HTT Processor and Mezzanines Cooling

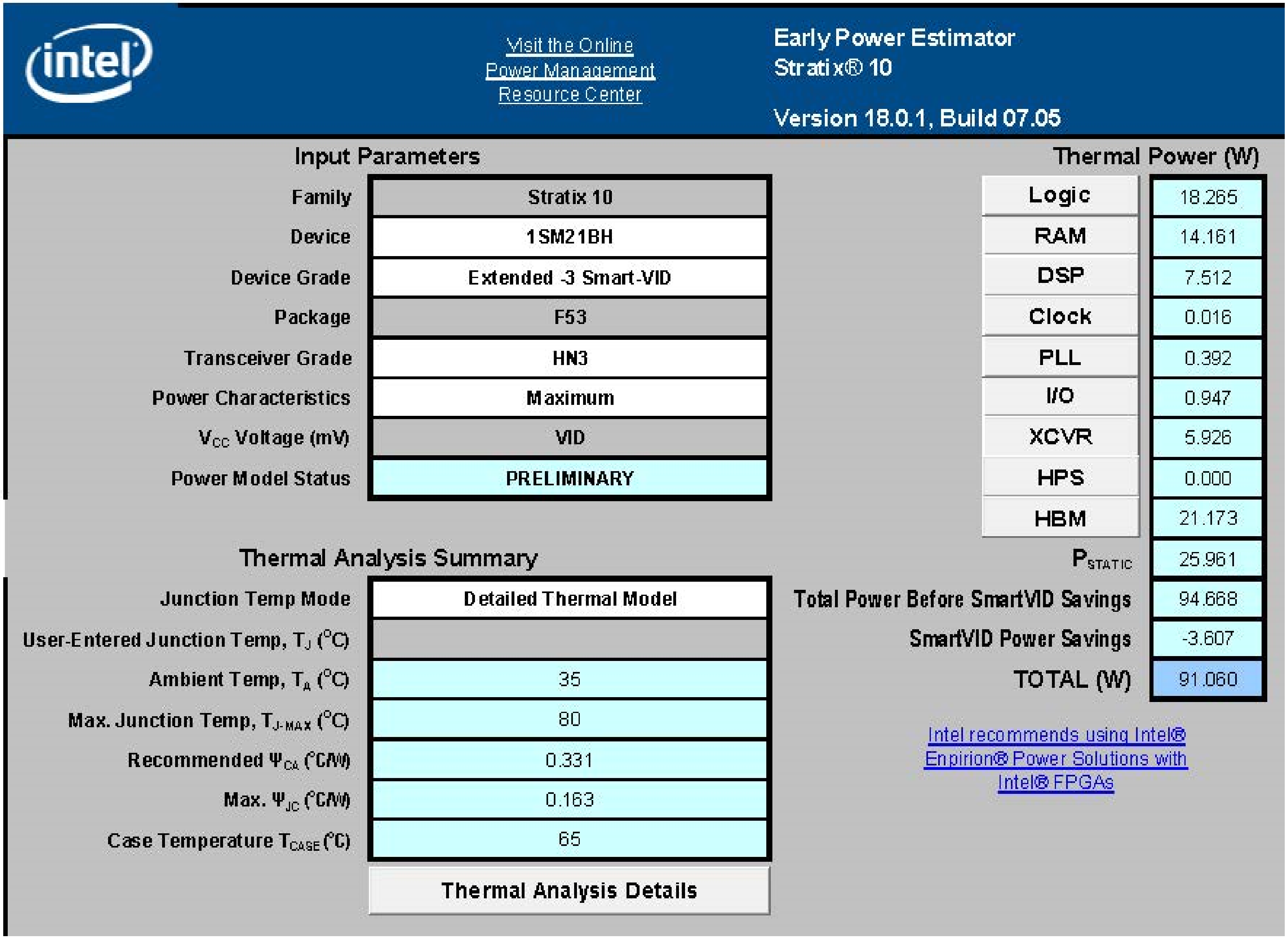
Mircea Bogdan
7/26/2018

The University of Chicago

ATCA Blade


90W
90W
90W
322.25
Pitch Line
6.61
23.00
30.48
.87
160.00
75.00
240.00
280.00

EPE - Mezzanine FPGA - Power



[Visit the Online Power Management Resource Center]

Early Power Estimator
Stratix® 10

Version 18.0.1, Build 07.05

Input Parameters

Family	Stratix 10
Device	1SM21BH
Device Grade	Extended -3 Smart-VID
Package	F53
Transceiver Grade	HN3
Power Characteristics	Maximum
V_{CC} Voltage (mV)	VID
Power Model Status	PRELIMINARY

Thermal Power (W)

Logic	18.265
RAM	14.161
DSP	7.512
Clock	0.016
PLL	0.392
I/O	0.947
XCVR	5.926
HPS	0.000
HBM	21.173
P_{STATIC}	25.961
Total Power Before SmartVID Savings	94.668
SmartVID Power Savings	-3.607
TOTAL (W)	91.060

Thermal Analysis Summary

Junction Temp Mode	Detailed Thermal Model
User-Entered Junction Temp, T_J (°C)	
Ambient Temp, T_A (°C)	35
Max. Junction Temp, $T_{J\text{-}MAX}$ (°C)	80
Recommended Ψ_{CA} (°C/W)	0.331
Max. Ψ_{JC} (°C/W)	0.163
Case Temperature T_{CASE} (°C)	65

Intel recommends using Intel® Enpirion® Power Solutions with Intel® FPGAs

http://edg.uchicago.edu/~bogdan/HTT_TrackFitterMezzanine/misc/stratix10_epe_TEST_1.xls

Please, Download and Test!

EPE - Mezzanine FPGA - Bottom

Total Power ~ 91W

80% Logic, 500MHz, HBM, etc.

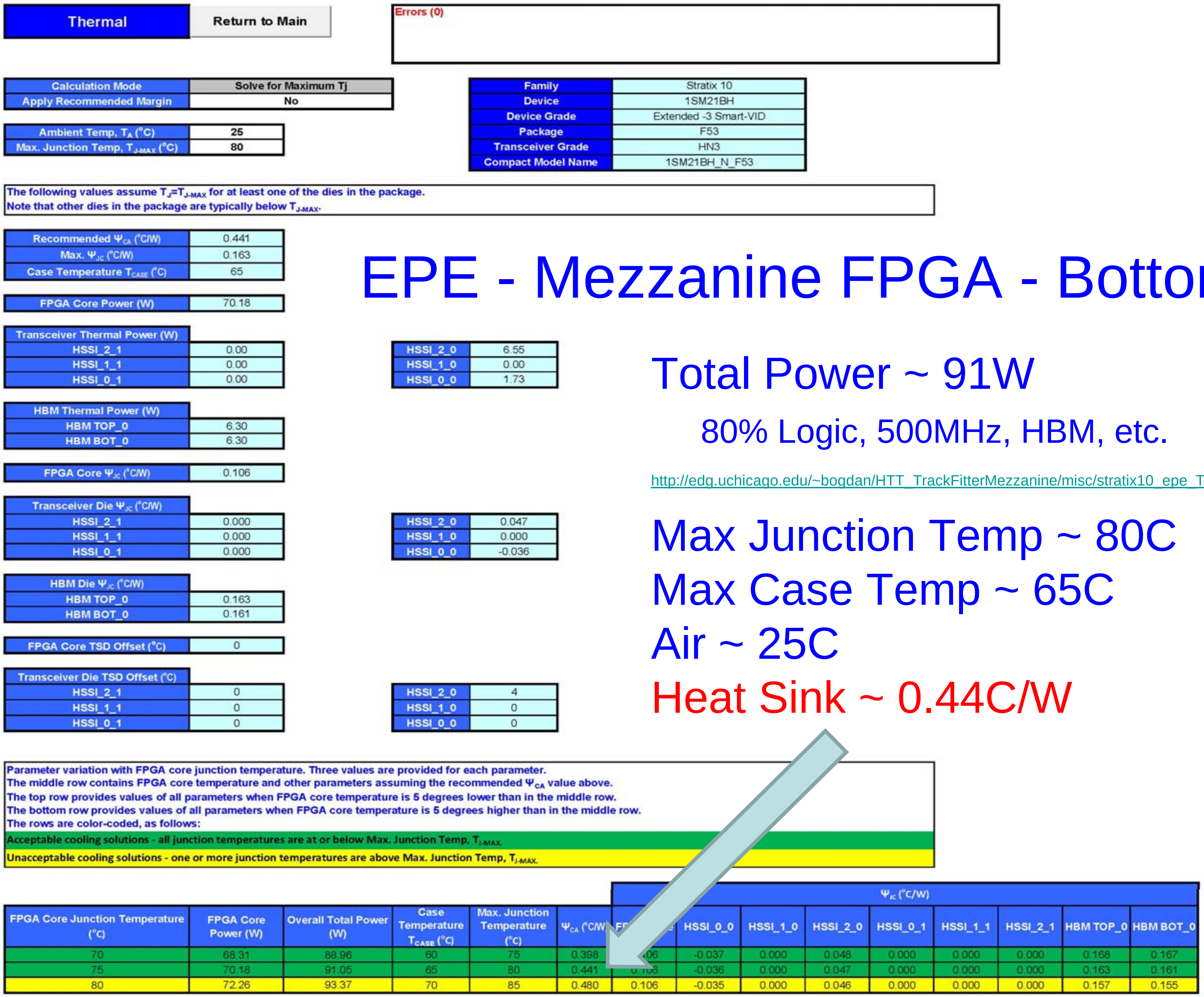
http://edg.uchicago.edu/~bogdan/HTT_TrackFitterMezzanine/misc/stratix10_epe_TEST_1.xls

Max Junction Temp ~ 80C

Max Case Temp ~ 65C

Air ~ 25C

Heat Sink ~ 0.44C/W



Thermal | Return to Main

Errors (0)

Calculation Mode	Solve for Maximum Tj
Apply Recommended Margin	No

Family	Stratix 10
Device	1SM21BH
Device Grade	Extended -3 Smart-VID
Package	F53
Transceiver Grade	HN3
Compact Model Name	1SM21BH_N_F53

Ambient Temp, T_A (°C)	25
Max. Junction Temp, $T_{J\text{-}MAX}$ (°C)	80

The following values assume T_J=$T_{J\text{-}MAX}$ for at least one of the dies in the package.
Note that other dies in the package are typically below $T_{J\text{-}MAX}$.

Recommended Ψ_{CA} (°C/W)	0.441
Max. Ψ_{JC} (°C/W)	0.163
Case Temperature T_{CASE} (°C)	65

FPGA Core Power (W)	70.18

Transceiver Thermal Power (W)			
HSSI_2_1	0.00	HSSI_2_0	6.55
HSSI_1_1	0.00	HSSI_1_0	0.00
HSSI_0_1	0.00	HSSI_0_0	1.73

HBM Thermal Power (W)	
HBM TOP_0	6.30
HBM BOT_0	6.30

FPGA Core Ψ_{JC} (°C/W)	0.106

Transceiver Die Ψ_{JC} (°C/W)			
HSSI_2_1	0.000	HSSI_2_0	0.047
HSSI_1_1	0.000	HSSI_1_0	0.000
HSSI_0_1	0.000	HSSI_0_0	-0.036

HBM Die Ψ_{JC} (°C/W)	
HBM TOP_0	0.163
HBM BOT_0	0.161

FPGA Core TSD Offset (°C)	0

Transceiver Die TSD Offset (°C)			
HSSI_2_1	0	HSSI_2_0	4
HSSI_1_1	0	HSSI_1_0	0
HSSI_0_1	0	HSSI_0_0	0

Parameter variation with FPGA core junction temperature. Three values are provided for each parameter.
The middle row contains FPGA core temperature and other parameters assuming the recommended Ψ_{CA} value above.
The top row provides values of all parameters when FPGA core temperature is 5 degrees lower than in the middle row.
The bottom row provides values of all parameters when FPGA core temperature is 5 degrees higher than in the middle row.
The rows are color-coded, as follows:

🟩 Acceptable cooling solutions - all junction temperatures are at or below Max. Junction Temp, $T_{J\text{-}MAX}$.

🟨 Unacceptable cooling solutions - one or more junction temperatures are above Max. Junction Temp, $T_{J\text{-}MAX}$.

						Ψ_{JC} (°C/W)								
FPGA Core Junction Temperature (°C)	FPGA Core Power (W)	Overall Total Power (W)	Case Temperature T_{CASE} (°C)	Max. Junction Temperature (°C)	Ψ_{CA} (°C/W	FF	HSSI_0_0	HSSI_1_0	HSSI_2_0	HSSI_0_1	HSSI_1_1	HSSI_2_1	HBM TOP_0	HBM BOT_0
🟩 70	68.31	88.96	60	75	0.398	06	-0.037	0.000	0.048	0.000	0.000	0.000	0.168	0.167
🟩 75	70.18	91.05	65	80	0.441	0.106	-0.036	0.000	0.047	0.000	0.000	0.000	0.163	0.161
🟨 80	72.26	93.37	70	85	0.480	0.106	-0.035	0.000	0.046	0.000	0.000	0.000	0.157	0.155

EPE - Mezzanine FPGA - Top

Total Power ~ 91W

80% Logic, 500MHz, HBM, etc.

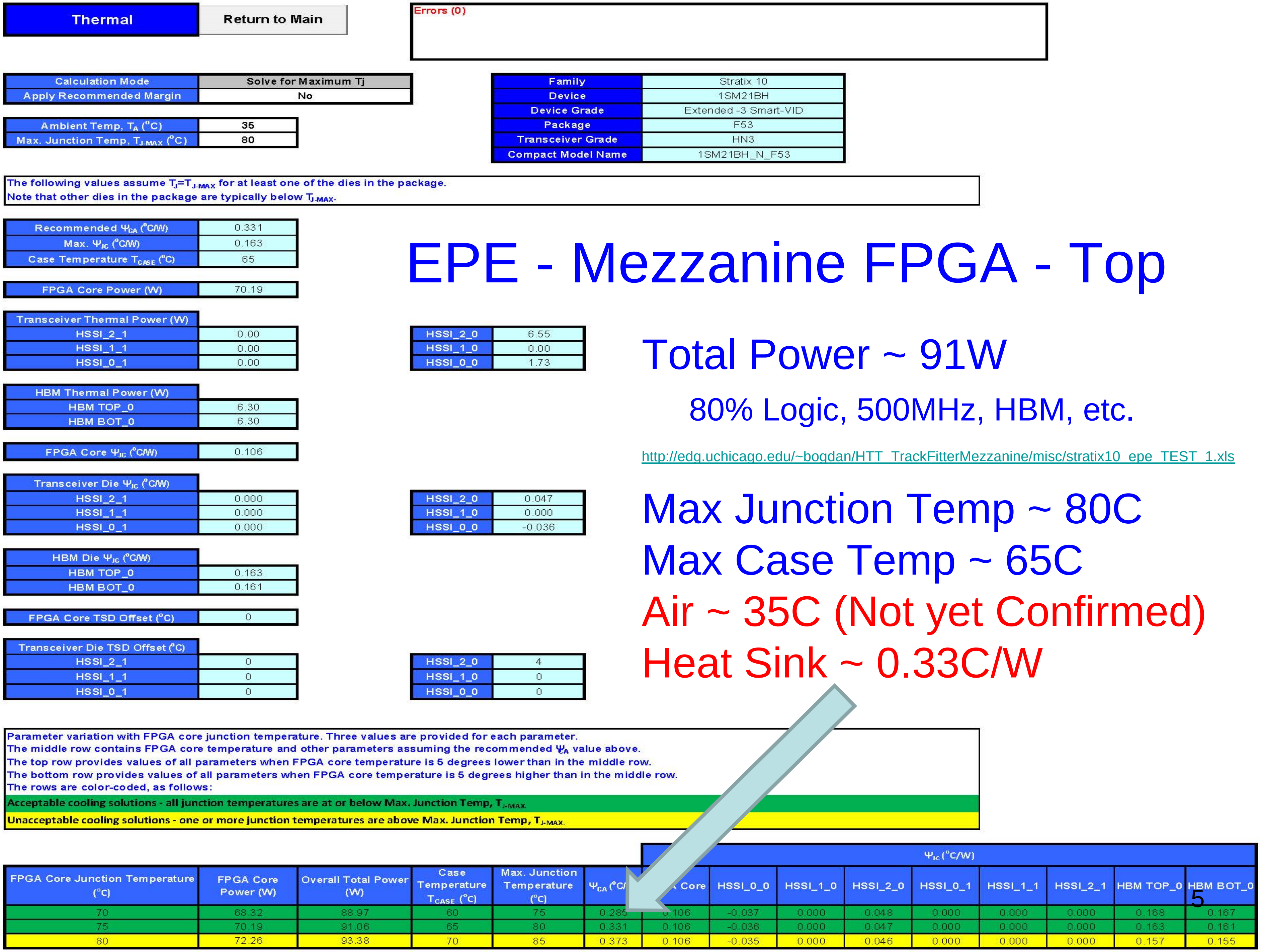
http://edg.uchicago.edu/~bogdan/HTT_TrackFitterMezzanine/misc/stratix10_epe_TEST_1.xls

Max Junction Temp ~ 80C

Max Case Temp ~ 65C

Air ~ 35C (Not yet Confirmed)

Heat Sink ~ 0.33C/W



Errors (0)

Calculation Mode	Solve for Maximum Tj
Apply Recommended Margin	No

Ambient Temp, T_A (°C)	35
Max. Junction Temp, T_{J-MAX} (°C)	80

Family	Stratix 10
Device	1SM21BH
Device Grade	Extended -3 Smart-VID
Package	F53
Transceiver Grade	HN3
Compact Model Name	1SM21BH_N_F53

The following values assume $T_J = T_{J-MAX}$ for at least one of the dies in the package.
Note that other dies in the package are typically below T_{J-MAX}.

Recommended Ψ_{CA} (°C/W)	0.331
Max. Ψ_{JC} (°C/W)	0.163
Case Temperature T_{CASE} (°C)	65

FPGA Core Power (W)	70.19

Transceiver Thermal Power (W)			
HSSI_2_1	0.00	HSSI_2_0	6.55
HSSI_1_1	0.00	HSSI_1_0	0.00
HSSI_0_1	0.00	HSSI_0_0	1.73

HBM Thermal Power (W)	
HBM TOP_0	6.30
HBM BOT_0	6.30

FPGA Core Ψ_{JC} (°C/W)	0.106

Transceiver Die Ψ_{JC} (°C/W)			
HSSI_2_1	0.000	HSSI_2_0	0.047
HSSI_1_1	0.000	HSSI_1_0	0.000
HSSI_0_1	0.000	HSSI_0_0	-0.036

HBM Die Ψ_{JC} (°C/W)	
HBM TOP_0	0.163
HBM BOT_0	0.161

FPGA Core TSD Offset (°C)	0

Transceiver Die TSD Offset (°C)			
HSSI_2_1	0	HSSI_2_0	4
HSSI_1_1	0	HSSI_1_0	0
HSSI_0_1	0	HSSI_0_0	0

Parameter variation with FPGA core junction temperature. Three values are provided for each parameter.
The middle row contains FPGA core temperature and other parameters assuming the recommended Ψ_{CA} value above.
The top row provides values of all parameters when FPGA core temperature is 5 degrees lower than in the middle row.
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🟩 Acceptable cooling solutions - all junction temperatures are at or below Max. Junction Temp, T_{J-MAX}.

🟨 Unacceptable cooling solutions - one or more junction temperatures are above Max. Junction Temp, T_{J-MAX}.

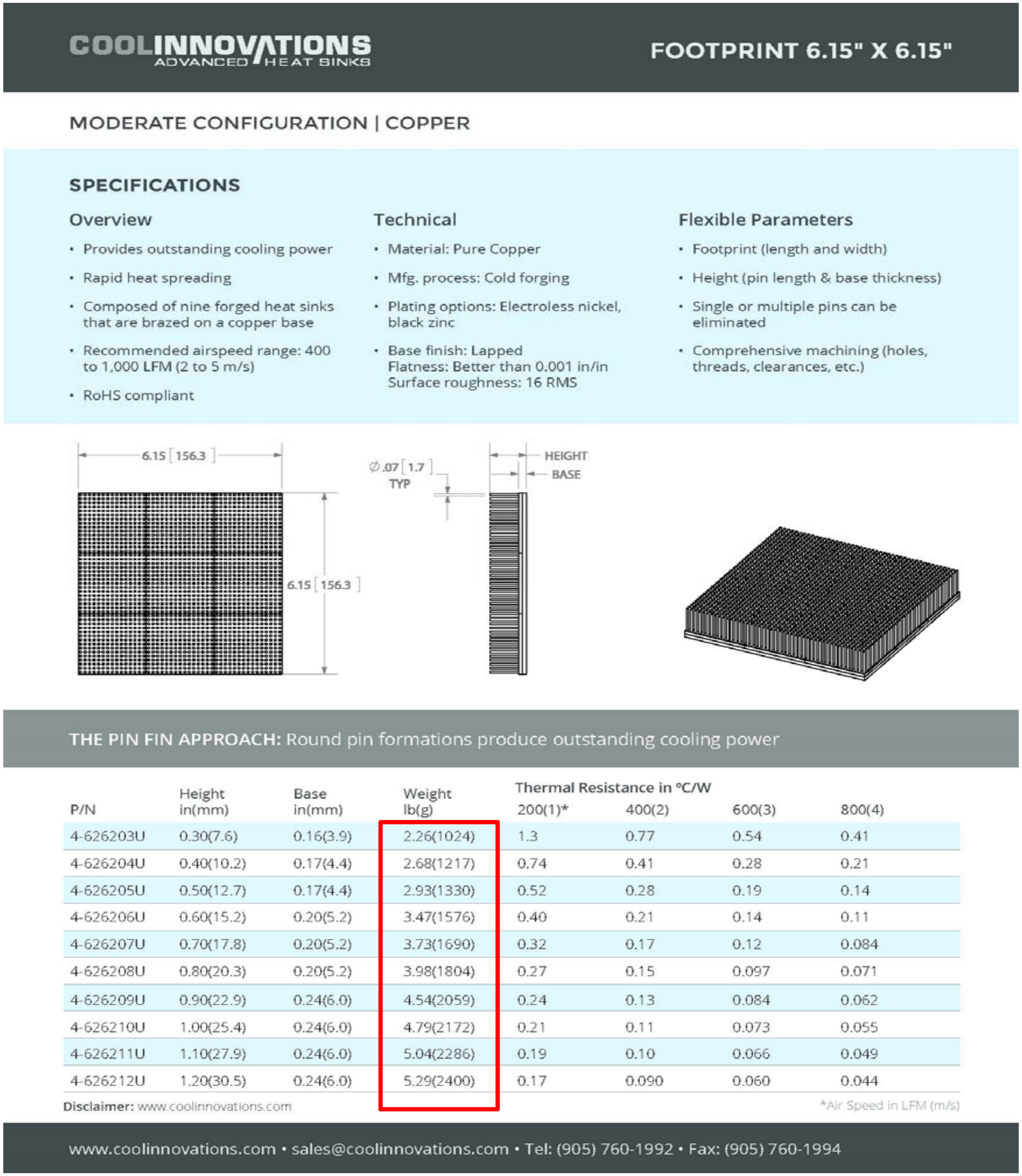
						Ψ_{JC} (°C/W)								
FPGA Core Junction Temperature (°C)	FPGA Core Power (W)	Overall Total Power (W)	Case Temperature T_{CASE} (°C)	Max. Junction Temperature (°C)	Ψ_{CA} (°C/	Core	HSSI_0_0	HSSI_1_0	HSSI_2_0	HSSI_0_1	HSSI_1_1	HSSI_2_1	HBM TOP_0	HBM BOT_0
70	68.32	88.97	60	75	0.285	0.106	-0.037	0.000	0.048	0.000	0.000	0.000	0.168	0.167
75	70.19	91.06	65	80	0.331	0.106	-0.036	0.000	0.047	0.000	0.000	0.000	0.163	0.161
80	72.26	93.38	70	85	0.373	0.106	-0.035	0.000	0.046	0.000	0.000	0.000	0.157	0.155

Heat Sink - 1

> $200/piece
> 2Lb/piece

Needs Solid Mechanical Attachment

130x130x13mm Heat Sink ~1kg.



COOLINNOVATIONS ADVANCED HEAT SINKS

FOOTPRINT 6.15" X 6.15"

MODERATE CONFIGURATION | COPPER

SPECIFICATIONS

Overview

- Provides outstanding cooling power
- Rapid heat spreading
- Composed of nine forged heat sinks that are brazed on a copper base
- Recommended airspeed range: 400 to 1,000 LFM (2 to 5 m/s)
- RoHS compliant

Technical

- Material: Pure Copper
- Mfg. process: Cold forging
- Plating options: Electroless nickel, black zinc
- Base finish: Lapped
  Flatness: Better than 0.001 in/in
  Surface roughness: 16 RMS

Flexible Parameters

- Footprint (length and width)
- Height (pin length & base thickness)
- Single or multiple pins can be eliminated
- Comprehensive machining (holes, threads, clearances, etc.)

THE PIN FIN APPROACH: Round pin formations produce outstanding cooling power

P/N	Height in(mm)	Base in(mm)	Weight lb(g)	Thermal Resistance in °C/W 200(1)*	400(2)	600(3)	800(4)
4-626203U	0.30(7.6)	0.16(3.9)	2.26(1024)	1.3	0.77	0.54	0.41
4-626204U	0.40(10.2)	0.17(4.4)	2.68(1217)	0.74	0.41	0.28	0.21
4-626205U	0.50(12.7)	0.17(4.4)	2.93(1330)	0.52	0.28	0.19	0.14
4-626206U	0.60(15.2)	0.20(5.2)	3.47(1576)	0.40	0.21	0.14	0.11
4-626207U	0.70(17.8)	0.20(5.2)	3.73(1690)	0.32	0.17	0.12	0.084
4-626208U	0.80(20.3)	0.20(5.2)	3.98(1804)	0.27	0.15	0.097	0.071
4-626209U	0.90(22.9)	0.24(6.0)	4.54(2059)	0.24	0.13	0.084	0.062
4-626210U	1.00(25.4)	0.24(6.0)	4.79(2172)	0.21	0.11	0.073	0.055
4-626211U	1.10(27.9)	0.24(6.0)	5.04(2286)	0.19	0.10	0.066	0.049
4-626212U	1.20(30.5)	0.24(6.0)	5.29(2400)	0.17	0.090	0.060	0.044

Disclaimer: www.coolinnovations.com

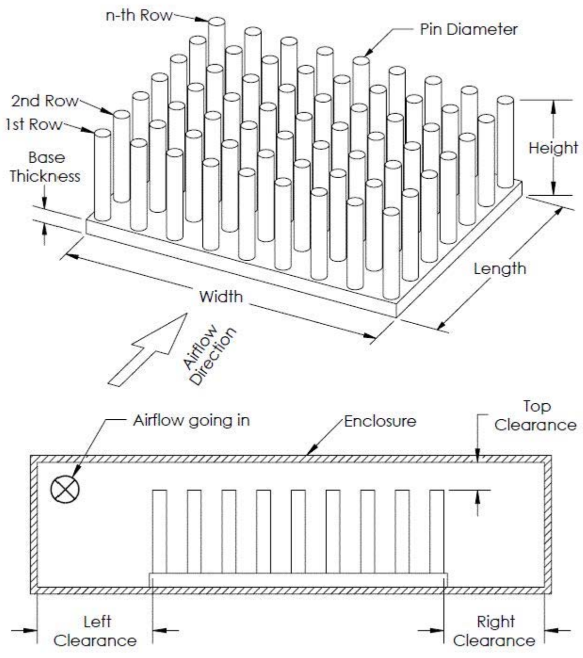
*Air Speed in LFM (m/s)

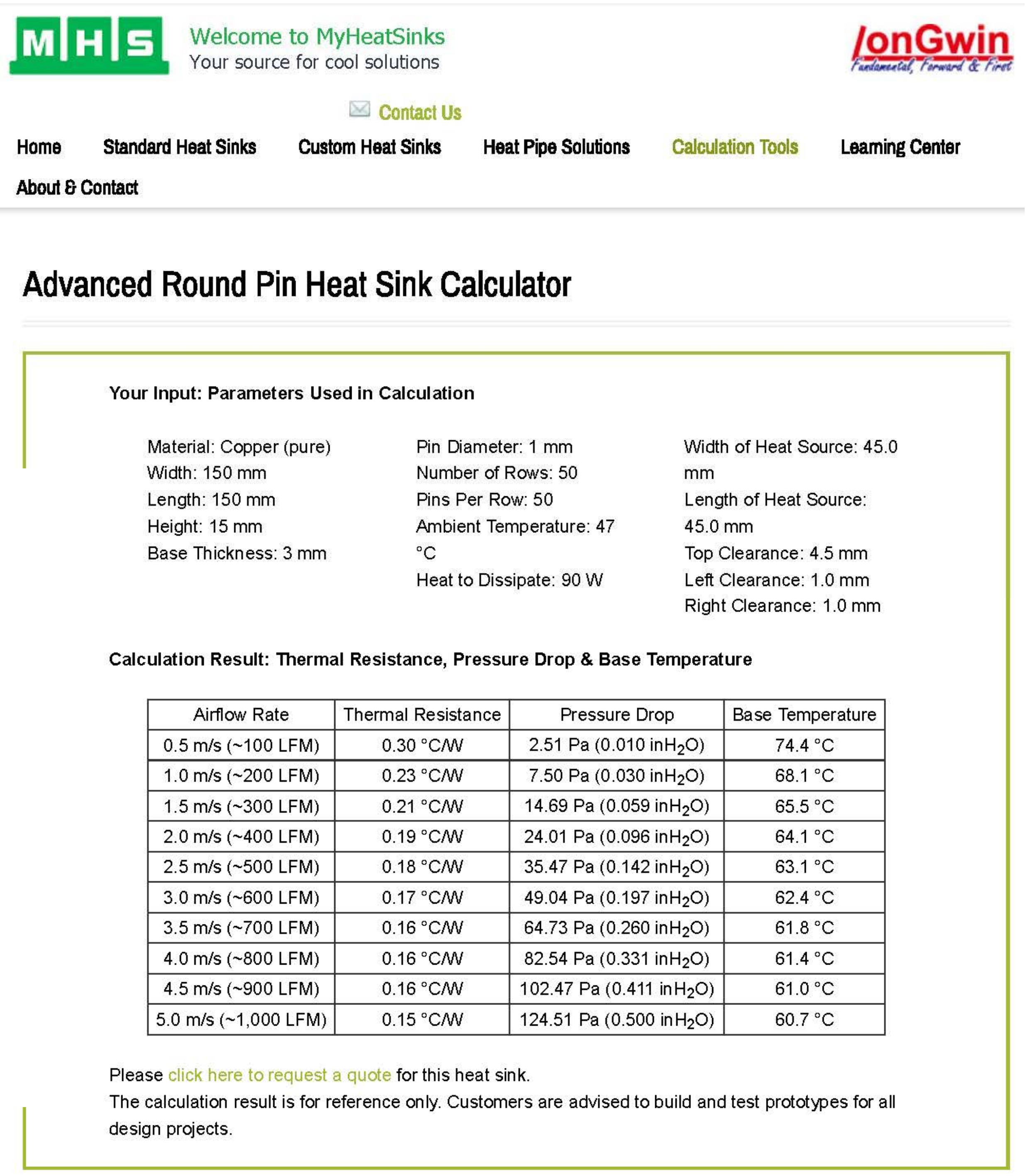
www.coolinnovations.com • sales@coolinnovations.com • Tel: (905) 760-1992 • Fax: (905) 760-1994

Heat Sink - 2

No Quote Yet

Example 1





Advanced Round Pin Heat Sink Calculator

Your Input: Parameters Used in Calculation

Material: Copper (pure)
Width: 150 mm
Length: 150 mm
Height: 15 mm
Base Thickness: 3 mm

Pin Diameter: 1 mm
Number of Rows: 50
Pins Per Row: 50
Ambient Temperature: 47 °C
Heat to Dissipate: 90 W

Width of Heat Source: 45.0 mm
Length of Heat Source: 45.0 mm
Top Clearance: 4.5 mm
Left Clearance: 1.0 mm
Right Clearance: 1.0 mm

Calculation Result: Thermal Resistance, Pressure Drop & Base Temperature

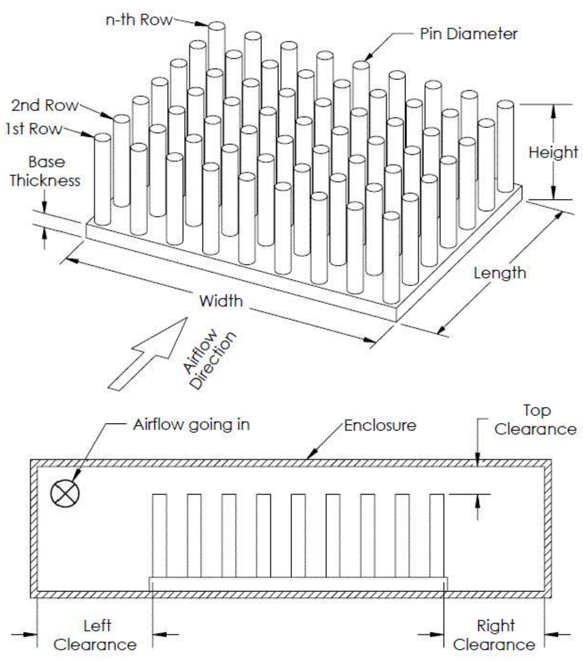
Airflow Rate	Thermal Resistance	Pressure Drop	Base Temperature
0.5 m/s (~100 LFM)	0.30 °C/W	2.51 Pa (0.010 inH$_2$O)	74.4 °C
1.0 m/s (~200 LFM)	0.23 °C/W	7.50 Pa (0.030 inH$_2$O)	68.1 °C
1.5 m/s (~300 LFM)	0.21 °C/W	14.69 Pa (0.059 inH$_2$O)	65.5 °C
2.0 m/s (~400 LFM)	0.19 °C/W	24.01 Pa (0.096 inH$_2$O)	64.1 °C
2.5 m/s (~500 LFM)	0.18 °C/W	35.47 Pa (0.142 inH$_2$O)	63.1 °C
3.0 m/s (~600 LFM)	0.17 °C/W	49.04 Pa (0.197 inH$_2$O)	62.4 °C
3.5 m/s (~700 LFM)	0.16 °C/W	64.73 Pa (0.260 inH$_2$O)	61.8 °C
4.0 m/s (~800 LFM)	0.16 °C/W	82.54 Pa (0.331 inH$_2$O)	61.4 °C
4.5 m/s (~900 LFM)	0.16 °C/W	102.47 Pa (0.411 inH$_2$O)	61.0 °C
5.0 m/s (~1,000 LFM)	0.15 °C/W	124.51 Pa (0.500 inH$_2$O)	60.7 °C

Please click here to request a quote for this heat sink.
The calculation result is for reference only. Customers are advised to build and test prototypes for all design projects.

Heat Sink - 2

No Quote Yet

Example 2



Advanced Round Pin Heat Sink Calculator

Your Input: Parameters Used in Calculation

Material: Copper (pure)
Width: 130 mm
Length: 130 mm
Height: 15 mm
Base Thickness: 3 mm

Pin Diameter: 1 mm
Number of Rows: 50
Pins Per Row: 50
Ambient Temperature: 47 °C
Heat to Dissipate: 90 W

Width of Heat Source: 45.0 mm
Length of Heat Source: 45.0 mm
Top Clearance: 4.5 mm
Left Clearance: 1.0 mm
Right Clearance: 1.0 mm

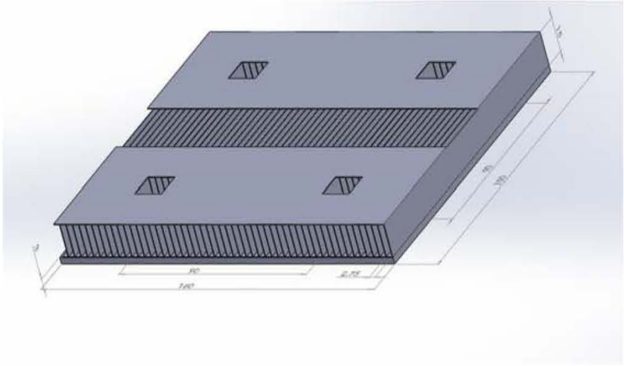
Calculation Result: Thermal Resistance, Pressure Drop & Base Temperature

Airflow Rate	Thermal Resistance	Pressure Drop	Base Temperature
0.5 m/s (~100 LFM)	0.30 °C/W	2.59 Pa (0.010 inH$_2$O)	73.7 °C
1.0 m/s (~200 LFM)	0.22 °C/W	7.92 Pa (0.032 inH$_2$O)	66.7 °C
1.5 m/s (~300 LFM)	0.19 °C/W	15.60 Pa (0.063 inH$_2$O)	64.0 °C
2.0 m/s (~400 LFM)	0.17 °C/W	25.56 Pa (0.103 inH$_2$O)	62.5 °C
2.5 m/s (~500 LFM)	0.16 °C/W	37.75 Pa (0.152 inH$_2$O)	61.5 °C
3.0 m/s (~600 LFM)	0.15 °C/W	52.18 Pa (0.209 inH$_2$O)	60.8 °C
3.5 m/s (~700 LFM)	0.15 °C/W	68.83 Pa (0.276 inH$_2$O)	60.2 °C
4.0 m/s (~800 LFM)	0.14 °C/W	87.71 Pa (0.352 inH$_2$O)	59.8 °C
4.5 m/s (~900 LFM)	0.14 °C/W	108.81 Pa (0.437 inH$_2$O)	59.4 °C
5.0 m/s (~1,000 LFM)	0.13 °C/W	132.14 Pa (0.530 inH$_2$O)	59.1 °C

Please click here to request a quote for this heat sink.
The calculation result is for reference only. Customers are advised to build and test prototypes for all design projects.

Heat Sink - 3

Forced Convection Fin Pack with Vapor Chamber Base



Module Dimension:W160*L150*H18mm

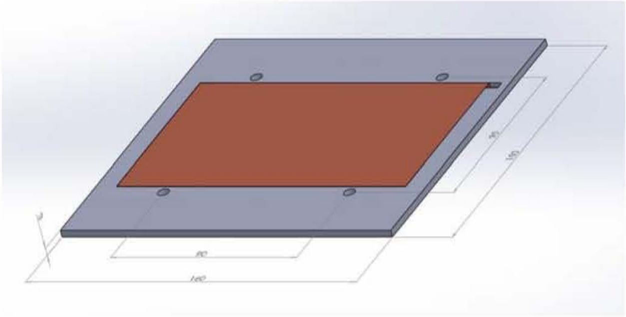
Base thickness:3mm

VC dimension: 82*145*3.0mm

Fin hight:15mm

Fin Gap:2.75mm

Fin thickness:0.3mm

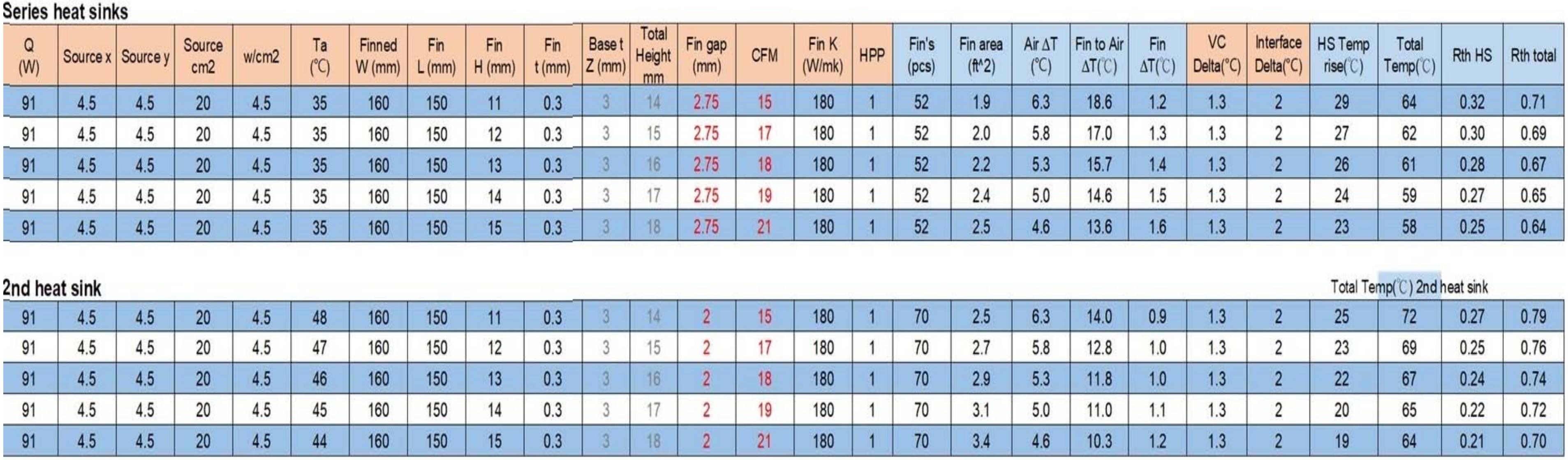


~$335/piece + NRE (~$6K)
~490g/piece

Heat Sink - 3

Simulation Received from Celsia Inc.

Results for 11 - 15mm Fin Heights



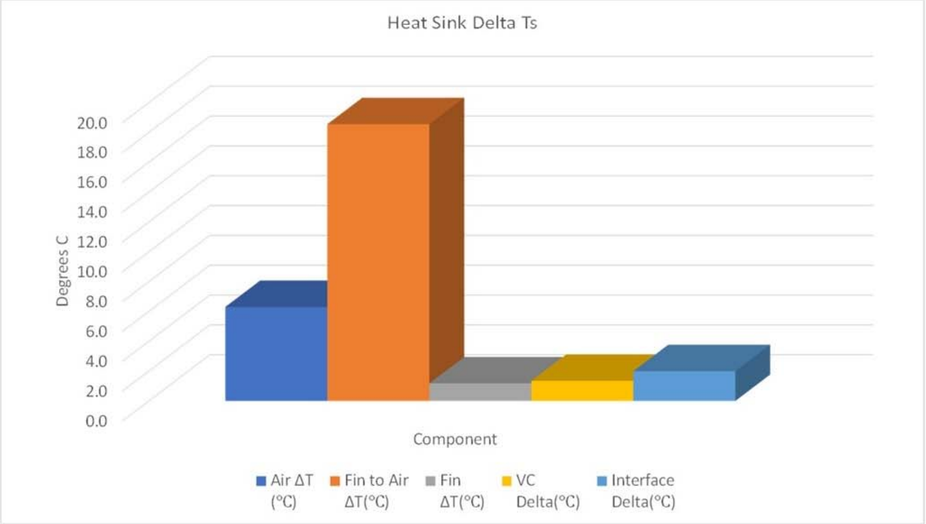
Series heat sinks

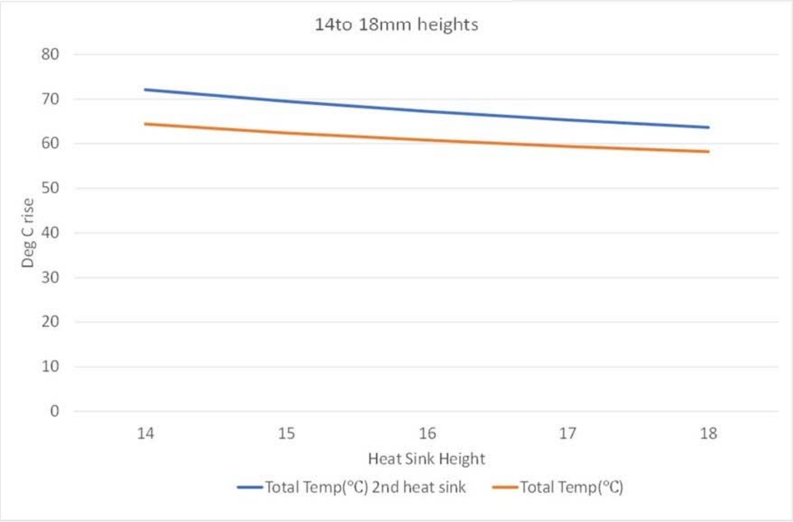
Q (W)	Source x	Source y	Source cm2	w/cm2	Ta (℃)	Finned W (mm)	Fin L (mm)	Fin H (mm)	Fin t (mm)	Base t Z (mm)	Total Height mm	Fin gap (mm)	CFM	Fin K (W/mk)	HPP	Fin's (pcs)	Fin area (ft^2)	Air ΔT (℃)	Fin to Air ΔT(℃)	Fin ΔT(℃)	VC Delta(°C)	Interface Delta(°C)	HS Temp rise(℃)	Total Temp(℃)	Rth HS	Rth total
91	4.5	4.5	20	4.5	35	160	150	11	0.3	3	14	2.75	15	180	1	52	1.9	6.3	18.6	1.2	1.3	2	29	64	0.32	0.71
91	4.5	4.5	20	4.5	35	160	150	12	0.3	3	15	2.75	17	180	1	52	2.0	5.8	17.0	1.3	1.3	2	27	62	0.30	0.69
91	4.5	4.5	20	4.5	35	160	150	13	0.3	3	16	2.75	18	180	1	52	2.2	5.3	15.7	1.4	1.3	2	26	61	0.28	0.67
91	4.5	4.5	20	4.5	35	160	150	14	0.3	3	17	2.75	19	180	1	52	2.4	5.0	14.6	1.5	1.3	2	24	59	0.27	0.65
91	4.5	4.5	20	4.5	35	160	150	15	0.3	3	18	2.75	21	180	1	52	2.5	4.6	13.6	1.6	1.3	2	23	58	0.25	0.64

2nd heat sink

Total Temp(℃) 2nd heat sink

91	4.5	4.5	20	4.5	48	160	150	11	0.3	3	14	2	15	180	1	70	2.5	6.3	14.0	0.9	1.3	2	25	72	0.27	0.79
91	4.5	4.5	20	4.5	47	160	150	12	0.3	3	15	2	17	180	1	70	2.7	5.8	12.8	1.0	1.3	2	23	69	0.25	0.76
91	4.5	4.5	20	4.5	46	160	150	13	0.3	3	16	2	18	180	1	70	2.9	5.3	11.8	1.0	1.3	2	22	67	0.24	0.74
91	4.5	4.5	20	4.5	45	160	150	14	0.3	3	17	2	19	180	1	70	3.1	5.0	11.0	1.1	1.3	2	20	65	0.22	0.72
91	4.5	4.5	20	4.5	44	160	150	15	0.3	3	18	2	21	180	1	70	3.4	4.6	10.3	1.2	1.3	2	19	64	0.21	0.70





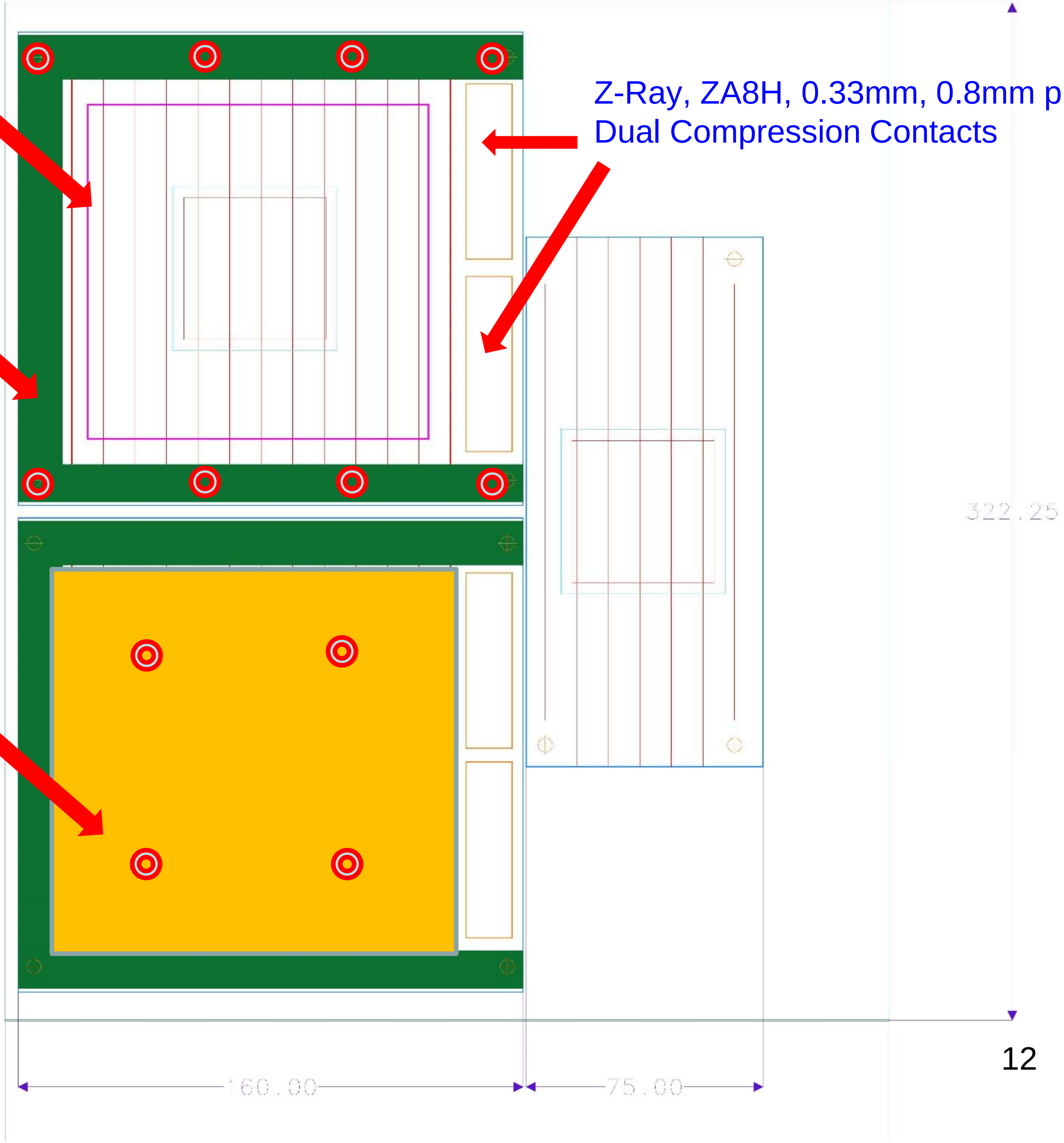
Comments – Questions -1

We have to reduce the gap between motherboards and mezzanines.

- Mezzanine Connectors Height < 0.5mm?
- Samtec Z-Ray Interposers?
- Can we cut hole in the mother board under each mezzanine card?
- Will mother board stay mechanically strong?
- Heavy Mezzanine Cards
  - Crate Manufacturer Discussion Needed?
  - We have to build and test dummy boards

Have to make sure the entire system is structurally sound before everything else

Mezzanine Mounting Example



100x100mm Cutout
In Motherboard

Gasket - 0.33mm

Heat Sink –
130x130x18mm

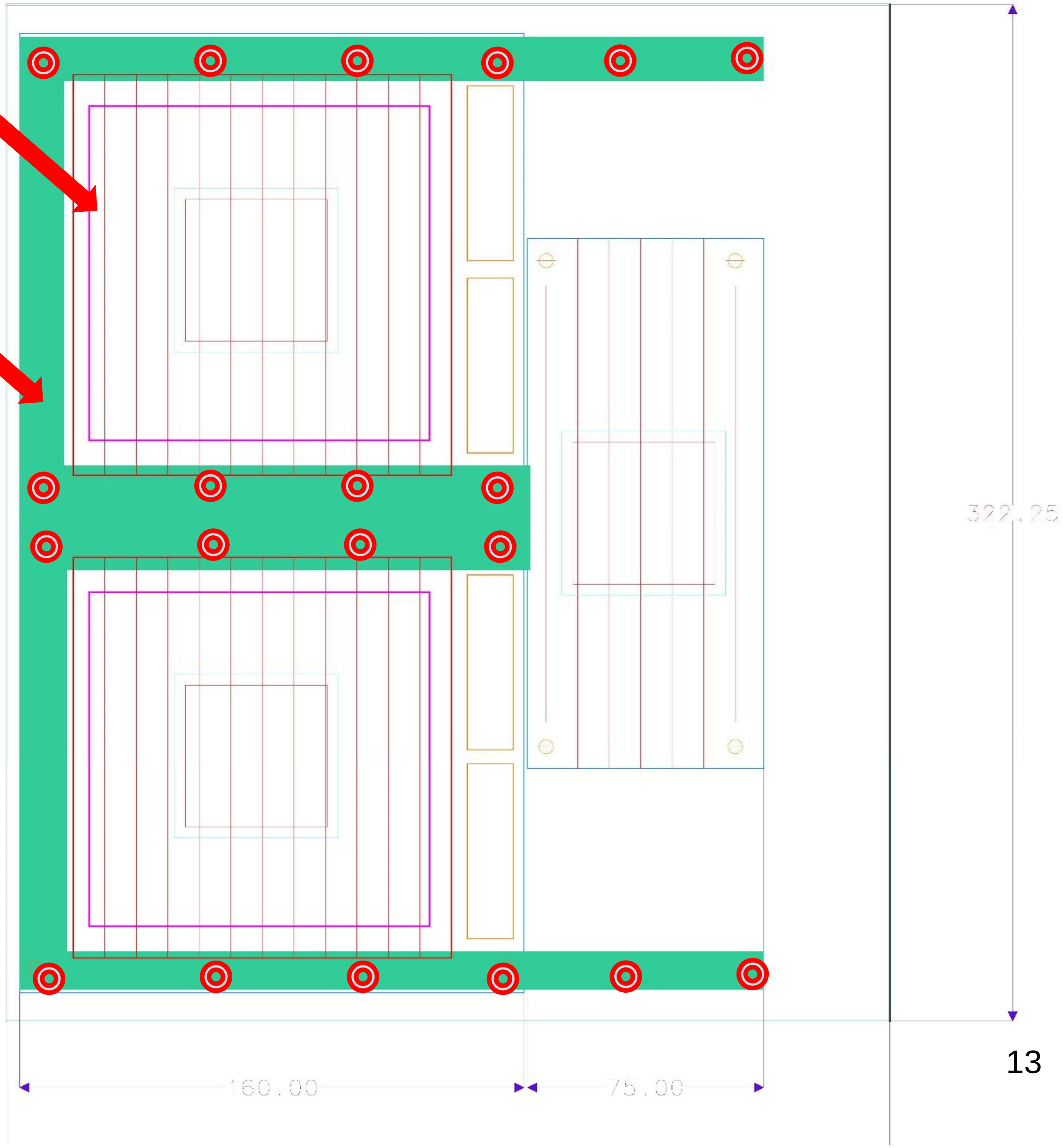
Z-Ray, ZA8H, 0.33mm, 0.8mm pitch
Dual Compression Contacts

Mezzanine Mounting Example

100x100mm Cutout
In Motherboard

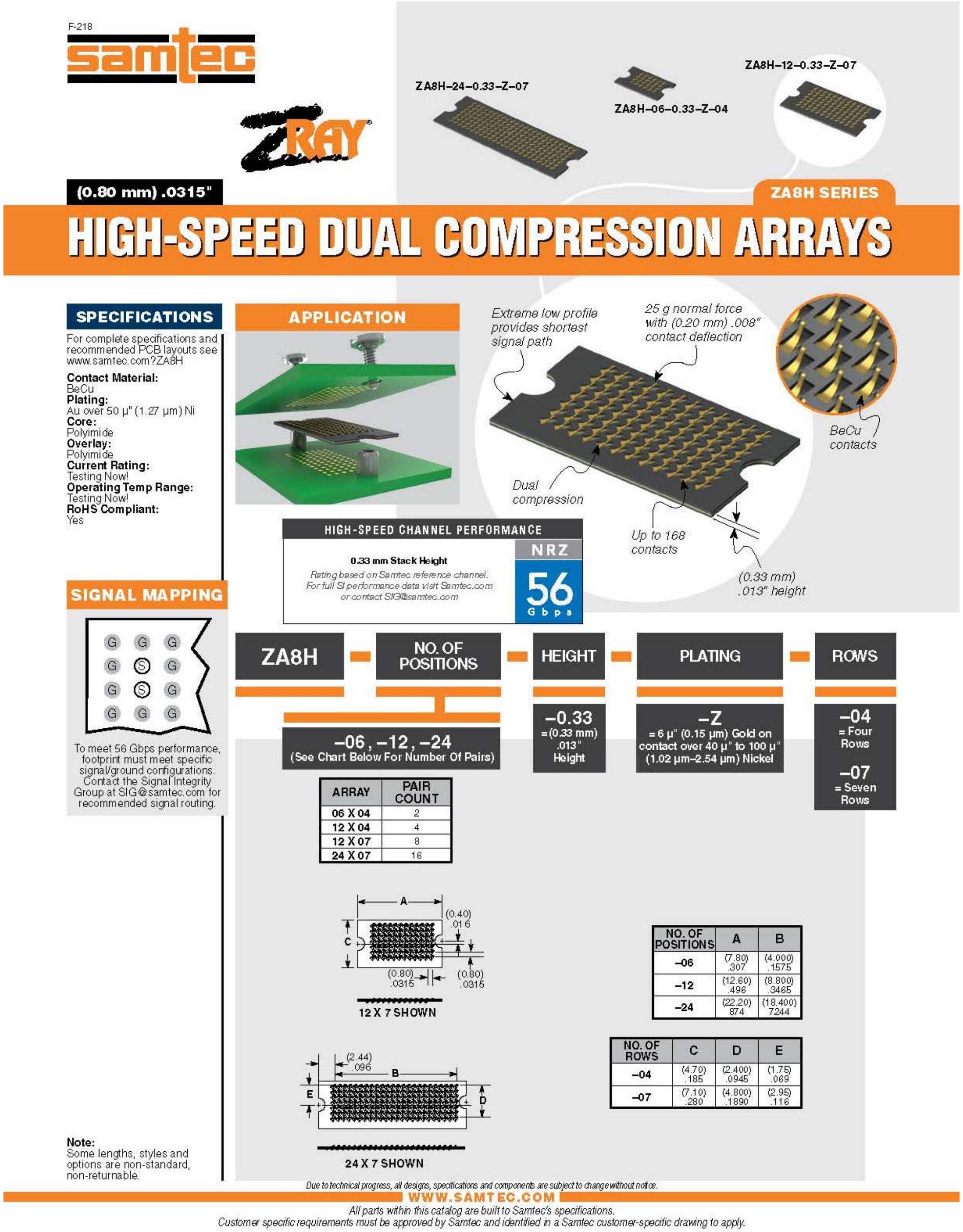
Stiffener – 1.5mm
On Bottom Side of
Motherboard

May need Stiffener on bottom of motherboard.



Z-Ray - ZA8H

Need to test this?



F-218

samtec

Z-RAY®

ZA8H–24–0.33–Z–07

ZA8H–06–0.33–Z–04

ZA8H–12–0.33–Z–07

(0.80 mm) .0315"

ZA8H SERIES

HIGH-SPEED DUAL COMPRESSION ARRAYS

SPECIFICATIONS

For complete specifications and recommended PCB layouts see www.samtec.com?ZA8H

Contact Material:
BeCu
Plating:
Au over 50 µ" (1.27 µm) Ni
Core:
Polyimide
Overlay:
Polyimide
Current Rating:
Testing Now!
Operating Temp Range:
Testing Now!
RoHS Compliant:
Yes

APPLICATION

Extreme low profile provides shortest signal path

25 g normal force with (0.20 mm) .008" contact deflection

BeCu contacts

Dual compression

Up to 168 contacts

(0.33 mm) .013" height

HIGH-SPEED CHANNEL PERFORMANCE

0.33 mm Stack Height

Rating based on Samtec reference channel. For full SI performance data visit Samtec.com or contact SIG@samtec.com

NRZ 56 Gbps

SIGNAL MAPPING

G G G
G S G
G S G
G G G

To meet 56 Gbps performance, footprint must meet specific signal/ground configurations. Contact the Signal Integrity Group at SIG@samtec.com for recommended signal routing.

ZA8H	NO. OF POSITIONS	HEIGHT	PLATING	ROWS
	–06, –12, –24 (See Chart Below For Number Of Pairs)	–0.33 = (0.33 mm) .013" Height	–Z = 6 µ" (0.15 µm) Gold on contact over 40 µ" to 100 µ" (1.02 µm–2.54 µm) Nickel	–04 = Four Rows –07 = Seven Rows

ARRAY	PAIR COUNT
06 X 04	2
12 X 04	4
12 X 07	8
24 X 07	16

A
(0.40) .016
C
(0.80) .0315
(0.80) .0315

12 X 7 SHOWN

(2.44) .096
B
E
D

24 X 7 SHOWN

NO. OF POSITIONS	A	B
–06	(7.80) .307	(4.000) .1575
–12	(12.60) .496	(8.800) .3465
–24	(22.20) 874	(18.400) 7244

NO. OF ROWS	C	D	E
–04	(4.70) .185	(2.400) .0945	(1.75) .069
–07	(7.10) .280	(4.800) .1890	(2.95) .116

Note:
Some lengths, styles and options are non-standard, non-returnable.

Due to technical progress, all designs, specifications and components are subject to change without notice.

WWW.SAMTEC.COM

All parts within this catalog are built to Samtec's specifications.
Customer specific requirements must be approved by Samtec and identified in a Samtec customer-specific drawing to apply.

Comments – Questions -3

- Over 360W/slot - Not a Trivial Issue
- It looks like it can be done with sufficient power and cooling

Thermal Simulation in Steps:

- Simulate one and two mezzanines
  - In Chicago, we plan to download and test FloTERM in the next few weeks. We’ll see how this goes.
- One full ATCA Blade and the Full Crate will need to be simulated in the future.
- Does vendor simulate the crates they manufacture?

Comments – Questions - 4

We have to agree about acceptable architecture: connectors, PCB geometries, PCB cutouts, etc. before we start simulating.

If we end up with not enough margin:

- Double width ATCA Carrier Blade?