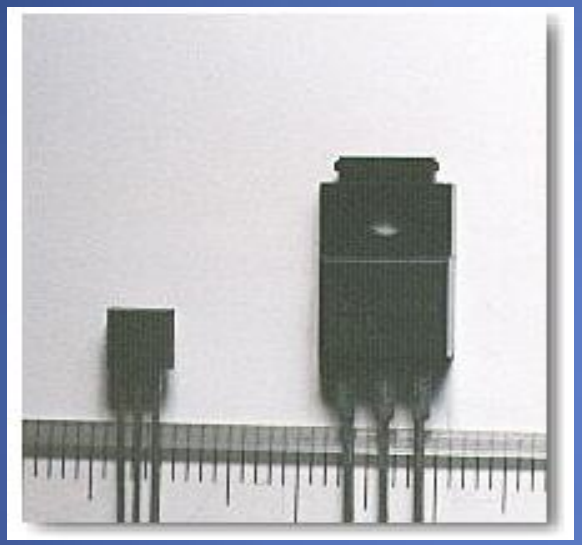
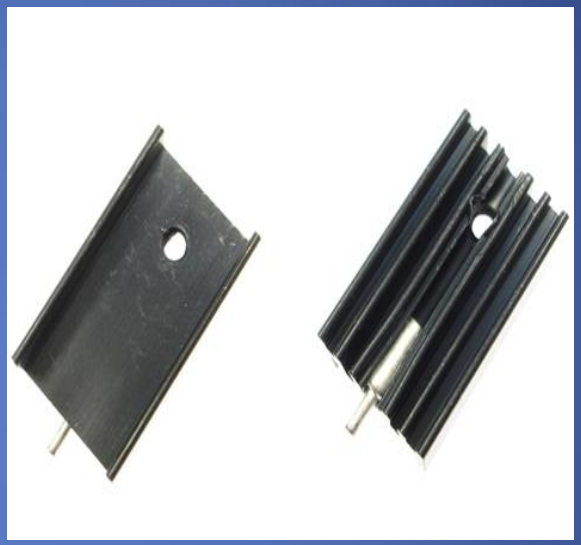
Regulator Heat Sink Design





15th October

S & O (6sigma & optimization)

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- 2003007000 정현욱

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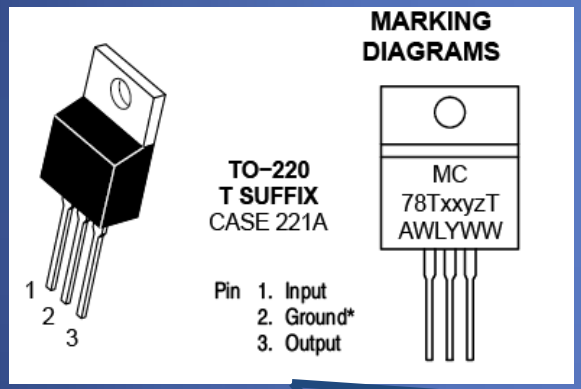
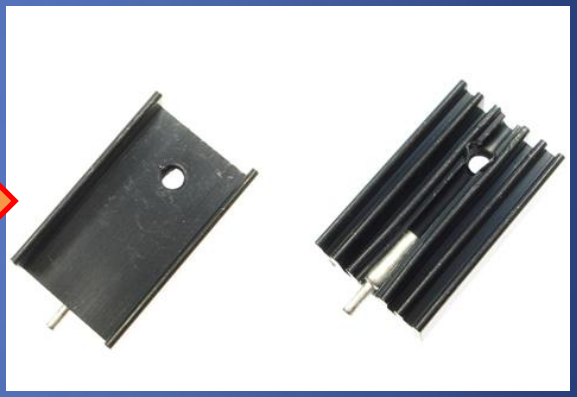
Introduction of Design Object

- Voltage Regulator & Heat Sink

입력 전압과 출력 부하가 변화더라도 항상 일정한 출력 전압을 유지하도록 설계된 장치.



발열량 해결



시리즈 방식

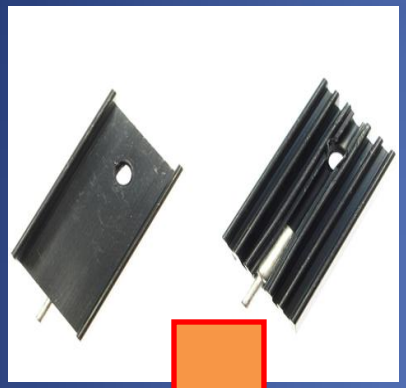
- 전압 차이만큼 레귤레이터 발열
- 비교적 간단한 회로
- 저가인 반면, 발열량이 크다

스위칭 방식

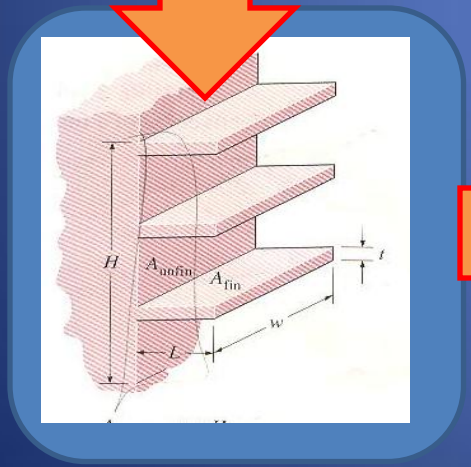
- 시리즈 방식에서 개선된 방법
- PWM 제어로 평균전압을 제어
- 가격이 상대적으로 고가이다.

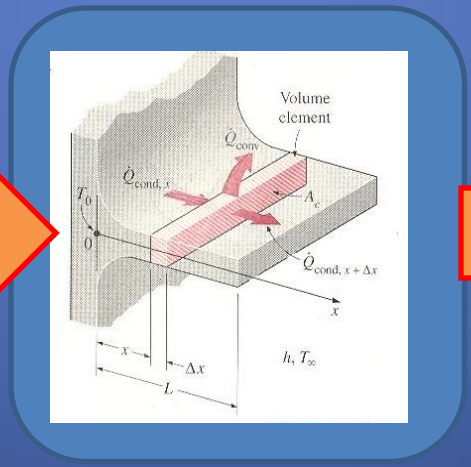
Procedure of Design

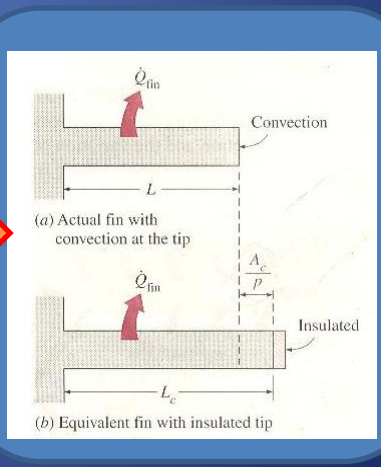
- Analysis & Modeling of Heat Sink



- 기하학적인 모습 단순화 (Rectangular)
- Fin 한 개의 열전달량 해석 후, 전체에 적용
- Fin 의 Tip=insulated 수학적 모델링 단순화하여 해석 (Tip=Convection의 결과와 유사함)
- 열 물성치는 constant로 가정

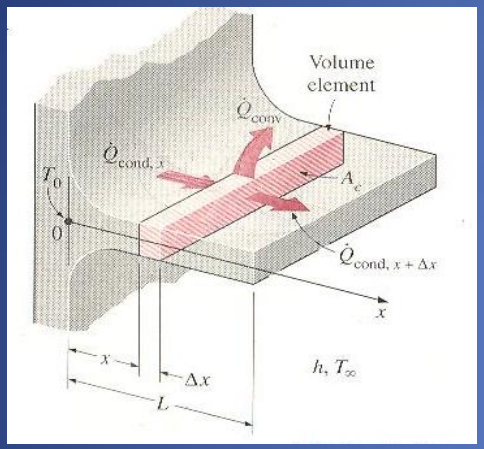






Procedure of Design

- Design Variables & Object Function



- 기하학적 형상 변형을 위한 설계 변수
  b(Height) & L(Length)
- 최소 단가(Cost)를 위한 목적 함수

$$V = ALn = btL\frac{a}{t+2.714\frac{b}{\left(\frac{g\beta(T_b-T_\infty)}{\nu^2}Prb^3\right)^{0.25}}} = btL\frac{a\left(\frac{g\beta(T_b-T_\infty)}{\nu^2}Prb^3\right)^{0.25}}{t\left(\frac{g\beta(T_b-T_\infty)}{\nu^2}Prb^3\right)^{0.25}+2.714b}$$

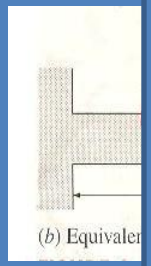
가장 효율적인 방열특성을 가진 방열핀의 설계

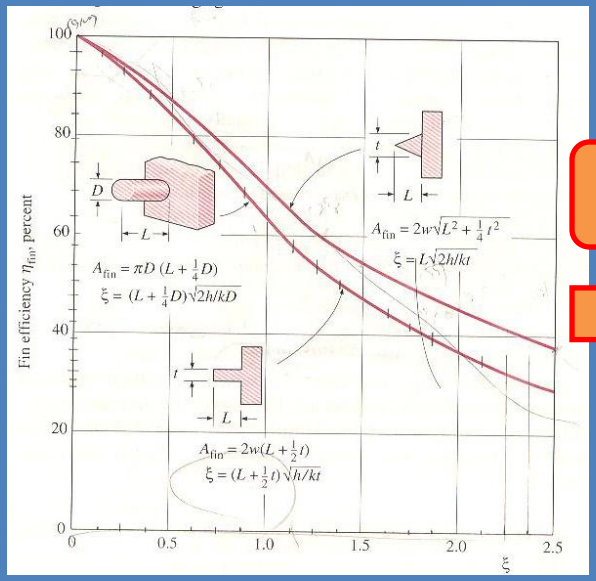
Procedure of Design

- Constraint

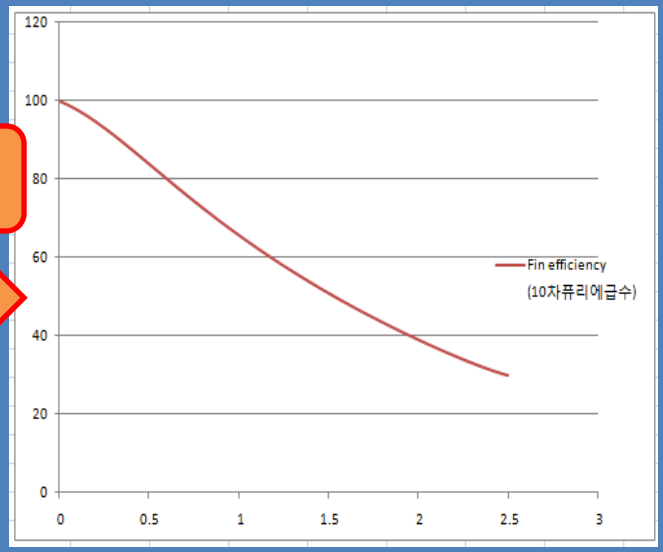
He

Efficiency



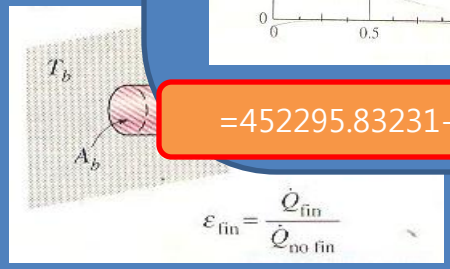


수치화



=452295.83231-206704.38431*COS(0.1x)-18975307.85584*SIN(0.1x) -409137.61405COS(0.2x)...

E

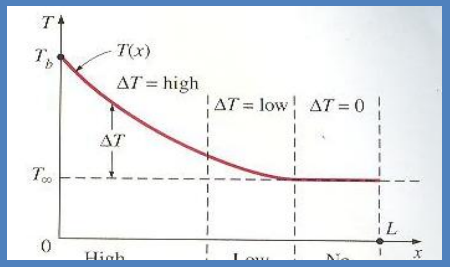


$$g2 = 1 - \frac{\bar{b}(a - tn) + 2Ln(b + t)}{ab}\eta_{fin} \leqq 0$$

Procedure of Design

- Constraint

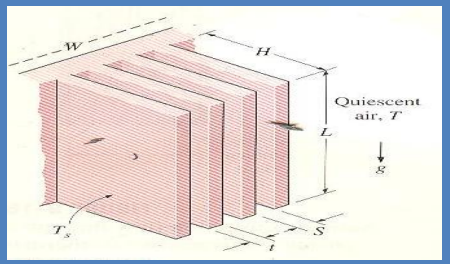
Proper Length of Fin



$$\frac{Q_{fin}}{Q_{longfin}} = \frac{\sqrt{kAhP}\triangle T\tanh(mL)}{\sqrt{kAhP}\triangle T} = \tanh(mL) \leqq 1.0$$

$$g3 = \sqrt{\frac{kA}{hp}}\,L - 5.0 \leqq 0$$

Gerometry



$$10\,mm \leqq h\,(Height) \leqq 25\,mm$$

$$0\,mm \leqq L\,(Length) \leqq 70\,mm$$

$$S_{opt} = 2.714\frac{L}{RaL^{0.25}} = 2.714a\left(\frac{g\beta(T_b - T_\infty)}{\nu^2}Prb^3\right)^{-0.25}L$$

Procedure of Design

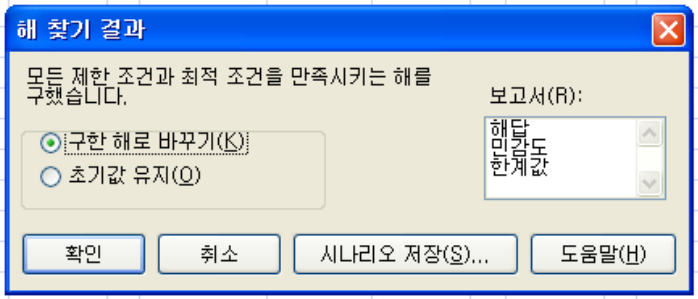
- Find a solution by Solver-method

		mm	m	
Area	=	13.37	1.337E-05	
Length	=	3.40	0.0033974	
Lc	=	3.897358281	0.0038974	
Constraint				
Q_case3	=	0.699991427	>=	0.70
e_fin	=	3.919825286	>=	1
Q_fin/Q_longfin	=	0.055763985	<=	5
0.00001	<=	Area [m]	<=	0.000025
0	<=	L [m]	<=	0.07

		[m^3]	[mm^3]
V(cost)_case3	=	2.72528E-07	272.52816

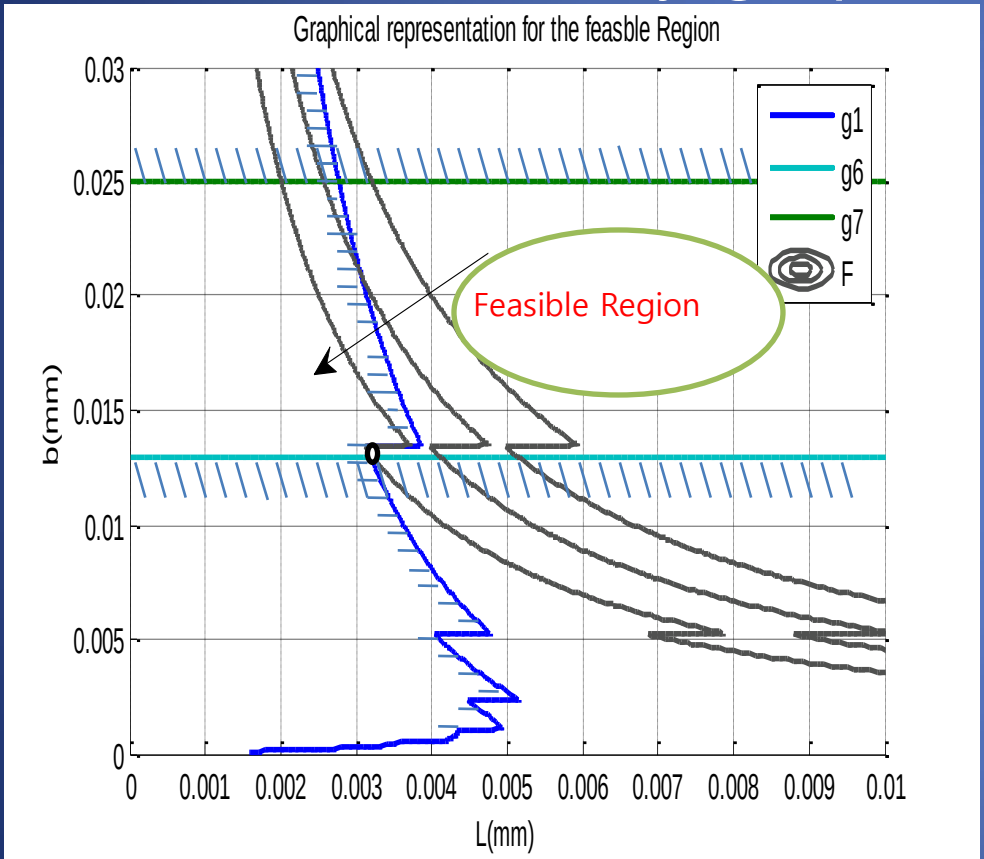
초기값 13.00 / 2.00

		mm	m				
a	=	15	0.015		p	=	0.028739222	
t	=	1	0.001		m	=	14.30814946	
h	=	20	[w/m^2k]		n	=	6.0000	6.003072
k	=	210	[w/mk]		Lc	=	0.0005	
T_o	=	60	['c]		RaL	=	6153.277749	
T_inf	=	25	['c]		s	=	0.004096868	
Q_max	=	0.7	[W]		효율n	=	0.992086161	
g	=	9.81	[m/s^2]		크사이	=	0.038034322	
v	=	0.00001749	[m^2/s]					
pr	=	0.7241						
beta	=	0.00316807	[k^-1]					
b	=	13.3696112	0.01337					



Procedure of Design MATLAB

- Find a solution by graphic method



도해법에 의한 최적값
Active constraints g1, g6에 의해 결정

```
h=20;
k=210;
T_b=60;
T_in=25;
a=0.015;
t=0.001;
v=1.749*10^-5;
g=9.81;
pr=0.7241;
beta=((T_b+T_in)/2+273.15)^-1;

[L,b]=meshgrid(0:0.0001:0.07,0:0.0001:0.07);

A=b.*t;
p=2*(t+b);
m=sqrt(h*p./(k*A));
Ral=g*beta*(T_b-T_in)*pr/v^2*b.^3;
s=2.714*b./(Ral.^0.25);
n=floor(a./(t+s)*1.7)+1;
Lc=L+t/2;

f=A.*L.*n;

g1=0.7-h*(b.*s.*n)*(T_b-T_in)-sqrt(h*p.*k*A).*(T_b-
T_in).*(tanh(m.*Lc)).*n;
g2=1-(b.*(a-
t*n)+2*Lc.*n.*(b+t))./(a.*b)*(tanh(m.*Lc)./(m.*Lc));
g3=m.*Lc-5;
g4=-L;
g5=L-0.07;
g6=0.000013-A;
g7=0.000025-A;
```

Comments

- 수학적 모델링의 간단화를 위하여 불필요한 요소 생략
  (Ex. Fin의 방열량 해석 간단화 및 방열판과 Regulator사이의 저항 무시)

- 수학적 모델링이 타당한지 검증하기 위해서는 실제 Regulator
  방열량과 비교하기 위한 정립된 데이터 필요

- 실제 Regulator 방열판과 단순 크기면에서 비교해 본 결과
  약 30% 작은 치수로도 60°c로 유지 가능

Reference

- Heat transfer((2nd edi) // Yunus A Cengel // Mcgraw Hill //2003
- Introduction to Optimum Design // Arora, J. S. // Academic Press, 2004
- Recent advances in analysis of heat transfer for fin type surfaces/ Sundn, Bengt/WIT Press/2000/