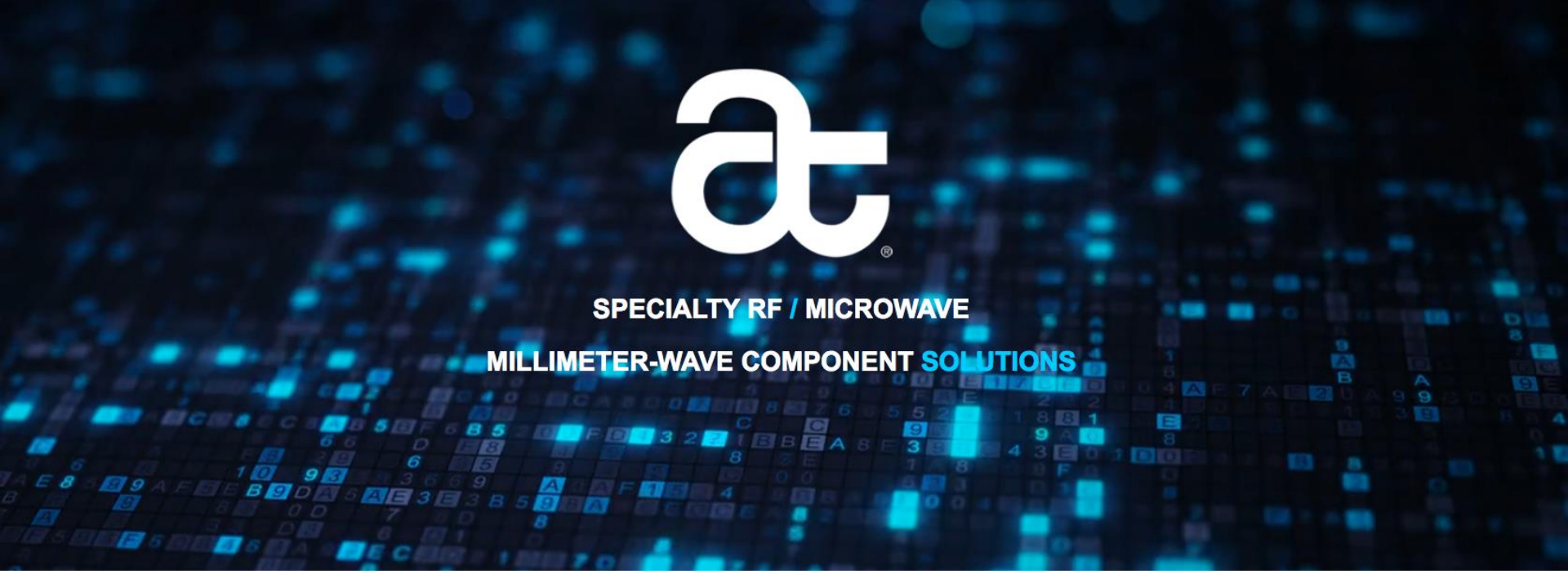

SMT Heat Pipes: A Novel Thermal Control Option

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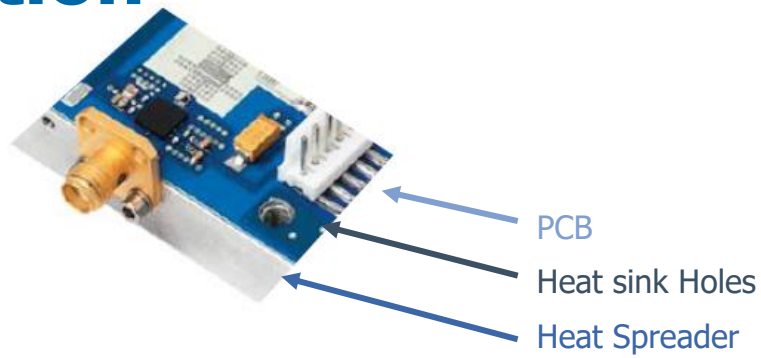
OUTLINE

- The problem:
  - Advanced IC technology generating massive heat flux
- The solution:
  - "Cooling"
- SMT Heat Pipe
  - Concept
  - parameters
- Application Use Studies
- Summary

Problem & Solution



Problem

High power semiconductor generating large amounts of power in a small area

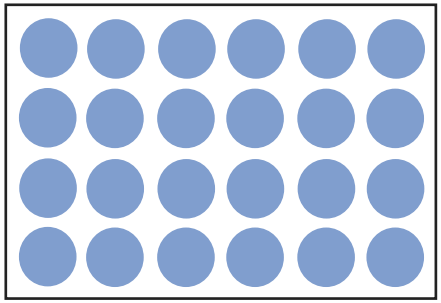
Solutions

CONDUCTION, CONVECTION, RADIATION through one or more of:

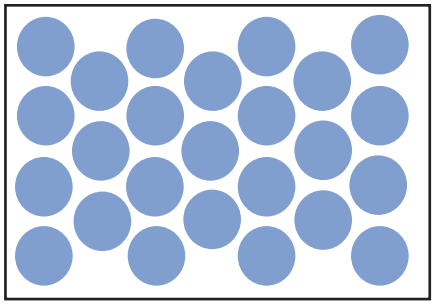
- 2-layer PCB with Heat spreaders & via stitched copper planes
- PCB Mounted to an aluminum heat spreader - thermal relief & mechanical support .
- Heat sink
- Heat pipes
- Fans
- Other means
  - top cooled
  - bottom cooled

These solutions work – but there is a new alternative

PC Board: Rogers Corp.4350 or FR4; 30 mills thick; ½-pz (0.7-mils-thick) copper cladding

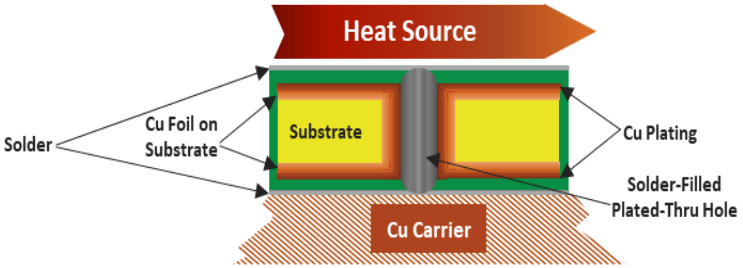


Rectangular Via Array



Triangular Via Array

2-Layer PCB with Heat Spreaders & Via Stitched Copper Plane Example



Cross Section of Typical Via Hole

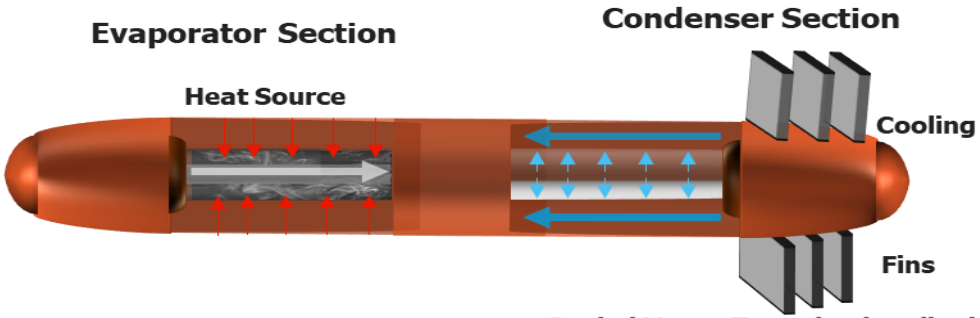
mm (Inches)

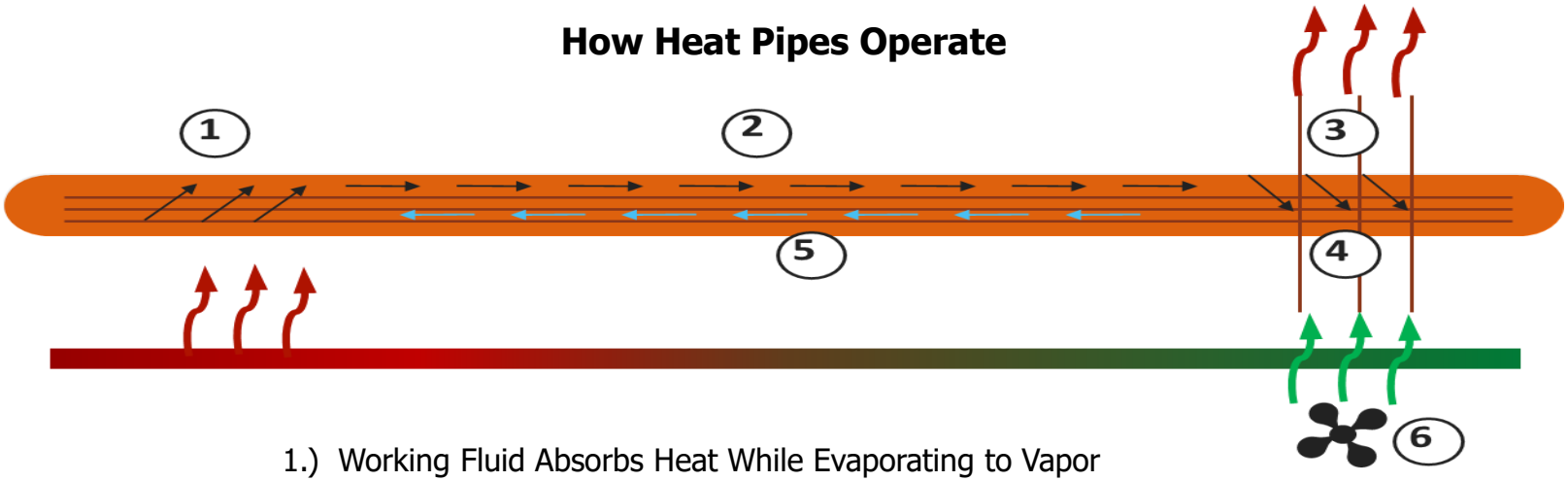
Assumptions			
Hole Dia	0.41 (0.016)	Thick_Sol	0.05 (0.002)
Thick_Cu_Plate	0.05 (0.002)	Kth_Cu	$9.9\frac{W}{in°C}$
Kth_Sub	$0.02\frac{W}{in°C}$	Thick_Cu_Foil	0.02 (0.0007)
Thick_Sub	0.76 (0.030)	Theta_1Via_Hole	$35.1\frac{°C}{Watt}$
K_Sol	$1.290\frac{W}{in°C}$		

mm (Inches)

Power Resistor Example	Chip Rated Power (W)	# Vias	Board Thermal Resistance ($\frac{°C}{W}$)	Temp. Drop Across Board @ Rated Power (°C)
5.08 x 2.54 (0.200 x 0.100)	10	30	1.17	11.7
6.35 x 6.35 (0.250 x 0.250)	20	88	0.40	8.0
9.53 x 6.35 (0.375 x 0.250)	30	132	0.27	8.1
9.53 x 9.53 (0.375 x 0.375)	40	204	0.17	6.9

Heat Pipe Example

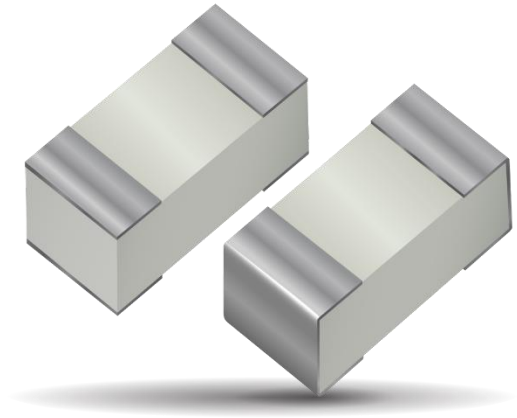




1.) Working Fluid Absorbs Heat While Evaporating to Vapor
2.) Vapor Transfers Along the Cavity to the Lower Temperature Area
3.) Vapor Condenses Back to Fluid, Discharging Heat
4.) Fluid is Absorbed by the Sintered/ Powdered Wick Structure
5.) Fluid Returns to High Temperature End Via Capillary Force in the Wick Structure
6.) Natural or Forced Convection Air Flow Dissipates Excess Heat to Ambient

Comparison:
SMT vs Traditional

SMT Heat Pipe



Heat pipe **only thermally conductive**

Small size 0302

Low parasitic electrical load (cap, leakage)

Efficiency not dependent upon orientation

High Shock & Vibration capability

High reliability

Traditional Heat Pipe

Heat pipe are electrically & thermally conductive

Heat pipe operating orientation affects the amount of power it can transfer

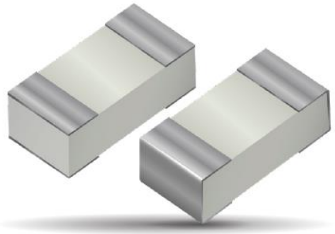
Shock & Vibration effect reliability

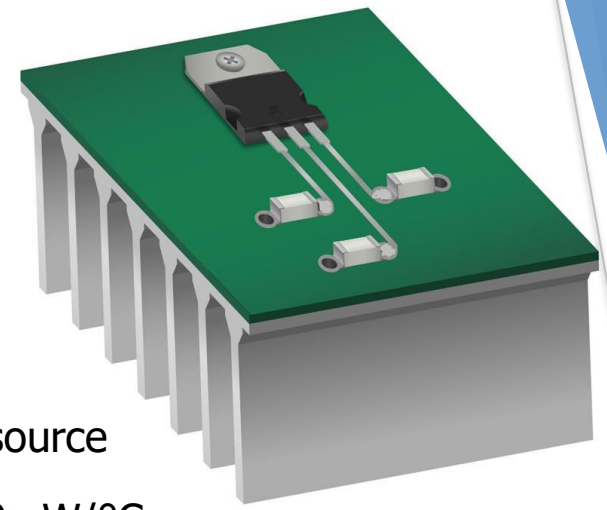
Internal corrosion may occur leading to failure

SMT Heat Pipe Outline

- Device description, picture, spec & cross section showing material systems
- Device package limitations sizes offered
- Device characteristics – DWV. IR, S21, Cap
- Application Studies & Guidelines in order – such a new part
- Resistor paper & effect of through hoe vias
- GaN MMIC example
- Summary

SMT Heat Pipe Description





SMT Heat pipes

Solid state device that route heat away from source

Thermal conductivity ranges from 40 to > 500mW/°C

Miniature device – 0302 to 0805 (up to 3737) custom dimensions easily created

AlN or optional BeO core with end metallization's

Termination Options: Sn/Ni/Pt, Ag/Pt, Ag/non magnetic layer

No phase transformation involved

Low cap loading

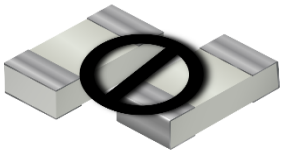
High Resistance

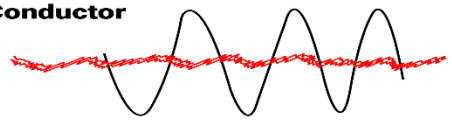
High DWV

SMT Heat Pipe Description

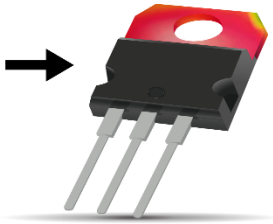
Without Thermal Management

Without Q Bridge Thermal Conductor

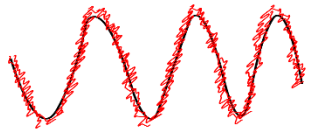




Input Signal & Noise



LNA &
High Thermal Noise



Output Signal
(Poor SNR Due to Thermal Noise)

Applications:

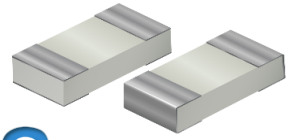
- GaN Power Amplifiers
- High RF Power Amplifiers
- Filters
- Synthesizers
- Industrial Computers
- Switch Mode Power Supplies
- Pin & Laser Diodes

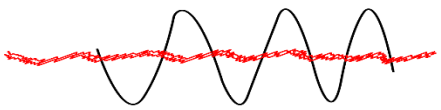
- Active Pins to Conduction, Convection or Radiator Point
- Contact Pad to Contact Pad
- Specific Contact Pad to Case
- Direct Component Contact to Via Pad or Trace
- Active Device and Adjacent Ground Planes

Case Size	Length (L)	Width (W)	Thickness (T)	Terminal (t)	Thermal Resistance (°C/W)		Thermal Conductivity (mW/°C)		Capacitance (pF)
					AlN	BeO	AlN	BeO	
0302	.030 ± .002 (.77 ± .051)	.020 ± .002 (0.51 ± .051)	20 (0.51 ± .05)	10 (0.25)	19	12	53	81	0.006 – 0.039
0402	.040 ± .002 (1.02 ± .051)	.020 ± .002 (0.51 ± .051)	20 (0.51 ± .05)	10 (0.25)	25	16	40	61	0.009 – 0.028
0505	.050 ± .002 (1.27 ± .051)	.050 ± .002 (1.27 ± .051)	25 (0.64 ± .05)	15 (0.38)	10	7	100	153	0.027 – 0.070
0603	.060 ± .002 (1.52 ± .051)	.030 ± .002 (.77 ± .051)	25 (0.64 ± .05)	15 (0.38)	20	13	50	76	0.007 – 0.035
0805	.080 ± .002 (2.03 ± .051)	.050 ± .002 (1.27 ± .051)	40 (1.02 ± .05)	20 (0.51)	10	7	100	153	0.015 – 0.081
1005	.100 ± .002 (2.54 ± .051)	.050 ± .002 (1.27 ± .051)	40 (1.02 ± .05)	20 (0.51)	13	8	77	122	0.007 – 0.046
1020	.100 ± .002 (2.54 ± .051)	.200 ± .002 (5.08 ± .051)	40 (1.02 ± .05)	20 (0.51)	3	2	320	508	0.019 – 0.204
1111	.110 ± .002 (2.79 ± .051)	.110 ± .002 (2.79 ± .051)	40 (1.02 ± .05)	20 (0.51)	7	4	153	240	0.031 – 0.096
2010	.195 ± .010 (4.95 ± .254)	.095 ± .010 (2.41 ± .254)	60 (1.52 ± .05)	30 (0.77)	10	6	100	159	0.042 – 0.086
2525	.240 ± .010 (6.10 ± .254)	.250 ± .010 (6.35 ± .254)	60 (1.52 ± .05)	40 (1.02)	4	3	240	380	0.075 – 0.156
3725	.370 ± .010 (9.40 ± .254)	.245± .010 (6.22 ± .254)	60 (1.52 ± .05)	50 (1.27)	6	4	160	254	0.058 – 0.105
3737	.365 ± .010 (9.27 ± .254)	.375 ± .010 (9.53 ± .254)	60 (1.52 ± .05)	50 (1.27)	4	3	240	380	0.099 – 0.164

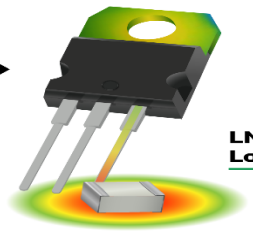
With Thermal Management

Q Bridge Thermal Conductor

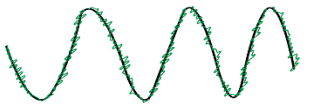




Input Signal & Noise

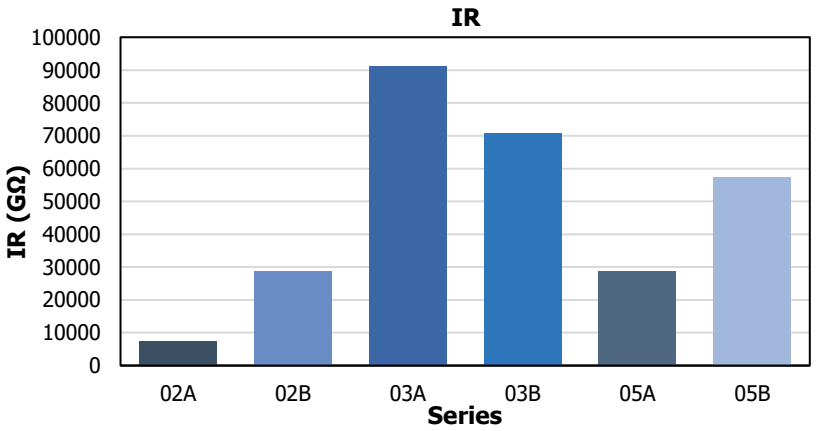


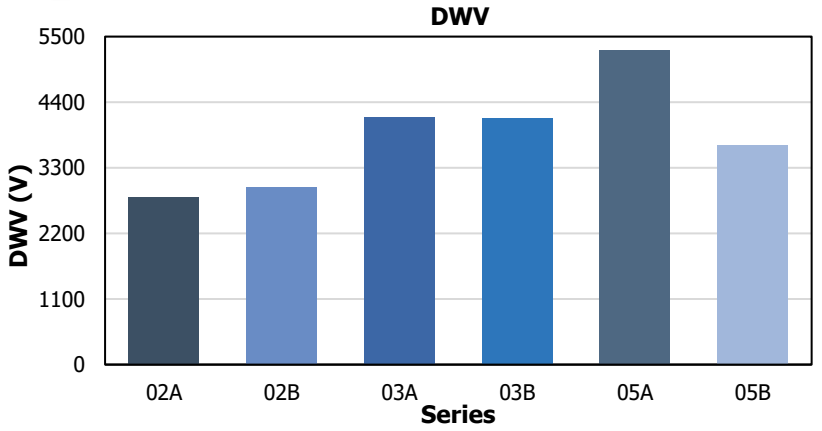
LNA &
Low Thermal Noise



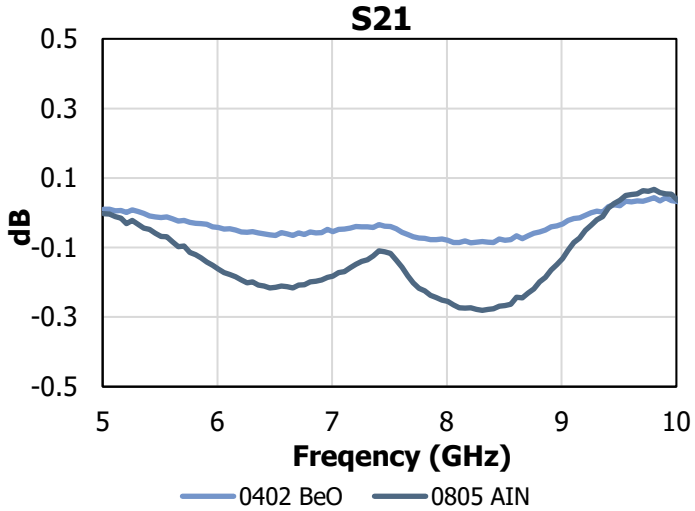
Output Signal
(Good SNR with Low Thermal Noise)

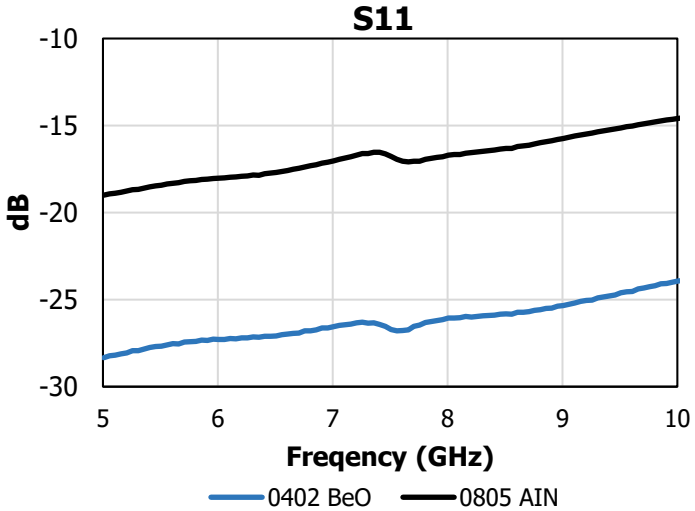
SMT Heat Pipe Description





Series #	Case size	Cap (pF) @ 1MHz	DWV (V)	IR (GΩ)
02A	0402	0.02816	2818.6	7635
02B	0402	0.024534	2977.2	28763
03A	0603	0.034798	4152.8	91347
03B	0603	0.028642	4129	70802
05A	0805	0.081266	5272.8	28781
05B	0805	0.054982	3680.8	57426

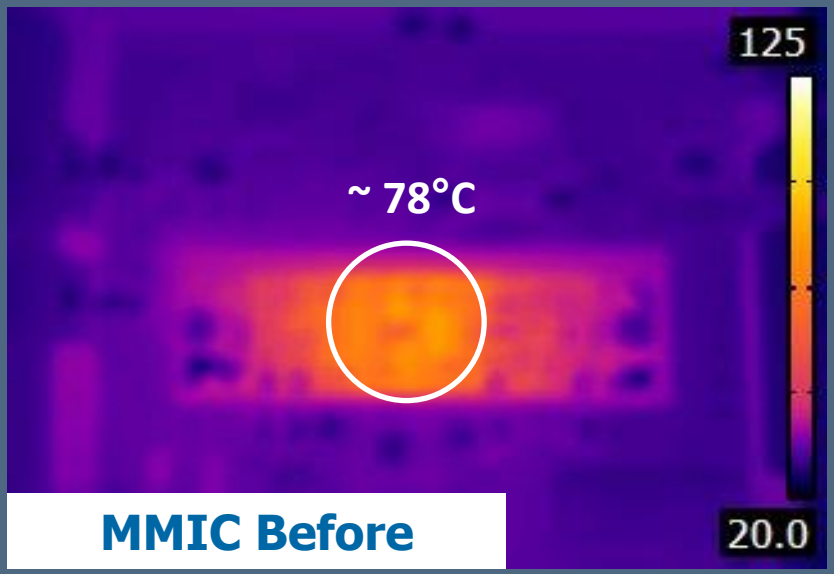


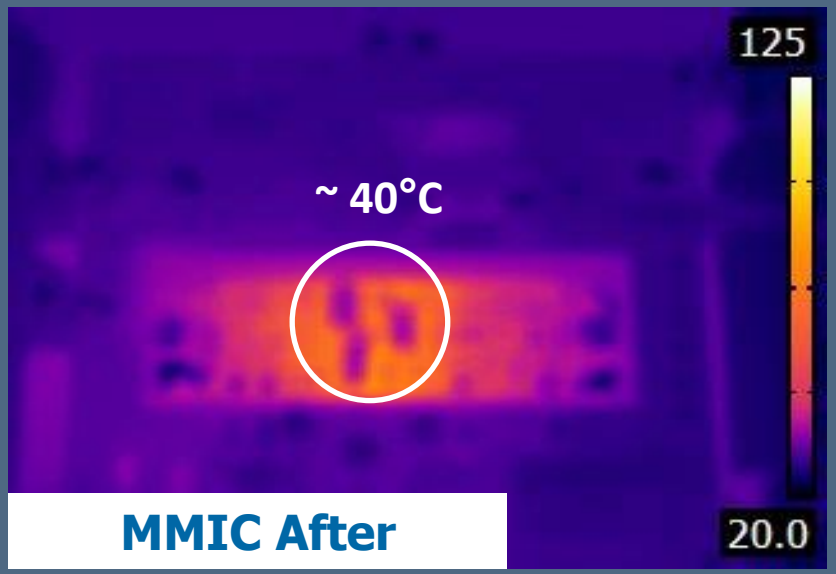


Application Study 1: GaN PA

- High Performance
- Ultra Miniature GaN VHF/UHF PA
- 100W output
- 100% duty cycle
- Data taken at 60 seconds with/without SMT heat pipe
- ~ 38°C thermal improvement with 3 SMT Heat pipes on MMIC

Traditional Heat Pipes Concern: Degradation
From leaks between inside/ outside of the heat pipe and gas generation within the heat pipe envelope

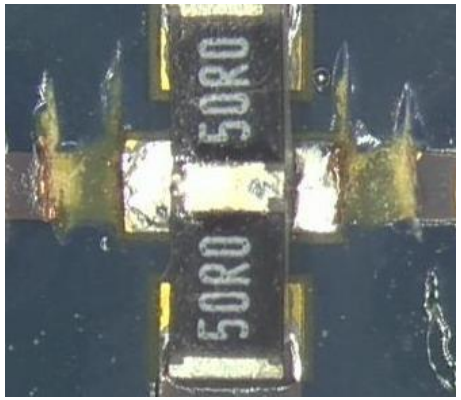




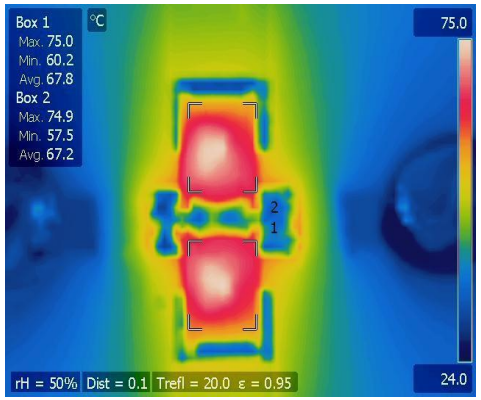
Application Study 2: Power Resistor

- Two 50 Ω, 1/8 W Resistors
- FR4 Soft Board
- Input Power: 1/2 W
- 18°C Drop in Average Temperatures > 50% More Power

Resistors in Series: Without Heat Pipe

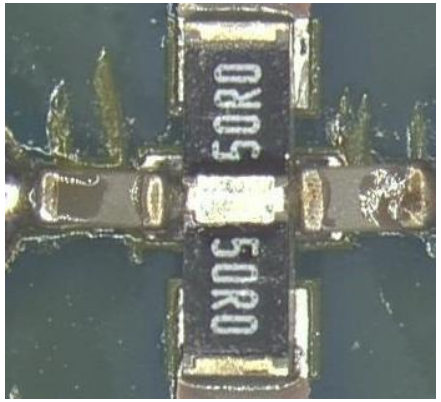


Without Heat Pipe

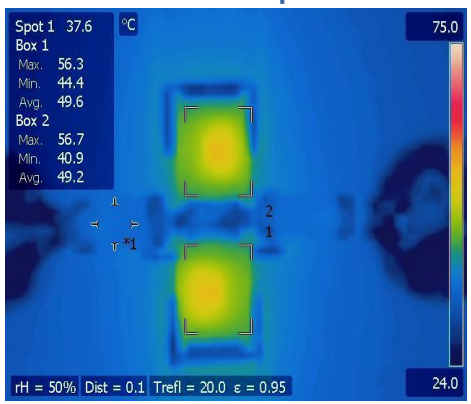


Applied voltage = 7.1V

Resistors in Series: With Heat Pipe



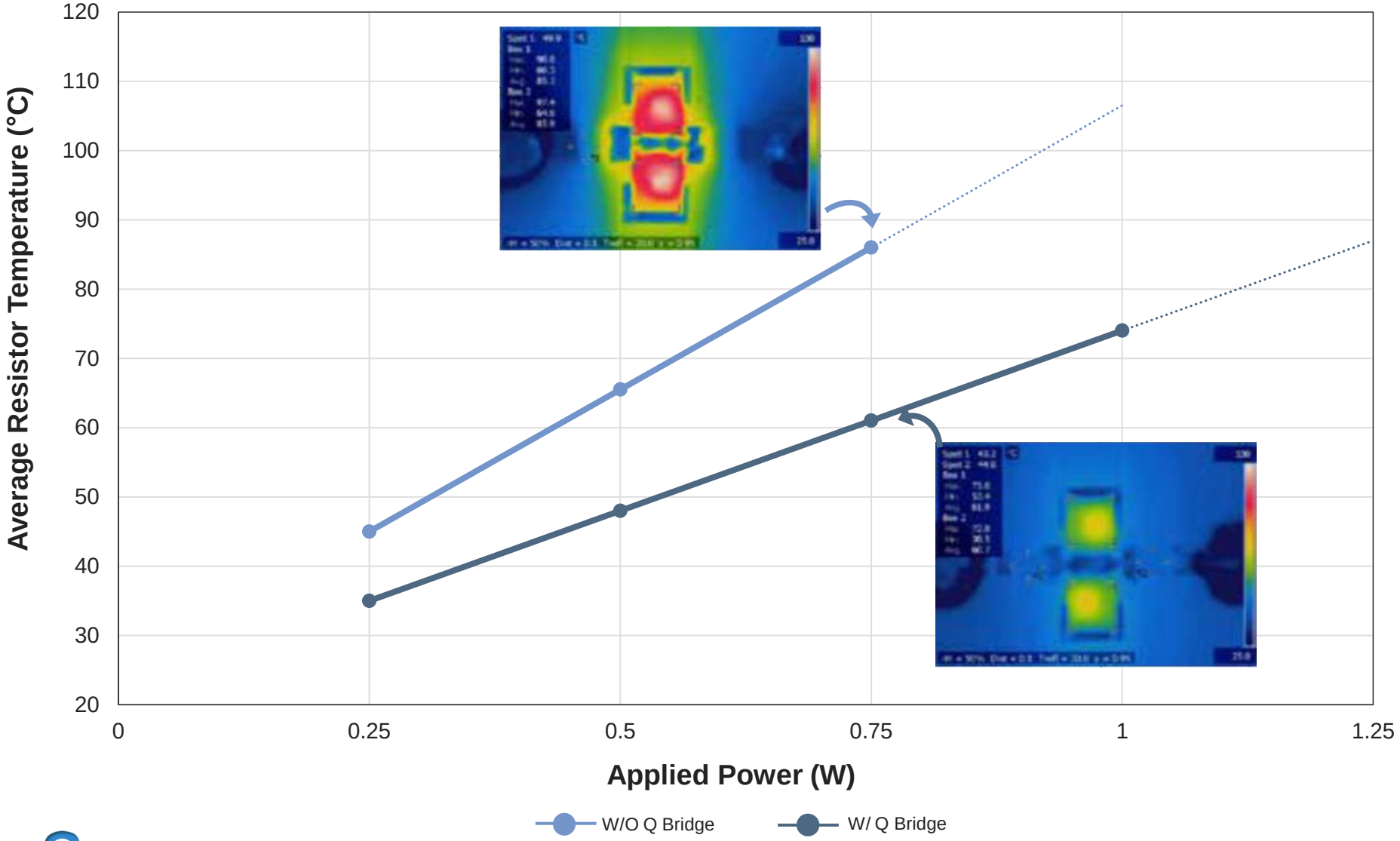
With Heat Pipe



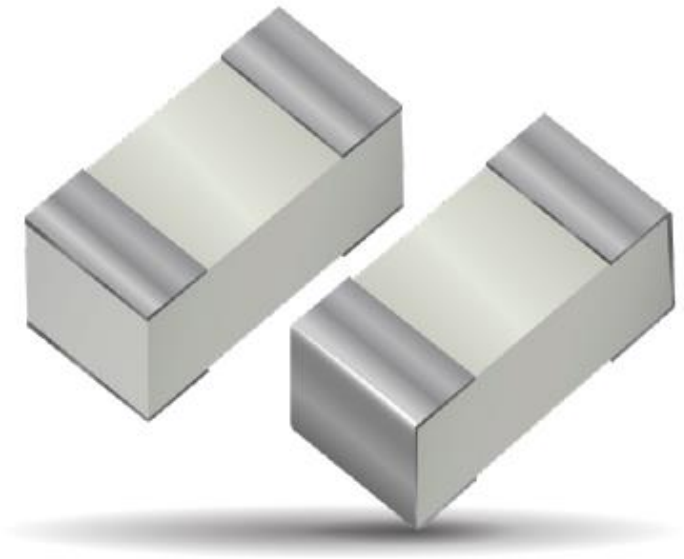
Applied voltage = 7.1V

Application Study 2: Power Resistor

The Use of SMT heat pipe results in >50% more power at the same temperature



Summary



- SMT Heat pipes are a new option for heat control via active pin connection
- SMT heat pipes exhibit low cap loading, high DWV and high resistance
- Special sizes and termination packages possible
- Improve heat flow from miniaturization sources : MMICs to laser diodes
- High Reliability / constant performance