Motor Driver ICs
Power Dissipation and PCB Layout

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Motor Drivers – Power Dissipation and PCB Design

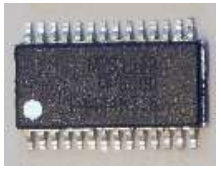
Introduction to Motor Driver ICs

Power Dissipation in Drivers

PCB Design for Power Dissipation

Summary / Q&A

An Introduction to Motor Driver ICs

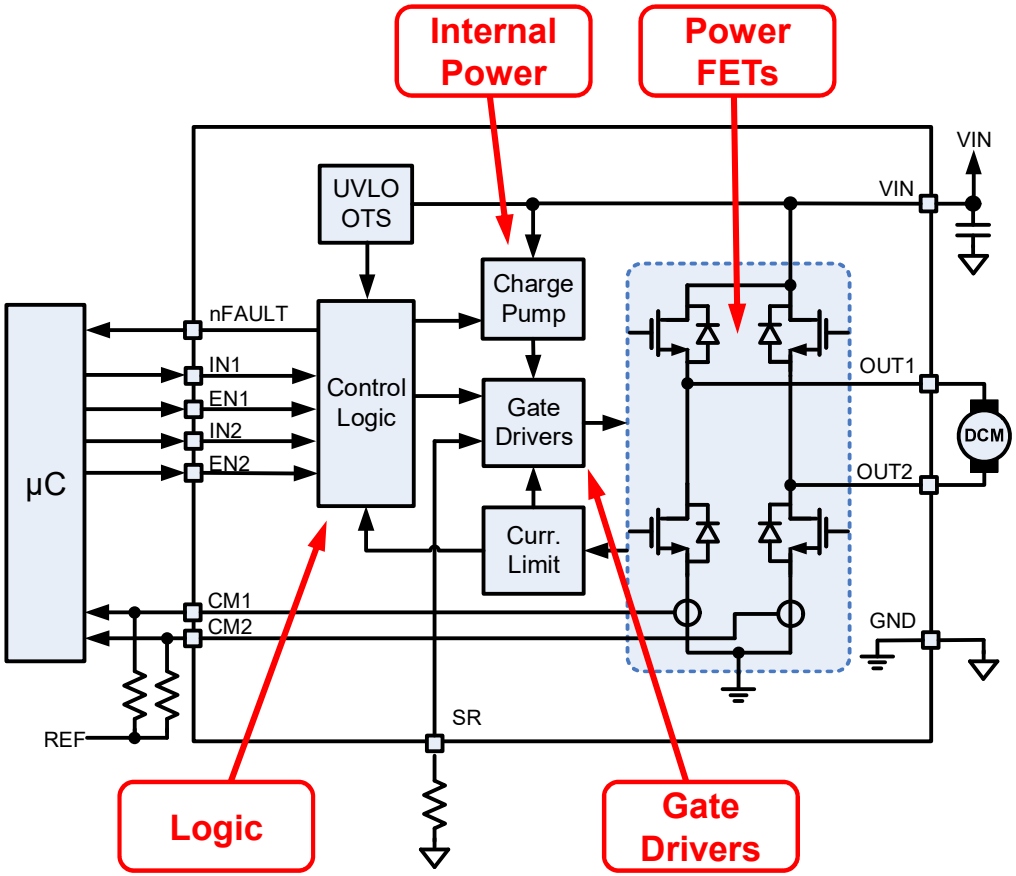


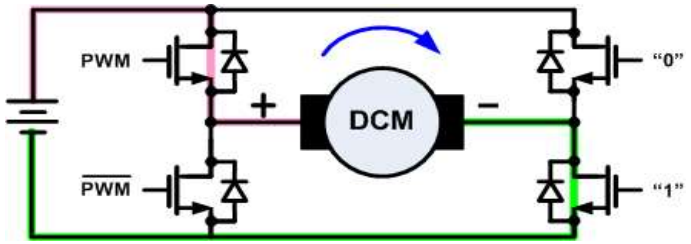
Brushed DC Motor

Brushless DC Motor

Stepper Motor

Inside a DC Motor Driver IC

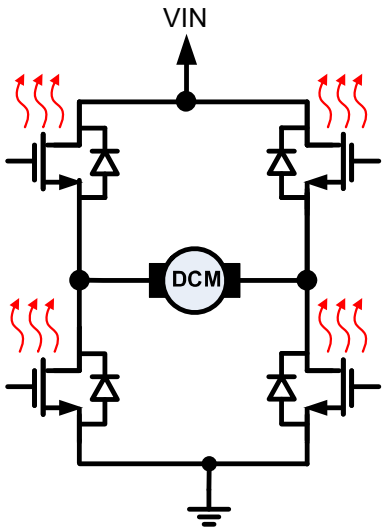




Power Dissipation in Motor Drivers

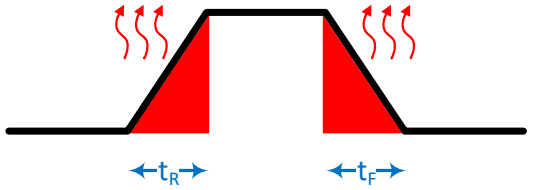
Resistive Losses

$P_R = I^2R$



Switching Losses

$P_S \approx ½ \times V \times I \times f_{sw} \times t_R + ½ \times V \times I \times f_{sw} \times t_F$



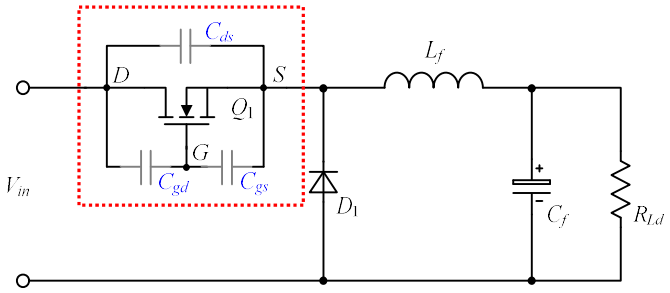
Static Losses

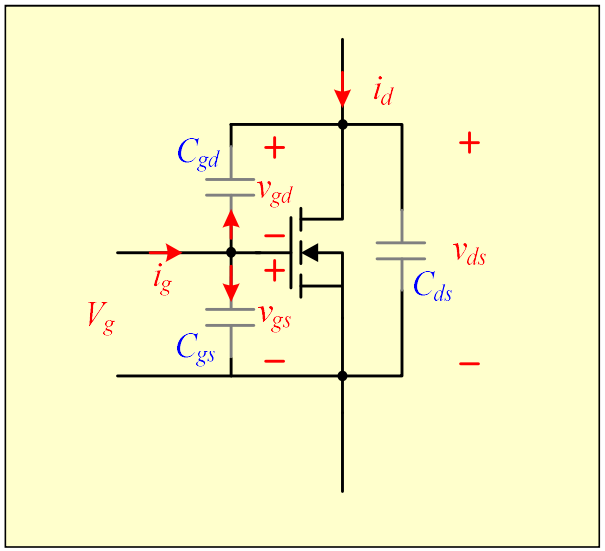
$P_Q = V_{IN} \times I_Q$

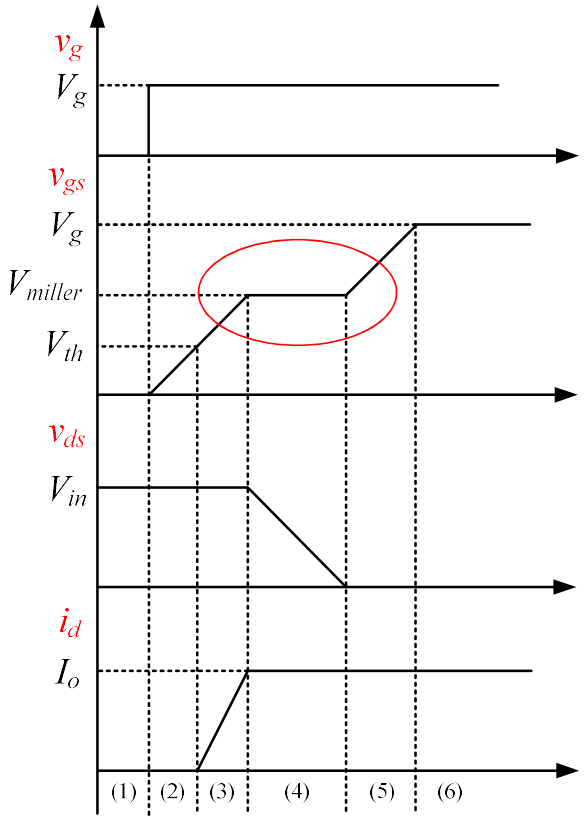
Total Power

$P = P_R + P_S + P_Q$

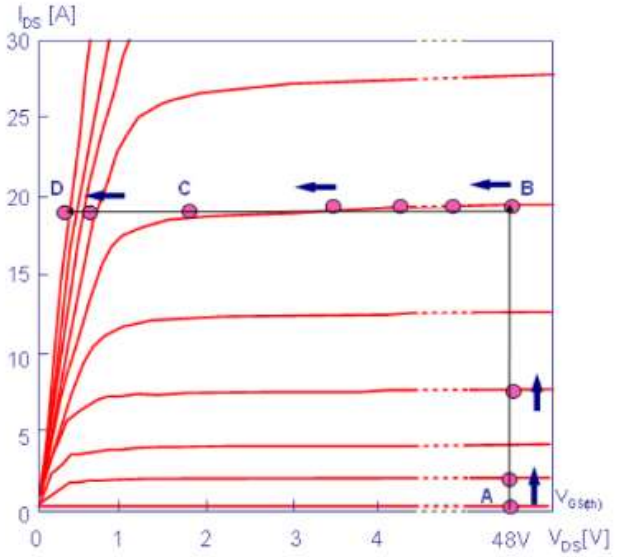
MOSFET Turn On Process

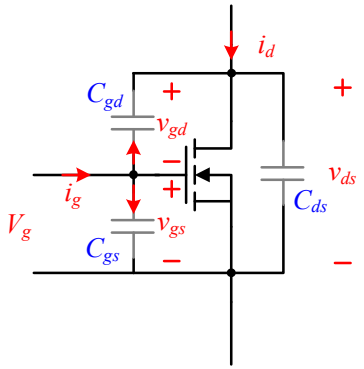


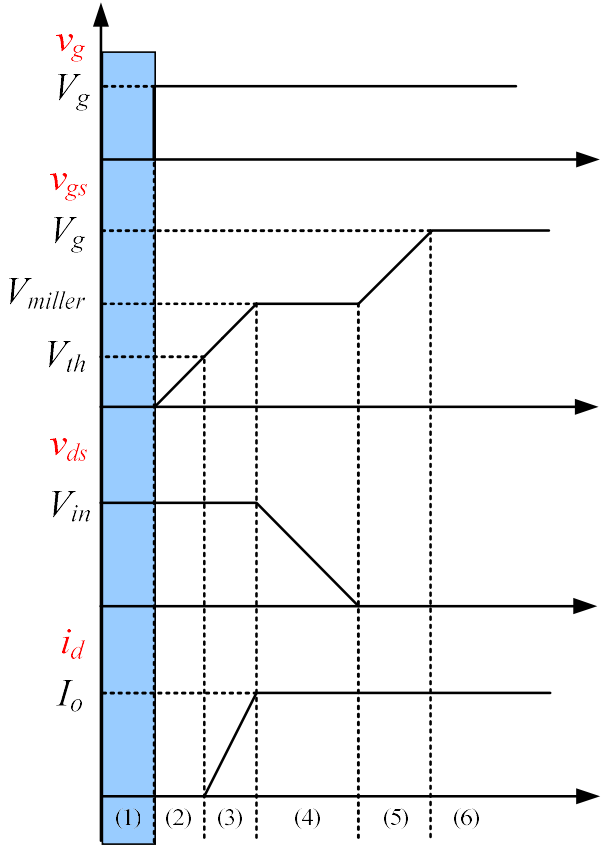




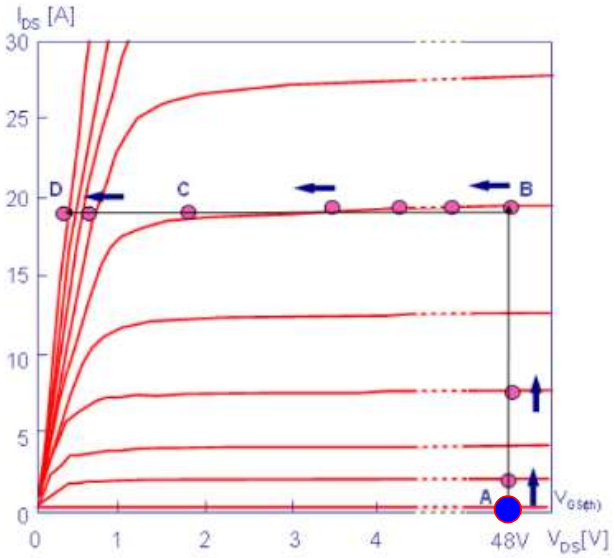
MOSFET Turn On Process

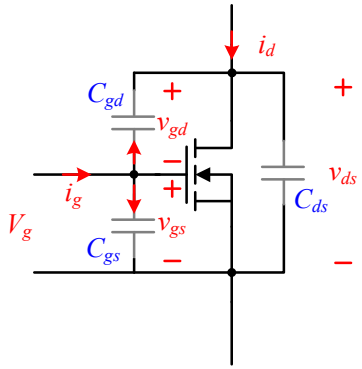


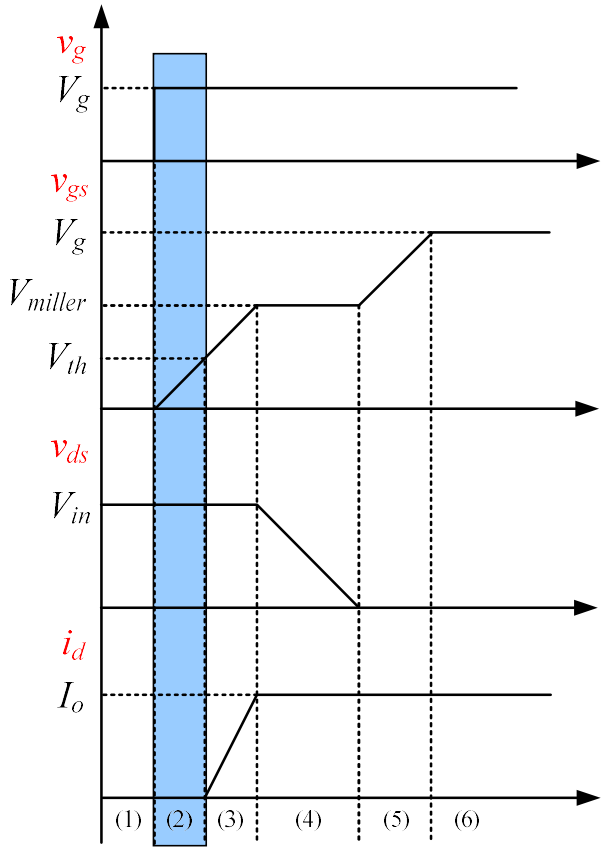




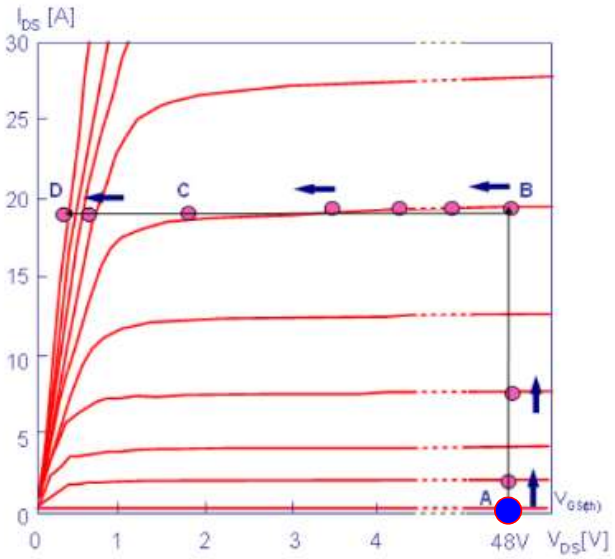
MOSFET Turn On Process

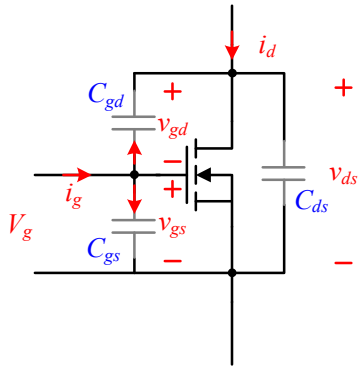


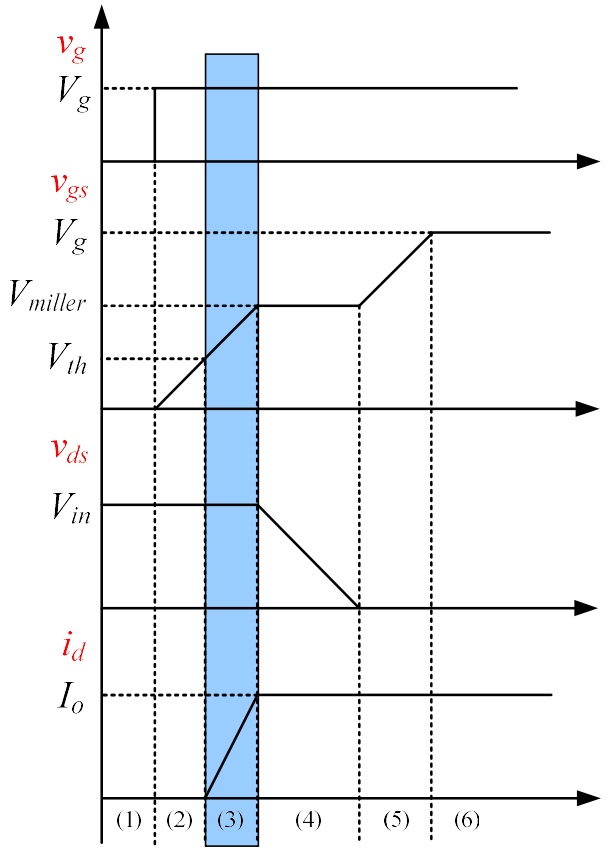




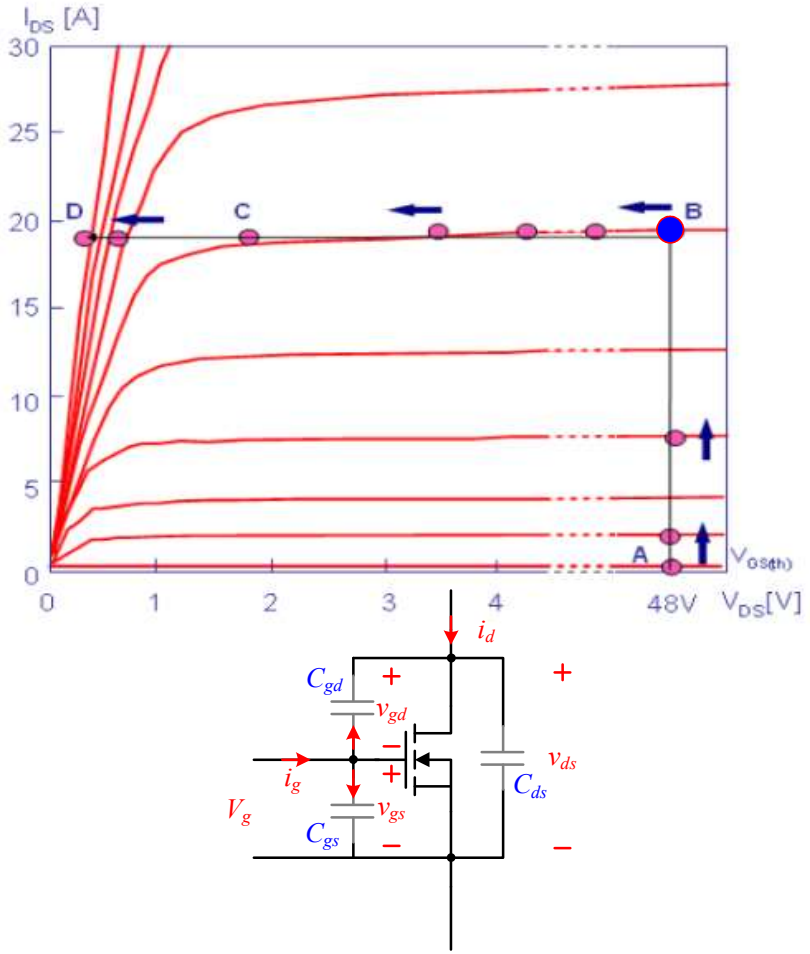
MOSFET Turn On Process

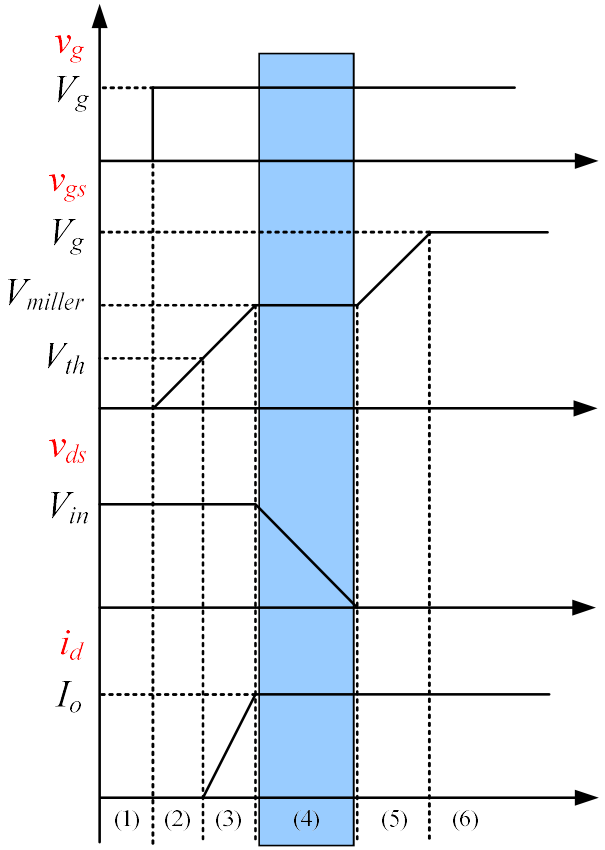




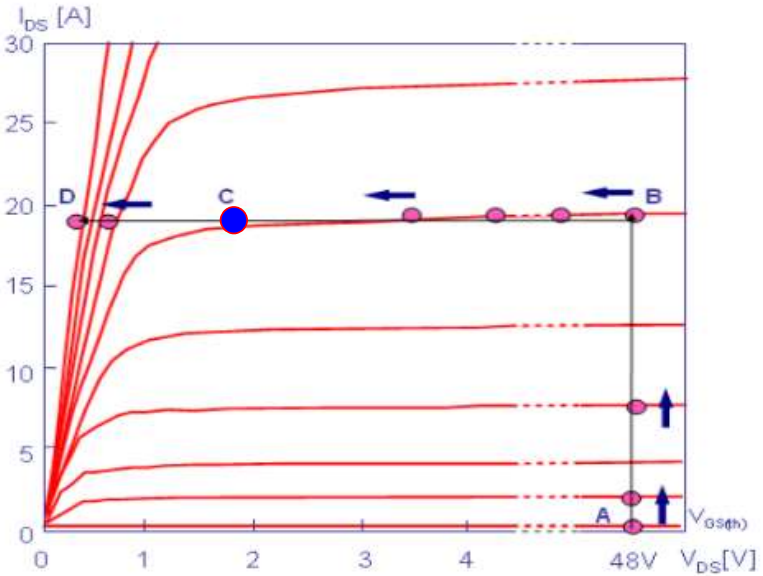


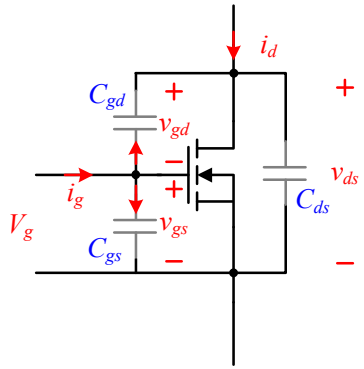
MOSFET Turn On Process

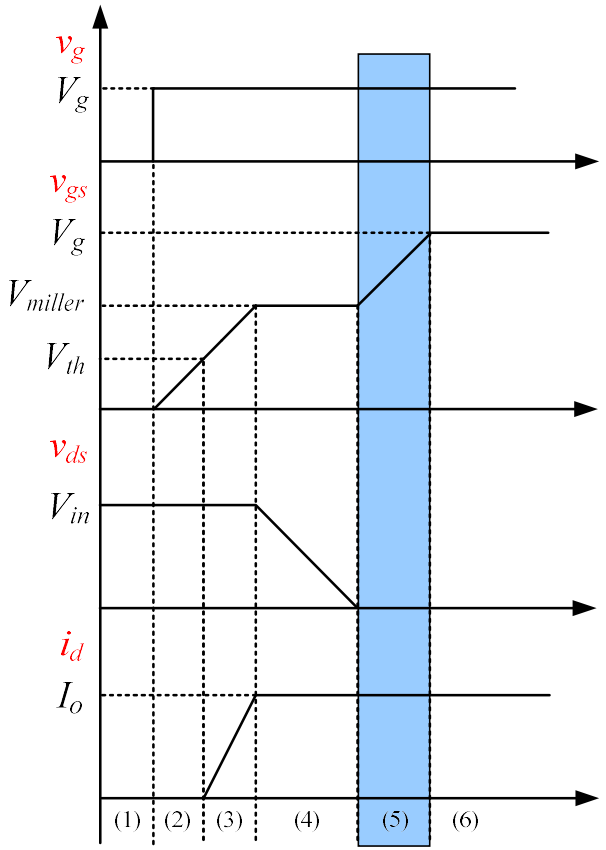




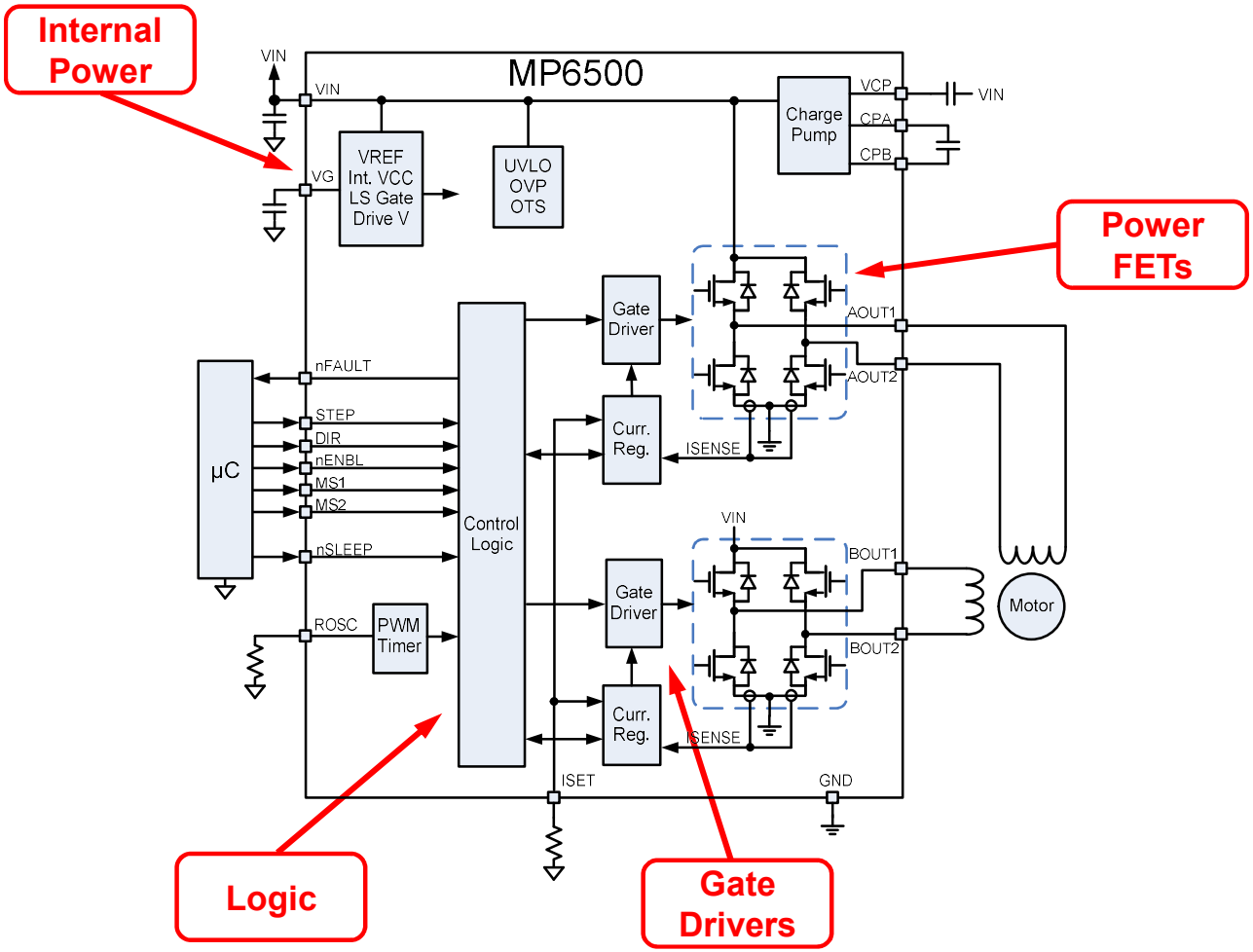
MOSFET Turn On Process

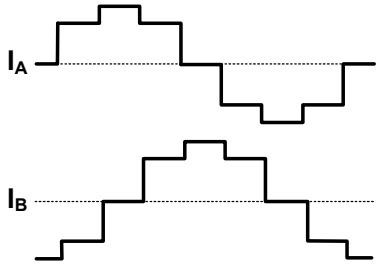




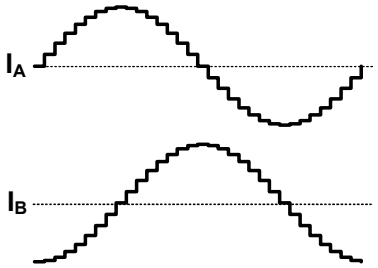


Power Dissipation in Stepper Motor Driver ICs



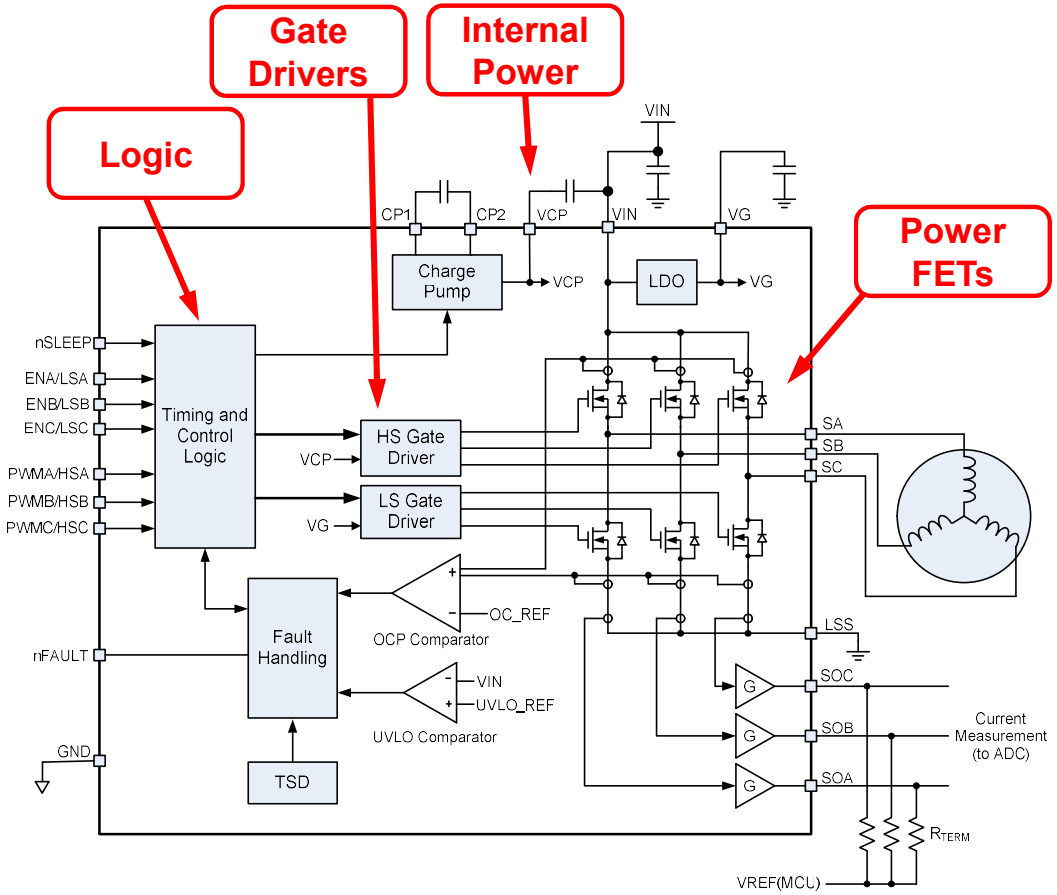


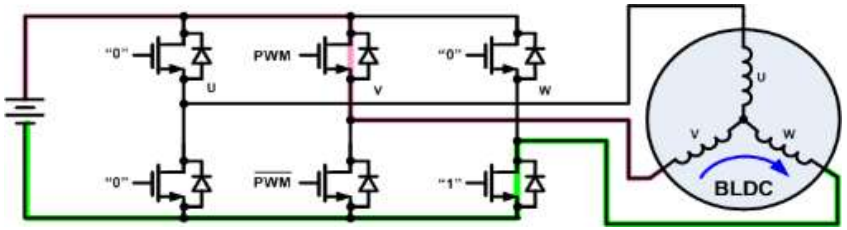
8 Segments Half-Step



32 Segments Eighth-Step

Brushless Motor Drivers





Power Dissipation Example

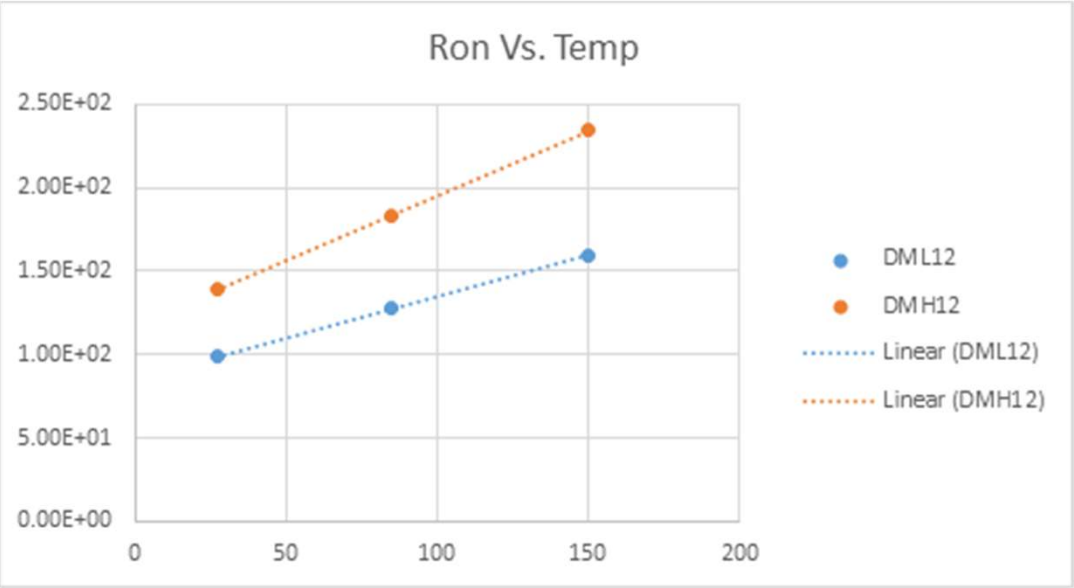
Using the MP6550 IC as an example:

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		0.85	1.1	mA
		50-kHz PWM, no load, nSLEEP_HB = 5V, nSLEEP_LDO = 0		1.2	1.5	mA
Output rise time		RL = 20Ω			100	ns
Output fall time		RL = 20Ω			100	ns

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

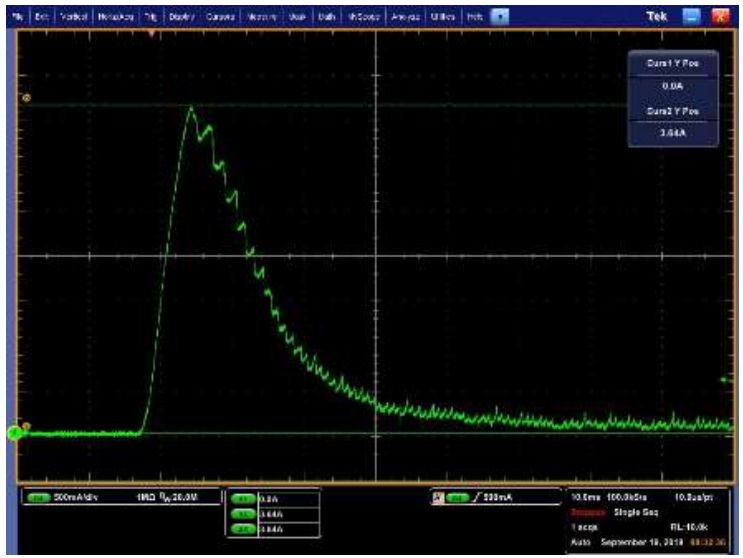
- Using the $R_{DS(ON)}$, we will dissipate $(2A)^2$ x 0.1Ω = 0.4W in the high side, and $(2A)^2$ x 0.1Ω = 0.4W in the low side
- Static power will be 5V x 1.2mA = 0.006W
- Switching loss is approximately (1/2 x 100ns x 50kHz x 5V x 2A) + (1/2 x 100ns x 50kHz x 5V x 2A) = 0.05W
- Total power is then 0.856W

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



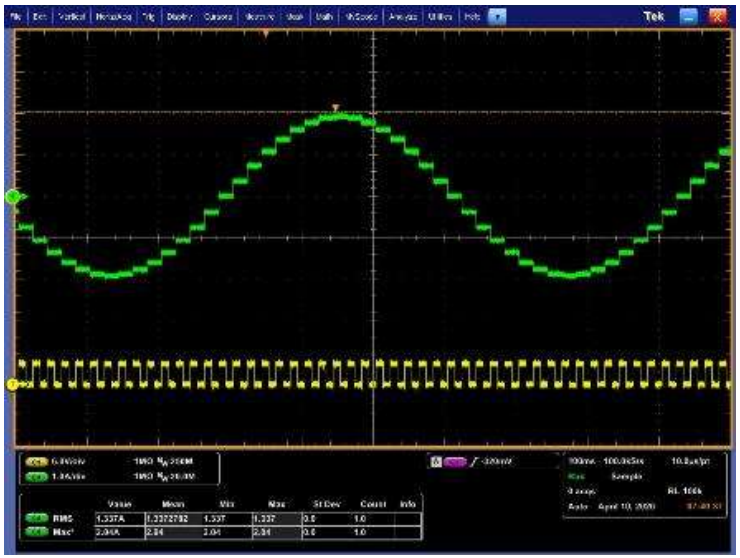
Peak vs. Average and RMS Load Current

DC Motor Start-Up Current



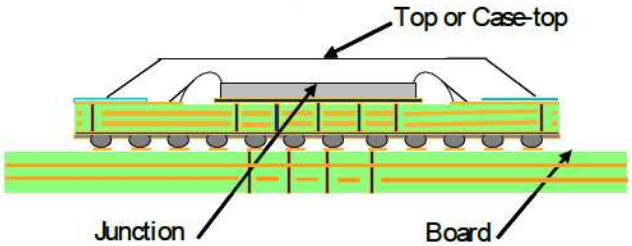
3.6A Peak for ~20ms

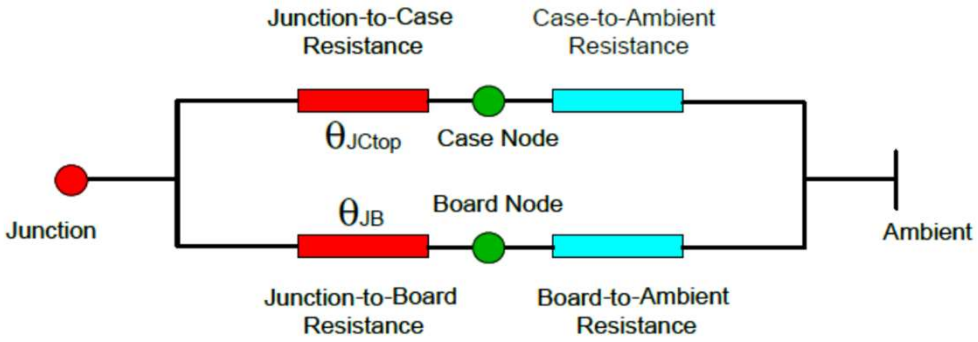
Stepper Motor RMS Current



2A peak ≈ 1.4A RMS

Thermal Resistance & Models





Continuous Power Dissipation (T_A = +25°C) (2) 1.56W
Junction Temperature .....150°C

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 [6]	T_{TSD}			160		°C
Thermal shutdown hysteresis [6]				25		°C

Total power dissipation is 0.856W:

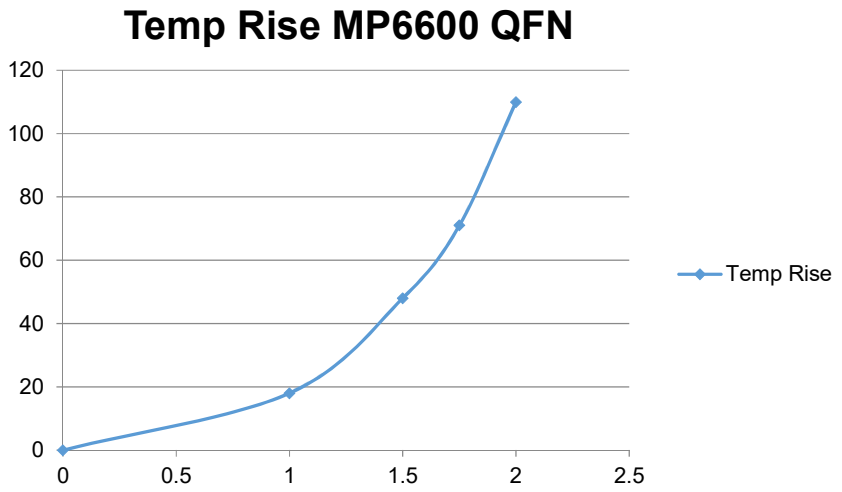
- Temperature rise is P x Θ_{JA}, so 0.856 x 80 = 68.48°C
- Junction temperature is T_A + T_R.

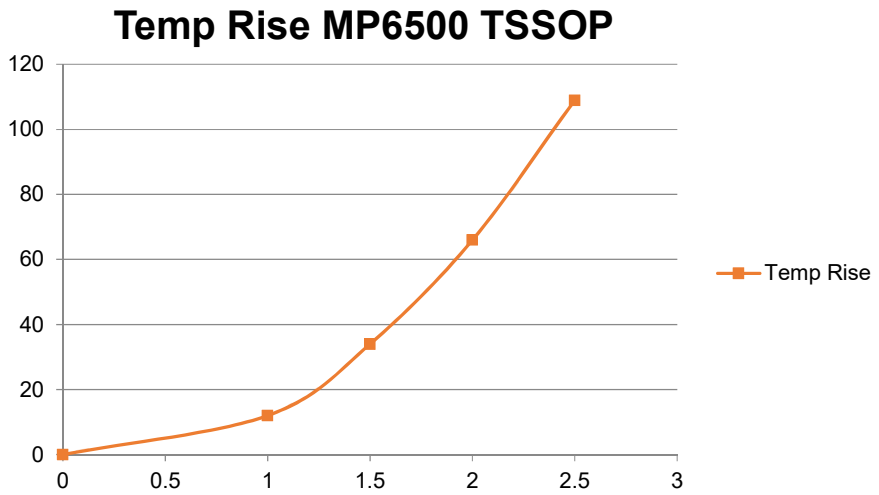
  If we assume room temperature of 25°C, then the junction is at 25 + 68.48 = 93.48°C.

  If the ambient is 70°C, then the junction temperature will be 138.48°C.

Temperature Rise vs. Output Current

Bigger Package = Better Thermals





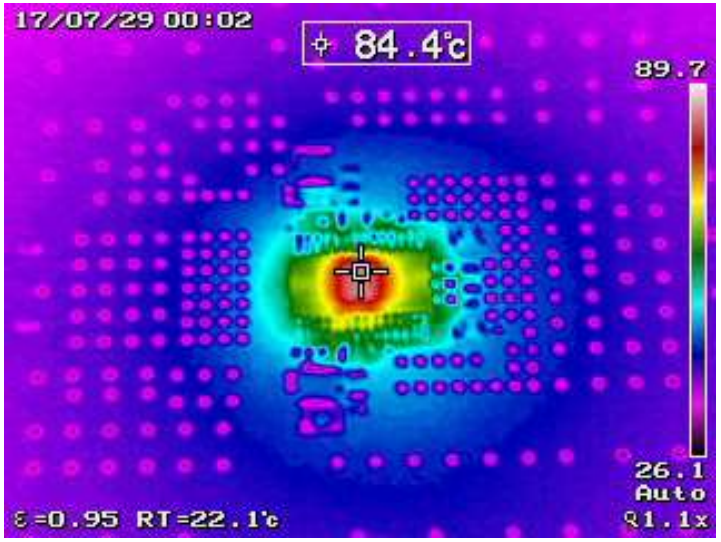
PCB Design for Power Dissipation

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

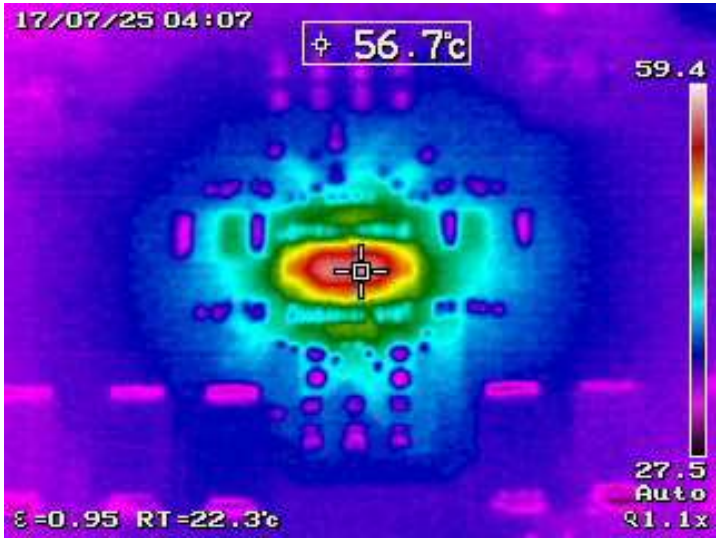
Dimension	Specification	User
Board Finish Thickness	1.60 mm ± 10%	
Board Dimension (pkg length < 27 mm)	76.2 mm x 114.3 mm	
Board Dimension (27 mm ≤ pkg length ≤ 48 mm)	101.6 mm x 114.3 mm	
Board material	FR-4	
Trace Copper Thickness	0.070 mm ± 20%	
Trace Width, Finished	0.25 mm ± 10% for ≥ 0.50 mm pin 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

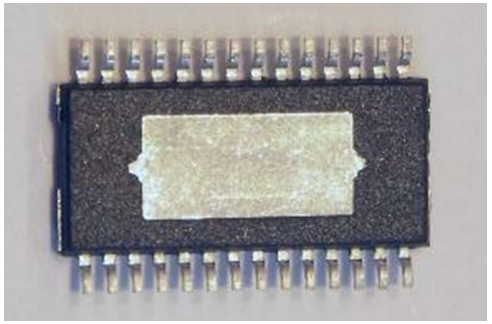


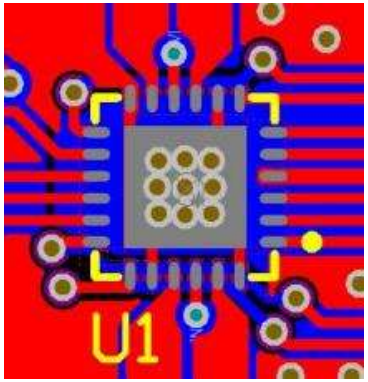
2 Layers

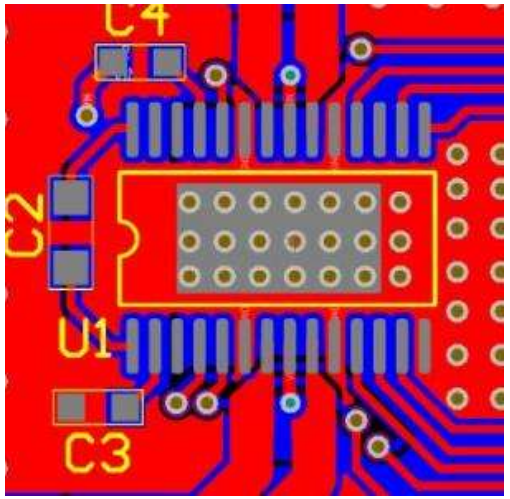


4 Layers (2 Planes)

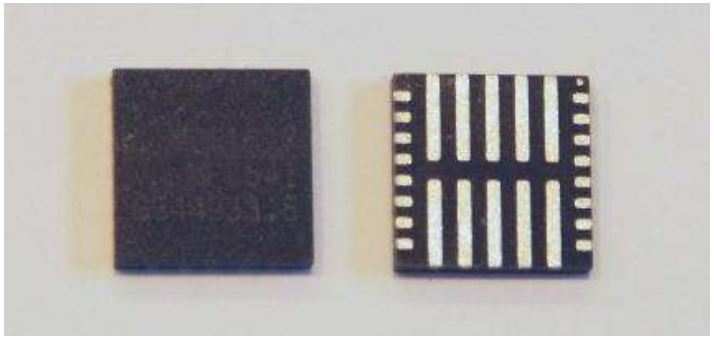
Exposed Pads on TSSOP & QFN

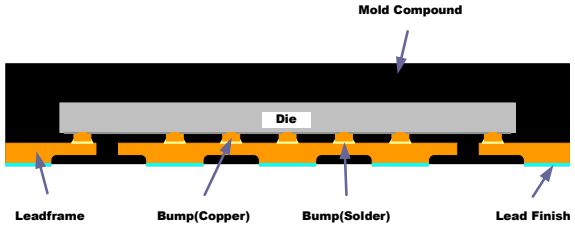


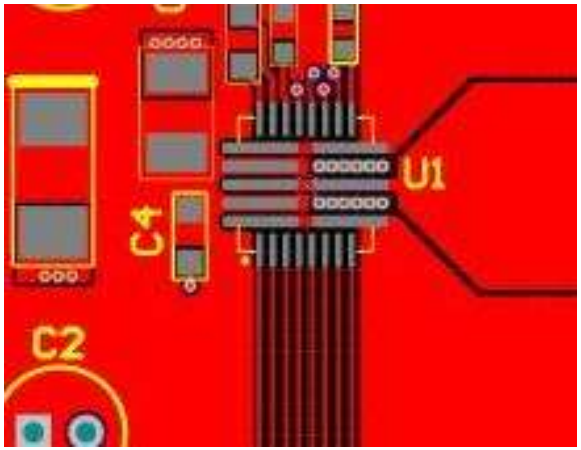


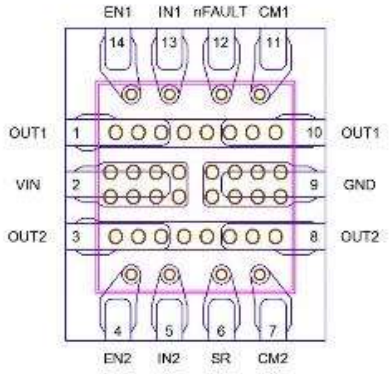


Flip-Chip QFN and LGA Packages

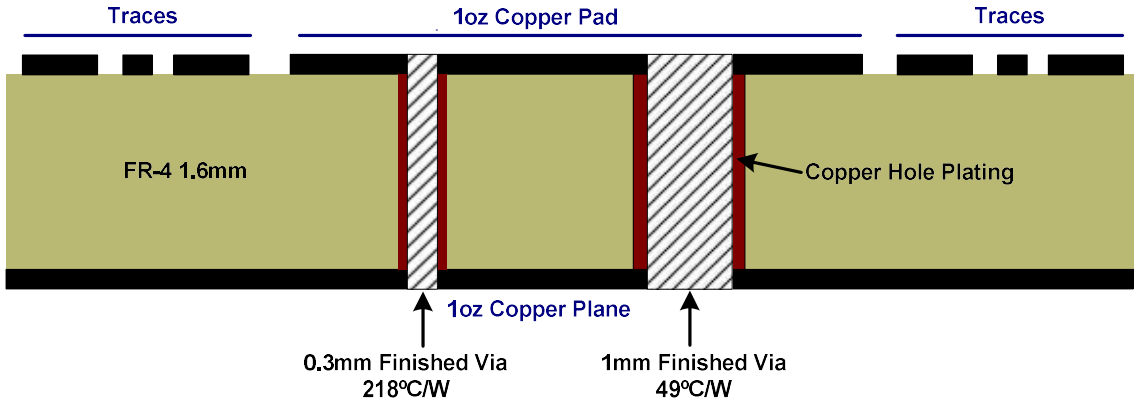


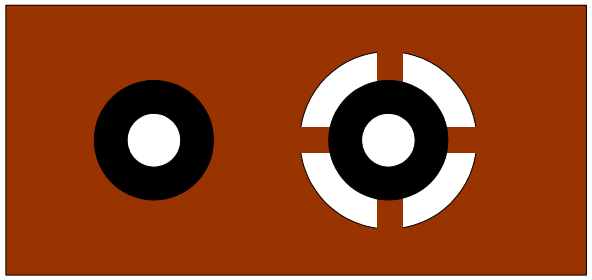






Thermal Vias





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