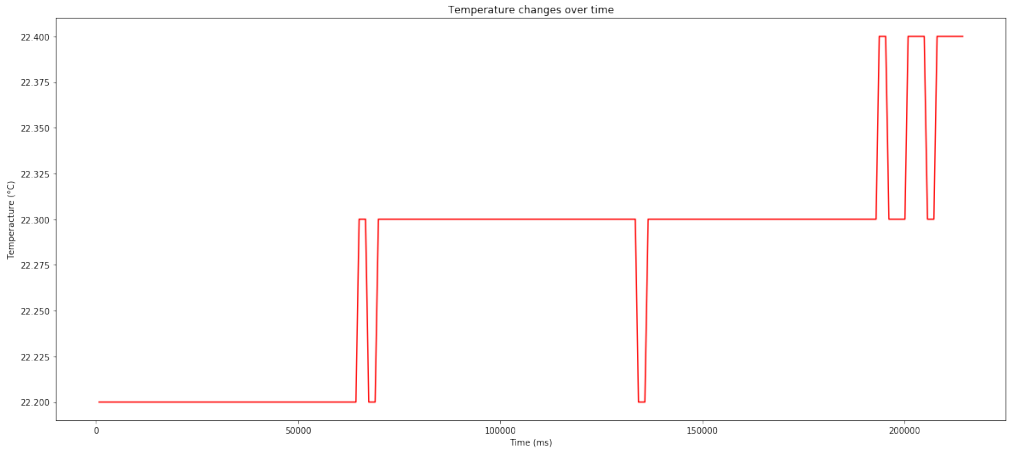
**Data graphics**

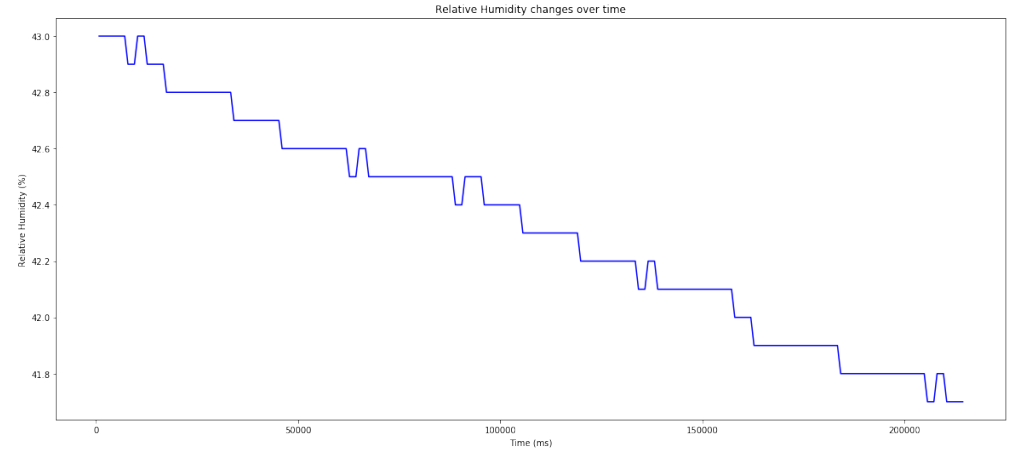
```
In [111]: plt.figure(figsize=(20,10))
          plt.subplot(121)
          plt.scatter(Din.Temperature,Din.RH,marker='.',color='red')
          plt.xlabel('Temperacture (řC)')
          plt.ylabel('Relative humidity (%)')
          plt.title('$T$ vs. $RH$')
          plt.subplot(122)
          plt.scatter(Din.Voltage,Din.Current,marker='*',color='green')
          plt.xlabel('Voltage (V)')
          plt.ylabel('Current (A)')
          plt.title('$V$ vs. $I$')
          #plt.savefig('Exp1_Pro_3')

Out[111]: Text(0.5,1,'$V$ vs. $I$')
```

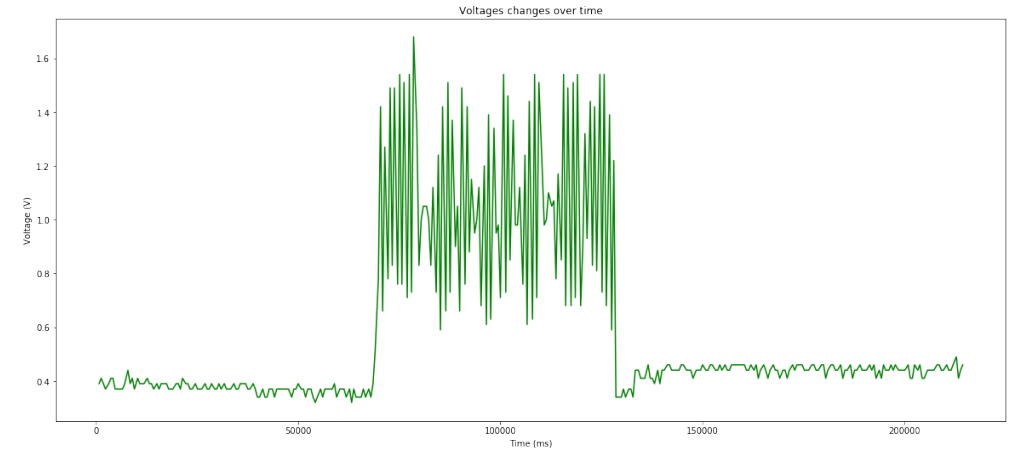


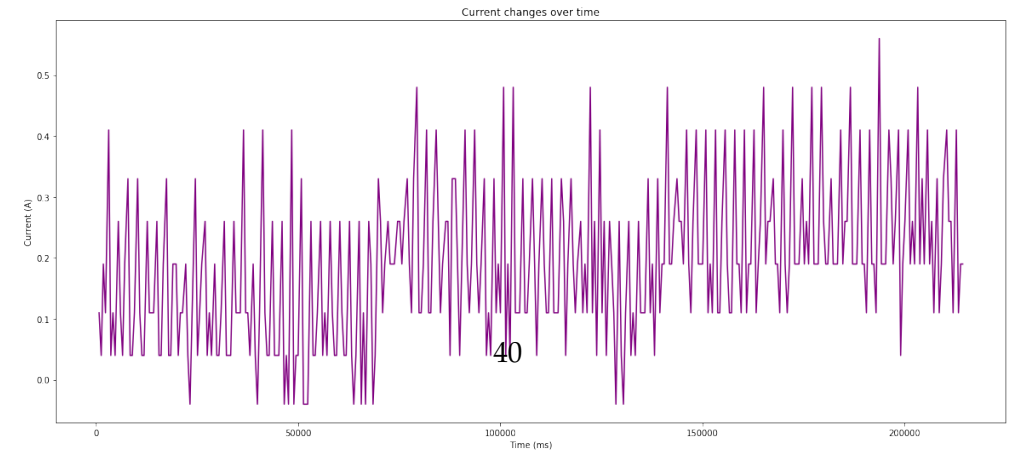




```
In [112]: plt.figure(figsize=(20,40))
          plt.subplot(411)
          plt.plot(Din.Time,Din.Temperature,
                   color = 'red')
          plt.ylabel('Temperacture (řC)')
          plt.xlabel('Time (ms)')
          plt.title('Temperature changes over time')
          plt.subplot(412)
          plt.plot(Din.Time,Din.RH,
                   color = 'blue')
          plt.ylabel('Relative Humidity (%)')
          plt.xlabel('Time (ms)')
          plt.title('Relative Humidity changes over time')
          plt.subplot(413)
          plt.plot(Din.Time,Din.Voltage
                   ,color = 'green')
          plt.ylabel('Voltage (V)')
          plt.xlabel('Time (ms)')
          plt.title('Voltages changes over time')
          plt.subplot(414)
          plt.plot(Din.Time,Din.Current,
                   color =  'purple')
          plt.ylabel('Current (A)')
          plt.xlabel('Time (ms)')
          plt.title('Current changes over time')

Out[112]: Text(0.5,1,'Current changes over time')
```


Temperature changes over time
Temperacture (°C)
22.400
22.375
22.350
22.325
22.300
22.275
22.250
22.225
22.200
0
50000
100000
150000
200000
Time (ms)


Relative Humidity changes over time
Relative Humidity (%)
43.0
42.8
42.6
42.4
42.2
42.0
41.8
0
50000
100000
150000
200000
Time (ms)


Voltages changes over time
Voltage (V)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0
50000
100000
150000
200000
Time (ms)

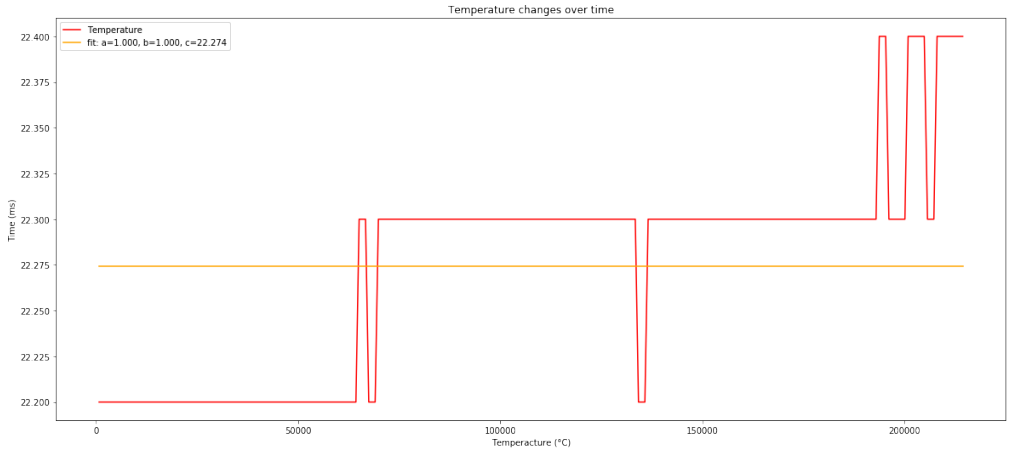

Current changes over time
Current (A)
0.5
0.4
0.3
0.2
0.1
0.0
0
50000
100000
150000
200000
Time (ms)

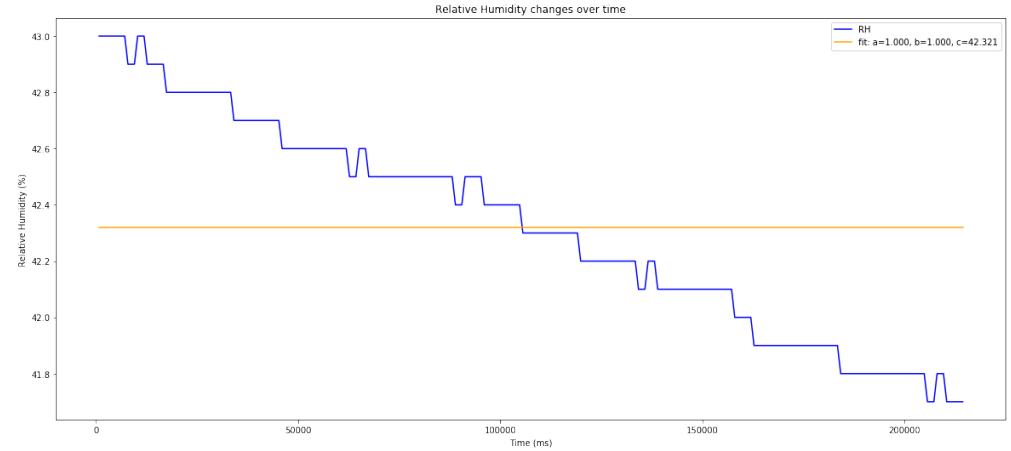
**Curve fitting into function** $f(x) = ae^{(-b*x)} + c$

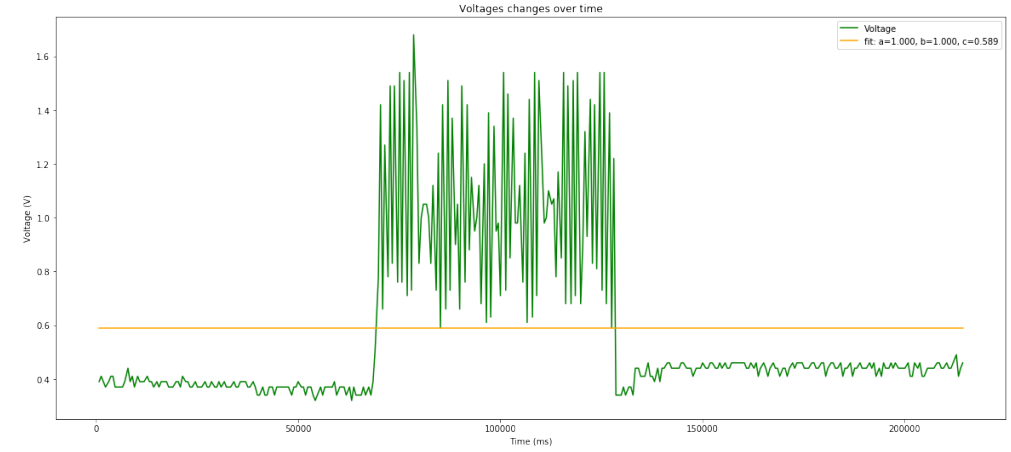
```
In [113]: plt.figure(figsize=(20,40))
          plt.subplot(411)
          plt.plot(Din.Time,Din.Temperature,
                   color = 'red')
          popt, pcov = curve_fit(func, Din.Time, Din.Temperature)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.xlabel('Temperacture (řC)')
          plt.ylabel('Time (ms)')
          plt.title('Temperature changes over time')
          plt.legend()
          plt.subplot(412)
          plt.plot(Din.Time,Din.RH,
                   color = 'blue')
          popt, pcov = curve_fit(func, Din.Time, Din.RH)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Relative Humidity (%)')
          plt.xlabel('Time (ms)')
          plt.title('Relative Humidity changes over time')
          plt.legend()
          plt.subplot(413)
          plt.plot(Din.Time,Din.Voltage
                   ,color = 'green',)
          popt, pcov = curve_fit(func, Din.Time, Din.Voltage)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Voltage (V)')
          plt.xlabel('Time (ms)')
          plt.title('Voltages changes over time')
          plt.legend()
          plt.subplot(414)
          plt.plot(Din.Time,Din.Current,
                   color =  'purple')
          popt, pcov = curve_fit(func, Din.Time, Din.Current)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Current (A)')
          plt.xlabel('Time (ms)')
          plt.title('Current changes over time')
          plt.legend()

C:\Users\Ghiordy F. Contreras\Anaconda3\lib\site-packages\scipy\optimize\minpack.py:794: Optim
```

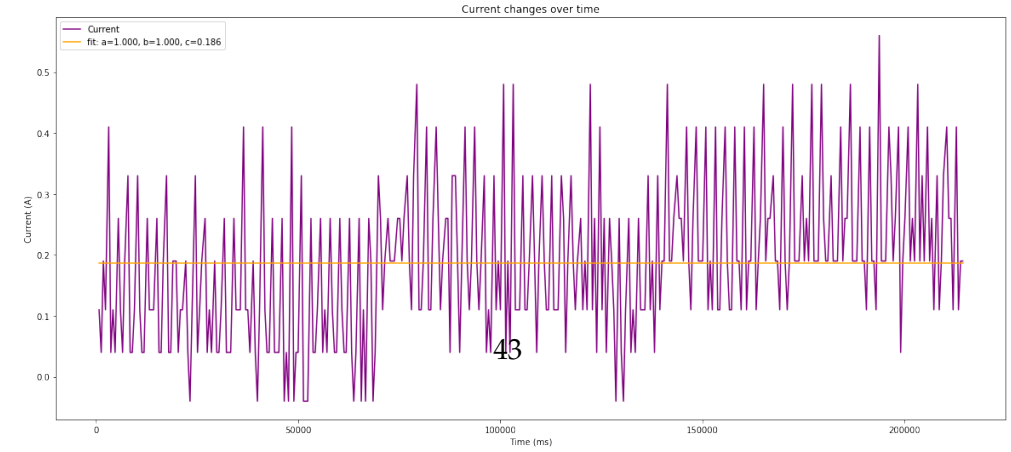
```
  category=OptimizeWarning)
```

```
Out[113]: <matplotlib.legend.Legend at 0x1f090cf0d68>
```


Temperature changes over time
Temperature
fit: a=1.000, b=1.000, c=22.274
Time (ms)
Temperature (°C)


Relative Humidity changes over time
RH
fit: a=1.000, b=1.000, c=42.321
Relative Humidity (%)
Time (ms)


Voltages changes over time
Voltage
fit: a=1.000, b=1.000, c=0.589
Voltage (V)
Time (ms)


Current changes over time
Current
fit: a=1.000, b=1.000, c=0.186
Current (A)
Time (ms)

**Prueba 7**

```
In [114]: Din = pd.read_csv('D20190213g.txt',
                            names=['Time','Temperature','RH','Voltage','Current'])
          Din
```

Out[114]:

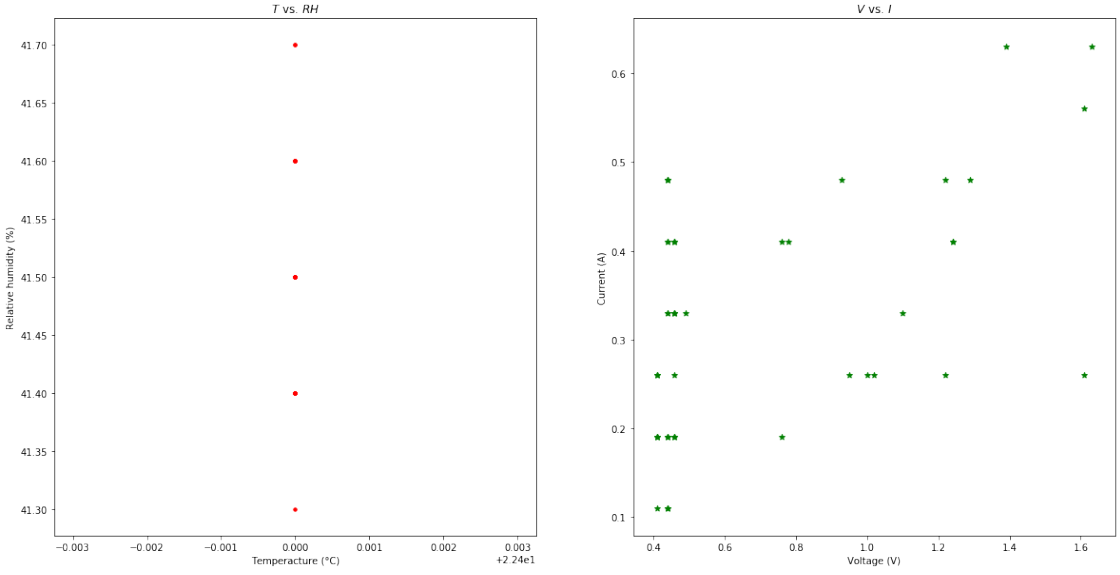
| | Time | Temperature | RH | Voltage | Current |
|---|---|---|---|---|---|
| 0 | 1284 | 22.4 | 41.7 | 0.46 | 0.19 |
| 1 | 2302 | 22.4 | 41.7 | 0.41 | 0.19 |
| 2 | 3593 | 22.4 | 41.7 | 0.44 | 0.41 |
| 3 | 4612 | 22.4 | 41.7 | 0.44 | 0.11 |
| 4 | 5902 | 22.4 | 41.6 | 0.46 | 0.41 |
| 5 | 1284 | 22.4 | 41.6 | 0.46 | 0.26 |
| 6 | 2302 | 22.4 | 41.6 | 0.44 | 0.11 |
| 7 | 3593 | 22.4 | 41.6 | 0.44 | 0.33 |
| 8 | 4612 | 22.4 | 41.6 | 0.41 | 0.26 |
| 9 | 5902 | 22.4 | 41.6 | 0.44 | 0.41 |
| 10 | 6921 | 22.4 | 41.6 | 0.41 | 0.19 |
| 11 | 8211 | 22.4 | 41.6 | 0.46 | 0.41 |
| 12 | 9253 | 22.4 | 41.6 | 0.41 | 0.19 |
| 13 | 10546 | 22.4 | 41.5 | 0.49 | 0.33 |
| 14 | 11565 | 22.4 | 41.5 | 0.41 | 0.19 |
| 15 | 12856 | 22.4 | 41.6 | 1.61 | 0.56 |
| 16 | 13876 | 22.4 | 41.6 | 1.10 | 0.33 |
| 17 | 15166 | 22.4 | 41.5 | 0.78 | 0.41 |
| 18 | 16185 | 22.4 | 41.5 | 0.95 | 0.26 |
| 19 | 17475 | 22.4 | 41.5 | 1.24 | 0.41 |
| 20 | 18494 | 22.4 | 41.5 | 1.61 | 0.26 |
| 21 | 19784 | 22.4 | 41.5 | 1.39 | 0.63 |
| 22 | 20804 | 22.4 | 41.5 | 0.76 | 0.19 |
| 23 | 22094 | 22.4 | 41.5 | 0.93 | 0.48 |
| 24 | 23113 | 22.4 | 41.5 | 1.24 | 0.41 |
| 25 | 24403 | 22.4 | 41.5 | 1.63 | 0.63 |
| 26 | 25422 | 22.4 | 41.5 | 1.22 | 0.26 |
| 27 | 26713 | 22.4 | 41.5 | 0.76 | 0.41 |
| 28 | 27731 | 22.4 | 41.5 | 1.00 | 0.26 |
| 29 | 29022 | 22.4 | 41.5 | 1.29 | 0.48 |
| 30 | 30044 | 22.4 | 41.5 | 1.02 | 0.26 |
| 31 | 31335 | 22.4 | 41.4 | 1.22 | 0.48 |
| 32 | 32354 | 22.4 | 41.4 | 0.41 | 0.11 |
| 33 | 33644 | 22.4 | 41.5 | 0.46 | 0.33 |
| 34 | 34663 | 22.4 | 41.5 | 0.44 | 0.19 |
| 35 | 35954 | 22.4 | 41.4 | 0.46 | 0.33 |
| 36 | 36973 | 22.4 | 41.4 | 0.44 | 0.19 |
| 37 | 38263 | 22.4 | 41.4 | 0.44 | 0.48 |

| | | | | | |
|---|---|---|---|---|---|
| 38 | 39282 | 22.4 | 41.4 | 0.44 | 0.11 |
| 39 | 40573 | 22.4 | 41.4 | 0.46 | 0.33 |
| 40 | 41592 | 22.4 | 41.4 | 0.41 | 0.26 |
| 41 | 42906 | 22.4 | 41.4 | 0.44 | 0.33 |
| 42 | 43925 | 22.4 | 41.4 | 0.44 | 0.19 |
| 43 | 45216 | 22.4 | 41.4 | 0.44 | 0.48 |
| 44 | 46235 | 22.4 | 41.4 | 0.41 | 0.26 |
| 45 | 47525 | 22.4 | 41.4 | 0.44 | 0.48 |
| 46 | 48544 | 22.4 | 41.4 | 0.46 | 0.19 |
| 47 | 49836 | 22.4 | 41.3 | 0.46 | 0.33 |
| 48 | 50857 | 22.4 | 41.3 | 0.46 | 0.19 |
| 49 | 52148 | 22.4 | 41.4 | 0.46 | 0.41 |

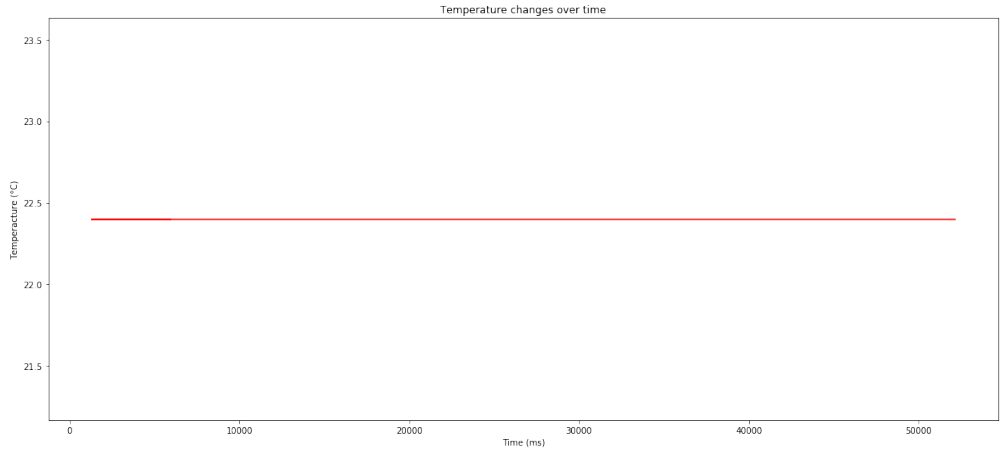
### Data graphics

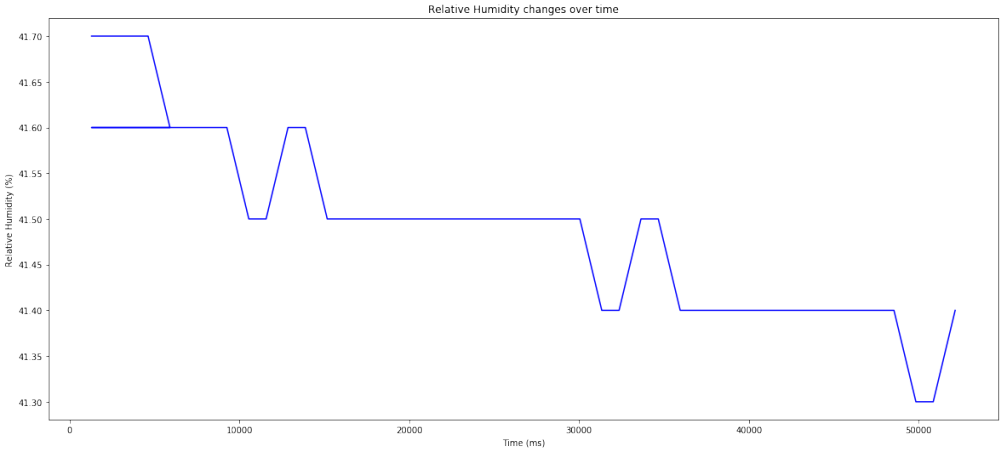
In [115]:
```
plt.figure(figsize=(20,10))
plt.subplot(121)
plt.scatter(Din.Temperature,Din.RH,marker='.',color='red')
plt.xlabel('Temperacture (řC)')
plt.ylabel('Relative humidity (%)')
plt.title('$T$ vs. $RH$')
plt.subplot(122)
plt.scatter(Din.Voltage,Din.Current,marker='*',color='green')
plt.xlabel('Voltage (V)')
plt.ylabel('Current (A)')
plt.title('$V$ vs. $I$')
#plt.savefig('Exp1_Pro_3')
```

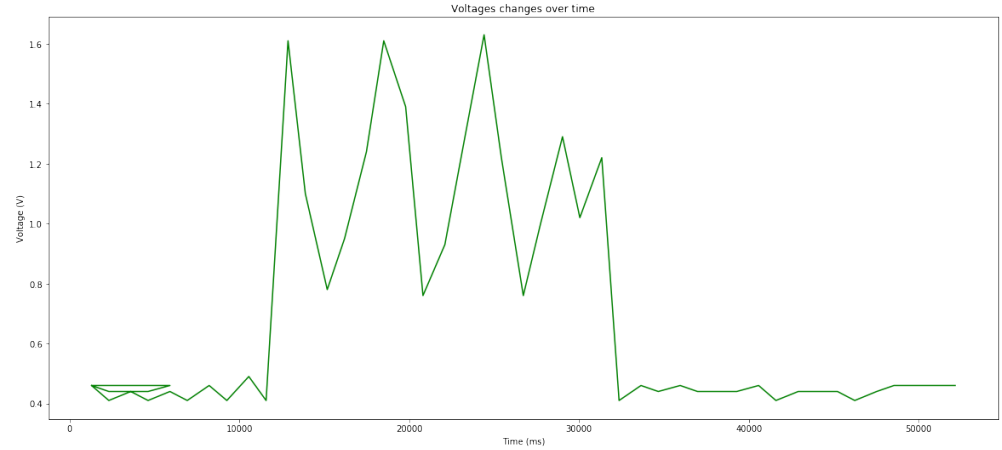
Out[115]: Text(0.5,1,'$V$ vs. $I$')

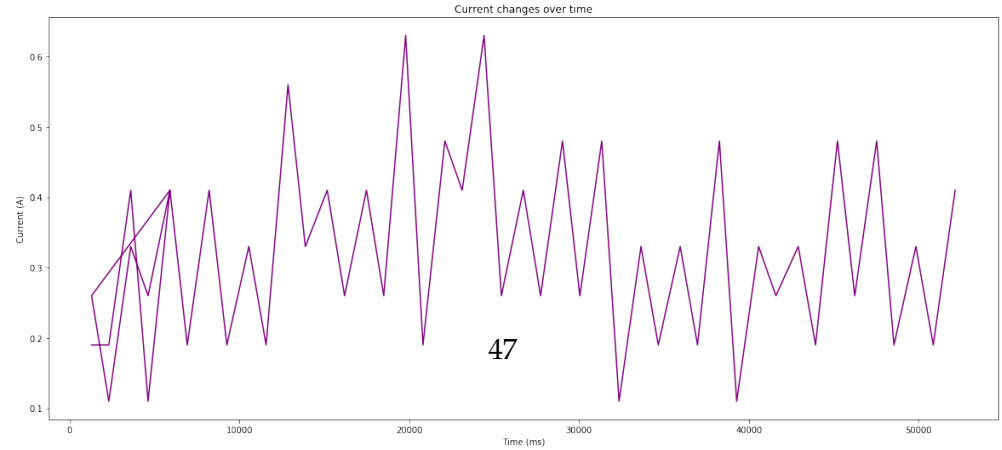


```
In [116]: plt.figure(figsize=(20,40))
          plt.subplot(411)
          plt.plot(Din.Time,Din.Temperature,
                   color = 'red')
          plt.ylabel('Temperacture (řC)')
          plt.xlabel('Time (ms)')
          plt.title('Temperature changes over time')
          plt.subplot(412)
          plt.plot(Din.Time,Din.RH,
                   color = 'blue')
          plt.ylabel('Relative Humidity (%)')
          plt.xlabel('Time (ms)')
          plt.title('Relative Humidity changes over time')
          plt.subplot(413)
          plt.plot(Din.Time,Din.Voltage
                   ,color = 'green')
          plt.ylabel('Voltage (V)')
          plt.xlabel('Time (ms)')
          plt.title('Voltages changes over time')
          plt.subplot(414)
          plt.plot(Din.Time,Din.Current,
                   color =  'purple')
          plt.ylabel('Current (A)')
          plt.xlabel('Time (ms)')
          plt.title('Current changes over time')

Out[116]: Text(0.5,1,'Current changes over time')
```


Temperature changes over time
Temperacture (°C)
23.5
23.0
22.5
22.0
21.5
0
10000
20000
30000
40000
50000
Time (ms)


Relative Humidity changes over time
Relative Humidity (%)
41.70
41.65
41.60
41.55
41.50
41.45
41.40
41.35
41.30
0
10000
20000
30000
40000
50000
Time (ms)


Voltages changes over time
Voltage (V)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0
10000
20000
30000
40000
50000
Time (ms)

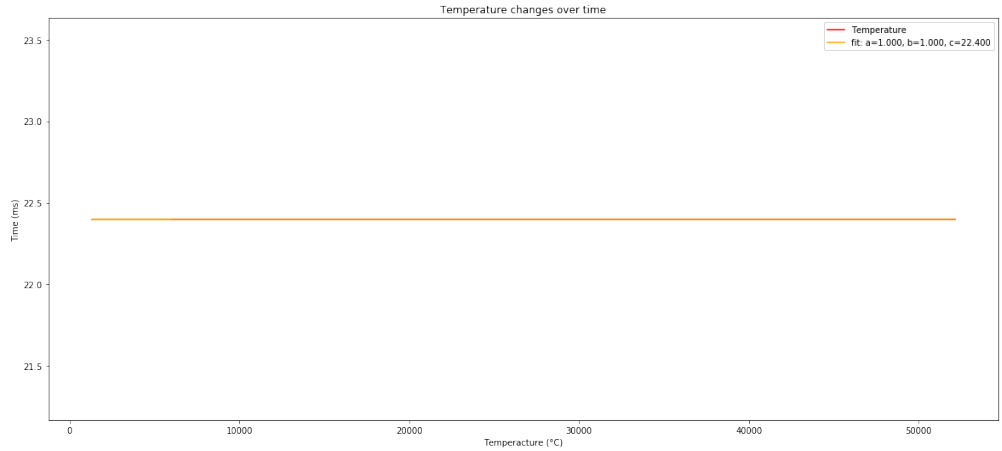

Current changes over time
Current (A)
0.6
0.5
0.4
0.3
0.2
0.1
0
10000
20000
30000
40000
50000
Time (ms)

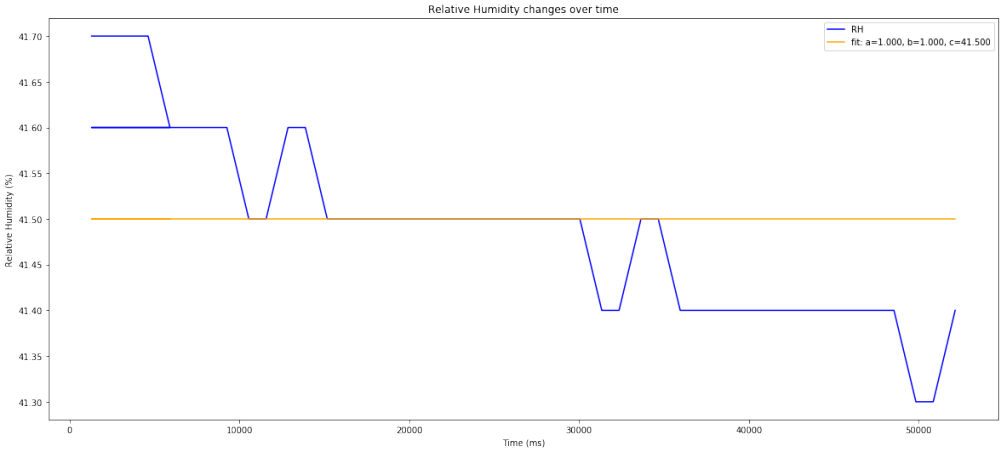
**Curve fitting into function** $f(x) = ae^{(-b*x)} + c$

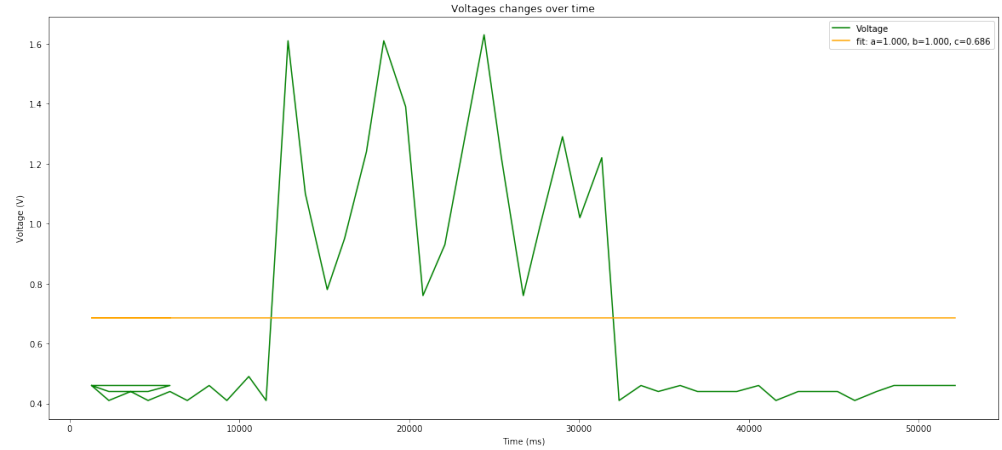
```
In [117]: plt.figure(figsize=(20,40))
          plt.subplot(411)
          plt.plot(Din.Time,Din.Temperature,
                   color = 'red')
          popt, pcov = curve_fit(func, Din.Time, Din.Temperature)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.xlabel('Temperacture (řC)')
          plt.ylabel('Time (ms)')
          plt.title('Temperature changes over time')
          plt.legend()
          plt.subplot(412)
          plt.plot(Din.Time,Din.RH,
                   color = 'blue')
          popt, pcov = curve_fit(func, Din.Time, Din.RH)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Relative Humidity (%)')
          plt.xlabel('Time (ms)')
          plt.title('Relative Humidity changes over time')
          plt.legend()
          plt.subplot(413)
          plt.plot(Din.Time,Din.Voltage
                   ,color = 'green',)
          popt, pcov = curve_fit(func, Din.Time, Din.Voltage)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Voltage (V)')
          plt.xlabel('Time (ms)')
          plt.title('Voltages changes over time')
          plt.legend()
          plt.subplot(414)
          plt.plot(Din.Time,Din.Current,
                   color =  'purple')
          popt, pcov = curve_fit(func, Din.Time, Din.Current)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Current (A)')
          plt.xlabel('Time (ms)')
          plt.title('Current changes over time')
          plt.legend()

C:\Users\Ghiordy F. Contreras\Anaconda3\lib\site-packages\scipy\optimize\minpack.py:794: Optim
```

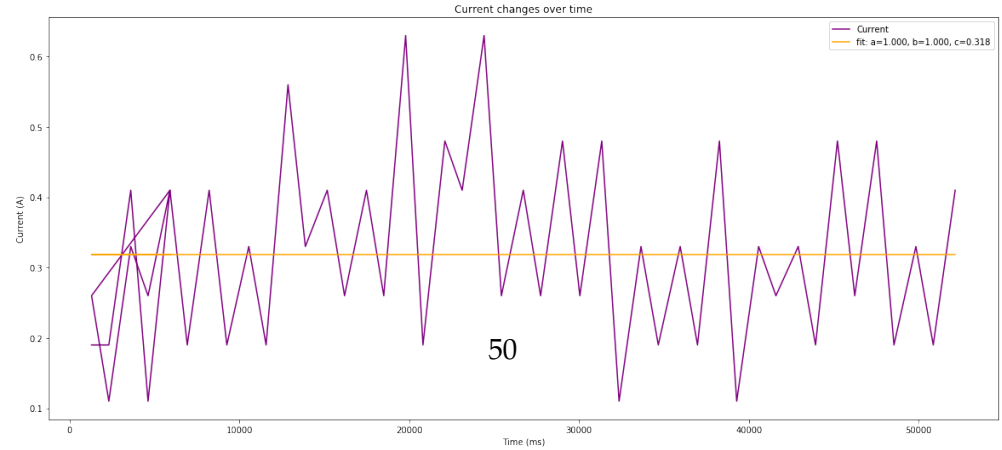
```
  category=OptimizeWarning)
```

```
Out[117]: <matplotlib.legend.Legend at 0x1f09259b6a0>
```


Temperature changes over time
Temperature
fit: a=1.000, b=1.000, c=22.400
Time (ms)
Temperacture (°C)


Relative Humidity changes over time
RH
fit: a=1.000, b=1.000, c=41.500
Relative Humidity (%)
Time (ms)


Voltages changes over time
Voltage
fit: a=1.000, b=1.000, c=0.686
Voltage (V)
Time (ms)


Current changes over time
Current
fit: a=1.000, b=1.000, c=0.318
Current (A)
Time (ms)

**Prueba 8**

```
In [118]: Din = pd.read_csv('D20190213h.txt',
                            names=['Time','Temperature','RH','Voltage','Current'])
          Din
```

Out[118]:

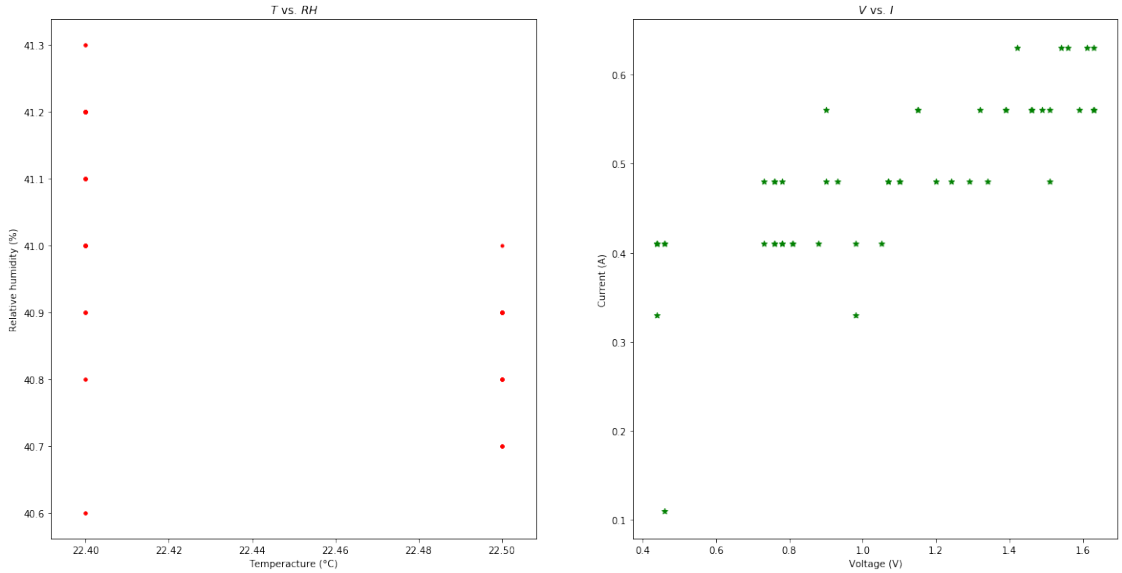
| | Time | Temperature | RH | Voltage | Current |
|---|---|---|---|---|---|
| 0 | 2283 | 22.4 | 41.3 | 0.46 | 0.11 |
| 1 | 4574 | 22.4 | 41.3 | 0.44 | 0.41 |
| 2 | 6864 | 22.4 | 41.2 | 0.44 | 0.33 |
| 3 | 9154 | 22.4 | 41.2 | 0.44 | 0.41 |
| 4 | 11446 | 22.4 | 41.2 | 0.44 | 0.41 |
| 5 | 13736 | 22.4 | 41.2 | 0.46 | 0.41 |
| 6 | 16026 | 22.4 | 41.2 | 0.46 | 0.41 |
| 7 | 18317 | 22.4 | 41.2 | 0.88 | 0.41 |
| 8 | 20608 | 22.4 | 41.2 | 0.98 | 0.41 |
| 9 | 22898 | 22.4 | 41.2 | 1.56 | 0.63 |
| 10 | 25188 | 22.4 | 41.2 | 1.46 | 0.56 |
| 11 | 27479 | 22.4 | 41.2 | 1.05 | 0.41 |
| 12 | 29769 | 22.4 | 41.2 | 0.76 | 0.41 |
| 13 | 32059 | 22.4 | 41.1 | 1.63 | 0.56 |
| 14 | 34350 | 22.4 | 41.1 | 0.93 | 0.48 |
| 15 | 36640 | 22.4 | 41.1 | 1.54 | 0.63 |
| 16 | 38933 | 22.4 | 41.1 | 1.10 | 0.48 |
| 17 | 41224 | 22.4 | 41.1 | 1.15 | 0.56 |
| 18 | 43514 | 22.4 | 41.1 | 1.20 | 0.48 |
| 19 | 45804 | 22.4 | 41.0 | 1.15 | 0.56 |
| 20 | 48095 | 22.4 | 41.0 | 1.07 | 0.48 |
| 21 | 50408 | 22.4 | 41.0 | 1.63 | 0.56 |
| 22 | 52699 | 22.4 | 41.0 | 0.78 | 0.41 |
| 23 | 54989 | 22.4 | 41.0 | 1.63 | 0.56 |
| 24 | 57279 | 22.4 | 41.0 | 0.90 | 0.56 |
| 25 | 59570 | 22.4 | 41.0 | 1.42 | 0.63 |
| 26 | 61860 | 22.4 | 40.9 | 1.32 | 0.56 |
| 27 | 64151 | 22.4 | 41.0 | 0.81 | 0.41 |
| 28 | 66441 | 22.4 | 40.9 | 1.39 | 0.56 |
| 29 | 68731 | 22.4 | 40.9 | 1.51 | 0.56 |
| 30 | 71022 | 22.4 | 40.9 | 0.98 | 0.33 |
| 31 | 73312 | 22.5 | 41.0 | 0.73 | 0.48 |
| 32 | 75602 | 22.5 | 40.9 | 1.51 | 0.48 |
| 33 | 77893 | 22.5 | 40.9 | 1.24 | 0.48 |
| 34 | 80186 | 22.5 | 40.9 | 1.46 | 0.56 |
| 35 | 82477 | 22.4 | 40.8 | 1.29 | 0.48 |
| 36 | 84766 | 22.4 | 40.8 | 0.78 | 0.48 |
| 37 | 87057 | 22.5 | 40.9 | 1.59 | 0.56 |

| | | | | | |
|---|---|---|---|---|---|
| 38 | 89348 | 22.5 | 40.9 | 0.90 | 0.48 |
| 39 | 91638 | 22.5 | 40.9 | 1.63 | 0.63 |
| 40 | 93928 | 22.5 | 40.9 | 0.73 | 0.41 |
| 41 | 96219 | 22.5 | 40.8 | 1.07 | 0.48 |
| 42 | 98509 | 22.5 | 40.9 | 1.61 | 0.63 |
| 43 | 100800 | 22.5 | 40.8 | 0.76 | 0.48 |
| 44 | 103090 | 22.5 | 40.8 | 1.49 | 0.56 |
| 45 | 105380 | 22.5 | 40.8 | 0.76 | 0.41 |
| 46 | 107671 | 22.5 | 40.8 | 1.34 | 0.48 |
| 47 | 109962 | 22.5 | 40.7 | 0.76 | 0.48 |
| 48 | 112251 | 22.5 | 40.7 | 1.39 | 0.56 |
| 49 | 114542 | 22.4 | 40.6 | 0.81 | 0.41 |
| 50 | 116832 | 22.5 | 40.7 | 1.46 | 0.56 |
| 51 | 119148 | 22.4 | 40.6 | 1.10 | 0.48 |
| 52 | 121439 | 22.5 | 40.7 | 0.78 | 0.41 |

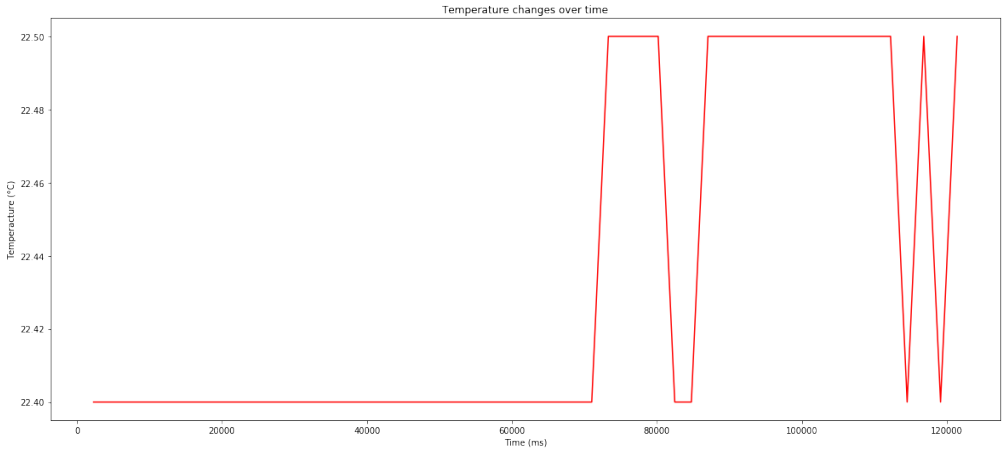
### Data graphics

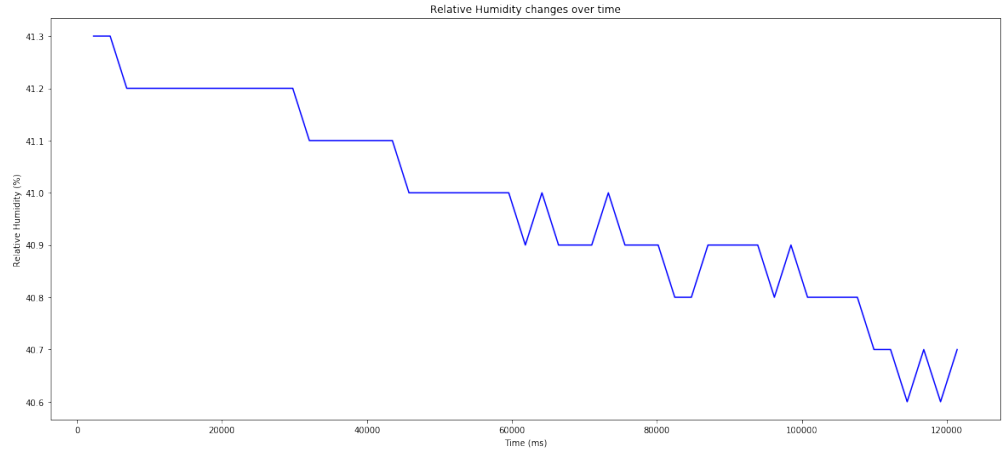
In [119]:
```
plt.figure(figsize=(20,10))
plt.subplot(121)
plt.scatter(Din.Temperature,Din.RH,marker='.',color='red')
plt.xlabel('Temperacture (řC)')
plt.ylabel('Relative humidity (%)')
plt.title('$T$ vs. $RH$')
plt.subplot(122)
plt.scatter(Din.Voltage,Din.Current,marker='*',color='green')
plt.xlabel('Voltage (V)')
plt.ylabel('Current (A)')
plt.title('$V$ vs. $I$')
#plt.savefig('Exp1_Pro_3')
```

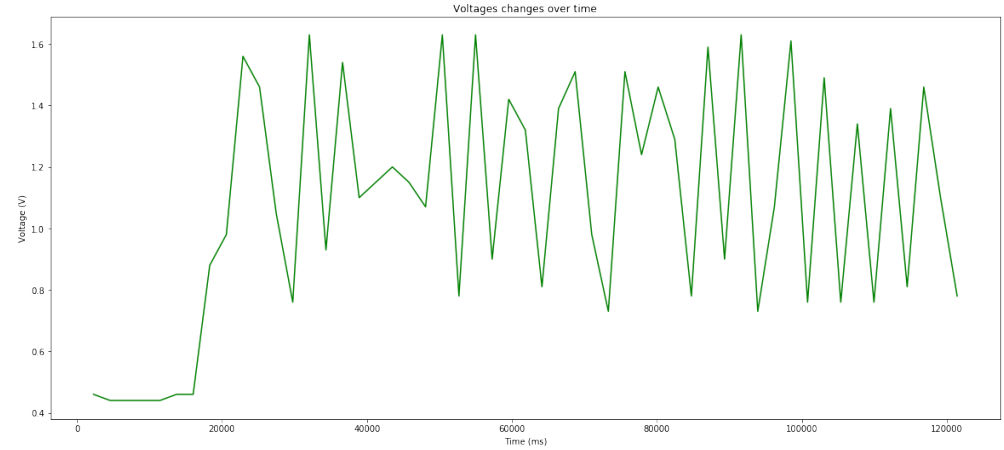
Out[119]:
```
Text(0.5,1,'$V$ vs. $I$')
```

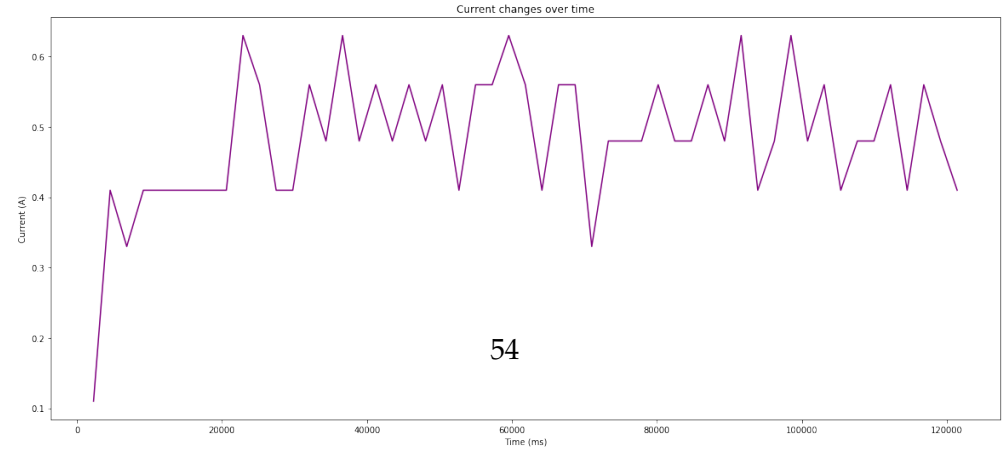


```
In [120]: plt.figure(figsize=(20,40))
          plt.subplot(411)
          plt.plot(Din.Time,Din.Temperature,
                   color = 'red')
          plt.ylabel('Temperacture (řC)')
          plt.xlabel('Time (ms)')
          plt.title('Temperature changes over time')
          plt.subplot(412)
          plt.plot(Din.Time,Din.RH,
                   color = 'blue')
          plt.ylabel('Relative Humidity (%)')
          plt.xlabel('Time (ms)')
          plt.title('Relative Humidity changes over time')
          plt.subplot(413)
          plt.plot(Din.Time,Din.Voltage
                   ,color = 'green')
          plt.ylabel('Voltage (V)')
          plt.xlabel('Time (ms)')
          plt.title('Voltages changes over time')
          plt.subplot(414)
          plt.plot(Din.Time,Din.Current,
                   color =  'purple')
          plt.ylabel('Current (A)')
          plt.xlabel('Time (ms)')
          plt.title('Current changes over time')

Out[120]: Text(0.5,1,'Current changes over time')
```


Temperature changes over time
Temperacture (°C)
22.50
22.48
22.46
22.44
22.42
22.40
0
20000
40000
60000
80000
100000
120000
Time (ms)


Relative Humidity changes over time
Relative Humidity (%)
41.3
41.2
41.1
41.0
40.9
40.8
40.7
40.6
0
20000
40000
60000
80000
100000
120000
Time (ms)


Voltages changes over time
Voltage (V)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0
20000
40000
60000
80000
100000
120000
Time (ms)

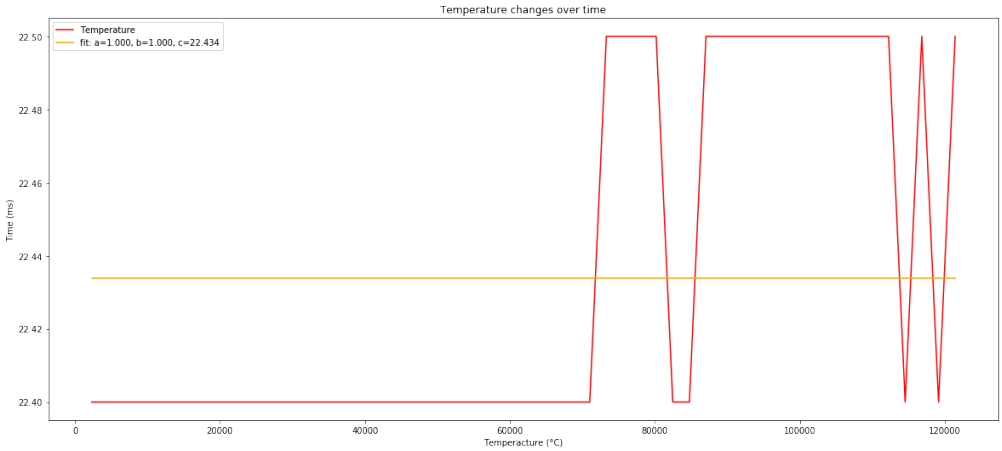

Current changes over time
Current (A)
0.6
0.5
0.4
0.3
0.2
0.1
0
20000
40000
60000
80000
100000
120000
Time (ms)

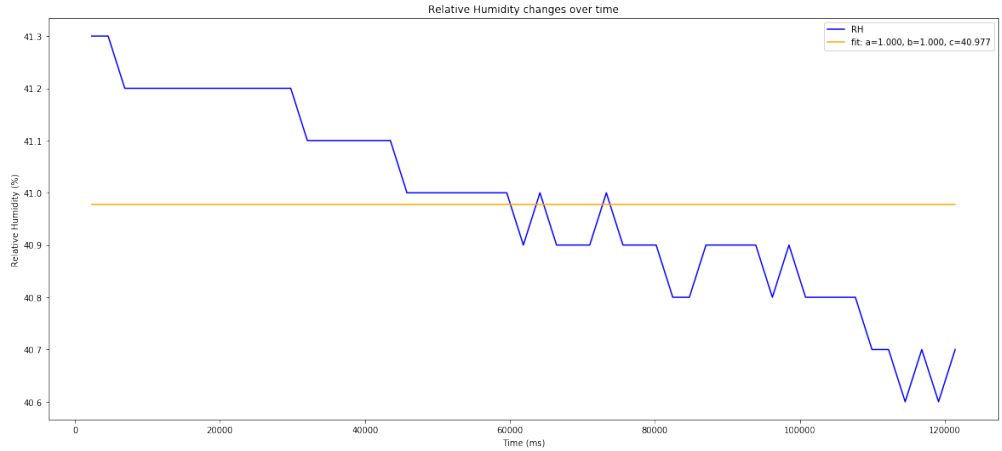
**Curve fitting into function** $f(x) = ae^{(-b*x)} + c$

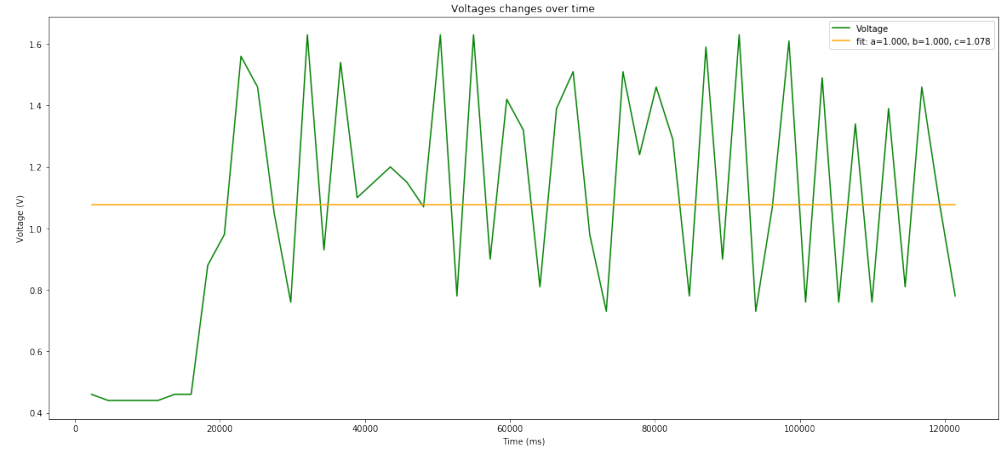
```
In [121]: plt.figure(figsize=(20,40))
          plt.subplot(411)
          plt.plot(Din.Time,Din.Temperature,
                   color = 'red')
          popt, pcov = curve_fit(func, Din.Time, Din.Temperature)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.xlabel('Temperacture (řC)')
          plt.ylabel('Time (ms)')
          plt.title('Temperature changes over time')
          plt.legend()
          plt.subplot(412)
          plt.plot(Din.Time,Din.RH,
                   color = 'blue')
          popt, pcov = curve_fit(func, Din.Time, Din.RH)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Relative Humidity (%)')
          plt.xlabel('Time (ms)')
          plt.title('Relative Humidity changes over time')
          plt.legend()
          plt.subplot(413)
          plt.plot(Din.Time,Din.Voltage
                   ,color = 'green',)
          popt, pcov = curve_fit(func, Din.Time, Din.Voltage)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Voltage (V)')
          plt.xlabel('Time (ms)')
          plt.title('Voltages changes over time')
          plt.legend()
          plt.subplot(414)
          plt.plot(Din.Time,Din.Current,
                   color =  'purple')
          popt, pcov = curve_fit(func, Din.Time, Din.Current)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Current (A)')
          plt.xlabel('Time (ms)')
          plt.title('Current changes over time')
          plt.legend()

C:\Users\Ghiordy F. Contreras\Anaconda3\lib\site-packages\scipy\optimize\minpack.py:794: Optim
```

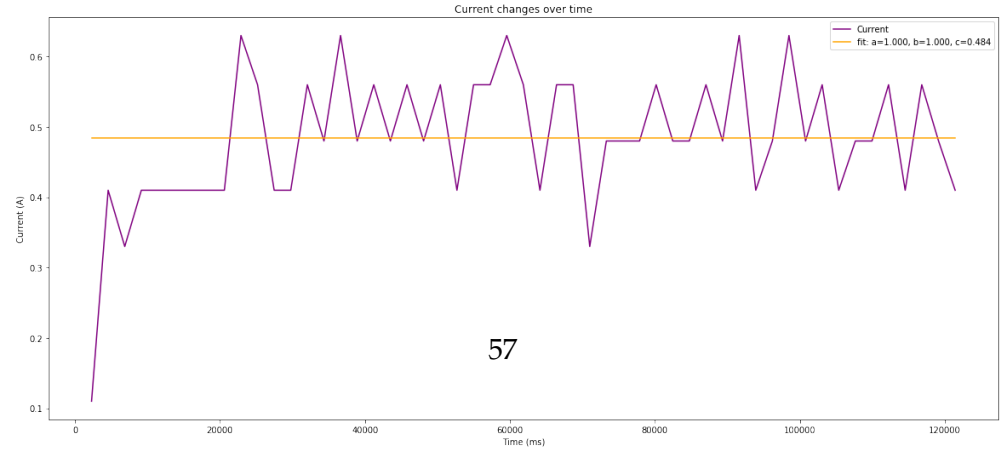
```
  category=OptimizeWarning)
```

```
Out[121]: <matplotlib.legend.Legend at 0x1f0826a3be0>
```


Temperature changes over time
Temperature
fit: a=1.000, b=1.000, c=22.434
Time (ms)
Temperacture (°C)


Relative Humidity changes over time
RH
fit: a=1.000, b=1.000, c=40.977
Relative Humidity (%)
Time (ms)


Voltages changes over time
Voltage
fit: a=1.000, b=1.000, c=1.078
Voltage (V)
Time (ms)


Current changes over time
Current
fit: a=1.000, b=1.000, c=0.484
Current (A)
Time (ms)

**Prueba 9**

```
In [122]: Din = pd.read_csv('D20190213i.txt',
                            names=['Time','Temperature','RH','Voltage','Current'])
          Din
```

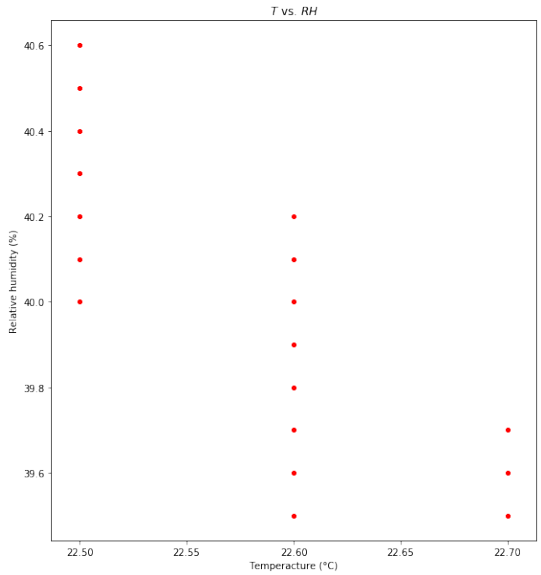
Out[122]:

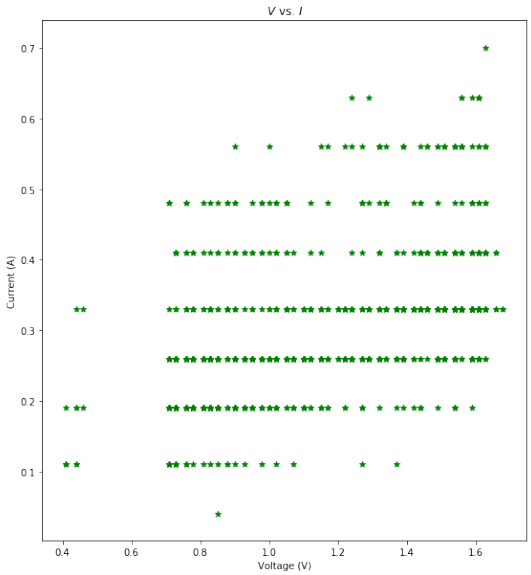
| | Time | Temperature | RH | Voltage | Current |
|---|---|---|---|---|---|
| 0 | 484 | 22.5 | 40.6 | 1.49 | 0.26 |
| 1 | 702 | 22.5 | 40.6 | 1.24 | 0.33 |
| 2 | 921 | 22.5 | 40.6 | 0.76 | 0.26 |
| 3 | 1140 | 22.5 | 40.6 | 1.61 | 0.41 |
| 4 | 1359 | 22.5 | 40.6 | 0.93 | 0.26 |
| 5 | 1579 | 22.5 | 40.6 | 1.32 | 0.26 |
| 6 | 1798 | 22.5 | 40.6 | 1.22 | 0.33 |
| 7 | 2017 | 22.5 | 40.6 | 0.71 | 0.19 |
| 8 | 2507 | 22.5 | 40.6 | 1.56 | 0.56 |
| 9 | 2726 | 22.5 | 40.6 | 0.85 | 0.26 |
| 10 | 2946 | 22.5 | 40.6 | 1.54 | 0.41 |
| 11 | 3165 | 22.5 | 40.6 | 1.10 | 0.33 |
| 12 | 3384 | 22.5 | 40.6 | 0.83 | 0.19 |
| 13 | 3602 | 22.5 | 40.6 | 1.51 | 0.33 |
| 14 | 3821 | 22.5 | 40.6 | 0.81 | 0.26 |
| 15 | 4040 | 22.5 | 40.6 | 1.56 | 0.33 |
| 16 | 4534 | 22.5 | 40.6 | 1.00 | 0.56 |
| 17 | 4753 | 22.5 | 40.6 | 1.44 | 0.26 |
| 18 | 4972 | 22.5 | 40.6 | 0.83 | 0.19 |
| 19 | 5191 | 22.5 | 40.6 | 1.59 | 0.33 |
| 20 | 5410 | 22.5 | 40.6 | 0.95 | 0.26 |
| 21 | 5628 | 22.5 | 40.6 | 1.29 | 0.26 |
| 22 | 5848 | 22.5 | 40.6 | 1.22 | 0.33 |
| 23 | 6067 | 22.5 | 40.6 | 0.76 | 0.26 |
| 24 | 6557 | 22.5 | 40.6 | 1.44 | 0.48 |
| 25 | 6776 | 22.5 | 40.6 | 0.83 | 0.26 |
| 26 | 6995 | 22.5 | 40.6 | 1.61 | 0.41 |
| 27 | 7238 | 22.5 | 40.6 | 1.32 | 0.26 |
| 28 | 7457 | 22.5 | 40.6 | 0.71 | 0.26 |
| 29 | 7676 | 22.5 | 40.6 | 1.63 | 0.33 |
| .. | ... | ... | ... | ... | ... |
| 925 | 236924 | 22.7 | 39.6 | 0.76 | 0.11 |
| 926 | 237146 | 22.7 | 39.6 | 1.17 | 0.19 |
| 927 | 237368 | 22.7 | 39.6 | 1.56 | 0.33 |
| 928 | 237860 | 22.7 | 39.5 | 0.90 | 0.48 |
| 929 | 238082 | 22.7 | 39.5 | 0.95 | 0.26 |
| 930 | 238304 | 22.7 | 39.5 | 1.49 | 0.26 |
| 931 | 238525 | 22.7 | 39.5 | 1.27 | 0.26 |

```
932  238746         22.7  39.5     0.81     0.19
933  238967         22.7  39.5     1.27     0.26
934  239192         22.7  39.5     1.22     0.33
935  239414         22.7  39.5     1.54     0.26
936  239906         22.7  39.5     0.81     0.41
937  240153         22.7  39.5     0.93     0.33
938  240374         22.7  39.5     1.42     0.19
939  240595         22.7  39.5     1.39     0.26
940  240818         22.7  39.5     0.78     0.19
941  241039         22.7  39.5     1.15     0.26
942  241260         22.7  39.5     1.59     0.26
943  241482         22.7  39.5     0.71     0.11
944  241975         22.7  39.5     0.44     0.33
945  242196         22.7  39.5     0.44     0.11
946  242418         22.7  39.5     0.44     0.19
947  242639         22.7  39.5     0.44     0.11
948  242861         22.7  39.5     0.41     0.11
949  243083         22.7  39.5     0.44     0.19
950  243304         22.7  39.5     0.41     0.19
951  243528         22.7  39.5     0.41     0.11
952  244021         22.7  39.5     0.46     0.33
953  244242         22.7  39.5     0.46     0.19
954  244464         22.7  39.5     0.41     0.11

[955 rows x 5 columns]
```

### Data graphics

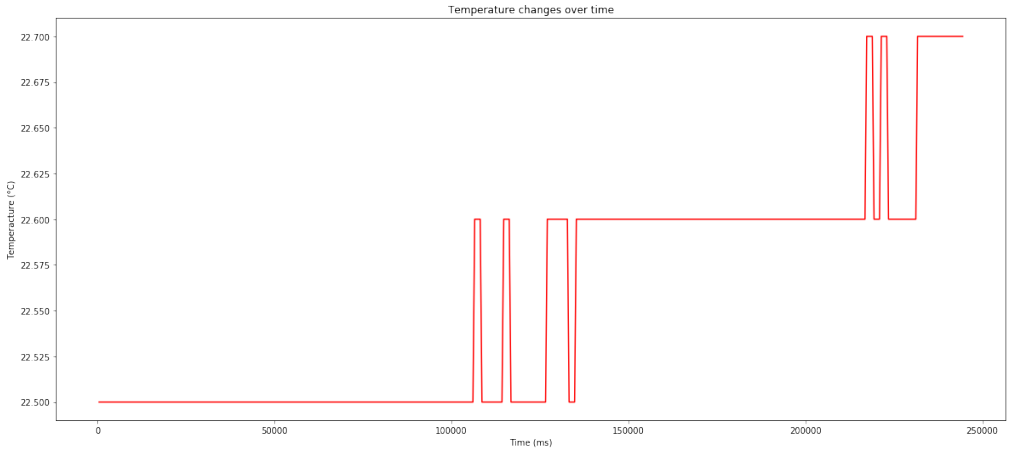
```
In [123]: plt.figure(figsize=(20,10))
          plt.subplot(121)
          plt.scatter(Din.Temperature,Din.RH,marker='.',color='red')
          plt.xlabel('Temperacture (řC)')
          plt.ylabel('Relative humidity (%)')
          plt.title('$T$ vs. $RH$')
          plt.subplot(122)
          plt.scatter(Din.Voltage,Din.Current,marker='*',color='green')
          plt.xlabel('Voltage (V)')
          plt.ylabel('Current (A)')
          plt.title('$V$ vs. $I$')
          #plt.savefig('Exp1_Pro_3')

Out[123]: Text(0.5,1,'$V$ vs. $I$')
```

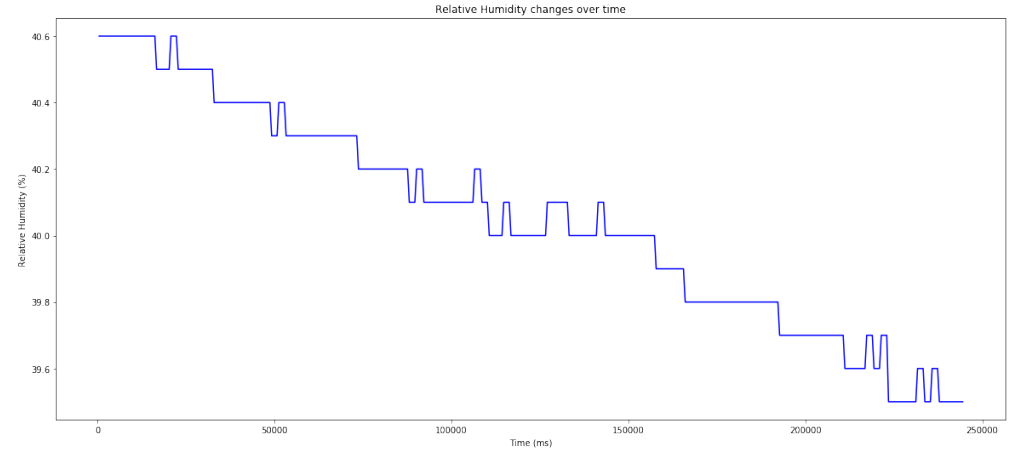


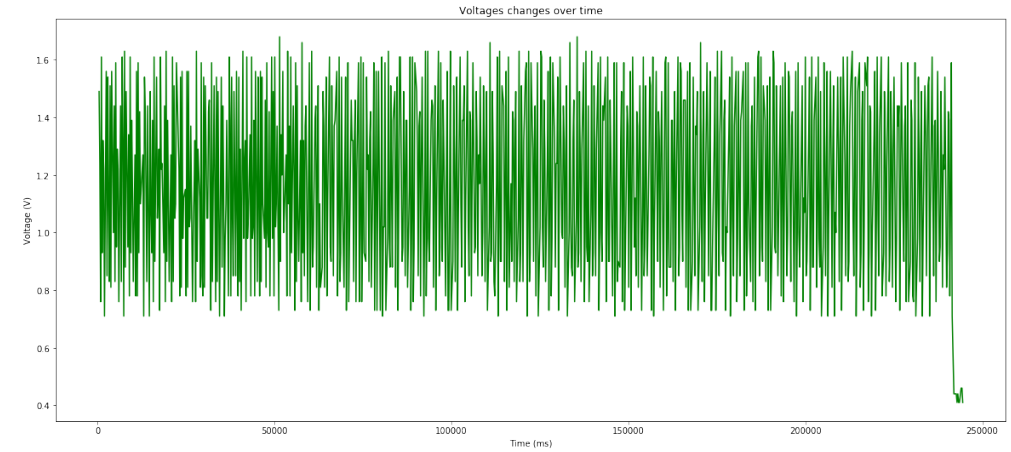



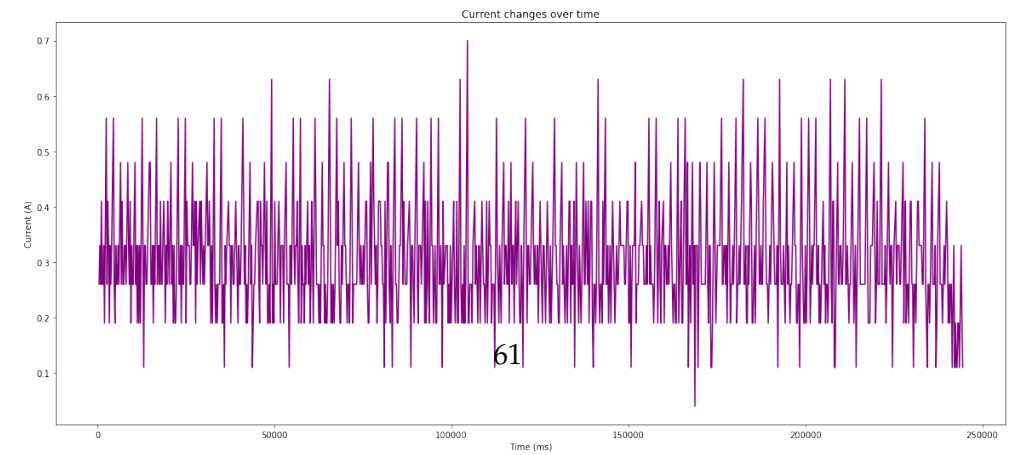

In [124]:
```
plt.figure(figsize=(20,40))
plt.subplot(411)
plt.plot(Din.Time,Din.Temperature,
         color = 'red')
plt.ylabel('Temperacture (řC)')
plt.xlabel('Time (ms)')
plt.title('Temperature changes over time')
plt.subplot(412)
plt.plot(Din.Time,Din.RH,
         color = 'blue')
plt.ylabel('Relative Humidity (%)')
plt.xlabel('Time (ms)')
plt.title('Relative Humidity changes over time')
plt.subplot(413)
plt.plot(Din.Time,Din.Voltage
         ,color = 'green')
plt.ylabel('Voltage (V)')
plt.xlabel('Time (ms)')
plt.title('Voltages changes over time')
plt.subplot(414)
plt.plot(Din.Time,Din.Current,
         color =  'purple')
plt.ylabel('Current (A)')
plt.xlabel('Time (ms)')
plt.title('Current changes over time')
```

Out[124]:
```
Text(0.5,1,'Current changes over time')
```


Temperature changes over time
Temperacture (°C)
22.700
22.675
22.650
22.625
22.600
22.575
22.550
22.525
22.500
0
50000
100000
150000
200000
250000
Time (ms)


Relative Humidity changes over time
Relative Humidity (%)
40.6
40.4
40.2
40.0
39.8
39.6
0
50000
100000
150000
200000
250000
Time (ms)


Voltages changes over time
Voltage (V)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0
50000
100000
150000
200000
250000
Time (ms)

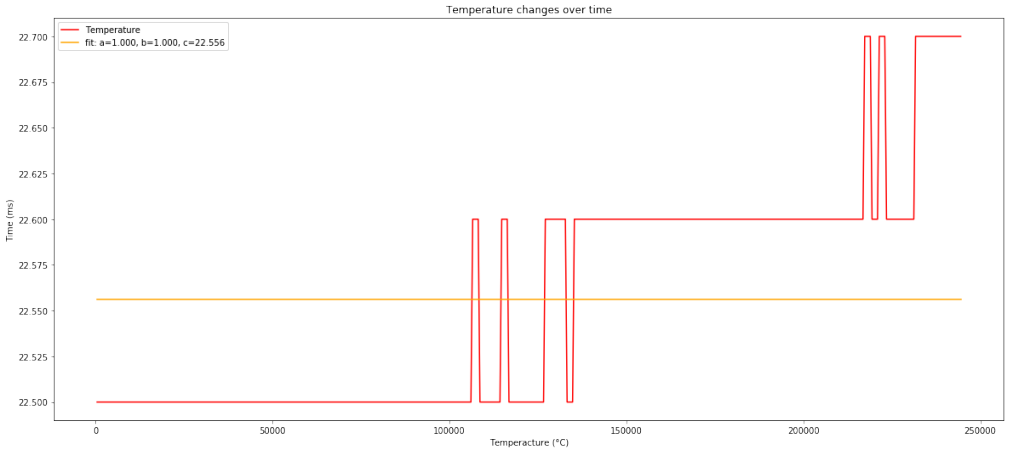

Current changes over time
Current (A)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
50000
100000
150000
200000
250000
Time (ms)

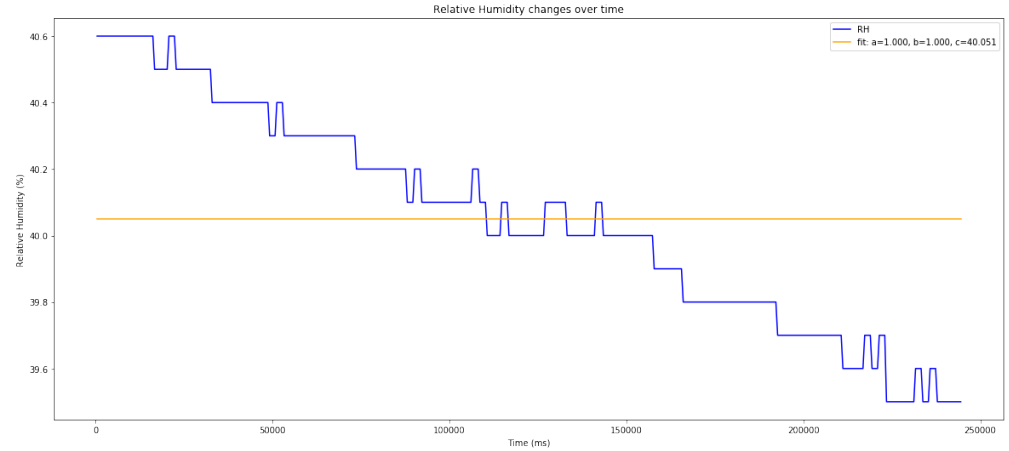
**Curve fitting into function** $f(x) = ae^{(-b*x)} + c$

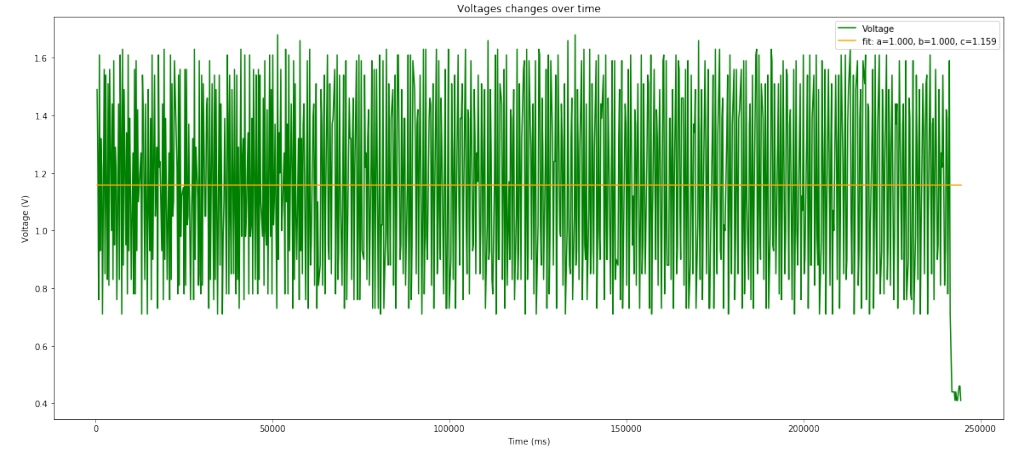
```
In [125]: plt.figure(figsize=(20,40))
          plt.subplot(411)
          plt.plot(Din.Time,Din.Temperature,
                   color = 'red')
          popt, pcov = curve_fit(func, Din.Time, Din.Temperature)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.xlabel('Temperacture (řC)')
          plt.ylabel('Time (ms)')
          plt.title('Temperature changes over time')
          plt.legend()
          plt.subplot(412)
          plt.plot(Din.Time,Din.RH,
                   color = 'blue')
          popt, pcov = curve_fit(func, Din.Time, Din.RH)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Relative Humidity (%)')
          plt.xlabel('Time (ms)')
          plt.title('Relative Humidity changes over time')
          plt.legend()
          plt.subplot(413)
          plt.plot(Din.Time,Din.Voltage
                   ,color = 'green',)
          popt, pcov = curve_fit(func, Din.Time, Din.Voltage)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Voltage (V)')
          plt.xlabel('Time (ms)')
          plt.title('Voltages changes over time')
          plt.legend()
          plt.subplot(414)
          plt.plot(Din.Time,Din.Current,
                   color =  'purple')
          popt, pcov = curve_fit(func, Din.Time, Din.Current)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Current (A)')
          plt.xlabel('Time (ms)')
          plt.title('Current changes over time')
          plt.legend()

C:\Users\Ghiordy F. Contreras\Anaconda3\lib\site-packages\scipy\optimize\minpack.py:794: Optim
```

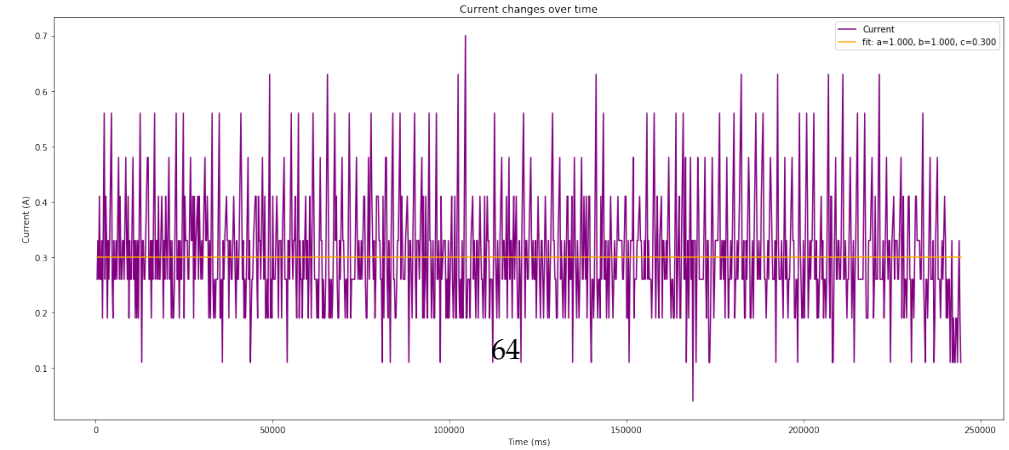
```
  category=OptimizeWarning)
```

```
Out[125]: <matplotlib.legend.Legend at 0x1f096a4a7b8>
```


Temperature changes over time
Temperature
fit: a=1.000, b=1.000, c=22.556
Time (ms)
Temperacture (°C)


Relative Humidity changes over time
RH
fit: a=1.000, b=1.000, c=40.051
Relative Humidity (%)
Time (ms)


Voltages changes over time
Voltage
fit: a=1.000, b=1.000, c=1.159
Voltage (V)
Time (ms)


Current changes over time
Current
fit: a=1.000, b=1.000, c=0.300
Current (A)
Time (ms)

**Prueba 10**

```
In [126]: Din = pd.read_csv('D20190213j.txt',
                            names=['Time','Temperature','RH','Voltage','Current'])
          Din
```

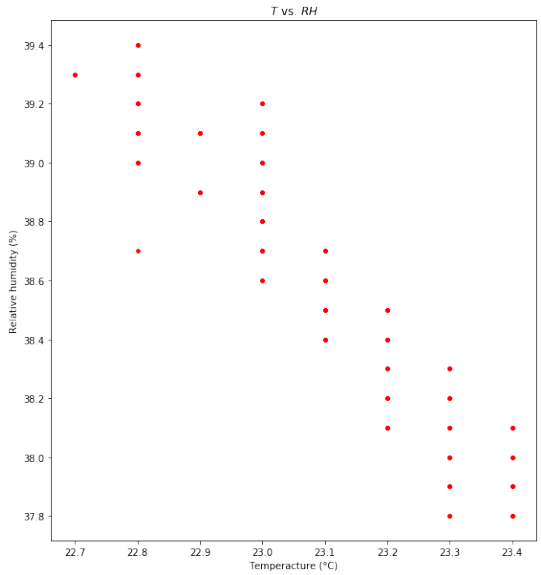
Out[126]:

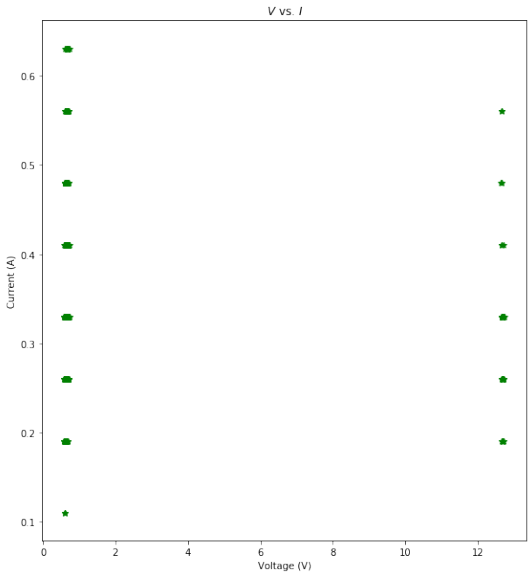
| | Time | Temperature | RH | Voltage | Current |
|---|---|---|---|---|---|
| 0 | 486 | 22.8 | 38.7 | 0.63 | 0.33 |
| 1 | 707 | 22.8 | 38.7 | 0.61 | 0.33 |
| 2 | 928 | 22.8 | 38.7 | 0.66 | 0.33 |
| 3 | 486 | 22.8 | 39.4 | 12.69 | 0.33 |
| 4 | 707 | 22.8 | 39.4 | 12.71 | 0.33 |
| 5 | 928 | 22.8 | 39.4 | 12.69 | 0.26 |
| 6 | 1149 | 22.8 | 39.4 | 12.69 | 0.26 |
| 7 | 1371 | 22.8 | 39.4 | 12.69 | 0.33 |
| 8 | 1593 | 22.8 | 39.4 | 12.69 | 0.33 |
| 9 | 1814 | 22.8 | 39.4 | 12.69 | 0.26 |
| 10 | 2061 | 22.8 | 39.4 | 12.66 | 0.33 |
| 11 | 2553 | 22.7 | 39.3 | 12.66 | 0.48 |
| 12 | 2775 | 22.7 | 39.3 | 12.69 | 0.19 |
| 13 | 2996 | 22.7 | 39.3 | 12.66 | 0.26 |
| 14 | 3220 | 22.7 | 39.3 | 12.69 | 0.26 |
| 15 | 3441 | 22.7 | 39.3 | 12.69 | 0.26 |
| 16 | 3662 | 22.7 | 39.3 | 12.66 | 0.33 |
| 17 | 3885 | 22.7 | 39.3 | 12.69 | 0.19 |
| 18 | 4106 | 22.7 | 39.3 | 12.69 | 0.33 |
| 19 | 4598 | 22.8 | 39.3 | 12.66 | 0.56 |
| 20 | 4819 | 22.8 | 39.3 | 12.71 | 0.33 |
| 21 | 5041 | 22.8 | 39.3 | 12.69 | 0.26 |
| 22 | 5263 | 22.8 | 39.3 | 12.69 | 0.26 |
| 23 | 5484 | 22.8 | 39.3 | 12.69 | 0.33 |
| 24 | 5705 | 22.8 | 39.3 | 12.66 | 0.33 |
| 25 | 5926 | 22.8 | 39.3 | 12.69 | 0.26 |
| 26 | 6148 | 22.8 | 39.3 | 12.66 | 0.33 |
| 27 | 6640 | 22.8 | 39.3 | 12.66 | 0.56 |
| 28 | 6862 | 22.8 | 39.3 | 12.69 | 0.26 |
| 29 | 7084 | 22.8 | 39.3 | 12.71 | 0.26 |
| ... | ... | ... | ... | ... | ... |
| 1433 | 367030 | 23.4 | 37.9 | 0.61 | 0.26 |
| 1434 | 367251 | 23.4 | 37.9 | 0.61 | 0.19 |
| 1435 | 367744 | 23.4 | 37.8 | 0.61 | 0.41 |
| 1436 | 367965 | 23.4 | 37.8 | 0.63 | 0.26 |
| 1437 | 368186 | 23.4 | 37.8 | 0.63 | 0.26 |
| 1438 | 368408 | 23.4 | 37.8 | 0.61 | 0.19 |
| 1439 | 368629 | 23.4 | 37.8 | 0.61 | 0.26 |

```
1440  368850         23.4  37.8     0.61     0.19
1441  369072         23.4  37.8     0.61     0.33
1442  369296         23.4  37.8     0.63     0.19
1443  369788         23.4  37.8     0.61     0.56
1444  370010         23.4  37.8     0.63     0.26
1445  370232         23.4  37.8     0.61     0.26
1446  370453         23.4  37.8     0.61     0.26
1447  370674         23.4  37.8     0.63     0.26
1448  370895         23.4  37.8     0.61     0.11
1449  371143         23.4  37.8     0.61     0.33
1450  371364         23.4  37.8     0.61     0.26
1451  371857         23.4  37.8     0.61     0.48
1452  372079         23.4  37.8     0.61     0.33
1453  372300         23.4  37.8     0.61     0.26
1454  372521         23.4  37.8     0.61     0.26
1455  372743         23.4  37.8     0.66     0.19
1456  372965         23.4  37.8     0.63     0.26
1457  373186         23.4  37.8     0.66     0.33
1458  373407         23.4  37.8     0.61     0.33
1459  373903         23.4  37.8     0.63     0.41
1460  374124         23.4  37.8     0.63     0.19
1461  374345         23.4  37.8     0.61     0.26
1462  374567         23.4  37.8     0.61     0.26

[1463 rows x 5 columns]
```

### Data graphics

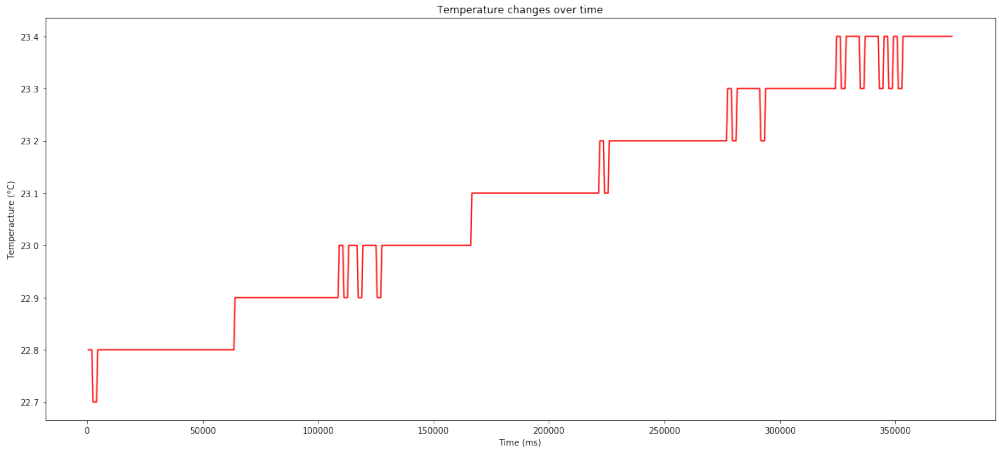
```
In [127]: plt.figure(figsize=(20,10))
          plt.subplot(121)
          plt.scatter(Din.Temperature,Din.RH,marker='.',color='red')
          plt.xlabel('Temperacture (řC)')
          plt.ylabel('Relative humidity (%)')
          plt.title('$T$ vs. $RH$')
          plt.subplot(122)
          plt.scatter(Din.Voltage,Din.Current,marker='*',color='green')
          plt.xlabel('Voltage (V)')
          plt.ylabel('Current (A)')
          plt.title('$V$ vs. $I$')
          #plt.savefig('Exp1_Pro_3')

Out[127]: Text(0.5,1,'$V$ vs. $I$')
```

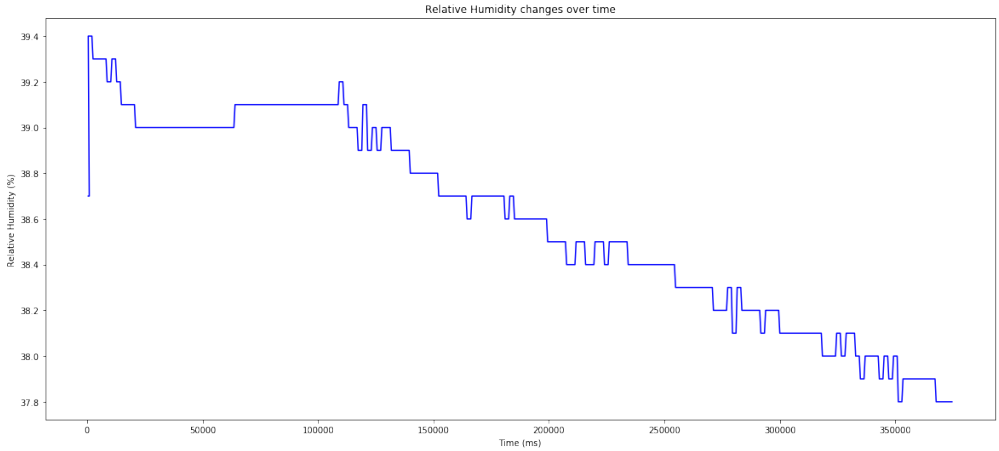


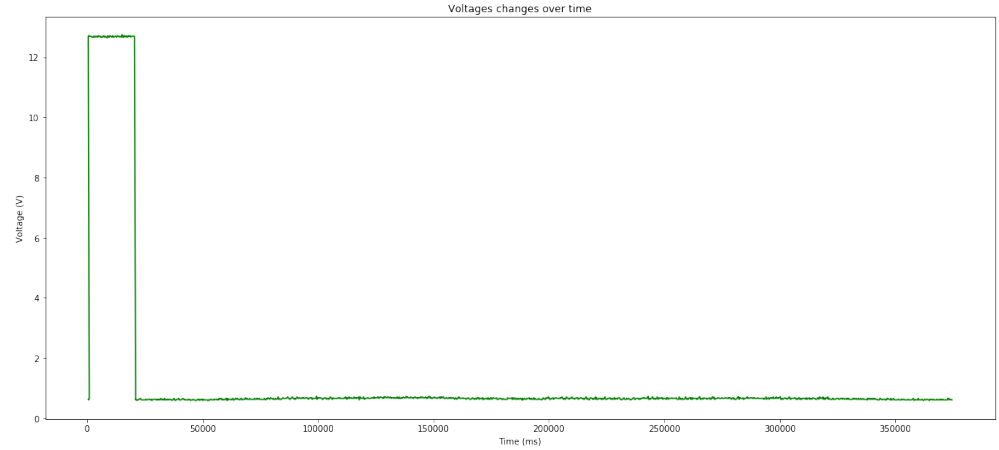



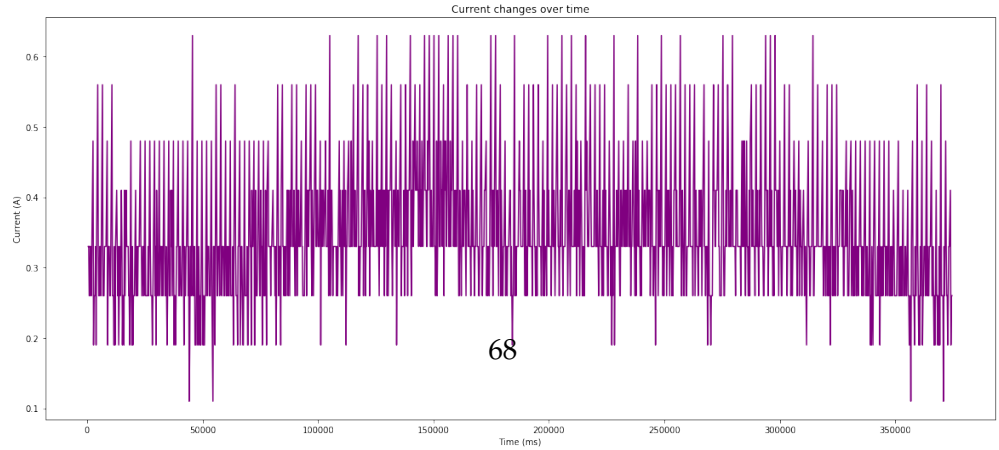

In [128]:
```
plt.figure(figsize=(20,40))
plt.subplot(411)
plt.plot(Din.Time,Din.Temperature,
         color = 'red')
plt.ylabel('Temperacture (řC)')
plt.xlabel('Time (ms)')
plt.title('Temperature changes over time')
plt.subplot(412)
plt.plot(Din.Time,Din.RH,
         color = 'blue')
plt.ylabel('Relative Humidity (%)')
plt.xlabel('Time (ms)')
plt.title('Relative Humidity changes over time')
plt.subplot(413)
plt.plot(Din.Time,Din.Voltage
         ,color = 'green')
plt.ylabel('Voltage (V)')
plt.xlabel('Time (ms)')
plt.title('Voltages changes over time')
plt.subplot(414)
plt.plot(Din.Time,Din.Current,
         color =  'purple')
plt.ylabel('Current (A)')
plt.xlabel('Time (ms)')
plt.title('Current changes over time')
```

Out[128]:
```
Text(0.5,1,'Current changes over time')
```


Temperature changes over time
Temperacture (°C)
Time (ms)


Relative Humidity changes over time
Relative Humidity (%)
Time (ms)


Voltages changes over time
Voltage (V)
Time (ms)


Current changes over time
Current (A)
Time (ms)

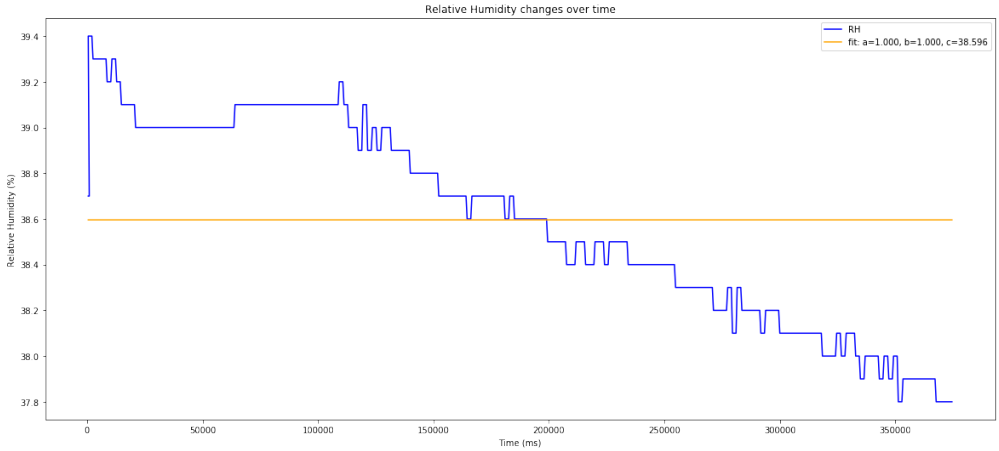
**Curve fitting into function** $f(x) = ae^{(-b*x)} + c$

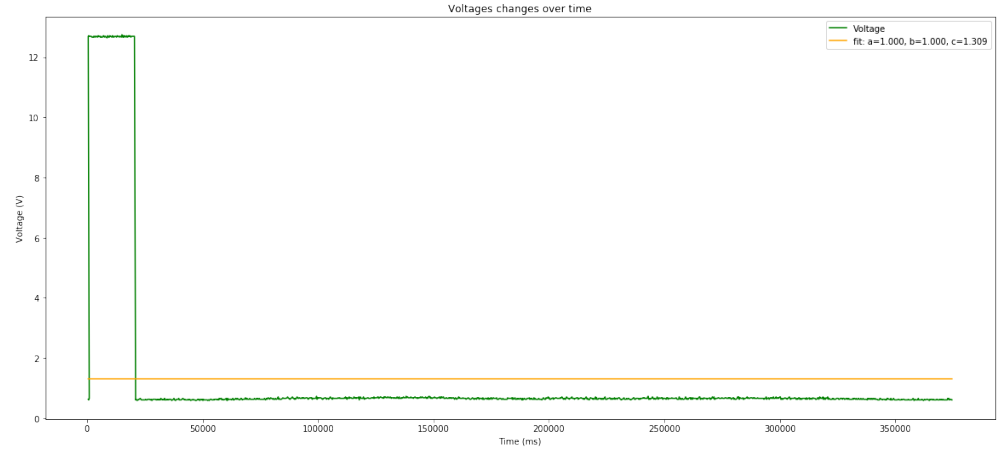
```
In [129]: plt.figure(figsize=(20,40))
          plt.subplot(411)
          plt.plot(Din.Time,Din.Temperature,
                   color = 'red')
          popt, pcov = curve_fit(func, Din.Time, Din.Temperature)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.xlabel('Temperacture (řC)')
          plt.ylabel('Time (ms)')
          plt.title('Temperature changes over time')
          plt.legend()
          plt.subplot(412)
          plt.plot(Din.Time,Din.RH,
                   color = 'blue')
          popt, pcov = curve_fit(func, Din.Time, Din.RH)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Relative Humidity (%)')
          plt.xlabel('Time (ms)')
          plt.title('Relative Humidity changes over time')
          plt.legend()
          plt.subplot(413)
          plt.plot(Din.Time,Din.Voltage
                   ,color = 'green',)
          popt, pcov = curve_fit(func, Din.Time, Din.Voltage)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Voltage (V)')
          plt.xlabel('Time (ms)')
          plt.title('Voltages changes over time')
          plt.legend()
          plt.subplot(414)
          plt.plot(Din.Time,Din.Current,
                   color =  'purple')
          popt, pcov = curve_fit(func, Din.Time, Din.Current)
          plt.plot(Din.Time, func(Din.Time, *popt), color = 'orange',
                   label='fit: a=%5.3f, b=%5.3f, c=%5.3f' % tuple(popt))
          plt.ylabel('Current (A)')
          plt.xlabel('Time (ms)')
          plt.title('Current changes over time')
          plt.legend()

C:\Users\Ghiordy F. Contreras\Anaconda3\lib\site-packages\scipy\optimize\minpack.py:794: Optim
```

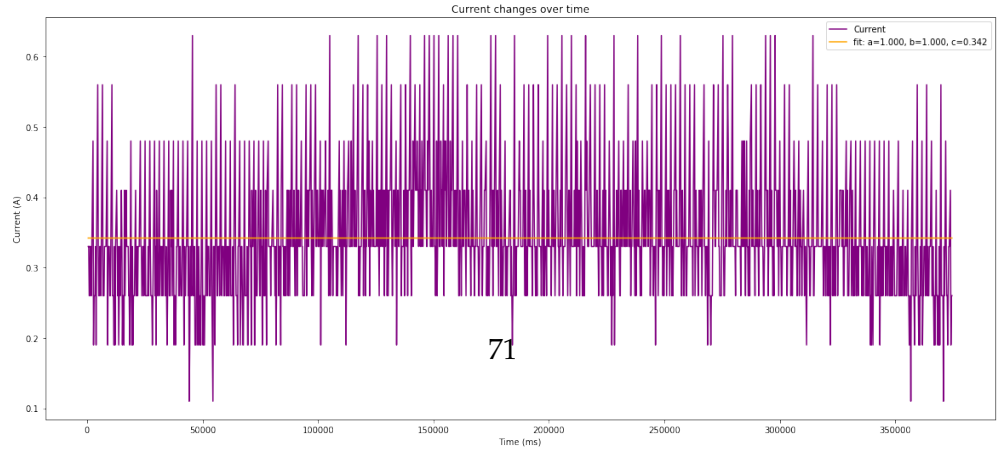
```
  category=OptimizeWarning)
```

```
Out[129]: <matplotlib.legend.Legend at 0x1f097640a90>
```


Temperature changes over time
Temperature
fit: a=1.000, b=1.000, c=23.083
Time (ms)
Temperacture (°C)

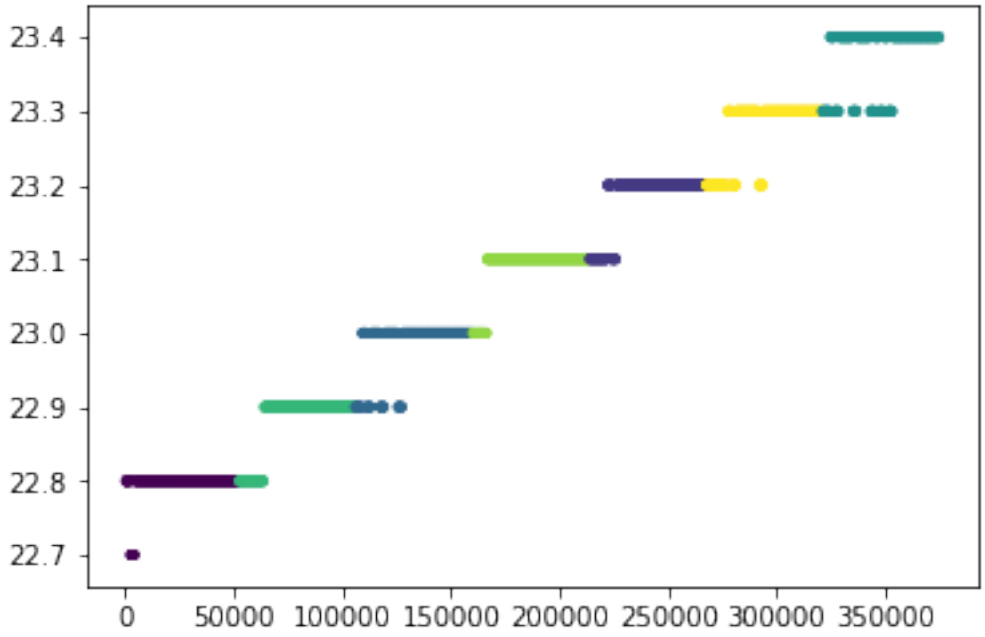

Relative Humidity changes over time
RH
fit: a=1.000, b=1.000, c=38.596
Relative Humidity (%)
Time (ms)


Voltages changes over time
Voltage
fit: a=1.000, b=1.000, c=1.309
Voltage (V)
Time (ms)


Current changes over time
Current
fit: a=1.000, b=1.000, c=0.342
Current (A)
Time (ms)

*k*-means analisys

```
In [135]: x = np.transpose(np.array([Din.Time,Din.Temperature]))
          labelskm = KMeans(n_clusters = 7,
                            random_state = 0).fit_predict(x)
          plt.scatter(Din.Time,Din.Temperature,marker='.',c=labelskm)

Out[135]: <matplotlib.collections.PathCollection at 0x1f09a3aa198>
```




```
In [145]: %system date

Out[145]: ['The current date is: Thu 02/14/2019 ', 'Enter the new date: (mm-dd-yy) ']

In [150]: %system time

Out[150]: ['The current time is: 20:03:11.03', 'Enter the new time: ']

In [149]: #%notebook Report.ipynb
```