General Module Thermal Considerations

General

The Glary DC/DC converter product series are designed to operate in a variety of thermal environments; however sufficient cooling should be helpful for reliable operation. General speaking, the heat is removed from module by conduction, convection and radiation to the surrounding but convection is the most important method for the normal application at sea level. Increased airflow may strong influence the module thermal performance. Proper cooling can be verified by measuring the temperature of base plate.

The available load current with different ambient air temperature and airflow at nominal input voltage for each model is according to real test done in a wind tunnel. However the actual derating performance of each module may have small difference compared with the derating curves given by real test in the data sheet, the 90% of available current shown in the derating curves is the highest recommended value for reliable system design. The actual system design is strongly affect the derating performance and generally have three variable factors to affect the module derating performance described as below:

Conversion Efficiency

The heat is generated by power loss, board mount power module convert input power for output to load always has an efficiency between 0%~100%, the synchronous rectification technology can make power module convert required power with dramatic efficiency and loss power fewer compared with traditional technology. This lead a lower temperature rise if the module thermal resistance is the same, it means higher efficiency is better for any kind of cooling conditions because the temperature is always lower and the reliability also better.

However! Most data sheet shows high efficiency with full load condition not with the real load condition for practical system. It is better to select a power module has highest efficiency with specified load condition. This almost lead a solid answer that choice a power module rated about 1.2~1.5 times of required power would be reliable than a power module rated at double the required power or even higher, because large derating always has poor efficiency and more temperature rise. It always reduces the operation life due to large derating because the temperature factor has more negative effect on MTBF to cancel the positive effect due to reduced electrical stress.

Roughly calculations of Glary COQ module by change the temperature stress and electrical stress to have different results as below could be used as an example referenced for power module selection in system design stage. The 10% more of module temperature rise (90ºC at 25ºC to 96.5ºC at 25ºC) will cause life reduce to about 75%. Module derating from 100% to 75% will cause life improve about 2% more.

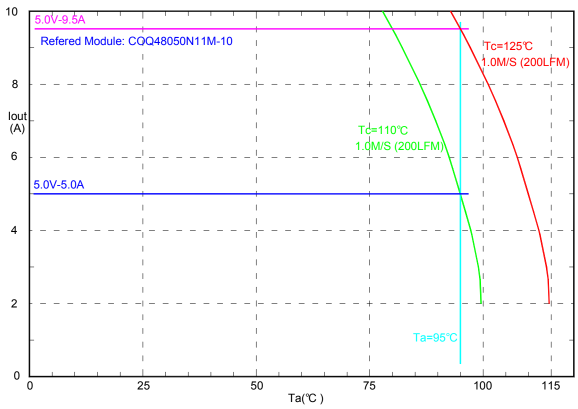
Efficiency change between different modules also has significant effect on the temperature rise to affect the derating performance. This effect can be seen more clearly in high temperature operation especially. For example: Ta=83ºC, maximum allowable temperature Tc=110ºC, Airflow=200LFM, a COQ48050N11M-10 module with 90.2% efficiency can have 9.5A output current with 5.16W power loss. If the efficiency is 2% lower (88.2%) at 9.5A output may loss power 6.35W to cause over temperature to Tc=114ºC or the maximum operable temperature should reduced to Ta=75ºC.

Module Temperature

Follow the result of conversion efficiency section, some of power module makers provide derating curves by increase the maximum board temperature and semiconductor junction temperature to 125ºC to have better derating performance. This method can have big effect to extend the available output current range for operates at high temperature environment. Increase maximum allowable temperature may have two effects on the thermal characteristics:

The first effect of Increase maximum allowable temperature is to increases the temperature rise between module and the air may cause more heat flow through module surface to air if module thermal resistance is constant. Typically the thermal resistance of specified form factor is determined by the properties of air and the contacted surface area. The properties of air are fixed when the temperature and pressure ware specified. The only variation is the air contacted surface area of power module, but same form factor has almost same construction and contacted surface area due to no big difference on the components selection and its counts that the thermal resistance can be given at the same level. The second effect is to reduce thermal resistance by increase nature convection due to increased temperature rise. It has about 8% improvement for thermal resistance with nature convection by change the maximum allowable temperature from Tc=110ºC to Tc=125ºC.

Simple calculations of Glary COQ module by change the maximum allowable temperature from Tc=110ºC to Tc=125ºC is able to demonstrate the improvement of derating performance. A COQ48050N11M-10 module with 90.9% efficiency operated under Ta=95ºC, Tc=110ºC and Airflow=200LFM conditions can deliver 5.0A output current with 2.50W power loss. If the allowable maximum temperature is Tc=125ºC, the allowable power loss will high to 4.76W and the available current could be 9.5A. Plot-1 shows comparison of derating curves for reference.



Plot-1: Derating curves for Tc=110ºC and Tc=125ºC

However! Even increase the maximum allowable temperature from Tc=110ºC to Tc=125ºC is able to make dramatic improvement for derating performance. It pays too much for operation life, the most circuit components who used in modern power modules may reduced its life significantly due to operate under Tc=125ºC condition and the total effect is to reduce module life about 50%. Generally derating rule request 38ºC derating for power semiconductor junction temperature and 15ºC derating for tg=130ºC rated PCB that meaning the maximum operable temperature is 112ºC. All Glary products are limited under 110ºC for safe operation and longer life. Set the case temperature of Glary module below 90ºC during operation would be better for high reliability system.

Module Thermal Resistance

Follow the result of module temperature section; the maximum allowable temperature for operation is limited under Tc=110ºC. Glary provide Sink-Plate technology for almost all Glary modules to reduce the module thermal resistance, improve thermal performance such as the derating performance and temperature deviation between components. By select the Sink-Plate, the derating performance was improved dramatically and no any compromise for the reliability and operation life that it can be used as integrated heat sink to reduce module thermal resistance when no additional cooling assemblies were attached to the module.

In generally Glary modules were design for board mount application but the Sink-Plate has at least 2pcs of M3 screws allow module attaching to the casing or heat sink extent its thermal performance to meet the requirements of high temperature operated system. The Sink-Plate is able to reduce the deflection that it has special geometry to hold flowed gap filler due mounting force during screw mounting process and improve the thermal contact to has unified temperature map to improve the reliability again.

The simple calculations for COQ with different type of base plate are describe as below may reflected to all Glary products to give better understanding about thermal performance and derating for specified application conditions:

For the 1.0mm metal plate:

The module thermal resistance θ_M of COQ with 1.0mm metal plate is similar to traditional power module can be listed as below:

θ_M = 11.29 (Free-Air), 7.36 (100LFM), 5.65(200LFM)
4.20 (300LFM), 3.47 (400LFM), 3.03 (500LFM)

The thermal resistance data and efficiency plot in the data sheet can be applied to the equation below to determine the available power with specified operation ambient temperature.

$$P_O= (110-Ta)/ (\theta_M)(1/\eta-1)$$

For example: 200LFM at Ta=80ºC for COQ with 1.0mm metal plate. The available power is P_O=(110-80)/ (5.65)(1/0.9-1)=47.6W, or equal to 5.0V/9.5A output also can be seen in the derating plot in the data sheet directly.

For the3.0mm Sink-Plate:

The module thermal resistance θ_{S3} of COQ with 3.0mm Sink-Plate is about 30% lower compared to 1.0mm metal plate COQ module were listed as below:

Θ_{S3} = 9.13 (Free-Air), 5.95 (100LFM), 4.49 (200LFM)
3.40 (300LFM), 2.81 (400LFM), 2.45 (500LFM)

The thermal resistance data and efficiency plot in the data sheet can be applied to the equation below to determine the available power with specified operation ambient temperature.

$$P_O= (110-Ta)/ (\theta_{S3})(1/\eta-1)$$

For example: 200LFM at Ta=85ºC for COQ with 3.0mm metal plate. The available power is P_O=(110-85)/ (4.49)(1/0.9-1)=50.01W, or equal to 5.0V/10A output.

For the5.0mm Sink-Plate:

The module thermal resistance θ_{S5} of COQ with 5.0mm Sink-Plate is about 50% lower compared to 1.0mm metal plate COQ module were listed as below:

Θ_{S5} = 7.28 (Free-Air), 4.91 (100LFM), 3.17(200LFM)
2.44 (300LFM), 2.01 (400LFM), 1.83 (500LFM)

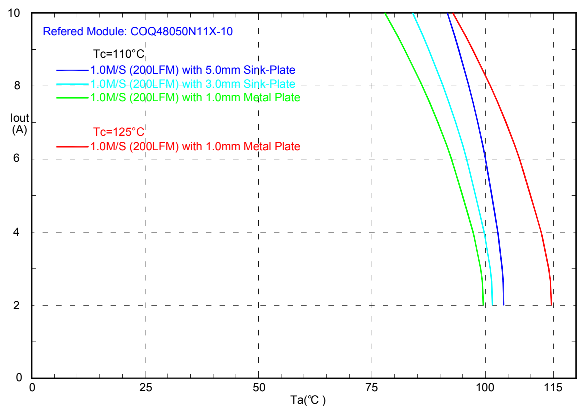
The thermal resistance data and efficiency plot in the data sheet can be applied to the equation below to determine the available power with specified operation ambient temperature.

$$P_O= (110-Ta)/ (\theta_{S5})(1/\eta-1)$$

For example: 200LFM at Ta=92ºC for COQ with 5.0mm metal plate. The available power is P_O=(110-93)/(3.17)(1/0.9-1)=48.26W, or equal to 5.0V/9.6A output.

Comparison

Simple comparison between module with 1.0mm metal plat, 3.0mm Sink-Plate, 5.0mm Sink-Plate and change setting for Tc=125ºC can be made by using COQ module shown as Plot-2.



Plot-2: Comparison for Tc=110ºC and Tc=125ºC

The result shows the improvement of derating performance was achieved and very closed to result of Tc=125ºC by using 5.0mm Sink-Plate with no increase the maximum allowable temperature. The 3.0mm Sink-Plate also have significant improvement for high load condition. The Sink-Plate technology has no significant improvement for the light load condition that it is limited by the fixed no load power consumption.

Conclusion

The high conversion efficiency characteristic is the basic requirement for the modern power module to achieve lowest power loss. However! The latest application is request more power again with smaller package may cause module temperature higher. This technical challenge can be solved by two methods. One is to upper the thermal limit for safe operation have the best effect to extract the available current but pay much for safe operation life.

Another method is to reduce module thermal resistance by adding more air contacted surface area request low profile converter design with single board single component side mounting technology. It is able to cooling down module for higher power delivery with no impact on the reliability and safe operation life.