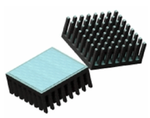
XP Power

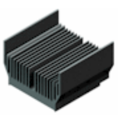
Heatsinks and Thermal Resistance - Module 26

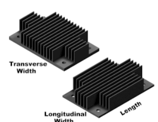
Les Chant

Overview

- WHY
  - Why do we need heatsinks
- HOW
- Theoretical analysis of heatsinks
- WHAT
  - What factors affect heatsink selection







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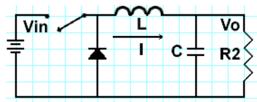
WHY

Why do we need heatsinks?

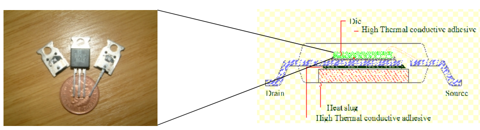
Why does it get hot - Joule Heating

- Idealised analysis, efficiency is 100%
- Practically, efficiency is not 100%
  - Losses in the transistor, the diode, the inductor and the capacitor.
  - Most power losses in the silicon devices.



Idealised switcher circuit

What gets hot - the silicon



Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Storage Temperature Range	
TO-39 Metal Can	−65°C to +175°C
TO-220 Package	−65°C to +150°C
Operating Junction Temperature Range	0°C to +150°C

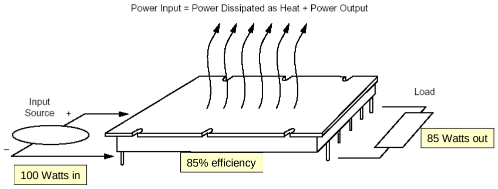
Lead Temperature
TO-39 Metal Can (Soldering, 60 sec.)
TO-220 Package (Soldering, 60 sec.)
Power Dissipation
Input Voltage
5.0V to 15V
24V
ESD Susceptibility

LM78M05C
Electrical Characteristics
$0°C \le T_A \le 125°C$, $V_I = 10V$, $I_O = 350$ mA, $C_I = 0.33\ \mu F$, $C_O = 0.1\ \mu F$, unless otherwise specified

Why does it get hot - power losses

15 Watts dissipated as heat
(used in ALL heatsink calculations)

Power Input = Power Dissipated as Heat + Power Output

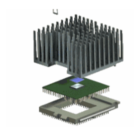
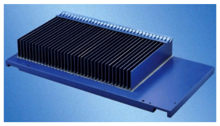
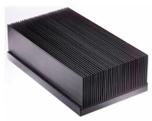


Power Dissipated = (1 - η)/η x Power Output

Power Input x Efficiency (η) = Power Output

What gets hot - How do we reduce the heat

- T_j must be kept below T_{max}
- This can be accomplished by:
  - minimizing power dissipation, P
  - decreasing the ambient temperature, T_a
  - decreasing the thermal resistance with a heat sink
- Of the three, adding a heat sink is usually the easiest and least expensive method.

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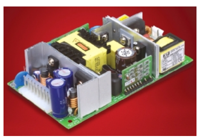
What gets hot - in practice



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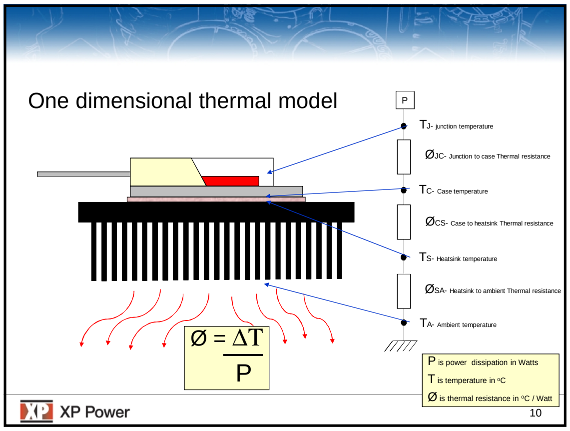
The HOW

Theoretical analysis of heatsinks


One dimensional thermal model
P
TJ- junction temperature
ØJC- Junction to case Thermal resistance
TC- Case temperature
ØCS- Case to heatsink Thermal resistance
TS- Heatsink temperature
ØSA- Heatsink to ambient Thermal resistance
TA- Ambient temperature
Ø = ΔT / P
P is power dissipation in Watts
T is temperature in °C
Ø is thermal resistance in °C / Watt
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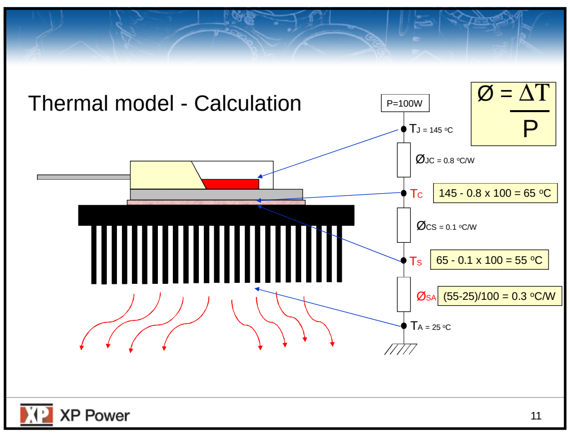
Thermal model - Calculation
P=100W
Ø = ΔT / P
TJ = 145 °C
ØJC = 0.8 °C/W
TC
145 - 0.8 x 100 = 65 °C
ØCS = 0.1 °C/W
TS
65 - 0.1 x 100 = 55 °C
ØSA
(55-25)/100 = 0.3 °C/W
TA = 25 °C
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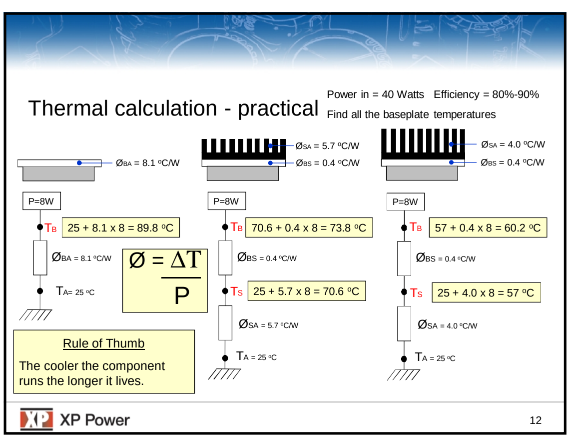
Thermal calculation - practical
Power in = 40 Watts Efficiency = 80%-90%
Find all the baseplate temperatures
ØBA = 8.1 °C/W
ØSA = 5.7 °C/W
ØBS = 0.4 °C/W
ØSA = 4.0 °C/W
ØBS = 0.4 °C/W
P=8W
TB
25 + 8.1 x 8 = 89.8 °C
ØBA = 8.1 °C/W
TA= 25 °C
Ø = ΔT / P
P=8W
TB
70.6 + 0.4 x 8 = 73.8 °C
ØBS = 0.4 °C/W
TS
25 + 5.7 x 8 = 70.6 °C
ØSA = 5.7 °C/W
TA = 25 °C
P=8W
TB
57 + 0.4 x 8 = 60.2 °C
ØBS = 0.4 °C/W
TS
25 + 4.0 x 8 = 57 °C
ØSA = 4.0 °C/W
TA = 25 °C
Rule of Thumb
The cooler the component runs the longer it lives.
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Thermal calculation - The formula

$$\varnothing_{SA} = \frac{T_B - T_A}{P_{DISS}}$$

P_{DISS} is power dissipation in Watts
T_B is the baseplate temperature in ºC
T_A is the ambient temperature in ºC
$\varnothing_{SA}$ is the thermal resistance in ºC / Watt of the heatsink

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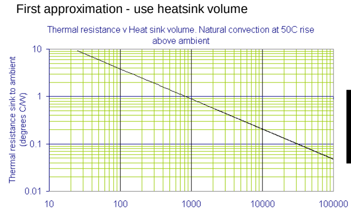
The WHAT

What factors effect heatsink selection

Heatsink implementation - Size matters

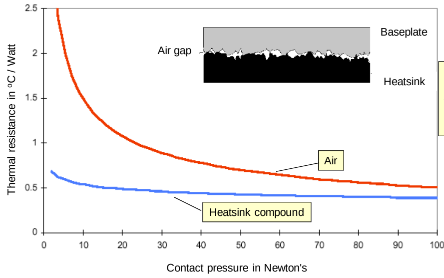
- Size and shape directly effect $\varnothing_{SA}$
- $\varnothing_{SA}$ is inversely proportional to heatsink dissipation area
- First approximation - use heatsink volume



Rule of Thumb

To reduce thermal resistance by 50% the heatsink volume must be quadrupled.

Heatsink implementation - Mounting



Rule of Thumb

Always use a heatsink compound.

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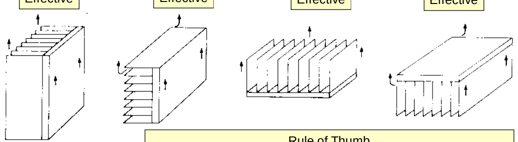
Heatsink implementation - Orientation

- Heatsink effectiveness is dependant on orientation
- Also on fin spacing, height, thickness, length and temperature

100% Effective | 85% Effective | 70% Effective | 60% Effective



Rule of Thumb

Mount heatsink so convection air “chimneys” past the fins.

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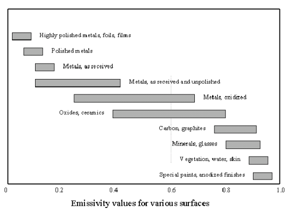
Heatsink implementation - Emissivity (ability to radiate heat)



Material and Finish	Emissivity
Aluminum – polished	0.04
Aluminum – rough	0.06
Aluminum - anodized (any color)	0.8
Copper - commercial polished	0.03
Copper – machined	0.07
Copper - thick oxide coating	0.78
Steel - rolled sheet	0.55
Steel - oxidized	0.78
Stainless Steel - alloy 316	0.28
Nickel Plate - dull finish	0.11
Silver – Polished	0.02
Tin – bright	0.04
Paints & Lacquers - any color - flat finish	0.94
Paints & Lacquers - any color - gloss finish	0.89

Rule of Thumb

Heatsink with a black surface will be 6%-8% better than a plain or bright surface

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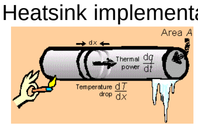
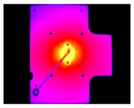
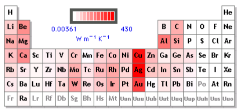
Heatsink implementation - Material conductivity





- Not all metals conduct heat at the same rate
- Steel and iron are surprisingly bad conductors



Rule of Thumb

Steel and iron are bad, copper and aluminium are best.

Thermal Conductivity, W/cm-K

Metals

- Aluminum 2.165
- Beryllium 1.772
- Beryllium-copper 1.063
- Brass 70% copper, 30% zinc 1.220
- Copper 3.937
- Gold 2.913
- Iron .669
- Lead .343
- Magnesium 1.575
- Molybdenum 1.299
- Monel .197
- Nickel .906
- Platinum .734
- Silver 4.173
- Stainless Steel-321 .146
- Stainless Steel-410 .240
- Steel, low carbon .669
- Tin .630
- Titanium .157
- Tungsten 1.969
- Zinc 1.024

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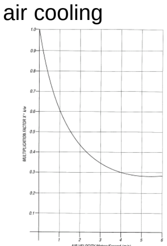
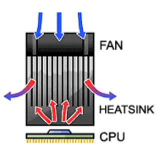
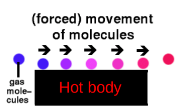
Heatsink implementation - Forced air cooling

- Reduces heatsink ØSA substantially
- Must look to data sheets for detailed calculations
- Not to be used as an afterthought







Rule of Thumb

The more turbulent the airflow the better

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Heatsink implementation - Environment

- All heatsink ØSA are calculated assuming ambient temperatures of 25 ºC at sea level
- Higher ambient temperatures or altitudes require ØSA de-rating.

Air temperature °C	Correction factor
30	1.02
40	1.06
50	1.09
60	1.12

Altitude (Metres)	Altitude (Feet)	Derating Factor
0 (sea level)	0	1.00
1,000	3,000	0.95
1,500	5,000	0.90
2,000	7,000	0.86
3,000	10,000	0.80
3,500	12,000	0.75

Rule of Thumb

Don't assume the target environment is standard temperature and pressure.

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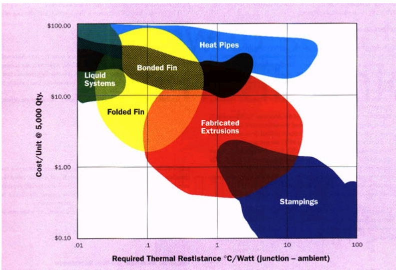
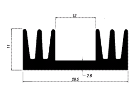
Heatsink implementation - The costs



Heatsink implementation - The data sheet



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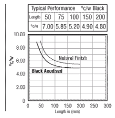
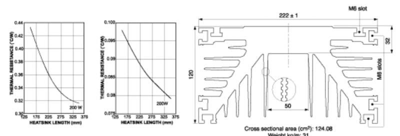
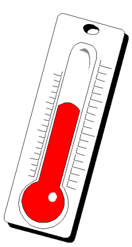
Typical Performance	°c/w Black				
Length	50	75	100	150	200
°c/w	7.00	5.85	5.20	4.90	4.80





Air Natural | Forced Air (5m/s) | Heatsink Profile : EM

Finally - How hot is hot ?



- With a wetted finger and a touch on the surface of a component. If the liquid evaporates quickly it is above 75 °C if it sizzles its above 90 °C (most likely too hot to touch anyway with the bare fingers).
- Any temperature below 60°C is not "nice to touch" but you can stand it for at least several seconds.
- If you are capable of keeping your finger on that particular part for much longer (or a very long time) it will be below 50°C.

Rule of finger
<50°C - **J**
60°C - **K**
>75°C - **L**

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