Thermal simulations in Valencia

C. Lacasta, C. Marinas, M. Vos

1.- Thermal studies over the T-shape diamond option

- ✓ Influence of the cooling's block temperature
- ✓ Influence of the speed of air

2.- Extended diamond

- ✓ Influence of the cooling's block temperature
- ✓Influence of the speed of air

3.- Diamond bridge length (distance between ladder and cooling block)

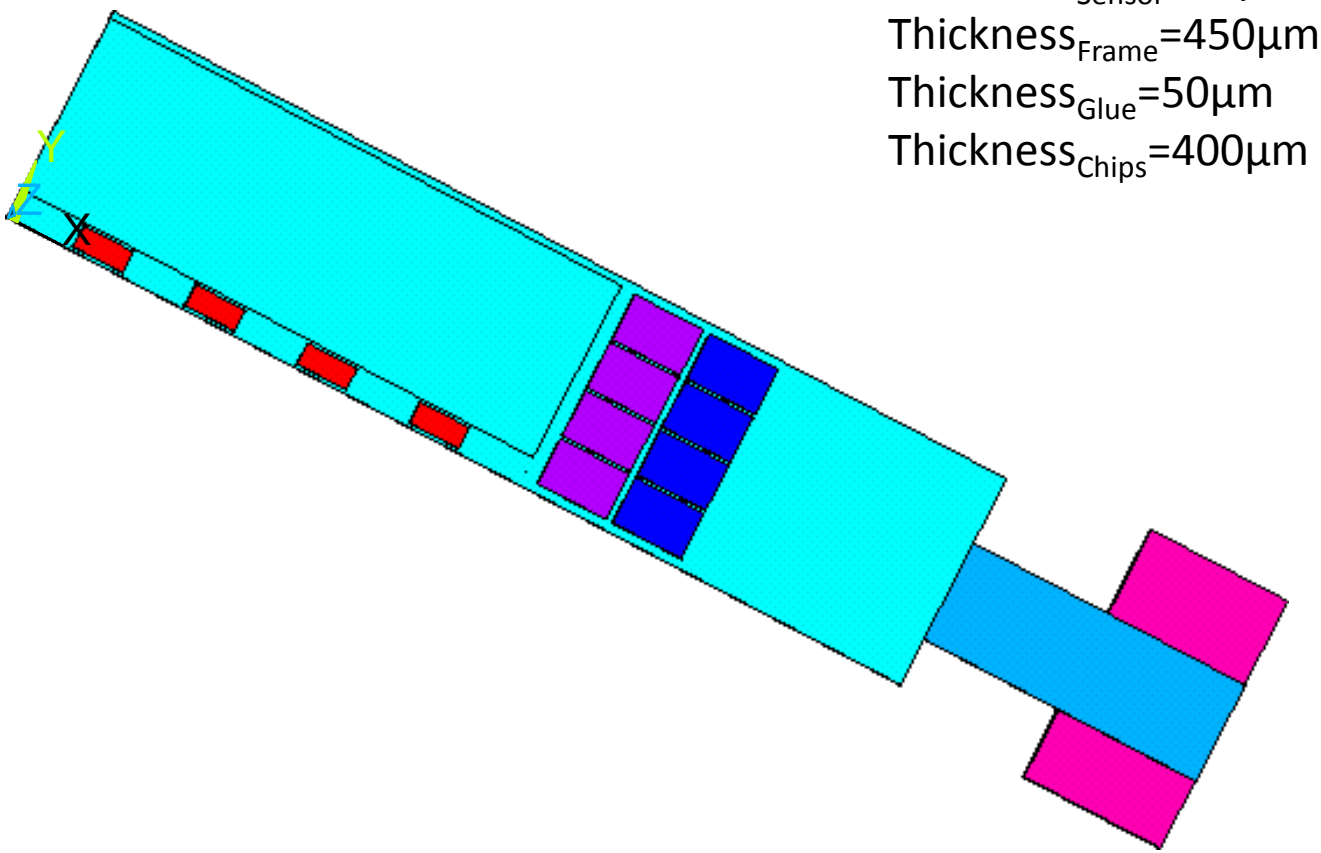
4.- Cooling's block temperature

5.- Environment temperature

6.- Effect on the Switcher power consumption

7.- Cross-check Valencia and Karlsruhe simulations

$Thickness_{Sensor}$=50µm
$Thickness_{Frame}$=450µm
$Thickness_{Glue}$=50µm
$Thickness_{Chips}$=400µm

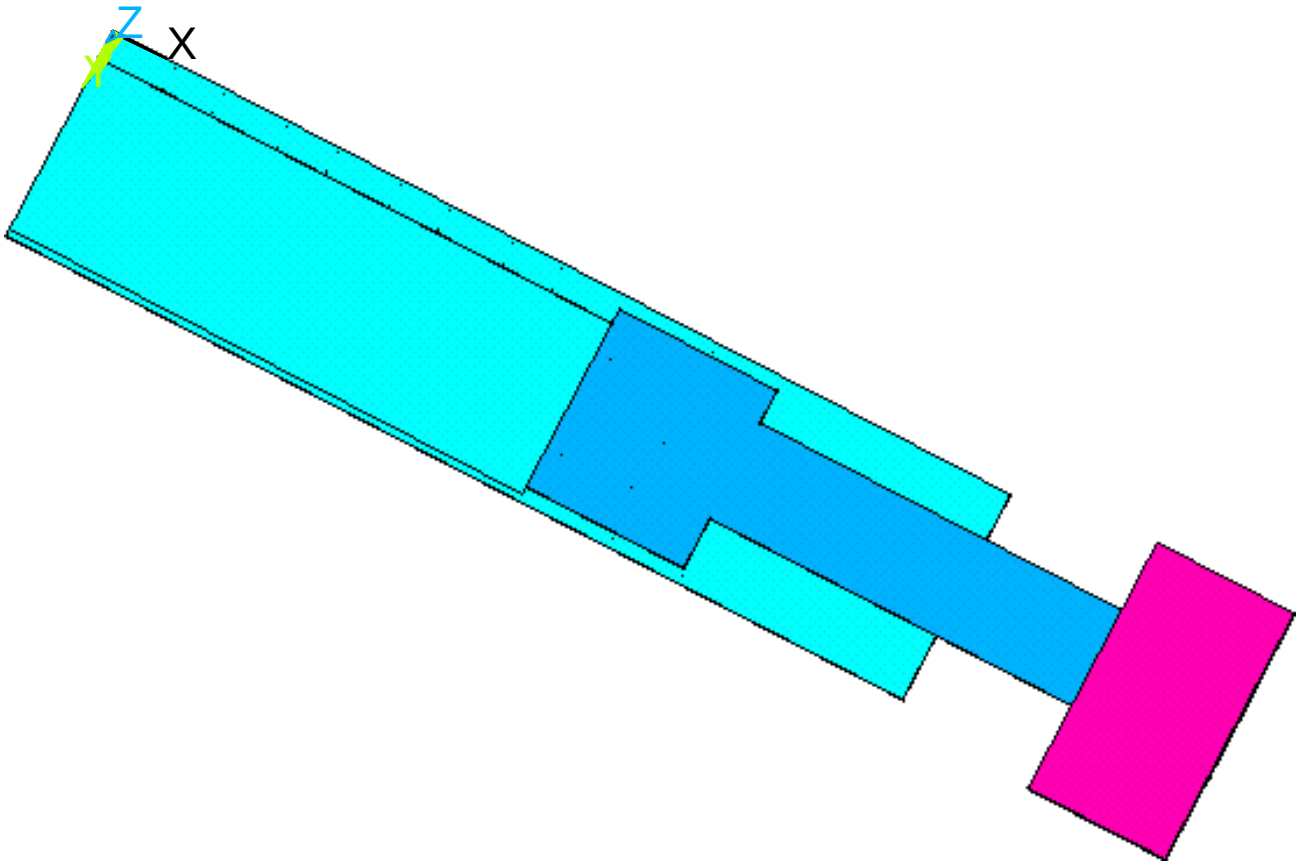


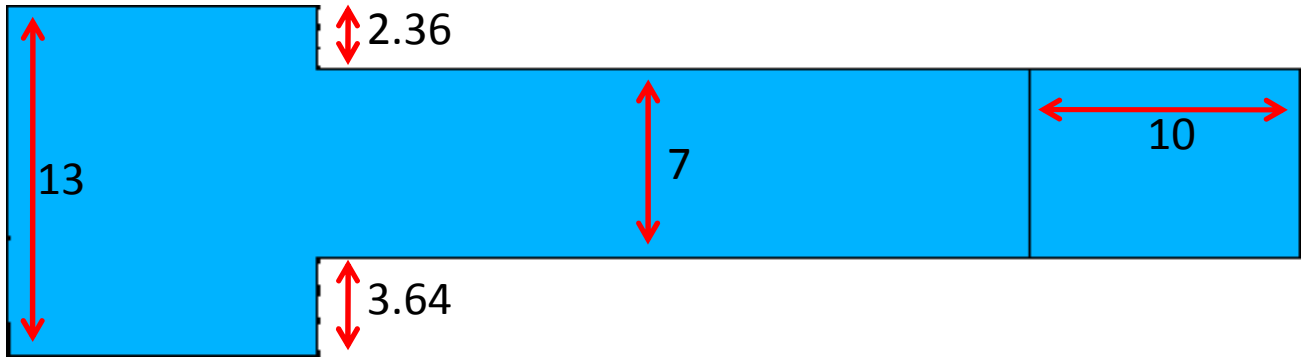
General statement

Ladder's dimension and chip's power consumption as defined in our "Parameter list"

→ Constant values all over this slides!

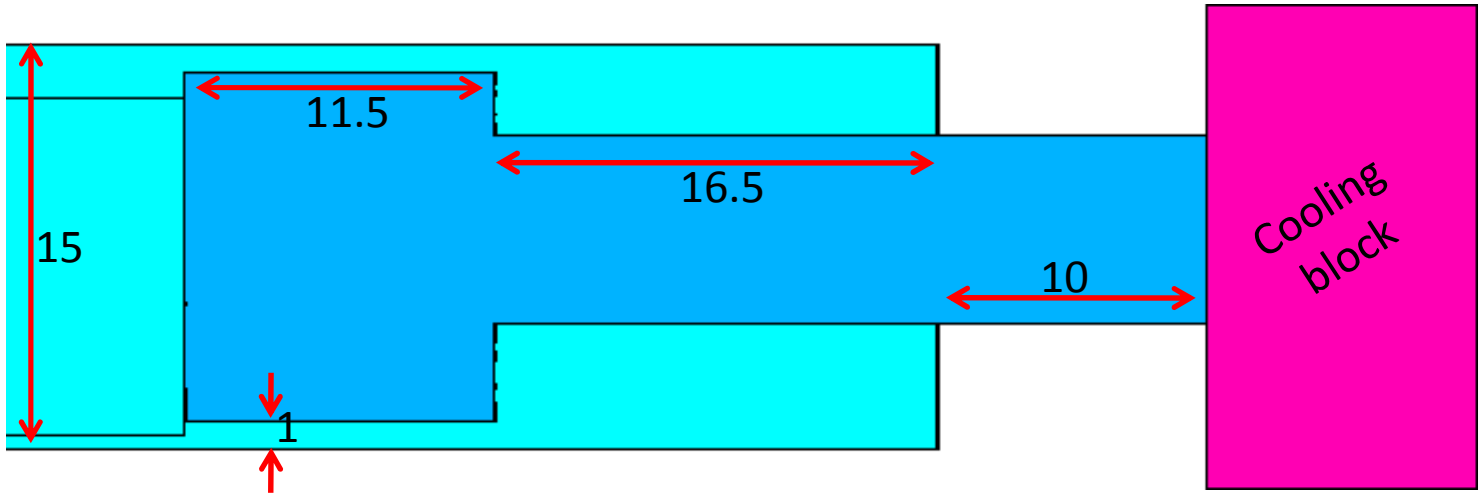
1.- T-shape

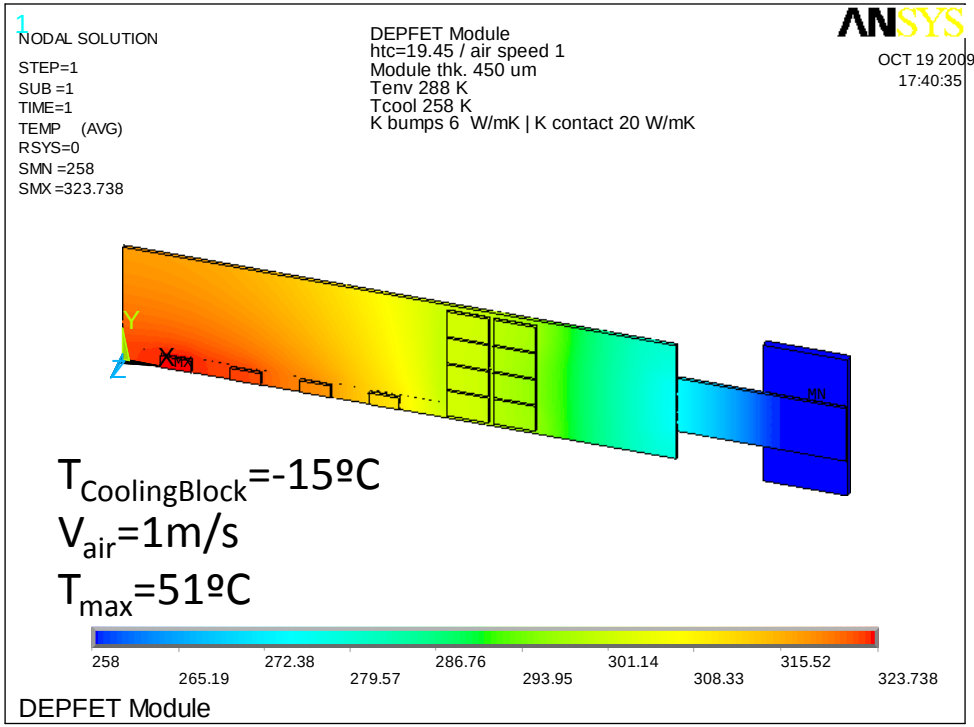


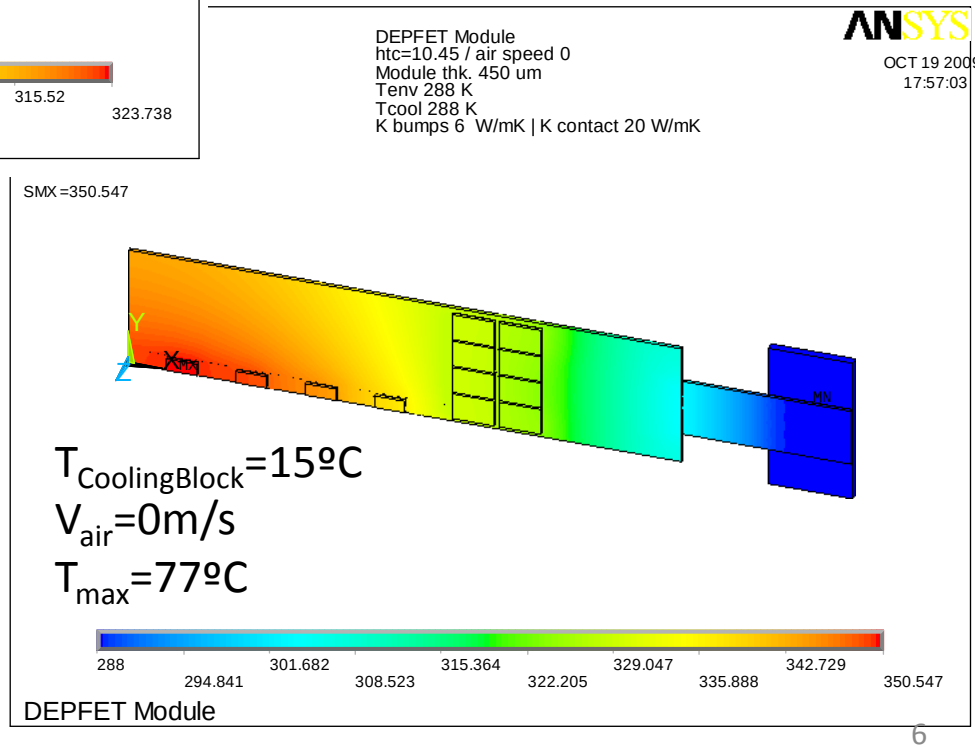


Thickness$_{Diamond}$=400µm

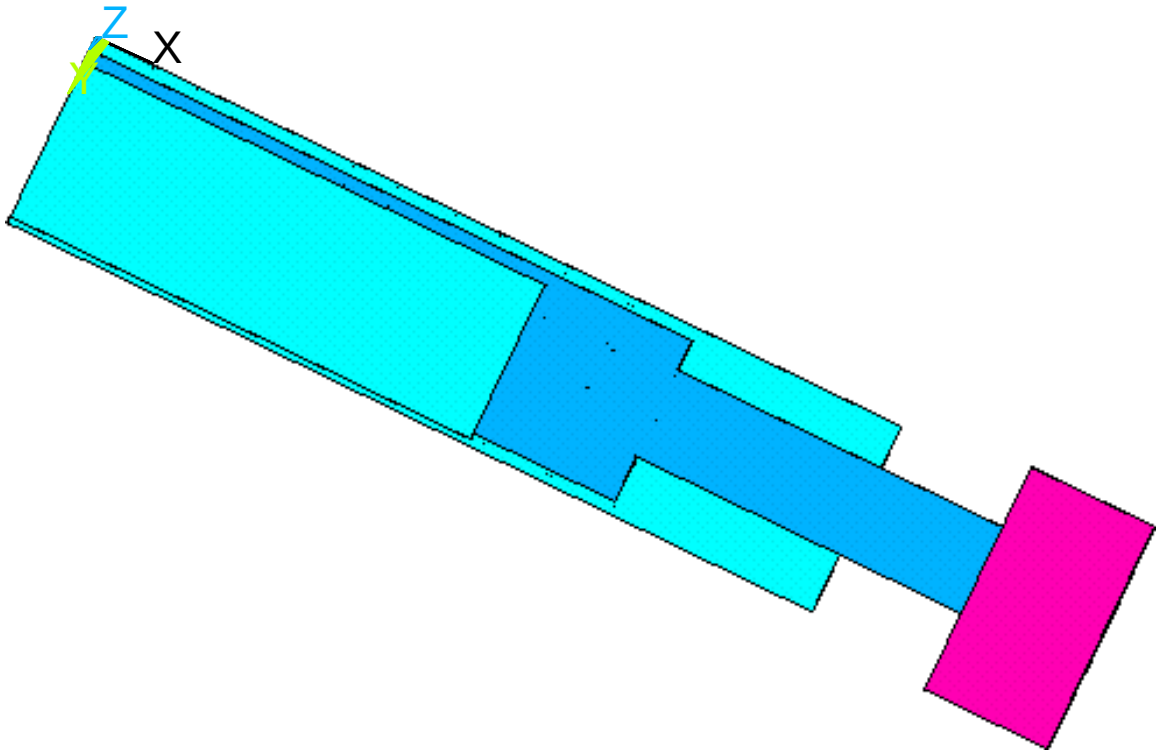
All in mm

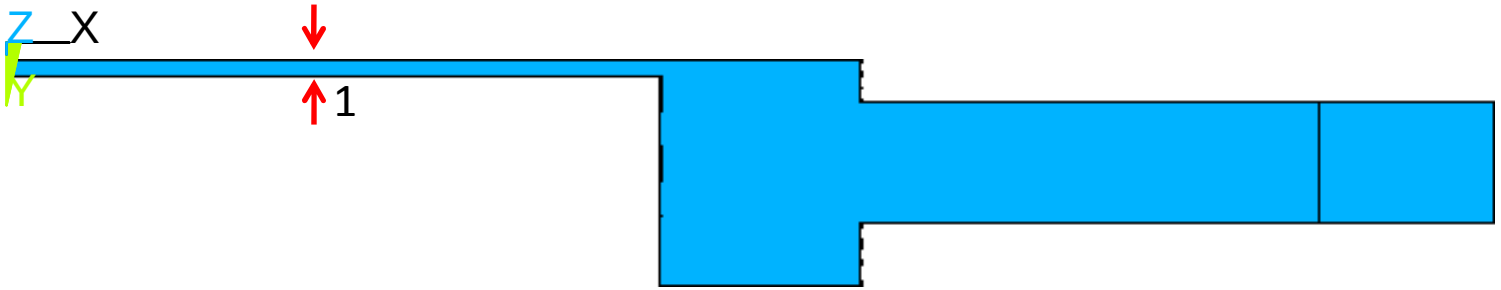



1
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =258
SMX =323.738
DEPFET Module
htc=19.45 / air speed 1
Module thk. 450 um
Tenv 288 K
Tcool 258 K
K bumps 6 W/mK | K contact 20 W/mK
ANSYS
OCT 19 2009
17:40:35
Y
Z
X
MX
MN
$T_{CoolingBlock}$=-15ºC
V_{air}=1m/s
T_{max}=51ºC
258
265.19
272.38
279.57
286.76
293.95
301.14
308.33
315.52
323.738
DEPFET Module

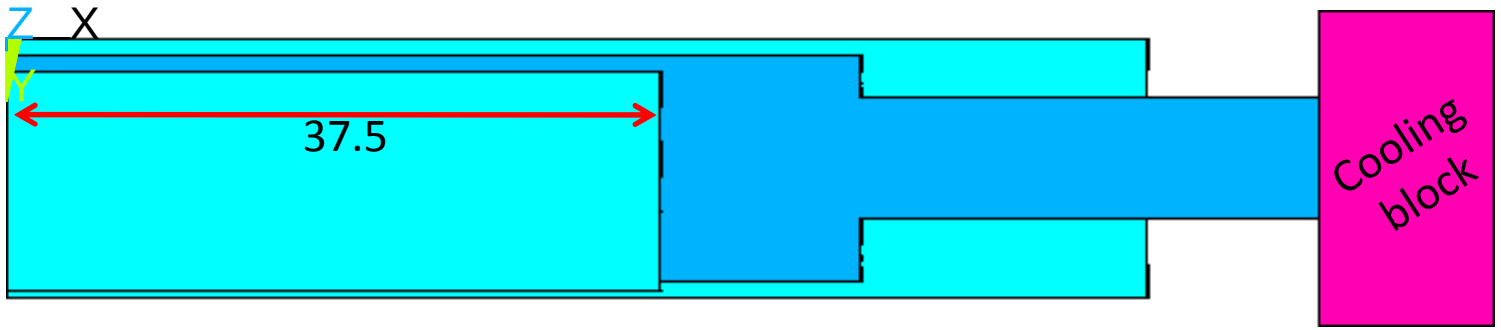

DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 288 K
K bumps 6 W/mK | K contact 20 W/mK
ANSYS
OCT 19 2009
17:57:03
SMX =350.547
Y
Z
X
MX
MN
$T_{CoolingBlock}$=15ºC
V_{air}=0m/s
T_{max}=77ºC
288
294.841
301.682
308.523
315.364
322.205
329.047
335.888
342.729
350.547
DEPFET Module

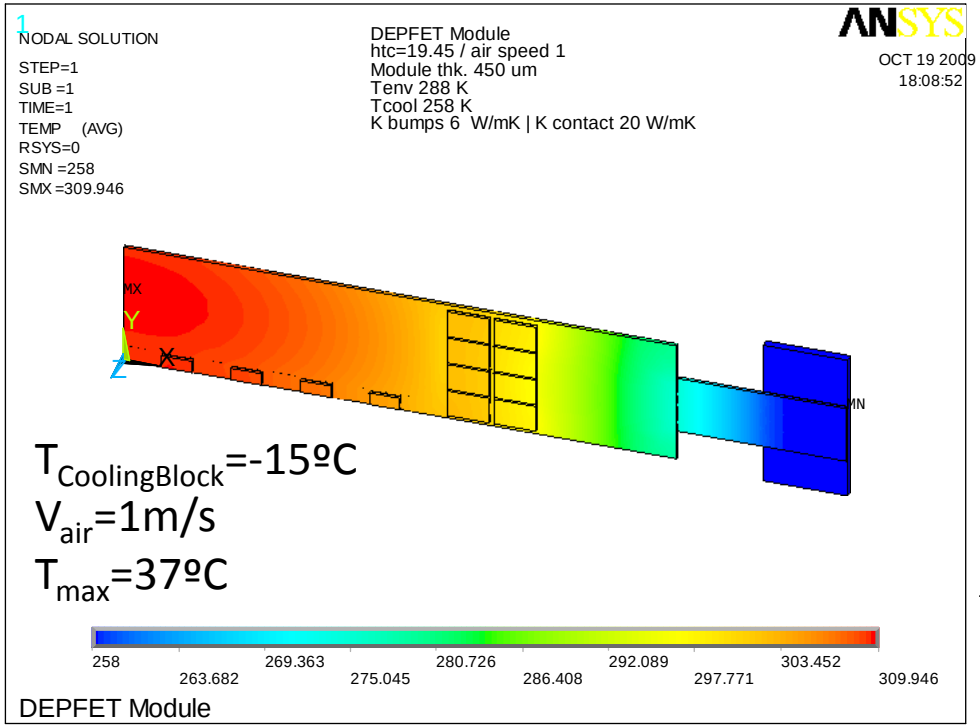
2.- T-shape extended





All in mm

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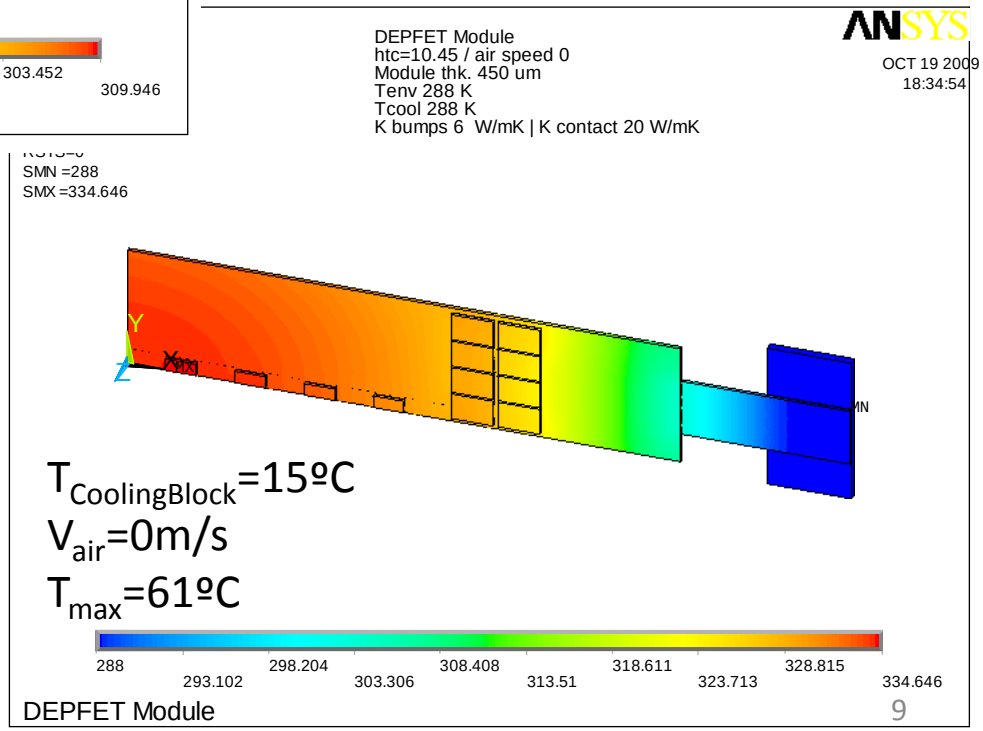
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =258
SMX =309.946
DEPFET Module
htc=19.45 / air speed 1
Module thk. 450 um
Tenv 288 K
Tcool 258 K
K bumps 6 W/mK | K contact 20 W/mK
ANSYS
OCT 19 2009
18:08:52
MX
Y
Z
X
MN
$T_{CoolingBlock}$=-15ºC
V_{air}=1m/s
T_{max}=37ºC
258
263.682
269.363
275.045
280.726
286.408
292.089
297.771
303.452
309.946
DEPFET Module


DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 288 K
K bumps 6 W/mK | K contact 20 W/mK
ANSYS
OCT 19 2009
18:34:54
SMN =288
SMX =334.646
Y
Z
X
MN
$T_{CoolingBlock}$=15ºC
V_{air}=0m/s
T_{max}=61ºC
288
293.102
298.204
303.306
308.408
313.51
318.611
323.713
328.815
334.646
DEPFET Module

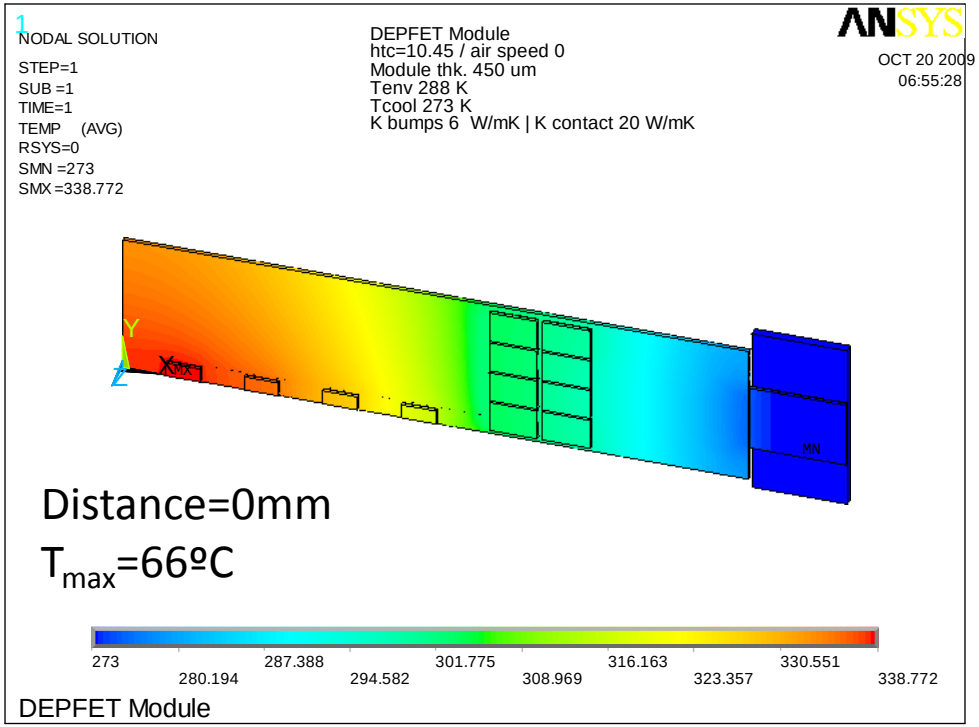
SUMMARY

$T_{CoolingBlock}$ (ºC)	V_{air} (m/s)	T_{max} (ºC) T-Shape	T_{max} (ºC) Extended
-15	0	66	44
-15	1	51	**37**
0	0	71	52
0	1	54	44
+15	0	77	61
+15	1	58	52

The diamond under the Switcher's balcony helps a lot!

3.- Diamond bridge length

$T_{CoolingBlock}$=0ºC
V_{air}=0m/s
Overlap with the cooling block=70mm^2
Diamond length=0mm … 50mm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NODAL SOLUTION
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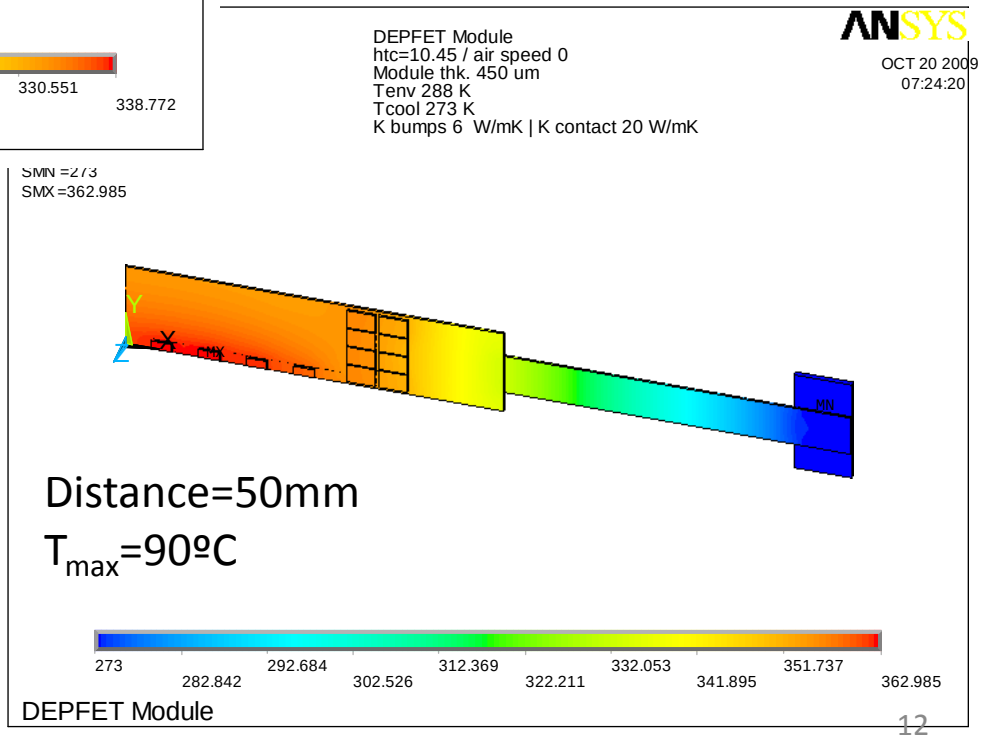
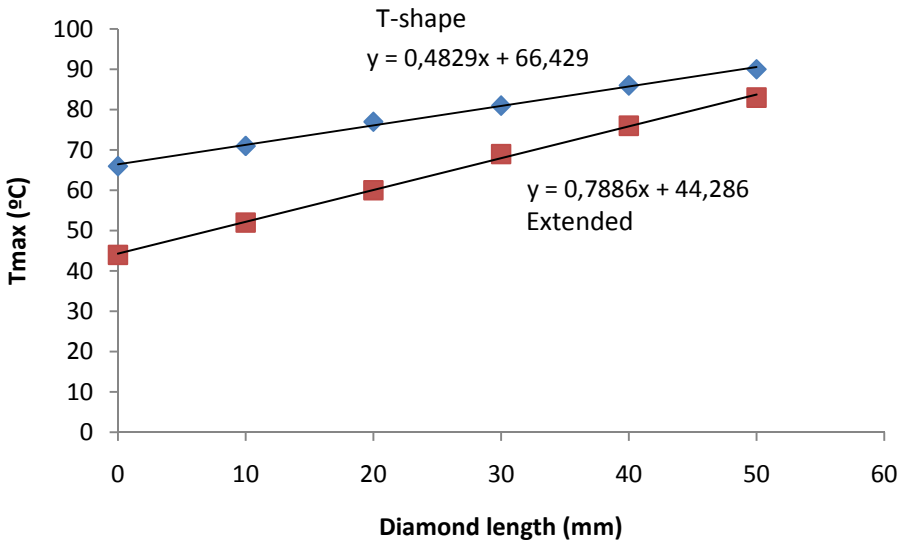
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =273
SMX =338.772
DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 273 K
K bumps 6 W/mK | K contact 20 W/mK
ANSYS
OCT 20 2009
06:55:28
Y
Z
X
MX
MN
Distance=0mm
T_{max}=66ºC
273
280.194
287.388
294.582
301.775
308.969
316.163
323.357
330.551
338.772
DEPFET Module


DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 273 K
K bumps 6 W/mK | K contact 20 W/mK
ANSYS
OCT 20 2009
07:24:20
SMN =273
SMX =362.985
Y
Z
X
MX
MN
Distance=50mm
T_{max}=90ºC
273
282.842
292.684
302.526
312.369
322.211
332.053
341.895
351.737
362.985
DEPFET Module

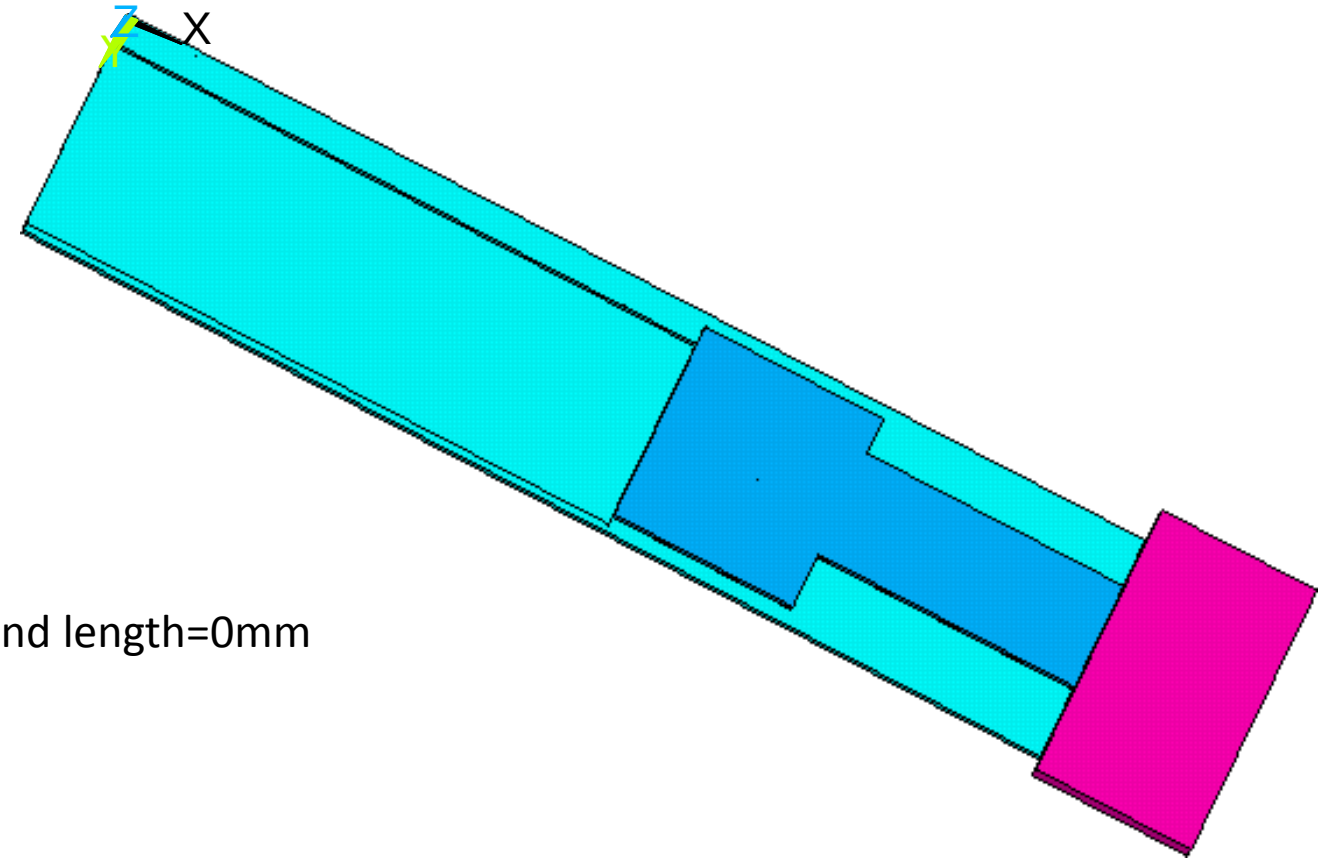
SUMMARY

Diamond length (mm)	T_{max} (ºC) T-shape	T_{max} (ºC) Extended
0	66	44
10	71	52
20	77	60
30	81	69
40	86	76
50	90	83

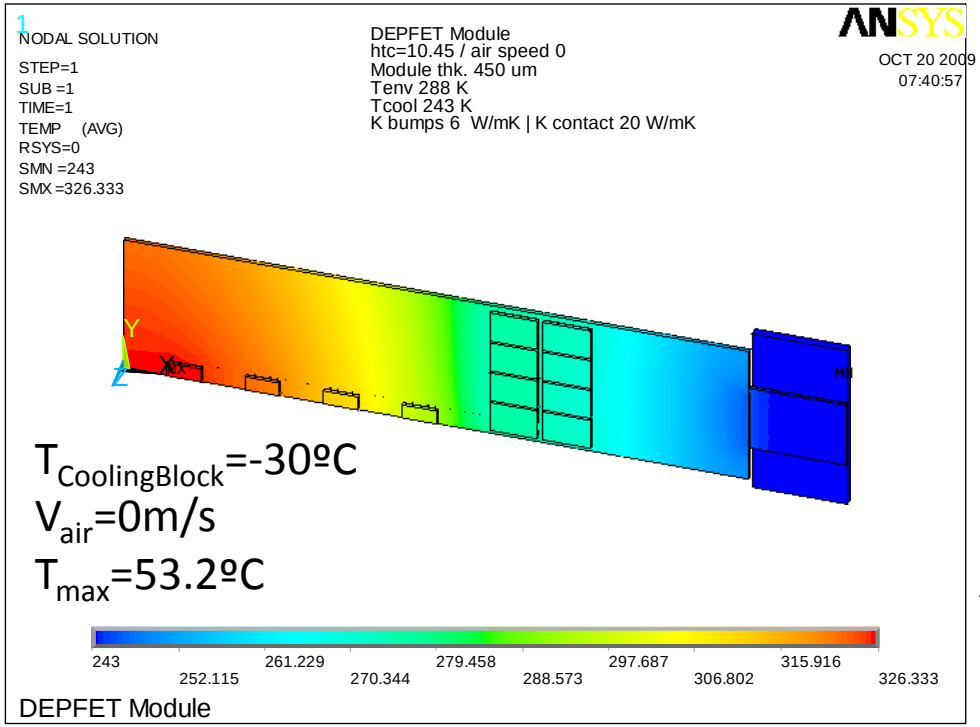


We need to be as close as possible of the cooling block!
With the “Diamond extended” option: dT~20ºC!

4.- Cooling’s block temperature



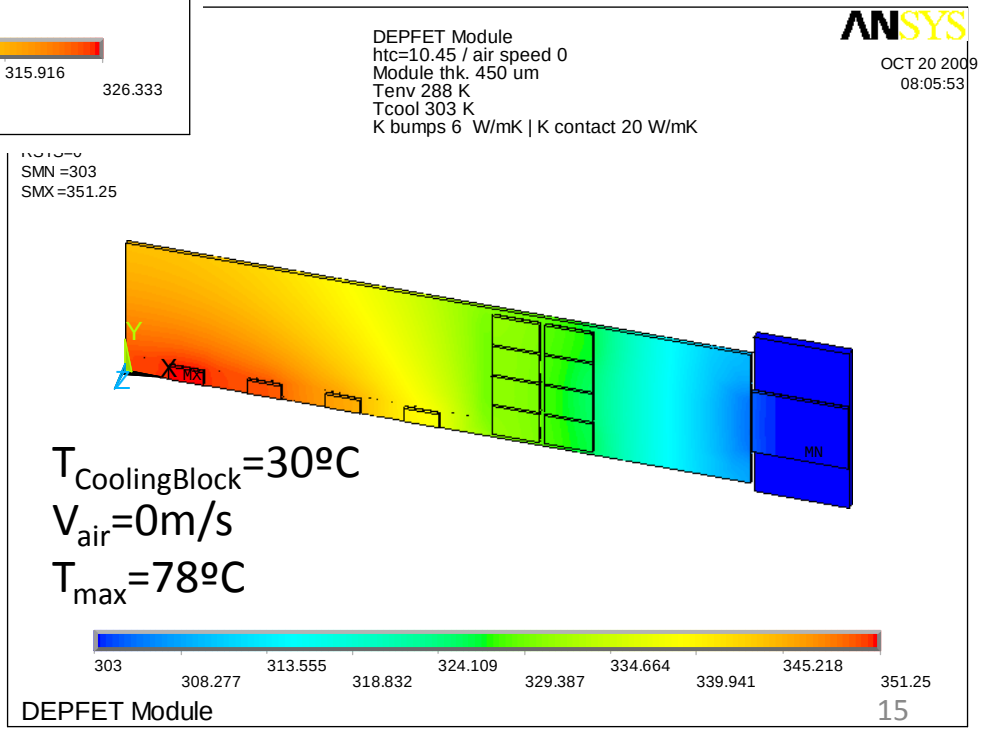
Diamond length=0mm



$T_{CoolingBlock}$=-30ºC

V_{air}=0m/s

T_{max}=53.2ºC



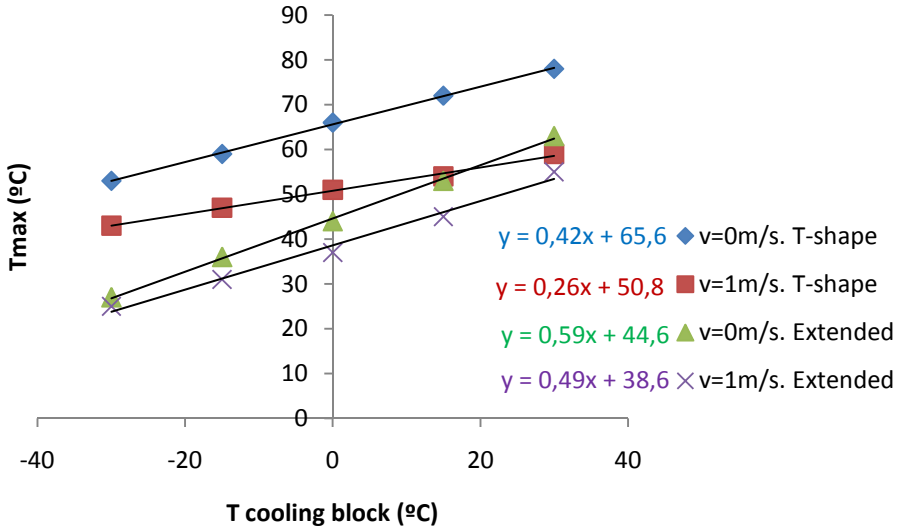
$T_{CoolingBlock}$=30ºC

V_{air}=0m/s

T_{max}=78ºC

SUMMARY

$T_{CoolingBlock}$ (ºC)	T_{max} (ºC), v=0m/s, T-shape	T_{max} (ºC), v=0m/s, Extended	T_{max} (ºC), v=1m/s, T-shape	T_{max} (ºC), v=1m/s, Extended
-30	53	27	43	25
-15	59	36	47	31
0	66	44	51	37
+15	72	53	54	45
+30	78	63	59	55

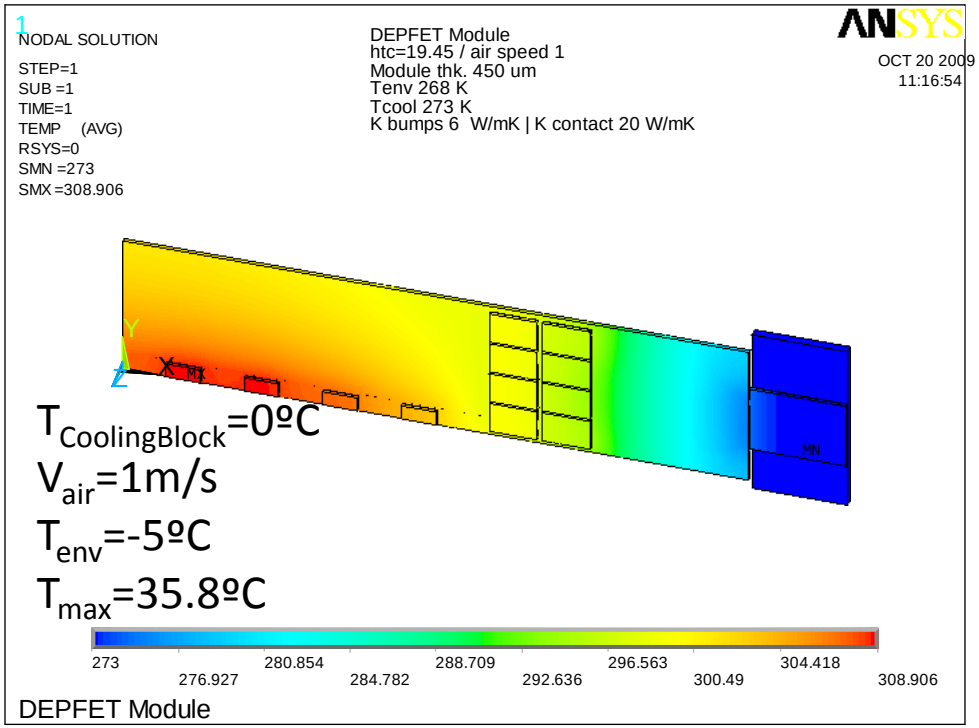


- Small efficiency… Big changes in the cooling block give not such big differences in the maximum temperature

- Once again, the "Extended" is the best option!

→ Bigger slope

5.- Environment temperature

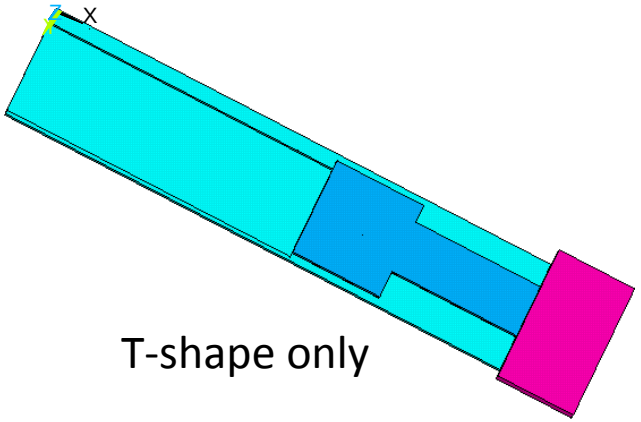


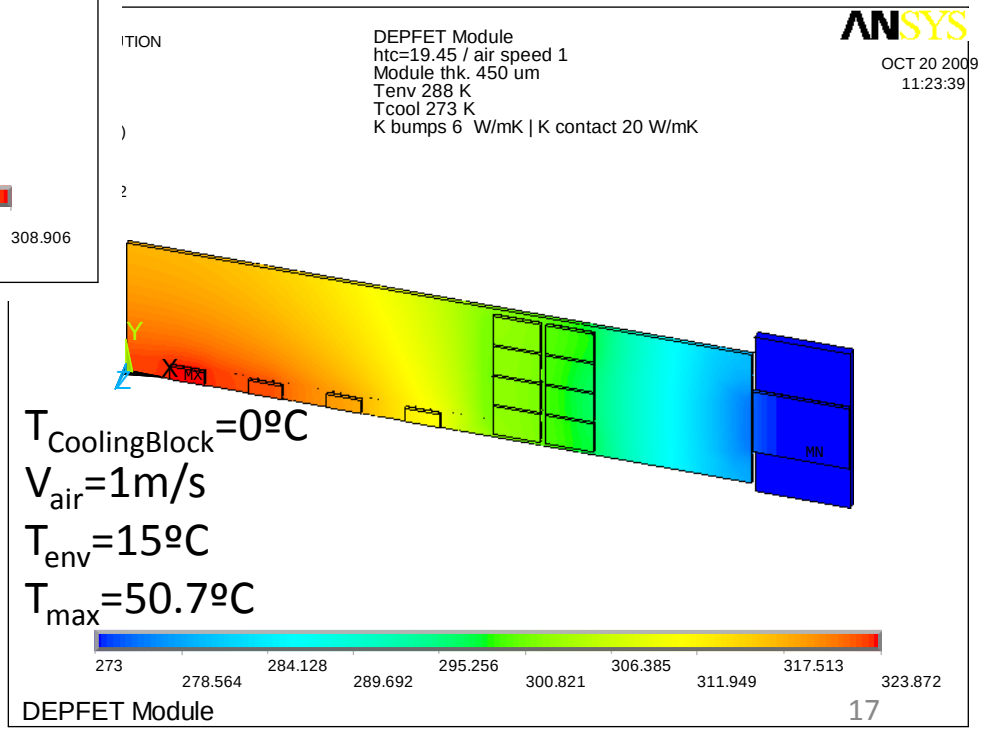
$T_{CoolingBlock}$=0ºC

V_{air}=1m/s

T_{env}=-5ºC

T_{max}=35.8ºC





$T_{CoolingBlock}$=0ºC

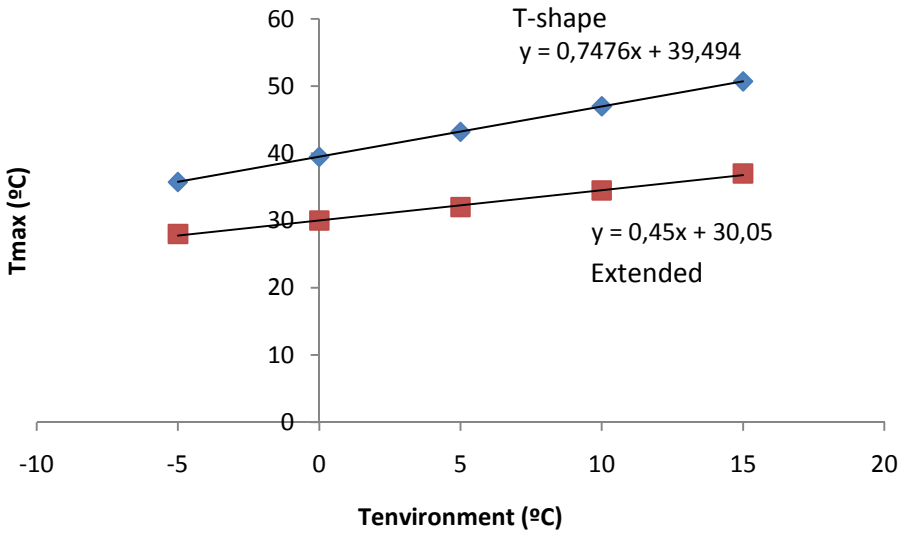
V_{air}=1m/s

T_{env}=15ºC

T_{max}=50.7ºC

SUMMARY

$T_{Environment}$ (ºC)	T_{max} (ºC), v=1m/s, T-shape	T_{max} (ºC), v=1m/s, Extended
-5	36	28
0	40	30
+5	43	32
+10	47	34
+15	50.7	37

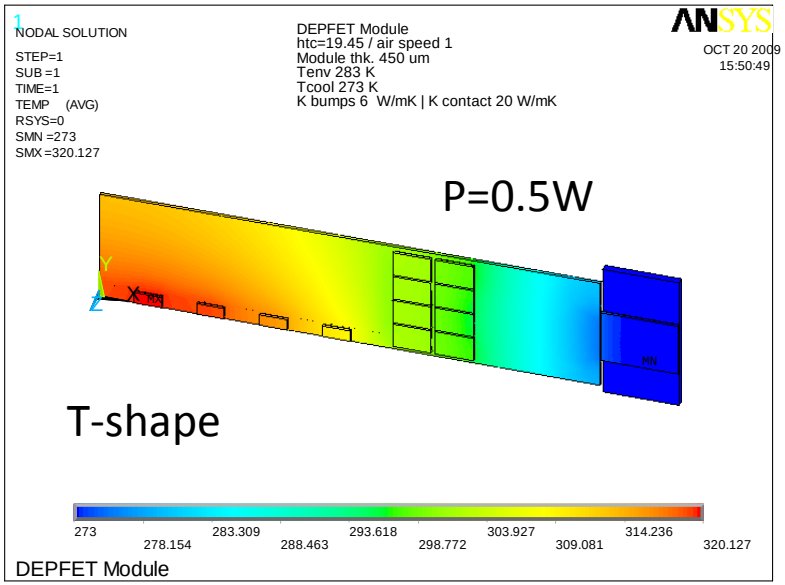


Cool down the air is a hard job…

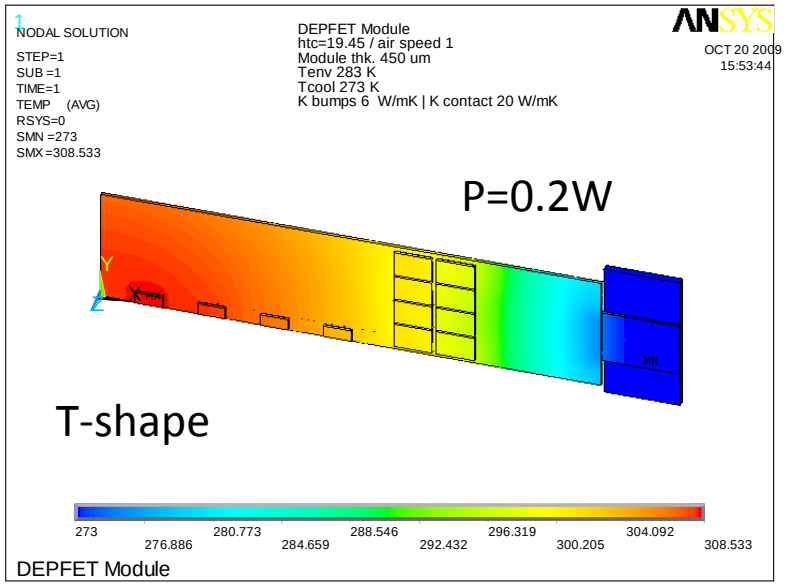
In the “Extended” option, this variable is less important.

6.-Switcher power consumption

Remember we are assuming P=0.5W, while a more realistic approach will be 0.2W (with a security factor 2).



$T_{CoolingBlock}$=0ºC
V_{air}=1m/s
T_{env}=10ºC
T_{max}=47ºC

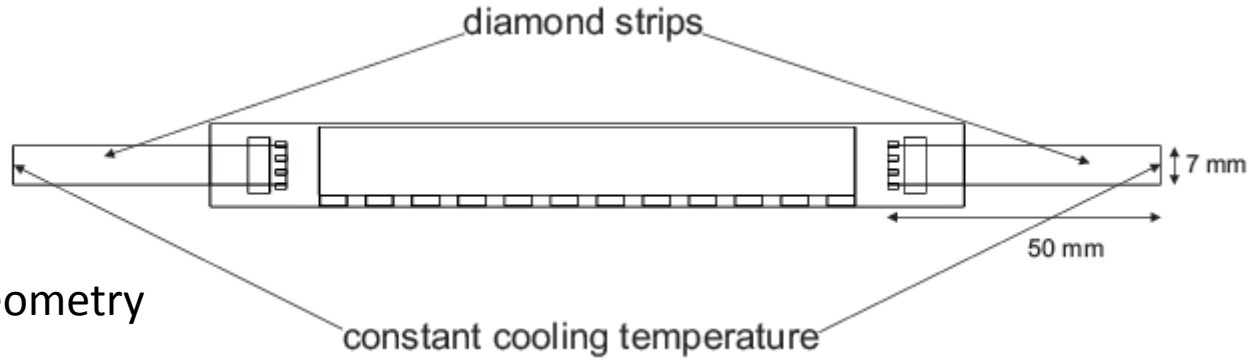


$T_{CoolingBlock}$=0ºC
V_{air}=1m/s
T_{env}=10ºC
T_{max}=35ºC

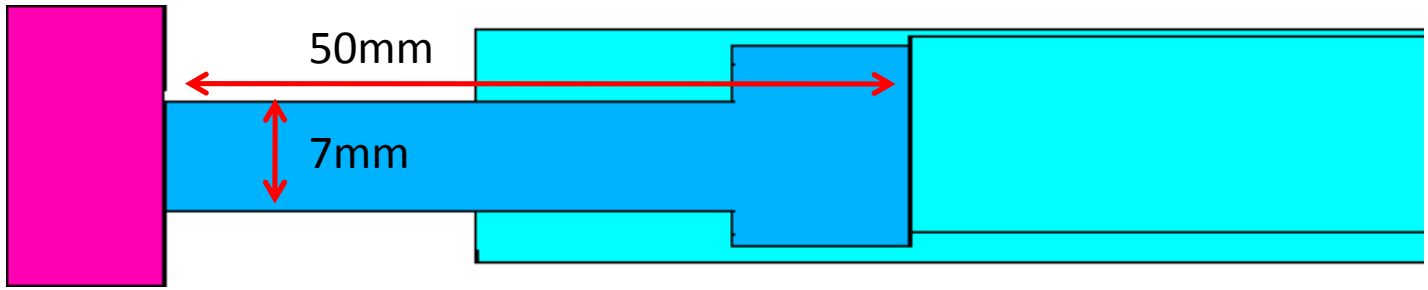
→ Realistic numbers

With the “diamond extended”, the temperature decreases even more, down to 31 ºC

7.- Cross-check Karlsruhe and Valencia simulations



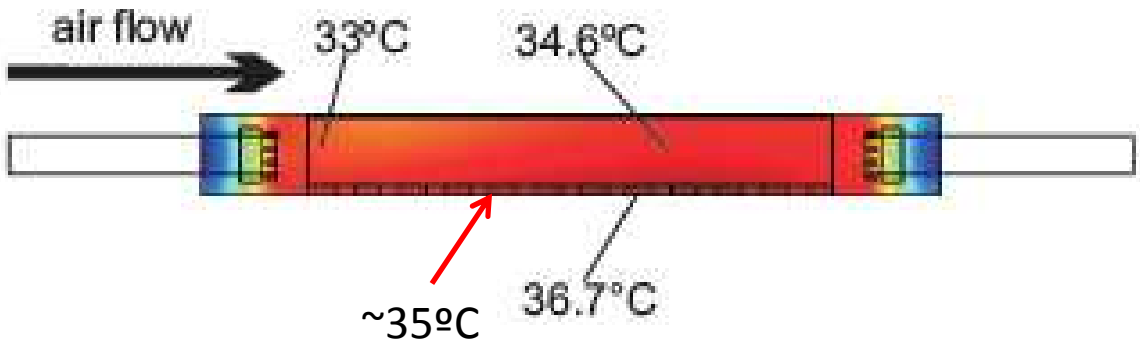
Karlsruhe geometry



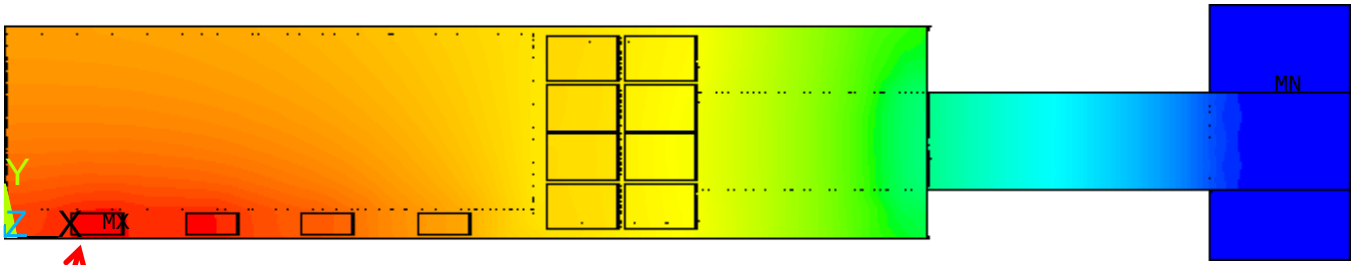
Valencia geometry

For details, see Oksana's talk in Barcelona

Karlsruhe

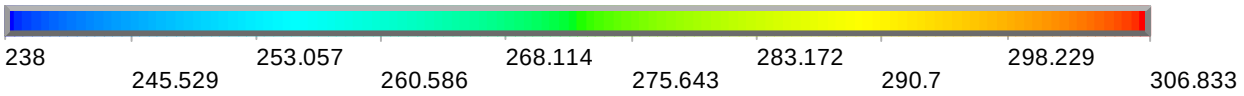


Valencia



33.6ºC

The small difference is because in VLC we assume an isotropic air flow around the module



$T_{CoolingBlock}$=-35ºC
V_{air}=5m/s
T_{env}=Room temperature

Conclusions

- The diamond underneath the balcony is mandatory!
  - Will help to support the module as well
  - On the other hand, it's expensive… Let's exchange the "one-diamond-piece" for TPG underneath the switchers balcony (under study)
  - Another option, increase the width of the diamond under the ladder's end

- Keep the diamond bridge as short as possible.

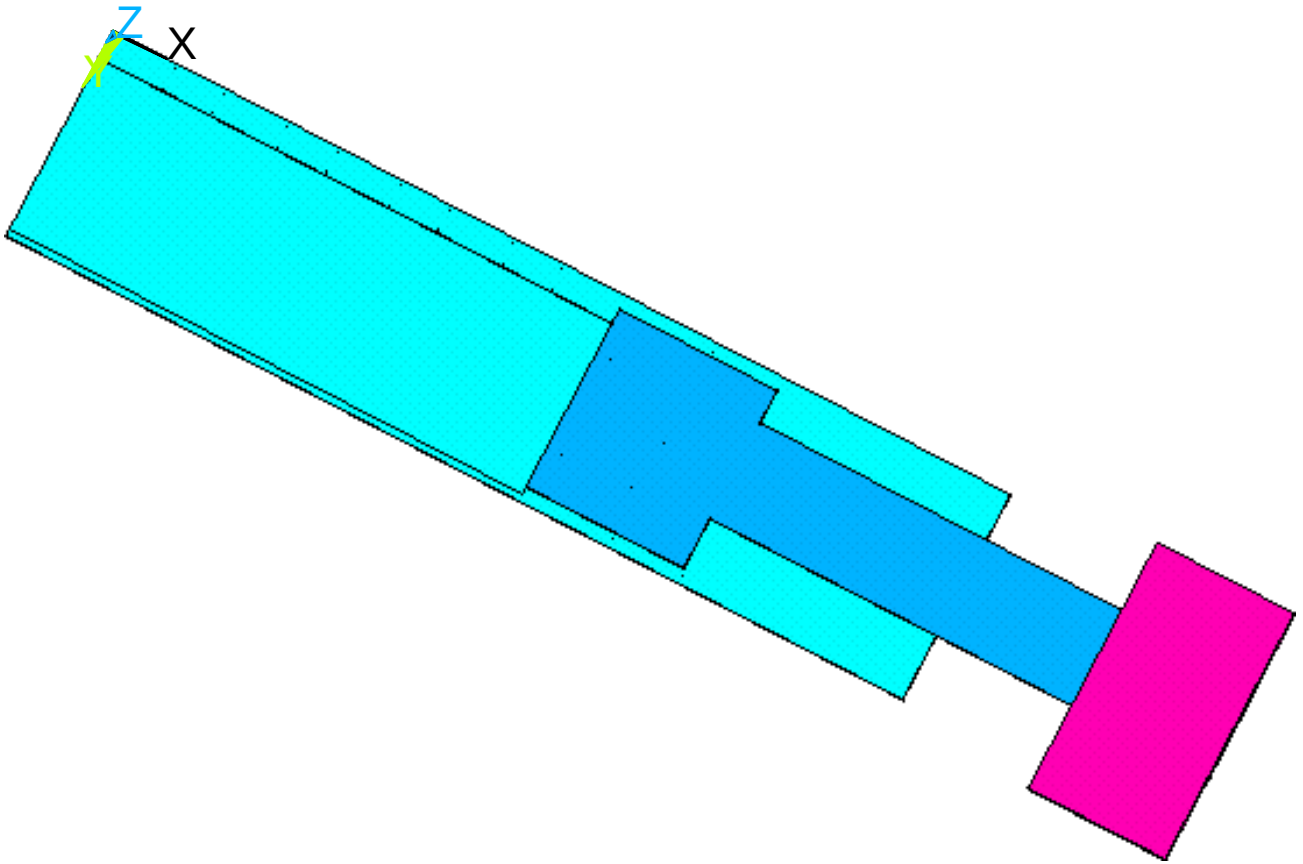
- A combination of cooling temperature and ambient temperature may help but is not the driving factor.

- Cross-check between Valencia and Karlsruhe simulations is on the way…

Thank you very much!

Summary of figures

1.- T-shape



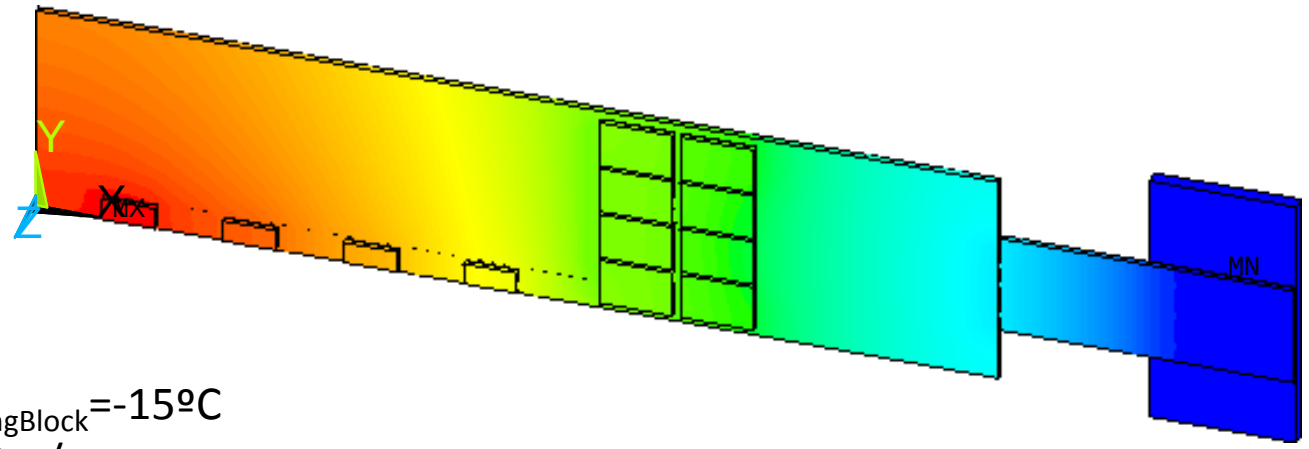
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =258
SMX =338.725

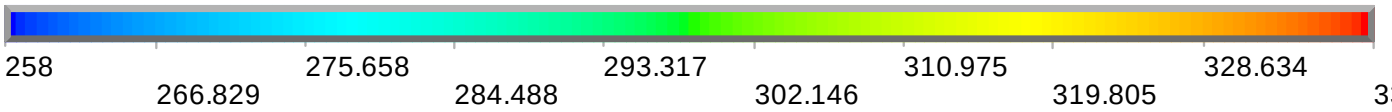
DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 258 K
K bumps 6 W/mK | K contact 20 W/mK

ANSYS

OCT 19 2009
17:54:48



$T_{CoolingBlock}$=-15ºC
V_{air}=0m/s
T_{max}=66ºC



DEPFET Module

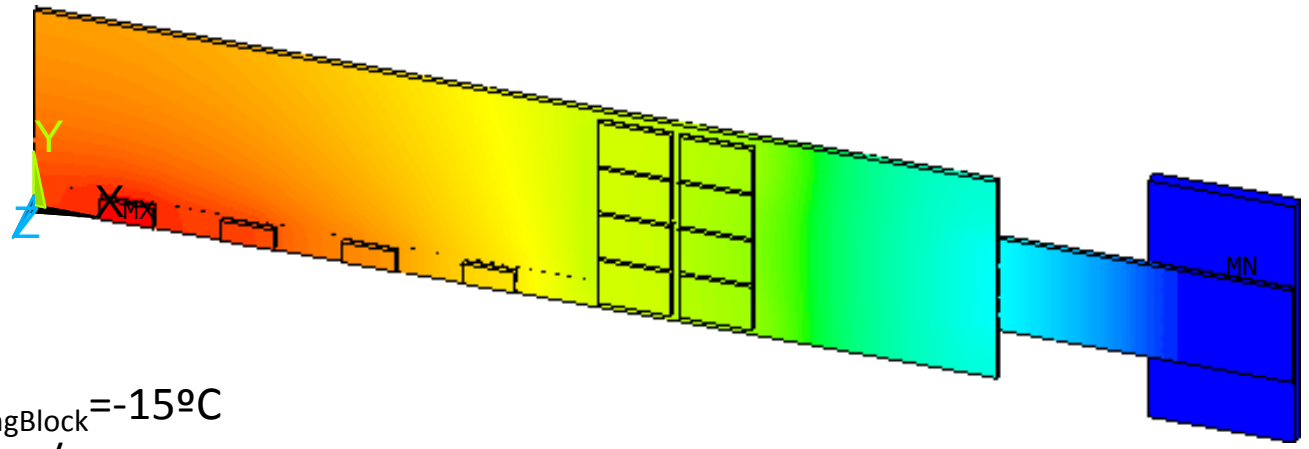
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =258
SMX =323.738

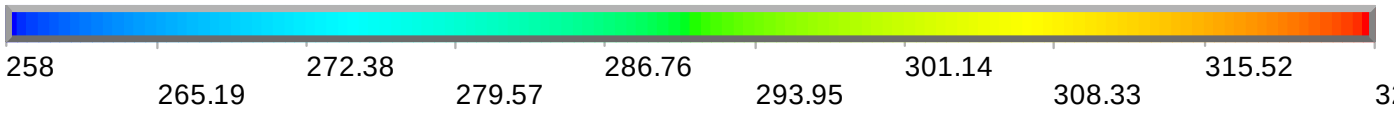
DEPFET Module
htc=19.45 / air speed 1
Module thk. 450 um
Tenv 288 K
Tcool 258 K
K bumps 6 W/mK | K contact 20 W/mK

ANSYS

OCT 19 2009
17:40:35



$T_{CoolingBlock}$=-15ºC
V_{air}=1m/s
T_{max}=51ºC



DEPFET Module

1
NODAL SOLUTION

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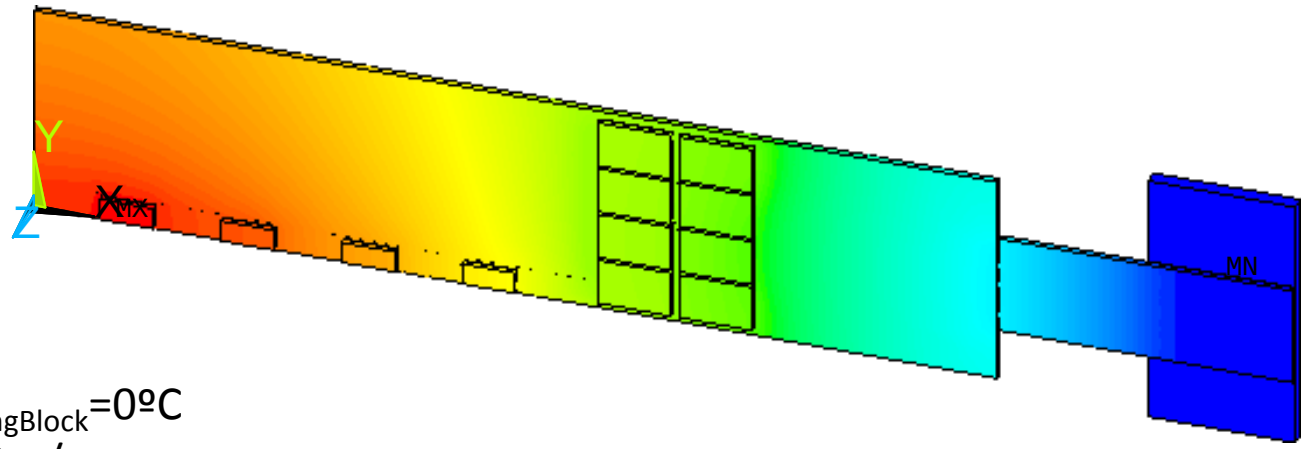
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =273
SMX =344.63

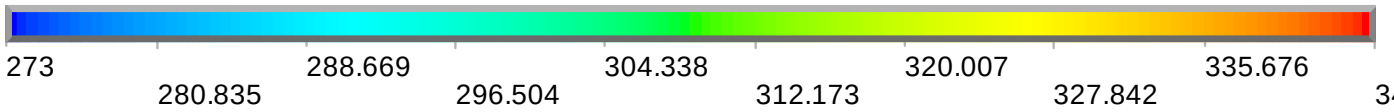
DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 273 K
K bumps 6 W/mK | K contact 20 W/mK

ANSYS

OCT 19 2009
17:50:56



$T_{CoolingBlock}$=0ºC
V_{air}=0m/s
T_{max}=71ºC



DEPFET Module

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NODAL SOLUTION

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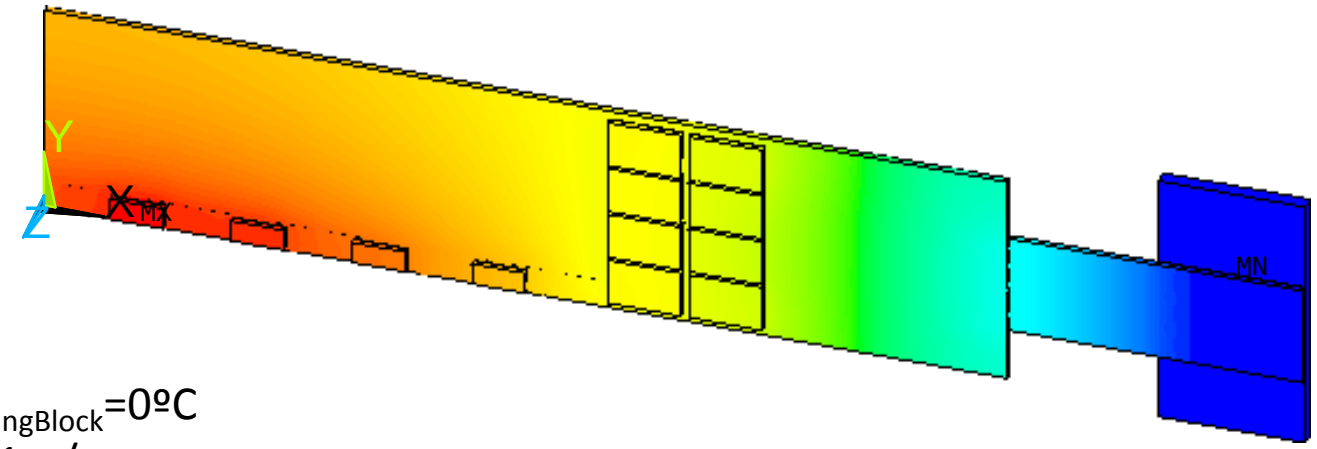
TIME=1
TEMP (AVG)
RSYS=0
SMN =273
SMX =327.187

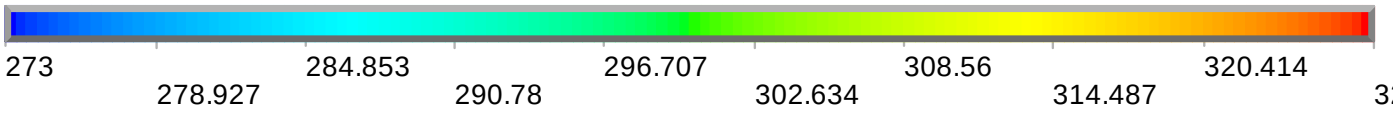
DEPFET Module
htc=19.45 / air speed 1
Module thk. 450 um
Tenv 288 K
Tcool 273 K
K bumps 6 W/mK | K contact 20 W/mK

ANSYS

OCT 19 2009
17:52:22



$T_{CoolingBlock}$=0ºC
V_{air}=1m/s
T_{max}=54ºC



DEPFET Module

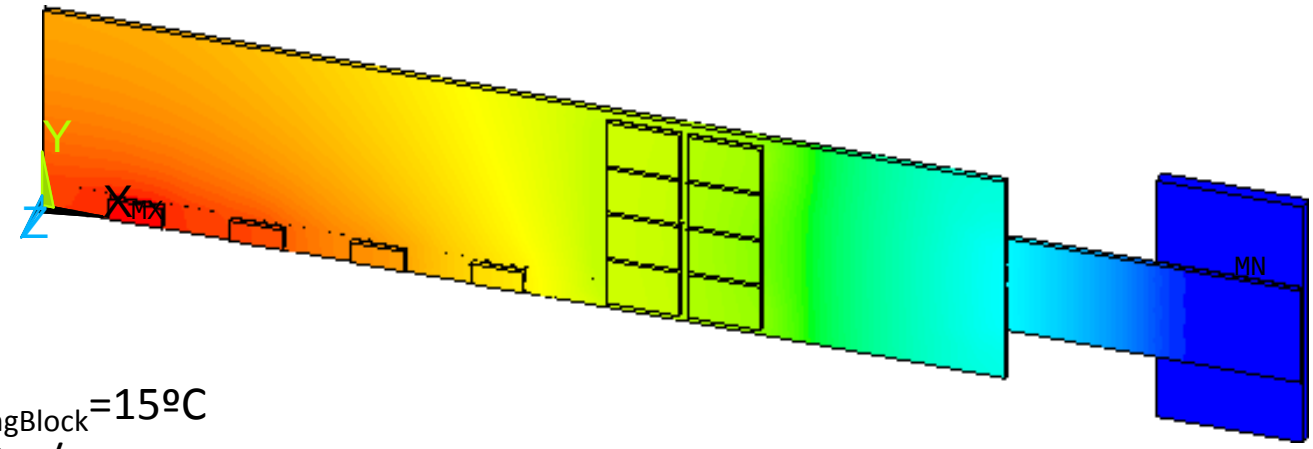
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =288
SMX =350.547

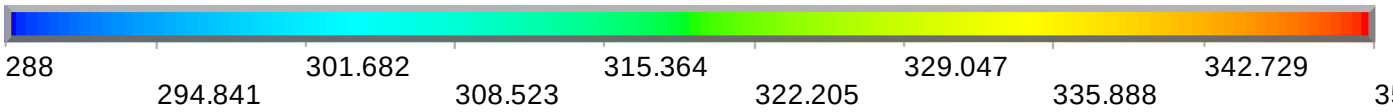
DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 288 K
K bumps 6 W/mK | K contact 20 W/mK

ANSYS

OCT 19 2009
17:57:03



$T_{CoolingBlock}$=15ºC
V_{air}=0m/s
T_{max}=77ºC



DEPFET Module

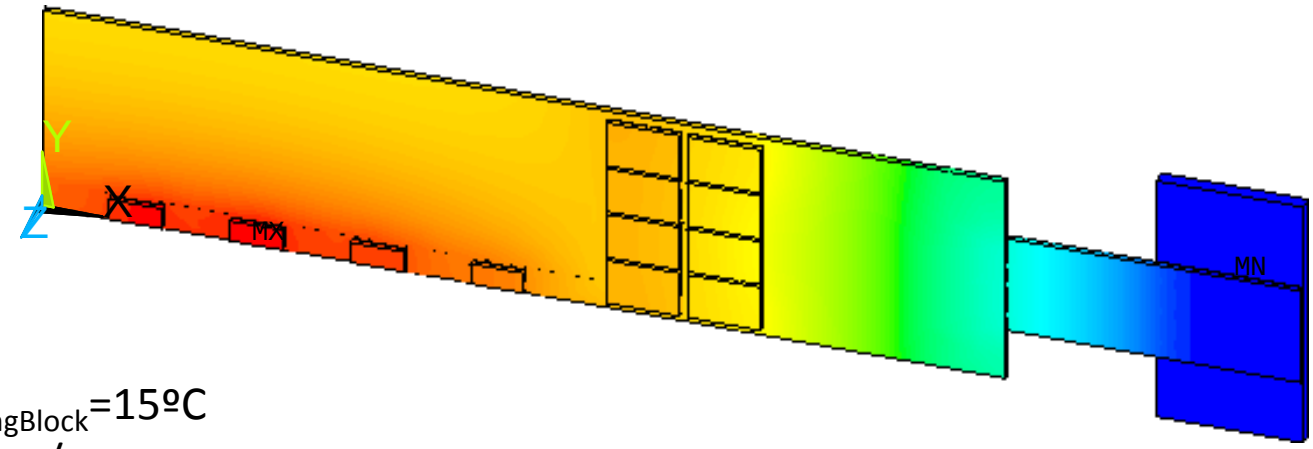
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =288
SMX =330.885

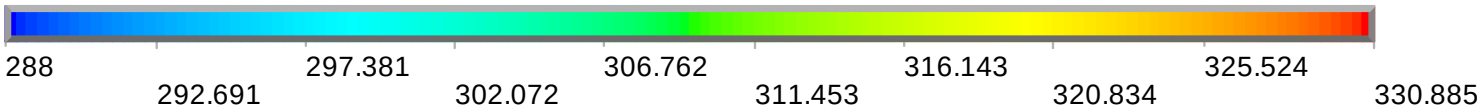
DEPFET Module
htc=19.45 / air speed 1
Module thk. 450 um
Tenv 288 K
Tcool 288 K
K bumps 6 W/mK | K contact 20 W/mK

ANSYS

OCT 19 2009
17:59:06

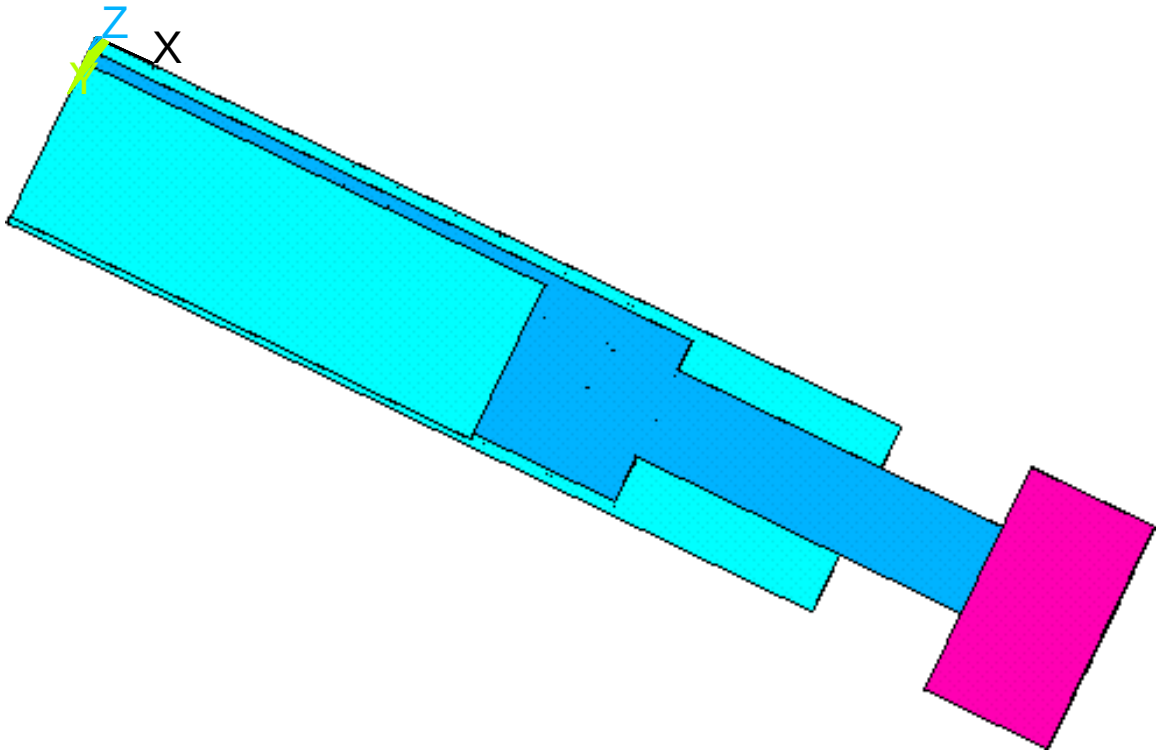


$T_{CoolingBlock}$=15ºC
V_{air}=1m/s
T_{max}=58ºC



DEPFET Module

2.- T-shape extended



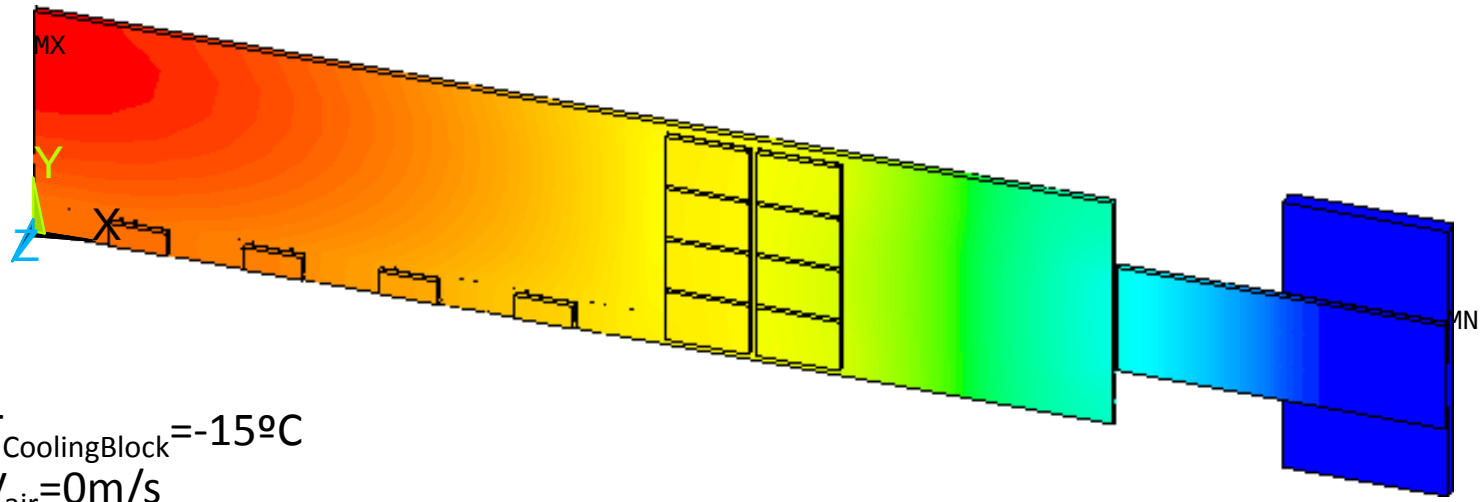
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =258
SMX =317.372

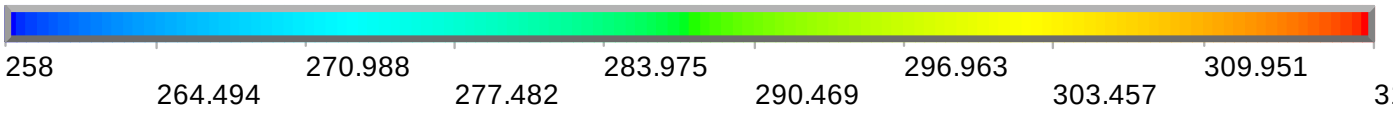
DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 258 K
K bumps 6 W/mK | K contact 20 W/mK

ANSYS

OCT 19 2009
18:05:05



$T_{CoolingBlock}$=-15ºC
V_{air}=0m/s
T_{max}=44ºC



DEPFET Module

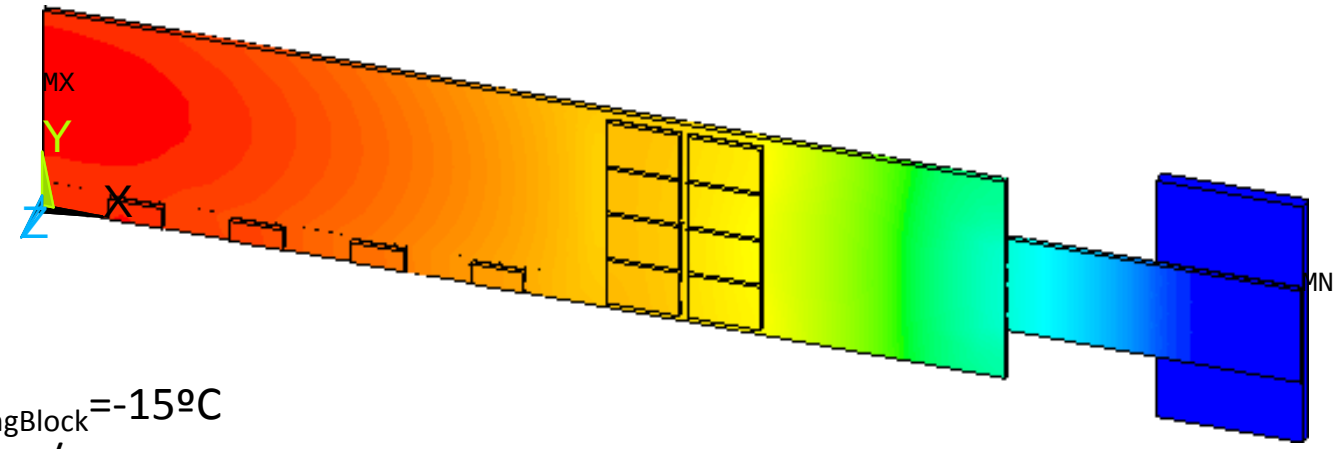
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =258
SMX =309.946

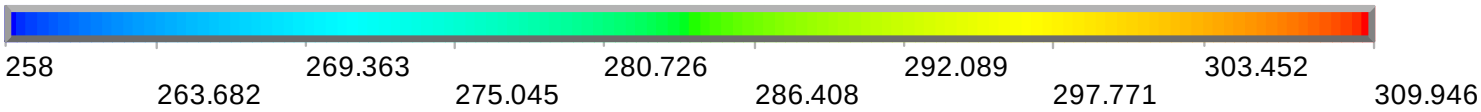
DEPFET Module
htc=19.45 / air speed 1
Module thk. 450 um
Tenv 288 K
Tcool 258 K
K bumps 6 W/mK | K contact 20 W/mK

ANSYS

OCT 19 2009
18:08:52



$T_{CoolingBlock}$=-15ºC
V_{air}=1m/s
T_{max}=37ºC



DEPFET Module

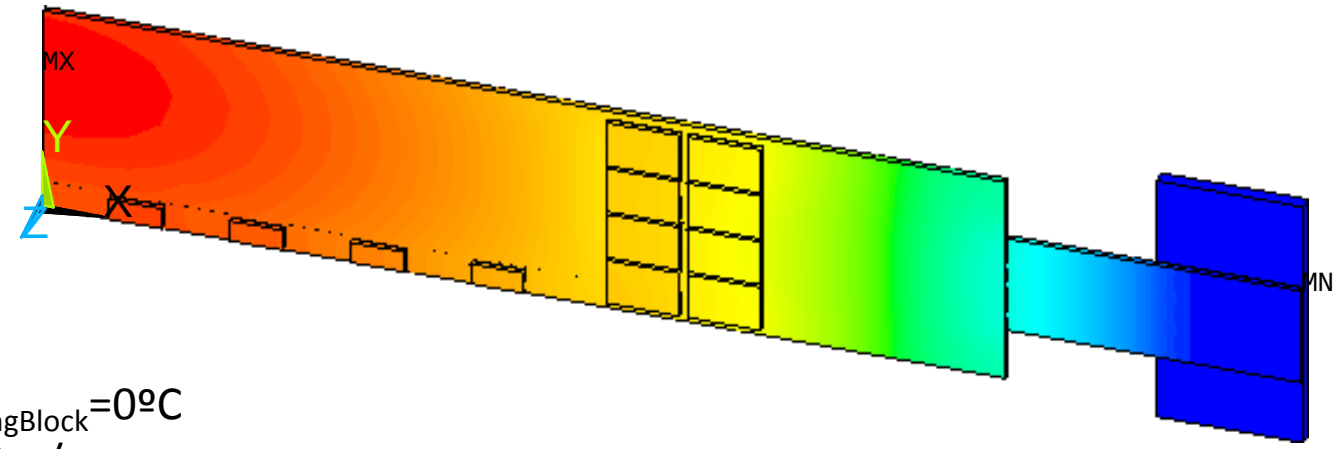
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =273
SMX =325.523

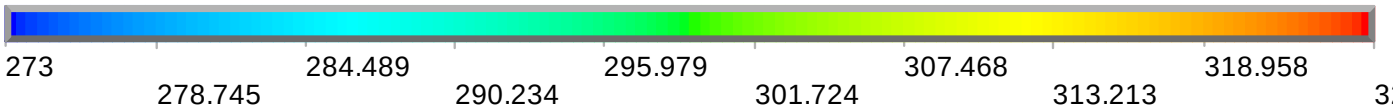
DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 273 K
K bumps 6 W/mK | K contact 20 W/mK

ANSYS

OCT 19 2009
18:29:11



$T_{CoolingBlock}$=0ºC
V_{air}=0m/s
T_{max}=52ºC



DEPFET Module

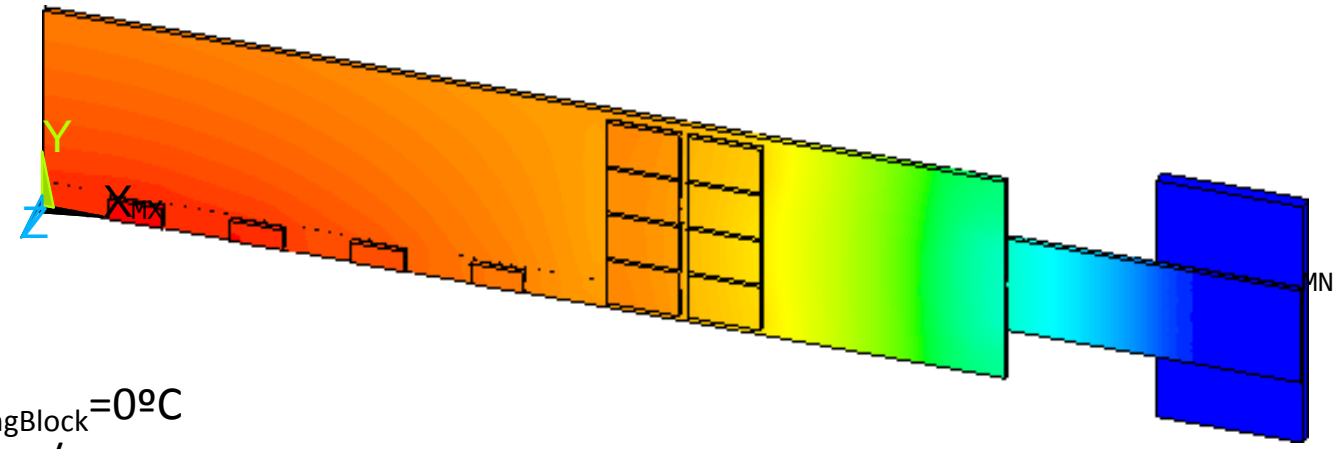
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =273
SMX =317.289

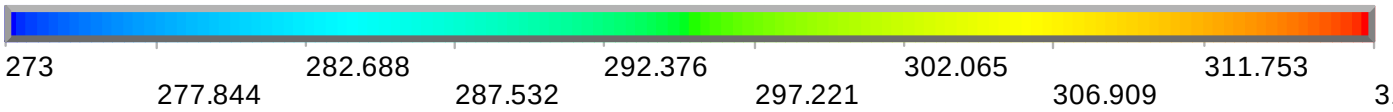
DEPFET Module
htc=19.45 / air speed 1
Module thk. 450 um
Tenv 288 K
Tcool 273 K
K bumps 6 W/mK | K contact 20 W/mK

ANSYS

OCT 19 2009
18:31:11



$T_{CoolingBlock}$=0ºC
V_{air}=1m/s
T_{max}=44ºC



DEPFET Module

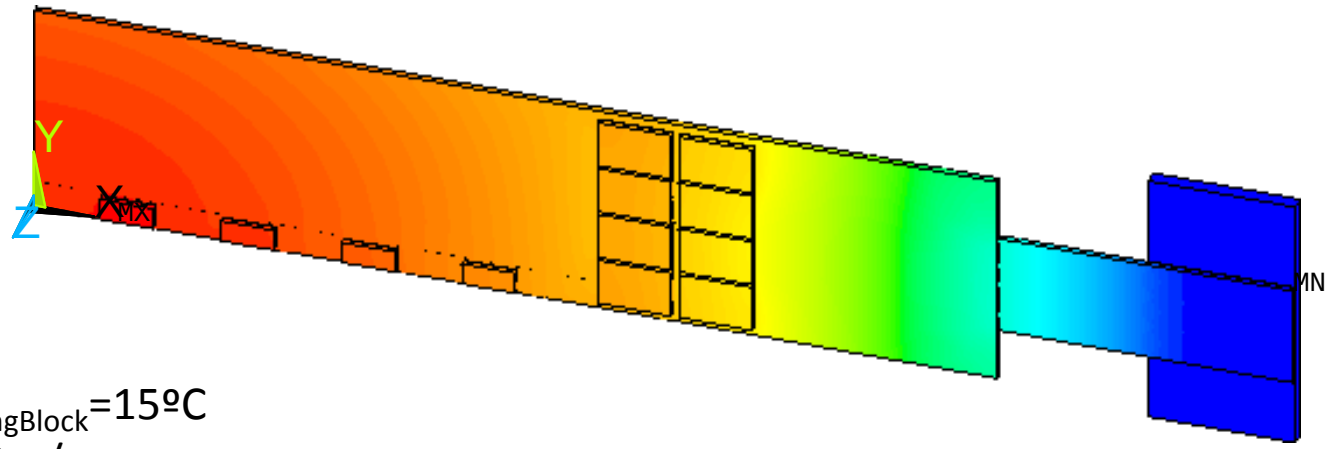
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =288
SMX =334.646

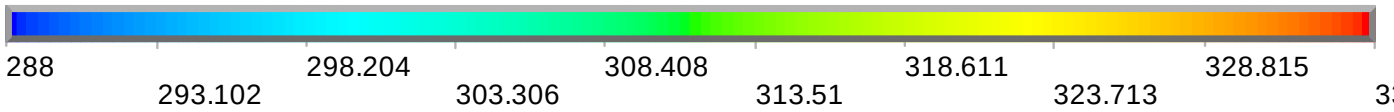
DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 288 K
K bumps 6 W/mK | K contact 20 W/mK

ANSYS

OCT 19 2009
18:34:54



$T_{CoolingBlock}$=15ºC
V_{air}=0m/s
T_{max}=61ºC



DEPFET Module

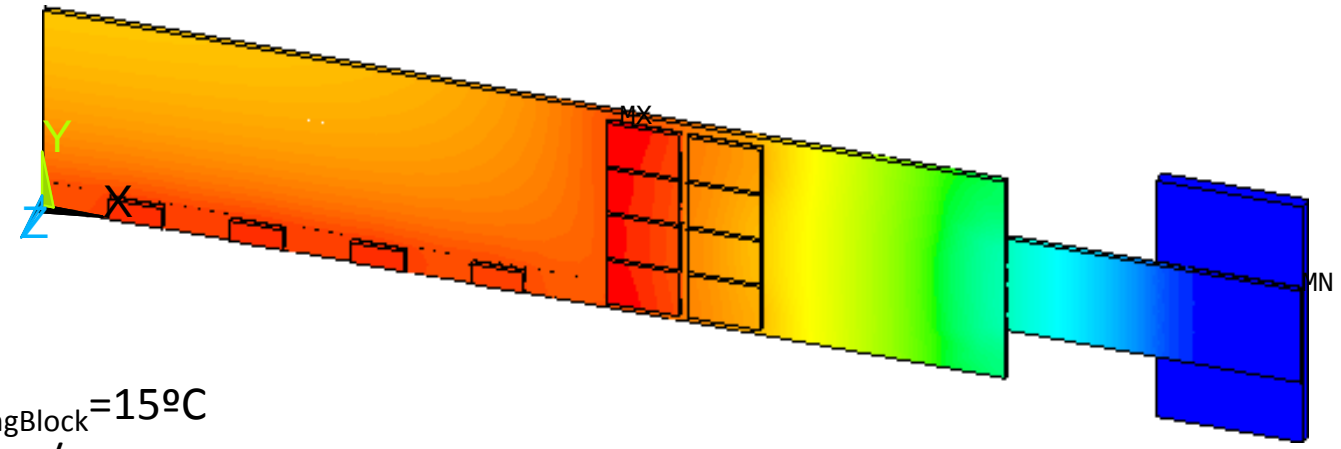
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =288
SMX =325.404

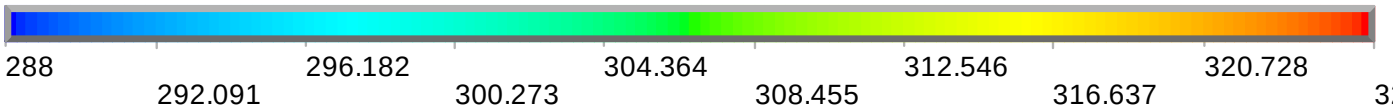
DEPFET Module
htc=19.45 / air speed 1
Module thk. 450 um
Tenv 288 K
Tcool 288 K
K bumps 6 W/mK | K contact 20 W/mK

ANSYS

OCT 19 2009
18:36:34



$T_{CoolingBlock}$=15ºC
V_{air}=1m/s
T_{max}=52ºC



DEPFET Module

3.- Diamond length

$T_{CoolingBlock}$=0ºC
V_{air}=0m/s
Overlap with the cooling block=70mm^2
Diamond length=0mm … 50mm

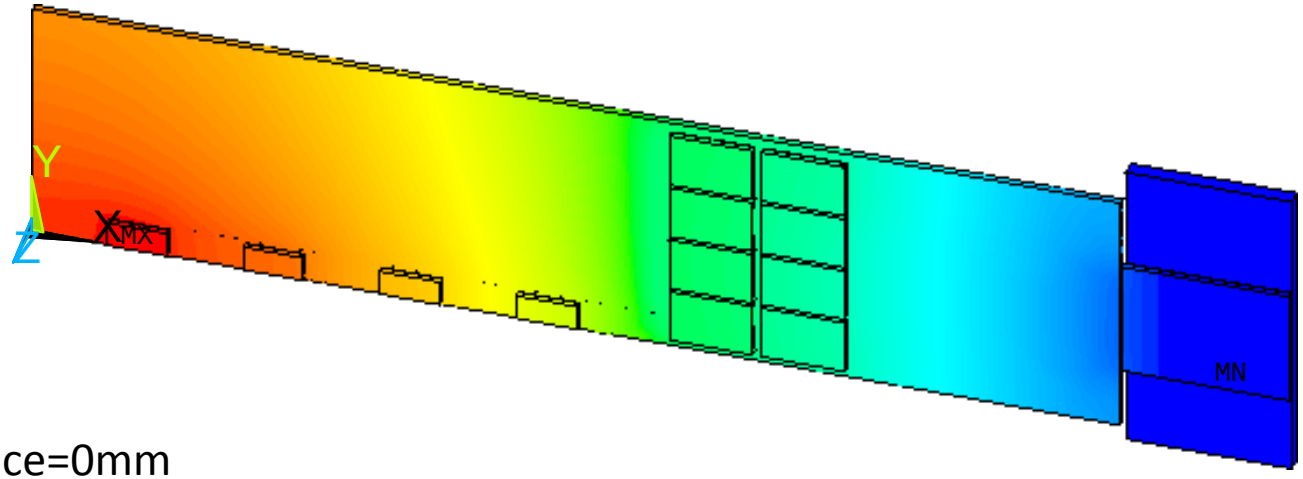
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =273
SMX =338.772

DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 273 K
K bumps 6 W/mK | K contact 20 W/mK

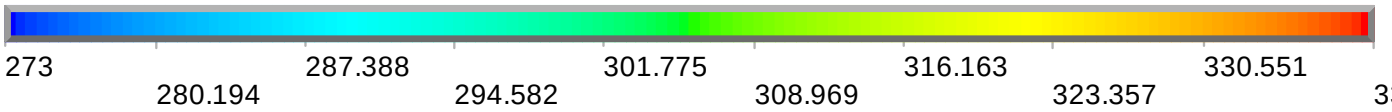
ANSYS

OCT 20 2009
06:55:28



Distance=0mm

T_{max}=66ºC



DEPFET Module

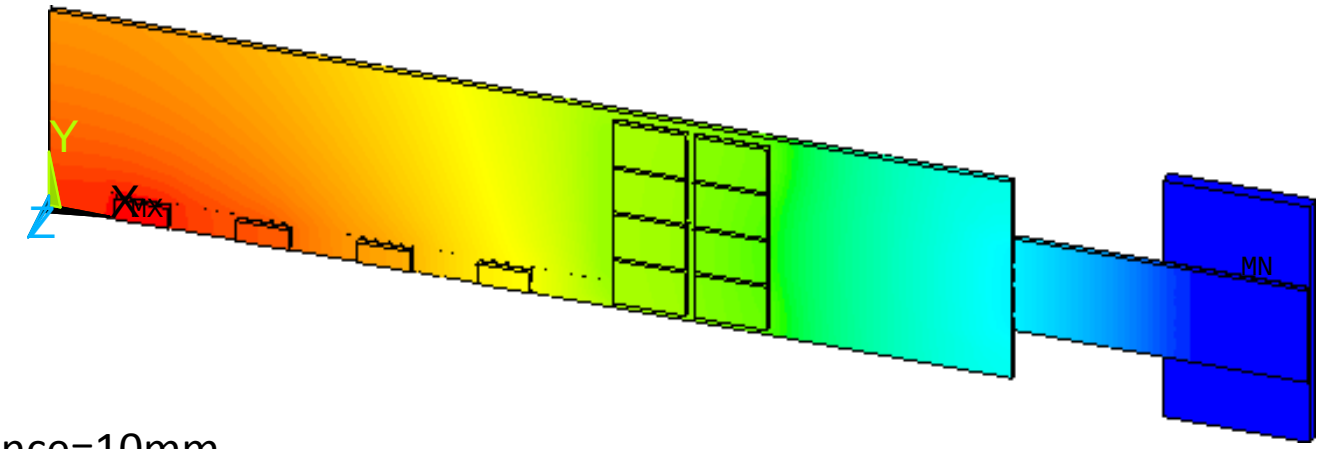
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =273
SMX =344.63

DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 273 K
K bumps 6 W/mK | K contact 20 W/mK

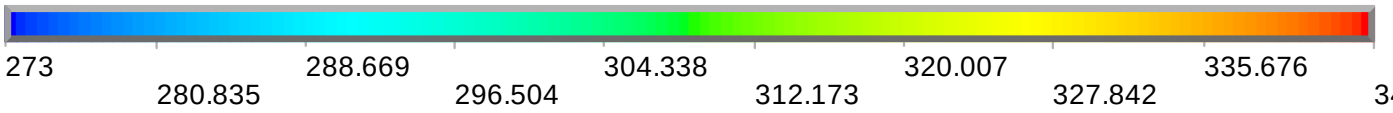
ANSYS

OCT 20 2009
06:57:46



Distance=10mm

T_{max}=71ºC



DEPFET Module

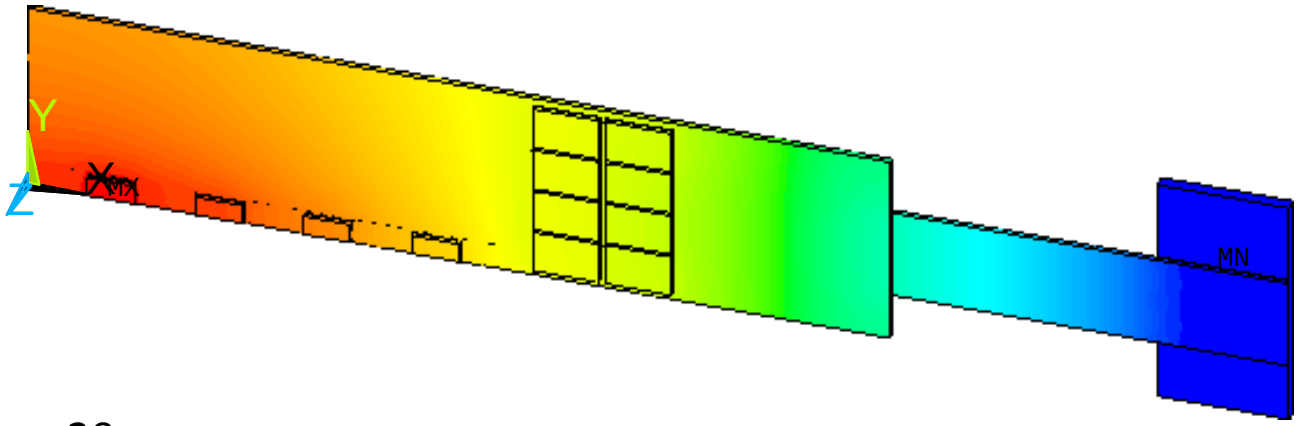
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =273
SMX =349.916

DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 273 K
K bumps 6 W/mK | K contact 20 W/mK

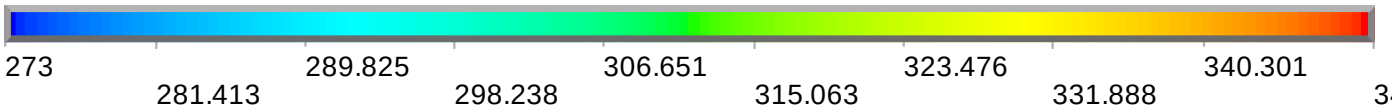
ANSYS

OCT 20 2009
07:15:57



Distance=20mm

T_{max}=77ºC



DEPFET Module

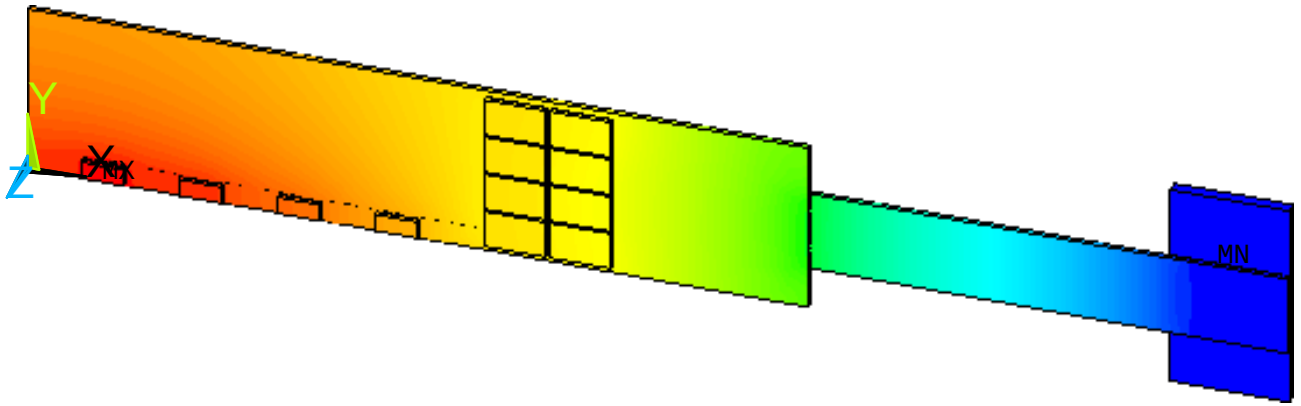
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =273
SMX =354.688

DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 273 K
K bumps 6 W/mK | K contact 20 W/mK

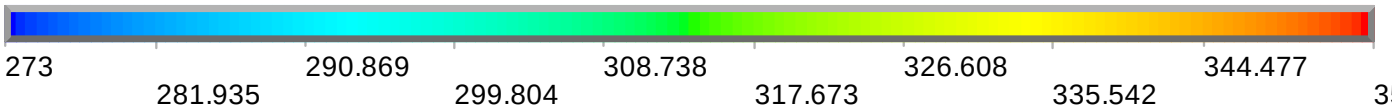
ANSYS

OCT 20 2009
07:19:42



Distance=30mm

T_{max}=81ºC



DEPFET Module

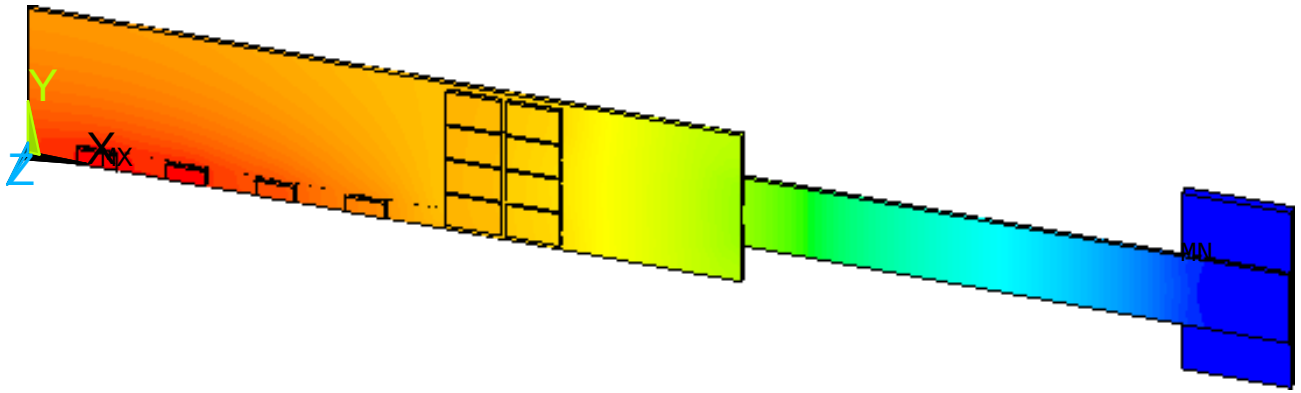
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =273
SMX =358.997

DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 273 K
K bumps 6 W/mK | K contact 20 W/mK

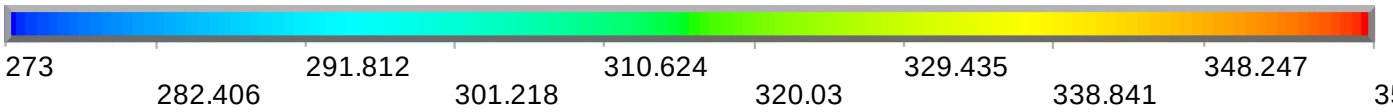
ANSYS

OCT 20 2009
07:22:49

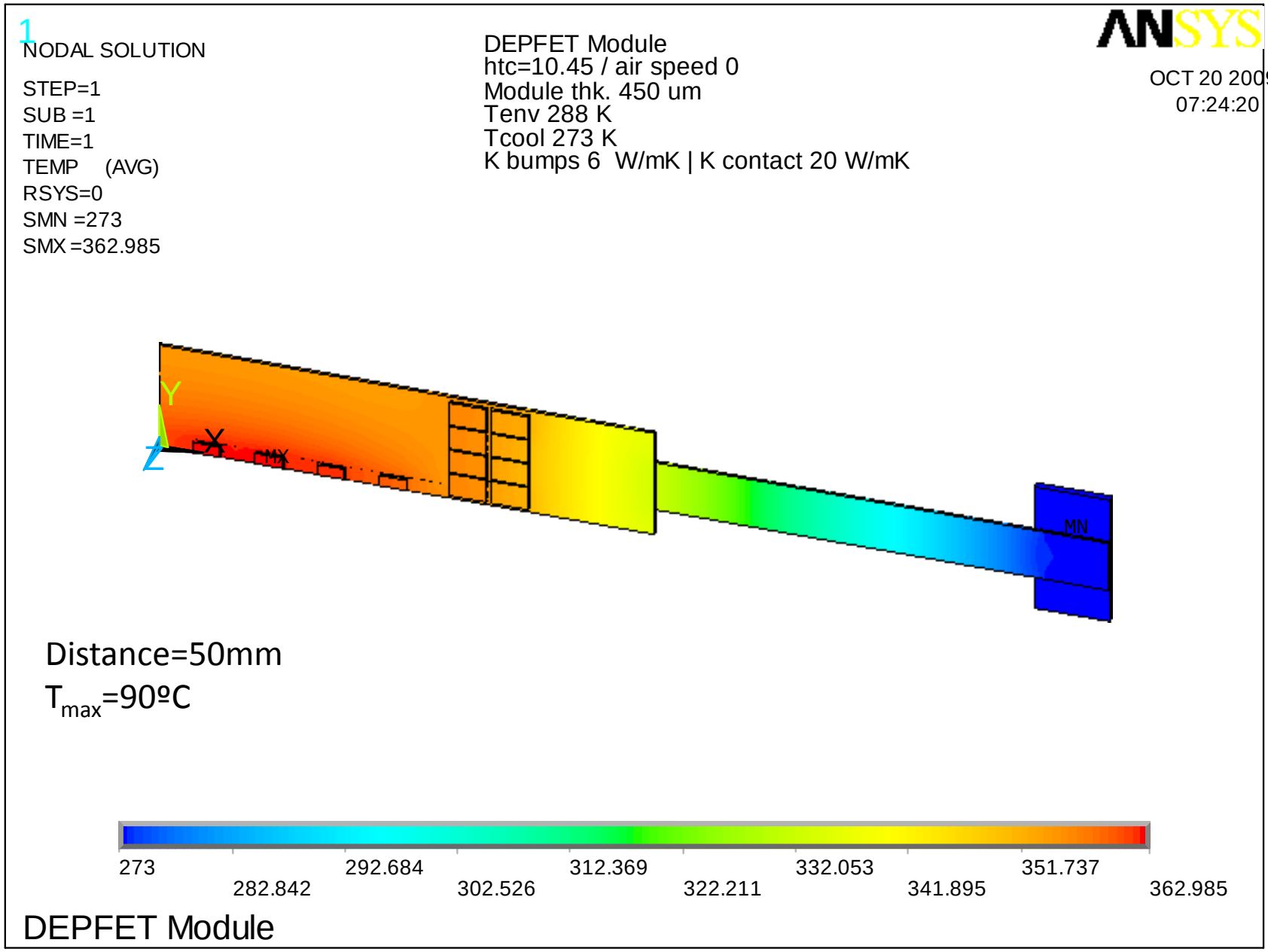


Distance=40mm

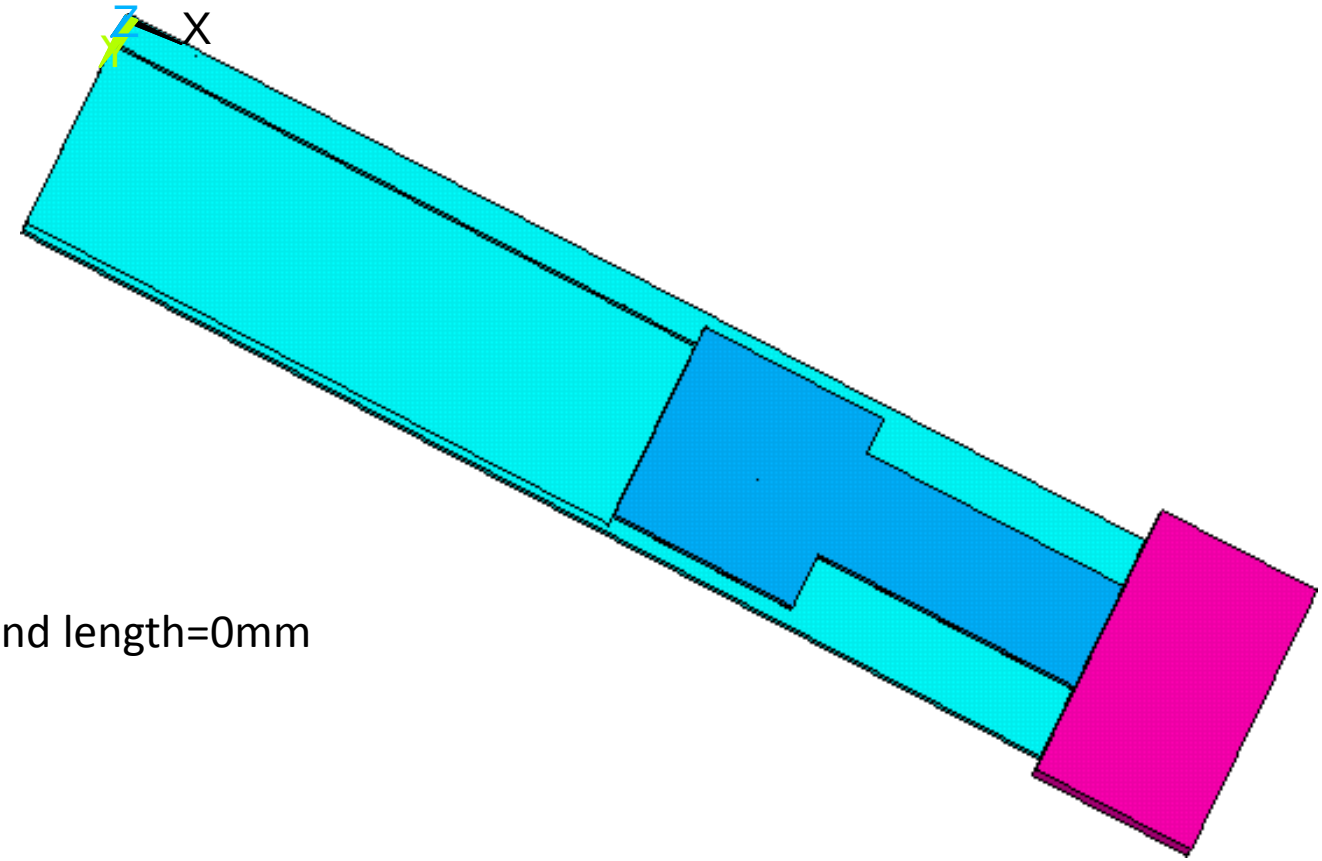
T_{max}=86ºC



DEPFET Module


1
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =273
SMX =362.985
DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 273 K
K bumps 6 W/mK | K contact 20 W/mK
ANSYS
OCT 20 2009
07:24:20
Y
X
Z
MX
MN
Distance=50mm
T_{max}=90ºC
273
282.842
292.684
302.526
312.369
322.211
332.053
341.895
351.737
362.985
DEPFET Module

4.- Cooling’s block temperature



Diamond length=0mm

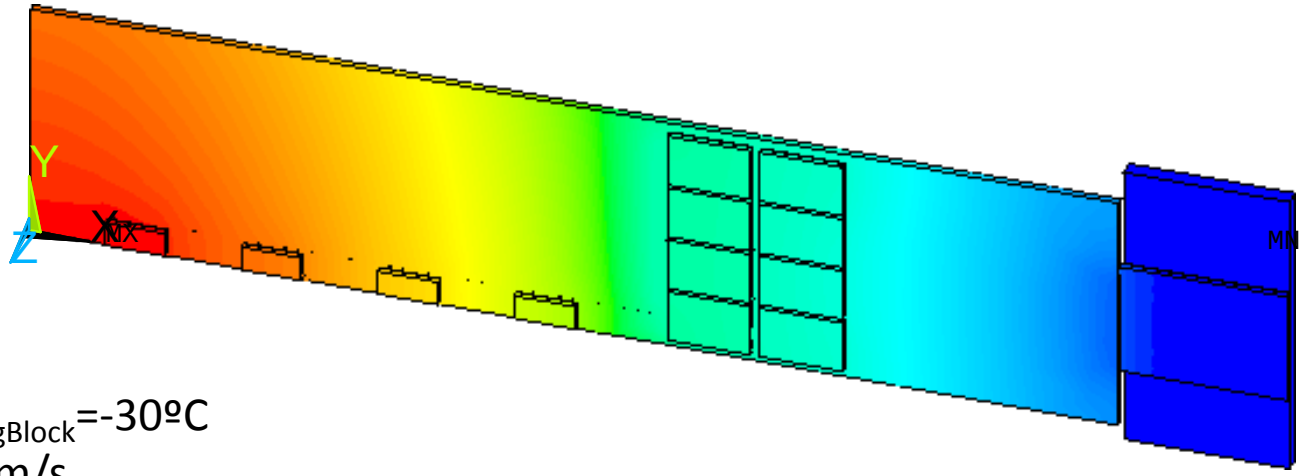
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =243
SMX =326.333

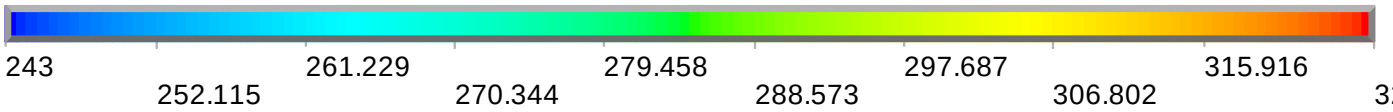
DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 243 K
K bumps 6 W/mK | K contact 20 W/mK

ANSYS

OCT 20 2009
07:40:57



$T_{CoolingBlock}$=-30ºC
V_{air}=0m/s
T_{max}=53.2ºC



DEPFET Module

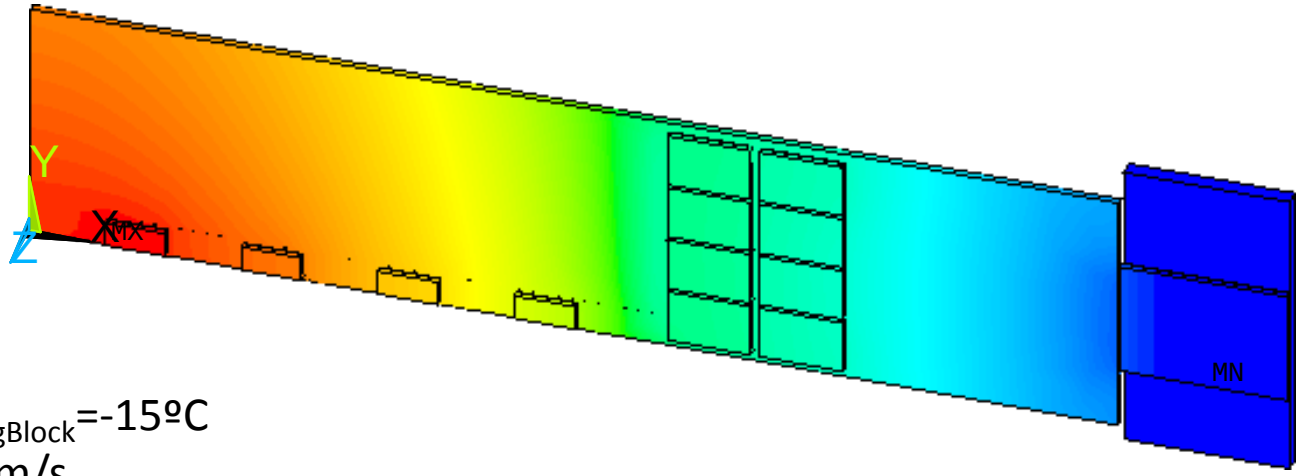
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =258
SMX =332.549

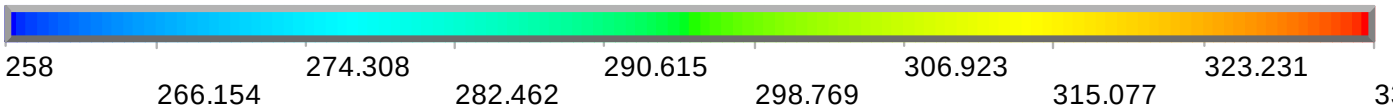
DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 258 K
K bumps 6 W/mK | K contact 20 W/mK

ANSYS

OCT 20 2009
07:59:06



$T_{CoolingBlock}$=-15ºC
V_{air}=0m/s
T_{max}=59ºC



DEPFET Module

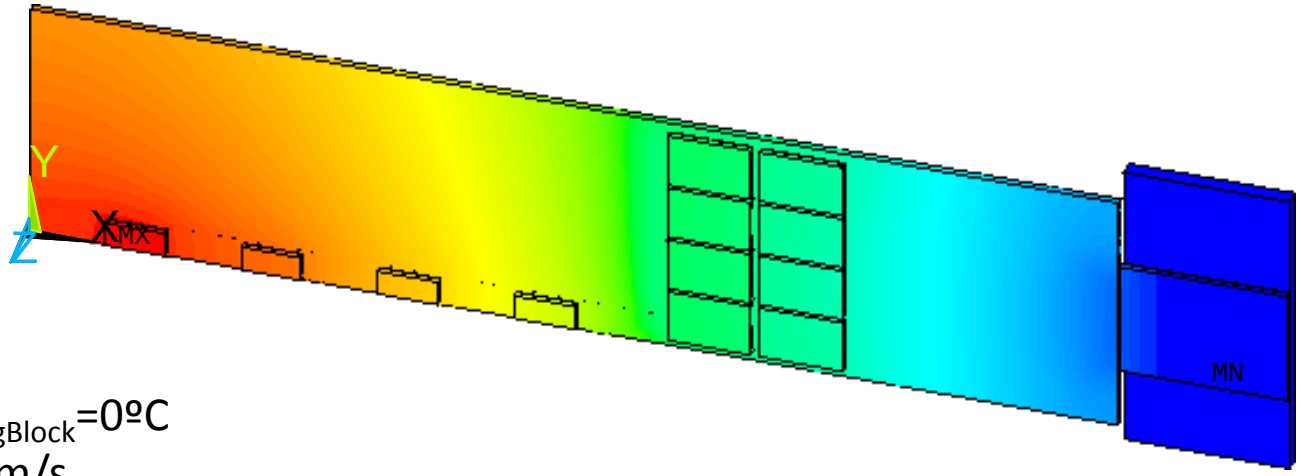
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =273
SMX =338.772

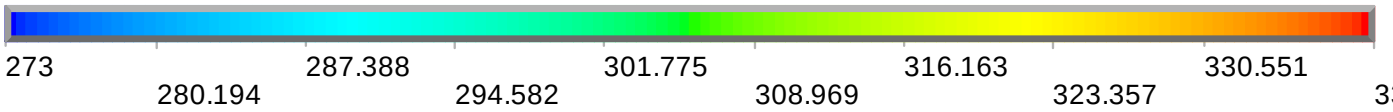
DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 273 K
K bumps 6 W/mK | K contact 20 W/mK

ANSYS

OCT 20 2009
08:00:38



$T_{CoolingBlock}$=0ºC
V_{air}=0m/s
T_{max}=66ºC



DEPFET Module

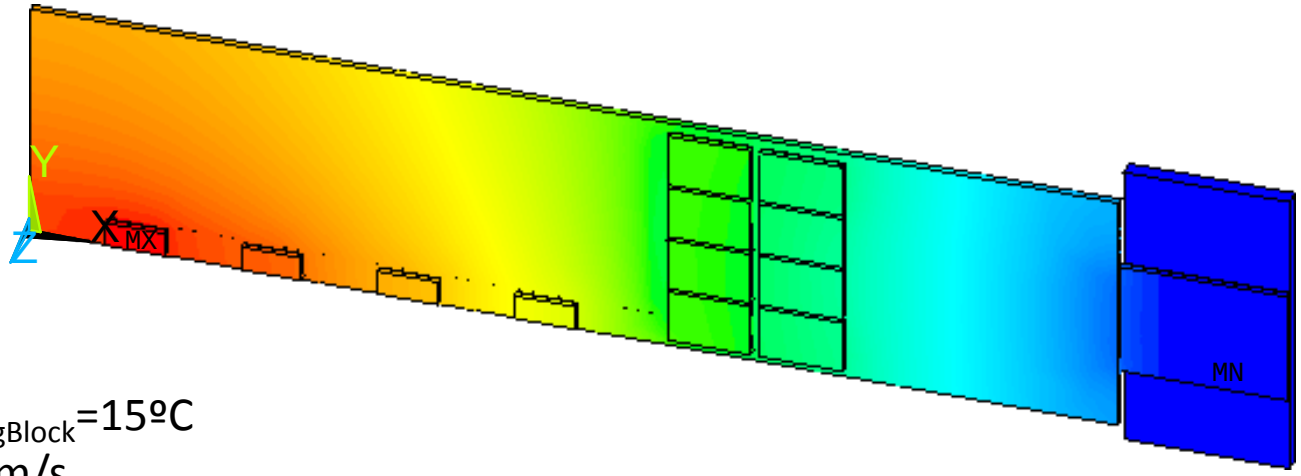
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =288
SMX =345.004

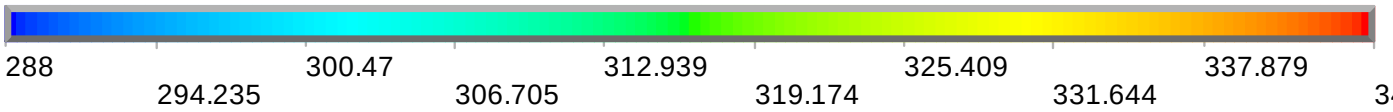
DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 288 K
K bumps 6 W/mK | K contact 20 W/mK

ANSYS

OCT 20 2009
08:02:26



$T_{CoolingBlock}$=15ºC
V_{air}=0m/s
T_{max}=72ºC



DEPFET Module

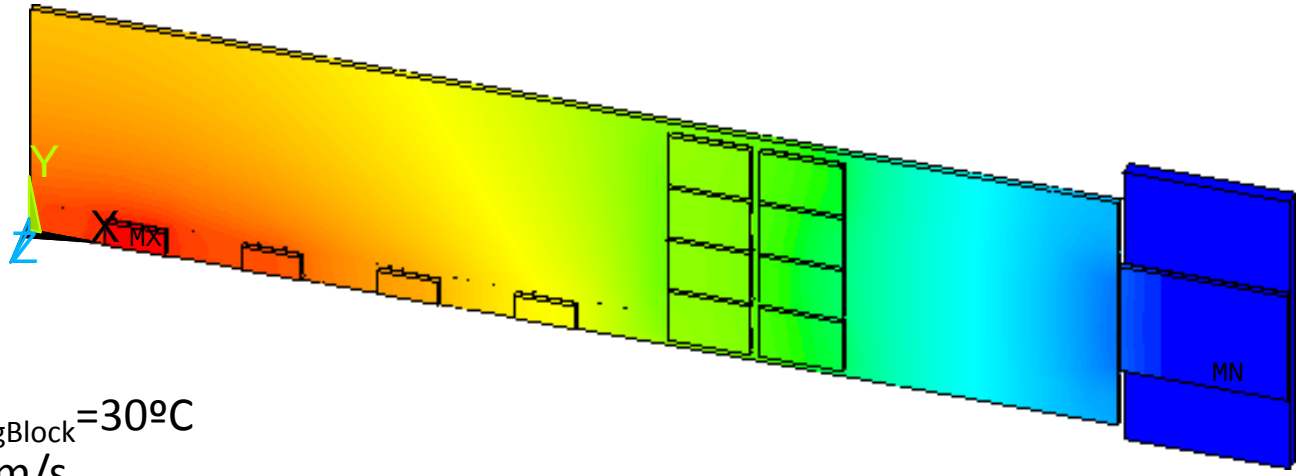
1
NODAL SOLUTION

STEP=1
SUB =1
TIME=1
TEMP (AVG)
RSYS=0
SMN =303
SMX =351.25

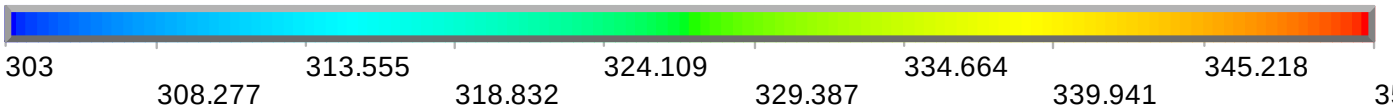
DEPFET Module
htc=10.45 / air speed 0
Module thk. 450 um
Tenv 288 K
Tcool 303 K
K bumps 6 W/mK | K contact 20 W/mK

ANSYS

OCT 20 2009
08:05:53



$T_{CoolingBlock}$=30ºC
V_{air}=0m/s
T_{max}=78ºC



DEPFET Module