How to Calculate

Continuous Current

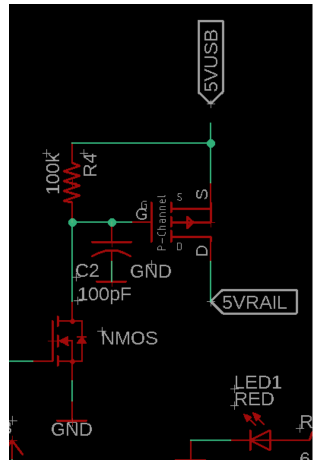
at a Specific Temperature

Description: In this guide, we will go through how to calculate the max continuous current that can go through DMP3099L when the junction of the part is at 150°C (max operating temperature) and 80°C (suggested temperature). Besides, this guide will also consider the trace width on PCBs, power supply and connections type (male-female 0.1” pitch header). All of the calculation is based on parts and design of Hypnos V2.1.

Updated on 4/17/2020 by Bao

We are looking at the P-Channel MOSFET for the 5Vrail of

Hypnos V2.1



Datasheet:

https://www.diodes.com/assets/Datasheets/DMP3099L.pdf

Step 1: Get datasheet value for $R_{DS(ON)}$, $R_{\Theta JA}$, and Operating and Storage Temperature range

These tables are extracted from the datasheet

Product Summary

$V_{(BR)DSS}$	$R_{DS(ON)}$ max	I_D max $T_A = +25°C$
-30V	65mΩ @ V_{GS} = -10V	-3.8A
	99mΩ @ V_{GS} = -4.5V	-3.0A

Thermal Characteristics

Characteristic	Symbol	Value	Units
Total Power Dissipation (Note 5)	P_D	1.08	W
Thermal Resistance, Junction to Ambient @T_A = +25°C (Note 5)	$R_{\theta JA}$	115	°C/W
Operating and Storage Temperature Range	T_J, T_{STG}	-55 to +150	°C

Since we are driving the P-MOS with V_{GS} = -5V, we can estimate using V_{GS}=-4.5V

- $R_{DS(ON)}$ = 0.099 ohm <- $R_{DS(ON)}$ changes with temperature but this is a good estimation
- $R_{\Theta JA}$ = 115°C/W
- Max operating temperature = 150°C

Step 2: Determine what temperature you would like the part to operate at. Suggested Max = 80°C, or 45°C for normal prolong operation.

Ex: Let's use 150°C for the 1st calculation, and then 80°C for the 2nd calculation

Max **operating temperature** is 150°C, mean that we assume the part baking hot at 150°C while the outside air is 25°C for the calculation. If the part will be outside under the sun, modify the ambient temperature to your case.

Step 3: Calculate total power dissipation and continuous current at that specific temperature

$$P_{at\ x°C} = \frac{x - 25}{\mathrm{R_{\Theta JA}}} \quad | \quad I_{continuous} = \sqrt{\frac{P_{at\ x°C}}{R_{DS(ON)}}}$$

Ex: $P_{at\ 150°C} = \frac{150°C - 25°C}{115°C/W} = 1.08W$ => $I_{continous\ at\ 150°C} = \sqrt{P/R_{on}} = \sqrt{1.08/R_{on}}$

Know R_{on} = 0.099ohm => $I_{continous\ at\ 150°C} = \sqrt{1.08/0.099} = 3.3A$

The current calculated to be 3.3A, higher than the 3.0A mentioned in product summary section. It is because we are using 0.099 ohm as a quick estimation. To get the resistance with temperature, we need **Figure 6 in the datasheet**.

If we are driving the gate at -4.5V like the datasheet at 150°C (Figure 6)

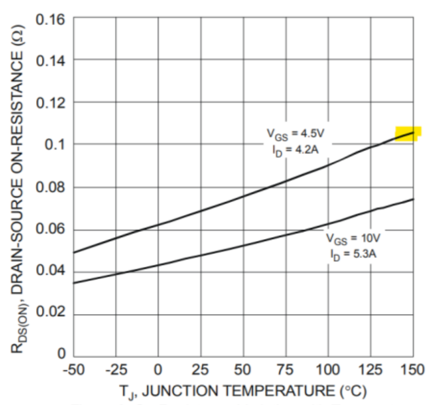


Figure 6 On-Resistance Variation with Temperature

Figure 6

Using new R_{on} = 0.113 ohm => $I_{continous\ at\ 150°C} = \sqrt{1.08/0.113} = 3.09A$ (closer to the datasheet)

The actual 3.0 A continuous current is usually tested in the lab and not through calculation like this.

Now, let's say we want to operate the part at a temperature that is acceptable ≈ 80°C for a long period.

$$P_{at\ 80°C} = \frac{80°C - 25°C}{115C/W} = 0.478W \Rightarrow I = \sqrt{0.478/0.09} = 2.3A$$

$R_{DS(ON)}$ = 0.09ohm is from Figure 6

A quick way to calculate max power your device can dissipate

$$P_d = \frac{Max(Tj) - Ta}{R_{\Theta JA}}$$

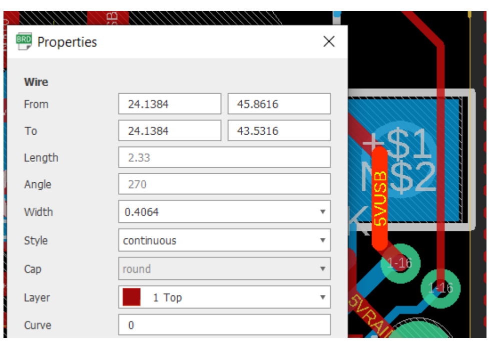
With: Max(Tj) : Max junction temperature
Ta : Ambient temperature
$R_{\Theta JA}$: Thermal resistance

Step 4: Consider other limiting factors

Now, for Hypnos V2

- 3V rail: Anything more than 500mA is more than enough to burn the onboard regulator. So, no worry about the MOSFET or the trace (0.4mm trace is good for more than 1A external PCB layer)
- 5V rail: This rail takes power from the USB port; a good power port can deliver up to 2A. For 5V, Vgs=-5V so we can just use the data from Vgs=-4.5V. However, looking at [Adafruit documentation], the VBUS (power from USB) only can handle 500mA. This might due to the internal trace width.

Trace calculation for 5V rail:



Right click -> Properties on the 5VUSB gives us 0.4064mm trace thickness

Inputs:

Current	1.2	Amps
Thickness	1	oz/ft^2

Optional Inputs:

Temperature Rise	10	Deg C
Ambient Temperature	25	Deg C
Trace Length	1	inch

Results for Internal Layers:

Required Trace Width	1.00	mm
Resistance	0.0128	Ohms
Voltage Drop	0.0153	Volts
Power Loss	0.0184	Watts

Results for External Layers in Air:

Required Trace Width	0.386	mm
Resistance	0.0332	Ohms
Voltage Drop	0.0398	Volts
Power Loss	0.0478	Watts

Go to **[Trace calculator]**

- **Thickness** is 1oz/ft^2 in our case.
- **Temperature Rise** for the trace to be 10°C (standard)

We change the **Current** until the External Later in Air – **Required Trace Width** goes up to what we have in the PCB which is 0.4mm

⇨ We can run up to 1.2A on the trace.

Step 5:

But it all together:

- MOSFET: 2.3A
- Trace: 1.2A
- Header pin: 3A
- USB supply: 2A
- Feather M0 note: 0.5A

=>Max continuous current for the 5V rail is 0.5A

Reference: AddOhms MOSFET Worksheet

Extra video: Other current calculation for MOSFET - https://www.youtube.com/watch?v=qkJ4MS54Jl8