# Temperature Compensation

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AHCAL Analysis Workshop at U. Tokyo

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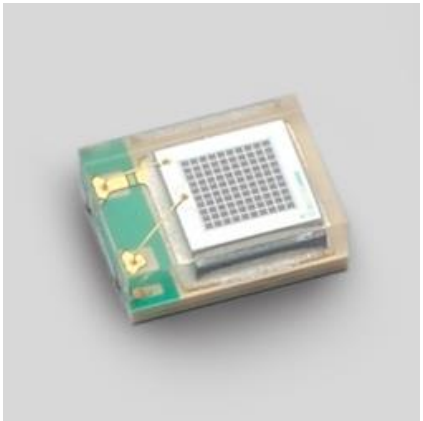
# Motivation of Temperature Compensation

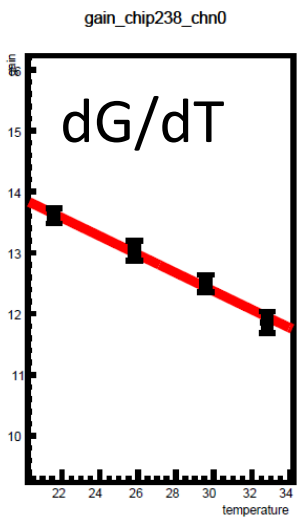
- SiPM gain depends on temperature. Because breakdown voltage depends on temperature. (large quenching resistor )

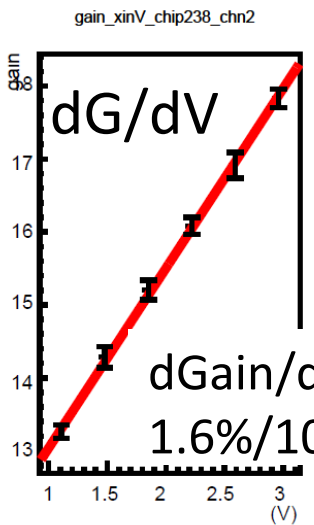
$$V_{ov} = V_{bias} - V_{break\ down}$$

- We want to keep gain ($V_{ov}$)same as a value at reference point. Adjust bias voltage against temperature shift.

1. Measure dG/dT, dG/dV and calculate dV/dT
2. Test temperature compensation (change bias voltage and temperature manually)
3. Automatic HV adjustment





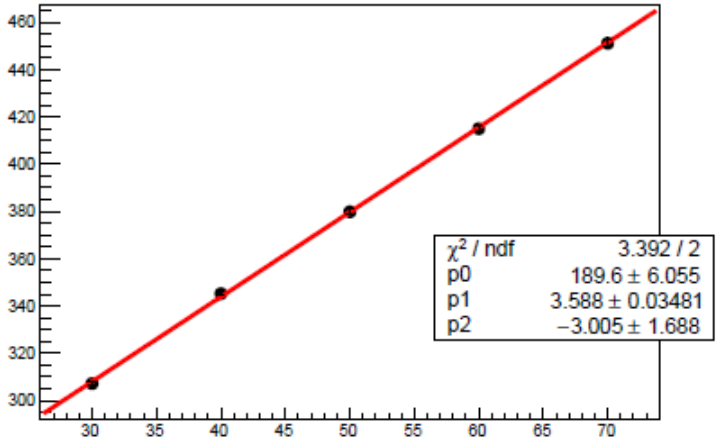




$$\frac{(dG/dV)}{(dG/dT)} = dV/dT$$

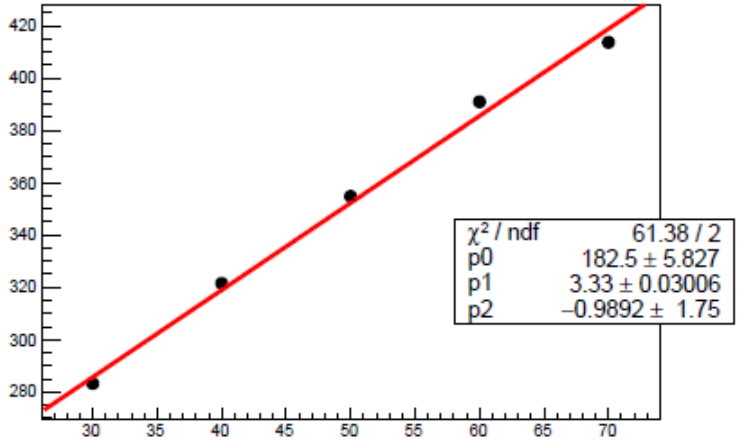
# dMIP/dV of central 4 channels

- dMIP/dV : 3.1-3.6 ADC/DAC (1 DAC ~37mV)
- MIP value shifts ~ 1.1% value at the 50 DAC per 1 DAC

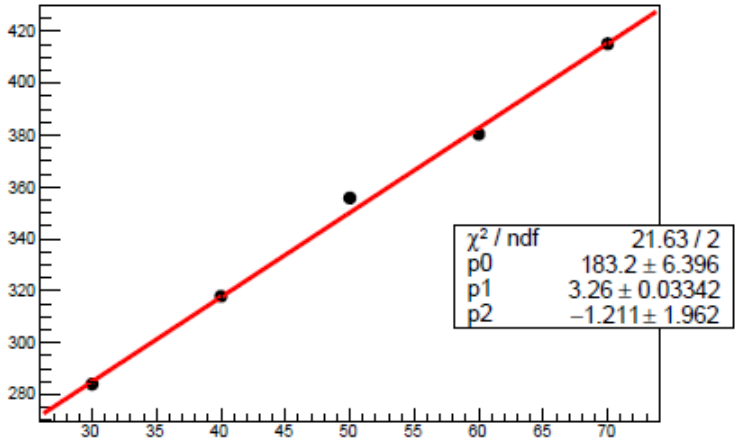
chip245 channel0



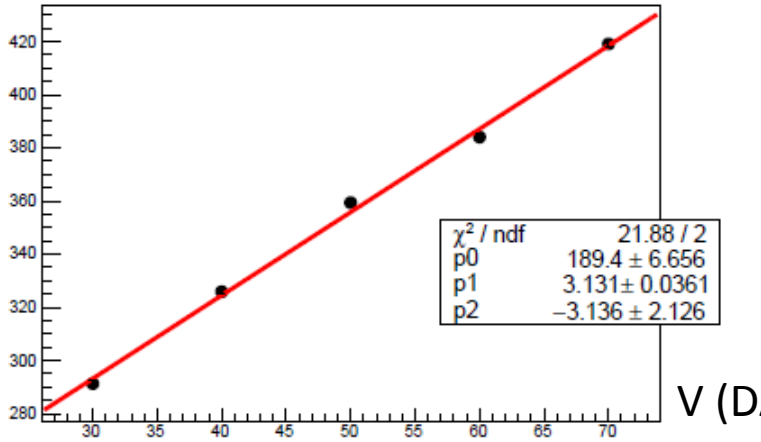

chip246 channel5




chip247 channel35




chip248 channel30




MIP constant (ADC)

V (DAC)

# dMIP/dV is larger than dGain/dV of MPPC

- dMIP/dV is ~1.1%/DAC

but

- dGain/dV of MPPC is ~ 0.6%/DAC

There is 0.5% gap between dMIP/dV and dGain/dV

- What is considered cause of the gap?

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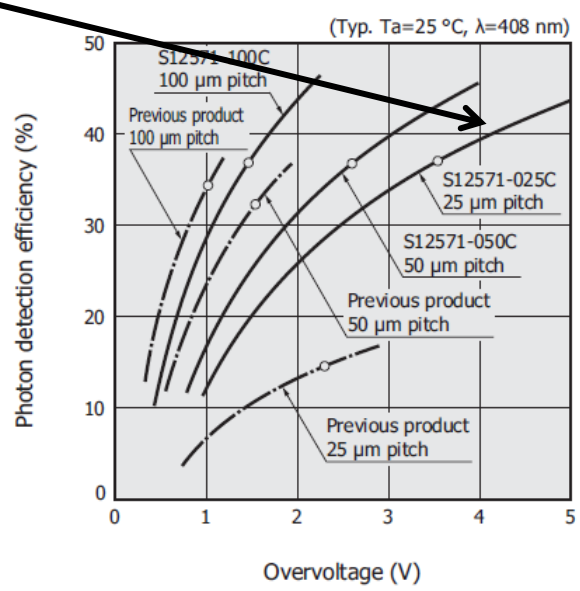
bias voltage dependence on properties of MPPC

- photon detection efficiency
- after pulsing probability
- cross talk probability
- …

$$V_{ov} = V_{bias} - V_{break\ down}$$

ref. e03_handbook_si_apd_mppc.pdf

[Figure 2-8] Photon detection efficiency vs. overvoltage



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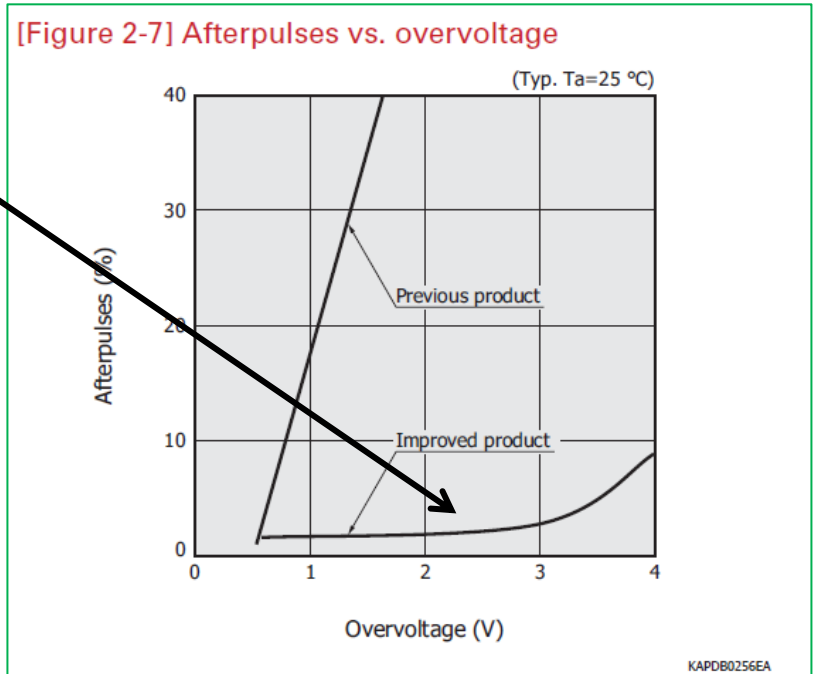

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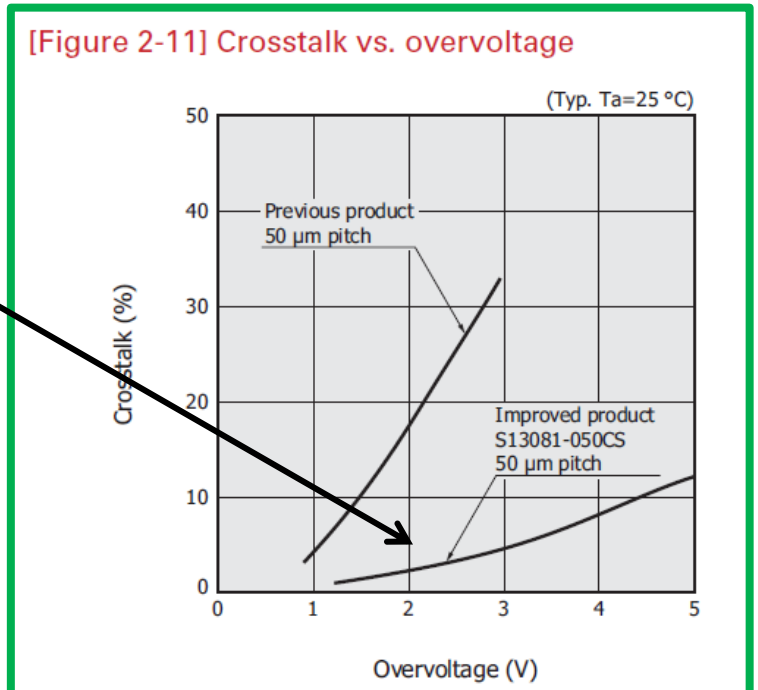



$$V_{ov} = V_{bias} - V_{break\ down}$$

ref. e03_handbook_si_apd_mppc.pdf

# Specification of the S13360 series

**Electrical and optical characteristics (Typ. Ta=25 °C, unless otherwise noted)**

| Type no. | Measure-ment conditions | Spectral response range λ (nm) | Peak sensitivity wavelength λp (nm) | Photon detection efficiency PDE*4 λ=λp (%) | Dark count*5 Typ. (kcps) | Dark count*5 Max. (kcps) | Terminal capaci-tance Ct (pF) | Gain M | Break-down voltage VBR (V) | Crosstalk probability (%) | Recom-mended operating voltage Vop (V) | Tem-perature coefficient at recom-mended operating voltage ΔTVop (mV/°C) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S13360-1325CS | Vover =5 V | 270 to 900 | 450 | 25 | 70 | 210 | 60 | 7.0 × 10^5 | 53 ± 5 | 1 | VBR + 5 | 54 |
| S13360-1325PE | | 320 to 900 | | | | | | | | | | |
| S13360-3025CS | | 270 to 900 | | | 400 | 1200 | 320 | | | | | |
| S13360-3025PE | | 320 to 900 | | | | | | | | | | |
| S13360-6025CS | | 270 to 900 | | | 1600 | 5000 | 1280 | | | | | |
| S13360-6025PE | | 320 to 900 | | | | | | | | | | |
| S13360-1350CS | Vover =3 V | 270 to 900 | | 40 | 90 | 270 | 60 | 1.7 × 10^6 | | 3 | VBR + 3 | |
| S13360-1350PE | | 320 to 900 | | | | | | | | | | |
| S13360-3050CS | | 270 to 900 | | | 500 | 1500 | 320 | | | | | |
| S13360-3050PE | | 320 to 900 | | | | | | | | | | |
| S13360-6050CS | | 270 to 900 | | | | | | | | | | |
| S13360-6050PE | | 320 to 900 | | | | | | | | | | |
| S13360-1375CS | Vover =3 V | 270 to 900 | | 50 | 500 | 1500 | 320 | 4.0 × 10^6 | | 7 | VBR + 3 | |
| S13360-1375PE | | 320 to 900 | | | | | | | | | | |
| S13360-3075CS | | 270 to 900 | | | | | | | | | | |
| S13360-3075PE | | 320 to 900 | | | | | | | | | | |
| S13360-6075CS | | 270 to 900 | | | 2000 | 6000 | 1280 | | | | | |
| S13360-6075PE | | 320 to 900 | | | | | | | | | | |

Temperature coefficient of $V_{br}$ = 54mV/˚C

→1DAC/0.685˚C

# Procedure of the Temperature Compensation

- preparation of reference files

measure current temperature → make a reference file of temperature set average of T3-T6 to 25 degree C.

make a reference file of HV adjust value from passport

make a dT/dV setting file

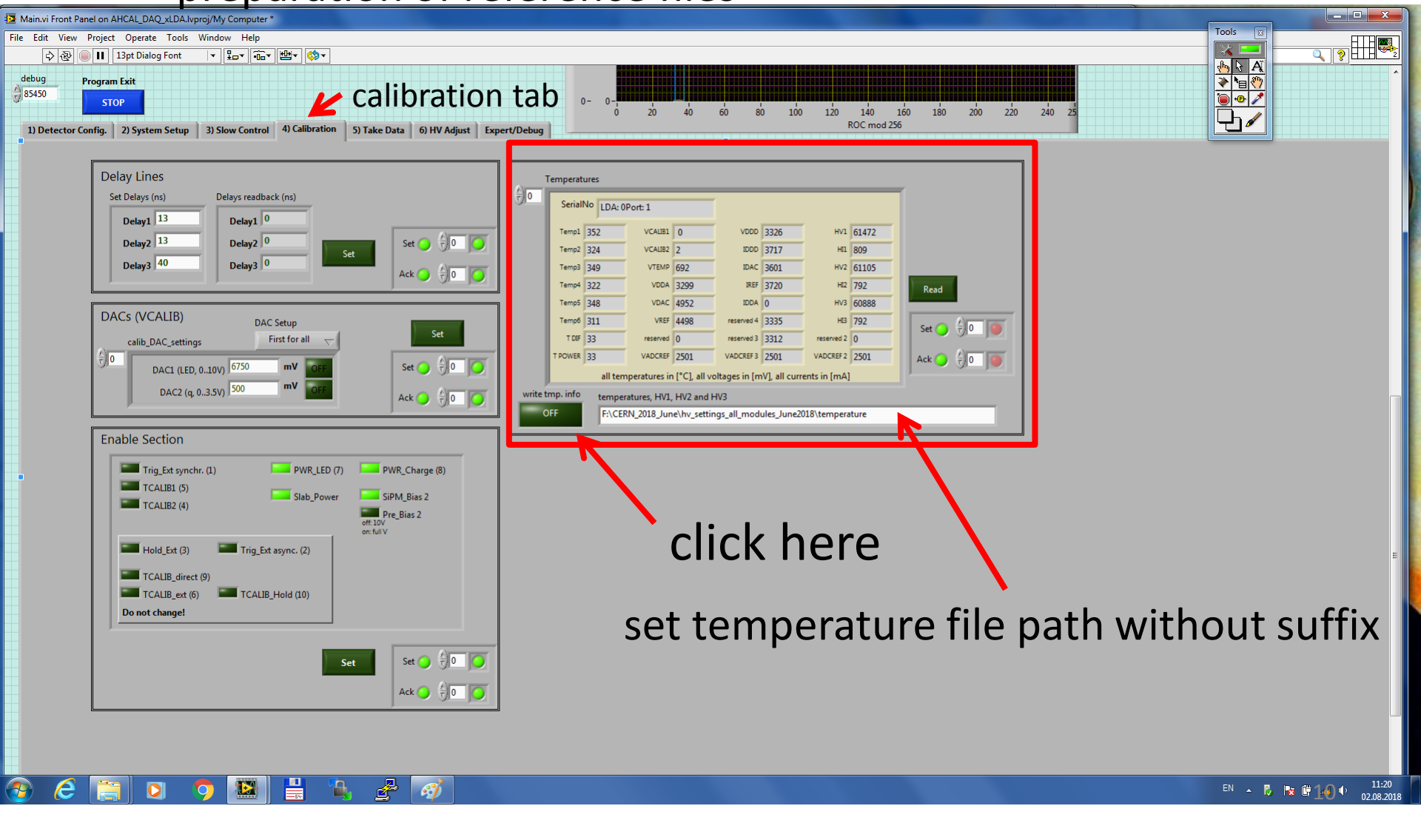
temperature_reference.txt - Notepad

File Edit Format View Help

```
#LDA Port T1 T2 T3 T4 T5 T6 TDIF TPower HV1
0       1          260,50  242,50  257,50  230
0       2          270,00  243,00  258,00  231
0       3          267,50  241,50  258,50  231
0       33         267,25  242,25  258,25  232
0       34         267,00  232,00  259,00  227
0       35         260,75  226,75  255,75  223
#EOF
```

# Procedure of the Temperature Compensation

- preparation of reference files



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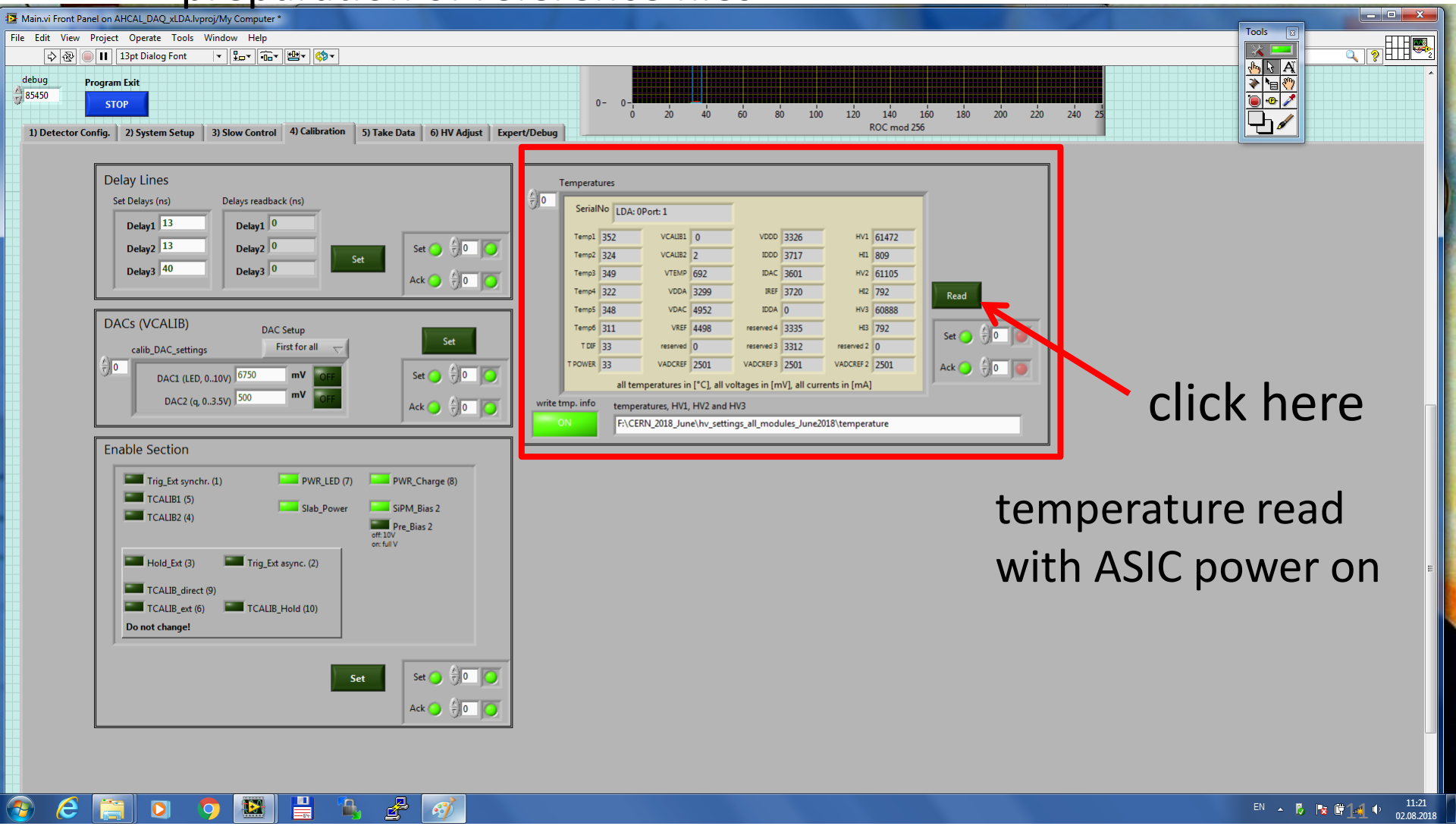
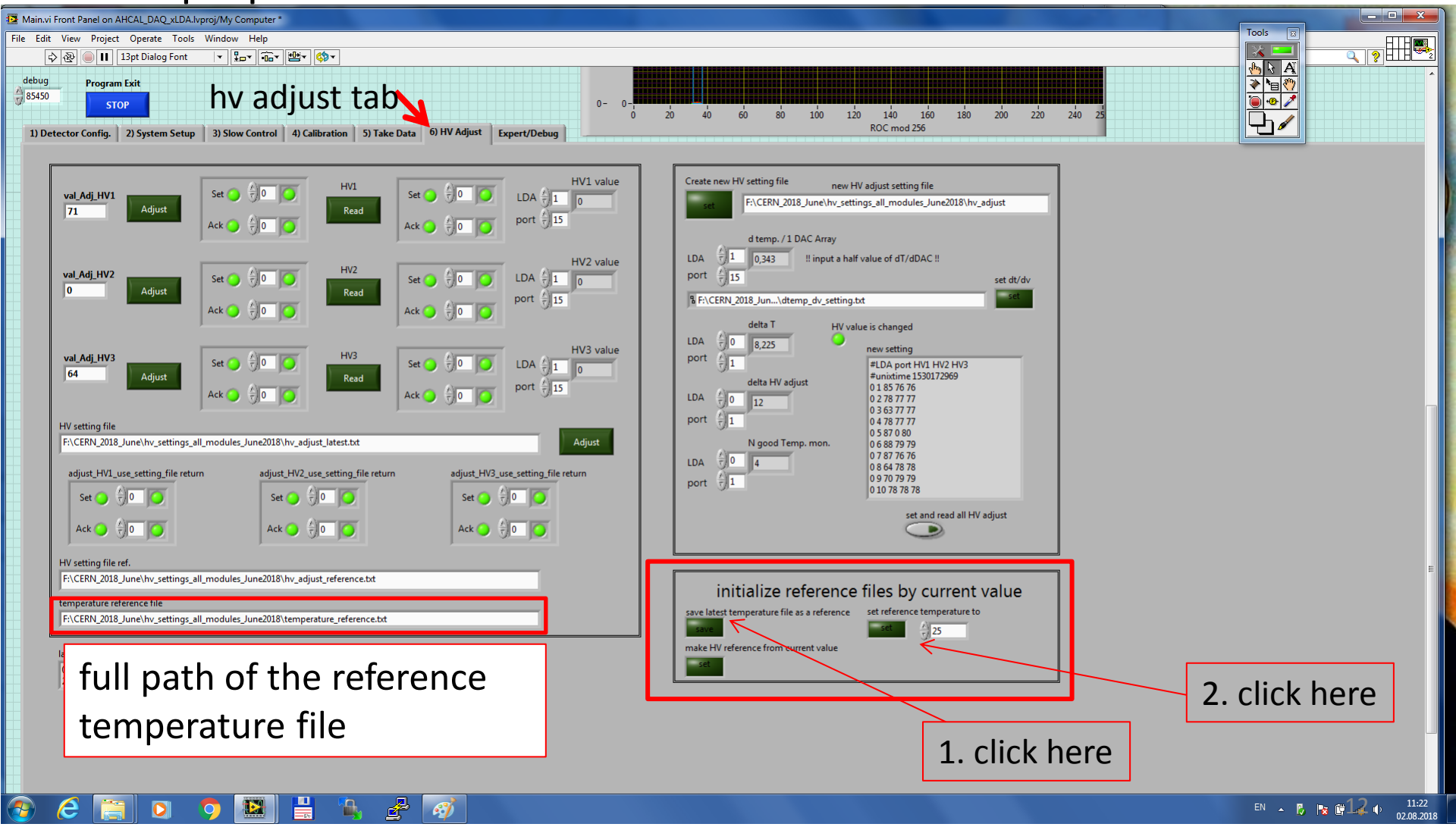



click here

temperature read
with ASIC power on

# Procedure of the Temperature Compensation

- preparation of reference files



# Procedure of the Temperature Compensation

- preparation of reference files

measure current temperature

make a reference file of temperature set average of T3-T6 to 25 degree C.

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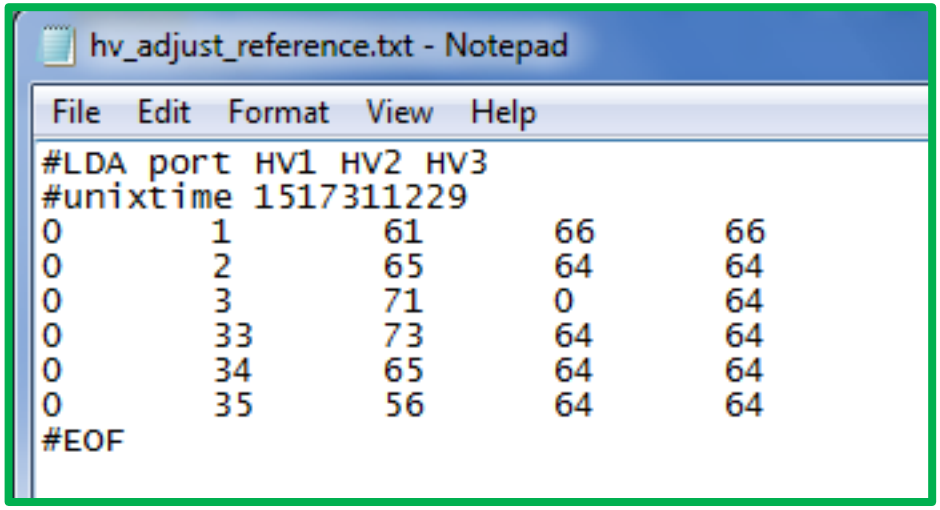


make a dT/dV setting file

# Procedure of the Temperature Compensation

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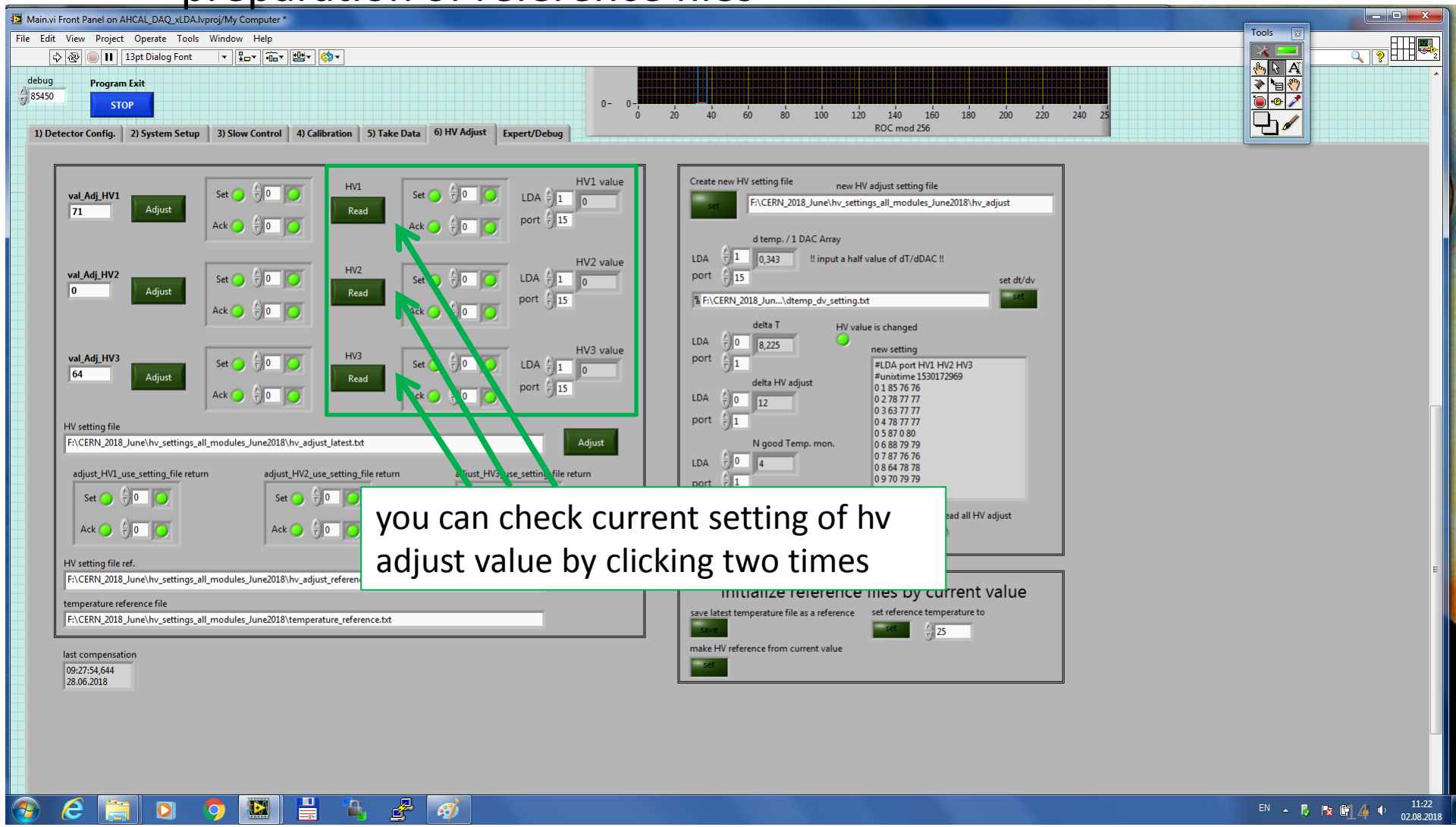

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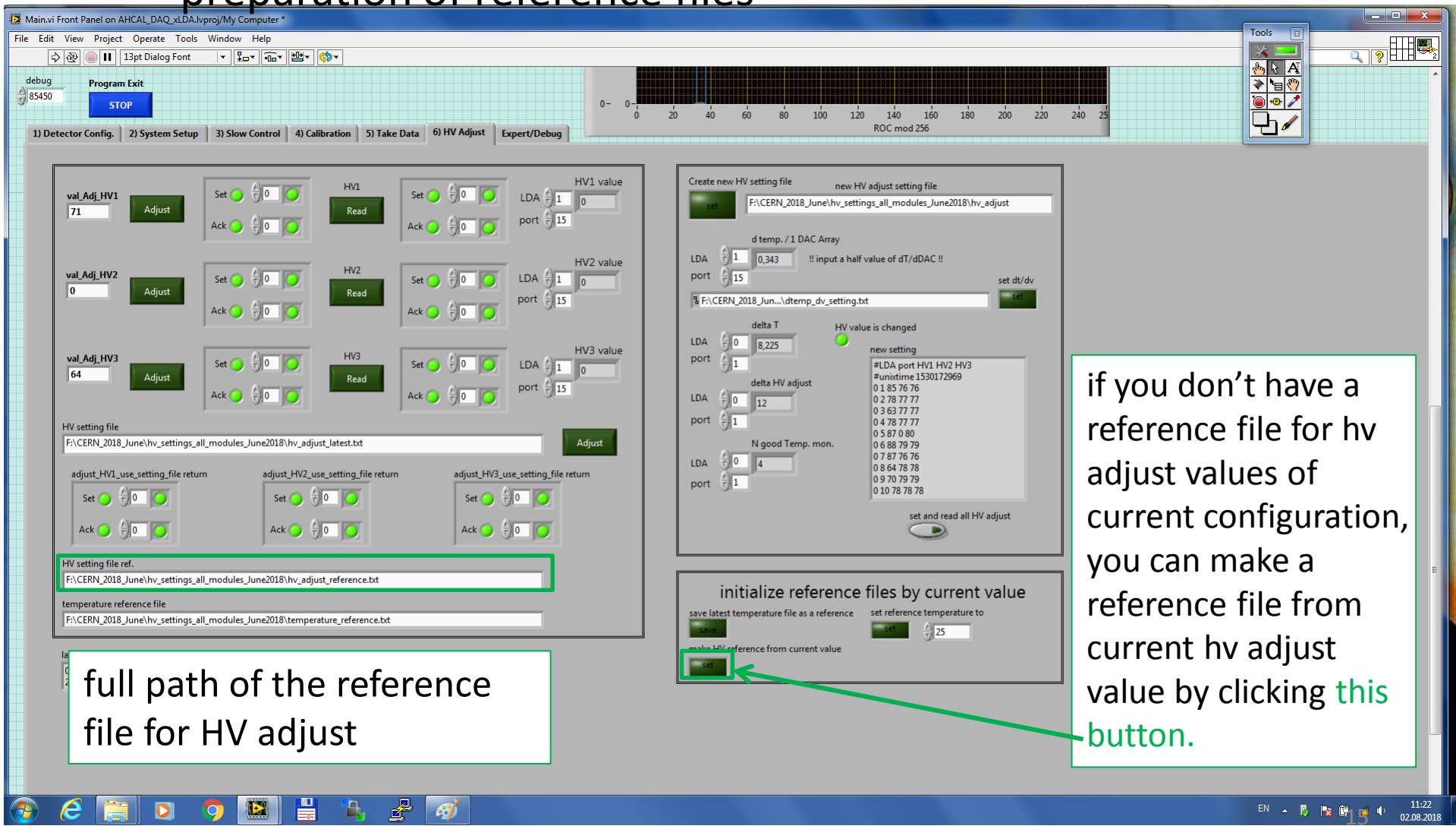
- preparation of reference files



# Procedure of the Temperature Compensation

- preparation of reference files

measure current temperature

make a reference file of temperature set average of T3-T6 to 25 degree C.

make a reference file of HV adjust value from passport

make a dT/dV setting file

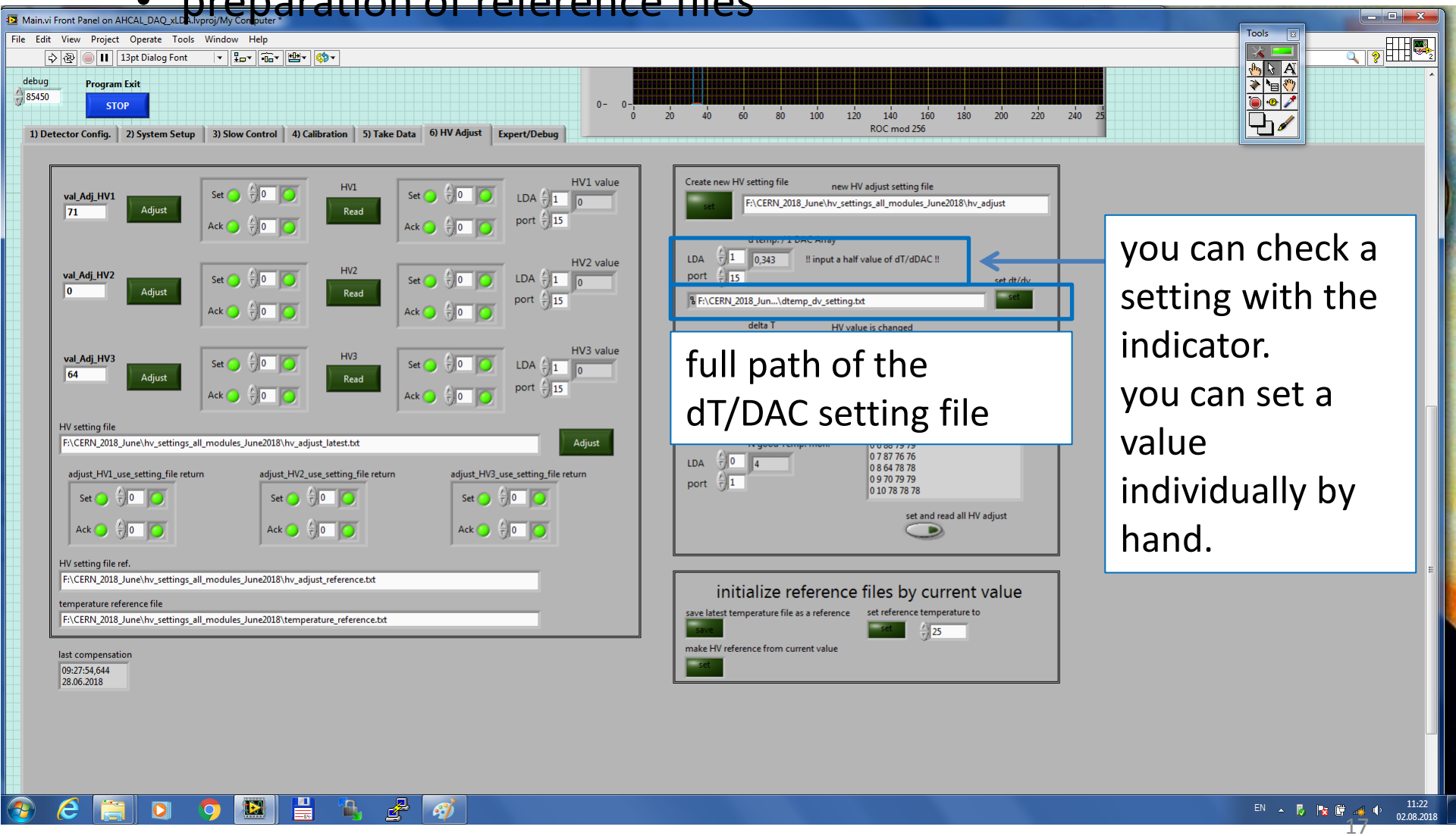
dtemp_dv_setting.txt - Notepad

File Edit Format View Help

```
#LDA port dtemp/dv 0,54/1deg 0,685deg/1DAC ! di
0        0        0,343
0        1        0,343
0        2        0,343
0        3        0,343
0        4        0,343
0        5        0,343
0        6        0,343
0        7        0,343
.....
0        40       0,343
0        41       0,343
0        42       0,343
0        43       0,343
0        44       0,343
0        45       0,343
0        46       0,343
0        47       0,343
#EOF
```

# Procedure of the Temperature Compensation

- preparation of reference files




full path of the dT/DAC setting file

you can check a setting with the indicator.
you can set a value individually by hand.

# Procedure of the Temperature Compensation

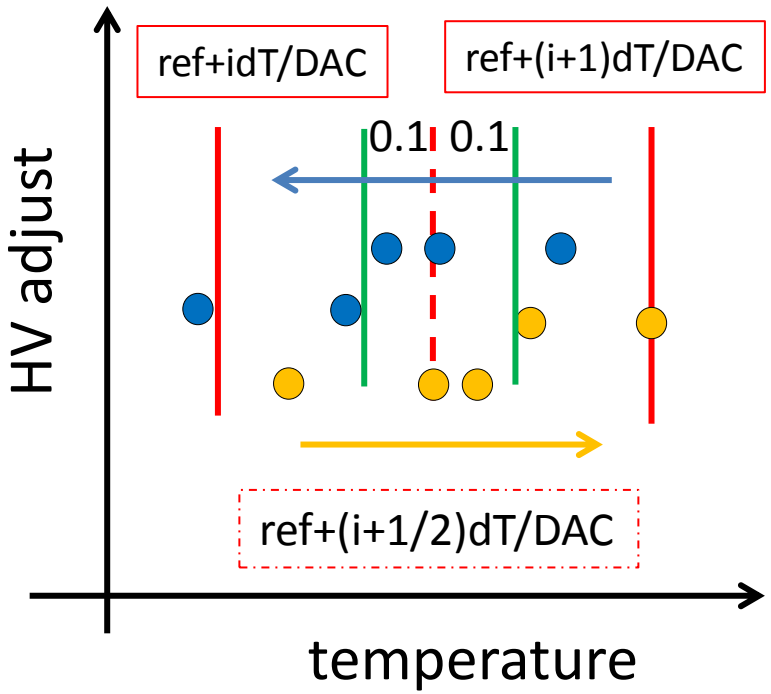
- make a new hv adjustment file

1. compute $\Delta T_1$ from current temperature and reference value
2. calculate new hv adjust value $\rightarrow HV_1$
3. compute $\Delta T_2$ from previous temperature and reference value
4. calculate hv adjust value with $\Delta T_2$ $\rightarrow HV_2$
5. classify $HV_1$ - $HV_2$ to 3 categories

   = 0, $\geq$2, $\leq$2 → HV1

   = 1 → take hysteresis into account

   = -1 → take hysteresis into account



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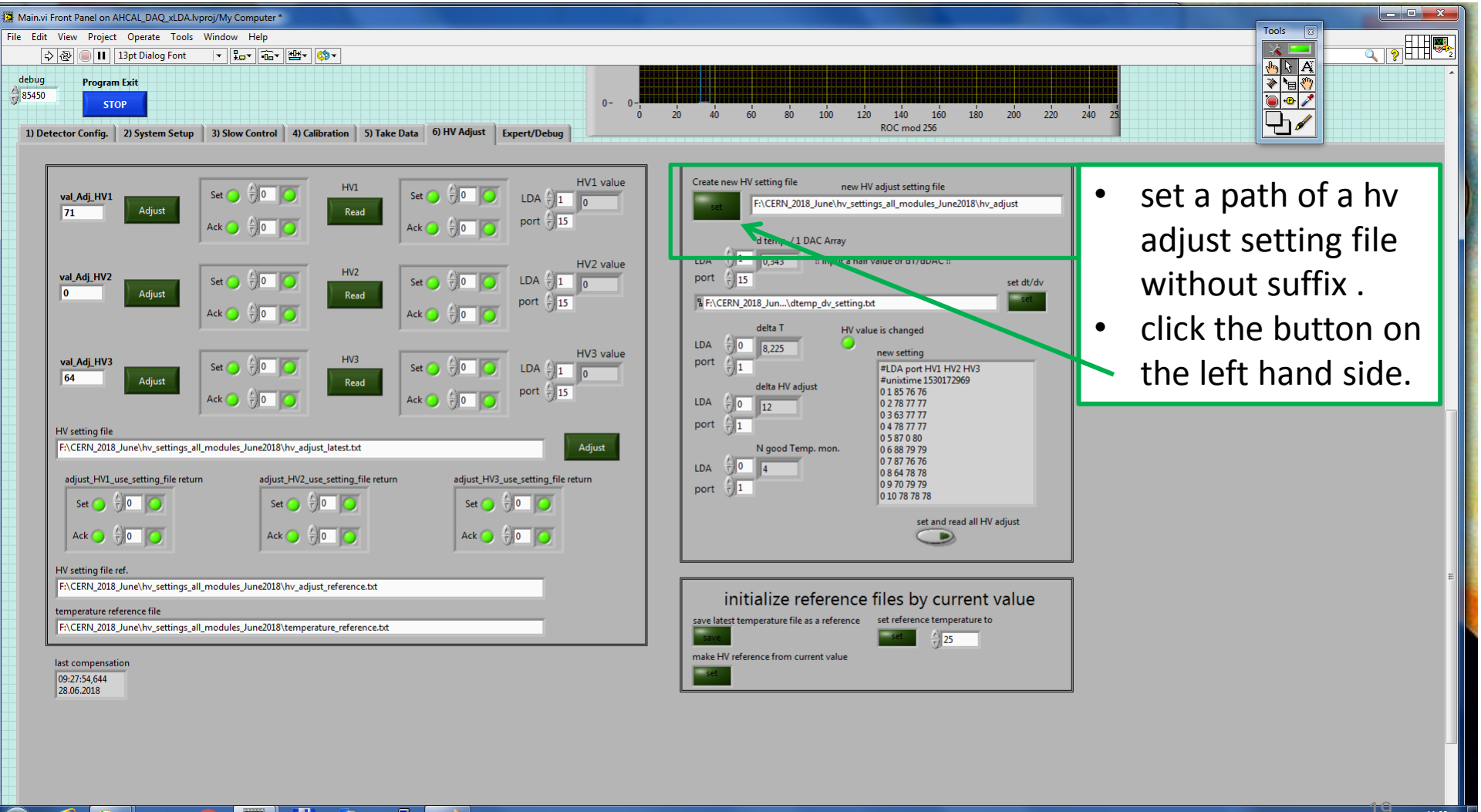

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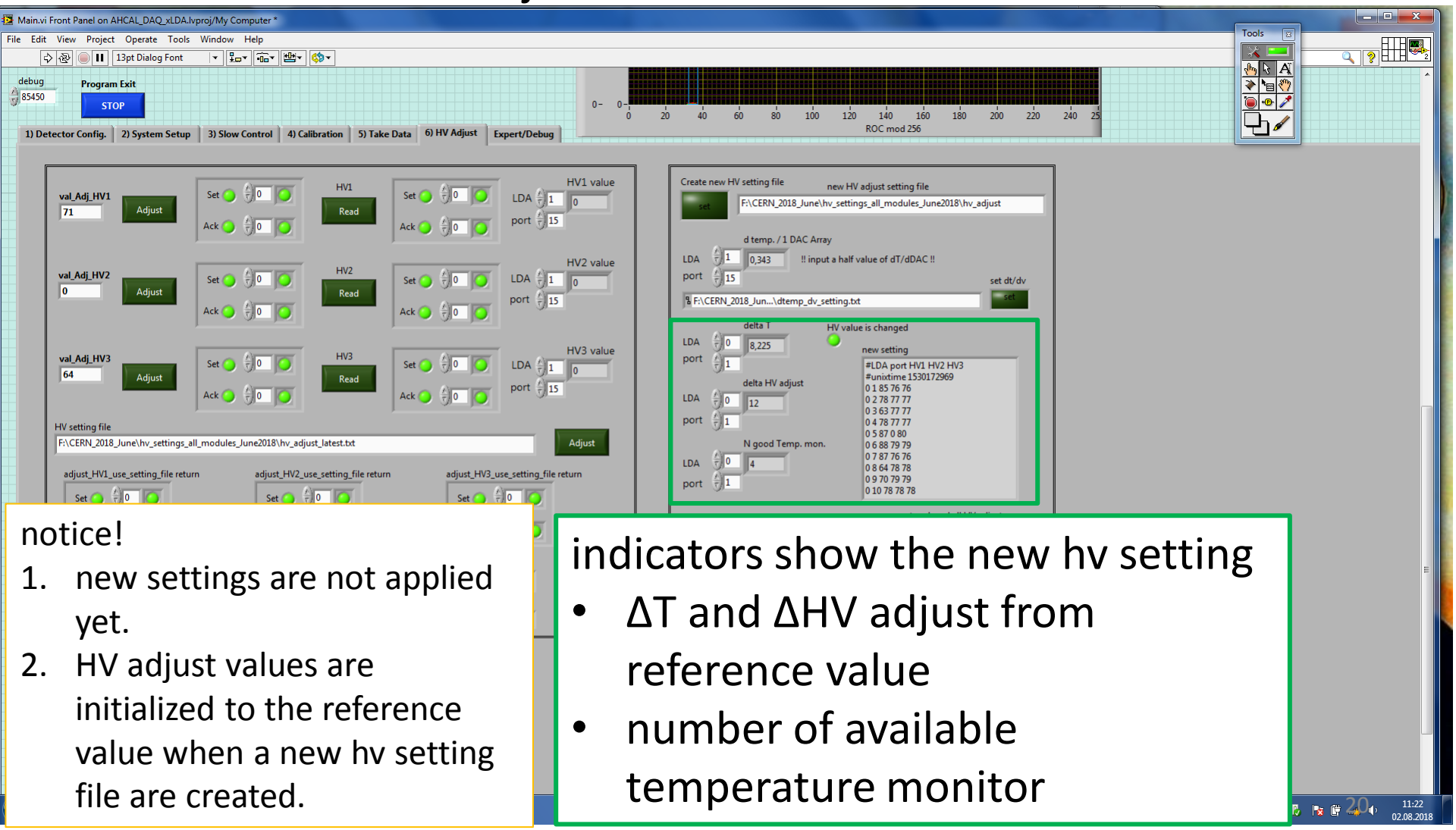



notice!

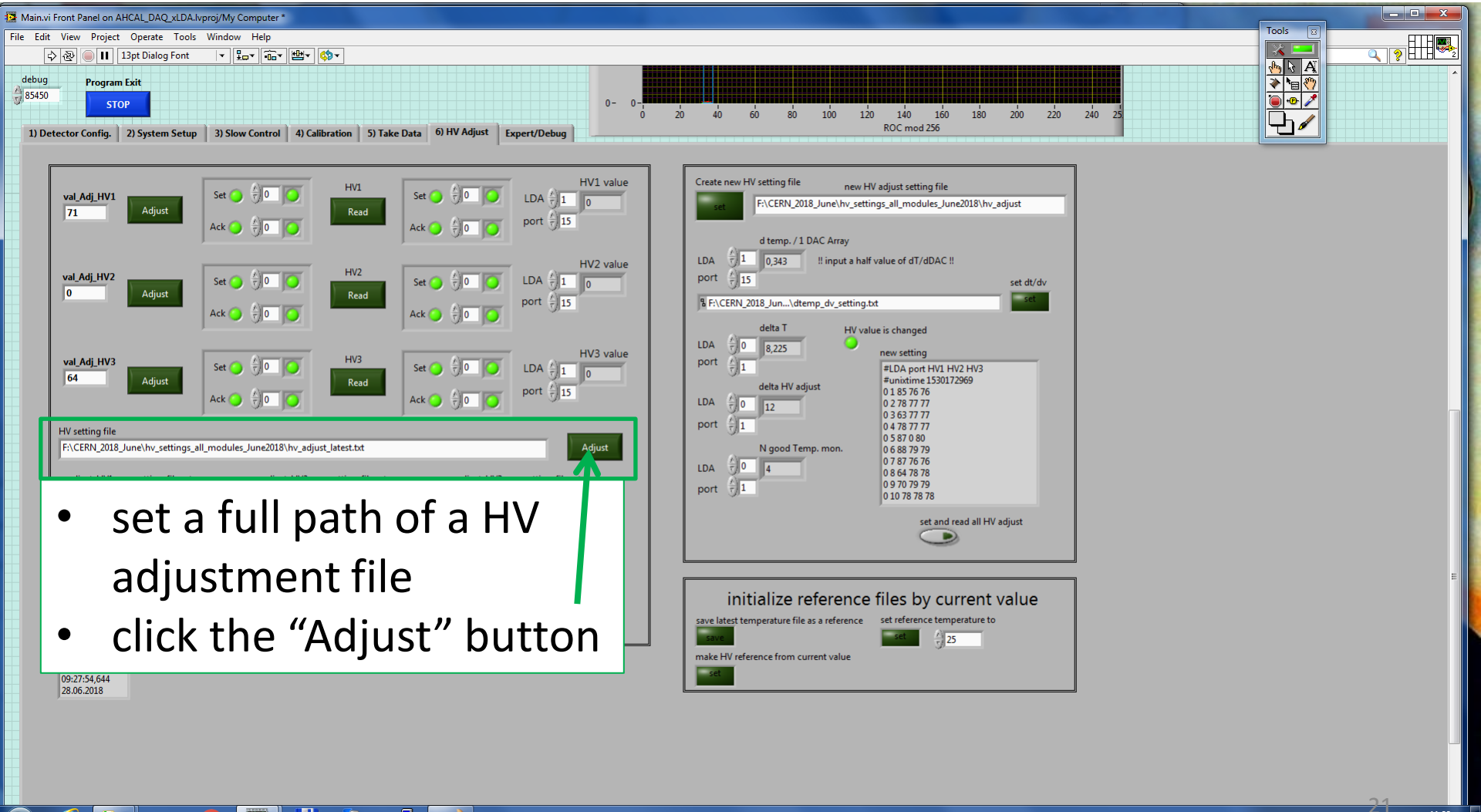
1. new settings are not applied yet.
2. HV adjust values are initialized to the reference value when a new hv setting file are created.

indicators show the new hv setting

- ΔT and ΔHV adjust from reference value
- number of available temperature monitor

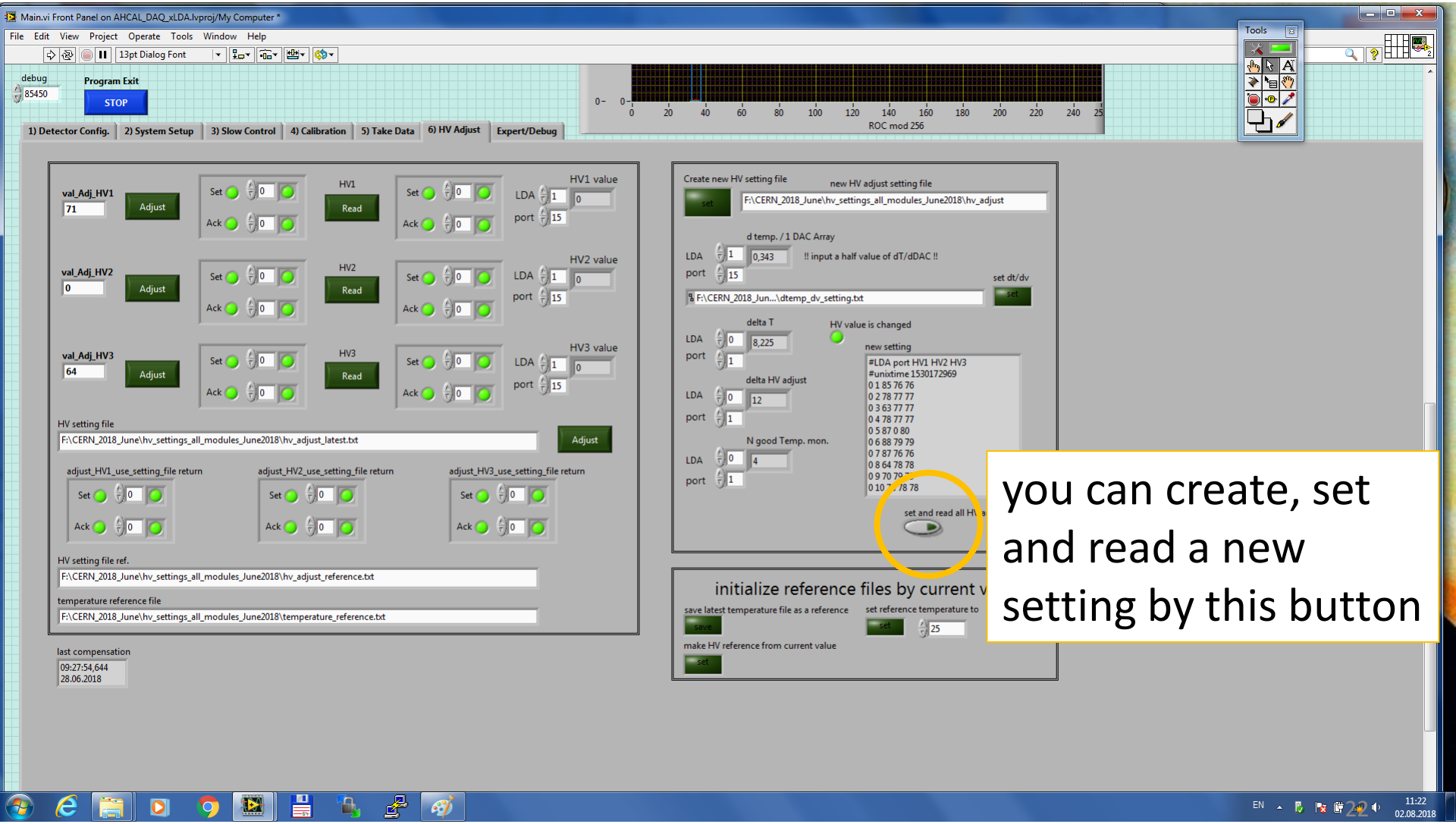
# Procedure of the Temperature Compensation

- set the new hv setting

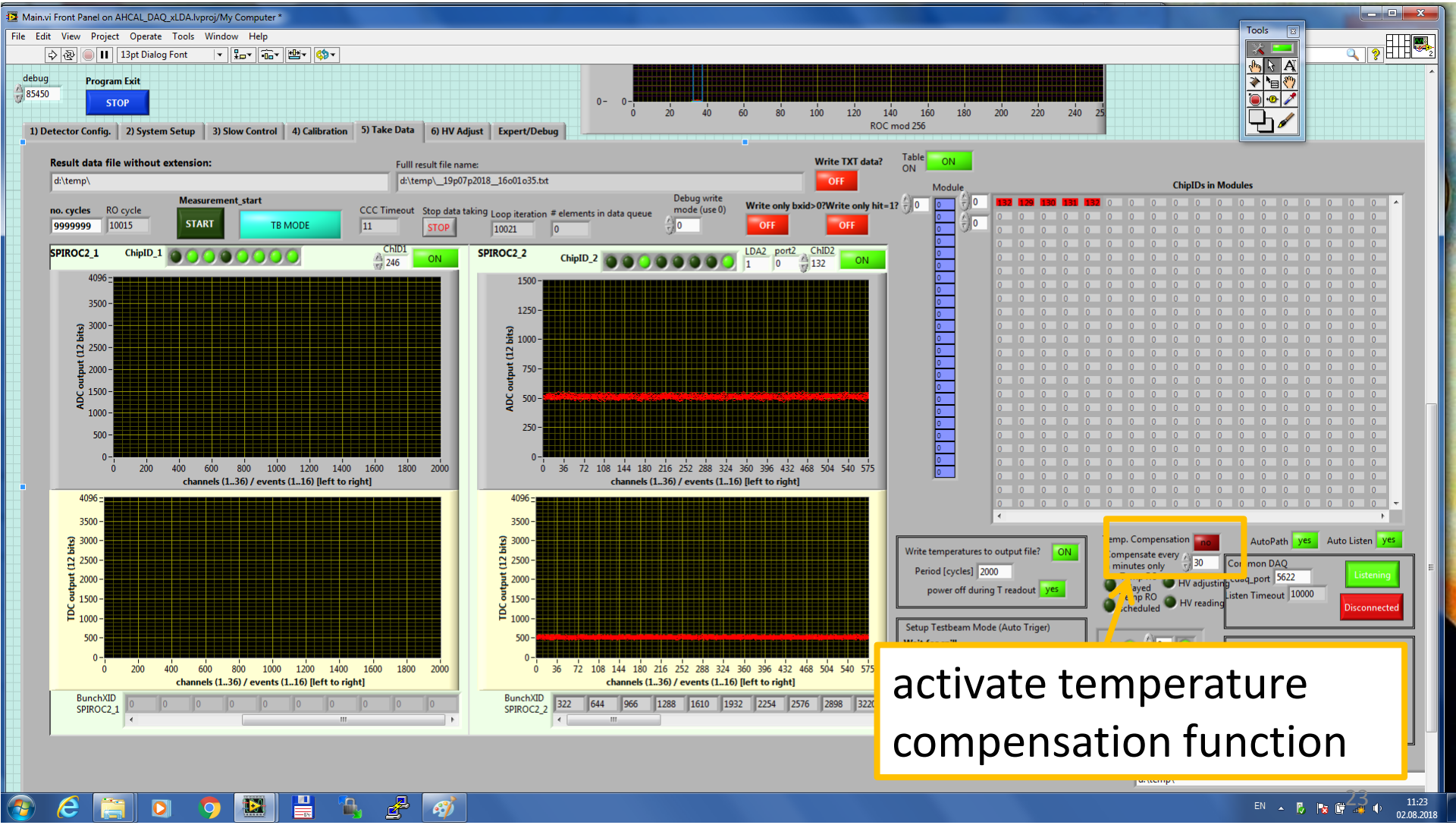



- set a full path of a HV adjustment file
- click the “Adjust” button

# Procedure of the Temperature Compensation



# Temperature Compensation in DAQ



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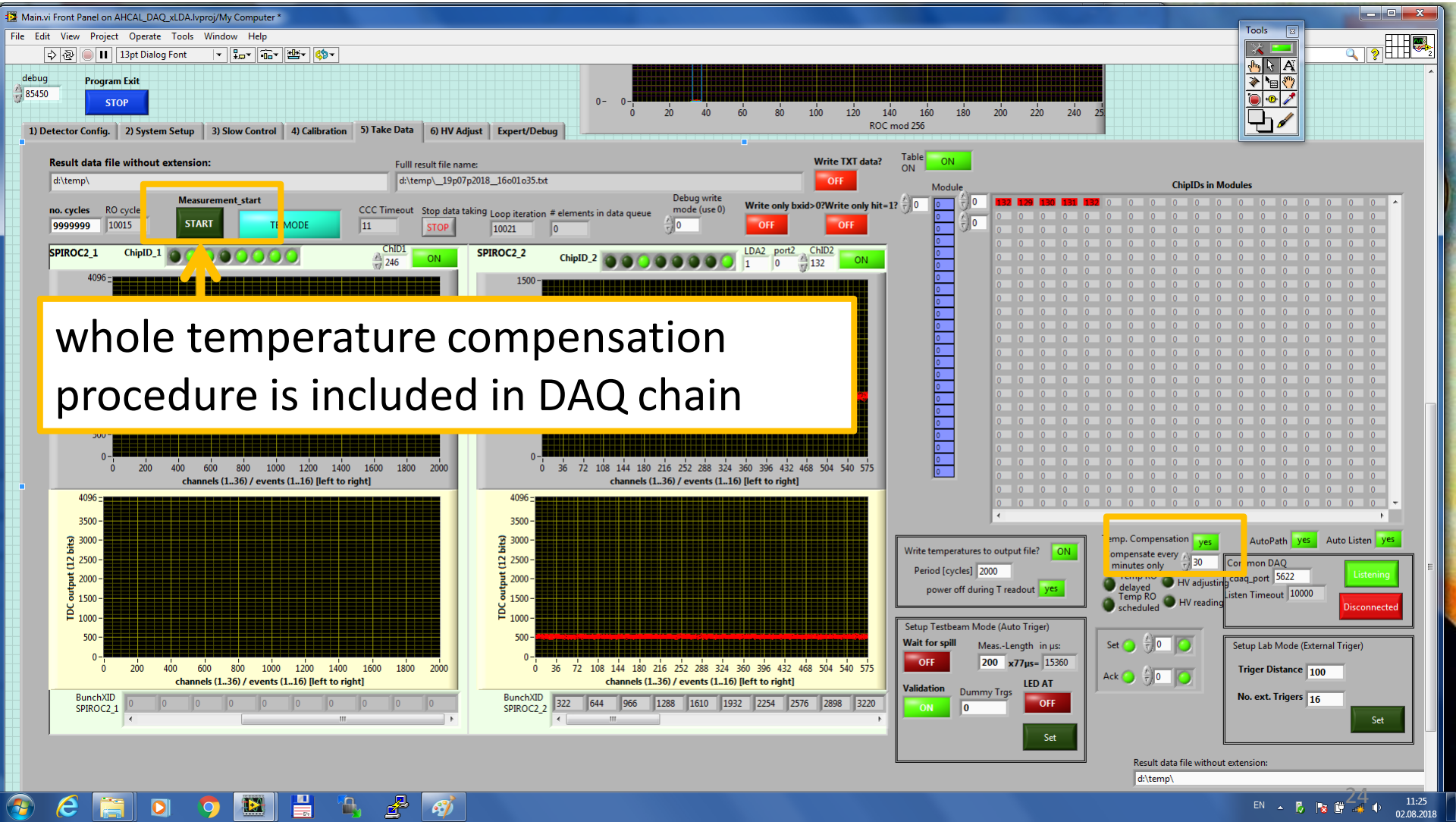
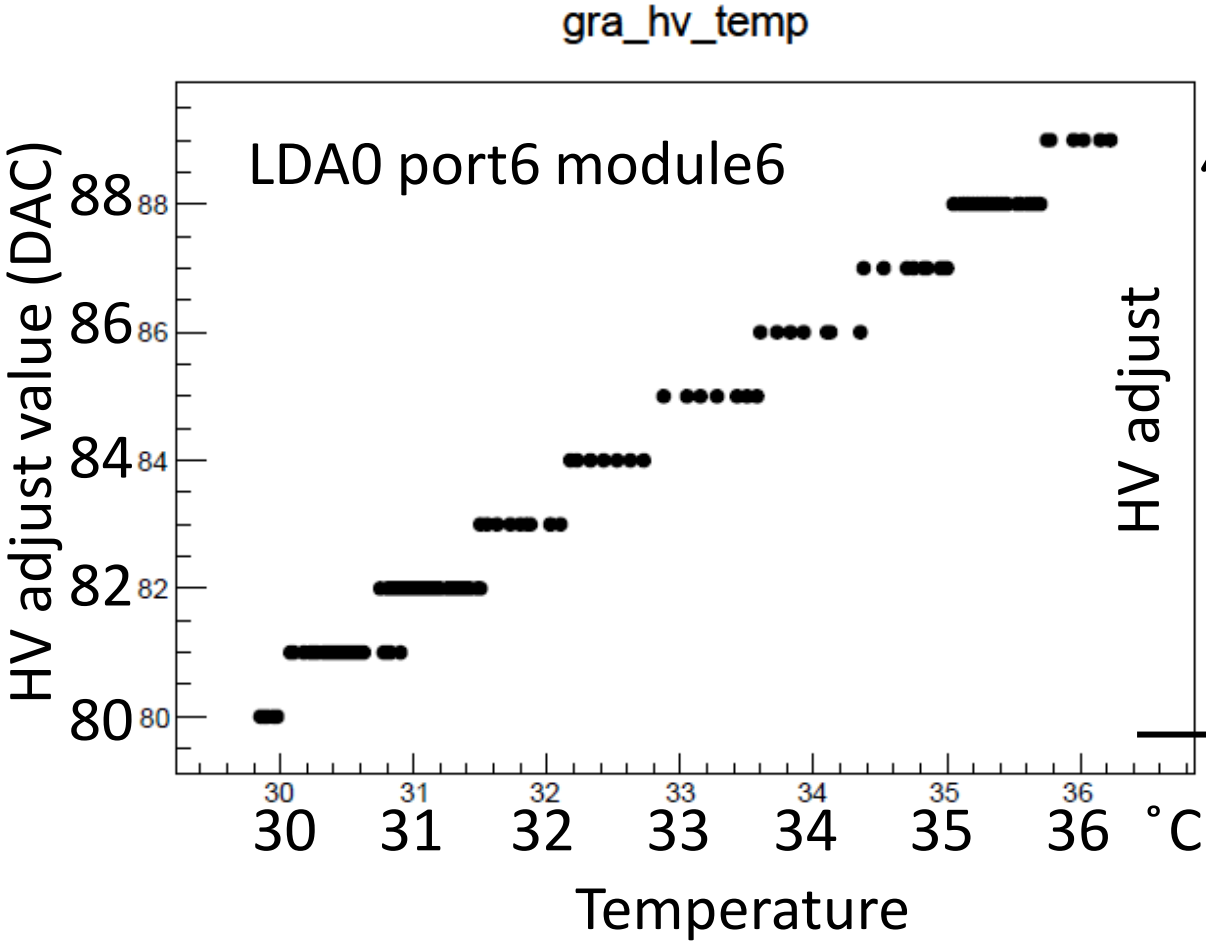
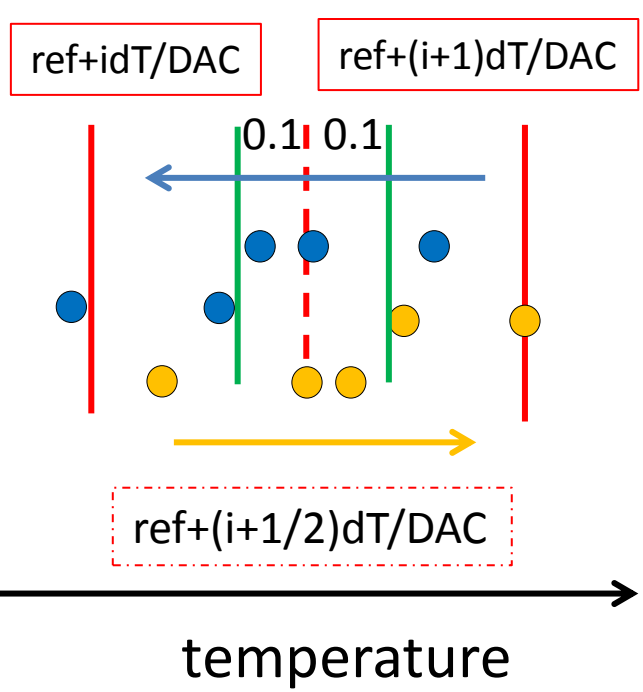



whole temperature compensation procedure is included in DAQ chain

# HV adjust vs Temperature

- 28th of June – 4th of July 2018
- There are over-lap of 0.2 degree C due to a hysteresis for stabilization at border



# outlook

- gain vs temperature plot for TB May and June 2018
- MIP vs  temperature plot for TB May and June 2018
- offline temperature correction