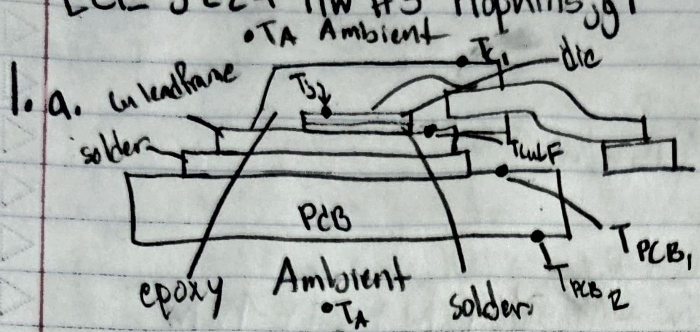
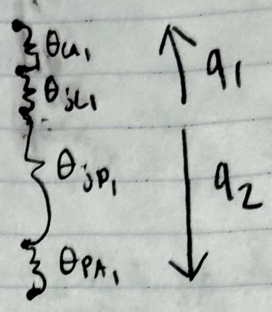
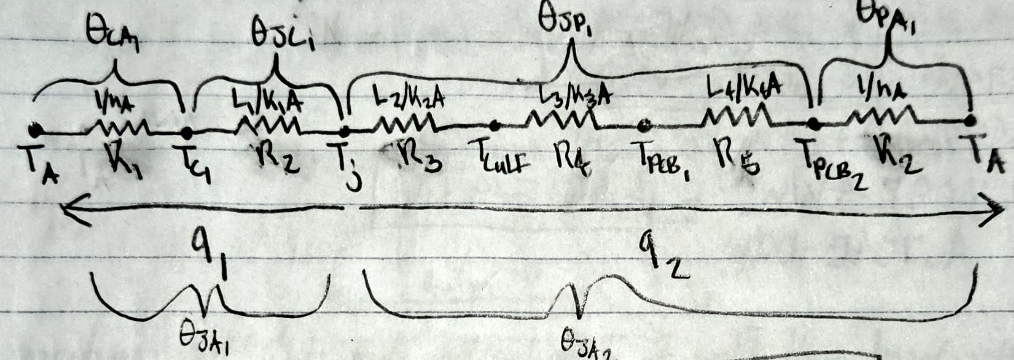
ECE 5224 HW #3 Hopkins, jgl

1. a.

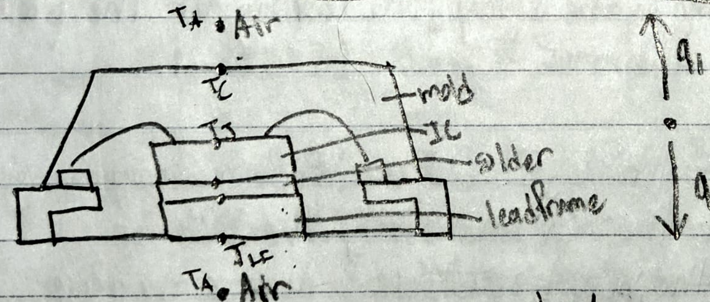






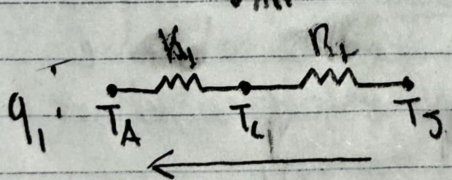
b. $$\theta_{JA} = \frac{(\theta_{CA_1} + \theta_{JC_1})(\theta_{JP_1} + \theta_{PA_1})}{(\theta_{CA_1} + \theta_{JC_1}) + (\theta_{JP_1} + \theta_{PA_1})} = \boxed{\frac{\theta_{JA_1}\theta_{JA_2}}{\theta_{JA_1} + \theta_{JA_2}}}$$

2.

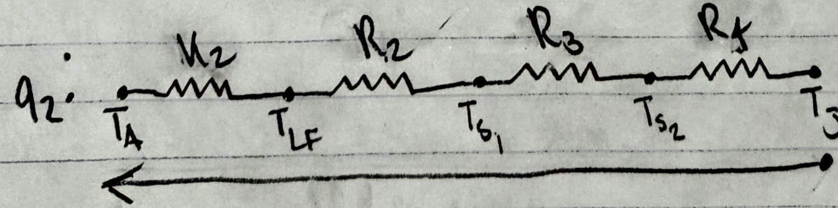


A_{die} and A_{LF} and A_S $= 4\,mm \cdot 4\,mm = 16\,mm^2 = \underline{.016\,m^2}$

$L_{JC} = 3\,mm - .5\,mm - .5\,mm - .1\,mm = 1.9\,mm = \underline{.0019\,m}$



$$R_1 = L_{JC}/kA = \frac{.0019\,m}{(0.25\,W/mK)(.016\,m^2)} = \underline{.475\,K/W}$$



$$R_4 = \frac{.0005\,m}{(120\,W/mK)(.016\,m^2)} = \underline{2.6E\text{-}4\,K/W}$$

$$R_2 = \frac{.0005\,m}{(390\,W/mK)(.016\,m^2)} = \underline{8.01E\text{-}5\,K/W} \qquad R_3 = \frac{.0001\,m}{(50\,W/mK)(.016\,m^2)} = \underline{1.25E\text{-}4\,K/W}$$

2 Continued:

Thermal Res of $q_1 = R_1 = .475 K/W$

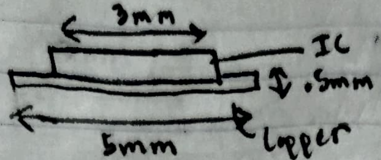
Thermal Res of $q_2 = R_2 + R_3 + R_4$
$= 8.01E-5 K/W + 1.25E-4 K/W + 2.6E-4 K/W$
$= 4.651E-4 K/W$

$$\theta_{JC} = \frac{(.475 K/W)(4.651E-4 K/W)}{(.475 K/W) + (4.651E-4 K/W)}$$
$$= \frac{2.209E-4 W/W}{4.754E-1 W/W} = \boxed{4.647E-4 W/W}$$

a. Most of the heat will flow to the bottom due to the resistance in the leadframe being the lowest and the resistance in the epoxy being significantly higher causing all the heat to push downward. Also since heat isn't spreading in the epoxy, it's looking for the path of least resistance to escape.

b. If I wanted to lower the resistance, I would switch out the epoxy with something w/ a higher thermal conductivity like FR4 or Aluminum. This would cause the highest resistance to decrease therefore decreasing everything. My second solution would be to put the epoxy or better material at the bottom of the leadframe so its not just exposed to air and giving the heat a path out.

3. a-1:



$w_{die} = 3mm \quad A_{die} = 3mm \cdot 3mm = 9mm^2$

$L_{BP} = 0.5mm \quad w_{BP} = 5mm$

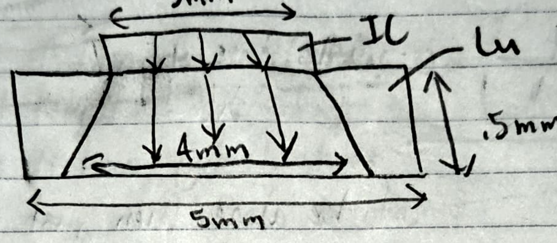
$w_{spread} = (2(.5) + 3) = 4mm \leq 5mm$ ✓

$A_{spread} = (2L_{BP} + w_{die})(2L_{BP} + w_{die}) = (2(.5) + 3)^2 = 16mm^2$

$A_{eff} = (A_{spread} + A_{die})/2 = (16 + 9)/2 = 12.5mm^2$

$R_{th,BP} = L_{BP} / (K_{BP} A_{eff}) = .0005m / (390W/mK \cdot .0125m^2)$

$= \underline{1.026E\text{-}4K/W}$



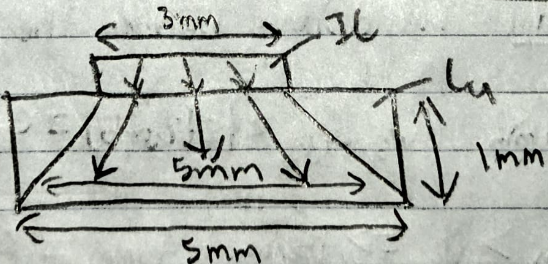
a-2: $w_{die} = 3mm$, $A_{die} = 9mm^2$, $L_{BP} = 1mm$, $W_{BP} = 5mm$

$w_{spread} = (2(1) + 3) = 5mm \leq 5mm$ ✓

$A_{spread} = 5 \cdot 5 = 25mm^2$

$A_{eff} = (25 + 9)/2 = 34/2 = 17mm^2$

$R_{th,BP} = .001m / (390W/mK \cdot .017m^2) = \underline{1.51E\text{-}4K/W}$



a-3: $w_{die} = 3mm$, $A_{die} = 9mm^2$, $L_{BP} = 3mm$, $W_{BP} = 5mm$

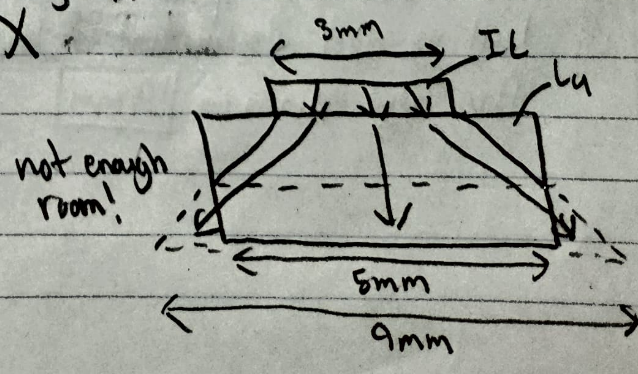
$w_{spread} = (2(3) + 3) = 9mm \geq 5mm$ X

$A_{spread} = 9 \cdot 9 = 81mm^2$

$A_{eff} = (81 + 9)/2 = 45mm^2$

$R_{th,BP} = .003m / (390W/mK \cdot .045m)$

$= \underline{1.71E\text{-}4K/W}$



3. b. $R_{th,cond} = \frac{L}{kA_c}$ and $R_{th,conv} = \frac{1}{hA_s}$

Combining the two would give a total R_{th} of $\frac{L}{kA_c} + \frac{1}{hA_s}$

=> If I do the derivative of R_{th} w/ respect to the length L, I can find the optimal thickness which would give the equation:

$$\frac{d}{dL}\left(\frac{L}{kA_c} + \frac{1}{hA_s}\right) = 0$$

Substitute A_c and A_s w/ the proper equations w/ respect to L, derive the whole thing, and then rearange for L to be alone. Then just solve to get the optimal thickness.

4. a. $w_{die_1} = 2mm$, $A_{die_1} = 4mm^2$, $L_{sp} = 2mm$
$A_{spread} = (2(2)+2)^2 = (6)^2 = 36mm^2$
=> meaning its spread is ~6mm
6mm − 2mm = 4mm/2 = 2mm spread on one side

$w_{die_2} = 5mm$, $A_{die_2} = 25mm^2$, $L_{sp} = 2mm$
$A_{spread} = (2(2)+5)^2 = 81mm^2$
=> meaning its spread is ~9mm
9mm − 5mm = 4/2 = 2mm spread on one side

=> 2mm + 2mm = $\underline{4mm}$ = min distance between the two

b. $w_{spread_1} = (2(2)+2) = 6mm$ $\quad w_{spread_2} = (2(2)+5) = 9mm$

$w_{spread,total} = 6+9 = 15mm > w_{sp}$ => 15mm + 4mm = $\boxed{19mm}$

=> The total w_{spread} is 15mm which is the smallest the w_{sp} can be but we must also account for the die distance from part a, so 15+4 gets the new minimum $\boxed{19mm}$

4. c. One negative consequence is the increase in size of the base plate therefore increasing weight and cost.
Another negative effect would be a increase in interconnect lengths which could lead to longer transmission delays or other unneeded consequences.

6. a. $K_{xy} = K_m t_m + k_i (1 - t_m)$

total insulator thickness $= 215\,\mu m \cdot 5 = 1075\,\mu m$

$t_m = \frac{t_{cu}}{1075 + t_{cu}}$ $\quad 60\,W/mK = (390\,W/mK)\left(\frac{t_{cu}}{1075 + t_{cu}}\right) + 0.25\,W/mK\left(1 - \frac{t_{cu}}{1075 + t_{cu}}\right)$

$\Rightarrow 60 = \frac{390 t_{cu}}{1075 + t_{cu}} + .25 - \frac{.25 t_{cu}}{1075 + t_{cu}} \Rightarrow 60 = \frac{389.75 t_{cu}}{1075 + t_{cu}} + .25$

$\Rightarrow 59.75 = \frac{389.75 t_{cu}}{1075 + t_{cu}} \Rightarrow 59.75(1075 + t_{cu}) = 389.75 t_{cu}$

$\Rightarrow 0.06423 + 59.75 t_{cu} = 389.75 t_{cu} \Rightarrow \frac{0.06423}{330} = \frac{330 t_{cu}}{330}$

$\Rightarrow 194.63\,\mu m = t_{cu} \Rightarrow \frac{194.63}{4} = 48.66\,\mu m =$ Cu thickness

Verify: $K_{xy} = (390\,W/mK)\frac{(48.66\,\mu m \cdot 4)}{(215\,\mu m)(5) + (48.66\,\mu m \cdot 4)} + (.25\,W/mK)\left(1 - \frac{(48.66\,\mu m \cdot 4)}{(215)(5) + (48.66 \cdot 4)}\right)$

$\Rightarrow 390(0.153303) + .25(1 - 0.153303) = 59.99 \approx 60 \checkmark$

$\Rightarrow$ <u>Cu thickness is $48.66\,\mu m$</u>