Motor Driver ICs
Power Dissipation and PCB Layout

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Pete Millett – Senior Technical Marketing Engineer

2014–Present

- MPS Senior Technical Marketing Engineer for motor driver ICs
- Responsible for new product definitions as well as application engineering

2005–2013

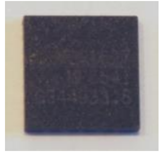
- Systems Engineer and Systems Manager at Texas Instruments
- Product definition and systems engineering for motor driver ICs (DRV8XXX)

1982–2005

- Board-level hardware design engineer at various computer and consumer electronics companies

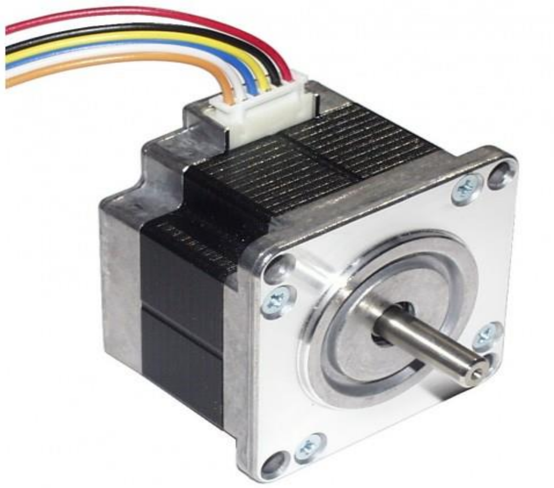
Motor Drivers – Power Dissipation and PCB Design

An Introduction to Motor Driver ICs



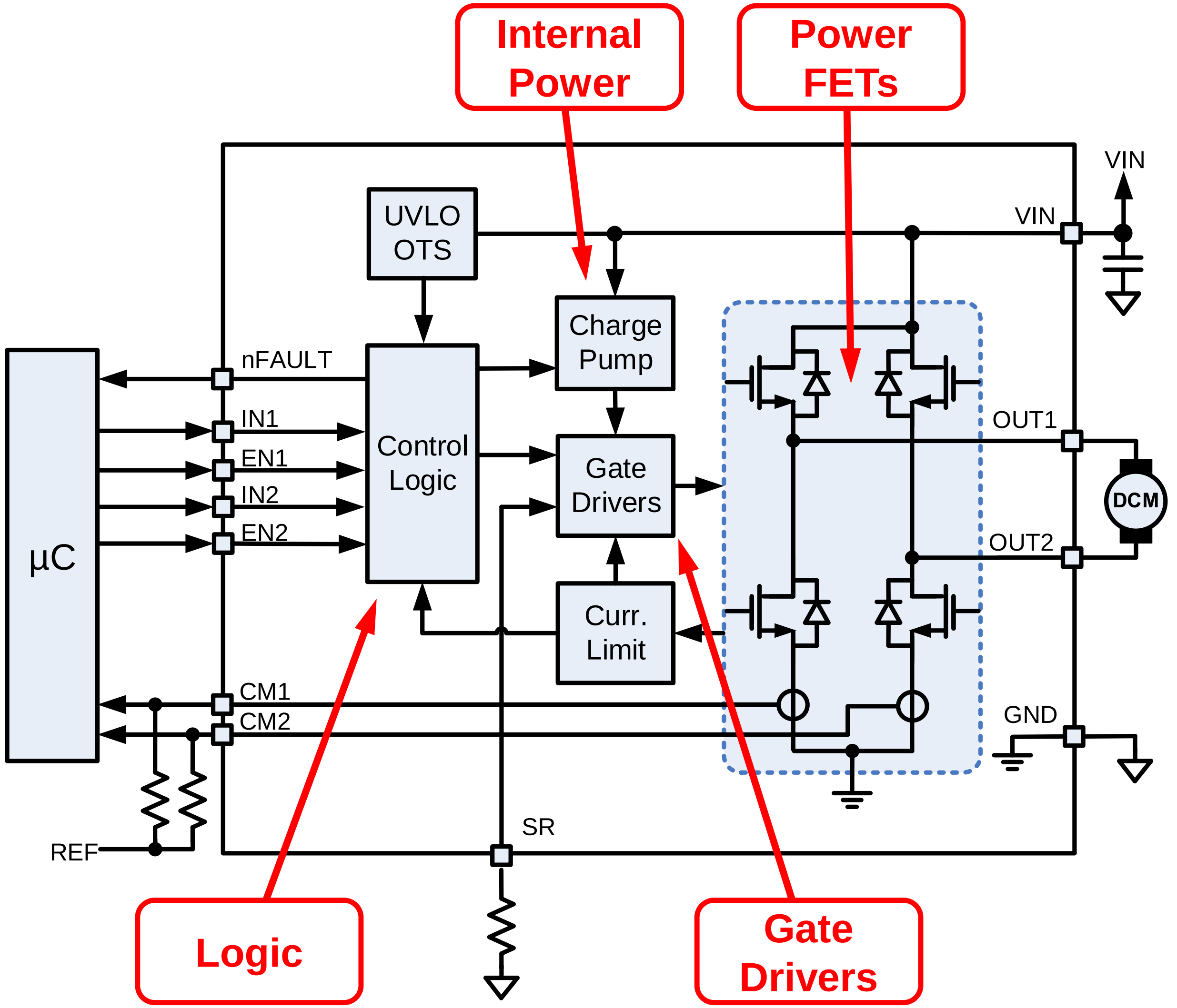
Brushed DC Motor

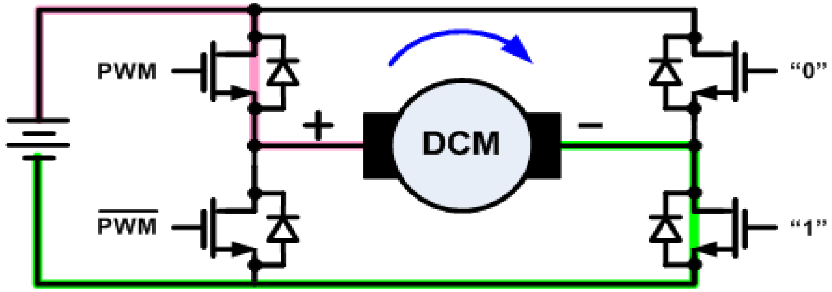
Brushless DC Motor



Stepper Motor

Inside a DC Motor Driver IC

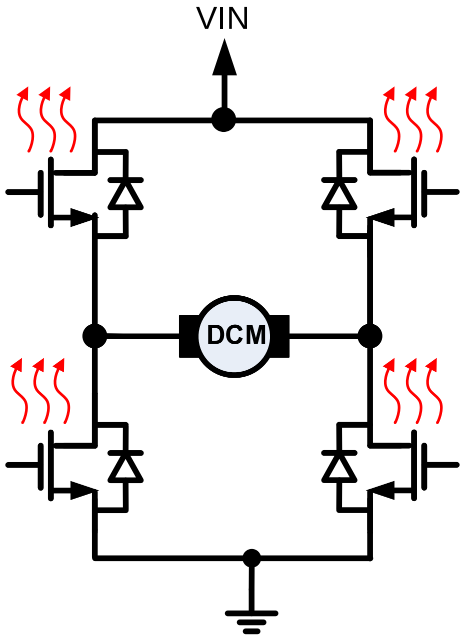




Power Dissipation in Motor Drivers

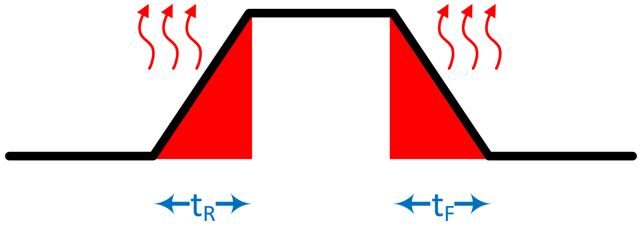
Resistive Losses

$P_R = I^2R$



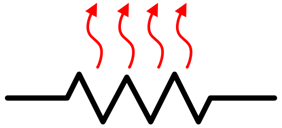
Switching Losses

$$P_S \approx \tfrac{1}{2} \times V \times I \times f_{SW} \times t_R + \tfrac{1}{2} \times V \times I \times f_{SW} \times t_F$$



Static Losses

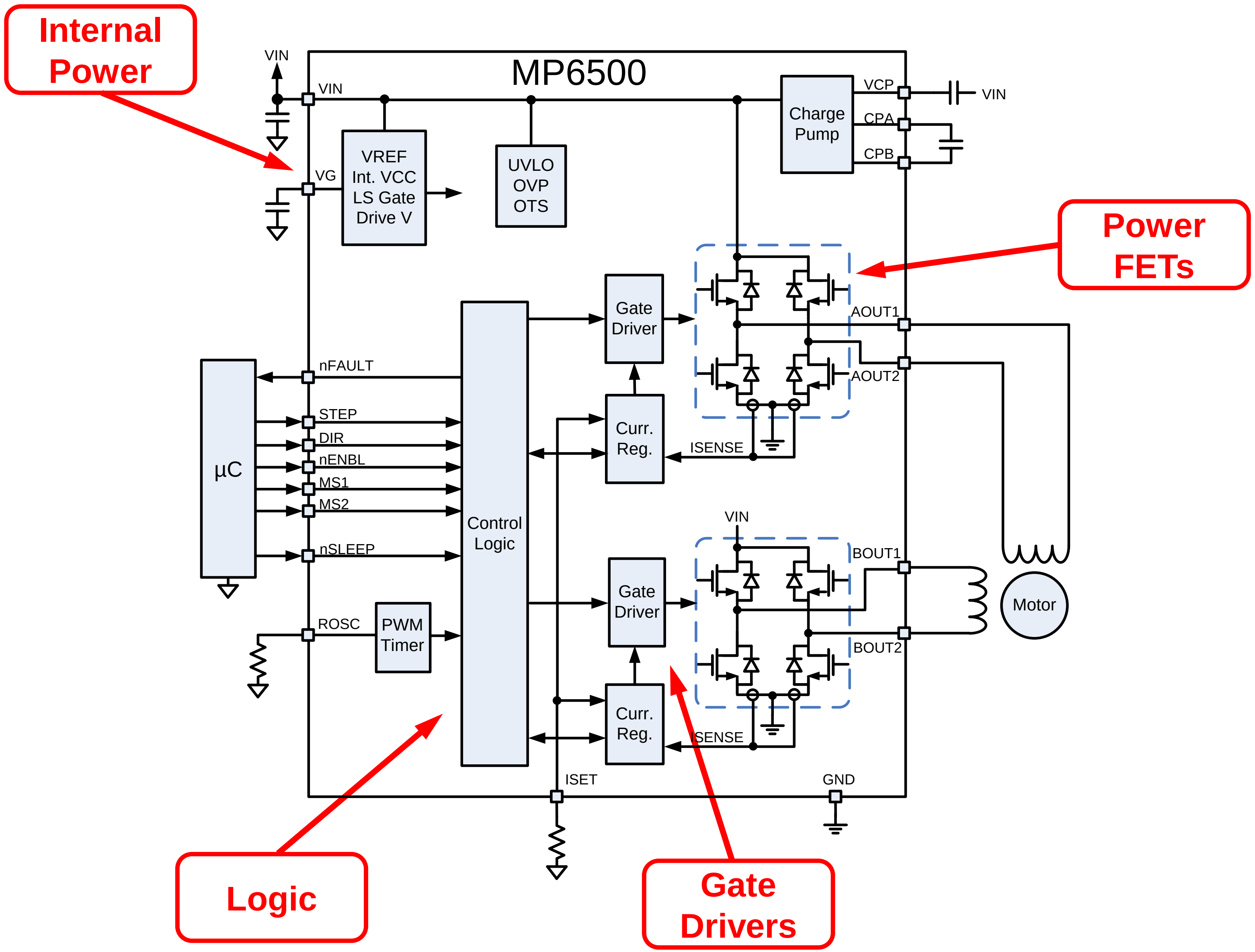
$P_Q = V_{IN} \times I_Q$

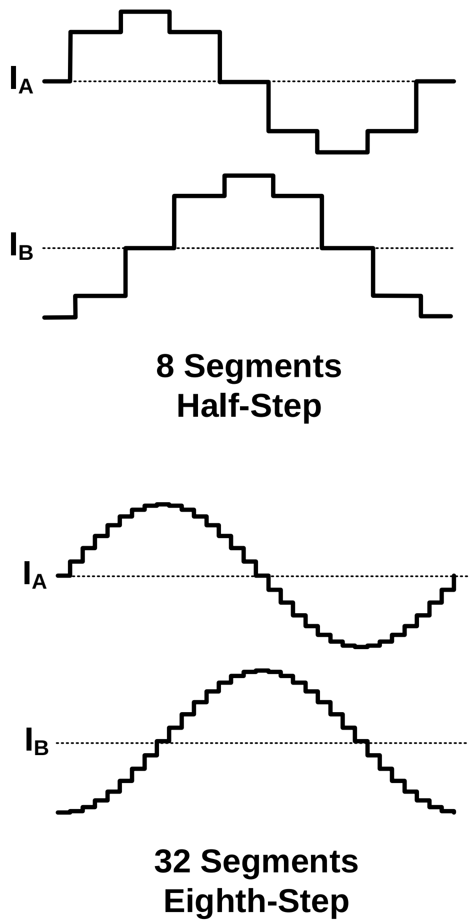


Total Power

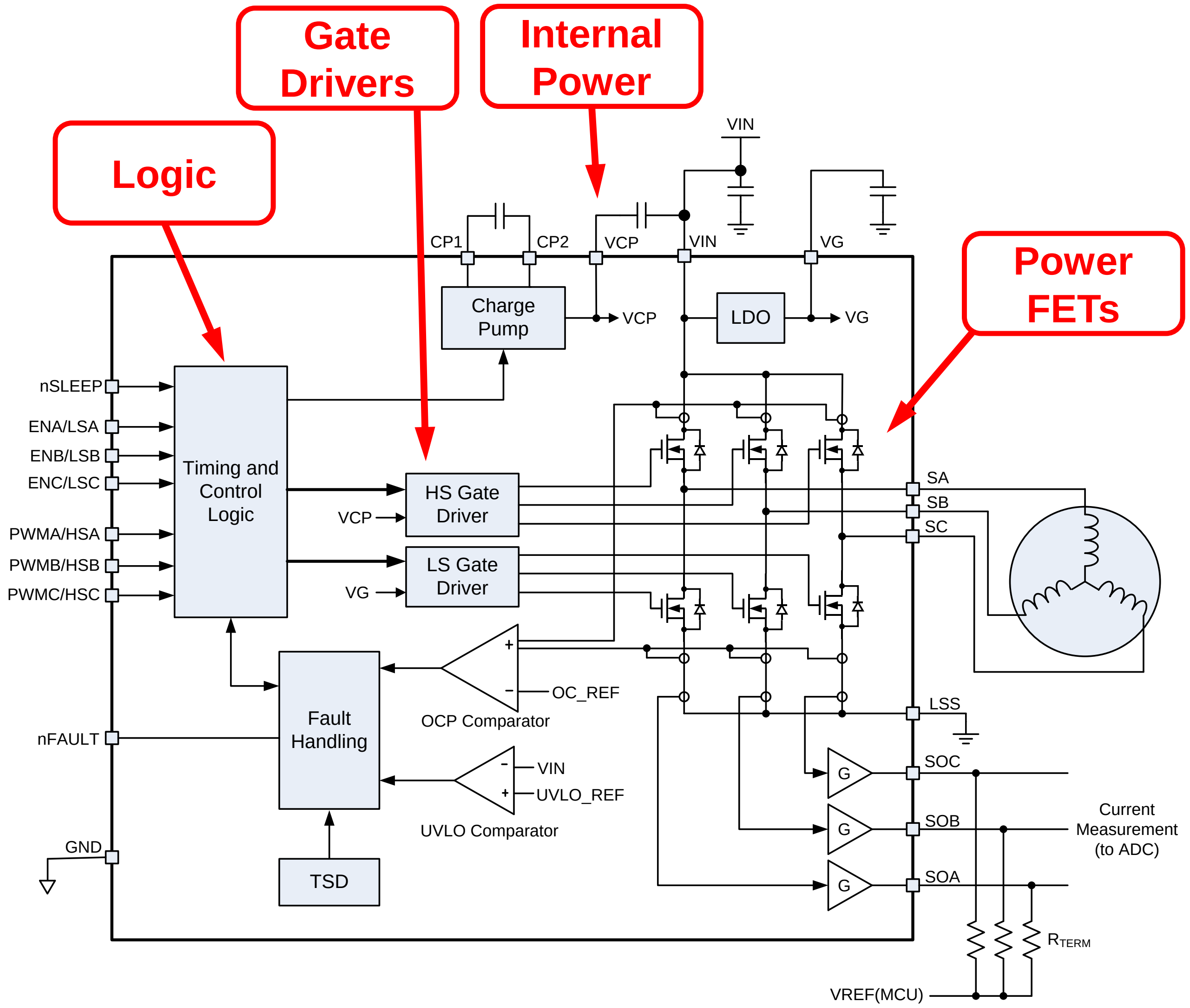
$P = P_R + P_S + P_Q$

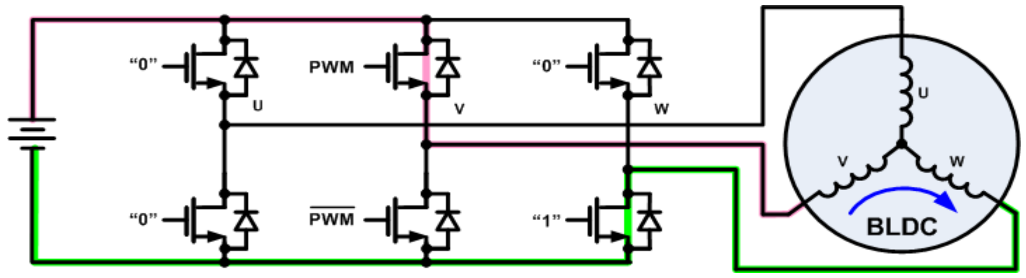
Power Dissipation in Stepper Motor Driver ICs





Brushless Motor Drivers





Power Dissipation Example

Using the MP6550 IC as an example:

HS Switch-On Resistance	RDS(ON)	IO=800mA, Ta = 25°C,		0.1	0.13	Ω
LS Switch-On Resistance	RDS(ON)	IO=800mA, Ta = 25°C,		0.1	0.13	Ω

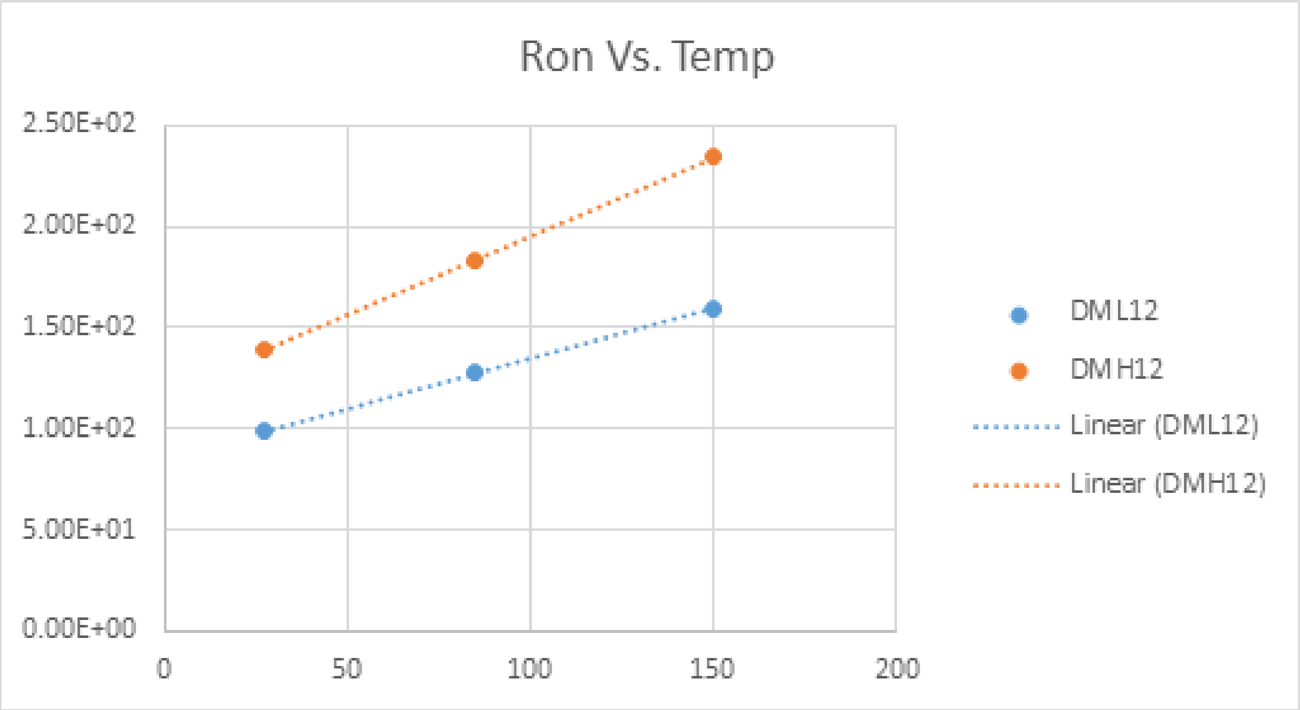
Operating supply current		no PWM, no load, nSLEEP_HB=5V, nSLEEP_LDO=0		900	1200	µA
		50-kHz PWM, no load, nSLEEP_HB=5V, nSLEEP_LDO=0		1.2	1.5	mA

Output rise time		RL=20 Ω	30		200	ns
Output fall time		RL=20 Ω	30		200	ns

Let's assume you are driving a load with 5V, 2A output current with a PWM frequency of:

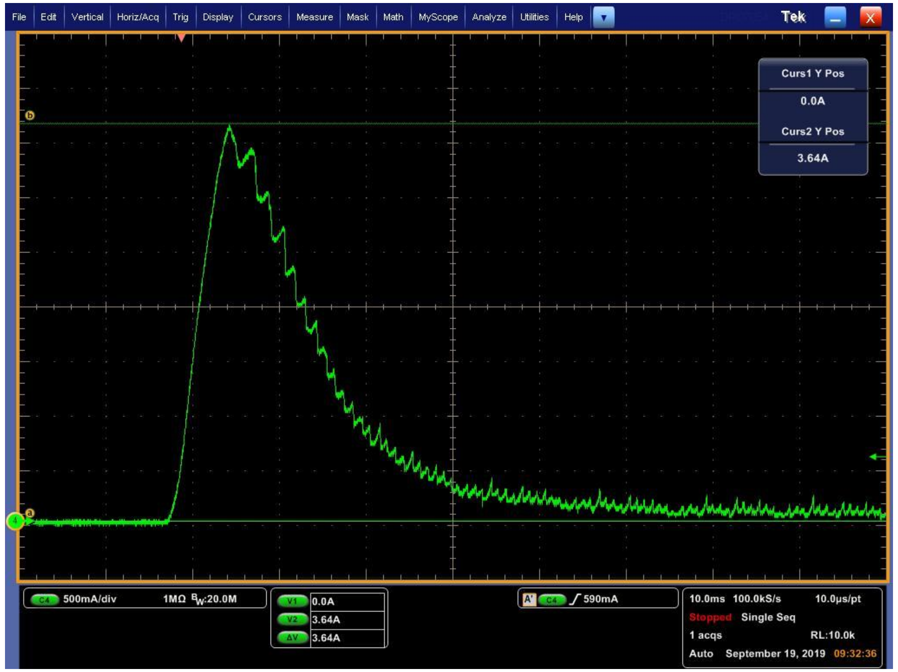
- Using the $R_{DS(ON)}$, we will dissipate $(5A)^2$ x 0.1Ω = 0.25W in the high side, and $(5A)^2$ x 0.1Ω = 0.25W in the low side
- Static power will be 5V x 1.2mA = 0.006W
- Switching loss is approximately (1/2 x 100ns x 50kHz x 5V x 2A) + (1/2 x 100ns x 50kHz x 5V x 2A) = 0.05W
- Total power is then 0.56W

A Problem: $R_{DS(ON)}$ vs. Temperature



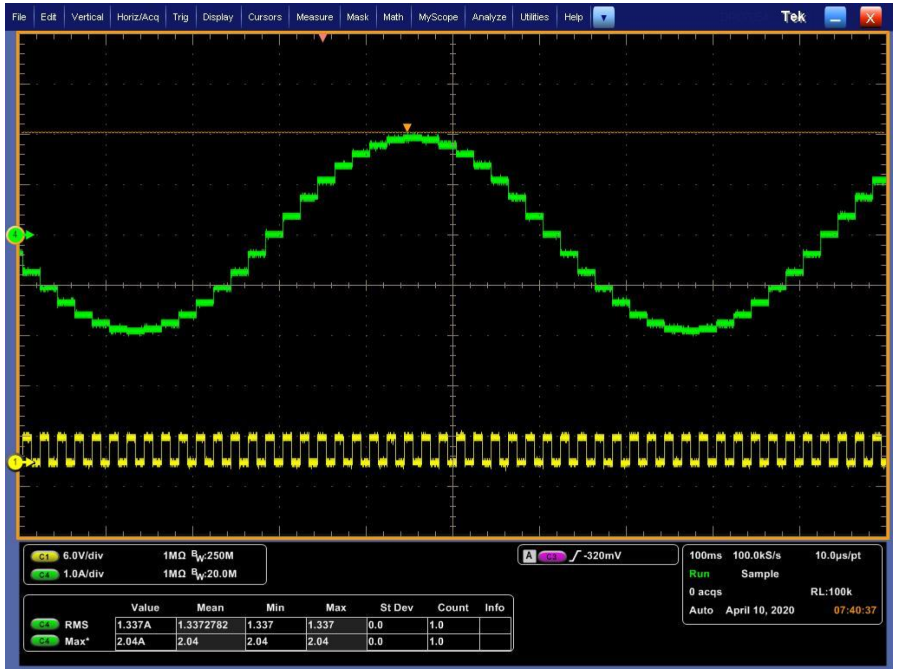
Peak vs. Average and RMS Load Current

DC Motor Start-Up Current



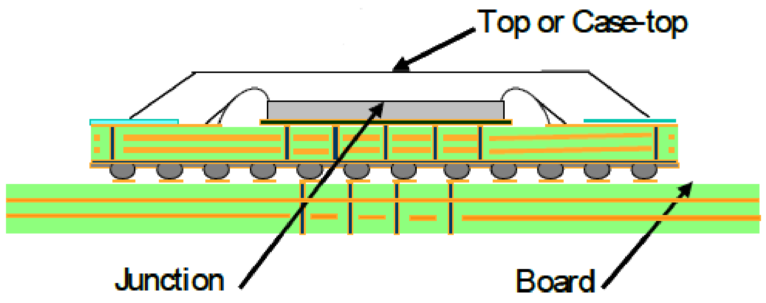
3.6A Peak for ~20ms

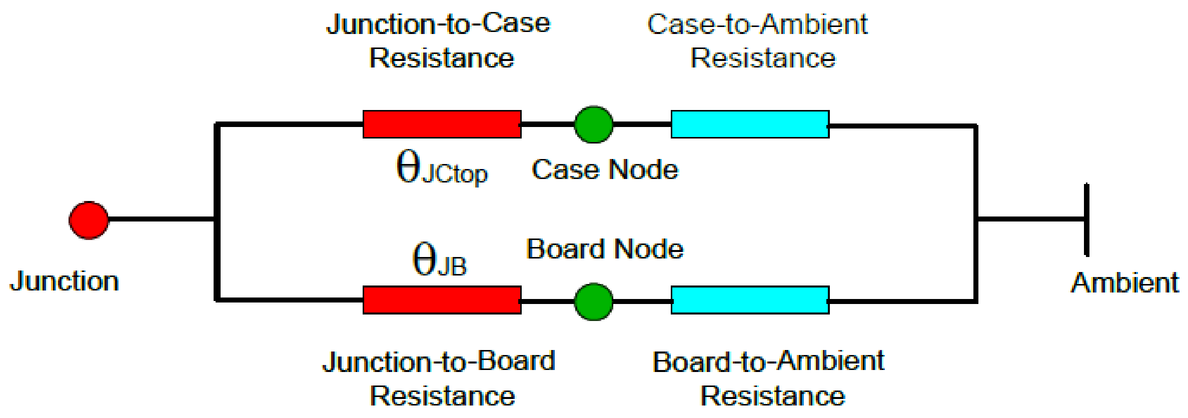
Stepper Motor RMS Current



2A peak ≈ 1.4A RMS

Thermal Resistance & Models





Simple Estimation:

Die temperature = ambient temp + (P x Θ_{JA})

Temperature Rise Example

Using the MP6550 IC as an example:

Thermal Resistance (4) ***θ_{JA}*** ***θ_{JC}***
QFN-12 (2mm×2mm)............... 80 .....16.....°C/W

Continuous Power Dissipation (T_A = +25°C) (2)
....1.56W

Thermal Shutdown Threshold(5)	T_{TSD}			160		°C
Thermal Shutdown Hysteresis(5)				25		°C

Total power dissipation is 560mW:

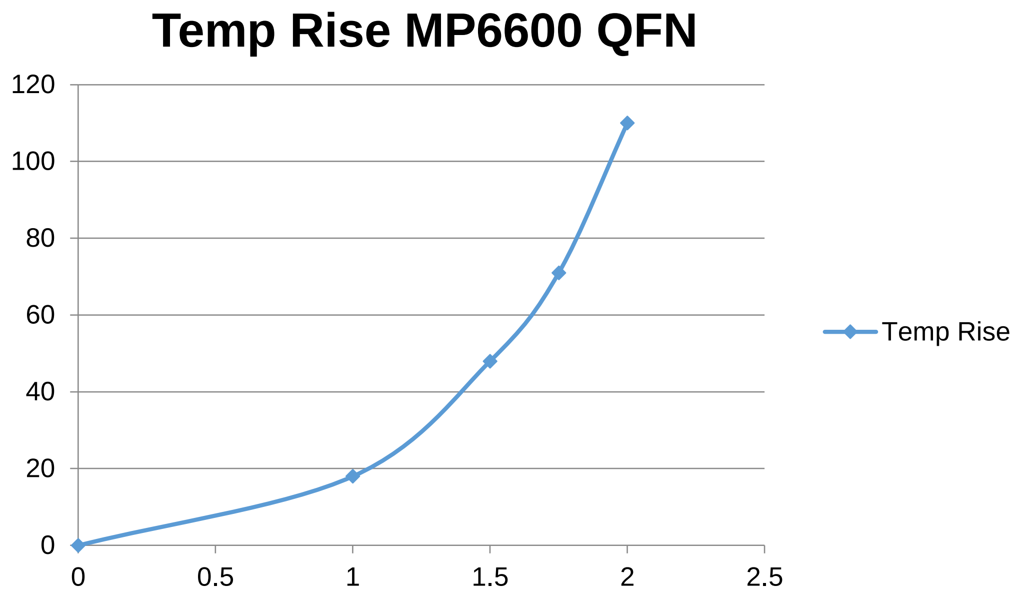
- Temperature rise is P x Θ_{JA}, so 0.56 x 80 = 44.8°C
- Junction temperature is $T_A + T_R$.

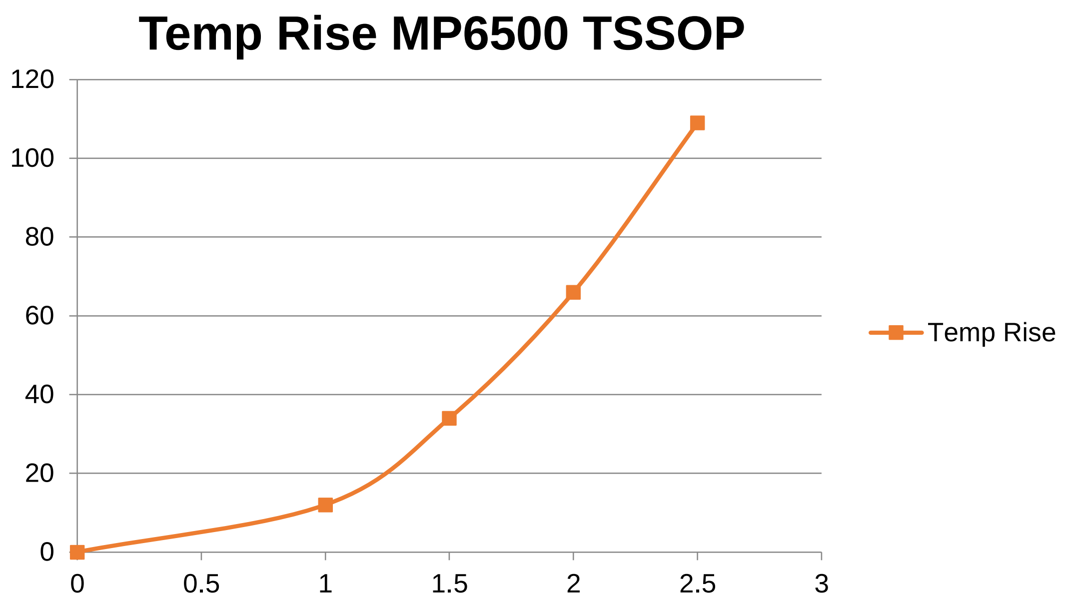
  If we assume room temperature of 25°C, then the junction is at 25 + 44.8 = 69.8°C.

  If the ambient is 70°C, then the junction temperature will be 114.8°C.

Temperature Rise vs. Output Current

Bigger Package = Better Thermals





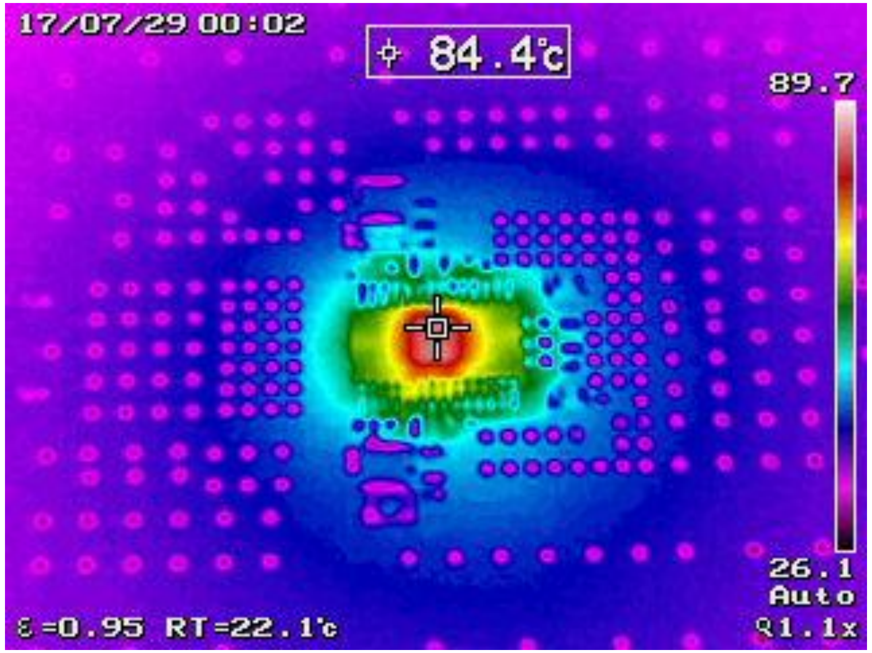
PCB Design for Power Dissipation

Table 7 — JESD51-7 High Thermal Conductivity Leaded SMT Test Board Parameters [8]

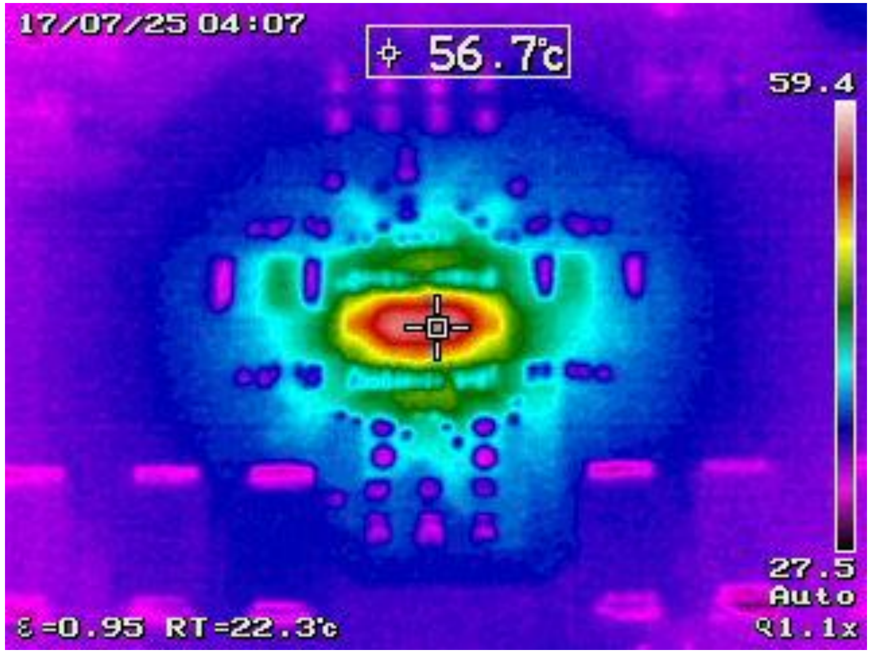
Dimension	Specification	User
Board Finish Thickness	1.60 mm ± 10%	
Board Dimension (pkg length < 27 mm)	76.2 mm x 114.3 mm	
Board Dimension (27 mm ≤ pkg length ≤ 48 mm)	101.6 mm x 114.3 mm	
Board material	FR-4	
Trace Copper Thickness	0.070 mm ± 20%	
Trace Width, Finished	0.25 mm ± 10% for ≥ 0.50 mm pin pitch Lead width for < 0.50 mm pin pitch	
Trace Coverage Area (Total)		
Power/Ground Thickness	35 µm (1oz) copper +0/-20%	

Effect of Layer Count & Planes

MP6500 Driving 2A Peak Stepper Motor

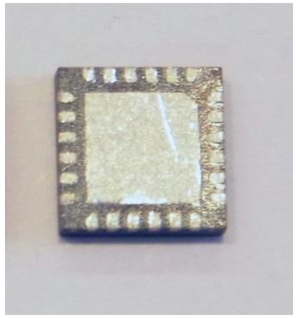


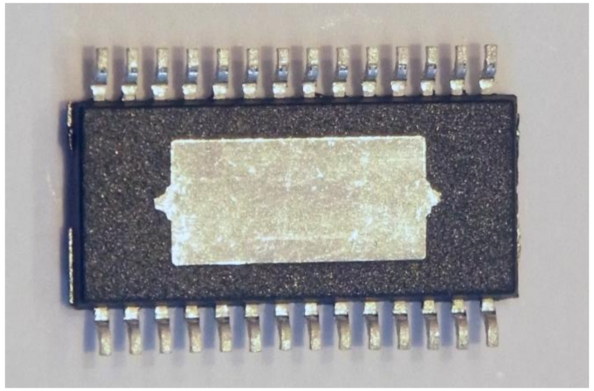
2 Layers

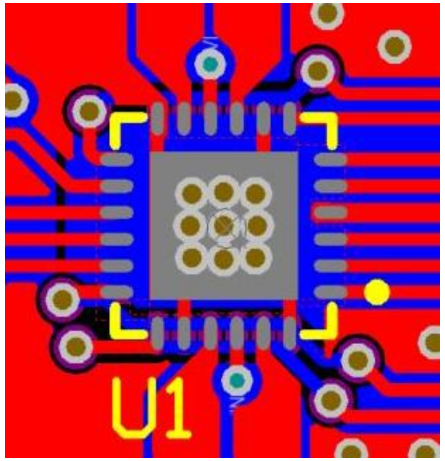


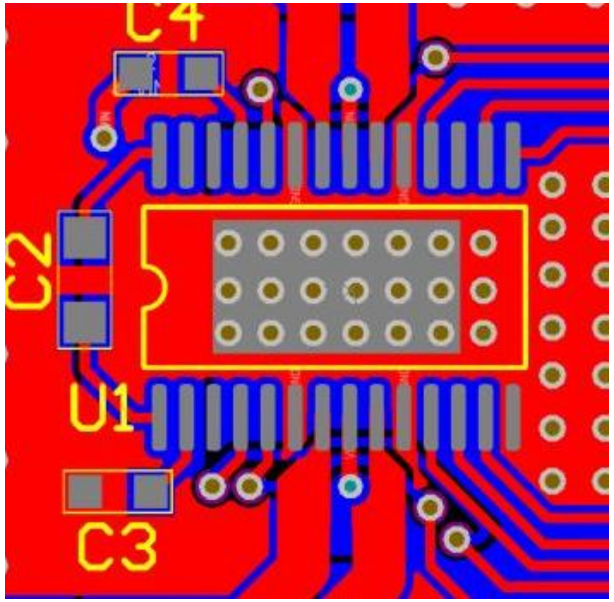
4 Layers (2 Planes)

Exposed Pads on TSSOP & QFN

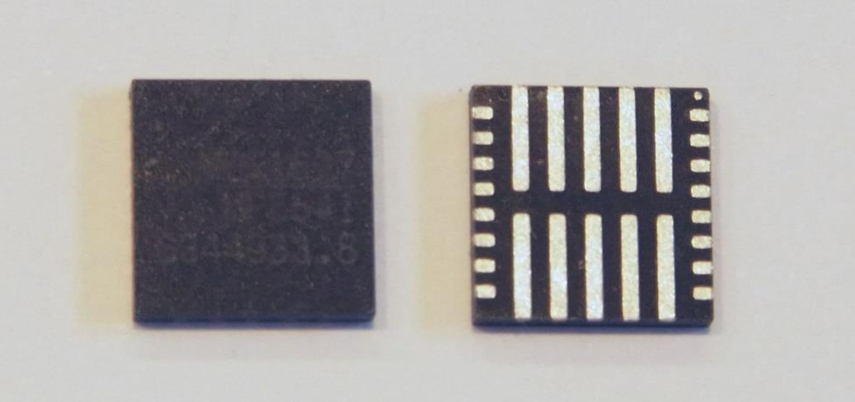


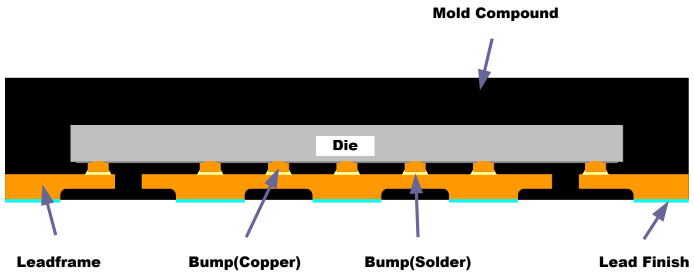


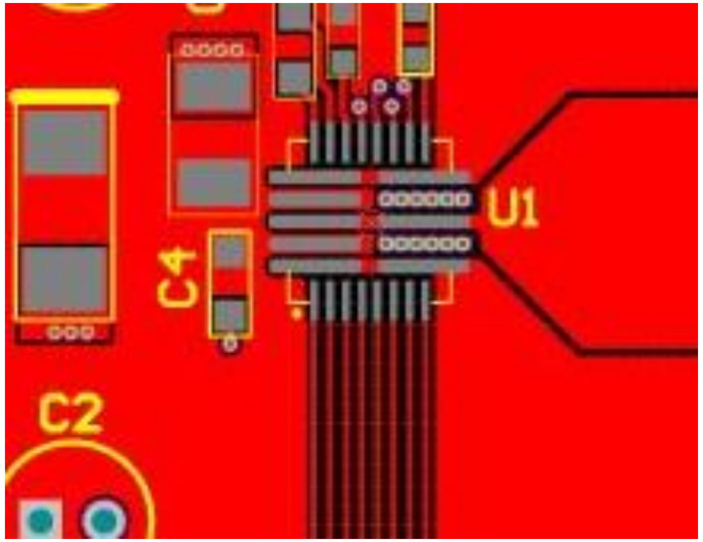


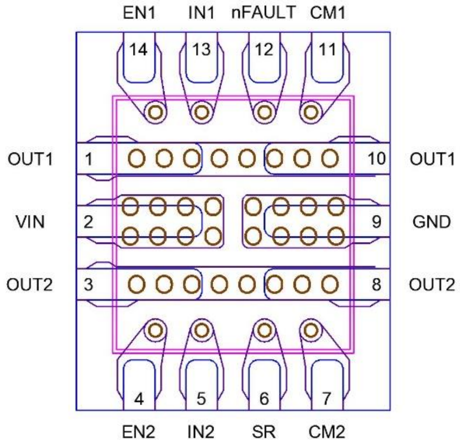


Flip-Chip QFN and LGA Packages

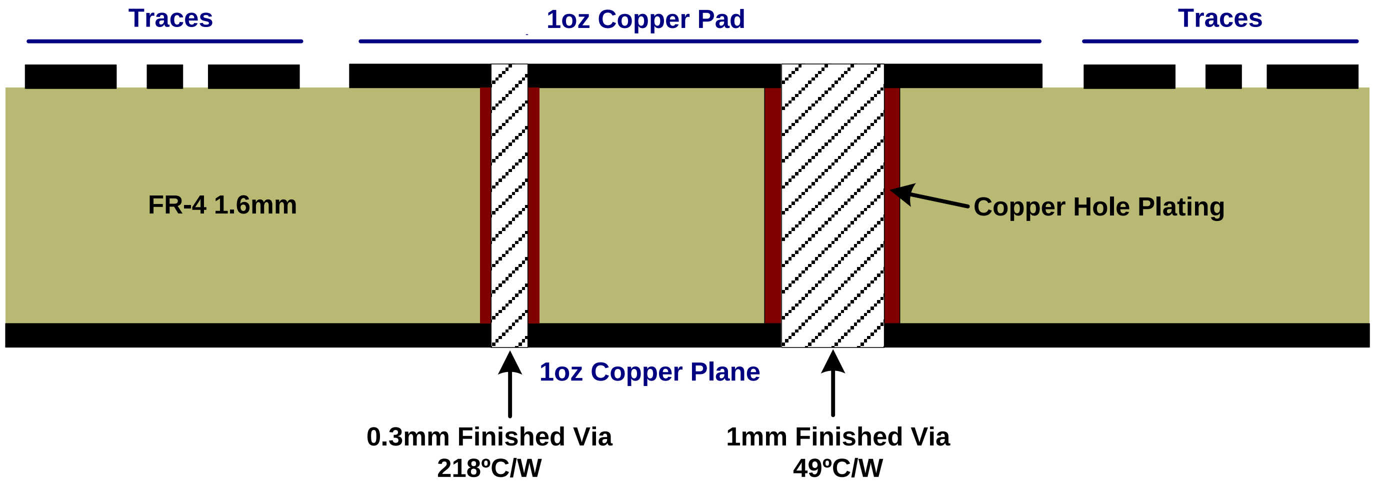


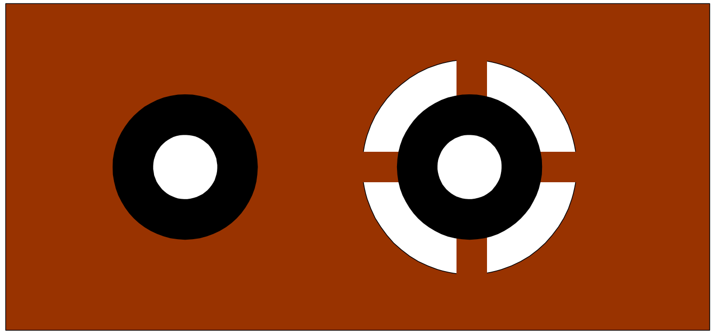






Thermal Vias





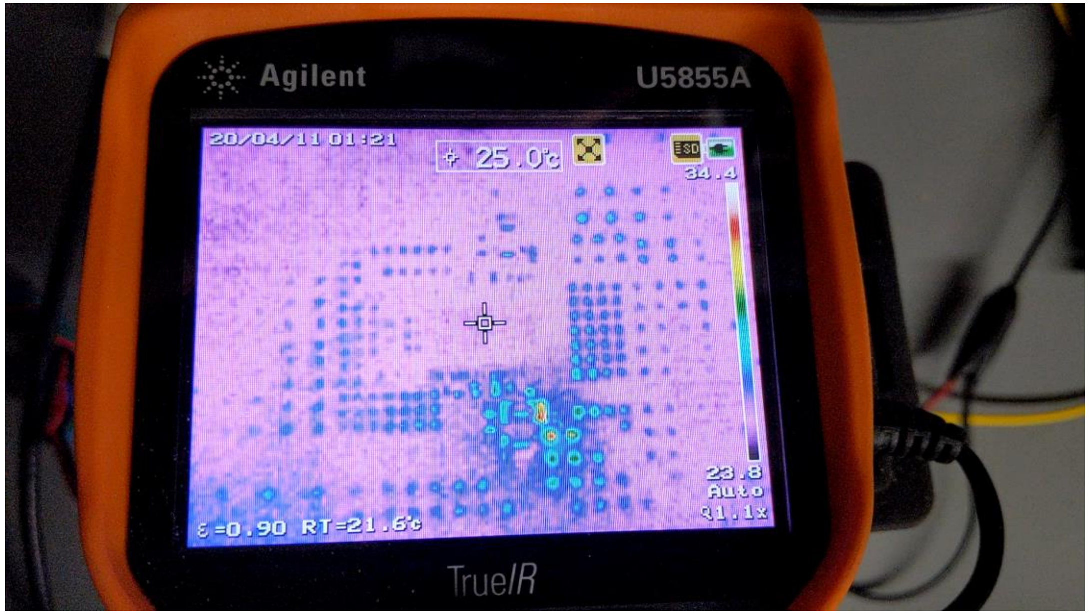
Solid Connection
YES!

Thermal Relief
NO!

What Happens if the Exposed Pad isn't Soldered?

MP6500 Driving 2A Peak Stepper Motor
4-Layer PCB

Exposed Pad Soldered



Exposed Pad Not Soldered

Summary

- Calculate the power dissipated in your motor driver IC
  - Or work backwards and calculate maximum current from thermal conditions
- Minimize thermal resistance
  - Bigger is always better
  - Multi-layer boards work best
- Use thermal vias to spread heat
- ALWAYS solder the exposed pad

Q&A

Please submit questions through the “Q&A” menu option in the Zoom app

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