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Thermal Management Calculator Discussion

Table of Contents

Charts	3
Calculations	4
Conductor Analysis Test Data and Weight Table	5
Vias and Thermals	6
Preferences	7
Features	8
Board Properties	9
Equivalent Thermal Conductivity Calculator	0
Table Preferences	ı 1
	Charts Calculations Conductor Analysis Test Data and Weight Table Vias and Thermals Preferences Features Board Properties Equivalent Thermal Conductivity Calculator

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Thermal Manangement Calculator

This "Calculator" is for sizing electrical conductors in printed circuit boards. The **Thermal Management Software** is a database of current carrying capacity data. Data from this software database were used to create "*Standard for Determining Conductor Current-Carrying Capacity In Printed Board Design*", IPC 2152. This design tool has more information than was published in the standard. It is for determining the size of electrical conductors based on the temperature rise of conductors as a function of PCB physical parameters and current.

As some people know and others are learning, the charts in IPC-2221 goes back to work performed by the National Bureau of Standards in 1955 and published in 1956. Their work only addressed external conductors. Those conductors were on Phenolic and Epoxy boards. In addition, their results were all compiled together to create a chart that was labeled "tentative". Their test results were a mix of variables that effect trace temperature, such as board thickness, board material, trace thickness and some of the test boards had copper planes on the back of them. All of these variables influence the temperature rise of the trace, some more significantly than others, which makes it difficult to ascertain the actual temperature change of a trace in various board configurations. That was for the external traces. The internal trace charts were not based on test data, they were simply based on half the current from the external trace chart. This has caused problems throughout the electronics design community due to increasing currents, high-density electronics and design standards that are not well understood.

Now with a fresh start, all of the variables are separated, so that design decisions can be made with a better understanding of conductor heating. The **Thermal Management Software** is a collection of years of research. The database contains test results that have been validated by a U.S. Air Force Independent Research group and a Navy test lab. The test data covers 1 and 2oz internal and 2oz external traces for FR4 and ½ oz, 1, 2, 3 oz internal and 2, 3 oz external traces for polyimide in Air and Vacuum.

Additional information is also included that shows the influence of copper planes on heat spreading and lowering trace temperatures. The software has the capability of importing new trace charts. A process of creating technology specific design charts is well defined.

As new charts are created they can be imported through an "Ingest Tool". The interface is simple and only requires data input through a comma separated variable format.

III Thermalman Ingest Tool	?	×
		~
Source Filename (EXCEL .csv file)		
Destination Path for output file		
Enter output filename		
Close Ing	est	

Figures 1-9 shows the initial graphical user interface for the calculator followed by other attributes.

Settings -												
Configura	ation N	like_fav		-		💽 ir	temal 🔿	External			Type:	Trace 💌
Thicknes	ss Table 🔲	PC Minimum Ex	temal _	-		Charts			-		Conduct	or: 0.5oz Copper
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click to s Results Ad Type Trace Trace Trace Trace	Id Location Internal Internal Internal	Modify Chart 5x5AirFr41ozp 1ozAirIntPoly 3ozVacIntPoly	Del	lete Thicknes 0.001200 0.001200 0.001200 0.001200 0.001200 0.001200	<u>0.01</u> 0.01 0.01	0 1.000 0 1.000 0 1.000 0 1.000 0 1.000	0.5ozVacInt Area (mi^2) 12.00000 12.00000 12.00000 12.00000	Current (1.736 1.736 1.736 1.736	A) Delta T (*C 10.00000 31.13496 54.19120 280.30965	(W/in^2) (W/	0.189 18.942 Columns (°C) Resist F (O) 0.0613279 0.0661374 0.0713841 50.1308047	0.394 39.404 Print hm) Vdrop F (V) 0.106 0.115 0.124
click to s Results Ad Type Trace Trace Trace Trace	Id Location Internal Internal Internal	Modify Chart 5x5AirFr41ozp 1ozAirIntPoly 3ozVacIntPoly	Del	lete Thickness 0.001200 0.001200 0.001200 0.001200 Ch The	<u>art</u> e chart	0 1.000 1.000 0 1.000	0.5ozVacInt 0.5ozVacInt 0.5ozVacInt 12.000000 12.000000 12.000000 12.000000 12.000000 12.000000 12.000000	Current (1.736 1.736 1.736 1.736 0 boa	A) Detta T (C 10.00000 31.13496 54.19120 280.30965 rd thickr	(W/in^2) (W/in^2) (W/in^2) (W/in^2) (W/in^2) (35.0000 56.13496 79.19120 305.3096 ness, b	0.189 18.942 Columns (°C) Resist F (O) 0.0613279 0.0661374 0.0713841 5 0.1308047 oard	0.394 39.404 Print hm) Vdrop F (V) 0.106 0.115 0.124

Figure 1. Charts

		Michael R. Jouppi					
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Settings							
Configuration	Mike_fav	•	Intem	al 🔿 External		Type:	Trace 💌
Thickness Table	IPC Minimum E	xtemal 💌	Charts	PC	-	Conducto	or: 0.5oz Copper
	<u> </u>						
Calculator Sizing					Electrical		
Cross Sectional Are	ea (mil^2) 12.000	Hold			Conductor Length (in)	1.000	Hold
Conductor Thickne	The second se				Ambient Temp (°C)	25.00000	305.30965
Conductor Widtl				l l l l l l l l l l l l l l l l l l l	tholene remp (c)	Initial State (0)	Final State (F)
				F	Resistance (Ohm)	0.0628811	0.1308047
Current * (A	-			N	/oltage Drop (V)	0.109	0.227
Temperature Ris	e*(°C) 280.30	0965		∮ F	ower Dissipation (W)	0.189	0.394
click to solve par	ameter. F	Reset		/ F	Power Density (W/in^2)	18.942	39.404
Results				/ -		·	
Add	Modify	Delete		/		Columns	Print
Trace Interna Trace Interna Trace Interna Trace Interna	al 1ozAirIntPoly al 3ozVacIntPol	07 0.001200 ly07 0.001200	0.010 1.000 12 0.010 1.000 12	2.000000 1.736 2.000000 1.736 2.000000 1.736 2.000000 1.736	10.00000 35.000 31.13496 56.134 54.19120 79.191 280.30965 305.30	96 0.0661374 20 0.0713841	0.106 0.115 0.124 0.227
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•		other two.		7			•
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		described in	n IPC 2152, sı	uch as trace p	power		
			and power de	-	•		
		-	-	-			
		I tha trage th	at you specify	·			
				•			
			the change in		nd –		

Figure 2. Calculations

ThermalMan Calculator			<u>_8×</u>
ile <u>E</u> dit E <u>t</u> c <u>H</u> elp			
Settings			
Chart: 1ozAirIntPoly07	Conductor: 1-3oz Copper		Type: Trace
Configuration Mike_Test	Weight Table Underwriter Laboratory		Location: Internal
Calculator			
Conductor Thickness (in)	0.00135	Conductor Length (in)	1.00000
Cross Sectional Area (mil^2)		Ambient Temp (*C)	25.000 35.000
Conductor Width * (in)			Initial State * Final State *
Current* (A)		Resistance (Ohm)	
Temperature Rise * (*C)	10.000	Voltage Drop (V)	
* click on buttons with an asterisk to solve for that	arameter.	Power Dissipation (W)	
Reset All Values		Power Density (W/in^2)	and the second se
Results			
Add Modify Delete			Columns Print
Type Location Method Thickr	ess (in) Width(in) Length (in) Area (mil^2) Current (A) Delta T (*C) Temp 0 (*C)	Resist 0 (Ohm) Vdrop 0 (V) Power	0 (W) Density 0 (W/in^2) Temp F (*C
Trace Internal 1ozAirIntPoly07 0.0013 Trace Internal IPC 0.0013		0.063 0.063 0.063 0.018 0.018 0.018	7.204 35.000 0.567 35.000
Via Internal 1ozAirIntPoly07 0.0010			11.586 35.000
	If you are participating in CAT testing		
	Analysis and Test Inc. Take advantag	ge of the data that	
	you have and include it in the Weight	Table. UL and	
	IPC minimum allowable values are in		
	If C infinition and wable values are in	ieruueu.	
	Research has shown that the resistivit	y of loz copper	
	and greater has a different value than	$\frac{1}{2}$ oz copper.	
	This impacts resistance, voltage drop	and nower	
	calculations. They are included in the	-	
	•	conductor	
	selection.		
1			
1			

Figure 3. Conductor Analysis Test Data and Weight Table

ThermalMan Calculator			_ 8 >
<u>File E</u> dit E <u>t</u> c <u>H</u> elp			
Chart 1ozAirIntPoly07 Configuration Mike_Test	Conductor: 1-3oz Copper 💽 Weight Table Underwriter Laboratory 💽	Type: Location:	Via 🔹
Calculator Conductor Thickness (in) 0.00100 Cross Sectional Area (mil^2) Via Diameter*(in) Current*(A) Temperature Rise*(*C)		Via Depth (in) 1.00000 Ambient Temp (*C) 25.000 Initial Sta Posistance (Ohm) Voltage Drop (V)	Thermal Embedded Resistor 35.000
* click on buttons with an asterisk to solve for that parameter. Reset All Values		Power Dissipation (W) Power Density (W/in^2)	
Add Modify Delete Type Location Method Thickness (in) Trace Internal 10zAirIntPoly07 0.00135 0.0031 Trace Internal IPC 0.00135 0.00314 Via Internal 10zAirIntPoly07 0.00100 0.0081	1 Length (in) Area (mil ²) Current (A) Delta T (2) Temp 0 (*C) Resist 0 1.00000 11.895 1.000 10.000 25.000 0.063 1.00000 42.394 1.000 10.000 25.000 0.018 Included is the utility to calculate capacity of vias and thermals. For vias, the input parameter now width to Via Diameter. The calculate copper cylinder based on the via o thickness that you choose. All values calculated can be added can be saved as a comma-separate	the current carryin changes from trac llation is through a liameter and coppe	2 35.000 g e er that

Figure 4. Vias and Thermals

ThermalMan Calculator		_ <u>_</u> 5×
Ele Edit Etc Help Settings Chart: 1ozAirIntPoly07 Configuration Mike_Test Calquiator	Conductor: 1-3oz Copper Weight Table Underwriter Laboratory Thermal Man Preferences 2 Preferences Materials Weights Columns Configuration Mike_Test Background Image pcuments/My Pictures/sunset.jpg Font Color Black Units Precision Thickness inch Units Precision Thickness inch Vidth inch Length inch Area sq mils Sq mils 3 Current Amps Amps 3 Voltage Volts Power Watts/aq inch Power Density Watts/aq inch Power Density Watts/inch-C Resistivity Ohm-in*2/in Board Dimensions inch	Type: Via Location: Internal Mia Depth (in) 1.00000 Ambient Temp (*C) 25.000 Initial State* Final State* Pesistance (Ohm) Initial State* Voltage Drop (*) Image: Columns Power Density (W/in*2) Columns Print M Vdrop 0 (*) Power Density (W/in*2) S000 0.063 0.063 7.204 0.063 0.063 7.204 0.094 0.094 11.586
units are inclupreferences the work in and sare calculation	enience of the user, both English and uded in the preferences section. In the user can select the units they wan set the precision of the parameters the g. ose parameters as a configuration.	he t to

Figure 5. Preferences

Click on buttons with an asterick to solve for the top anmeter Reset All Values Help Pesuits Add Modity Delete Type Location Method Thickness (inch) Width (inch) Length (inch) Area (sq mill Trace Trac	b) Cufrent (Arr 8.000 10.001 10.001 10.001 8.000 10.001 8.000 10.000 8.000 0.000 10.0000 10.000 10.000 10.0000 10.0000 10.0000 10.0000 10.0000 10.0000 10.	Configuration Background Image Thickness Width Length Area	Weights Column Mike's Preferences ents/My Pictures/SunIn Units inch inch sq mil Degrees C Amps Ohms	Water.jpg Precision 5 2 5 2 2 2 2 2 3 2 3	Print sity 0 (Watt/sq 25 31 35 34 99 50 55 55 55 55
favorite picture as a Background	8.000 10.000 F 1.586			5	95
Image.	F	Power Power Density	Voris	3 + 3 + 3 +	
		Close	<u>Save</u>	Delete	

Figure 6. Features

ThermalMan Calculator		_ 문 ×
<u>File Edit Etc Help</u>		
Settings Chart: 1ozAir/ntPoly07 Configuration Mike_Test	Conductor: 1-3oz Copper 💌	Type: Via 💌 Location: Internal 💌
Calculator	Preferences Materials Weights Columns	
Conductor Thickness (in) 0.00100 Cross Sectional Area (mil^2) Via Diameter * (in)	Name 1-3oz Copper Material Type © Qonductor © Djelectric © Besistor	pth (in) 1.00000 nt Temp (*C) 25.000 35.000 Initial State * Final State *
Current*(A)	Material Properties Thermal Conductivity (W/in-C) × 9.940	e Drop (V)
Temperature Rise * (*C) 10.000	Thermal Conductivity (W/in-C) Y 9.940	Dissipation (W)
* click on buttons with an asterisk to solve for that parameter. Reset All Values	Thermal Conductivity (W/in-C) Z 9.940	Density (W/in^2)
	Conductor Properties	
Add Modify Delete Type Location Method Thickness (in) Width (Trace Internal 10zAintPoly07 0.00135 0.0088 Trace Internal IPC 0.00135 0.0314 Via Internal 10zAintnPoly07 0.00100 0.0081	Weight (oz) 1.000 Resistivity (mOhm-in) 0.00070900 Base Temperature (C) 25.000 Temperature Coefficient (1/deg C) 0.0038536 Add Mod Del Name Type ThermalConX (W/in-C) Thermal 0.5oz Copper Conductor 9.940 9.941 Cyante Ester – S-Glass Insulator 0.009 0.008 G10 Insulator 0.012 0.012 Holometrix FR4 Insulator 0.012 0.012 Holometrix Polyimide Insulator 0.008 0.008 Penolic (X <xp)< td=""> Insulator 0.014 0.014 EC FR4 Insulator 0.009 0.002 Polyimide – Glass Insulator 0.015 0.011 Polyimide – Glass Insulator 0.013 0.011 Polyimide – Glass Insulator 0.009 0.002 Polyimide – Glass Insulator 0.015 0.015 Polyimide – Hirin, Kapton 20C Insulator 0.016 0.054</xp)<>	Columns Print rop 0 (v) Power 0 (v) Density 0 (w/in^*2) Temp F (*C) D53 0.063 7.204 35.000 D18 0.018 0.567 35.000 D34 0.094 11.586 35.000
Board material properties	are included for each test board. The th	ermal conductivity
1 1	as the z-axis for the FR4 and Polyimid	
	the properties for copper are in this data	
	1 1 11	
Calculator.	e with the Equivalent Thermal Condu	

Figure 7. Board Properties

ThermalMan Calculato le <u>E</u> dit E <u>t</u> c <u>H</u> elp	r					_8
Settings						
Chart IPC	-	Conductor: 0.5o	Copper 💌		Type:	Trace -
Configuration Jouppi1	-	and the second	erwriter Laboratory			Internal -
Conliguration [Jouppin		weight rable [Ond	erwhier Laboratory		Location:	Tintemai 🔳
Calculator						
Conductor Thickness (in)	0.00070			Conductor Length (in)	1.000	
Cross Sectional Area (mil^:	2)			Ambient Temp (*C)	25.000	
Constructors Middle				,		al State *
Conductor width	Equivilant Thermal Conductivity				<u> </u>	
Current*(A	Layer Type Material	Pct Conductor Thickness	(in) Thermal-Con X (W/in-C)	Thermal-Con Y (W/in-C)	Thermal-Con Z (W/in-C)	
Temperature Ris	1 Signal 👤 0.5oz Copper		00135 9.94000		9.94000	
	2 Dielectric - Holometrix Polyimide		01500 0.01380		0.00850	
* click on buttons with an ε	3 Power 💌 0.5oz Copper		00135 9.94000		9.94000	
Res	4 Dielectric Holometrix Polyimide		01500 0.01380		0.00850	
	5 Ground 💌 1-3oz Copper		00135 9.94000		9.94000	
Results	6 Dielectric - Holometrix Polyimide		01500 0.01380		0.00850	
Add Modify	7 Signa 0.5oz Copper	20.00000 0.	00135 9.94000	9.94000	9.94000	Print
Type Location Cha) Resist F
Type Location Cha) Resistr
		/				
	/					
		-Board Dimensions -			ermal Conductivity	
	Export Print	Width (in) 1.000		Width X (W/in-	C) 0.49133	
/		Length (in) 1.000		Length Y (W/ir	n-C) 0.49133	
/						
	<u>C</u> lose <u>S</u> olve	Depth (in) 0.050		Depth Z (W/in-	-C) [0.23014	
	/	Layers				
	/					

The Equivalent Thermal Conductivity Calculator is an aide for estimating the equivalent thermal conductivity of a board stack up. This accounts for external and internal copper planes and dielectric material.

Material properties in the database are available for the user or the user can input their own. Then the user defines the board dimensions, width, length, thickness and the number of layers. The user then defines the thickness of each layer and the percent copper on power, signal and ground layers.

This calculator is an aide for understanding what the trace heating will be in other board materials. If the effective thermal conductivity of the material is higher than the raw board material then the traces will run cooler. The important aspect to consider is that the traces dissipate power.

Figure 8. Equivalent Thermal Conductivity Calculator

ThermalMan Calculator		×
<u>File Edit Etc Help</u>		
Settings Chart 1ozAirIntPoly07 🔽	Conductor: 1-3oz Copper	Type: Via
Configuration Mike_Test	Weight Table Underwriter Laboratory	Location: Internal
Calculator		
Conductor Thickness (in) 0.00100		Via Depth (in) 1.00000
Cross Sectional Area (mil^2)		Ambient Temp (*C) 25.000 35.000
Via Diameter*(in)		Initial State * Final State *
Current*(A)	Thermal Man Preferences	2 × ence (Ohm) e Drop (V)
Temperature Rise * (*C) 10.000	Preferences Materials Weights Columns	Dissipation (W)
* click on buttons with an asterisk to solve for that parameter. Reset All Values		Density (W/in^2)
Results	Conductor Type	
Add Modify Delete	Internal/External	Columns Print
Type Location Method Thickness (in) Widt	h (rop 0 (V) Power 0 (W) Density 0 (W/in^2) Temp F (*C
Trace Internal 1ozAirIntPoly07 0.00135 0.000 Trace Internal IPC 0.00135 0.031	38	063 0.063 7.204 35.000 018 0.018 0.567 35.000
Via Internal 1ozAirIntPoly07 0.00100 🗶 0.008		034 0.094 11.586 35.000
1 /	Conductor Width	
	Conductor Thickness Conductor Rise	
	InitialTemperature InitialResistance FinalResistance	
The Columns in the	Initial Voltage Drop Initial Voltage Drop	
table are turned-on for	Initial Power Dissipation	
display and turned-off	✓ Initial Power Density ✓ Final Power Density	
when only specific		
values are of interest.		
values are of interest.	<u>C</u> lose <u>All N</u> one	
The Table can be saved		
as a comma-separated-		
variable file as)
mentioned previously or		
simply sent to your		
1,0,0,0		
printer.	Figure 9. Table Preferences	
	3	