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Detection of critical onboard temperature

Test description

Critical onboard temperatures will be observed with the infrared thermal camera.
To fulfill the EMC CISPR25 class 5 requirements the three TI TPS57x40-Q1 regulators were replaced by the PCB redesign with the LMR36015-Q1 regulators. These three new regulators are in focus of this thermal inspection.

Tech. characteristics of TI LMR36015FSCQRNXRQ1 regulators and circuits:

- Fully integrated compensation circuits,
- Designed with the 10µH/6.2A (WE-PD 1280, 74477010) or with the 3.3µH/3.3A (WE-PD 7345, 7447779003) power inductors;
- Fixed frequency of 2100 kHz with +/-4% spread spectrum clocking.
- Package dimensions: 2mm x 3mm, no exposed pad.
- Package thermal characteristics:
  Tjmax = 150°C; Tja = 72.5 K/W, Tjc(top) = 35.9 K/W, Tjunc-brd = 23.3 K/W;

Device under Test (DUT)

- ECU Board

Test equipment

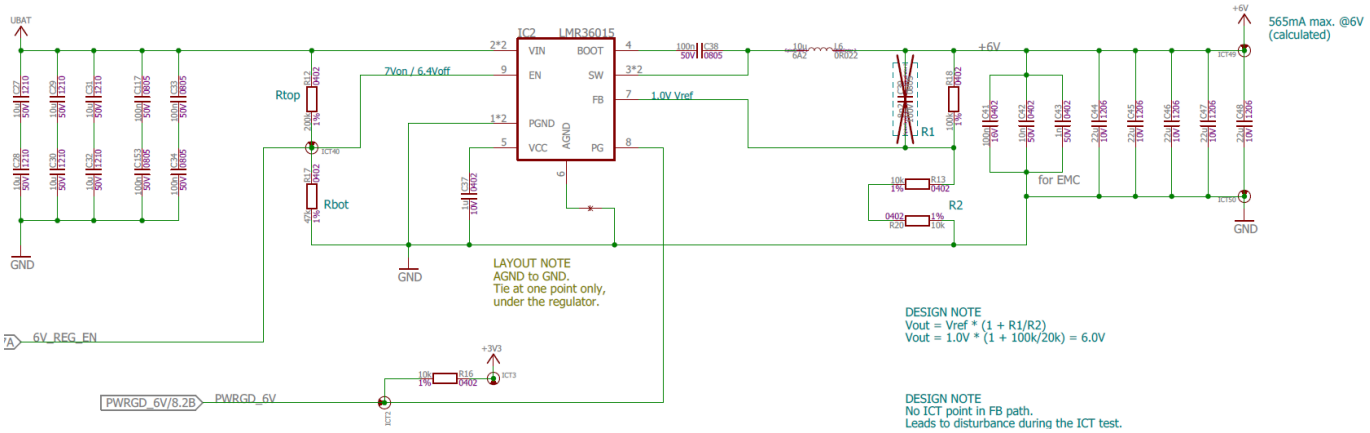
- Infrared thermal camera FLIR T335
- DF3010 Power Supply as UBAT 28,5V source (system current: 160mA)
- Test operating temperature, Tamb approx. 25°C

Result of hot spot measurements

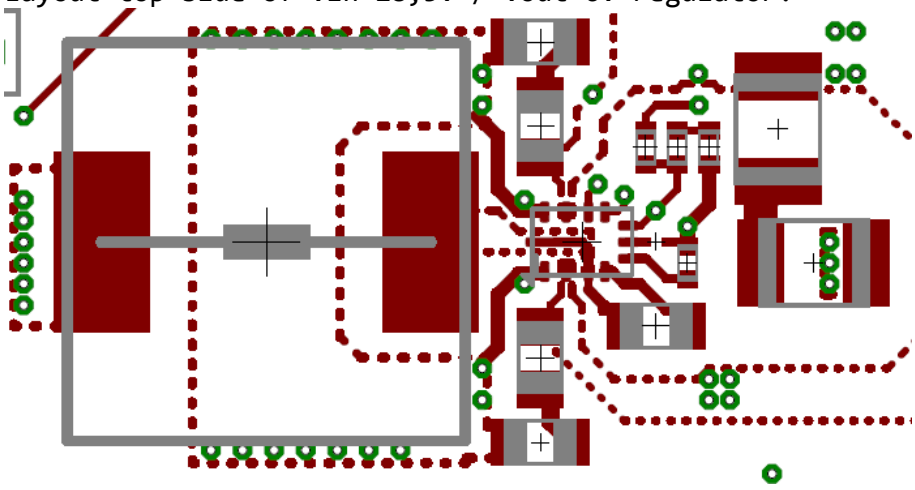
Critical components	Tcase	Result	Comment
IC2 (LMR36015) Vin=28.5V Vout=6V	80°C	**FAIL**	Test load current 200mA! (565mA max. required). ---------- Calculation Tamb max. @ Pmax ≈ 1.5W: Tj @25°C = 80°C + 36K/W * 1,5W = 134°C ->Tamb max = 150°C + 25°C - 134°C = **41°C**! Tamb max ≈ 100°C (required)
IC8 (LMR36015) Vin=28.5V Vout=12.7V	77°C	**FAIL**	Test load current 80mA! (155mA max. required). ---------- Calculation Tamb max. @ Pmax ≈ 1.0W: Tj @25°C = 77°C + 36K/W * 1,0W = 113°C ->Tamb max = 150°C + 25°C - 113°C = **62°C**! Tamb max ≈ 100°C (required)
IC8 (LMR36015) Vin=6V Vout=1.2V	52°C	**PASS**	Test load current 300mA! (475mA max. required). ---------- Calculation Tamb max. @ Pmax ≈ 0.5W: Tj @25°C = 52°C + 36K/W * 0,5W = 70°C ->Tamb max = 150°C + 25°C - 70°C = **105°C** Tamb max ≈ 100°C (required)

Measurements with Thermal Camera

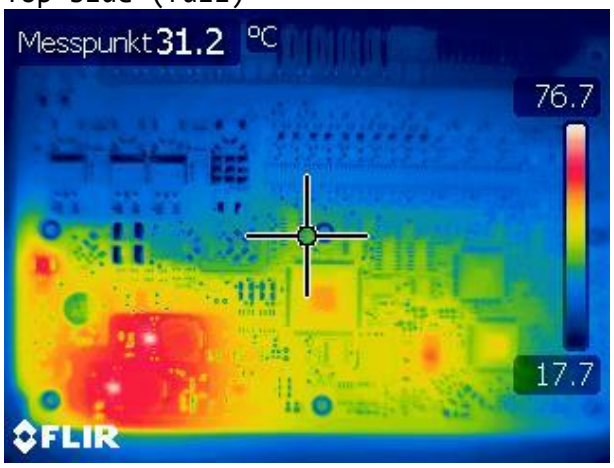
Schematics of Vin 28,5V / Vout 6V regulator:



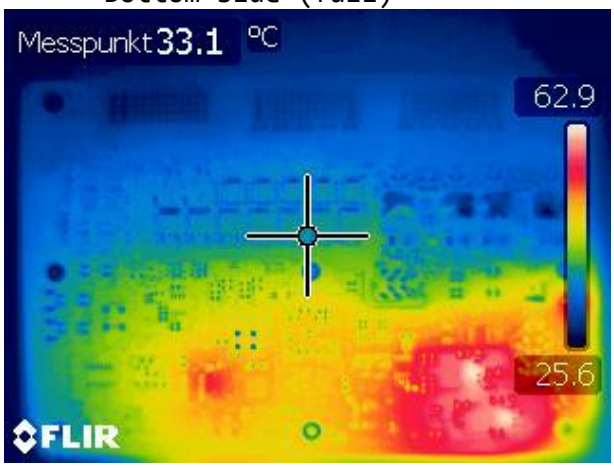
Layout top side of Vin 28,5V / Vout 6V regulator:



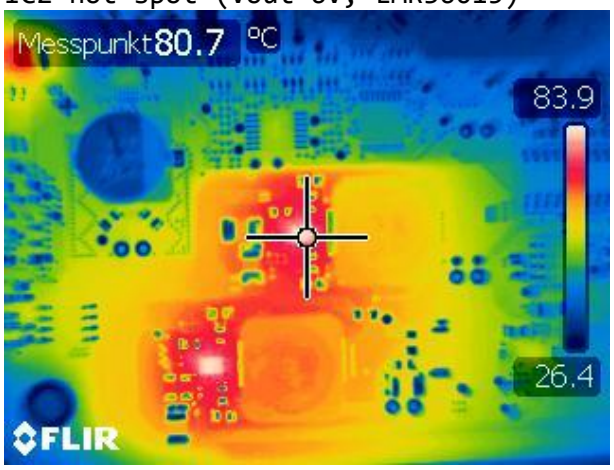
Top side (full)



Bottom side (full)



IC2 hot spot (Vout 6V, LMR36015)



IC8 hot spot (Vout 12V, LMR36015)

Improvements for IC2 and IC8 hot spots

For elimination of the hot spot the values of the power inductors will be varied.

Result of Test 1:

The L6 10µH (Vout 6V) power inductor is replaced with the 3.3µH/3.3A (WE-PD 7345, 7447779003).

➔ No hot spot changes on the regulator. The inductor temperature is decreased around 5-7°C.

Result of Test 2:

The L6 10µH (Vout 6V) power inductor is replaced with the 33µH/4.2A (WE-PD 1280).

➔ No hot spot changes on the regulator. No hot spot changes on the inductor.

Investigation

LMR36015FSCQRNXRQ1 (DUT). 1.5A, 2100 kHz, with SSC, with FPWM

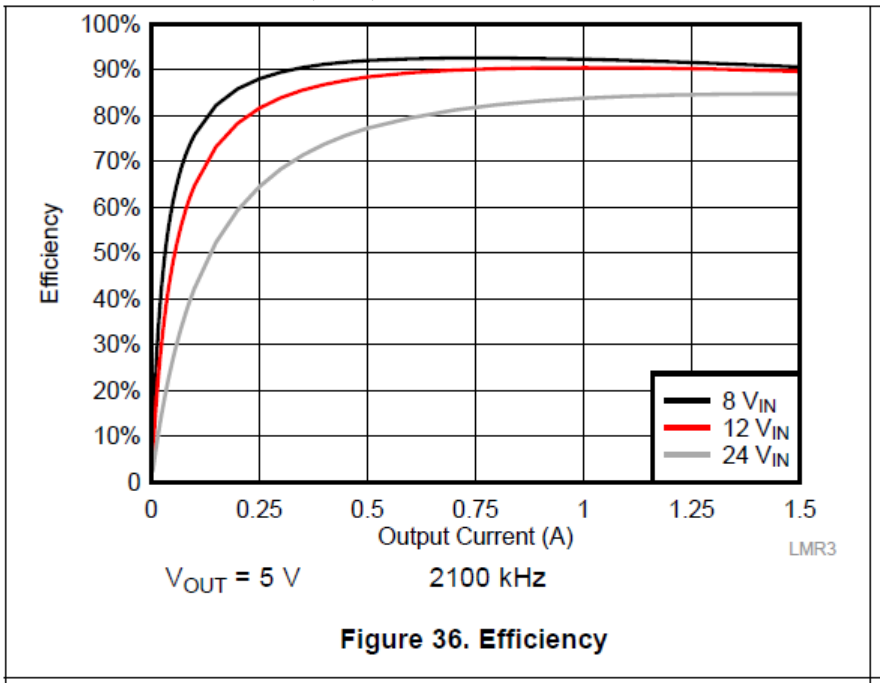


Figure 36. Efficiency

LMR36015AQRNXRQ1 (derivative). 1.5A, 400 kHz, no SSC, no FPWM

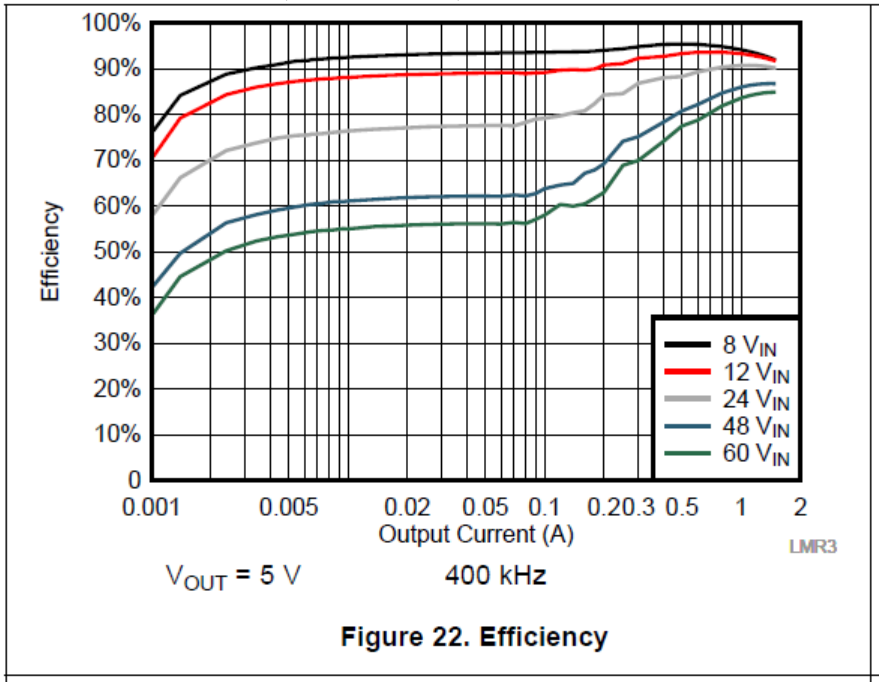


Figure 22. Efficiency

➔ The LMR36015AQRNXRQ1 400 kHz regulator has better efficiency at lower loads and higher input voltages! Is this the reason for such bad thermal behavior of the 2100 kHz DUT?

Efficiency comparison with LMR36006Q1 weaker derivatives:

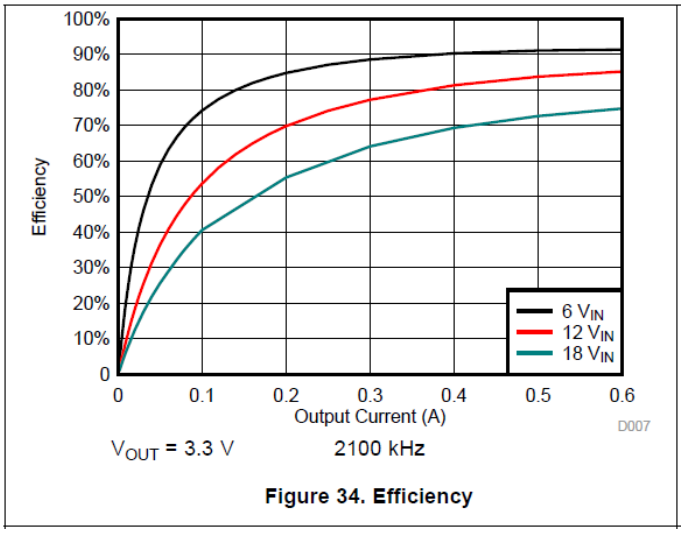


Figure 34. Efficiency

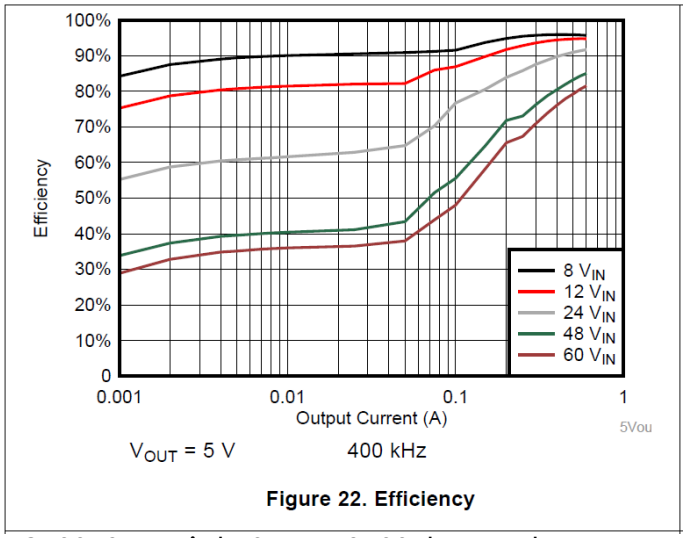


Figure 22. Efficiency

➔ The weaker package derivatives such LMR36006Q1, with 0,6A, 2100 kHz and 400 kHz show much worse efficiency behavior!

Efficiency comparison with previously designed TPS57x40-Q1 regulators:

TPS57140-Q1, 0.5A:

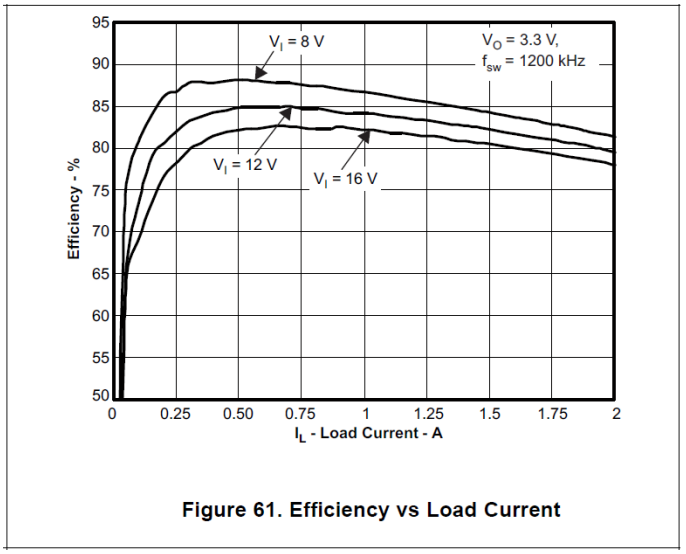


Figure 61. Efficiency vs Load Current

TPS57040-Q1, 0.5A

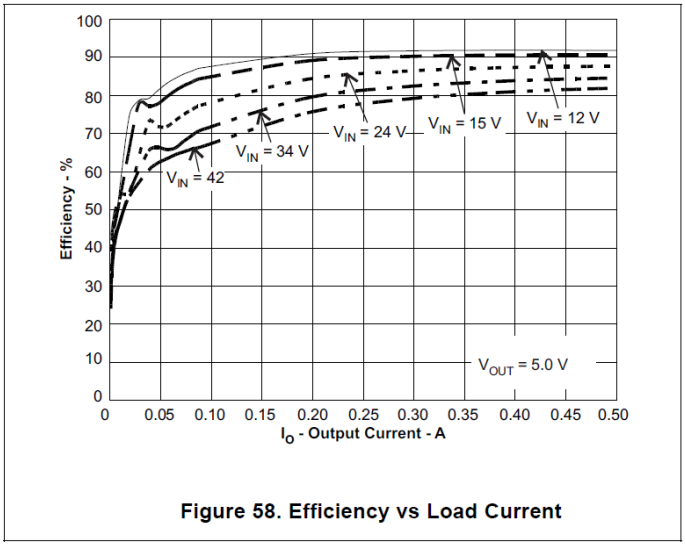


Figure 58. Efficiency vs Load Current

➔ The efficiency of the TPS57x40-Q1 regulators is better.
However, the goal of this regulator is the availability of an exposed pad on the package. The thermal resistance junction-to-case (bottom) is only 5.2 K/W!