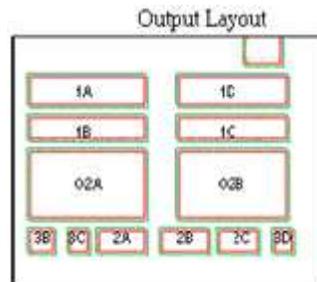


# *3D Transient Temperature Rise Interactions in DMOS*

[http://www.leapcad.com/Other\\_Tech/IC\\_DMOS\\_3D\\_Transient\\_Temperature\\_-\\_Greens.mcd](http://www.leapcad.com/Other_Tech/IC_DMOS_3D_Transient_Temperature_-_Greens.mcd)

## **Problem:**

Determine the transient temperature rises of an Power Integrated Circuit for multiple rectangular DMOS (two dimensional surface heat sources) from some ambient temperature,  $T_{\text{ambient}}$ .



Outputs

## **Solution:**

The method is to create Rectangular Green's Functions for an array of rectangular DMOS outputs.

## **Given Parameters:**

The Area of the die,  $A$ . The die and pedestal thickness.

Specifications for each output are vectors that define: Peak power (watts) and fall time (us) for the power transient.

The functional form for these power transients.

The dimensions of the outputs are the width,  $w$  and the height,  $h$  of the DMOS. Location on the DMOS on the die are given in terms of the  $x$  and  $y$  spacing between outputs,  $g_x$  and  $g_y$ . The variables  $g_x$  and  $g_y$  are used to replicate the same size outputs separated by  $g_x$  and  $g_y$ .

The Greens functions are expressed in terms of  $x$  and  $y$  coordinates of the left right edge of the DMOS,  $L_x$  and  $L_y$ .  $L_x$  and  $L_y$  can be composed from combinations of width, heights and spacings.

The nonlinearity of the heat conductivity is compensated by a Kirchoff transformation.

The final solution is to sum and plot the 2D thermal responses of the individual DMOS.

# 3D Transient Temperature Rise Interactions in DMOS

[3D Transient Temp - Greens DMOS.MCD]

Area<sub>dmos</sub> := 1211 · mil<sup>2</sup>

## Arrays: DMOS Power and Layout Coordinates:

Peak Snub Power (Ppk), Fall Time (Tf), Time End (us), Rds\_O2A,

Layout width (w), spacing (g), height (h), rectangle Lx, Ly edge,

Peak Snub, Ppk: 3B, O2A, 1B, 1A 3D, O2B, 1C, 1D 3C, 2A, 2B, 2C, DMOS

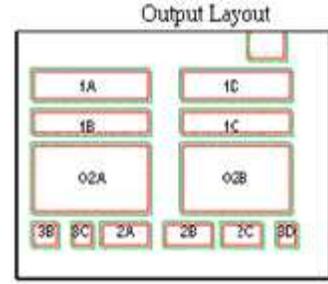
$$Ppk := (5 \ 0 \ 33 \ 33 \ 10 \ 0 \ 53.7 \ 33 \ 9 \ 11 \ 10 \ 9 \ 35.6)^T \cdot \text{watt}$$

$$T_{fs} := (2.2 \ 2.7 \ 2.7 \ 2.7 \ 2.7 \ 0.88 \ 1.8 \ 2 \ 2 \ 2 \ 2 \ 2)^T \cdot 10^{-3}$$

$$T_{amb} := 137 \text{ time}_{end\mu s} := 200 \text{ Rds\_O2A} := 0.1 \ T_{dly} := 110 \cdot 10^{-6}$$

Check  $\Delta T$  with  $w_{12} := \sqrt{\text{Area}_{dmos}}$   $g_{x_{12}} := 0 \cdot \text{mil}$   $L_{x_{12}} := 190 \cdot \text{mil}$

Output6  $h_{12} := \sqrt{\text{Area}_{dmos}}$   $g_{y_{12}} := 5.3 \cdot \text{mil}$   $L_{y_{12}} := 146.3 \cdot \text{mil}$



Outputs

$$A_{die} := 140 \cdot 160 \text{ mil}^2$$

### Left Outputs Layout

3B:  $w_0 := 21.1 \cdot \text{mil}$   $g_{x_0} := 0 \cdot \text{mil}$   $L_{x_0} := g_{x_0}$   $h_0 := 22 \cdot \text{mil}$   $g_{y_0} := 5.8 \cdot \text{mil}$   $L_{y_0} := g_{y_0}$

O2A:  $w_1 := 103 \cdot \text{mil}$   $g_{x_1} := 0 \cdot \text{mil}$   $L_{x_1} := g_{x_1}$   $h_1 := 54.3 \cdot \text{mil}$   $g_{y_1} := 33 \cdot \text{mil}$   $L_{y_1} := g_{y_1}$

1B:  $w_2 := w_1$   $g_{x_2} := 0 \cdot \text{mil}$   $L_{x_2} := g_{x_2}$   $h_2 := 22.6 \cdot \text{mil}$   $g_{y_2} := 3.2 \cdot \text{mil}$   $L_{y_2} := L_{y_1} + h_1 + g_{y_2}$

1A:  $w_3 := w_1$   $g_{x_3} := 0 \cdot \text{mil}$   $L_{x_3} := g_{x_3}$   $h_3 := 22.6 \cdot \text{mil}$   $g_{y_3} := 5.3 \cdot \text{mil}$   $L_{y_3} := L_{y_2} + h_2 + g_{y_3}$

### Right Outputs Layout

3D:  $w_4 := 21.1 \cdot \text{mil}$   $g_{x_4} := 22.9 \cdot \text{mil}$   $L_{x_4} := 211.9 \cdot \text{mil}$   $h_4 := 22 \cdot \text{mil}$   $g_{y_4} := 5.8 \cdot \text{mil}$   $L_{y_4} := g_{y_4}$

O2B:  $w_5 := 103 \cdot \text{mil}$   $g_{x_5} := 22.9 \cdot \text{mil}$   $L_{x_5} := L_{x_1} + w_1 + g_{x_5}$   $h_5 := 54.3 \cdot \text{mil}$   $g_{y_5} := 33 \cdot \text{mil}$   $L_{y_5} := g_{y_5}$

1C:  $w_6 := w_1$   $g_{x_6} := 22.9 \cdot \text{mil}$   $L_{x_6} := L_{x_2} + w_2 + g_{x_6}$   $h_6 := 22.6 \cdot \text{mil}$   $g_{y_6} := 3.2 \cdot \text{mil}$   $L_{y_6} := L_{y_5} + h_5 + g_{y_6}$

1D:  $w_7 := w_1$   $g_{x_7} := 22.9 \cdot \text{mil}$   $L_{x_7} := L_{x_3} + w_3 + g_{x_7}$   $h_7 := 22.6 \cdot \text{mil}$   $g_{y_7} := 5.3 \cdot \text{mil}$   $L_{y_7} := L_{y_6} + h_6 + g_{y_7}$

### Mid Bottom Outputs Layout

3C  $w_8 := 23 \cdot \text{mil}$   $g_{x_8} := 0 \cdot \text{mil}$   $L_{x_8} := 31.2 \cdot \text{mil}$   $h_8 := 22 \cdot \text{mil}$   $g_{y_8} := 5.8 \cdot \text{mil}$   $L_{y_8} := 5.8 \cdot \text{mil}$

2A  $w_9 := 46 \cdot \text{mil}$   $g_{x_9} := 0 \cdot \text{mil}$   $L_{x_9} := 58.6 \cdot \text{mil}$   $h_9 := 22 \cdot \text{mil}$   $g_{y_9} := 5.8 \cdot \text{mil}$   $L_{y_9} := 5.8 \cdot \text{mil}$

2B  $w_{10} := 46 \cdot \text{mil}$   $g_{x_{10}} := 0 \cdot \text{mil}$   $L_{x_{10}} := 111.3 \cdot \text{mil}$   $h_{10} := 22.7 \cdot \text{mil}$   $g_{y_{10}} := 5.8 \cdot \text{mil}$   $L_{y_{10}} := 5.8 \cdot \text{mil}$

2C  $w_{11} := 42.3 \cdot \text{mil}$   $g_{x_{11}} := 0 \cdot \text{mil}$   $L_{x_{11}} := 161.6 \cdot \text{mil}$   $h_{11} := 22.7 \cdot \text{mil}$   $g_{y_{11}} := 5.8 \cdot \text{mil}$   $L_{y_{11}} := 5.1 \cdot \text{mil}$

## Material Constants: Silicon, Aluminum, Pedestal

Thermal Conductivities Heat Capacity, cp, Thermal Diffusivity, D

$$\text{cond\_silicon}_{avg} := 0.8 \cdot \frac{\text{watt}}{\text{cm}} \quad k := \text{cond\_silicon}_{avg} \quad z_j := 1.55 \cdot \mu\text{m} \quad \text{cond\_si\_500C} := 0.41 \cdot \text{watt} \cdot \text{cm}^{-1}$$

$$\text{cp\_si} := 1.9 \cdot \text{watt} \cdot \text{sec} \cdot \text{cm}^{-3} \quad K_{si} := 0.87 \cdot \text{cm}^2 \cdot \text{sec}^{-1} \quad \text{c\_ped} := 1.5 \cdot \text{cp\_si} \quad T_{ambK} := T_{amb} + 273$$

Metal Parameters: Aluminum characteristic thermal length,  $\lambda \sim 25 - 200 \mu\text{m}$ . Lines  $> \lambda$  are thermally "long".

$$\text{cp\_al} := 0.637 \cdot \text{cal} \cdot \text{cm}^{-3} \quad k_{al} := 3.98 \cdot \frac{\text{watt}}{\text{cm}} \quad \text{th}_{al} := 2 \cdot \text{mil} \quad \lambda_{therm\_al} := 100 \cdot \mu\text{m}$$

$$\rho_{m\_al} := 2.7 \cdot \text{g} \cdot \text{cm}^{-3} \quad C\theta_{al} := \left( \text{cp\_al} \cdot w \cdot \frac{h}{2} \cdot \text{th}_{al} \right) \quad R\theta_{al} := \left[ \lambda_{therm\_al} \cdot (k_{al} \cdot w \cdot \text{th}_{al})^{-1} \right] \quad \tau_{\theta\_al} := (R\theta_{al} \cdot C\theta_{al})$$

$$K_{300} := 1.42 \cdot \frac{\text{watt}}{\text{cm}} \quad k_{tong}(T) := 1.5486 \cdot \left( \frac{T}{300} \right)^{-4} \cdot \frac{\text{watt}}{\text{cm}} \quad \rho C_p(T) := 1.574 \cdot \left( \frac{T}{300} \right)^{0.1} \cdot \frac{\text{joule}}{\text{cm}^3}$$

$$D_{siavg} := \frac{\text{cond\_silicon}_{avg}}{\text{cp\_si}} \quad D_{si} := \frac{k_{tong}(T_{ambK})}{\rho C_p(T_{ambK})} \quad k_{ped} := 2 \cdot \frac{\text{watt}}{\text{cm}} \quad DTDo(Tk) := \left( \frac{Tk}{T_{ambK}} \right)^{-4-0.1} \cdot \frac{\text{cm}^2}{\text{sec}}$$

$$\text{cpLaRosa} := 1.638 \cdot \text{watt} \cdot \text{sec} \cdot \text{cm}^{-3} \quad S_{LaRosa}(T) := \text{cpLaRosa} \cdot \left[ 1 + 1.106 \cdot 10^{-3} \cdot (T - 300) - 1.33 \cdot 10^{-6} \cdot (T - 300)^2 \right]$$

**One Dimensional Thermal Impedance Vector Function, Z $\theta$ , for Die Mount and Pedestal. Device Power Waveforms**

$$th_{die} := 14 \cdot \text{mil} \quad A_{dmos} := h_1 \cdot w_1 \quad R_{\theta die} := \frac{th_{die}}{k_{tong}(T_{ambK}) \cdot A_{dmos} \cdot 1.4} \quad C_{\theta die} := S_{LaRosa}(T_{ambK}) \cdot th_{die} \left( \frac{A_{dmos} + A_{die}}{2} \right)$$

$$th_{ped} := 50 \cdot \text{mil} \quad R_{\theta ped} := th_{ped} \cdot (k_{ped} \cdot 3A_{die})^{-1} \quad C_{\theta ped} := c_{ped} \cdot th_{ped} \cdot 3A_{die}$$

$$Z_{\theta die}(t) := R_{\theta die} \cdot \left( 1 - e^{-\frac{t \cdot \text{sec}}{R_{\theta die} \cdot C_{\theta die}}} \right) \quad Z_{\theta ped}(t) := R_{\theta ped} \cdot \left( 1 - e^{-\frac{t \cdot \text{sec}}{R_{\theta ped} \cdot C_{\theta ped}}} \right) \quad Z_{\theta al}(t) := \left[ R_{\theta al} \cdot \left( 1 - e^{-\frac{t \cdot \text{sec}}{\tau_{\theta al}}} \right) \right]$$

$$Z_{\theta pkg}(t) := Z_{\theta die}(t) + Z_{\theta ped}(t)$$

**DMOS Output 6 Load Waveforms and DMOS Case 11 from FE Simulation**

$$T_{Ssub} := \text{READPRN}("Ssub33W.TWP") \quad P_{Ssub} := \text{READPRN}("SsubPwr.prn") \quad P_{1C} := \text{READPRN}("DMOS1C-Case11.dat")$$

$$P_{pk} := (P_{Ssub}^{(1)})_3 \cdot \text{watt} \quad P_{tri}(t, n) := \Phi(t - T_{dly}) \cdot \left( 1 - \frac{t - T_{dly}}{T_{fs_n}} \right) \quad N := 30 \quad i := 0..26 \quad n := 0..N \quad tt_n := \frac{P_{Ssub}_{12,0} \cdot n}{N}$$

$$P_{htr}(t) := \left[ (8 - 4.5) \cdot \exp\left(\frac{-t}{2 \cdot 0.001}\right) + 4.5 \right]^2 \cdot R_{ds\_O2A} \cdot \text{watt} \quad P_{load}(t, n) := P_{pk_n} \cdot P_{tri}(t, n) + \left( \frac{-P_{pk}}{N} \right)_n \cdot P_{htr}(t)$$

**Solution for Green's Function to Transient Temperature Equation for Rectangle**

Surface Source Model Predicts higher temp and faster transients.

For x, sources have edge L<sub>ox</sub> and width W. For y, L<sub>oy</sub> and height H.

$$G(x, L_{ox}, W, y, L_{oy}, H, \tau) := \frac{1}{4 \cdot W \cdot H} \cdot \left( \text{erf}\left(\frac{-L_{ox} + x \cdot \text{mil}}{2 \cdot \sqrt{D_{si} \cdot \tau \cdot \text{sec}}}\right) + \text{erf}\left(\frac{L_{ox} + W - x \cdot \text{mil}}{2 \cdot \sqrt{D_{si} \cdot \tau \cdot \text{sec}}}\right) \right) \cdot \left( \text{erf}\left(\frac{-L_{oy} + y \cdot \text{mil}}{2 \cdot \sqrt{D_{si} \cdot \tau \cdot \text{sec}}}\right) + \text{erf}\left(\frac{L_{oy} + H - y \cdot \text{mil}}{2 \cdot \sqrt{D_{si} \cdot \tau \cdot \text{sec}}}\right) \right)$$

$$a := w_{12} \quad b := h_{12} \quad G_{S6}(x, y, \tau) := G(x, L_{x_{12}}, a, y, L_{y_{12}}, b, \tau) \quad P_{Sources}(x, y, t, \tau) := P_{pk} \cdot P_{tri}(t, 12) \cdot G_{S6}(x, y, t - \tau)$$

**Greens Transient Temperature Rise for Sources,  $\Delta T_o$**

$$ISqk\rho Cp := \left( \sqrt{\pi \cdot k_{tong}(T_{ambK}) \cdot \rho Cp(T_{ambK})} \right)^{-1} \quad ISqk\rho Cp := \left( \sqrt{\pi \cdot k_{tong}(T_{ambK}) \cdot \rho Cp(273 + 180)} \right)^{-1}$$

$$\Delta T_{OS}(x, y, z, t) := ISqk\rho Cp \cdot \int_0^t \frac{1}{[(t - \tau) \cdot \text{sec}]^{\frac{1}{2}}} \cdot \frac{1}{2} \cdot \left[ \exp\left[\frac{-(z \cdot \text{mil} - z_j)^2}{4 \cdot D_{si} \cdot (t - \tau) \cdot \text{sec}}\right] + \exp\left[\frac{-(z \cdot \text{mil} + z_j)^2}{4 \cdot D_{si} \cdot (t - \tau) \cdot \text{sec}}\right] \right] \cdot P_{Sources}(x, y, t, \tau) \cdot d\tau \cdot \text{sec}$$

$$\Delta T_O(x, L_x, W, y, L_y, H, z, t, n) := ISqk\rho Cp \cdot \int_0^t \frac{1}{[(t - \tau) \cdot \text{sec}]^{\frac{1}{2}}} \cdot \left[ \exp\left[\frac{-(z \cdot \text{mil} - z_j)^2}{4 \cdot D_{si} \cdot (t - \tau) \cdot \text{sec}}\right] + \exp\left[\frac{-(z \cdot \text{mil} + z_j)^2}{4 \cdot D_{si} \cdot (t - \tau) \cdot \text{sec}}\right] \right] \cdot P_{load}(t, n) \cdot G(x, L_x, W, y, L_y, H, z, t - \tau) \cdot d\tau \cdot \text{sec}$$

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$$\Delta T_O(x, L_x, W, y, L_y, H, z, t, n) := ISqk\rho Cp \cdot \int_0^t \frac{1}{[(t - \tau) \cdot \text{sec}]^{\frac{1}{2}}} \cdot \left[ \exp\left[\frac{-(z \cdot \text{mil} - z_j)^2}{4 \cdot D_{si} \cdot (t - \tau) \cdot \text{sec}}\right] + \exp\left[\frac{-(z \cdot \text{mil} + z_j)^2}{4 \cdot D_{si} \cdot (t - \tau) \cdot \text{sec}}\right] \right] \cdot P_{load}(t, n) \cdot G(x, L_x, W, y, L_y, H, z, t - \tau) \cdot d\tau \cdot \text{sec}$$

**Remove Heat Equation Nonlinearity from Temperature Dependence of Conductivity**

**Kirchhoff Transformation: K, D must have value at Tamb**

Tk Kirch is the Inverse of  $\Theta$ , the Integral Transform of Conductivity,  $\lambda_{si}(T)$

$$\lambda_{Si}(T) := K_{300} \cdot \left(\frac{300}{T}\right)^{\frac{4}{3}} \quad \theta = T_s + \frac{1}{\lambda_s} \cdot \int_{T_s}^T \lambda(T) dT \quad Tk_{Kirch34}(\theta, T_o) := \frac{27 \cdot T_o^4}{(4 \cdot T_o - \theta)^3}$$

**Calculate Temperature versus Time. Find Peak Temp at Given Output**

Evaluation Times:  $rt := 0..60$   $Time_{rt} := \frac{15 \cdot time_{end\mu s}}{700 \cdot 10^6} \cdot rt$   $Time_0 := 10^{-9}$

$$T_{MDj_{rt}} := \sum_{n=6}^6 \Delta T_o \left( \frac{L_{x_n}}{mil} + \frac{w_n}{2 \cdot mil}, L_{x_n}, w_n, \frac{L_{y_n}}{mil} + \frac{h_n}{2 \cdot mil}, L_{y_n}, h_n, 0, Time_{rt}, n \right)$$

$$T_{MDKj_{rt}} := \left( Tk_{Kirch34}(T_{MDj_{rt}} + T_{ambK}, T_{ambK}) - 273 \right) \max(T_{MDKj}) = 192.436$$

$$\text{match}(\max(T_{MDKj}), T_{MDKj}) = (13)$$

Check DMOS

Output 6

**Corrected Transient Temperature at midpoints, eg. DMOS Out 6, Q=12 or DMOS 1C, Q=6**

Q := 6

$$T_{DKjs_{rt}} := \left( Tk_{Kirch34} \left( \Delta T_o \left( \frac{L_{x_Q}}{mil} + \frac{w_Q}{2 \cdot mil}, L_{x_Q}, w_Q, \frac{L_{y_Q}}{mil} + \frac{h_Q}{2 \cdot mil}, L_{y_Q}, h_Q, 0, Time_{rt}, Q \right) + T_{ambK}, T_{ambK} \right) - 273 \right) \max(T_{DKjs}) = 192.436$$

**Compensate for Thermal Effects of Metal Runners with 1 D Thermal Impedance, Z $\theta$ al for Output Q**

$$\Delta T_{al}(\Delta T, P, Z\theta) := \Delta T \cdot \left[ 1 + \frac{\Delta T}{(P \cdot Z\theta)} \right]^{-1} \quad \Delta T_{al_{rt}} := \Delta T_{al}(T_{DKjs_{rt}} - T_{amb}, P_{pk} \cdot P_{tri}(Time_{rt}, Q), Z\theta_{al}(Time_{rt})_Q)$$

$$T_{DKjM_{rt}} := \Delta T_{al_{rt}} + T_{amb} \quad P_{tot_{rt}} := \sum_{n=1}^{11} P_{pk_n} \cdot P_{tri}(Time_{rt}, n) \quad \max(T_{DKjM}) = 162.978$$

$$T_{3DK_{rt}} := T_{DKjM_{rt}} + P_{tot_{rt}} Z\theta_{ped}(Time_{rt}) \quad \max(P_{tot}) = 199.955 \text{ watt} \quad \max(T_{3DK}) = 163.476$$

**Remove Heat Equation Time Nonlinearity from Temperature Dependence of Diffusivity**

**Time Variable,  $\zeta$ , Transformation for Diffusivity**

**"E-T Device and Ckt Sim with thermal nonlinearity" Batty and Snowden**

$$\zeta_{rt} := \int_0^{Time_{rt}} \left( \frac{\Delta T_o \left( \frac{L_{x_Q}}{mil} + \frac{w_Q}{2 \cdot mil}, L_{x_Q}, w_Q, \frac{L_{y_Q}}{mil} + \frac{h_Q}{2 \cdot mil}, L_{y_Q}, h_Q, 0, Time_{rt}, Q \right) + T_{ambK}}{T_{ambK}} \right)^{-1.35} dt$$

Above  $\Delta$ Time Solution is the  $\zeta$  domain from 0 to "time\_end = 0.04" sec.

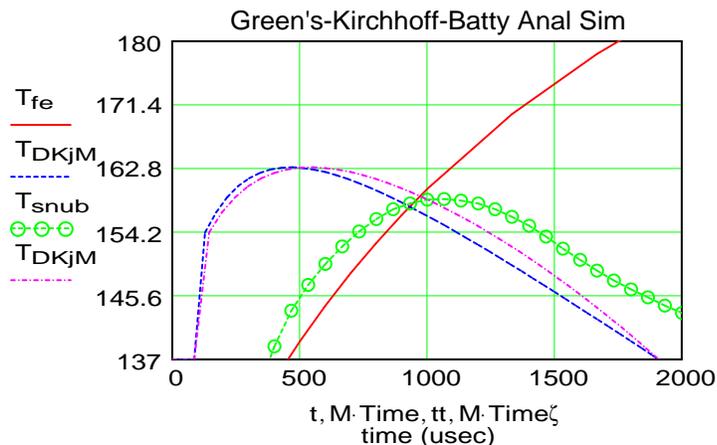
Linearize and then get solution in terms of time  $\zeta$ , i.e. given a  $\zeta$  sample from the transformed temperature solution, find the corresponding inverse Time value of real time. Matrix solution points, T3D and Time goes into above. Need to get inverse of transform, i.e. in terms of the above integral, want Ratio matrix, RT2 $\zeta$ , to get inverse. Then real time equals  $\zeta$  times T/ $\zeta$  equals T.

$$RT2\zeta F(t) := \text{linterp}(\zeta, Time, t) \quad Time_{\zeta_{rt}} := RT2\zeta F(Time_{rt})$$

**FE VERSUS ANALYTIC 3D: SIMULATION DMOS OUTPUT 6 AT 24W WITH A PEDESTAL TEMP OF 115C**

T5 := READPRN("TT24WH~1.prn")      Time      Max Temp      Bump Temp      TSD Temp  
 M := 10<sup>6</sup>      t := M·T5<sup>(0)</sup>      T<sub>fe</sub> := T5<sup>(1)</sup>      T<sub>bmp</sub> := T5<sup>(4)</sup>      T<sub>sen</sub> := T5<sup>(5)</sup>

**DMOS Out 6 FE 24W Short and Snub vs Greens ZMetal Snub**



max(T<sub>DKJM</sub>) = 162.978  
 ζ<sub>pk</sub> := match(max(T<sub>3DK</sub>), T<sub>3DK</sub>)  
 ζ<sub>pk</sub> = (11)  
 ρkζ := 1000 Time<sub>ζ</sub>(R<sub>pk0</sub>)  
 ρkζ = ■  
 ρk := 1000 Time(R<sub>pk0</sub>)  
 ζ<sub>pk3</sub> := match(max(T<sub>MDKj</sub>), T<sub>MDKj</sub>)  
 t<sub>pk3</sub> := 1000 · Time(R<sub>pk30</sub>)<sup>ζ</sup> (msec)  
 t<sub>pk3</sub> = 0.557

**Plot Spatial Thermal Response for DMOS Outputs at O2A Temp Peak**

$$r := 0..55 \quad rr := 0..37 \quad X_r := -10 + 5 \cdot (r - 1) \quad Y_{rr} := -10 + 5 \cdot (rr - 1)$$

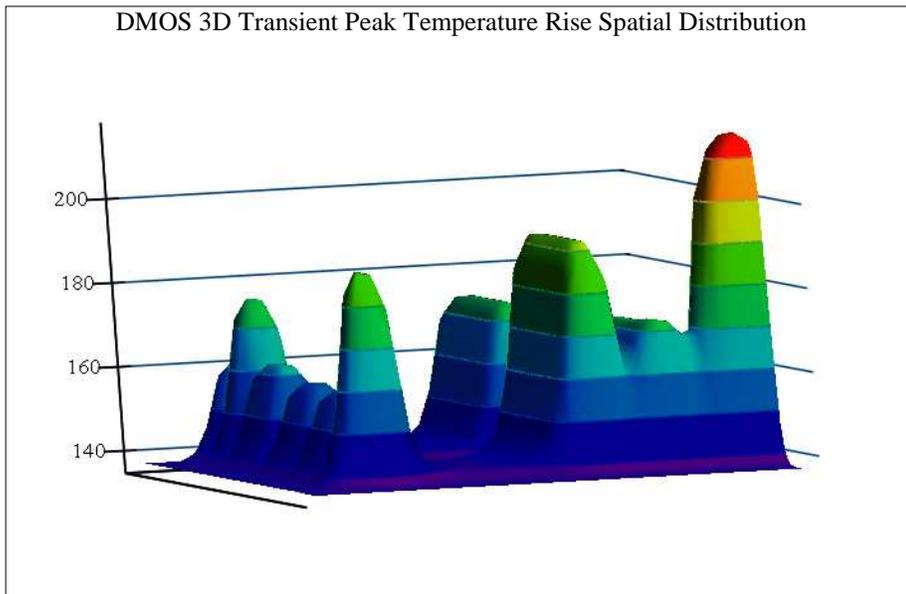
$$T_{XYj_{r,rr}} := \sum_{n=0}^{12} \Delta T_o \left( X_r, L_{x_n}, w_n, Y_{rr}, L_{y_n}, h_n, 0, \text{tpk3} \cdot 10^{-3}, n \right) \text{pk3} = 0.557$$

$$T_{XYKj_{r,rr}} := \left( \text{TkKirch34} \left( T_{XYj_{r,rr}} + T_{\text{ambK}}, T_{\text{ambK}} \right) - 273 \right) \quad \max(T_{\text{MDKj}}) = 192.436$$

$$T_{xy_{r,rr}} := \text{TkKirch34} \left( \Delta T_{\text{os}} \left( X_r, Y_{rr}, 0, \text{tpk3} \cdot 10^{-3} \right) + T_{\text{ambK}}, T_{\text{ambK}} \right) - 273$$

$$\text{WRITEPRN}(\text{"KTempXY00429s\_DMOS"}) := T_{XYKj}$$

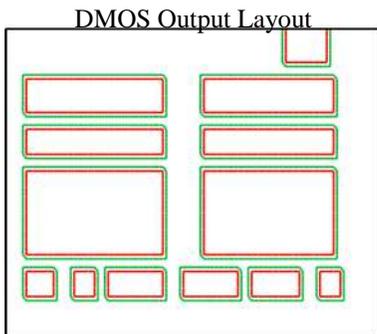
**2 Dimensional Transient Temp Solution for Outputs (Peak Power, Fall Time) from Green's Function with Kirchoff**



$$\max(T_{XYKj}) = 215.793$$

$T_{XYKj}$

$$\text{PS}(x, y, t) := \sum_{n=0}^{12} G(x, L_{x_n}, w_n, y, L_{y_n}, h_n, t) \text{Outputs}_{r,rr} := \text{if} \left[ \text{PS}(X_r, Y_{rr}, 10^{-20}) > \left( \frac{0.01}{\text{mm}} \right)^2, 1, 0 \right]$$



Outputs

**Find Peak Temp for Output 1B, v**  $v := 2$

$$\text{Out}_{r,rr} := w_v \cdot h_v \cdot G \left( X_r, L_{x_v}, w_v, Y_{rr}, L_{y_v}, h_v, 10^{-12} \right)$$

$$\max(\overrightarrow{\text{Out} \cdot T_{XYKj}}) = 173.962$$

**What is max temp increase from other outputs?**

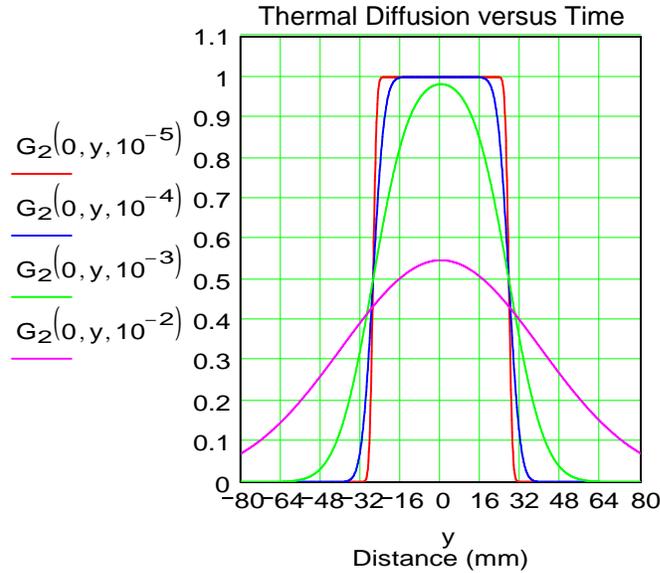
$$T_{XYjv_{r,rr}} := \Delta T_o \left( X_r, L_{x_v}, w_v, Y_{rr}, L_{y_v}, h_v, 10^{-12}, \text{tpk3} \cdot 10^{-3}, v \right)$$

$$T_{XYKjv_{r,rr}} := \left( \text{TkKirch34} \left( T_{XYjv_{r,rr}} + T_{\text{ambK}}, T_{\text{ambK}} \right) - 27 \right)$$

$$\max(T_{XYKjv}) = 173.529 \quad 166.277 - 165.775 = 0.502$$

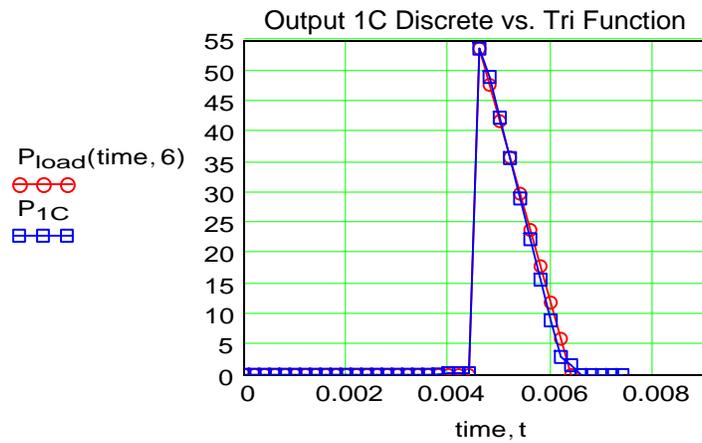
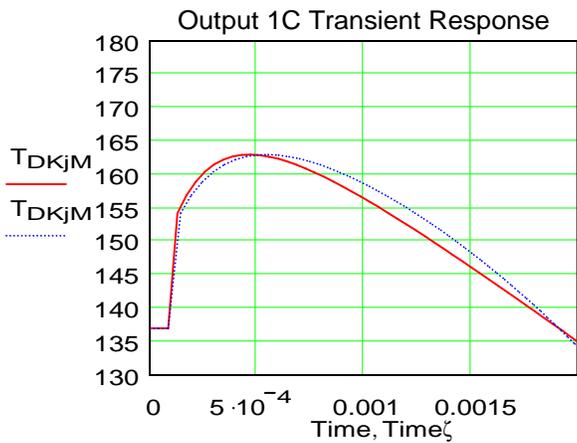
## Thermal Diffusion With Time

$$G_2(x, y, \tau) := \frac{1}{2} \cdot \left( \operatorname{erf} \left( \frac{\frac{h_1}{2} + y \cdot \text{mil}}{2 \cdot \sqrt{D_{\text{siavg}} \cdot \tau \cdot \text{sec}}} \right) + \operatorname{erf} \left( \frac{\frac{h_1}{2} - y \cdot \text{mil}}{2 \cdot \sqrt{D_{\text{siavg}} \cdot \tau \cdot \text{sec}}} \right) \right)$$



rows(P<sub>1C</sub>) = 38    r := 0.. 37    t<sub>r</sub> := r · 0.0002    time := 0, 0.0002.. 0.009    T<sub>dly</sub> := 0.0046

$$P_{\text{tri}}(t, n) := \Phi(t - T_{\text{dly}}) \cdot \left( 1 - \frac{t - T_{\text{dly}}}{0.0018} \right) \quad P_{\text{load}}(t, n) := P_{\text{pk}n} \cdot P_{\text{tri}}(t, n)$$



millihenry ≡ 10 <sup>-3</sup> · henry	usec ≡ 10 <sup>-6</sup> · sec	millisec ≡ 10 <sup>-3</sup> · sec	msec ≡ millisec
μohm ≡ 0.000001 · ohm	μF ≡ 0.000001 · farad	μm ≡ 10 <sup>-6</sup> · m	nm ≡ 10 <sup>-9</sup> · m
ms ≡ 10 <sup>-3</sup> · sec	mil ≡ 10 <sup>-3</sup> · in	mJ ≡ 10 <sup>-3</sup> · joule	μJ ≡ 10 <sup>-6</sup> · joule
A ≡ 10 <sup>-8</sup> · cm	Ω ≡ ohm		

)

$L_y, H, t - \tau) dt \cdot \text{sec}$