**Report on**
**LED Board Thermal Simulation**


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# 1 Introduction

The software “TRM” (Thermal Risk Management in Electronics”) from ADAM Research is calculating x-y-z-t temperatures of a printed circuit board due to component heating and current heating. The detailed layer structure and the conductor pattern are taken into account. The internal heat transport takes place via the heat conduction equation. Heat is dissipated to the outside via a specified heat transfer coefficient or objects with a fixed temperature.

The accuracy of the inputs is also decisive for the accuracy of the simulation. For geometric parameters it is the final copper thickness, for the material parameters it is the thermal conductivity, for the heating the power loss and for the heat dissipation the heat transfer coefficient which describes the measuring situation. More information [www.adam-research.com](http://www.adam-research.com) .

# 2 Input Data

## *2.1* Description/ Spec

Run 1: 24 Volt _1 minute @ 25°C
P_R1A= 0.48W
P_R1B= 0.48W
P_LD1= 0.162W *Power in LD1 is new in this series*

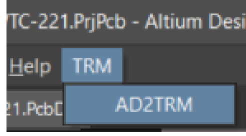
Run 2: 18 Volt _10 minutes @ 25°C
P_R1A= 0.248W
P_R1B= 0.248W
P_LD1= 0.107W

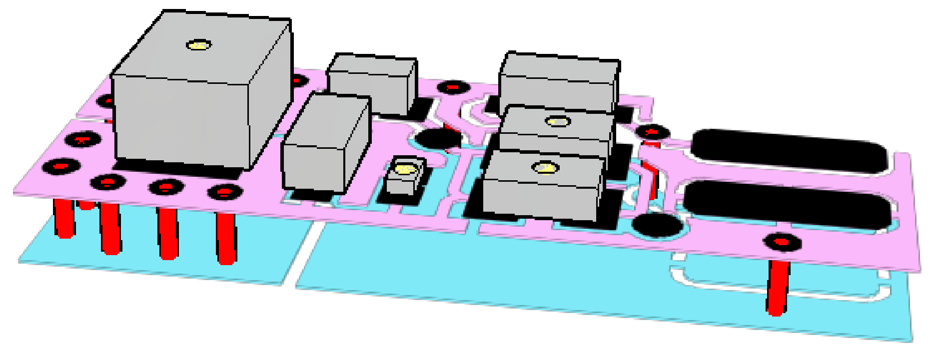
Run 3: 12,8 Volt _5 minutes @ 85°C
P_R1A = 0.099W
P_R1B = 0.099W
P_LD1 = 0.066W

# 3 Thermal Modelling

## 3.1 Board

The board design is output as Gerber, Excellon and IDF from Altium Designer with a special outjob for TRM.





View of the board in TRM. The yellow circles are thermal couples.

### 3.2 Board Size

| Altium Data | TRM model |
|---|---|
| 19.0 mm x 8.0 mm | Length x: 19 mm<br>Width y: 8 mm |

### 3.3 Layer Stackup

Altium Settings

| Top Solder | SM-001 | Solder Mask | | 0.025mm |
|---|---|---|---|---|
| Top Copper Plat... | Tin | Copper plating | | 0.001mm |
| Top Layer | CF-004 | Signal | 1oz | 0.035mm |
| Dielectric 1 | Core-043 | Core | | 1.499mm |
| Bottom Layer | CF-004 | Signal | 1oz | 0.035mm |

TRM model. Plating of 25 microns was added.

### 3.4 Materials

"FR4" is not a specific material designation. There are low-conductivity and better-conductivity glass-epoxy mixtures. Neither data about “CF-004” or “Core-043” provided nor found in the internet. We take a typical low thermal conductivity of 0.3 W/Km as worst case assumption.

| Data | TRM | | | | | |
|---|---|---|---|---|---|---|
| none | Name | | FR4$TRM | Name | | Cu$TRM |
| | Tc1 | (degC) | 20 | Tc1 | (degC) | 20 |
| | Tcon_x | (W/mK) | 0.3 | Tcon_x | (W/mK) | 350 |
| | Tcon_z | (W/mK) | 0.3 | Tcon_z | (W/mK) | 350 |
| | Tc2 | (degC) | 0 | Tc2 | (degC) | 100 |
| | Tcon_x2 | (W/mK) | 0 | Tcon_x2 | (W/mK) | 338 |
| | Tcon_z2 | (W/mK) | 0 | Tcon_z2 | (W/mK) | 338 |

### 3.5 Drilled holes

PTH only. Assumed copper plating 25 microns.

### 3.6 Environmental and cooling conditions

Cooling conditions are not specified by the client.

<u>Assumptions</u>:

Vertically standing.

Free convection + radiation cooling in free space (laboratory-like conditions).

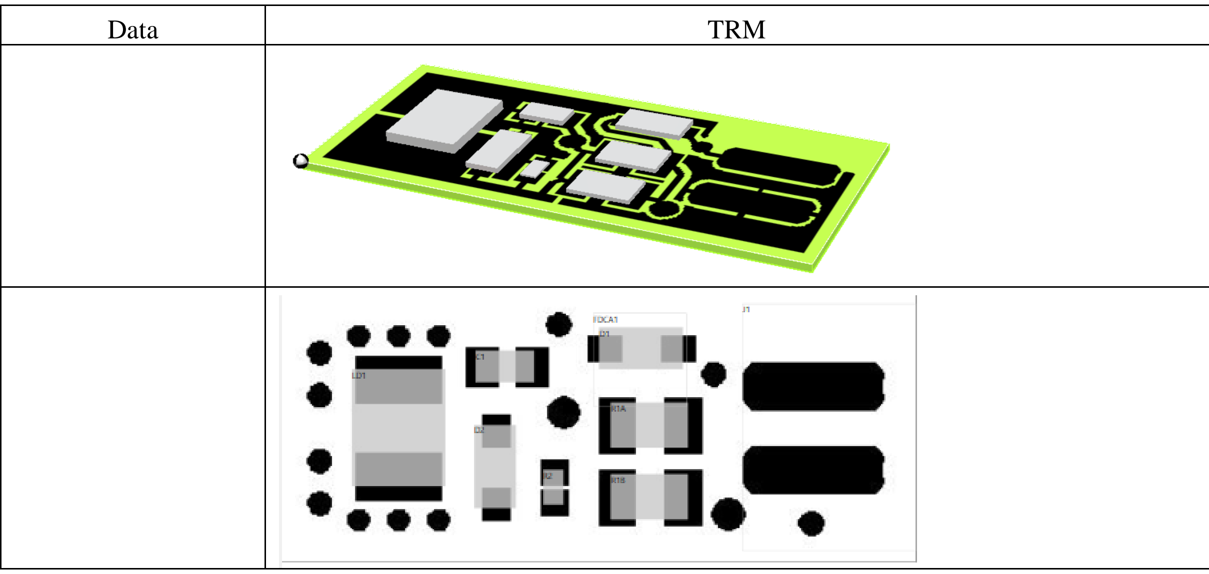
Cooling is described by a uniform heat transfer coefficient (h)

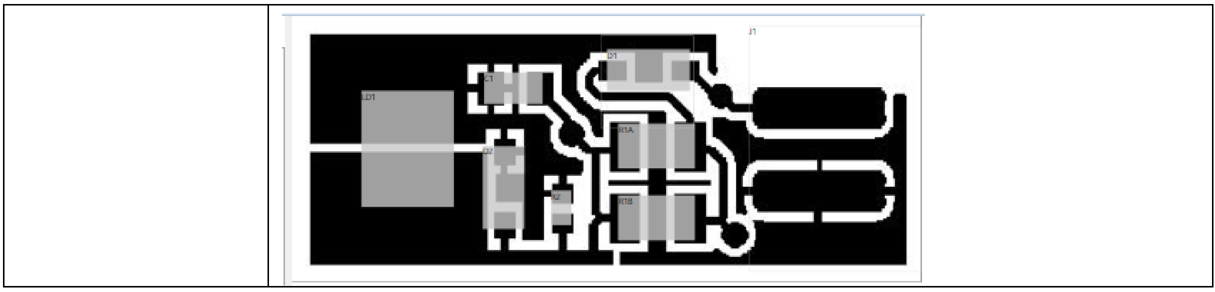
*h* also depends on the total power loss. The Calculator give an estimate. Example:

| Data | TRM |
|---|---|
| T-Ambient = 25°C | Standard (Calculator see below)<br>Top face / Bottom face<br>Ambient temperature °C: 25 / 25<br>Total heat transfer W/m²K: 26 / 26 |
| Calculator | Heat transfer co<br>Vertical plate: 25.9 W/m²K<br>Horizontal plate: 20.7 W/m²K |

### 3.7 Components

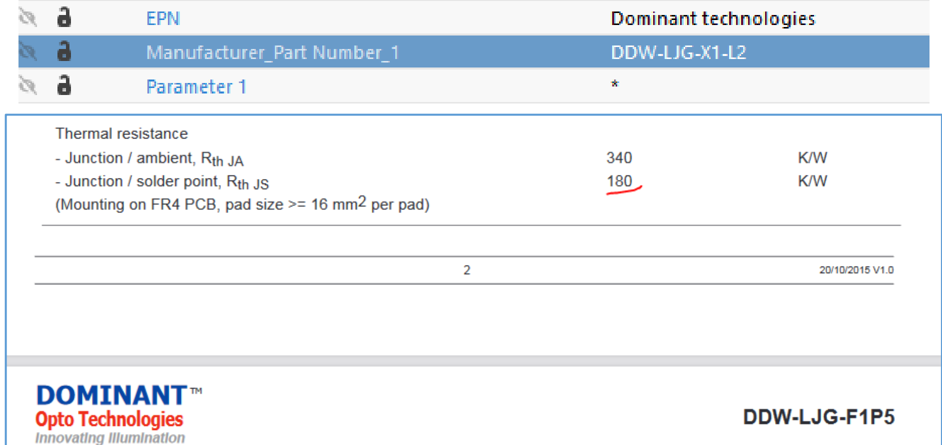
The component footprints and heights are imported as found in the Altium IDF file. Instead of the true size it could happen that the bounding box was found including some clearance. The footprint size determines the heat transfer to the board. In the calculation all components are taken into account except the jumpers J1. We do not want to assume that safe operation depends on heat dissipation/conduction through the plug.

| Data | TRM |
|---|---|
| |  |



1. The components in TRM are simple cuboids (or cylinders) that are assigned a typical bulk thermal conductivity of 20 W/Km (which we always like to use). However, thermal resistances to the board and to the air can be defined.

2. *The LED is now a power dissipating component.*




Data sheet with $R_{th,JS}$=180 K/W on the specific test board.

### 3.8 Modelling Mechanical Parts

None. No enclosure or housing.

### 3.9 Components/Loads Table

"Watt" is the dissipated power. Example Run 1:

| Index | Name | PosX (mm) | PosY (mm) | DimX (mm) | DimY (mm) | Height (mm) | Begin | End | Material | Form | K/W-board | K/W-air | Watt | C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | FDCA1 | 9.33 | 4.63 | 2.79 | 2.79 | 0.6 | 0 | 0 | Ignore$TRM | r | -1 | -1 | 0 | |
| 1 | R1B | 9.85 | 1.25 | 2.3 | 1.35 | 0.76 | 0 | 0 | Comp_diel_hic$TRM | r | -1 | -1 | 0.48 | |
| 2 | J1 | 13.8 | 0.3 | 5.2 | 7.4 | 8.85 | 0 | 0 | Ignore$TRM | r | -1 | -1 | 0 | |
| 3 | R2 | 7.82 | 1.71 | 0.6 | 1.04 | 0.34 | 0 | 0 | Comp_diel_hic$TRM | r | -1 | -1 | 0 | |
| 4 | R1A | 9.85 | 3.4 | 2.3 | 1.35 | 0.76 | 0 | 0 | Comp_diel_hic$TRM | r | -1 | -1 | 0.48 | |
| 5 | D2 | 5.763 | 1.58 | 1.25 | 2.5 | 0.99 | 0 | 0 | Comp_diel_loc$TRM | r | -1 | -1 | 0 | |
| 6 | D1 | 9.5 | 5.75 | 2.5 | 1.25 | 0.99 | 0 | 0 | Comp_diel_loc$TRM | r | -1 | -1 | 0 | |
| 7 | C1 | 5.797 | 5.344 | 1.77 | 0.95 | 0.95 | 0 | 0 | Comp_diel_loc$TRM | r | -1 | -1 | 0 | |
| 8 | LD1 | 2.102 | 2.25 | 2.8 | 3.5 | 1.9 | 0 | 0 | Cu$TRM | r | 180 | -1 | 0.162 | |

#### 3.9.1 Resistors

Components in TRM are simple cuboids (or cylinders) that are assigned a typical bulk thermal conductivity. We chose 20 W/m-K (library material Comp_diel_hic$TRM).

#### *3.9.2 LED model*

**Caution**: The LED model is using a thermal resistance $R_{th,J-B}$ = 180 K/W. Not necessarily the value applies also to this board if the pad size is different from the one on the test board of the data sheet. The result of $T_{LED}$ in the graphs and plots then is $T_J$, not $T_{surface}$! The thermal capacity of all components is unknown. We are using guesses.

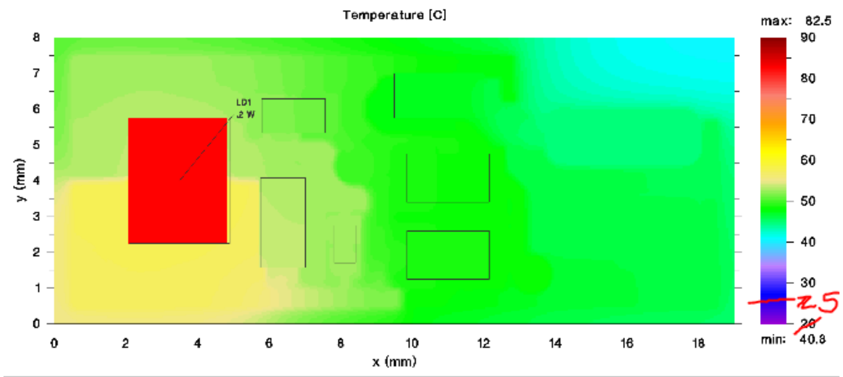
**Test calculation**: R1A, R1B=0 W, LD1=0.16 W, steady state, to compare with expectations from the data sheet.

TRM3: $T_J$=82 °C (@25 Ambient). $\Delta T_{JA}$ = 57 K √

Data sheet: $\Delta T_{JA}$=340 K/W * 0.16 W = 54 K

TRM3: $T_{pad} \approx$ 55°C → $\Delta T_{J\text{-}B}$= 82 °C – 55 °C = 27K √

Data sheet: $\Delta T_{J\text{-}pad}$ = 180 K/W * 0.16 W = 29 K




*This means: relying on the data sheet, the LED result is compatible.*

### 3.10 Dynamic conditions

As specified. A virtual thermal couple was placed at the center of each component.

# 4 *TRM Results*

The temperature value for the LED in plots and graphs is always the Junction temperature, because $R_{th\text{-}JS}$ was used!

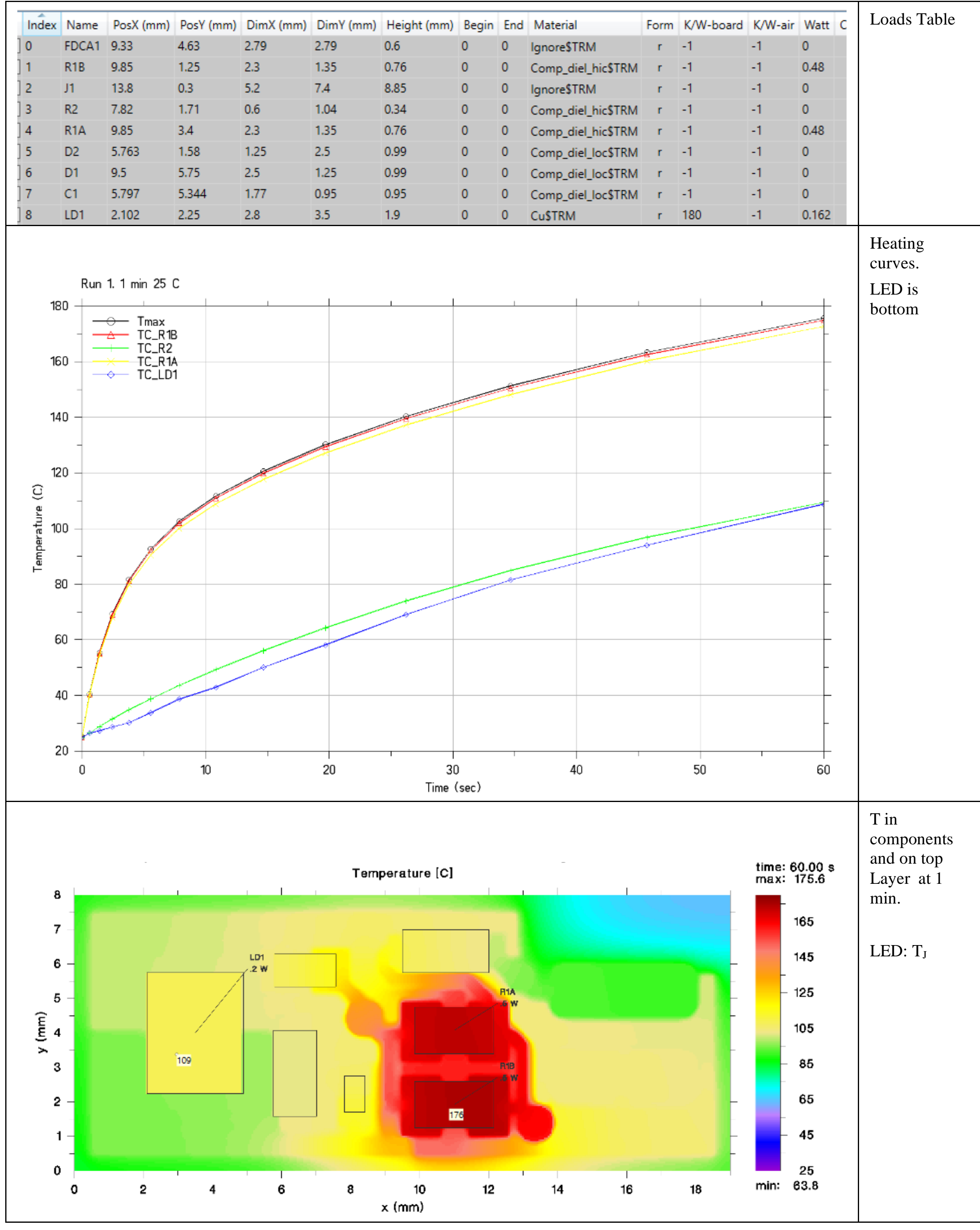
## *4.1 Run 1: 24 Volt _1 minute @ 25°C*

P_R1A= 0.48W

P_R1B= 0.48W

P_LD1= 0.162W

Heat transfer coefficient=26 W/m²K



| Index | Name | PosX (mm) | PosY (mm) | DimX (mm) | DimY (mm) | Height (mm) | Begin | End | Material | Form | K/W-board | K/W-air | Watt | C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | FDCA1 | 9.33 | 4.63 | 2.79 | 2.79 | 0.6 | 0 | 0 | Ignore$TRM | r | -1 | -1 | 0 | |
| 1 | R1B | 9.85 | 1.25 | 2.3 | 1.35 | 0.76 | 0 | 0 | Comp_diel_hic$TRM | r | -1 | -1 | 0.48 | |
| 2 | J1 | 13.8 | 0.3 | 5.2 | 7.4 | 8.85 | 0 | 0 | Ignore$TRM | r | -1 | -1 | 0 | |
| 3 | R2 | 7.82 | 1.71 | 0.6 | 1.04 | 0.34 | 0 | 0 | Comp_diel_hic$TRM | r | -1 | -1 | 0 | |
| 4 | R1A | 9.85 | 3.4 | 2.3 | 1.35 | 0.76 | 0 | 0 | Comp_diel_hic$TRM | r | -1 | -1 | 0.48 | |
| 5 | D2 | 5.763 | 1.58 | 1.25 | 2.5 | 0.99 | 0 | 0 | Comp_diel_loc$TRM | r | -1 | -1 | 0 | |
| 6 | D1 | 9.5 | 5.75 | 2.5 | 1.25 | 0.99 | 0 | 0 | Comp_diel_loc$TRM | r | -1 | -1 | 0 | |
| 7 | C1 | 5.797 | 5.344 | 1.77 | 0.95 | 0.95 | 0 | 0 | Comp_diel_loc$TRM | r | -1 | -1 | 0 | |
| 8 | LD1 | 2.102 | 2.25 | 2.8 | 3.5 | 1.9 | 0 | 0 | Cu$TRM | r | 180 | -1 | 0.162 | |

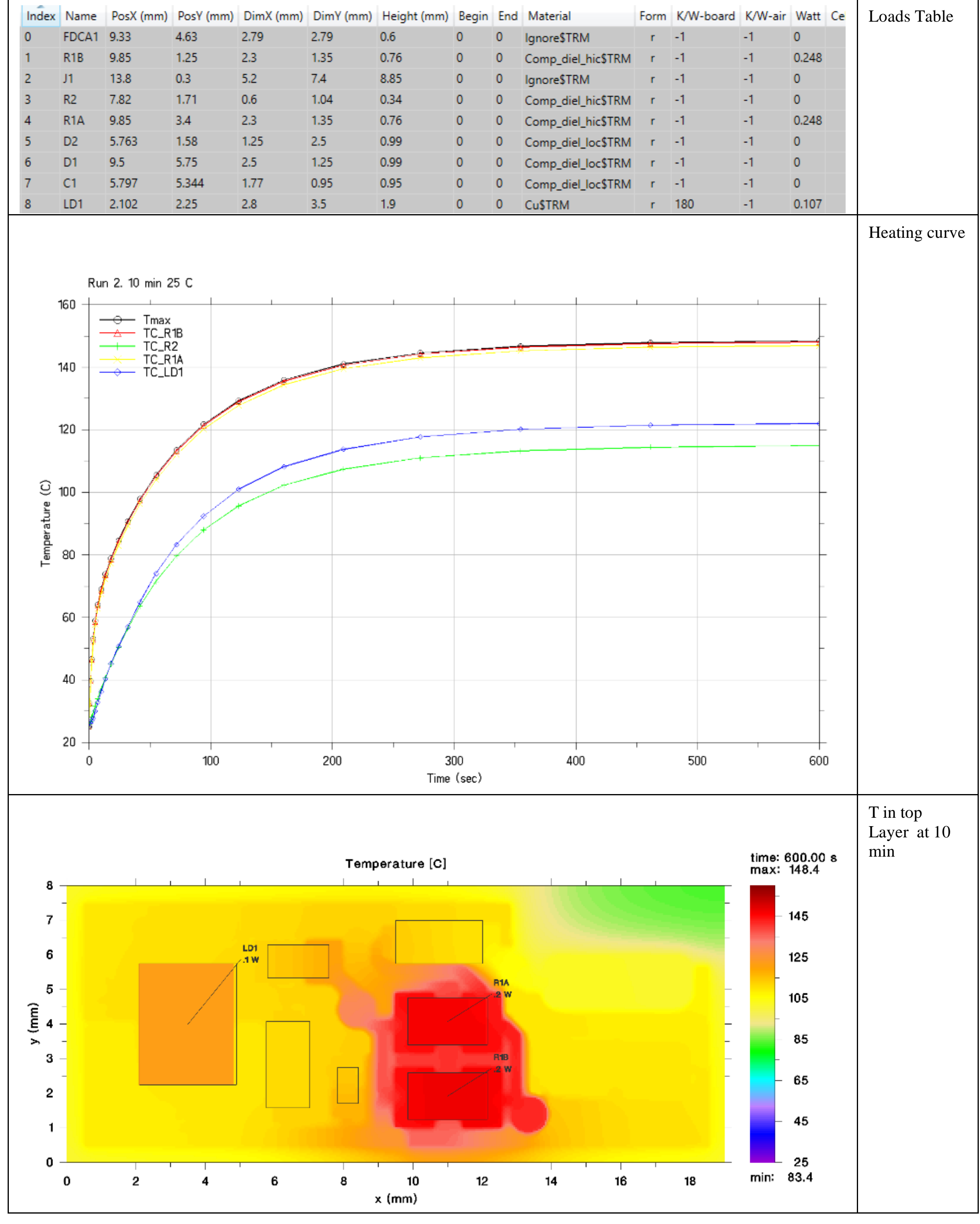
*4.2 Run 2: 18 Volt _10 minutes @ 25°C*

P_R1A= 0.248W

P_R1B= 0.248W

P_LD1= 0.107W

Heat transfer coefficient: 21 W/m²K



Loads Table

| Index | Name | PosX (mm) | PosY (mm) | DimX (mm) | DimY (mm) | Height (mm) | Begin | End | Material | Form | K/W-board | K/W-air | Watt | Ce |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | FDCA1 | 9.33 | 4.63 | 2.79 | 2.79 | 0.6 | 0 | 0 | Ignore$TRM | r | -1 | -1 | 0 | |
| 1 | R1B | 9.85 | 1.25 | 2.3 | 1.35 | 0.76 | 0 | 0 | Comp_diel_hic$TRM | r | -1 | -1 | 0.248 | |
| 2 | J1 | 13.8 | 0.3 | 5.2 | 7.4 | 8.85 | 0 | 0 | Ignore$TRM | r | -1 | -1 | 0 | |
| 3 | R2 | 7.82 | 1.71 | 0.6 | 1.04 | 0.34 | 0 | 0 | Comp_diel_hic$TRM | r | -1 | -1 | 0 | |
| 4 | R1A | 9.85 | 3.4 | 2.3 | 1.35 | 0.76 | 0 | 0 | Comp_diel_hic$TRM | r | -1 | -1 | 0.248 | |
| 5 | D2 | 5.763 | 1.58 | 1.25 | 2.5 | 0.99 | 0 | 0 | Comp_diel_loc$TRM | r | -1 | -1 | 0 | |
| 6 | D1 | 9.5 | 5.75 | 2.5 | 1.25 | 0.99 | 0 | 0 | Comp_diel_loc$TRM | r | -1 | -1 | 0 | |
| 7 | C1 | 5.797 | 5.344 | 1.77 | 0.95 | 0.95 | 0 | 0 | Comp_diel_loc$TRM | r | -1 | -1 | 0 | |
| 8 | LD1 | 2.102 | 2.25 | 2.8 | 3.5 | 1.9 | 0 | 0 | Cu$TRM | r | 180 | -1 | 0.107 | |

Heating curve



T in top Layer at 10 min

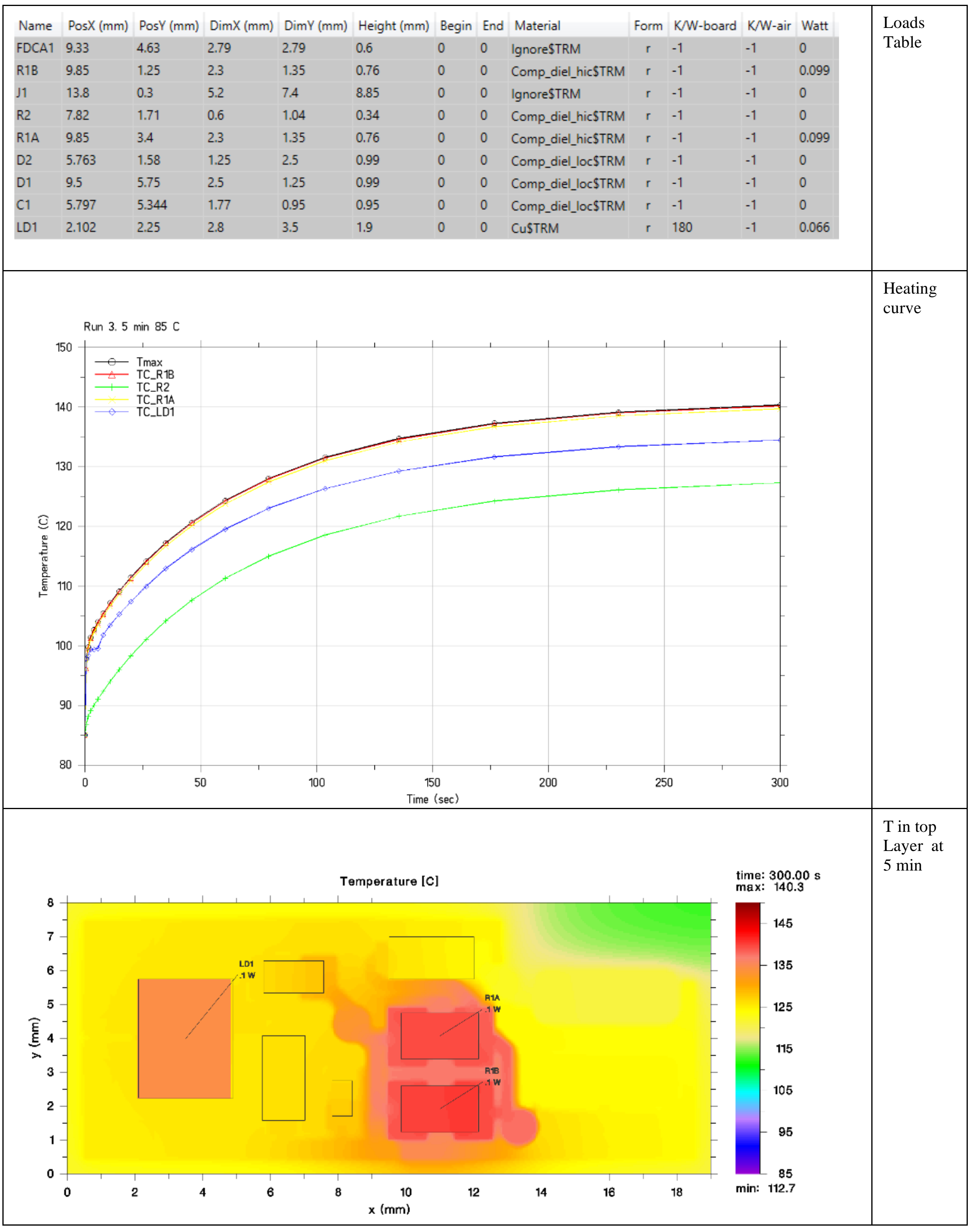
*4.3 Run 3: 12,8 Volt _5 minutes @ 85°C*

P_R1A = 0.099W

P_R1B = 0.099W

P_LD1 = 0.066W

Heat transfer coefficient 19 W/m²K



| Name | PosX (mm) | PosY (mm) | DimX (mm) | DimY (mm) | Height (mm) | Begin | End | Material | Form | K/W-board | K/W-air | Watt |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FDCA1 | 9.33 | 4.63 | 2.79 | 2.79 | 0.6 | 0 | 0 | Ignore$TRM | r | -1 | -1 | 0 |
| R1B | 9.85 | 1.25 | 2.3 | 1.35 | 0.76 | 0 | 0 | Comp_diel_hic$TRM | r | -1 | -1 | 0.099 |
| J1 | 13.8 | 0.3 | 5.2 | 7.4 | 8.85 | 0 | 0 | Ignore$TRM | r | -1 | -1 | 0 |
| R2 | 7.82 | 1.71 | 0.6 | 1.04 | 0.34 | 0 | 0 | Comp_diel_hic$TRM | r | -1 | -1 | 0 |
| R1A | 9.85 | 3.4 | 2.3 | 1.35 | 0.76 | 0 | 0 | Comp_diel_hic$TRM | r | -1 | -1 | 0.099 |
| D2 | 5.763 | 1.58 | 1.25 | 2.5 | 0.99 | 0 | 0 | Comp_diel_loc$TRM | r | -1 | -1 | 0 |
| D1 | 9.5 | 5.75 | 2.5 | 1.25 | 0.99 | 0 | 0 | Comp_diel_loc$TRM | r | -1 | -1 | 0 |
| C1 | 5.797 | 5.344 | 1.77 | 0.95 | 0.95 | 0 | 0 | Comp_diel_loc$TRM | r | -1 | -1 | 0 |
| LD1 | 2.102 | 2.25 | 2.8 | 3.5 | 1.9 | 0 | 0 | Cu$TRM | r | 180 | -1 | 0.066 |

Remark

Strictly speaking, the calculated temperature values are only valid for these input values. Accurate laboratory data are usually reproduced by TRM with an accuracy of +- 5%. A housing or other power losses will modify the result substantially.