

ON Semiconductor

Is Now

onsemi™

To learn more about onsemi™, please visit our website at
www.onsemi.com

onsemi and **onsemi** and other names, marks, and brands are registered and/or common law trademarks of Semiconductor Components Industries, LLC dba "**onsemi**" or its affiliates and/or subsidiaries in the United States and/or other countries. **onsemi** owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of **onsemi** product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. **onsemi** reserves the right to make changes at any time to any products or information herein, without notice. The information herein is provided "as-is" and **onsemi** makes no warranty, representation or guarantee regarding the accuracy of the information, product features, availability, functionality, or suitability of its products for any particular purpose, nor does **onsemi** assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using **onsemi** products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by **onsemi**. "Typical" parameters which may be provided in **onsemi** data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. **onsemi** does not convey any license under any of its intellectual property rights nor the rights of others. **onsemi** products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use **onsemi** products for any such unintended or unauthorized application, Buyer shall indemnify and hold **onsemi** and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that **onsemi** was negligent regarding the design or manufacture of the part. **onsemi** is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner. Other names and brands may be claimed as the property of others.



Design Note – DN06056/D

Power Supply For Audio Class D Amplifier

| Device | Application | Input Voltage | Output Voltage | Output Current | Topology |
|---------|-------------|---------------|----------------|----------------|----------|
| CS51221 | Audio | 7.6-45 V | 18V | 8.3A | Boost |

Table 1: CS51221 Audio Power Supply

| Characteristic | Min | Typ | Max | Unit |
|--|---------|---------|--------|---------|
| Output Voltage | 18.0453 | 18.0532 | 18.06 | V |
| Output Current | 1 | | 8.3 | A |
| Oscillator Frequency | | 140 | | kHz |
| Output Voltage Ripple | | 150 | | mVpk-pk |
| Load Regulation (Iout = 0.1-8.3A) Vin= 12V | | -.693 | | mV/A |
| Line Regulation to 5V | | | | |
| Iout = .1A) | 0.28 | 0.31 | 0.34 | % |
| Iout = 8.3A) | 0.25 | 0.28 | 0.32 | |
| Size | Length | Width | Height | mm |
| | 80 | 59 | 31 | |

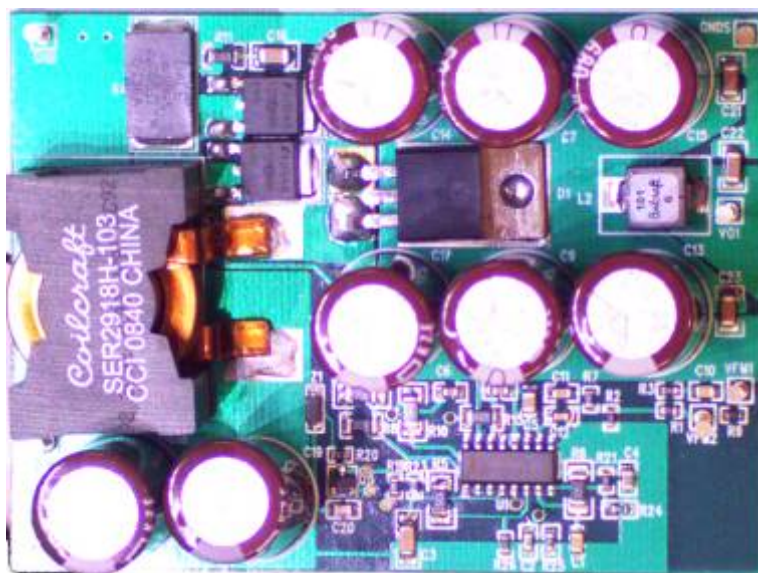


Figure 1: Demonstration Board Picture

Circuit Description

A boost power supply was developed for to feed 4 class D amplifiers and one auxiliary system. The design must minimize the use of through hole components, designed as small as possible on a 4 layer PCB, and only populated on the top side. The system level drawing is shown in Figure 2. The power supply is required to maintain an 18V output with input voltage variation from 7.6V to 18.4V. Above 18.4V the power supply will shutoff-minimizing losses and allow input voltage to flow to output voltage. The required voltage profile is shown in Figure 3.

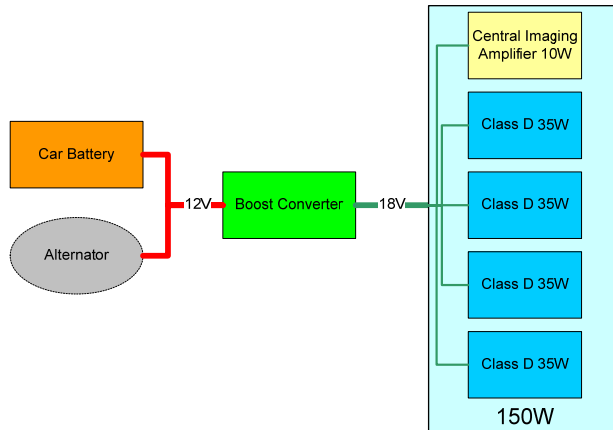


Figure 2: System Level Diagram of the Sony MCA 'Audiofile' radio

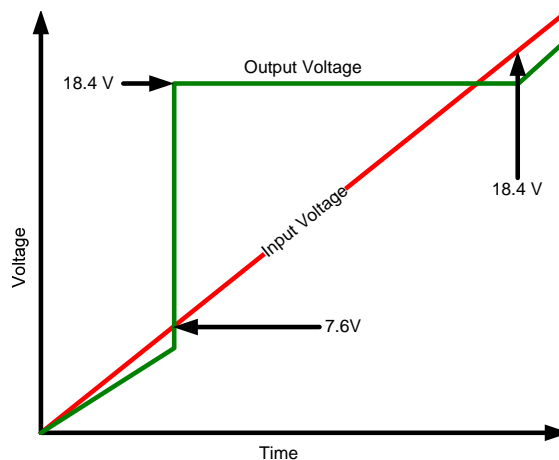


Figure 3: CS51221 Design Boost Curve

The design has the following features:

- Adjustable cycle by cycle current limiting
- Overvoltage Shutoff
- Undervoltage shutoff
- Can be synchronized to a higher frequency
- Wide operating range 7.6-18.4V operating and 18-45V nonoperating
- Programmable soft start
- Voltage feed forward

Performance Information

The following figures show typical performance of the evaluation board.

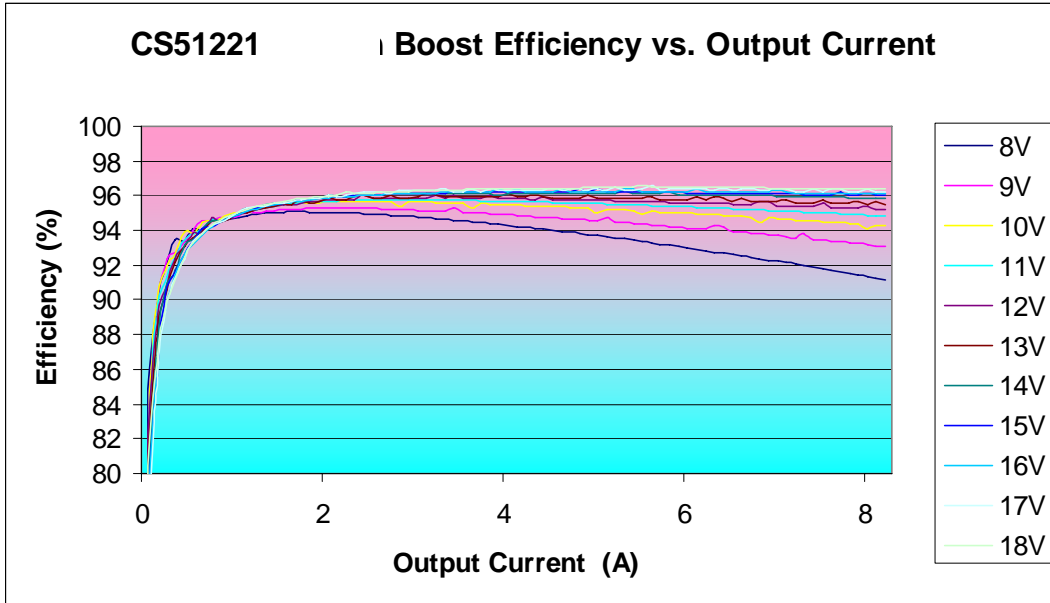


Figure 4: CS51221 Efficiency 8V – 18V input voltage with a 18V Output Voltage

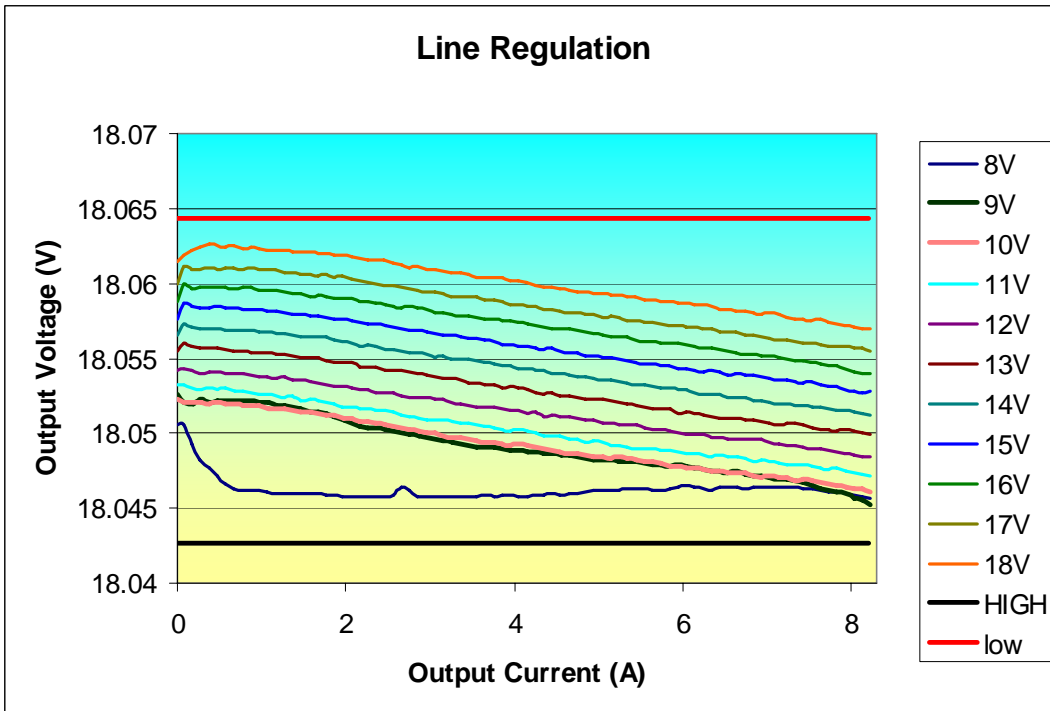


Figure 5: CS51221 Line Regulation

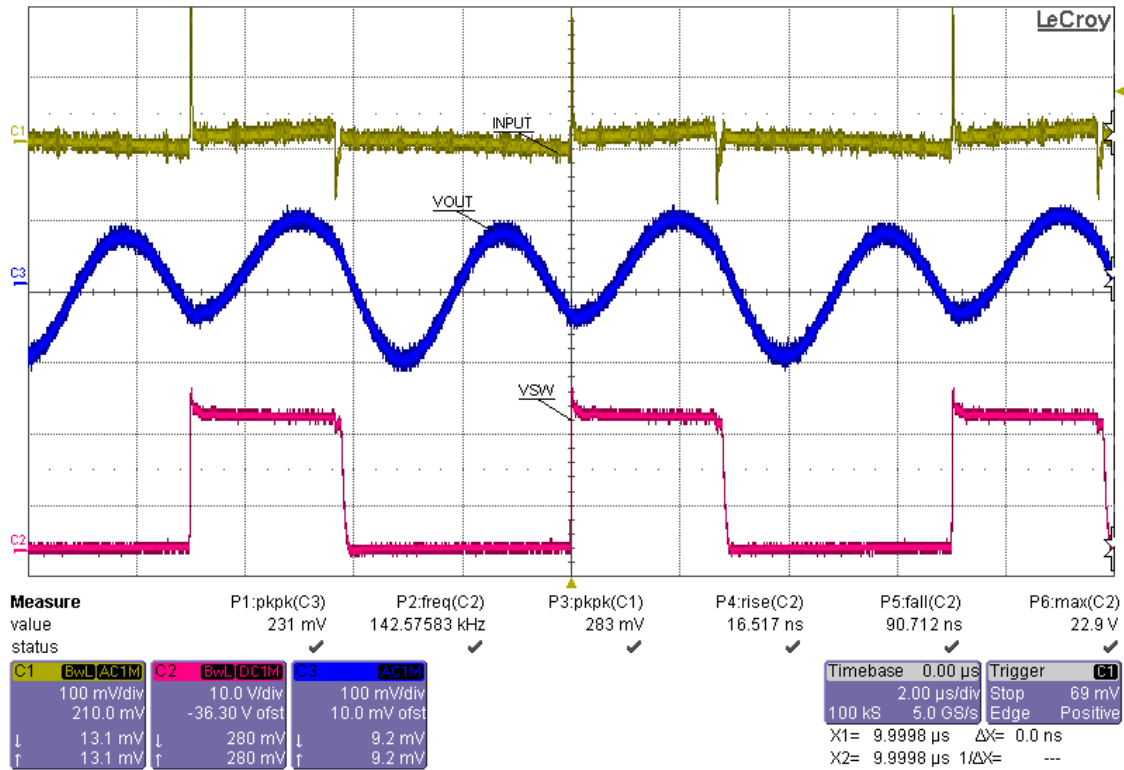


Figure 6: Input and Output Ripple Voltage $V_{in} = 8V$ $V_{out} = 18V$ $I_{out} = 8.3A$ 231 mVpp

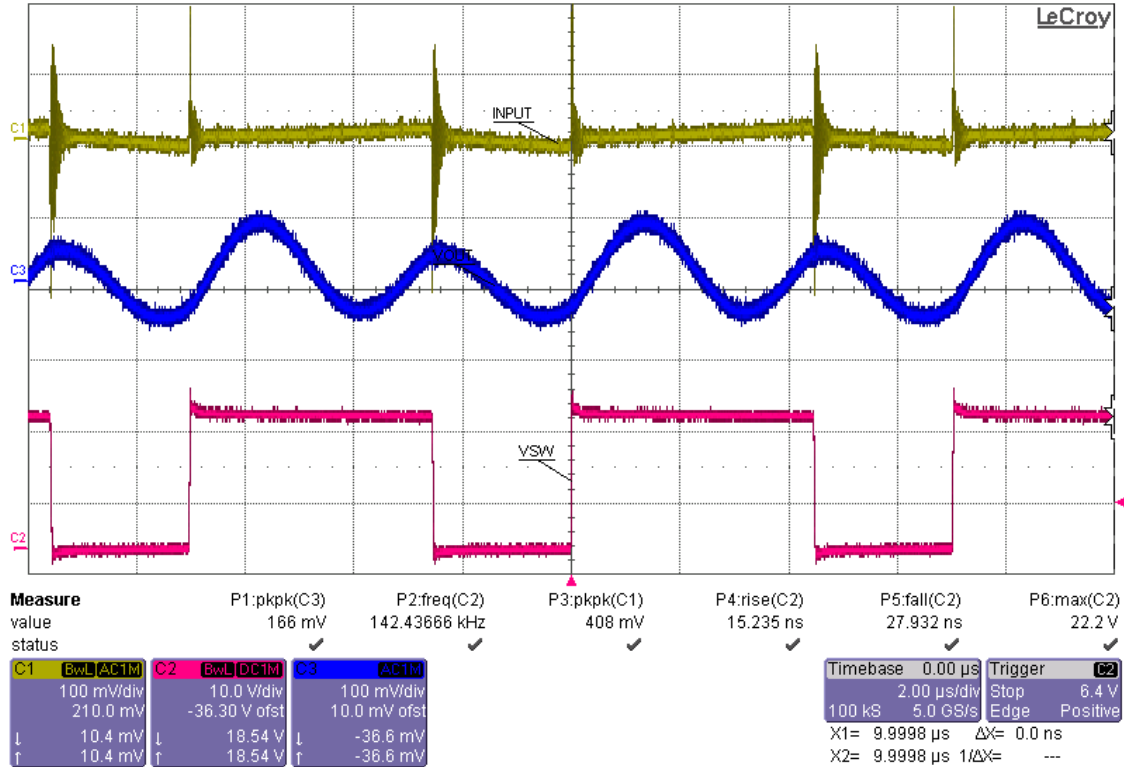


Figure 7: $V_{in} = 12V$ $V_{out} = 18V$ $I_{out} = 8.3A$ 166mVpp

ON Semiconductor Confidential – NDA Required

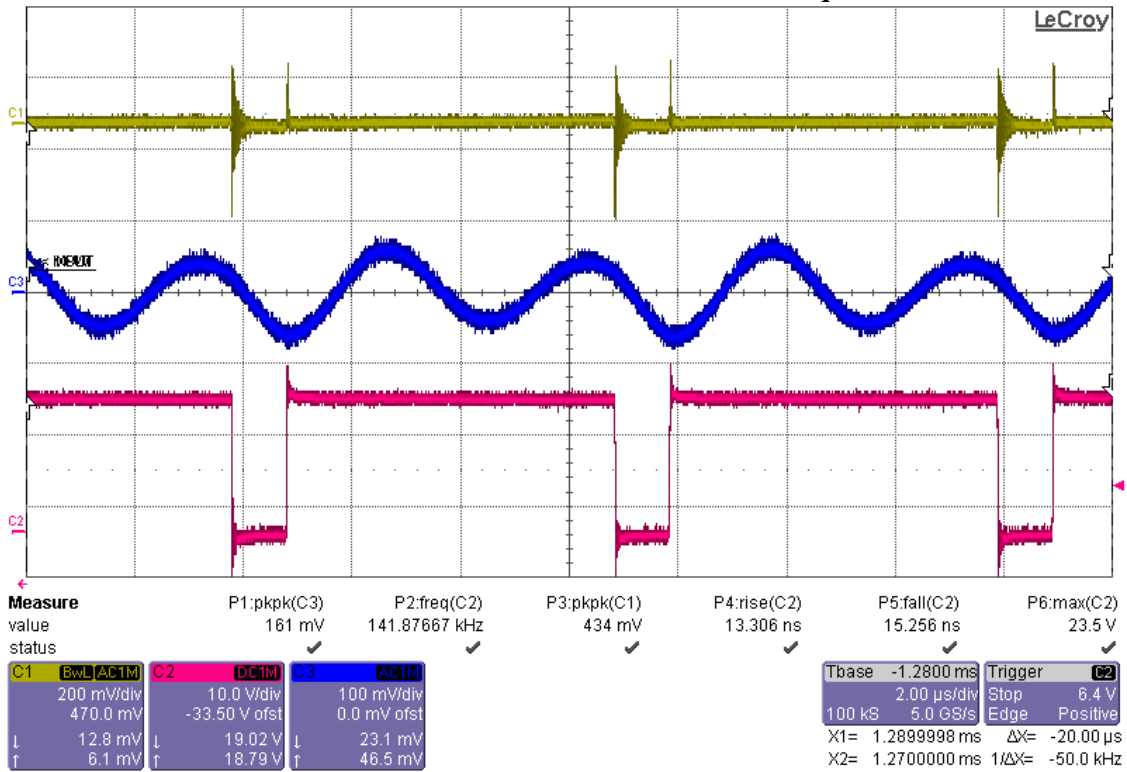


Figure 8: $V_{in} = 16V$ $V_{out} = 18V$ $I_{out} = 8.3A$ 161mVpp

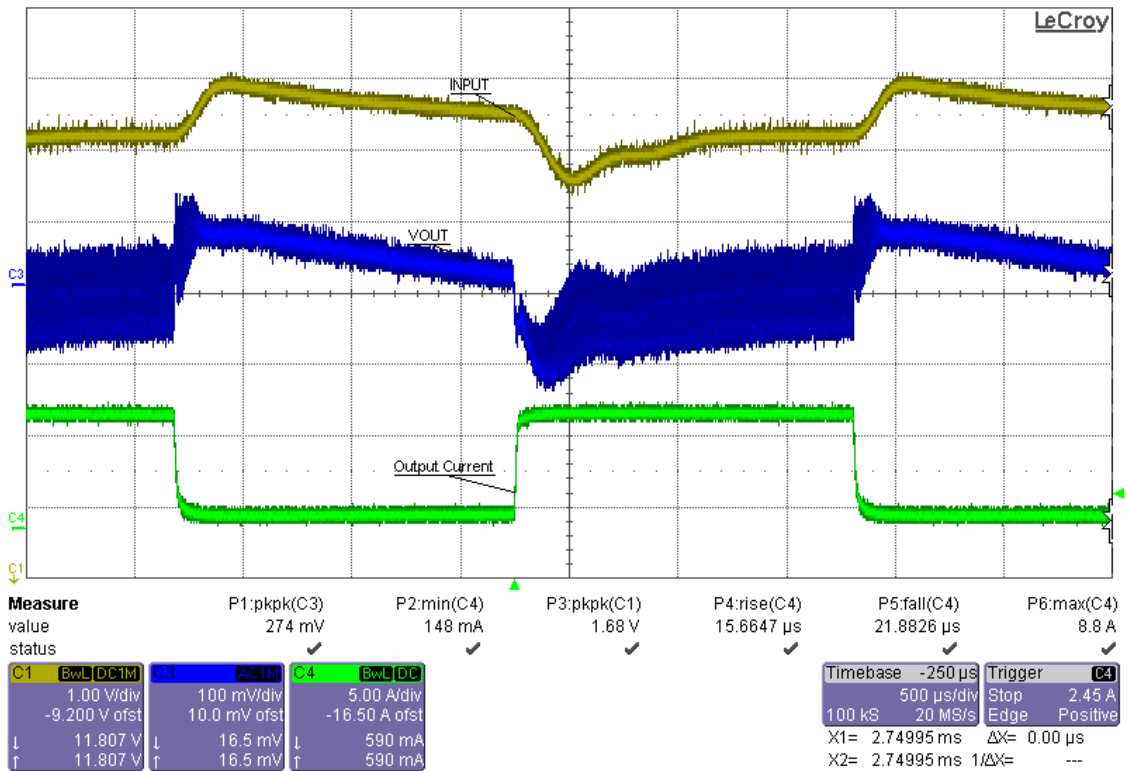


Figure 9: Transient Response Input Voltage = 12V output current step 1.0A to 8.0 A with 274 mV peek to peek

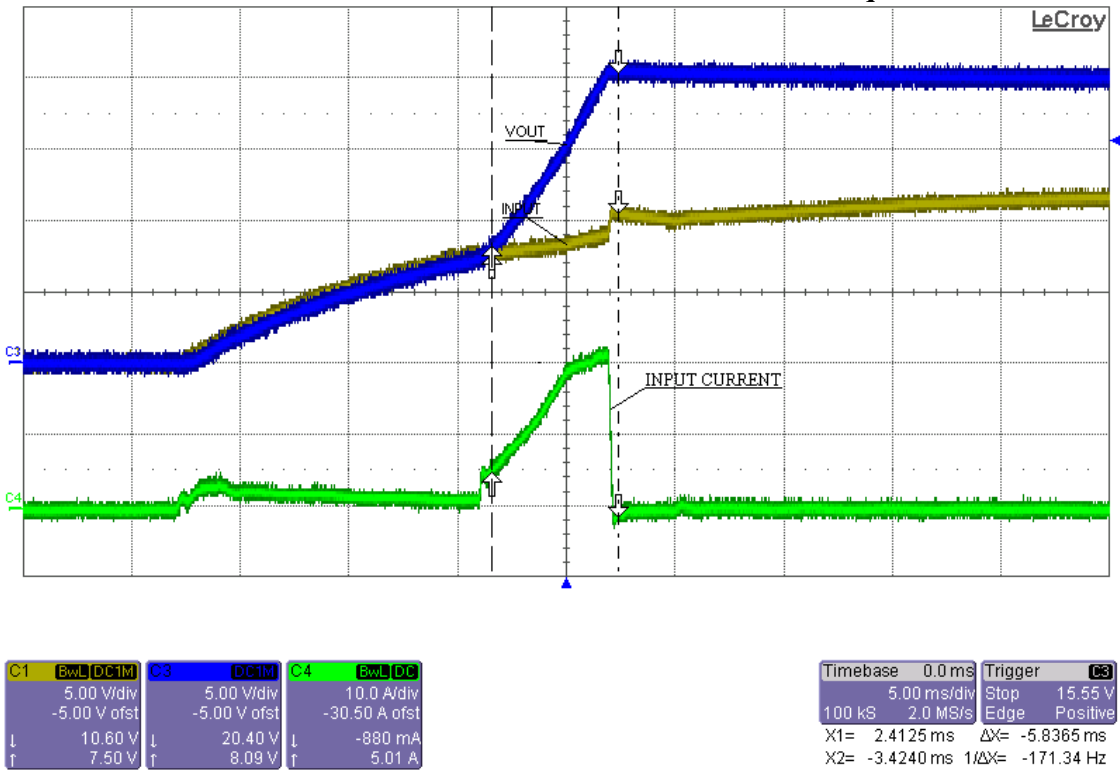


Figure 10: Soft Start Time is 5.8 ms from an Input voltage of 0V

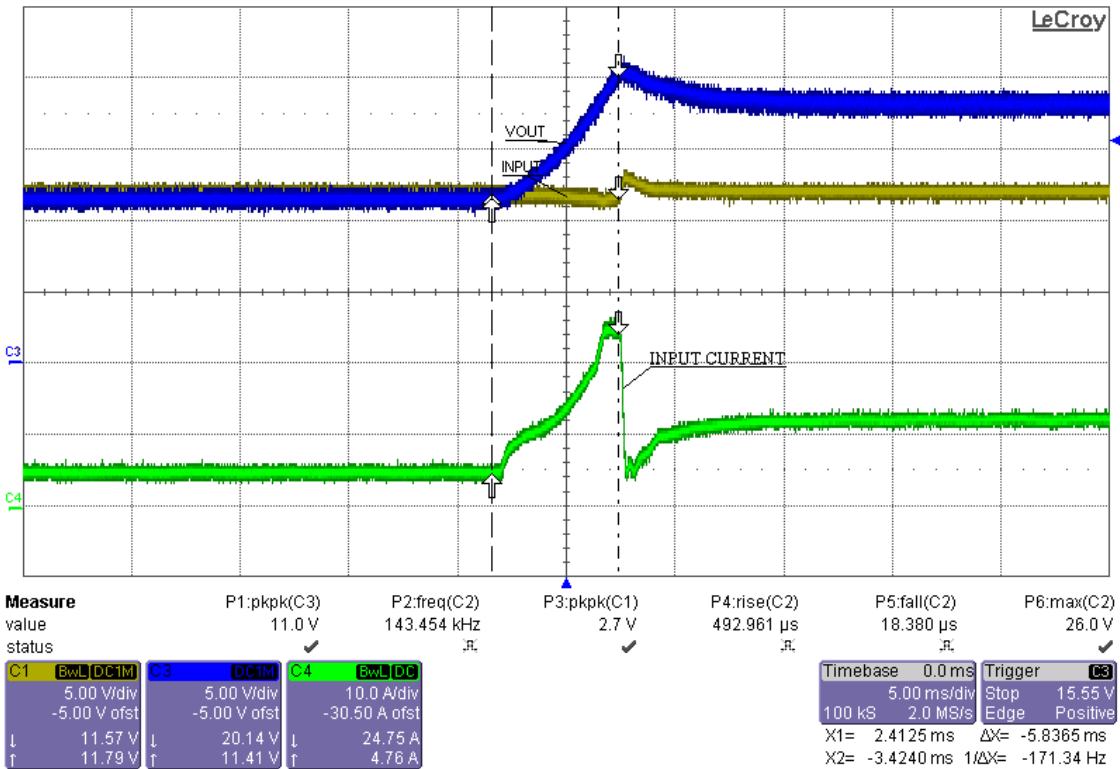


Figure 11: Soft Start Time is 5.8 ms from an Input voltage of 12V

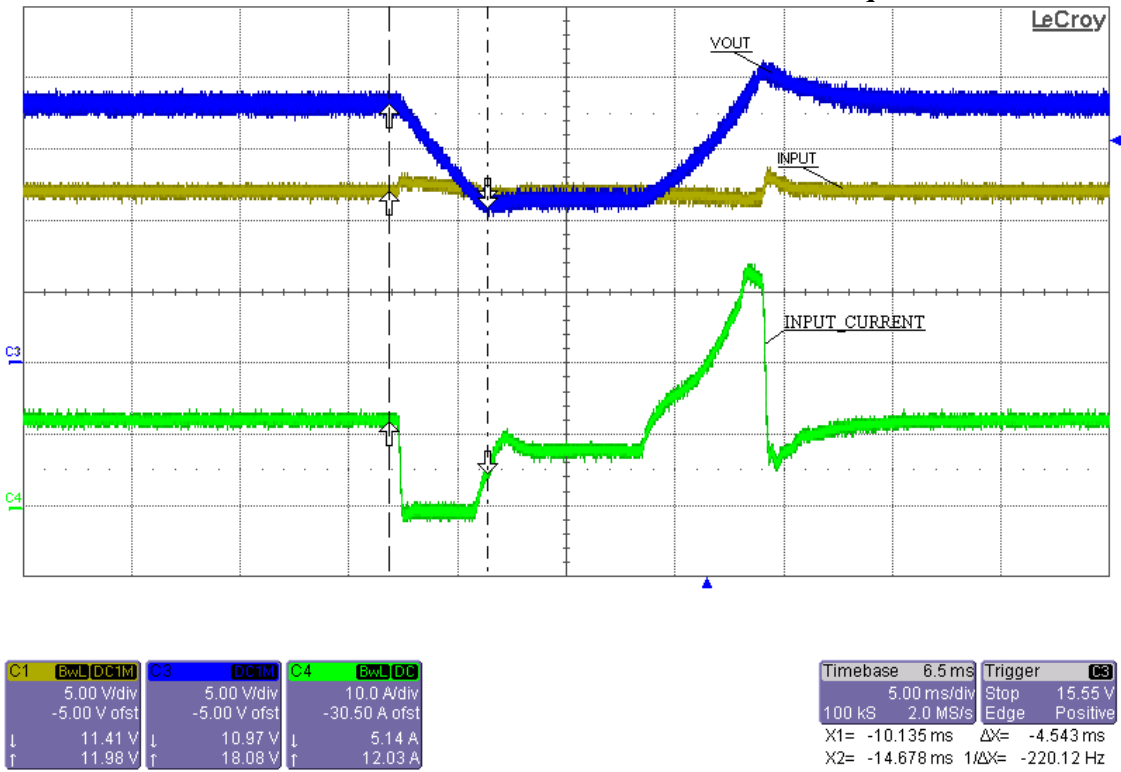


Figure 12: Soft Start and Soft Stop From 12V Volts

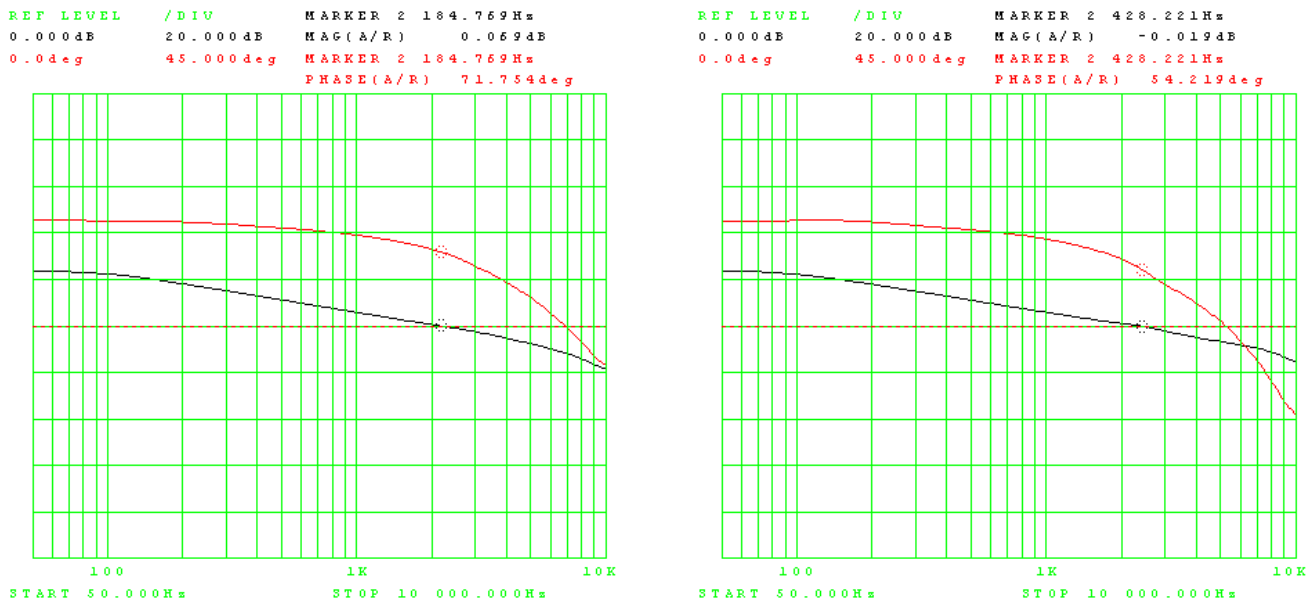


Figure 13: 8V Frequency Response 2.1 kHz and 2.4k Cross over at 71 and 54 Degrees of Phase Margin 2A Load at Full Load Right

ON Semiconductor Confidential – NDA Required

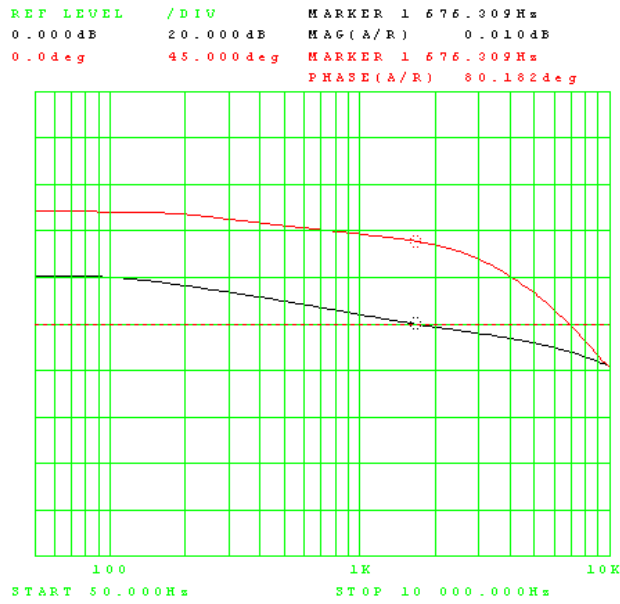


Figure 14: 12V Frequency Response 1.6kHz Cross over at 80 Full Load

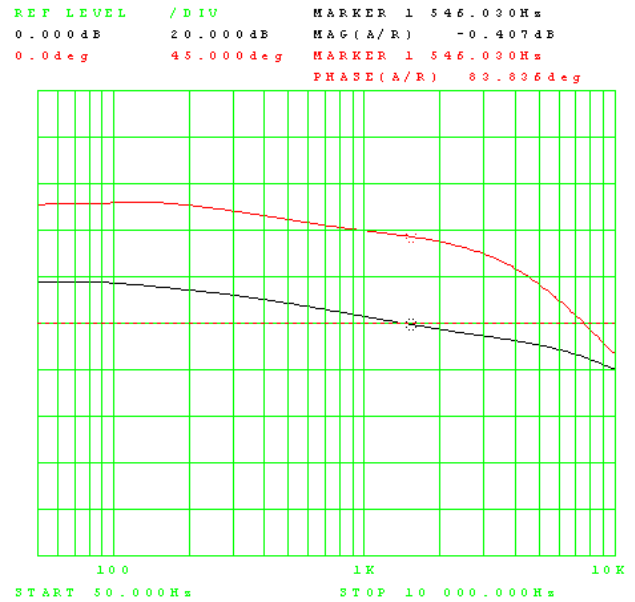
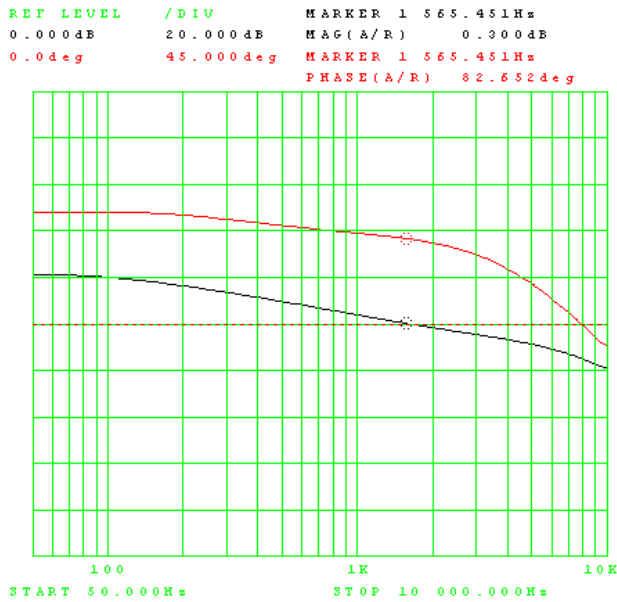


Figure 15: 16V Frequency Response 1.5 kHz and 1.5k Cross over at 82 and 83 Degrees of Phase Margin 2A Load at Full Load Right

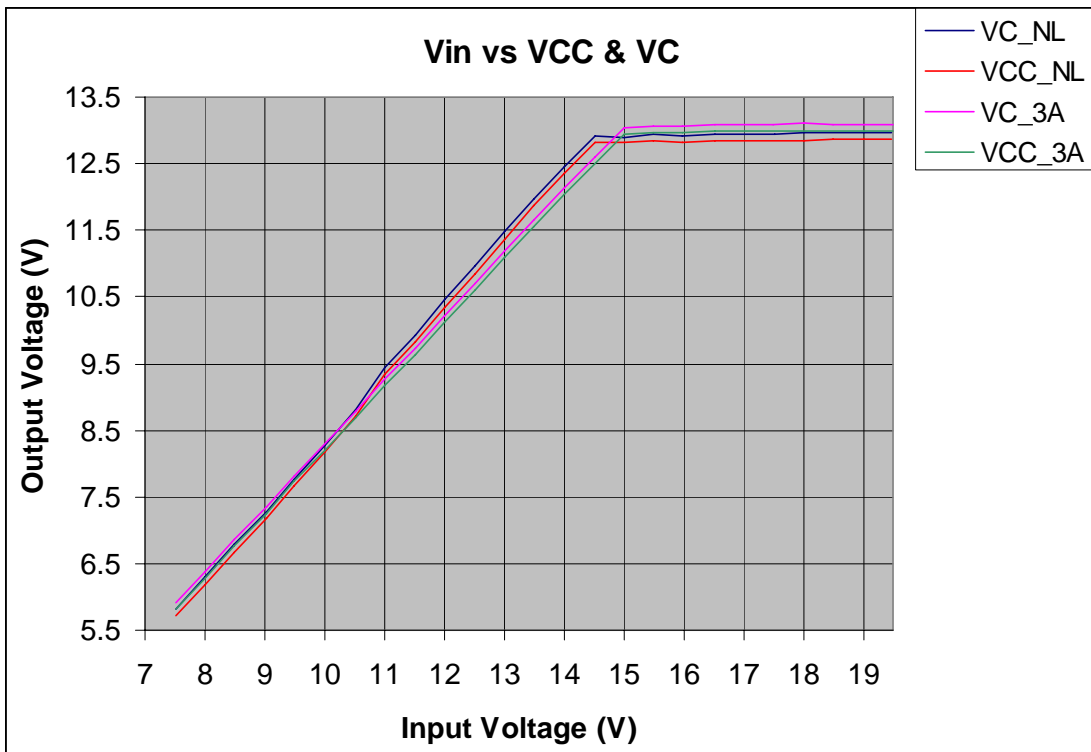


Figure 16: VCC and VC vs Input Voltage

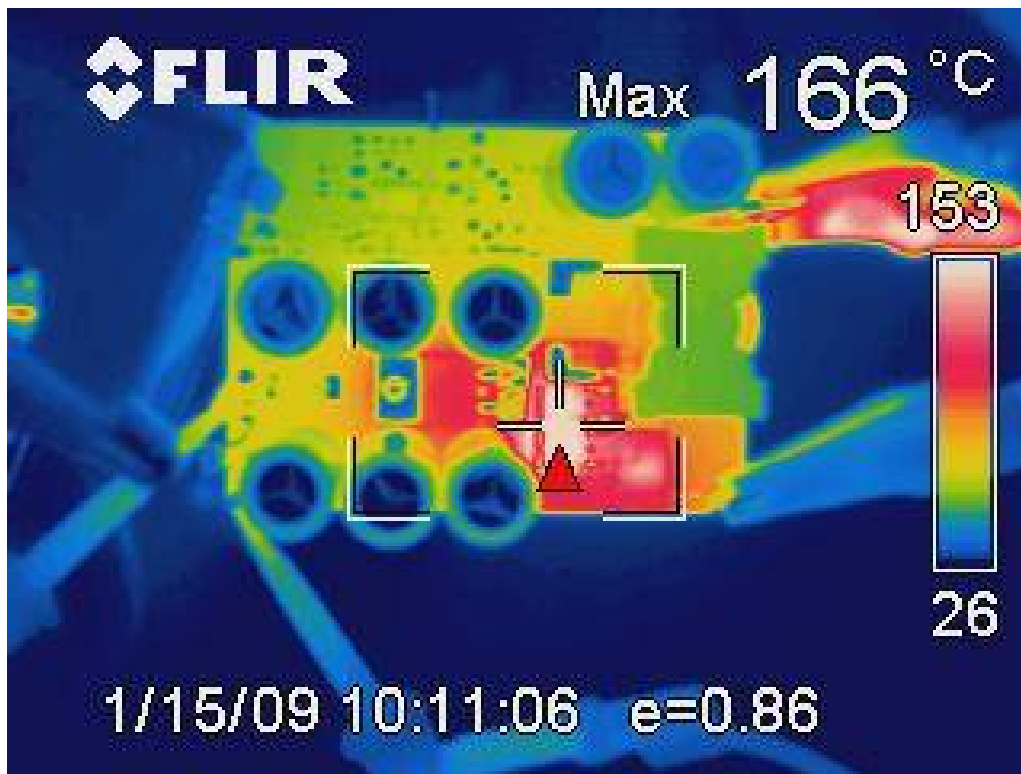


Figure 17: Thermal Image of PCB at 8V 8.3A Load with a 25C ambient



Figure 18: Thermal Image of PCB at 12V 8.3A Load with a 25C ambient

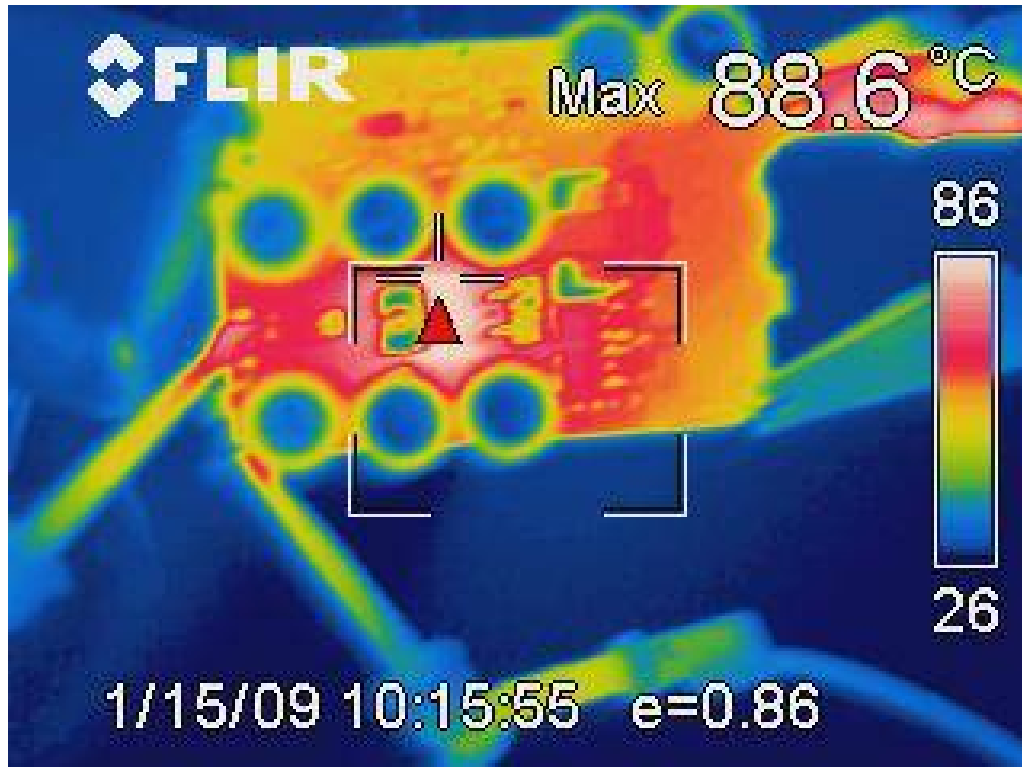


Figure 19: Thermal Image of PCB at 16V 8.3A Load with a 25C ambient

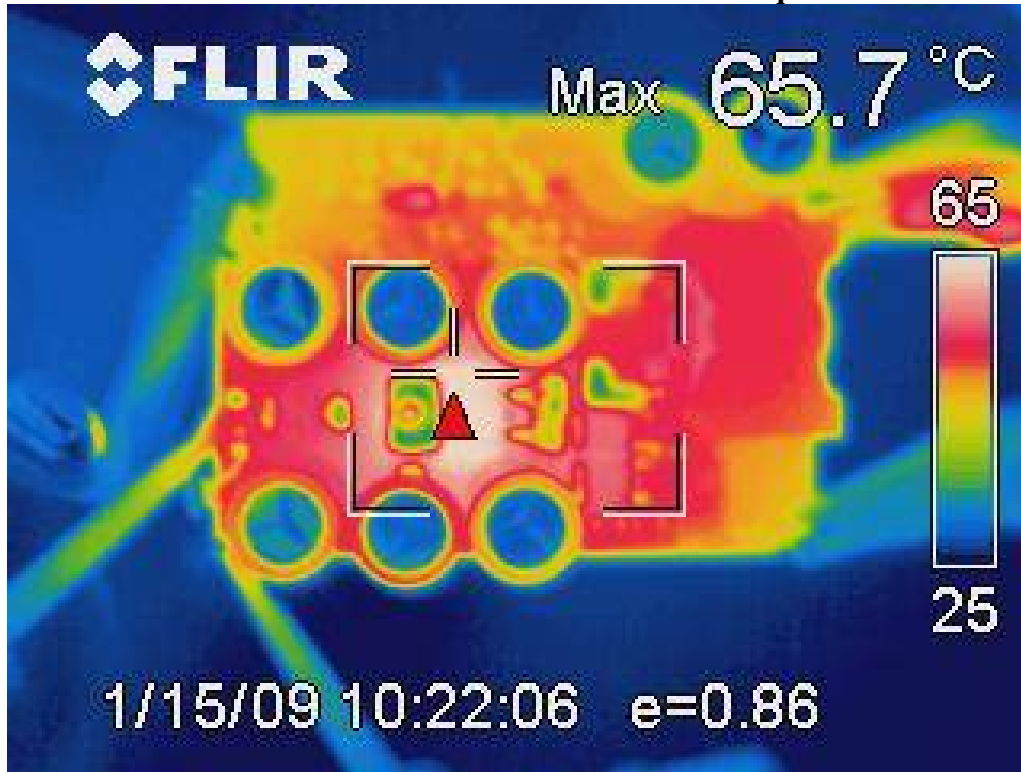


Figure 20: Thermal Image of PCB at 12V 4.15A Load with a 25C ambient

Schematic

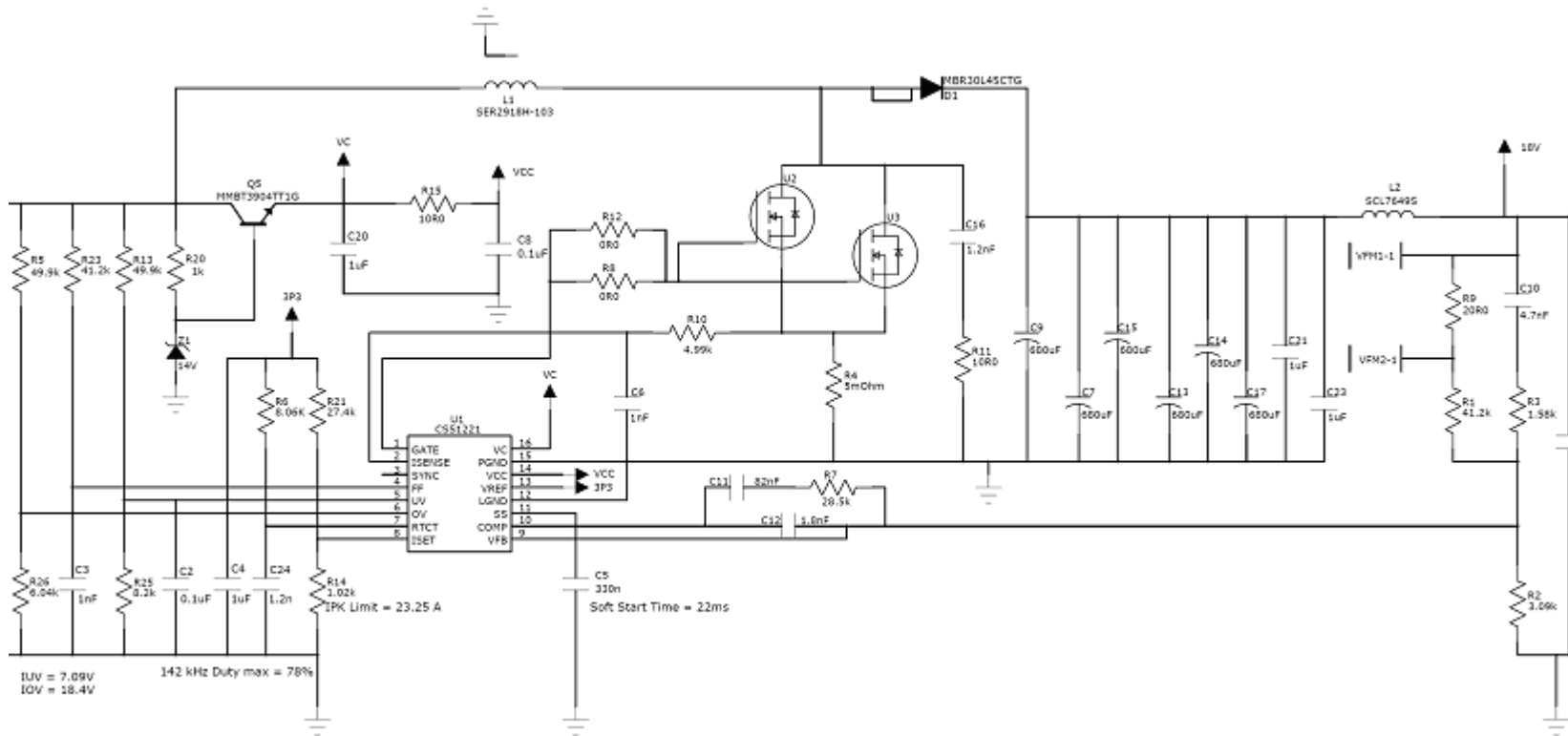


Figure 24: CS51221 Schematic

ON Semiconductor Confidential – NDA Required

Table 2 : CS51221 Bill of Materials

| Designator | Quantity | Description | Value | Tolerance | FootPrint | Manufacturer | Manufacturer Part Number |
|------------------------|----------|--------------------------------------|-----------|-----------|-----------|------------------|--------------------------|
| C5 | 1 | Ceramic Chip Capacitor 10V | 330n | 20% | 805 | AVX Corporation | 0805ZC334JAT2A |
| C2 C8 | 2 | Ceramic Chip Capacitor 25V | 0.1uF | 20% | 603 | AVX Corporation | 06033C104MAT2A |
| C12 | 1 | Ceramic Chip Capacitor 10V | 1.8nF | 10% | 603 | AVX Corporation | 0603ZC272KAT2A |
| C6 | 1 | Ceramic Chip Capacitor 50V | 1nF | 10% | 603 | AVX Corporation | 0603ZC102KA72A |
| C4 | 1 | Ceramic Chip Capacitor 6.3V | 1uF | 10% | 603 | AVX Corporation | 06036D105KAT2A |
| C20 | 1 | Ceramic Chip Capacitor 25V | 1uF | 20% | 603 | AVX Corporation | 06033D105MAT2A |
| C10 | 1 | Ceramic Chip Capacitor 100V | 4.7nF | ±10% | 603 | AVX Corporation | 06031C472KAT2A |
| C11 | 1 | Ceramic Chip Capacitor 10V | 82nF | 10% | 603 | AVX Corporation | 0603ZC184KAT2A |
| C24 | 1 | Ceramic Chip Capacitor 6.3V | 1.2n | 5% | 805 | AVX Corporation | 08056A122JAT2A |
| C16 | 1 | Ceramic Chip Capacitor 100V | 1.2nF | 10% | 1206 | AVX Corporation | 12061A122KAT2A |
| C3 | 1 | Ceramic Chip Capacitor 100V | 1nF | 10% | 1206 | AVX Corporation | 12061C102KAT2A |
| C21 C23 | 2 | Ceramic Chip Capacitor 50V | 1uF | 10% | 1206 | AVX Corporation | 12065C105KAT2A |
| C22 | 1 | Ceramic Chip Capacitor 50V | 4.7uF | ±10% | 1210 | AVX Corporation | 12105C475KAT2A |
| U1 | 1 | Enhanced Voltage Mode PWM Controller | 3V Ref | NA | SOIC 16 | ON Semiconductor | CS51221 |
| C7 C13-15 C9 C17-19 | 8 | Electrolytic Capacitor | 680uF | 20% | 12.5X25 | United Chemicon | EKZE500ELL681MK30S |
| D1 | 1 | Schottky Power Rectifier | 30A 45V | NA | TO-220 | ON Semiconductor | MBR30L45CTG |
| Q5 | 1 | General Purpose NPN Transistor | 40V 200mA | NA | SOT-23 | ON Semiconductor | MMBT3904TT1G |
| Z1 | 1 | Zener Diode | 14V | ±5% | SOD-123 | ON Semiconductor | MMSZ5244BT1G |
| U2-3 | 2 | N MOSFET 8.1mOhm | 60V 50A | NA | DPAK | Infineon | IPB081N06L3G |
| R5 | 1 | SMT Resistor | 49.9k | 1% | 1206 | Vishay | CRCW120649K9FKEA |
| R14 | 1 | SMD Resistor | 1.02k | ±1.0% | 603 | Vishay / Dale | CRCW06031K02FKEA |
| R3 | 1 | SMD Resistor | 1.58k | ±1.0% | 603 | Vishay / Dale | CRCW06031K58FKEA |
| R20 | 1 | SMD Resistor | 1k | ±1.0% | 603 | Vishay / Dale | CRCW060310K0FKEA |
| R9 | 1 | SMD Resistor | 20R0 | ±1.0% | 603 | Vishay / Dale | CRCW060320R0FKEA |
| R21 | 1 | SMD Resistor | 27.4k | ±1.0% | 603 | Vishay / Dale | CRCW060327K4FKEA |
| R7 | 1 | SMD Resistor | 28.5k | ±1.0% | 603 | Vishay / Dale | CRCW06033K01FKEA |
| R2 | 1 | SMD Resistor | 3.09k | ±1.0% | 603 | Vishay / Dale | CRCW06033K09FKEA |
| R1 R23 | 2 | SMD Resistor | 41.2k | ±1.0% | 603 | Vishay / Dale | CRCW060341K2FKEA |

ON Semiconductor Confidential – NDA Required

Table 2 : CS51221 Bill of Materials

| Designator | Quantity | Description | Value | Tolerance | FootPrint | Manufacturer | Manufacturer Part Number |
|-------------------|-----------------|-----------------------|--------------|------------------|--------------------|---------------------|---------------------------------|
| R13 | 1 | SMD Resistor | 49.9k | ±1.0% | 603 | Vishay / Dale | CRCW060349K9FKEA |
| R26 | 1 | SMD Resistor | 6.04k | ±1.0% | 603 | Vishay / Dale | CRCW06036K04FKEA |
| R25 | 1 | SMD Resistor | 8.2k | ±1.0% | 603 | Vishay / Dale | CRCW06038K20FKEA |
| R8 R12 | 2 | SMD Resistor | 0R0 | ±5.0% | 1206 | Vishay / Dale | CRCW12060000Z0EA |
| R11 R15 | 2 | SMD Resistor | 10R0 | ±5.0% | 1206 | Vishay / Dale | CRCW120610R0FKEA |
| R10 | 1 | SMD Resistor | 4.99k | ±1.0% | 1206 | Vishay / Dale | CRCW12064K99FKEA |
| R6 | 1 | SMD Resistor | 8.06K | ±1.0% | 1206 | Vishay / Dale | CRCW12068K06FKEA |
| R4 | 1 | SMD Resistor | 5mOhm | ±1.0% | 4527 | Vishay / Dale | WSR55L00F |
| L2 | 1 | SMT Inductor 0.17mOhm | .1 uH | 10% | 7.5mmX 7.6mm | Coilcraft | SLC7649S-101KL_ |
| L1 | 1 | SMT Inductor | 33 uH | 10% | 27.94mmX 27.9mm | Coilcraft | SER2918H-103 |

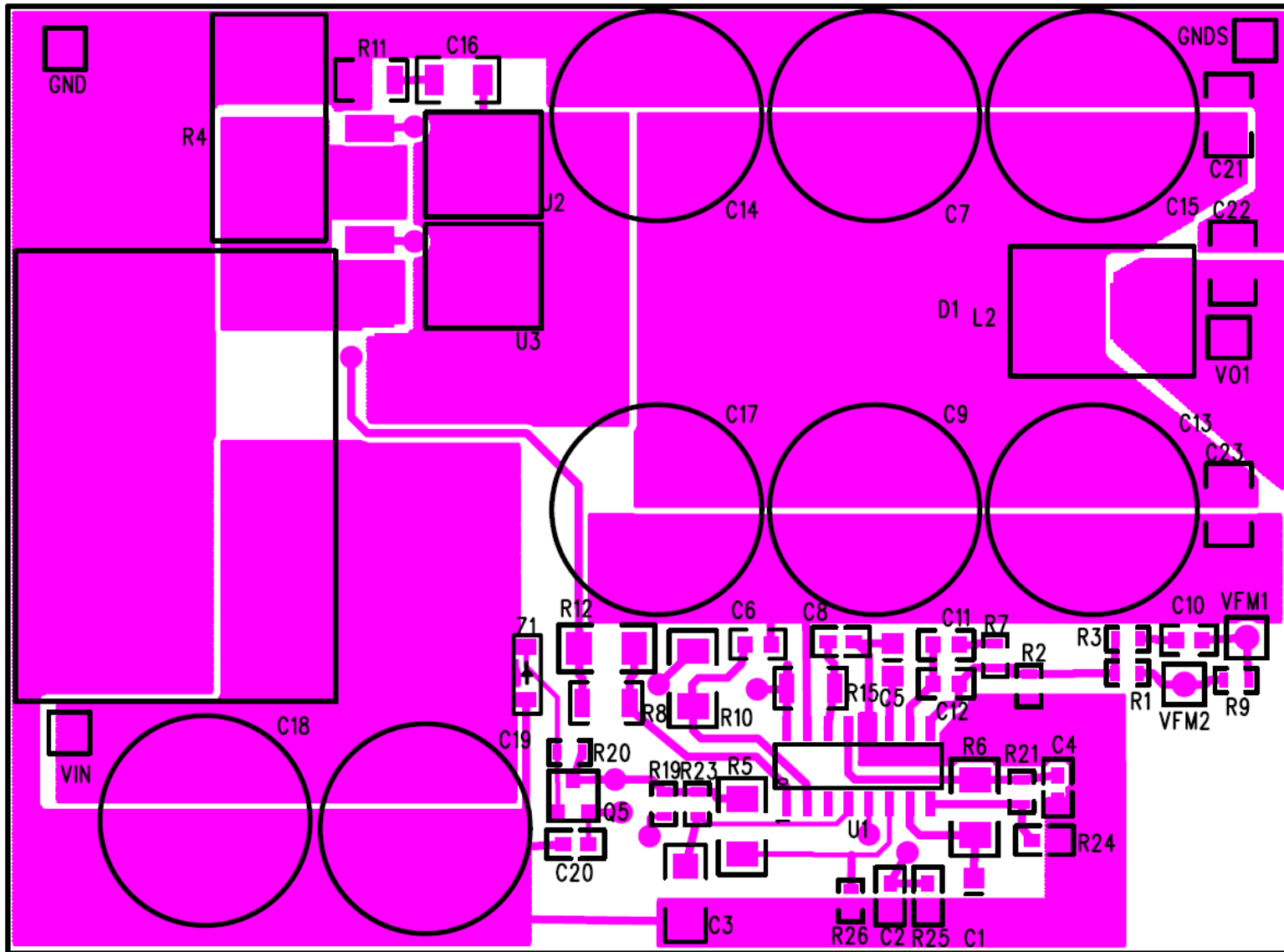


Figure 25: Layout Top

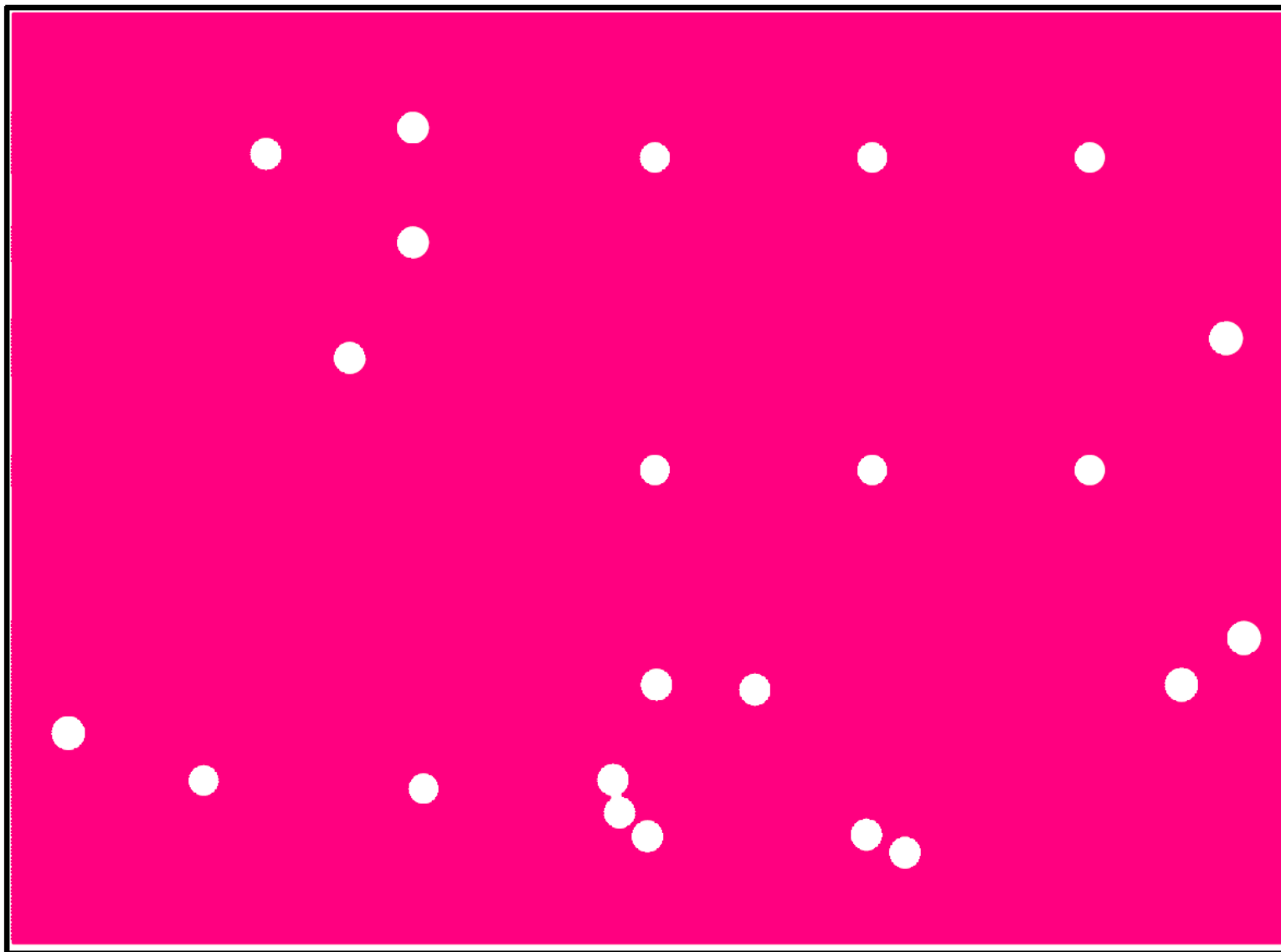


Figure 26: Layout Inner Top

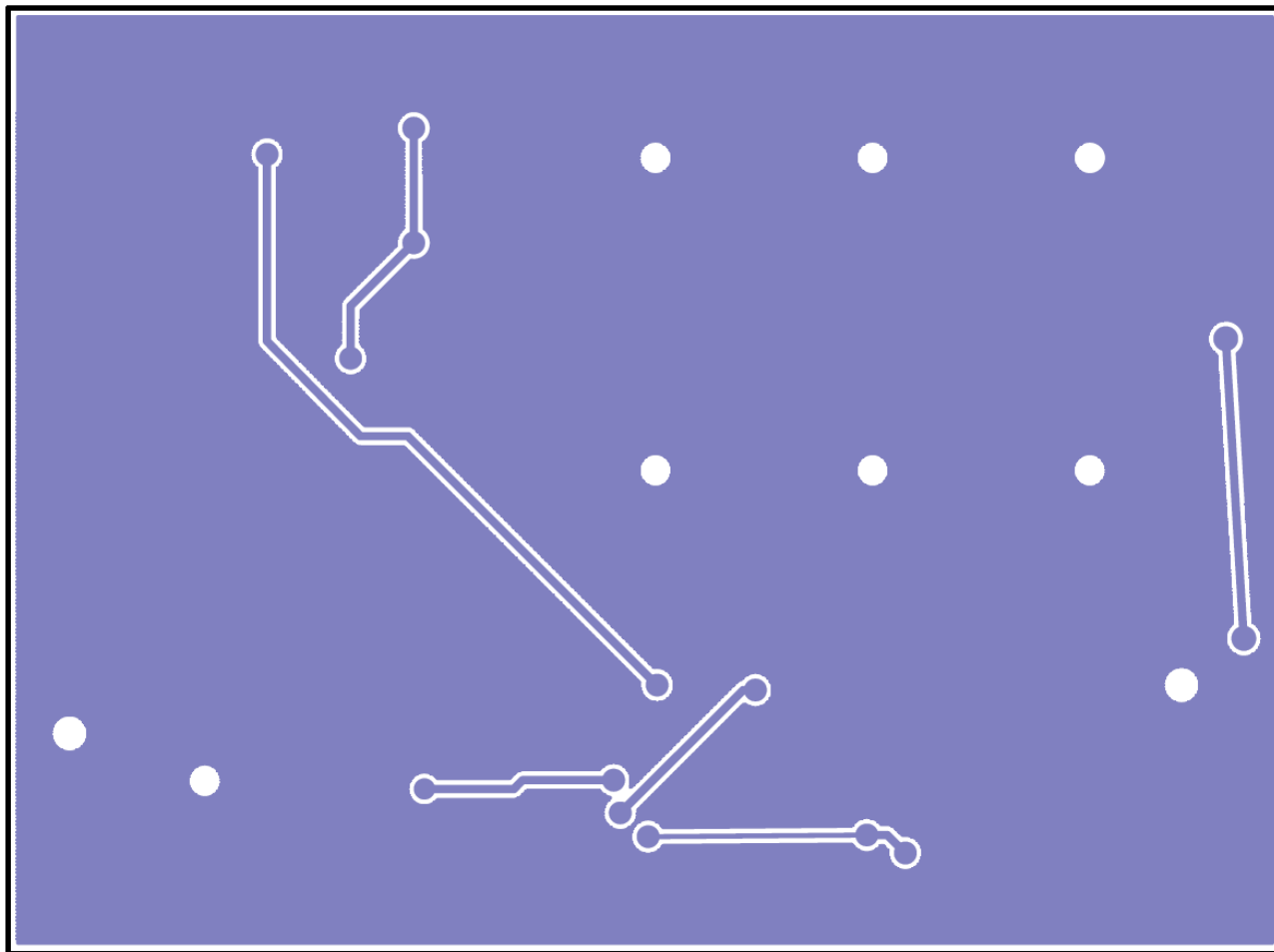


Figure 27: Layout Inner Bottom

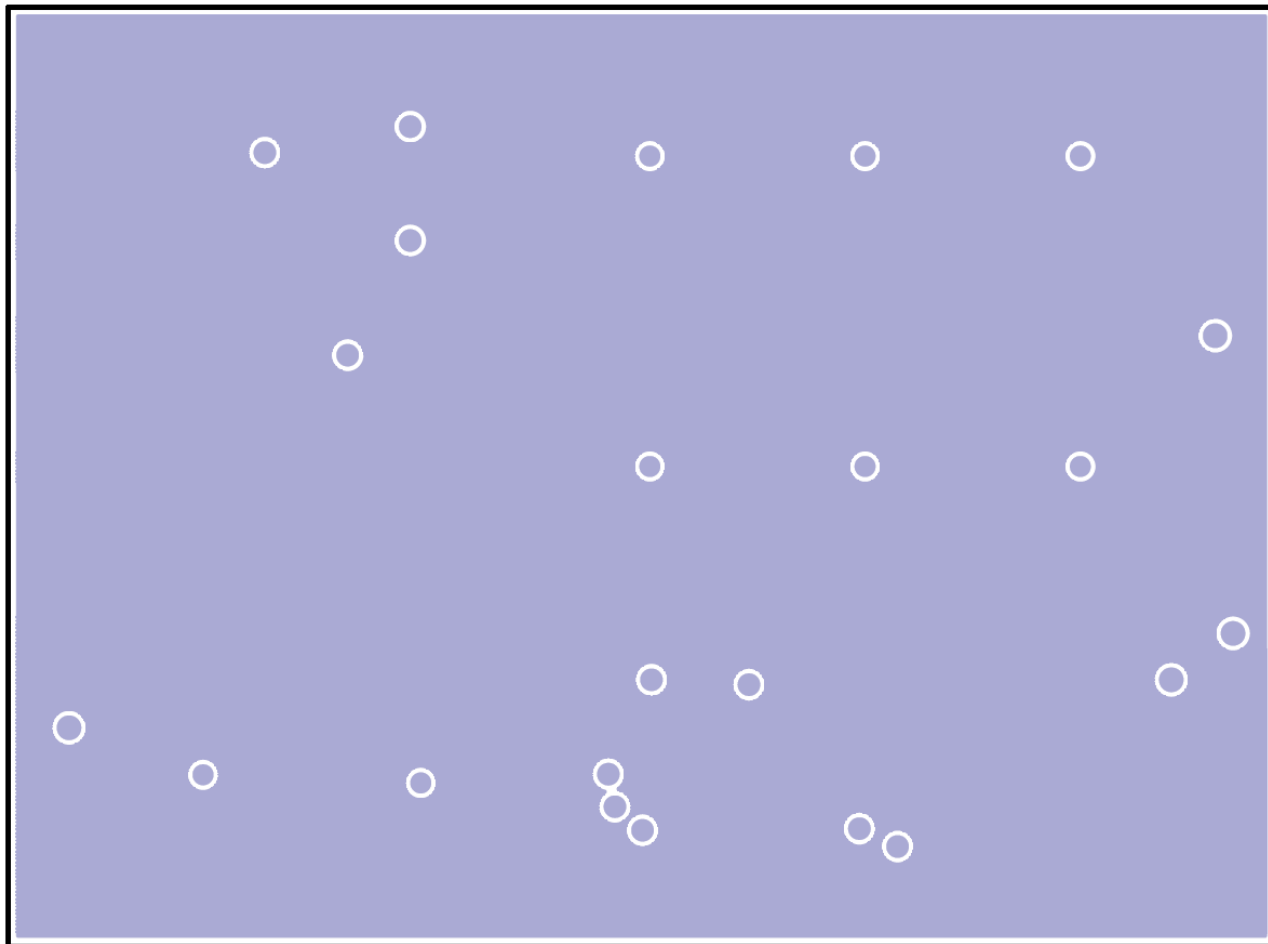


Figure 28: Layout Bottom

High Current Reverse Polarity Protection

The boost converter input current at low line is over 21 A creating large losses when standard reverse polarity protection is used. The power loss when using a schottky diode capable of 30A are as follows:

$$P_{DIODE} = IV \xrightarrow{\text{Solve}} 21A * 0.7V = 14.7W \quad P_{MOSFET} = I^2 R \xrightarrow{\text{Solve}} \frac{P_{MOSFET}}{I^2} = R = \frac{2W}{21A^2} = 4.5m\Omega$$

Since the MOSFET will be mostly on the user need only consider the RDSon as the switching losses can be negated. The final consideration is to determine how the MOSFET might be turned on when appropriate and turned off when the voltage is reversed. Figure 29 shows one solution for the low side reverse polarity protection

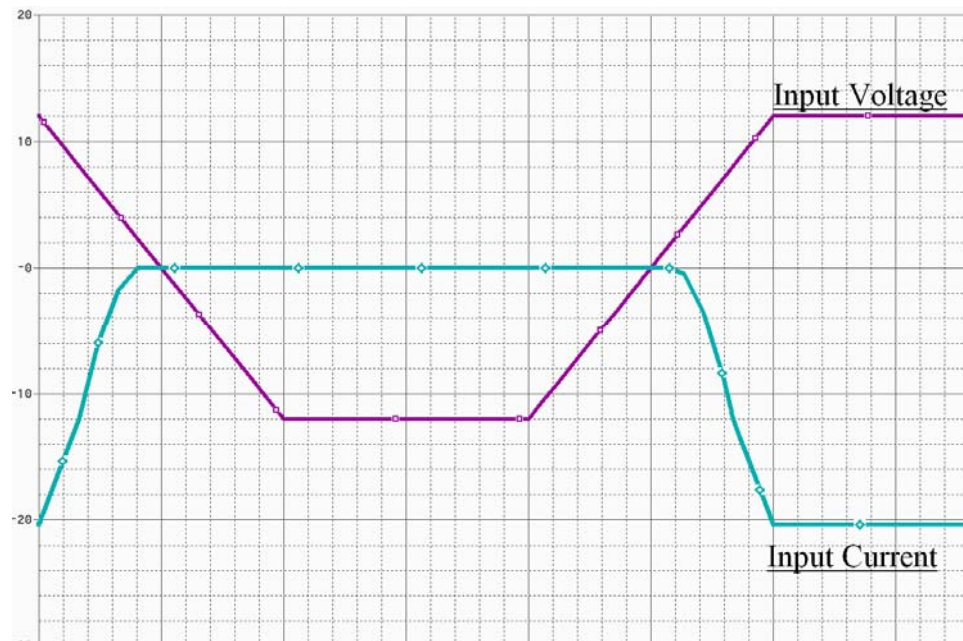
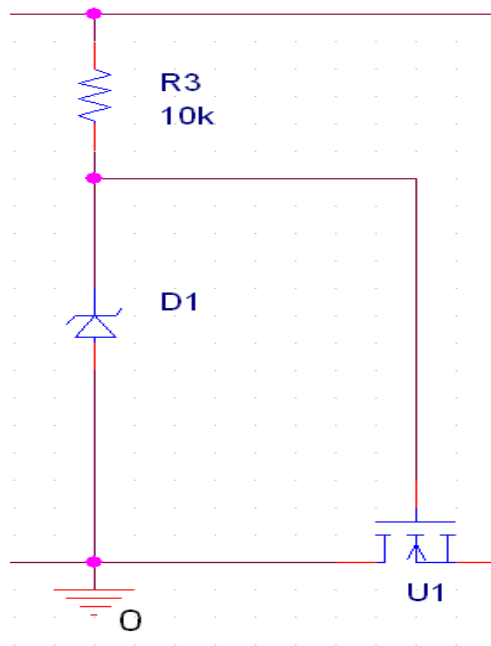


Figure 29: Low Side Reverse Polarity Protection and Simulated Results

Current Sharing of Parallel MOSFETS

ON Semiconductor Confidential – NDA Required

Efficiency Calculator

An efficiency calculator was constructed for boost converter applications to predict the effect of component changes on system efficiency and to aid the designer in making critical design tradeoffs. The user should enter all of the information they know about the design then change parameters like R_{DSon} and frequency to gauge the system sensitivity to the parameter. Figure 30 Shows the predicted efficiency of the design at 140kHz. The efficiency can also be predicted for the 375 kHz, 417kHz, and 500kHz .

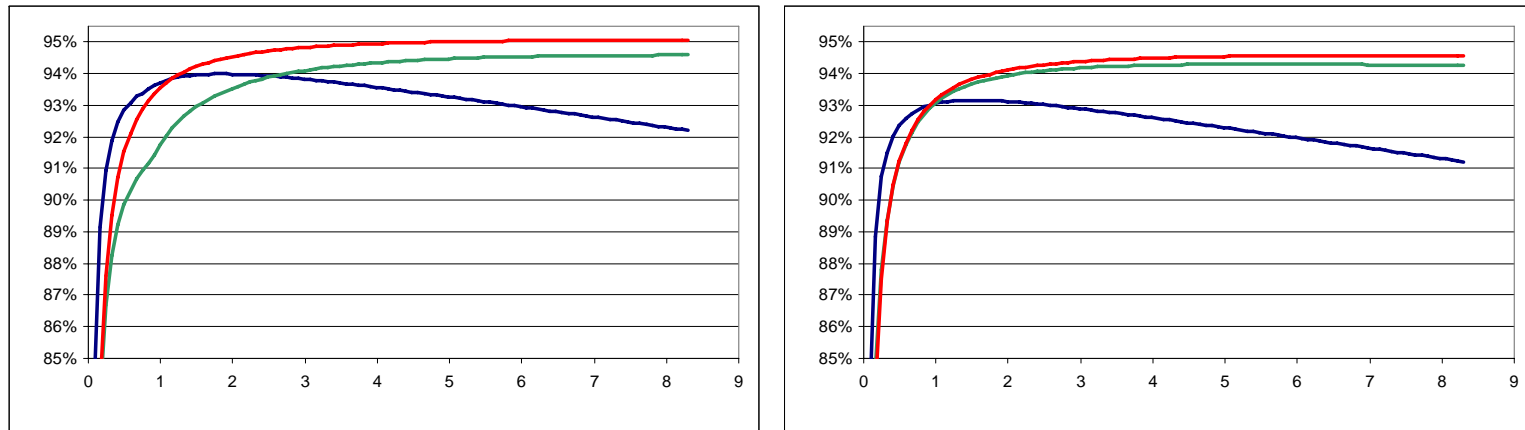


Figure 30: Predicted Efficiency of Design at 140 kHz Left 375 kHz Blue = 8V, Green = 12V, Red = 18V

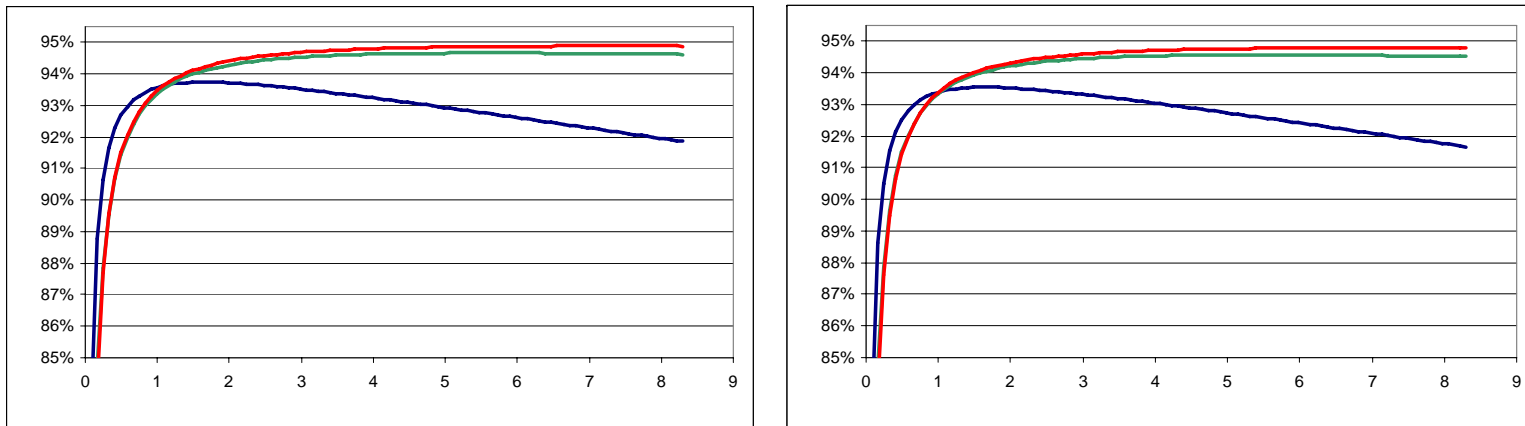


Figure 30: Predicted Efficiency of Design at 417 kHz Left 500 kHz Blue = 8V, Green = 12V, Red = 18V

ON Semiconductor Confidential – NDA Required

The on resistance of the MOSFET makes a large impact at low line on the system level efficiency. The charts below compare the Fairchild FDD13AN06A0CT with the On Semiconductor NTB45N06LT4G which has similar gate charge characteristics, and the NTB75N06G which has similar RDSon. The Infineon IPB081N06L3G can also be used for higher efficiency.

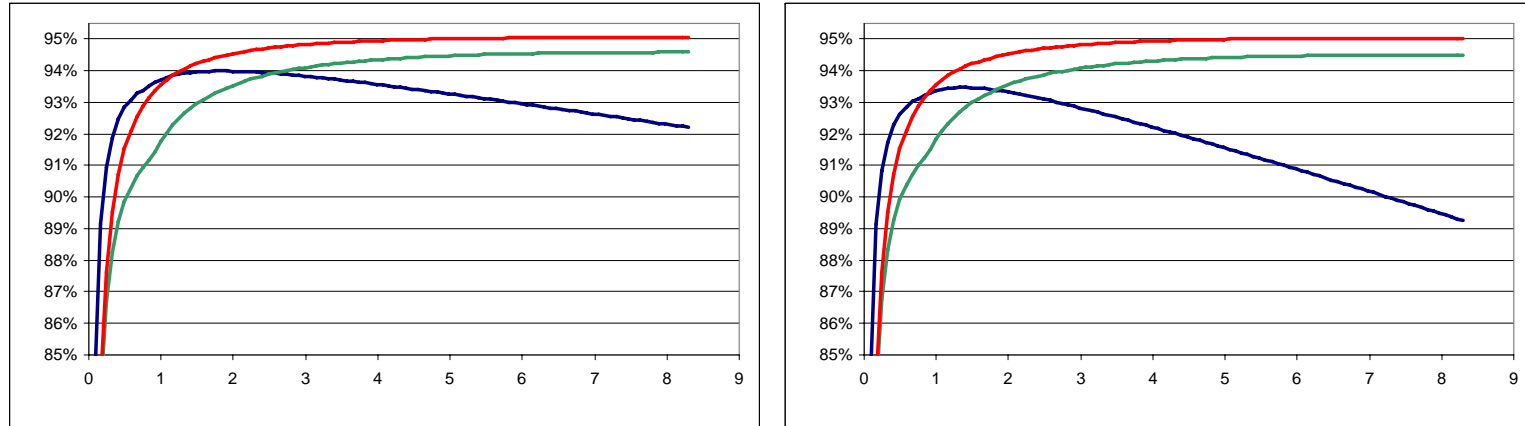


Figure 30: Predicted Efficiency of Design at 140 kHz FDD13AN06A0CT Left and NTB45N06LT4G right Blue = 8V, Green = 12V, Red = 18V

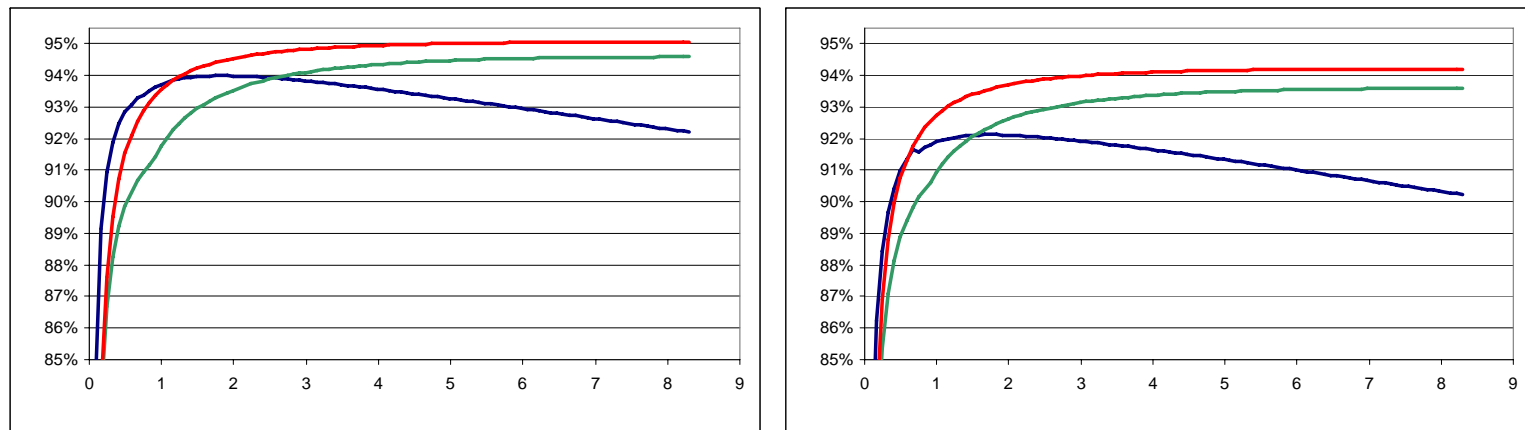


Figure 31: Predicted Efficiency of Design at 140 kHz FDD13AN06A0CT Left and NTB75N06G right Blue = 8V, Green = 12V, Red = 18V

ON Semiconductor Confidential – NDA Required

When calculating the component values for the worst case it is important to find to local ambient temperature. One way to predict the local temperature of components is to use linear super position as discussed in [1]. Using linear super position one can take a series of measurements of a PCB temperature shown in Figure 32 when major power component are made to dissipate a know power. The temperatures are then recorded and coefficients are calculated to determine the influence of all components running simultaneously at a given area of interest shown in Figure 33 . Once the data is collected the only remaining information needed is the power dissipation of each component.

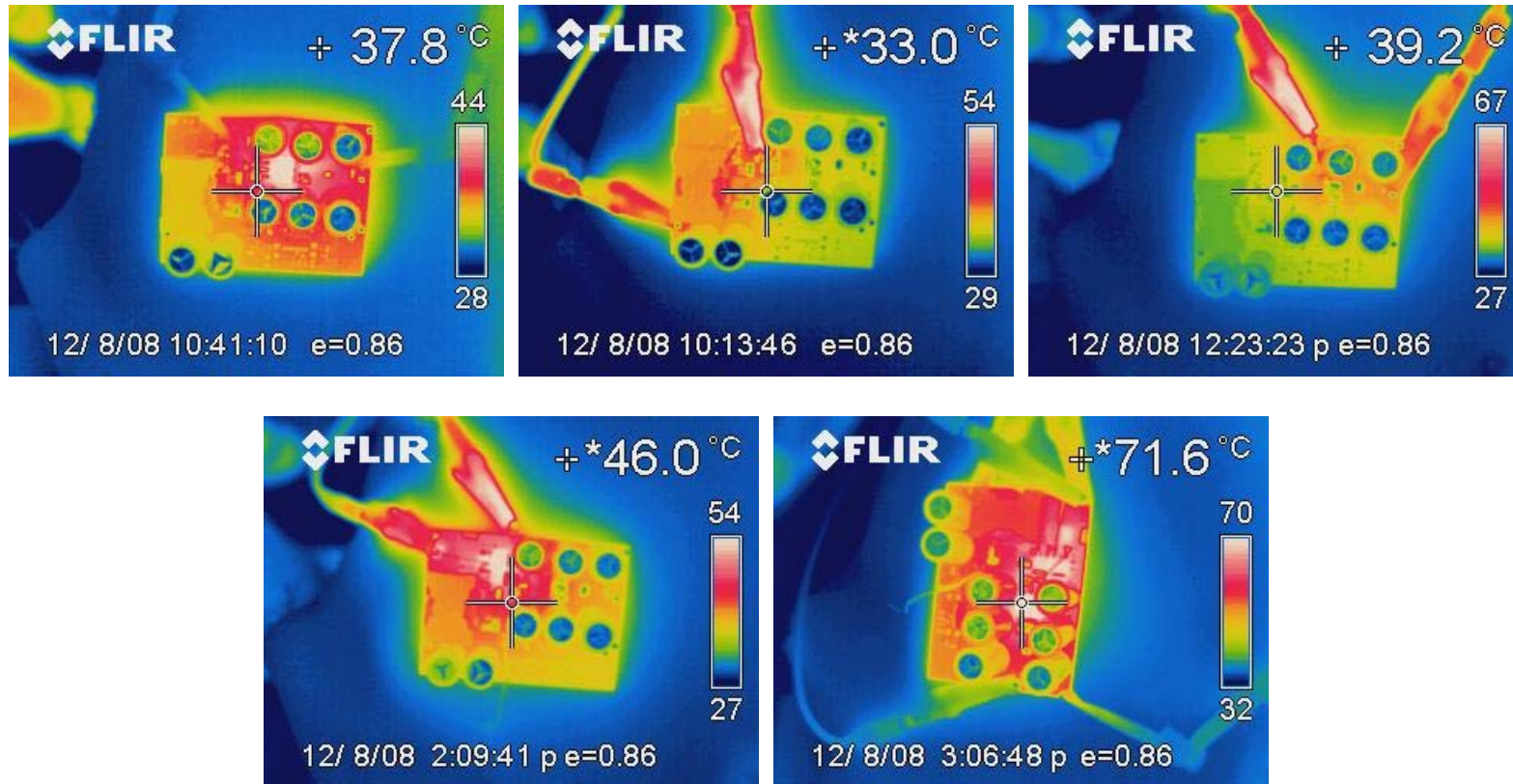


Figure 32: Steady State Thermal Image Captures on Individual Component Heating

ON Semiconductor Confidential – NDA Required

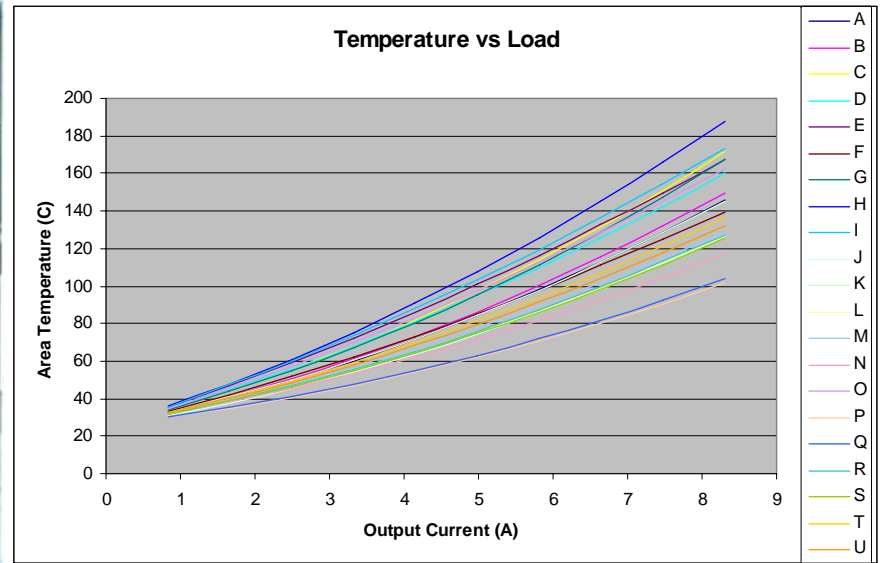
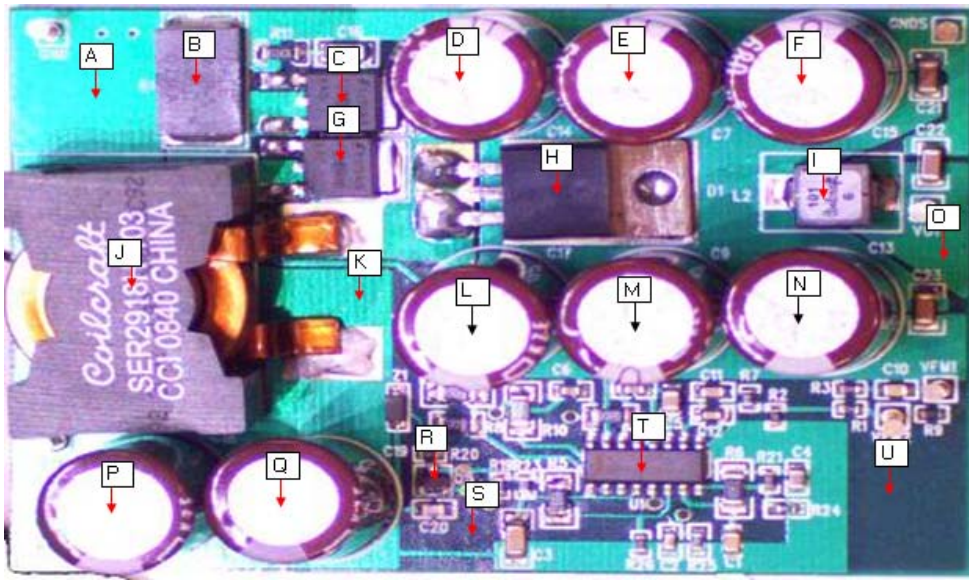


Figure 33: Area of Interest Selected for Temperature Evaluation and Calculated Thermal Data

© 2009 ON Semiconductor.

Disclaimer: ON Semiconductor is providing this design note "AS IS" and does not assume any liability arising from its use; nor does ON Semiconductor convey any license to its or any third party's intellectual property rights. This document is provided only to assist customers in evaluation of the referenced circuit implementation and the recipient assumes all liability and risk associated with its use, including, but not limited to, compliance with all regulatory standards. ON Semiconductor may change any of its products at any time, without notice.

Design note created by Tim Kaske and Bryan McCoy, e-mail: Tim.Kaske@onsemi.com ; Bryan.McCoy@onsemi.com