熱のパラメータを用いた電源ICの熱設計

MPSジャパン合同会社
シニアFAE
竹村 興

2024年12月

熱設計とは

ABSOLUTE MAXIMUM RATINGS (1)

Supply voltage (V_{IN}) .....-0.3V to +45V
VCP voltage (V_{CP}).....V_{IN} to V_{IN} + 6.5V
V_{OUTx} .....-0.3V to V_{IN} + 0.3V
PGND1, PGND2 to AGND.....-0.3V to +0.3V
All other pins to AGND.....-0.3V to +6.5V
Continuous power dissipation (T_A = 25°C) (2)
..... 2.6W
Junction temperature (T_J) .....150°C
Lead temperature .....260°C
Storage temperature..... -65°C to +150°C

1) Exceeding these ratings may damage the device.

Recommended Operating Conditions (3)

Supply voltage (V_{IN}) .....4V to 40V
Operating junction temp (T_J).... -40°C to +125°C

3) The device is not guaranteed to function outside of its operating conditions.

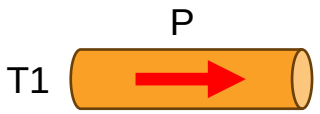
Thermal Metrics (4)

θ_{JA} (junction-to-ambient).....44.3°C/W
θ_{JC_TOP} (junction-to-case top).....37.5°C/W
Ψ_{JT} (junction-to-top).....1.1°C/W

4) According to JEDEC JESD51-2/-5/-7/-8/-14.

熱の伝わり方

✓ 熱抵抗 θ



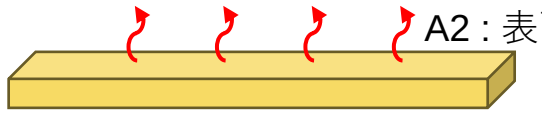
$$\theta = \frac{T1 - T2}{P} \ [℃/W]$$

熱	熱流量 P [W]	温度差 dT [℃]	熱抵抗 θ [℃/W]
電気	電流 I [A]	電圧差 dV [V]	電気抵抗 R [Ω]

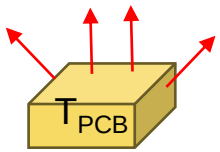
✓ 放熱経路

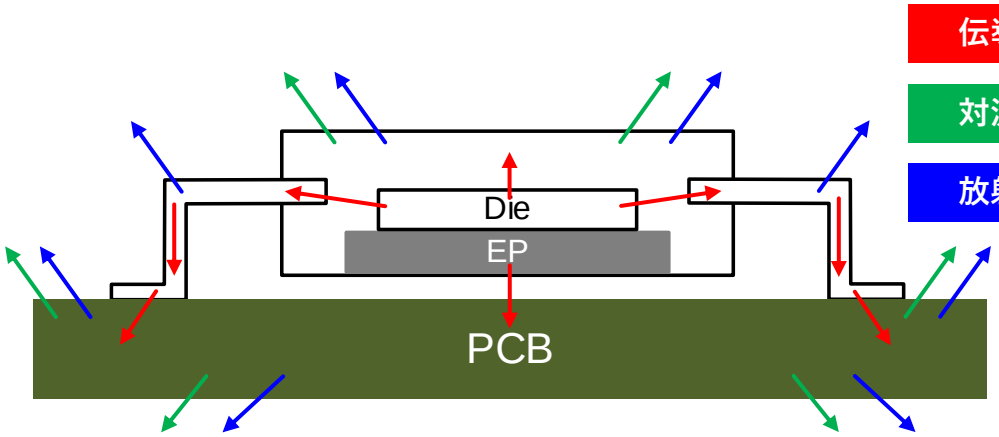
・伝導　$\theta_{CD} = \frac{L}{A_1 \times \lambda}$

・対流　$\theta_{CV} = \frac{1}{A_2 \times h}$



・放射　$\theta_{RD} = \frac{1}{A_3 \times \sigma \times \varepsilon \times ({T_{PCB}}^4 - {T_{AMB}}^4)}$

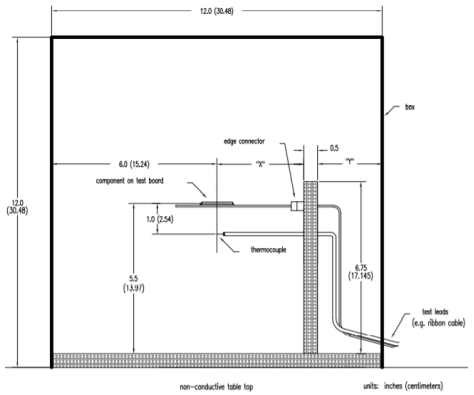


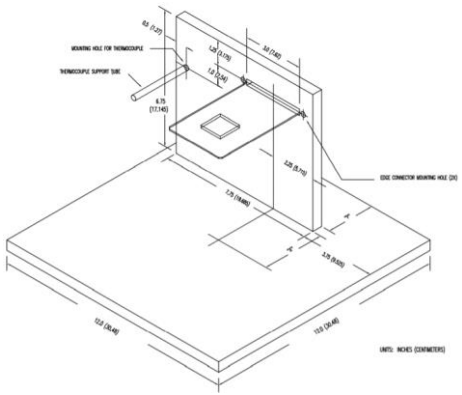


熱伝導経路

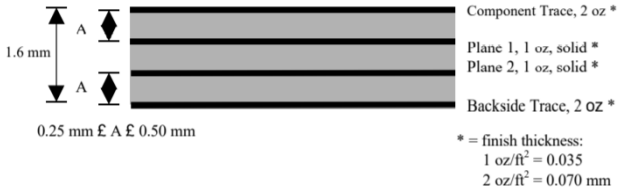
λ：熱伝導率、 h：対流熱伝導率、 σ：ボルツマン定数、 ε：放射係数（材料固有の値）

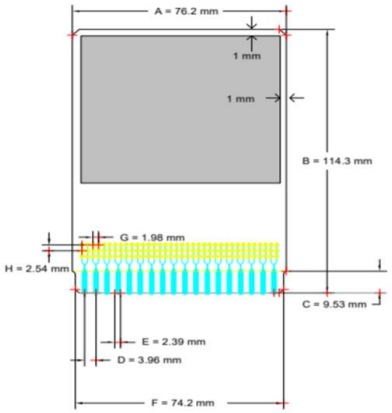
JEDEC JESD51 試験環境



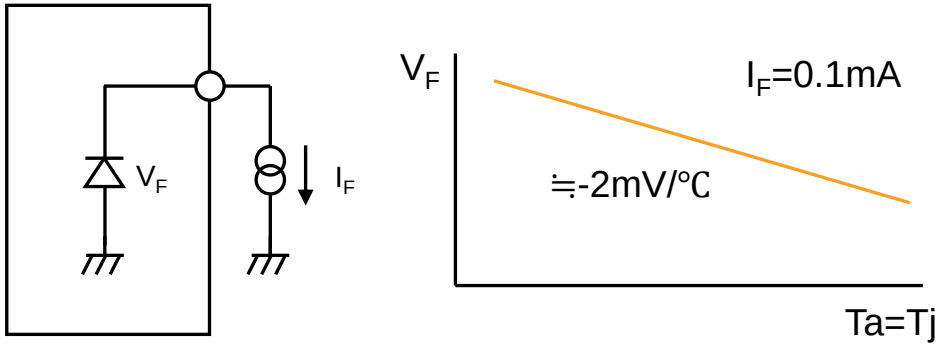


測定環境





PCB

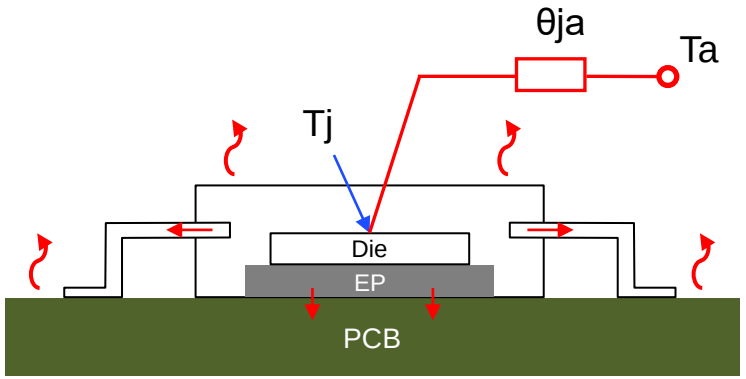


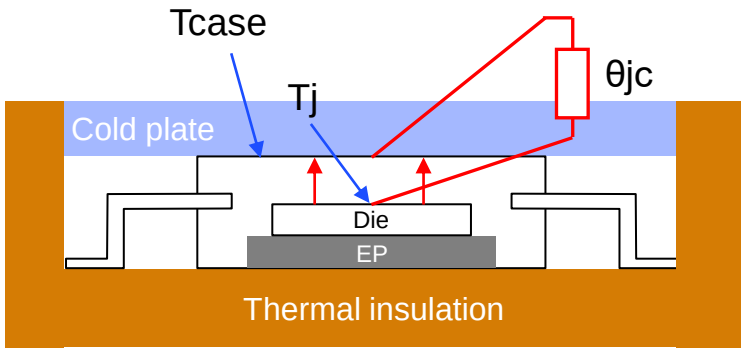
測定の事前準備

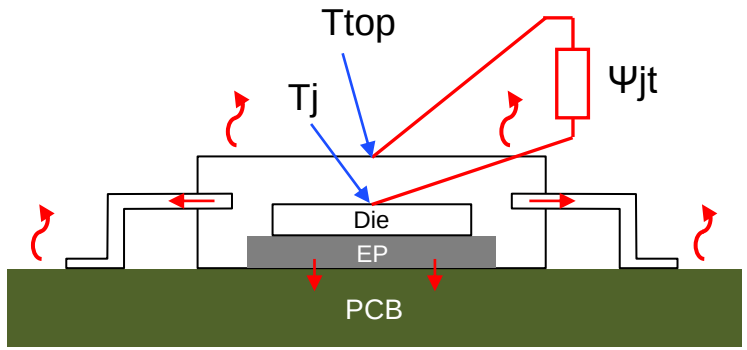
熱抵抗の測定

Thermal Metrics

θ_{JA} (junction-to-ambient).....44.3°C/W
θ_{JC_TOP} (junction-to-case top).....37.5°C/W
Ψ_{JT} (junction-to-top).....1.1°C/W







$$\theta_{ja} = \frac{Tj - Ta}{P} \ [℃/W]$$

$$\theta_{jc} = \frac{Tj - Tcase}{P} \ [℃/W]$$

$$\psi_{jt} = \frac{Tj - Ttop}{P} \ [℃/W]$$

θja

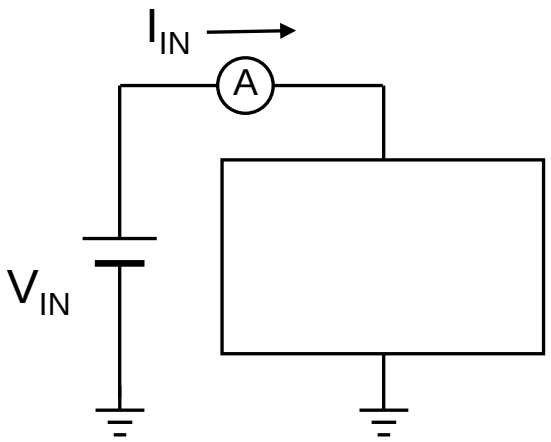
θjc

Ψjt

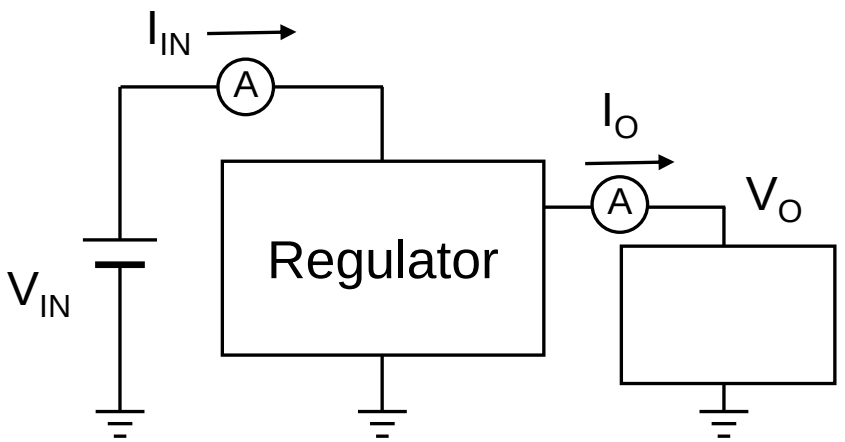
$$Tj = \theta_{ja} \times P + Ta \ [℃]$$

$$Tj = \psi_{jt} \times P + Ttop \ [℃]$$

電源の消費電力

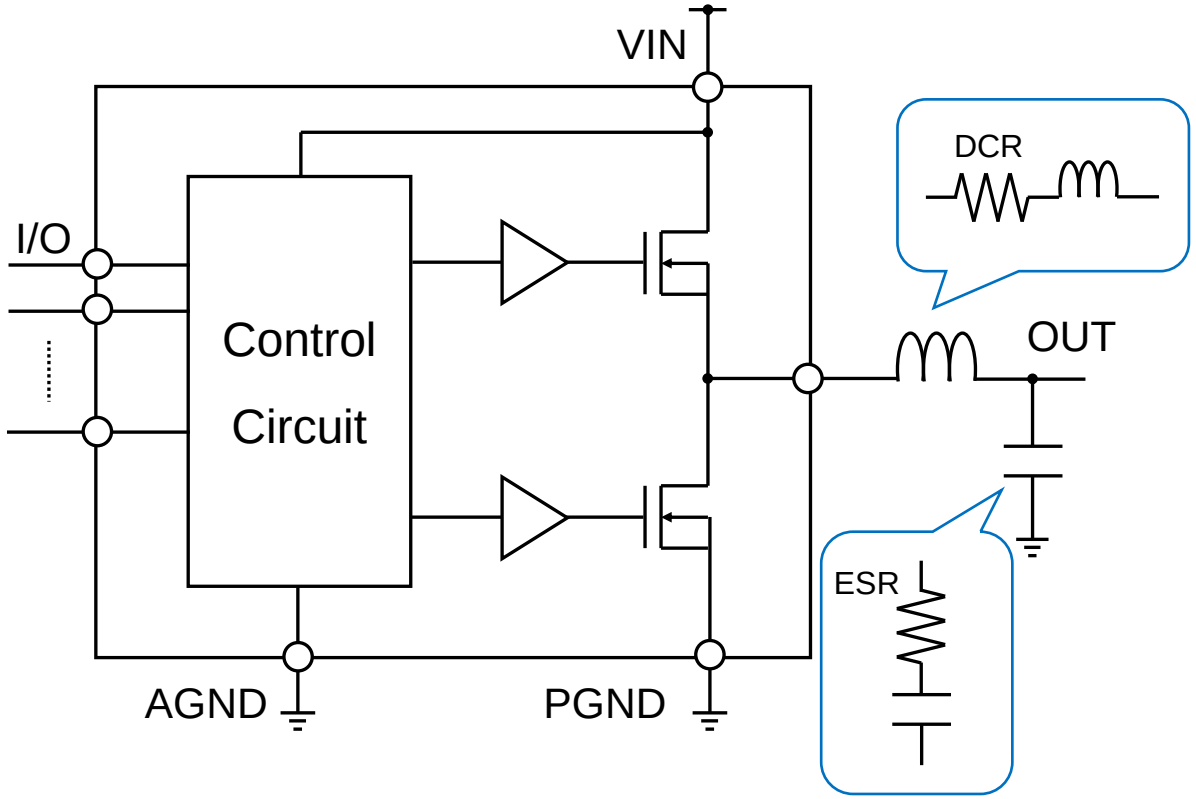


$$P = V_{IN} \times I_{IN}$$

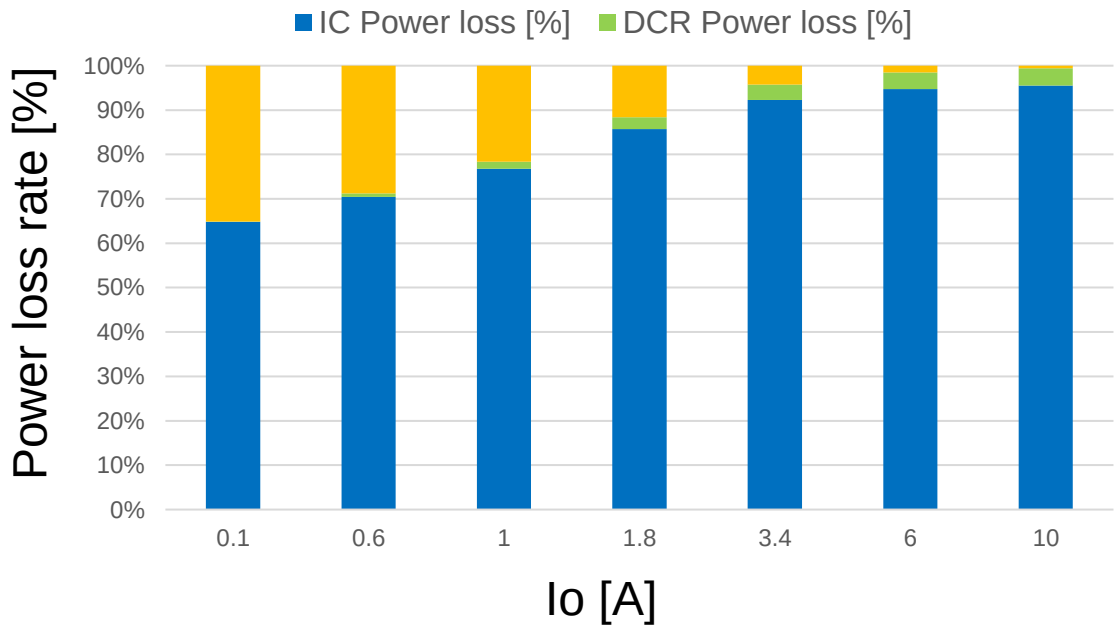


$$P = V_{IN} \times I_{IN} - V_O \times I_O$$

DCDCコンバータの消費電力



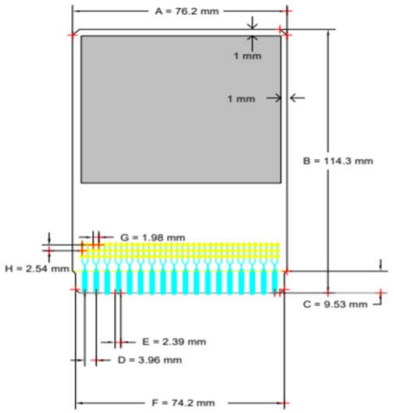
$$P_{loss} = P_{IC} + P_{DCR} + P_{ESR}$$

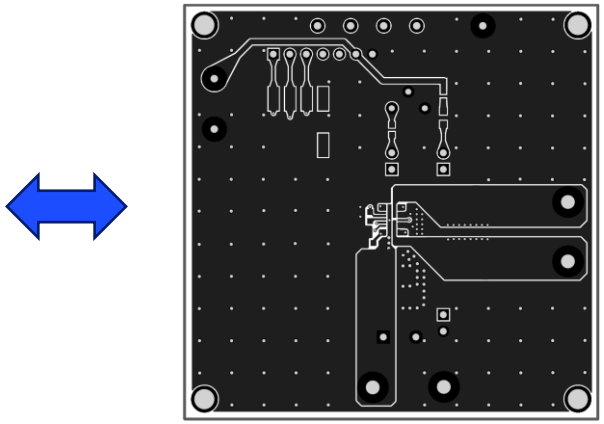


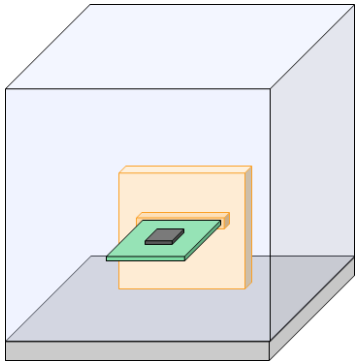
Tjの算出

$$Tj = \theta_{ja} \times P + Ta \ [℃]$$

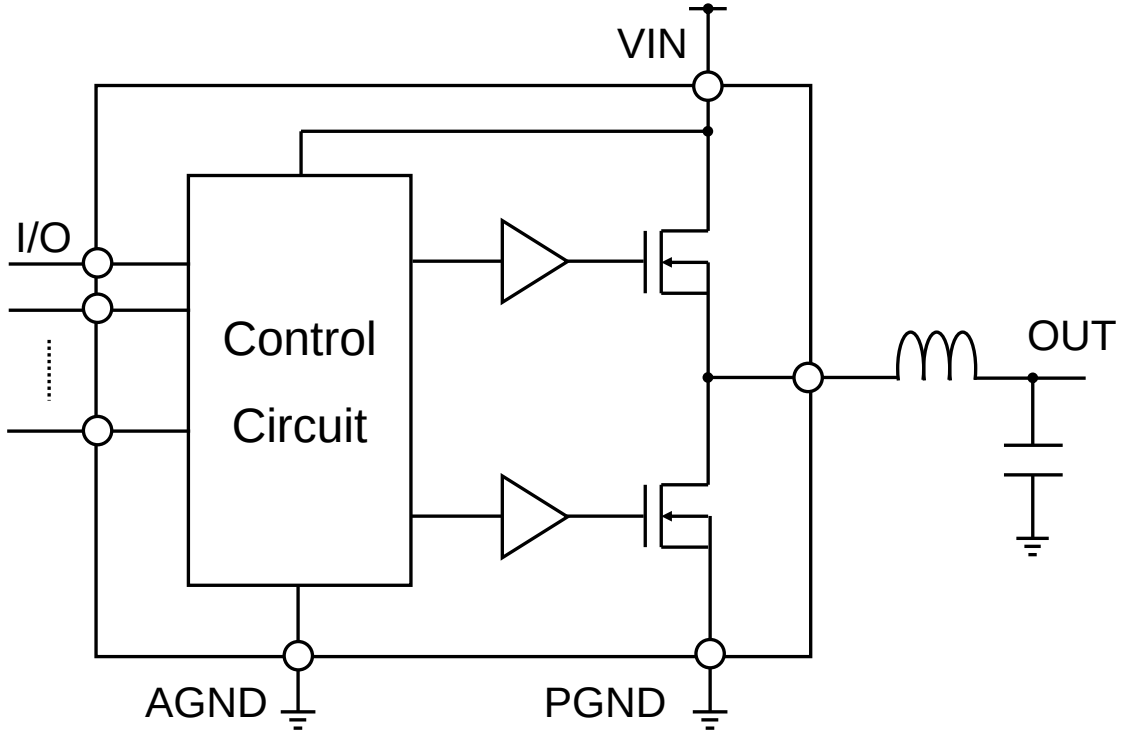
$$Tj = \psi_{jt} \times P + Ttop \ [℃]$$

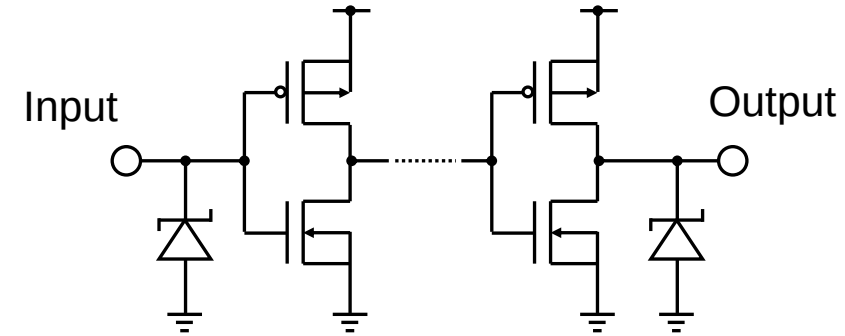




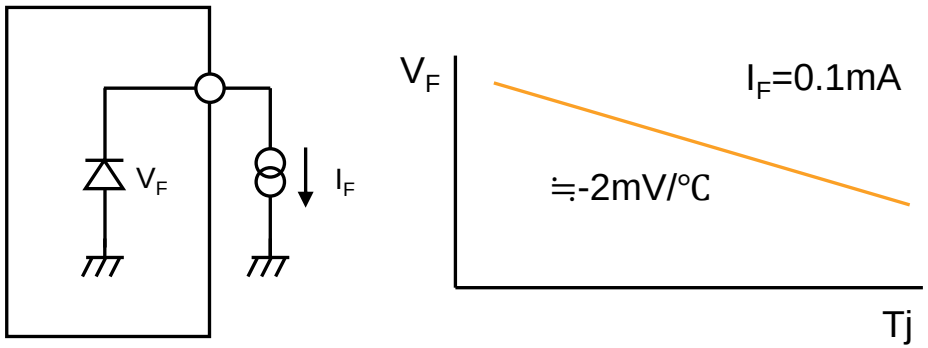


Tjの実測

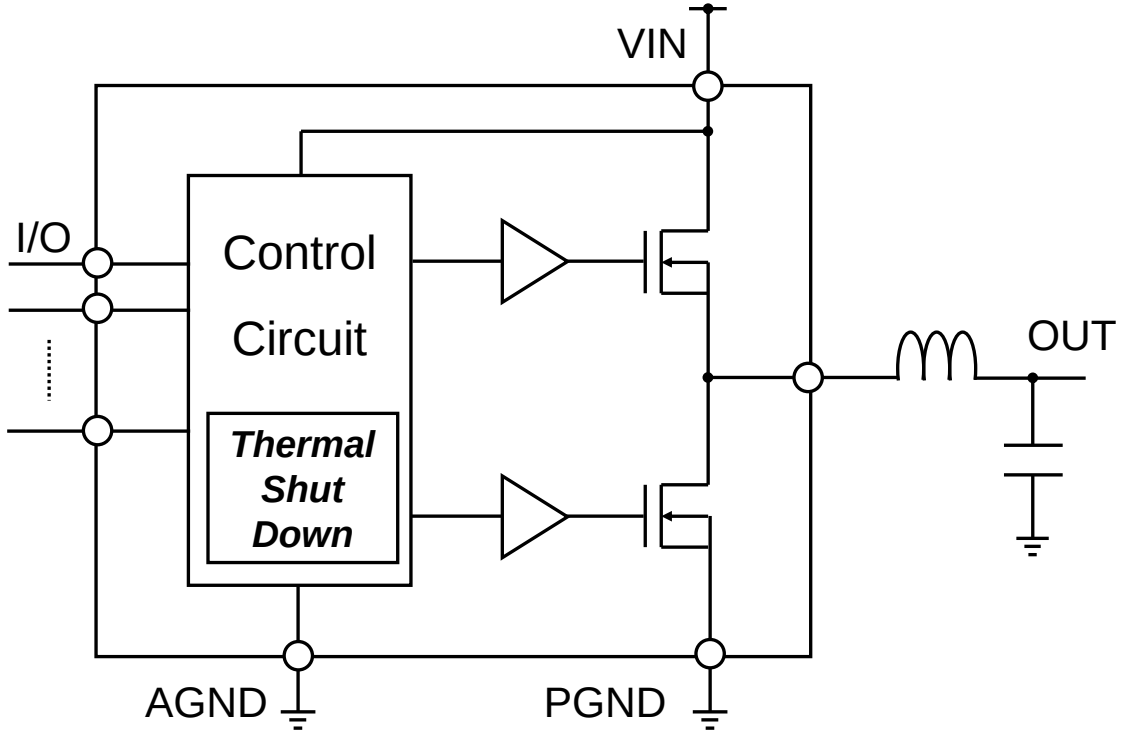


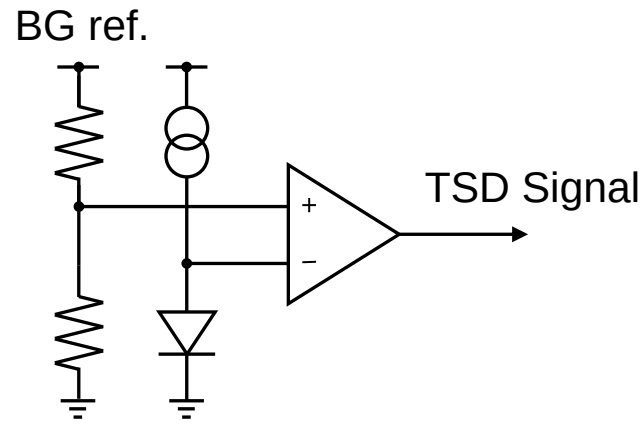


I/O Circuit

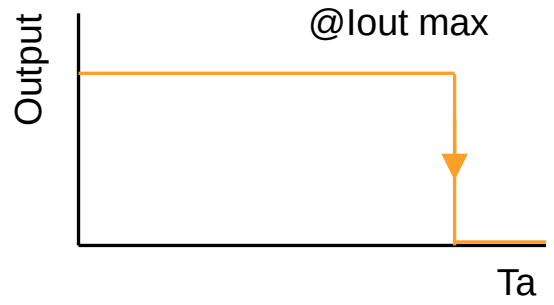


Tjの実測





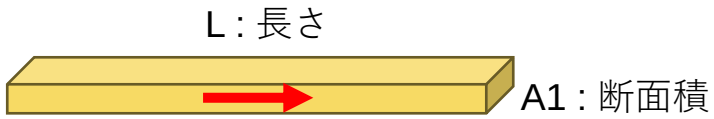
TSD Circuit



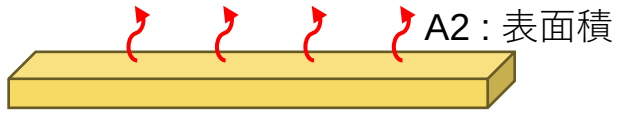
Tjを低減するPCB設計

✓ 放熱経路

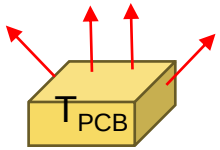
・伝導　$\theta_{CD} = \frac{L}{A_1 \times \lambda}$



・対流　$\theta_{CV} = \frac{1}{A_2 \times h}$

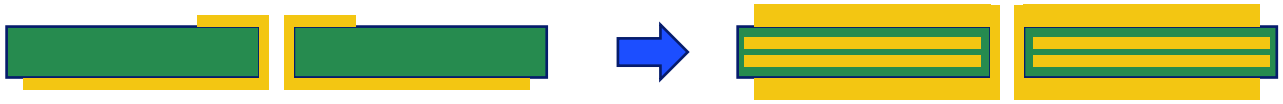


・放射　$\theta_{RD} = \frac{1}{A_3 \times \sigma \times \varepsilon \times ({T_{PCB}}^4 - {T_{AMB}}^4)}$

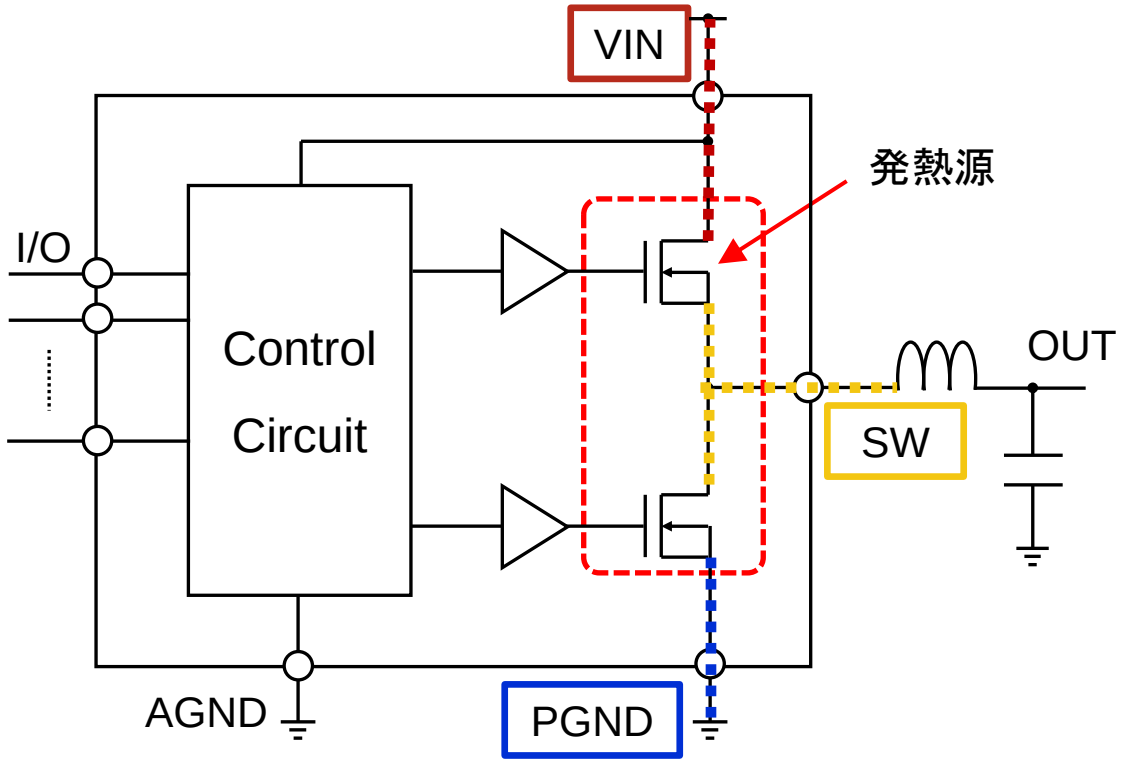


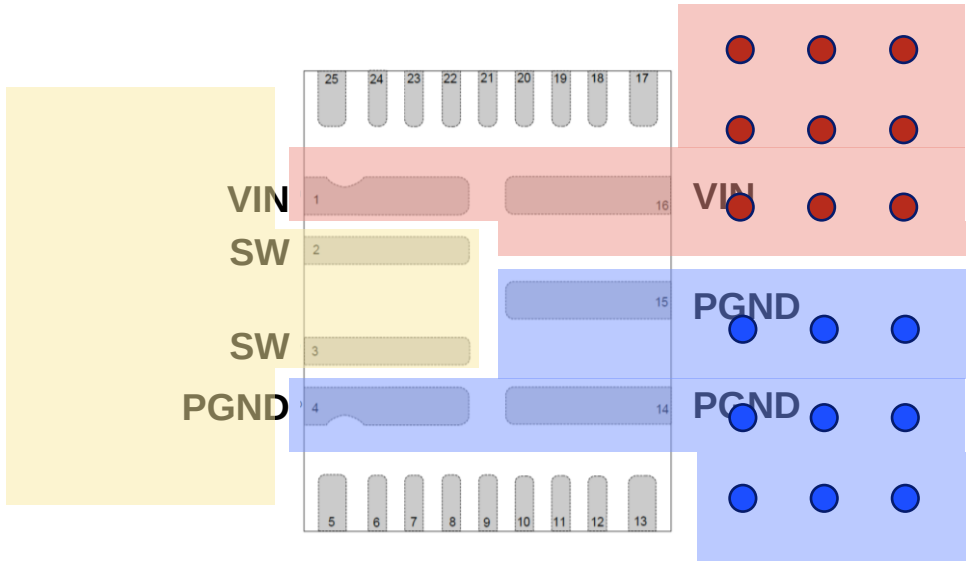
材料	熱伝導率 λ [W/mK]
銅	419
金	295
シリコン	162
半田	49
FR4	0.25

T=20℃, 1013.25hPa



PCBレイアウト例


VIN
発熱源
I/O
Control
Circuit
OUT
SW
AGND
PGND


VIN
SW
SW
PGND
VIN
PGND
PGND

サマリー

- ✓ 熱設計の重要性
- ✓ Tjを正しく把握
  - θja、Ψjtを用いた算出
  - ダイオード/ TSD機能を用いた測定
- ✓ 効果的なPCB設計
  - 伝熱を理解したPCBレイアウト