R6581 ADC Integral Nonlinearity Adjustment

1. Definition of R6581 ADC nonlinearity correction function:

H_i - CAL:INT:DCV:HOSEI parameters.

$$
\begin{aligned}
F(x,H) := \;& \text{return } H_{15}\cdot x \text{ if } (x < -10)\\
& \text{return } \left[x - 0.02\cdot(H_5+H_6+H_7+H_8+H_9) - 1.9\cdot H_{10} - 2\cdot(H_{11}+H_{12}+H_{13}) + (x+8)\cdot H_{14}\right]\cdot H_{15} \text{ if } (x \ge -10)\wedge(x < -8)\\
& \text{return } \left[x - 0.02\cdot(H_5+H_6+H_7+H_8+H_9) - 1.9\cdot H_{10} - 2\cdot(H_{11}+H_{12}) + (x+6)\cdot H_{13}\right]\cdot H_{15} \text{ if } (x \ge -8)\wedge(x < -6)\\
& \text{return } \left[x - 0.02\cdot(H_5+H_6+H_7+H_8+H_9) - 1.9\cdot H_{10} - 2\cdot H_{11} + (x+4)\cdot H_{12}\right]\cdot H_{15} \text{ if } (x \ge -6)\wedge(x < -4)\\
& \text{return } \left[x - 0.02\cdot(H_5+H_6+H_7+H_8+H_9) - 1.9\cdot H_{10} + (x+2)\cdot H_{11}\right]\cdot H_{15} \text{ if } (x \ge -4)\wedge(x < -2)\\
& \text{return } \left[x - 0.02\cdot(H_5+H_6+H_7+H_8+H_9) + (x+0.1)\cdot H_{10}\right]\cdot H_{15} \text{ if } (x \ge -2)\wedge(x < -0.1)\\
& \text{return } \left[x - 0.02\cdot(H_5+H_6+H_7+H_8) + (x+0.08)\cdot H_9\right]\cdot H_{15} \text{ if } (x \ge -0.1)\wedge(x < -0.08)\\
& \text{return } \left[x - 0.02\cdot(H_5+H_6+H_7) + (x+0.06)\cdot H_8\right]\cdot H_{15} \text{ if } (x \ge -0.08)\wedge(x < -0.06)\\
& \text{return } \left[x - 0.02\cdot(H_5+H_6) + (x+0.04)\cdot H_7\right]\cdot H_{15} \text{ if } (x \ge -0.06)\wedge(x < -0.04)\\
& \text{return } \left[x - 0.02\cdot H_5 + (x+0.02)\cdot H_6\right]\cdot H_{15} \text{ if } (x \ge -0.04)\wedge(x < -0.02)\\
& \text{return } (H_5\cdot x + x)\cdot H_{15} \text{ if } (x \ge -0.02)\wedge(x < 0)\\
& \text{return } H_0\cdot x + x \text{ if } (x \ge 0)\wedge(x < 2)\\
& \text{return } 2H_0 + x + (x-2)\cdot H_1 \text{ if } (x \ge 2)\wedge(x < 4)\\
& \text{return } 2\cdot(H_0+H_1) + x + (x-4)\cdot H_2 \text{ if } (x \ge 4)\wedge(x < 6)\\
& \text{return } 2\cdot(H_0+H_1+H_2) + x + (x-6)\cdot H_3 \text{ if } (x \ge 6)\wedge(x < 8)\\
& \text{return } 2\cdot(H_0+H_1+H_2+H_3) + x + (x-8)\cdot H_4 \text{ if } (x \ge 8)\wedge(x < 10)\\
& \text{return } (x-10)\cdot H_4 + x \text{ if } (x \ge 10)
\end{aligned}
$$

2. Resetting of correction factors in R6581 RAM:

```
CAL:INT:DCV:HOSEI 0,0
CAL:INT:DCV:HOSEI 1,0
CAL:INT:DCV:HOSEI 2,0
CAL:INT:DCV:HOSEI 3,0
CAL:INT:DCV:HOSEI 4,0
CAL:INT:DCV:HOSEI 5,0
CAL:INT:DCV:HOSEI 6,0
CAL:INT:DCV:HOSEI 7,0
CAL:INT:DCV:HOSEI 8,0
CAL:INT:DCV:HOSEI 9,0
CAL:INT:DCV:HOSEI 10,0
CAL:INT:DCV:HOSEI 11,0
CAL:INT:DCV:HOSEI 12,0
CAL:INT:DCV:HOSEI 13,0
CAL:INT:DCV:HOSEI 14,0
CAL:INT:DCV:HOSEI 15,1
```

3. Obtaining measurement results at reference points:

Reference voltages-DMM reading pairs must include the following values:
-10, -8, -6, -4, -2, -0.1, -0.08, -0.06, -0.04, -0.02, +2, +4, +6, +8, +10 V. Other intermediate values are optional.
In this example all of DMM readings are averaged over 3 values

4. Loading the array of reference voltages of the calibrator and the array of R6581 readings:

DCV_Source := READPRN("DCV_Source.csv") DMM_Response := READPRN("DMM_Response.csv")

DCV_Source =

	0
0	-9.9999811
1	-8.99996727
2	-7.99998157
3	-6.99997417
4	-5.9999813
5	-4.99999567
6	-3.99998503
7	-2.99999153
8	-1.99998827
9	-0.99999587
10	-0.09999497
11	-0.07999877
12	-0.05999893
13	...

DMM_Response =

	0	1	2
0	-10.0001049	-10.0001058	-10.0001048
1	-9.0000787	-9.0000786	-9.0000788
2	-8.0000811	-8.0000807	-8.0000811
3	-7.000061	-7.0000613	-7.0000612
4	-6.0000561	-6.0000561	-6.0000568
5	-5.0000584	-5.0000588	-5.0000583
6	-4.0000349	-4.0000349	-4.0000348
7	-3.0000293	-3.0000294	-3.0000293
8	-2.0000131	-2.0000132	-2.0000131
9	-1.0000074	-1.0000075	-1.0000074
10	-0.0999927	-0.0999931	-0.0999929
11	-0.0799966	-0.0799964	-0.0799961
12	-0.0599961	-0.059996	-0.0599962
13	-0.0399982	-0.0399982	...

Making of cell index aliases that store 0 V and +10 V voltage measurement results

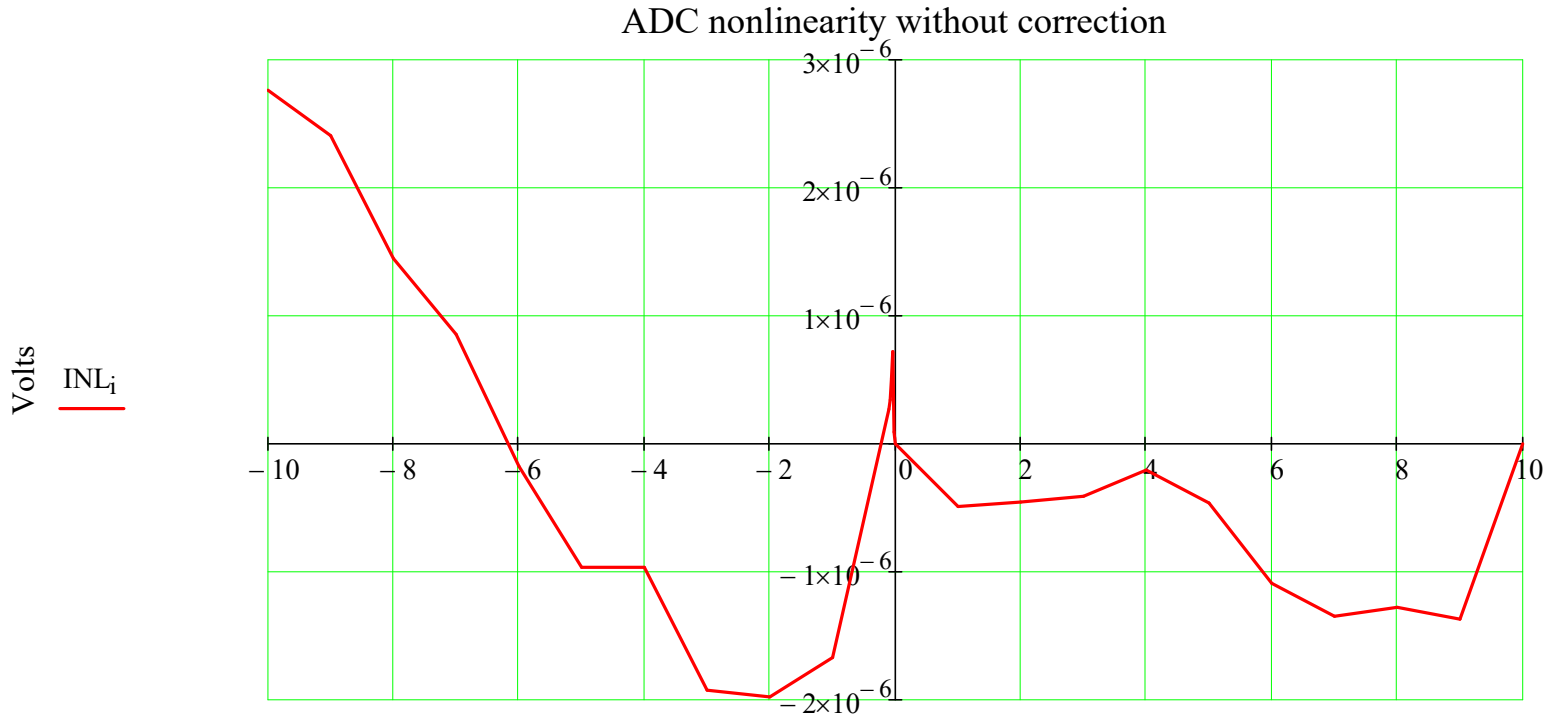
$N := \text{rows}(\text{DCV\_Source}) = 26$ idx0V := 15 idx10V := 25

Averaging of DMM measurement results

$i := 0 .. N-1$ $DMM_i := \dfrac{DMM\_Response_{i,0} + DMM\_Response_{i,1} + DMM\_Response_{i,2}}{3}$

5. Normalization of measurement results and calculation of absolute nonlinearity (in V):

$$INL_i := DMM_i \cdot \frac{DCV\_Source_{idx10V} - DCV\_Source_{idx0V}}{DMM_{idx10V} - DMM_{idx0V}} + \left(DCV\_Source_{idx0V} - DMM_{idx0V}\right) - DCV\_Source_i$$



Converting an array of non-linearity values into parametric voltage functions, separately for positive (INLP) and negative (INLN) scales

$$INLP(V) := \left| \begin{array}{l} res \leftarrow 10^6 \\ idx \leftarrow 0 \\ \text{for } i \in 0..N-1 \\ \quad \text{if } res > \left|DCV\_Source_i - V\right| \\ \quad\quad \left| \begin{array}{l} idx \leftarrow i \\ res \leftarrow \left|DCV\_Source_i - V\right| \end{array} \right. \\ \text{return } INL_{idx} \end{array} \right.$$

$$NOFFS := \frac{INLP(-10) - INLP(0)}{-10} \qquad INLN(V) := INLP(V) - V \cdot NOFFS$$

6. Calculation of H-parameters of the nonlinearity correction function:

For positive scale

$$H_0 := \frac{INLP(0) - INLP(2)}{2} \qquad H_1 := \frac{INLP(2) - INLP(4)}{2} \qquad H_2 := \frac{INLP(4) - INLP(6)}{2}$$

$$H_3 := \frac{INLP(6) - INLP(8)}{2} \qquad H_4 := -(H_0 + H_1 + H_2 + H_3)$$

For negative scale

$$H_5 := \frac{INLN(-0.02) - INLP(0)}{0.02} \qquad H_6 := \frac{INLN(-0.04) - INLN(-0.02)}{0.02} \qquad H_7 := \frac{INLN(-0.06) - INLN(-0.04)}{0.02}$$

$$H_8 := \frac{INLN(-0.08) - INLN(-0.06)}{0.02} \qquad H_9 := \frac{INLN(-0.1) - INLN(-0.08)}{0.02} \qquad H_{10} := \frac{INLN(-2) - INLN(-0.1)}{1.9}$$

$$H_{11} := \frac{INLN(-4) - INLN(-2)}{2} \qquad H_{12} := \frac{INLN(-6) - INLN(-4)}{2} \qquad H_{13} := \frac{INLN(-8) - INLN(-6)}{2}$$

$$H_{14} := -0.01 \cdot (H_5 + H_6 + H_7 + H_8 + H_9) - 0.95 \cdot H_{10} - (H_{11} + H_{12} + H_{13}) \qquad H_{15} := 1 - NOFFS$$

7. Saving H-parameters to file for downloading to the DMM:

$$PRNPRECISION := 10 \qquad WRITEPRN("hosei\_parameters.csv") := H$$