International Rectifier

APPLICATION NOTE

Application Note AN-1174

Thermal Derating of DC-DC Convertors using IR3899/98/97

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Thermal Derating of DC-DC Convertors using IR3899/98/97

Abstract: *Integrated synchronous buck convertors have PWM controller, Control MOSFET and Synchronous MOSFET along with their drivers integrated inside the same package which gives highest power density dc-dc convertor modules. Thermal management of this POL (point of load) Regulator is very important since the end use environment can vary a lot from application to application and not known at developmental phase of the system. This application note describes about the generation of the thermal derating graphs for IR3899/98/97 under different operating conditions and to predict the thermal performance of the POL regulators in the actual operating conditions.*

Introduction

Integrated synchronous buck convertors are used to increase power density, to increase efficiency, and to reduce overall size of DC-DC convertors. It has PWM controller, Switching Mosfets and drivers integrated inside the same package. Increased power density improves overall system cost and reduces system size but is not good from thermal point of view. Simple physics shows that certain amount of surface area is always required to dissipate certain amount of power for any given operating conditions. Forced air cooling can bring down the surface area required for a given amount of power dissipation.

Since the end-use environment is often not well known during the regulator evaluation stage, and the environment can vary from application to application, thermal derating graphs are included in data sheet of POL regulators. Thermal performance of the convertor can be characterized by thermal derating graphs which show how much current can be handled by the dc-dc convertor under different ambient temperature and air flow conditions. These curves define the thermal and electrical Safe Operating Area (SOA) of the regulator. Board size, copper thickness and its coverage on the PCB, thermal vias and number of power planes will also affect the thermal performance. To specify thermal performance of SupIRBuck regulators, output power derating test is conducted, which shows the amount of power, the regulator can safely handle under different ambient temperature and air flow conditions. The result is published as thermal derating graphs.

IR389X series SupIR buck regulators are used to conduct the experiment. These devices are tested with much higher current than their specified full load current in the data sheet to see their thermal limit. For general thermal test procedure, JEDEC EIA/JESD 51-X series of standards are followed. JESD 51-2 standard defines the procedure for thermal test with natural convection (still air) and JESD51-6 specifies thermal test method for forced convection cooling (fan cooled). JESD51-12 is the general guide lines for reporting and using electronic package thermal information.

IR3899 IR3898 and IR3897 are used for the thermal tests.IR3899 has a current rating of 9A but is tested upto 12A, IR3898 has a 6A rating and is tested upto 9A, and for 4A rated IR3897, test is conducted upto 6A. Tests are done at input voltage ranging from 6.8V to 16V and frequency from 300 kHz to 1.5MHz. So it covers the full rated input voltage and frequency range. Two output voltages are selected -1.2V and 3.3V to cover lower and higher range.

General Guidelines

General guide lines used for thermal derating are,

- Thermal derating is done using IR standard Evaluation board.
- Evaluation board PCB is a 4 layer board with FR4 material , 0.062" thick ,2 Oz copper
- Board size is 2.23"x2"
- Test is done at 6.8V, 12V and 16V input.
- The measurement is done at 300 kHz, 600kHz, 1MHz and 1.5 MHz frequencies.
- Test is done at 1.2V and 3.3V output.
- Test is done at 25ºC and 50ºC ambient with 0 LFM (convection cooling) and 200 LFM (Forced cooling)
- Extended thermal test is done upto 85°C ambient
- Junction temperature is kept below 125°C

Thermal Derating of IR3899

IR3899 is a 9A rated highly integrated SupIRBuck single input synchronous buck regulator available in 4x5mm PQFN package. Integrated top and bottom Mosfets have 18mΩ and 9mΩ rds on respectively.

The table below shows the inductors used for the thermal derating.

Frequency	Vout=1.2V	Vout=3.3V
300kHz	0.68uH,2.4mΩ (Delta MPT1040-R68M11)	1.2uH,2.9mΩ (Delta MPL105-1R2)
600kHz	0.51uH,0.29mΩ (Vitec 59PR9876N)	1.2uH,2.9mΩ (Delta MPL105-1R2)
1MHz	0.22uH,0.29mΩ (Vitec 59PR9873N)	0.51uH,0.29mΩ (Vitec 59PR9876N)
1.5MHz	0.22uH,0.29mΩ (Vitec 59PR9873N)	0.4uH,0.29mΩ (Vitec 59PR9875N)

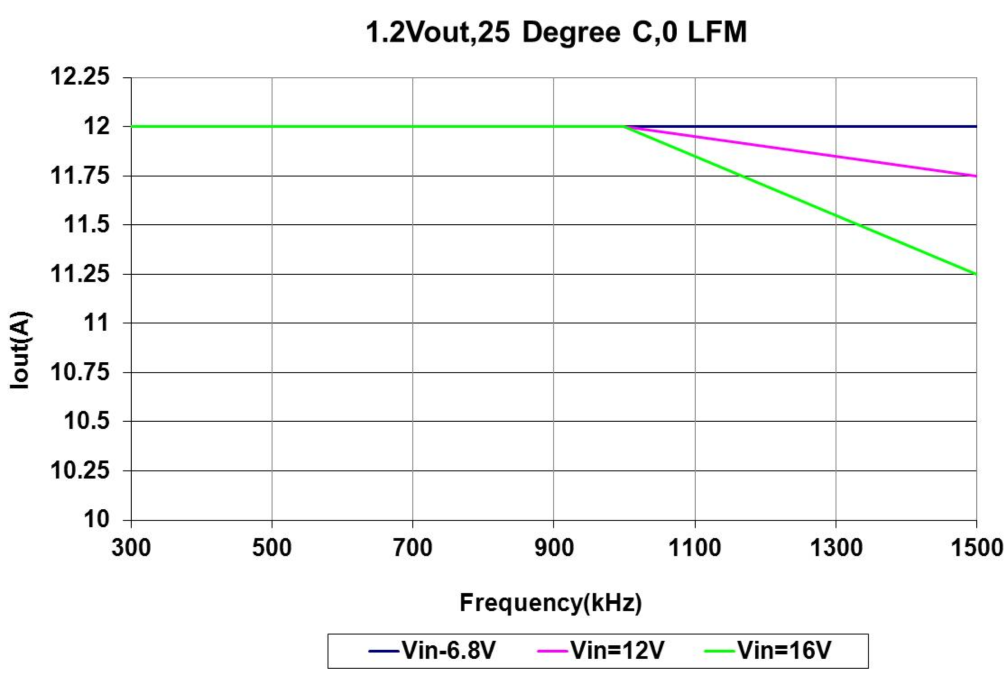


Fig (1)-IR3899 Thermal Derating for 1.2Vout at 25°C ambient with no air flow

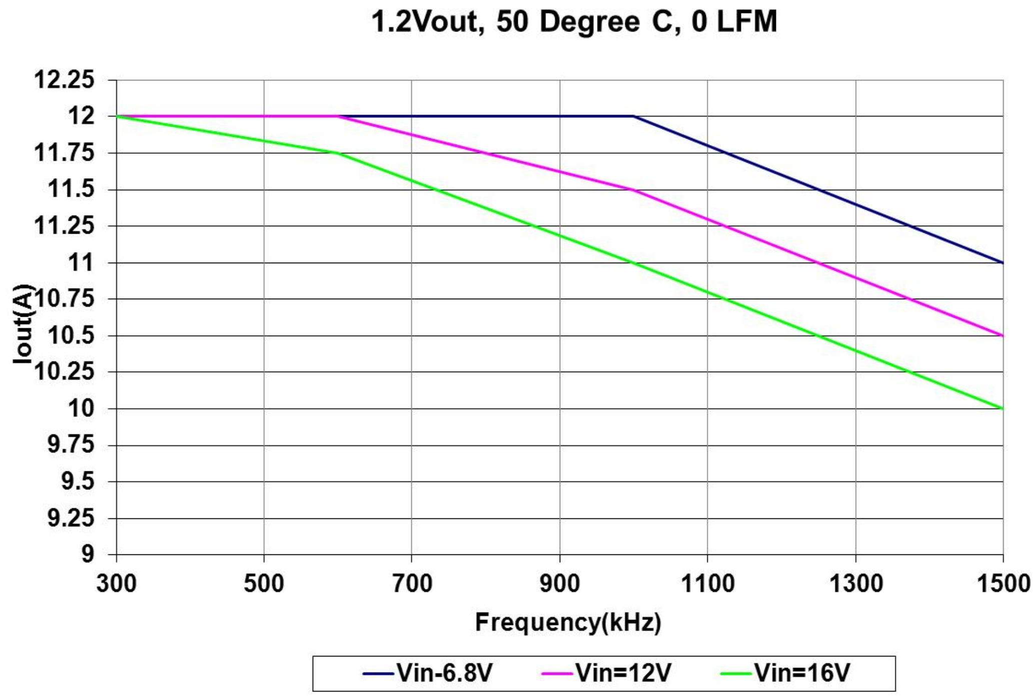
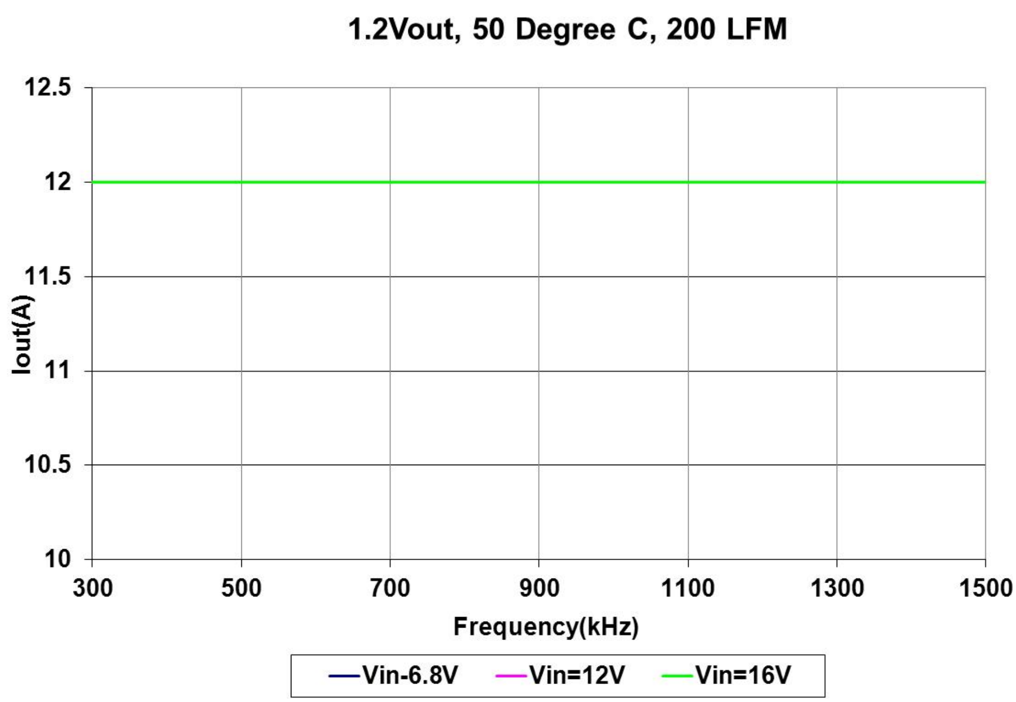


Fig (2)-IR3899 Thermal Derating for 1.2Vout at 50°C ambient with no air flow



Note: All three curves are overlapping.

Fig (3)-IR3899 Thermal Derating for 1.2Vout at 50°C ambient with 200LFM air flow

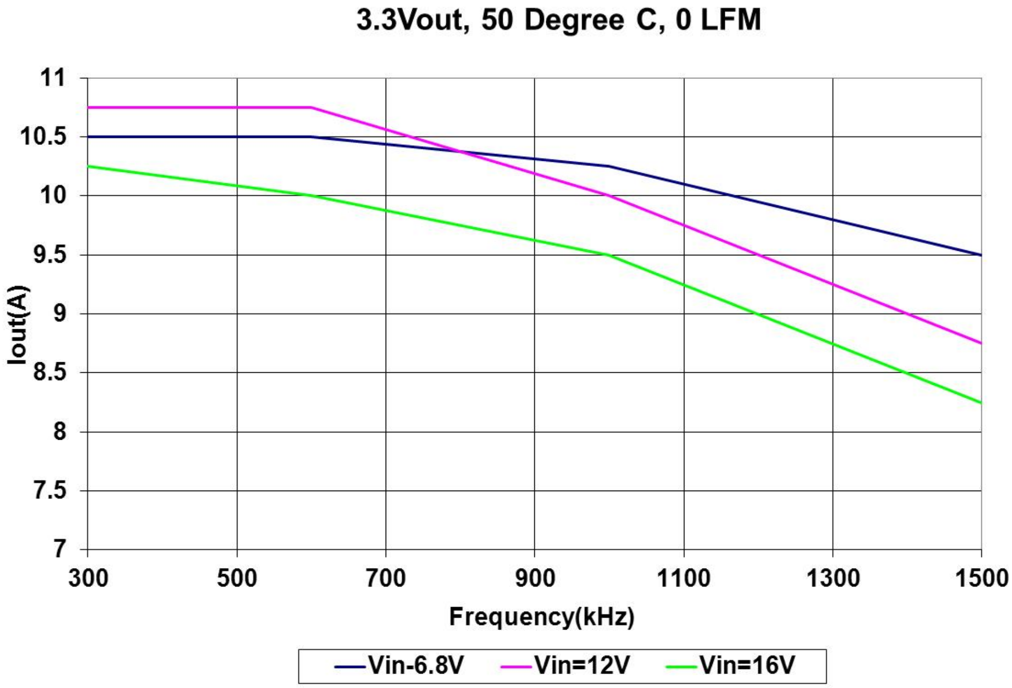


Fig (4)-IR3899 Thermal Derating for 3.3Vout at 50°C ambient with no air flow

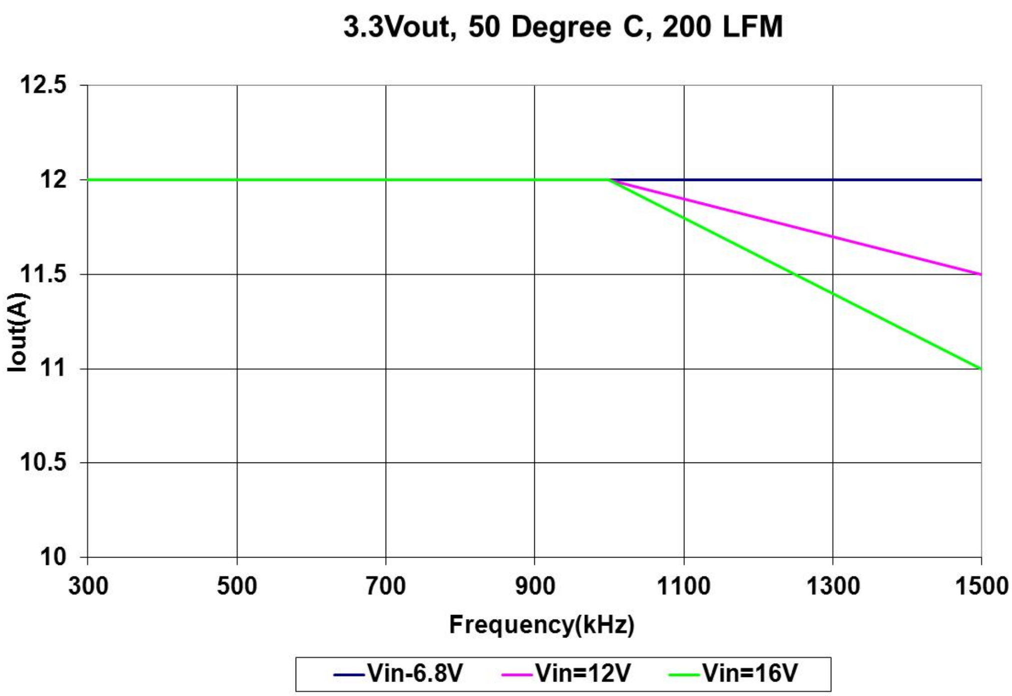


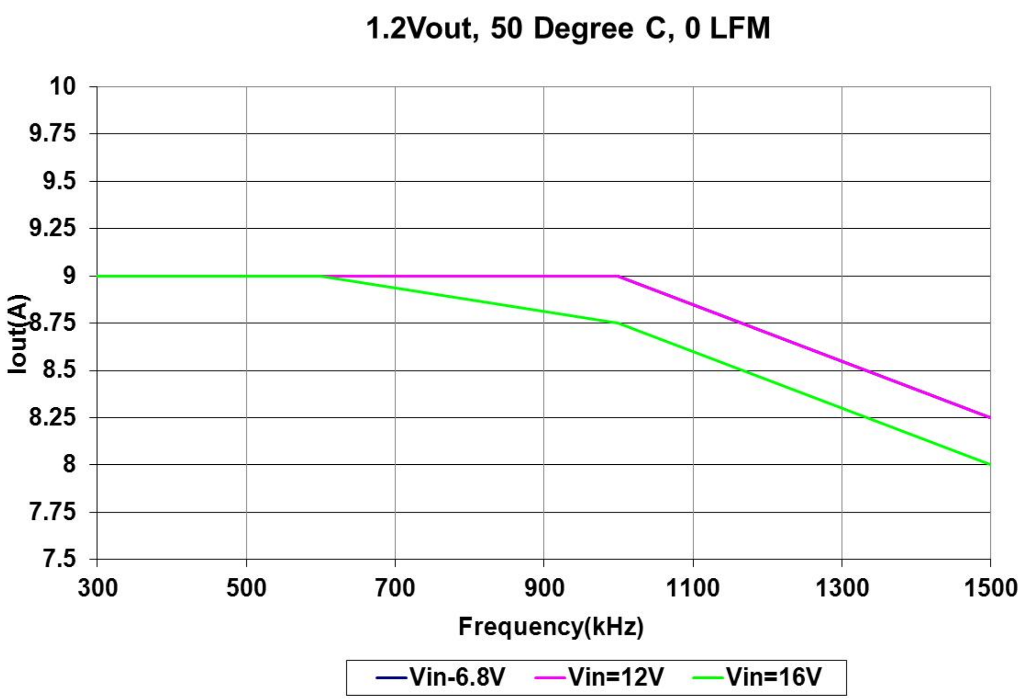
Fig (5)-IR3899 Thermal Derating for 3.3Vout at 50°C ambient with 200LFM air flow

Thermal Derating of IR3898

IR3898 is a 6A rated highly integrated SupIRBuck single input synchronous buck regulator available in 4x5mm PQFN package. Integrated top and bottom Mosfets have 18mΩ and 11.3mΩ rds on respectively.

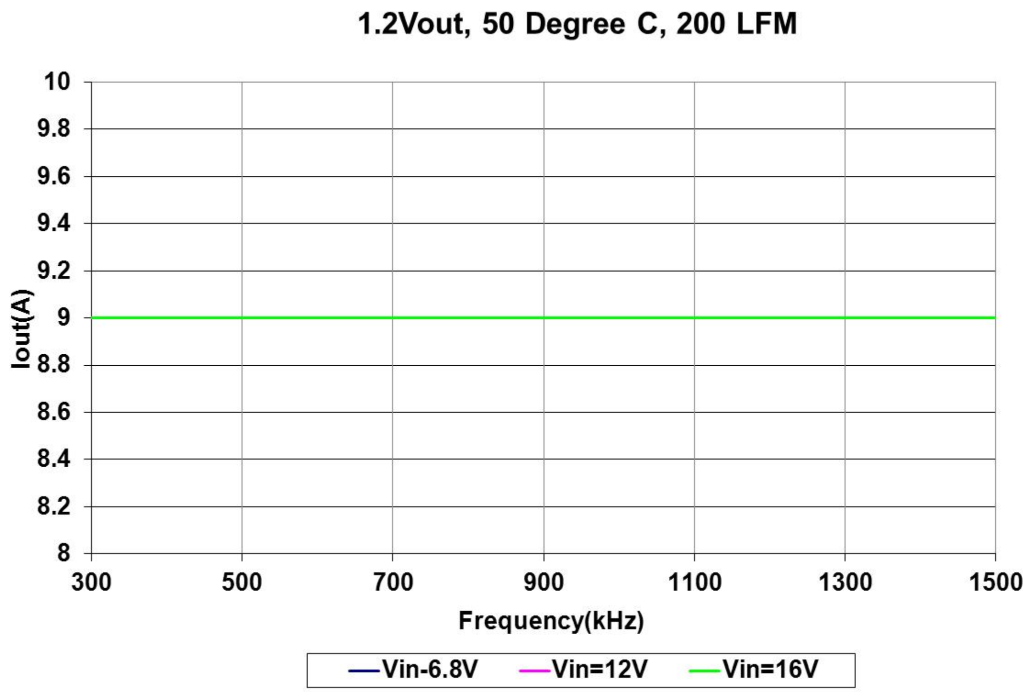
The table below shows the inductors used for the thermal derating.

Frequency	Vout=1.2V	Vout=3.3V
300kHz	1uH,4.7mΩ (TDK SPM6550T-1R0)	3.3uH,6.5mΩ (Wurth Elektronik 7443340330)
600kHz	1uH,4.7mΩ (TDK SPM6550T-1R0)	1uH,4.7mΩ (TDK SPM6550T-1R0)
1MHz	0.33uH,3.5mΩ (Vishay IHLP2525CZ01ERR33M01)	1uH,4.7mΩ (TDK SPM6550T-1R0)
1.5MHz	0.33uH,3.5mΩ (Vishay IHLP2525CZ01ERR33M01)	0.82uH,4.2mΩ (TDK SPM6550T-0R82)



Note: 6.8V and 12V curves are overlapping each other.

Fig (6)-IR3898 Thermal Derating for 1.2Vout at 50°C ambient with no air flow



Note: All three curves are overlapping each other

Fig (7)-IR3898 Thermal Derating for 1.2Vout at 50°C ambient with 200LFM air flow

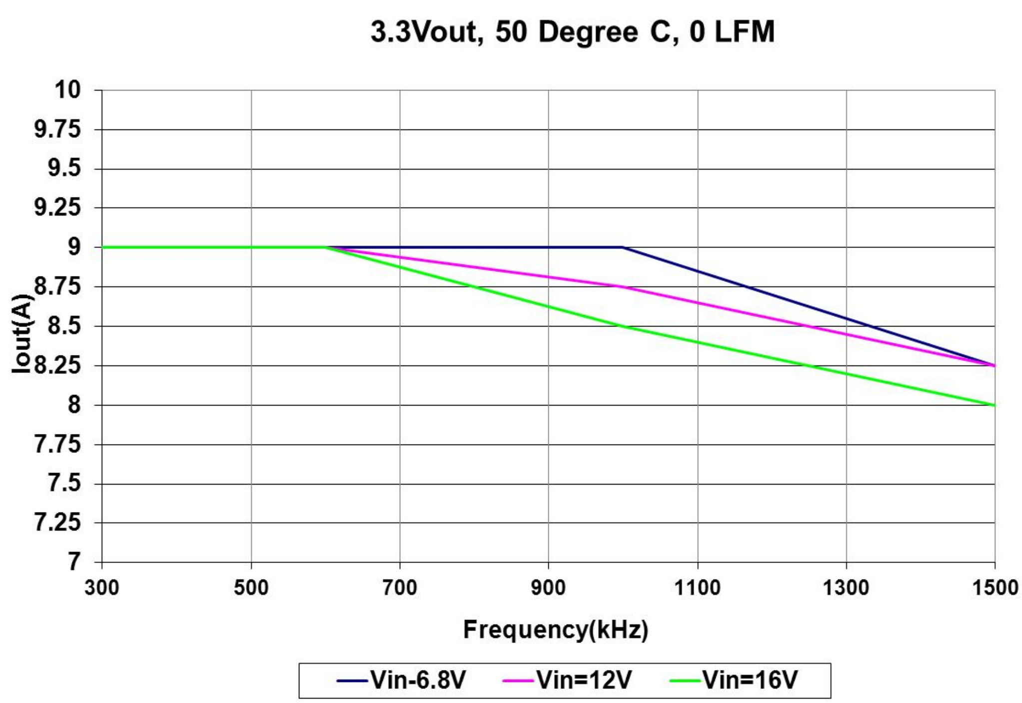
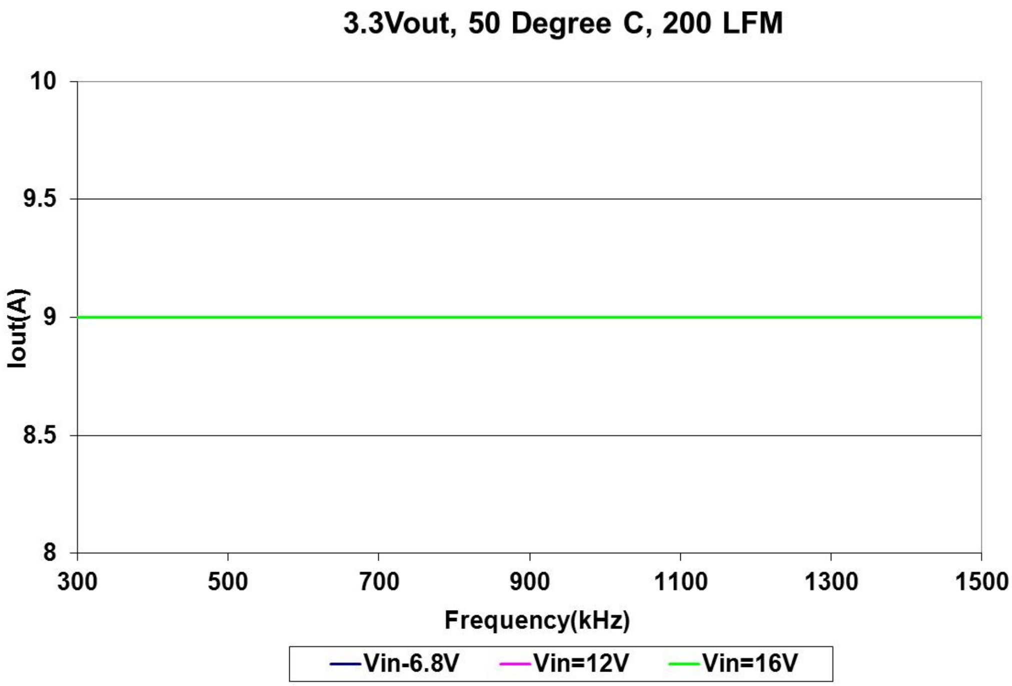


Fig (8)-IR3898 Thermal Derating for 3.3Vout at 50°C ambient with no air flow



Note: All three curves are overlapping each other

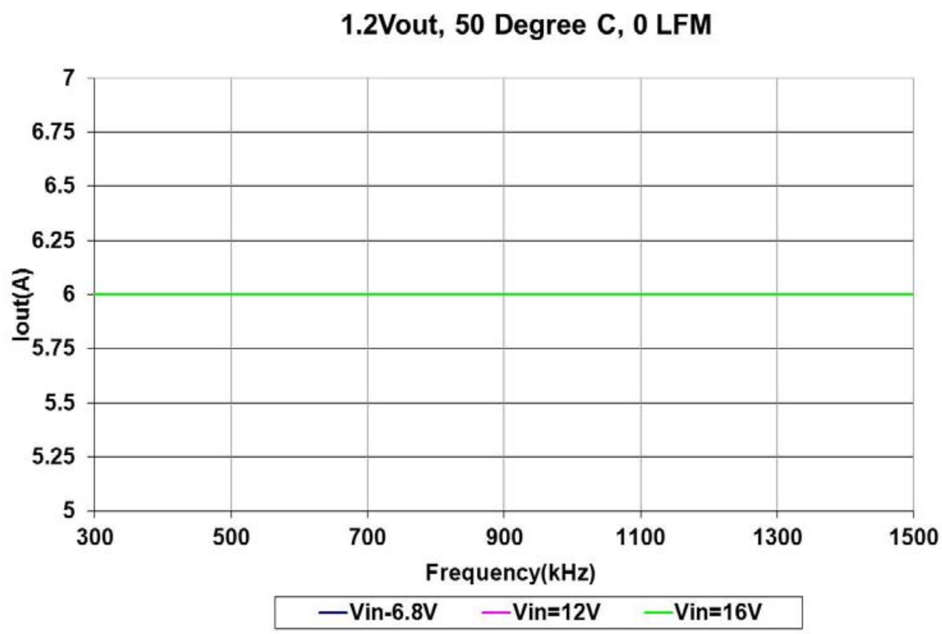
Fig (9)-IR3898 Thermal Derating for 3.3Vout at 50°C ambient with 200LFM air flow

Thermal Derating of IR3897

IR3897 is a 4A rated highly integrated SupIRBuck single input synchronous buck regulator available in 4x5mm PQFN package. Integrated top and bottom Mosfets have 18mΩ and 16.8mΩ rds on respectively.

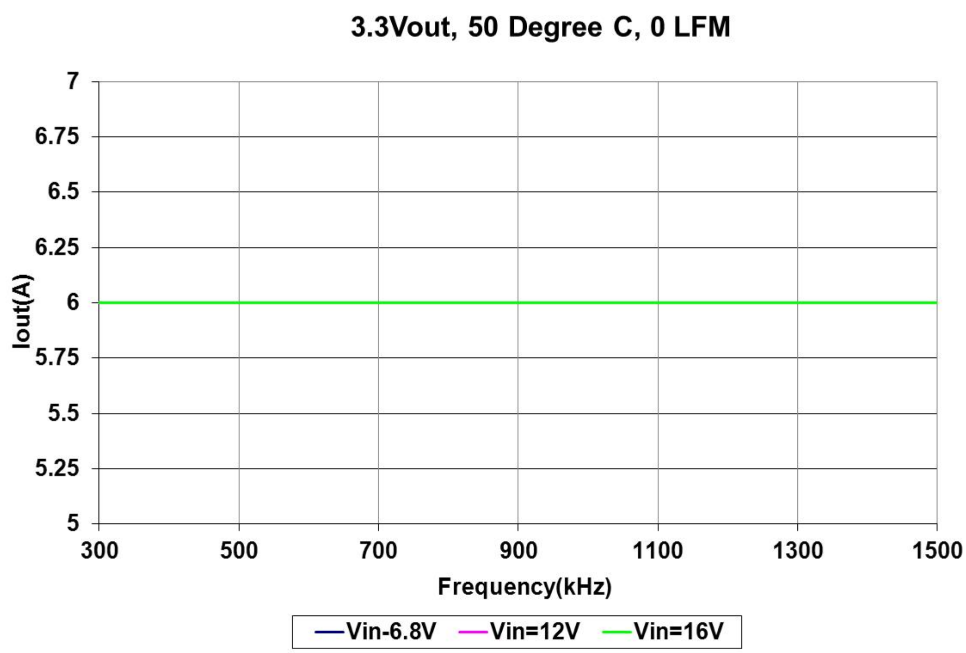
The table below shows the inductors used for the thermal derating.

Frequency	Vout=1.2V	Vout=3.3V
300kHz	1.5uH,6.7mΩ (CyntecPCMB065T-1R5)	3.3uH,6.5mΩ (Wurth Elektronik 7443340330)
600kHz	1.5uH,6.7mΩ (CyntecPCMB065T-1R5)	1.5uH,6.7mΩ (Cyntec PCMB065T-1R5)
1MHz	0.68uH,5mΩ (Vishay IHLP2525CZERR68M01)	1uH,4.7mΩ (TDK SPM6550T-1R0)
1.5MHz	0.33uH,3.5mΩ (Vishay IHLP2525CZ01ERR33M01)	0.82uH,4.2mΩ (TDK SPM6550T-0R82)



Note: All three curves are overlapping each other.

Fig (10)-IR3897 Thermal Derating for 1.2Vout at 50°C ambient with no air flow



Note: All three curves are overlapping each other.

Fig (11)-IR3897 Thermal Derating for 3.3Vout at 50°C ambient with no air flow

Extended thermal Derating upto 85°C

IR3899/98 /97 are also tested upto 85 °C for 1.2V and 3.3V output at 600 kHz with 12V input to see the thermal performance at higher ambient temperature.

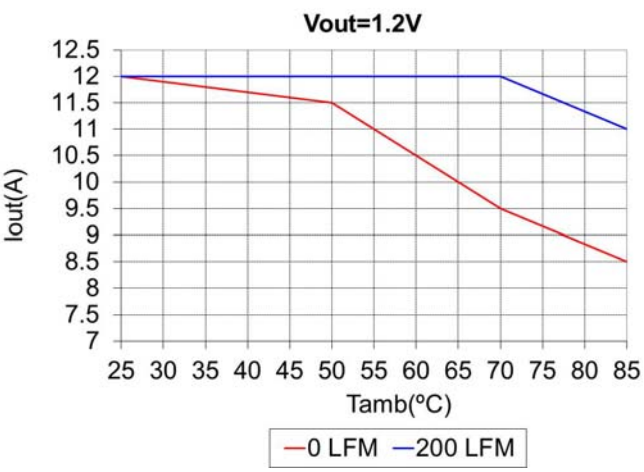


Fig 12(a)

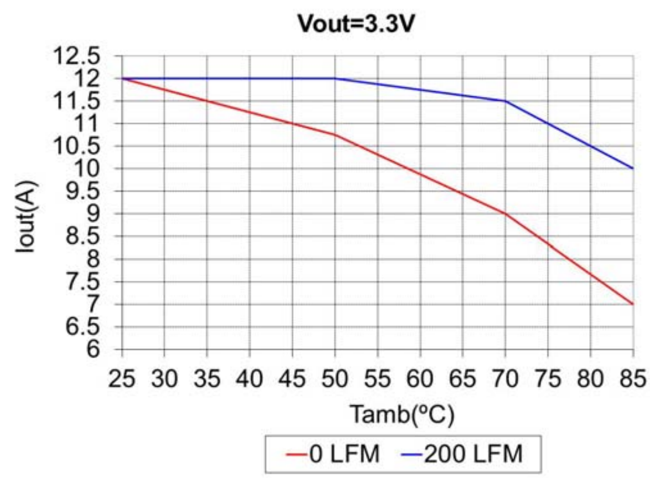


Fig 12(b)

Fig (12)-IR3899 Thermal Derating for Vin=12V, Vout=1.2V and 3.3V at 600 kHz

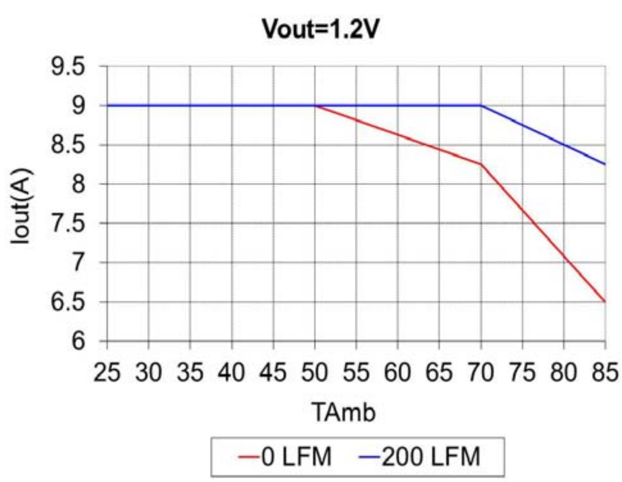


Fig 13(a)

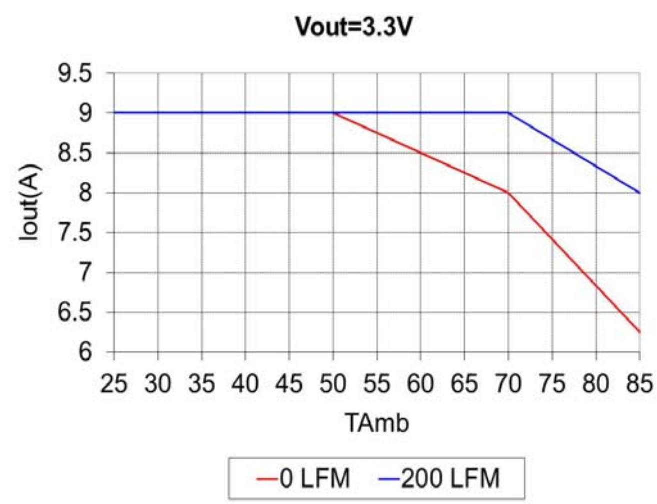


Fig 13 (b)

Fig (13)-IR3898 Thermal Derating for Vin=12V, Vout=1.2V and 3.3V at 600 kHz

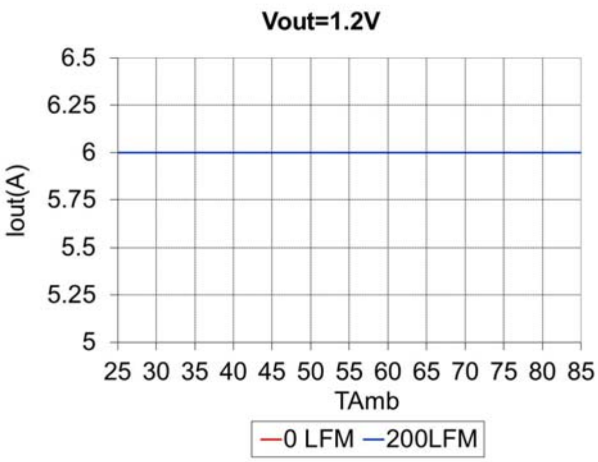


Fig 14(a)

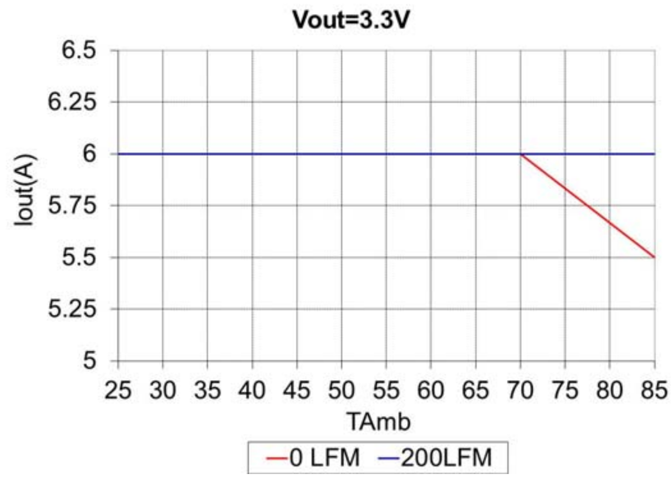


Fig 14 (b)

Fig (14)-IR3897 Thermal Derating for Vin=12V, Vout=1.2V and 3.3V at 600 kHz

Conclusion

The thermal performance of SupIRBuck ICs in the customer system can be affected by total power dissipation, number of layers of PCB used, PCB material, air velocity if available, direction of air flow, power dissipation in adjacent components, orientation of the adjacent boards and their thermal conditions. Since SupIRBuck ICs have thermal pads on the bottom, there are multiple paths for the heat transfer to the ambient. They can flow from junction to the case and then to the ambient and another path from junction to the thermal pads on the bottom to the board and then to the ambient.

- IR3899 can handle 12A current at all input voltage conditions with 200 LFM air flow for 1.2V output at 50 °C ambient.
  With 200LFM air flow, at 50 °C ambient for 3.3V output, there is a thermal derating above 1MHz Operation.

- IR3898 has no thermal derating upto 50 °C ambient with 200LFM air flow for 1.2V and 3.3V output up to 9A current.
  With no air flow at 50 °C ambient and above, there is thermal derating for both outputs.

- IR3897 can handle 6A current at 50°C ambient with no air flow for 1.2V and 3.3V output.

International Rectifier Corporation specifies current rating of SupIRBuck devices conservatively. The above thermal derating graphs have demonstrated the extended thermal capabilities of IR3899/98/97. However, the maximum current is limited by the internal current limit and designers need to consider enough guard bands between load current and minimum current limit as a guarantee for the device not to trip at steady state operating conditions.

References:

1) JEDEC EIA/JESD 51-X Series Standards for general thermal test procedures.

2) Optimize Thermal Derating of PWM ICs- Power Electronics Technology, February 2009. *http://powerelectronics.com/thermal_management/DesignFeature2-0209.pdf*

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