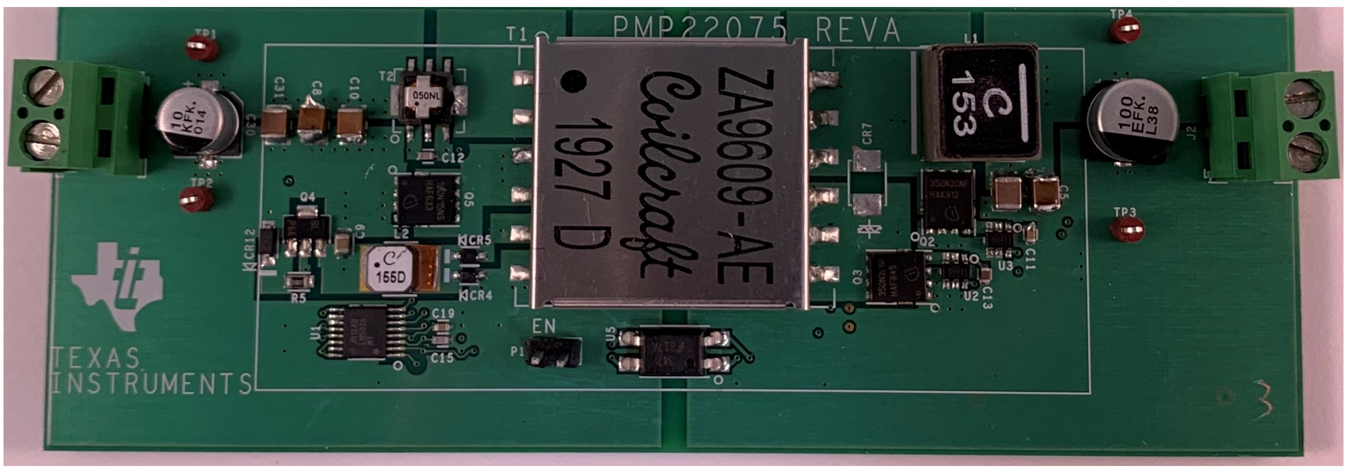
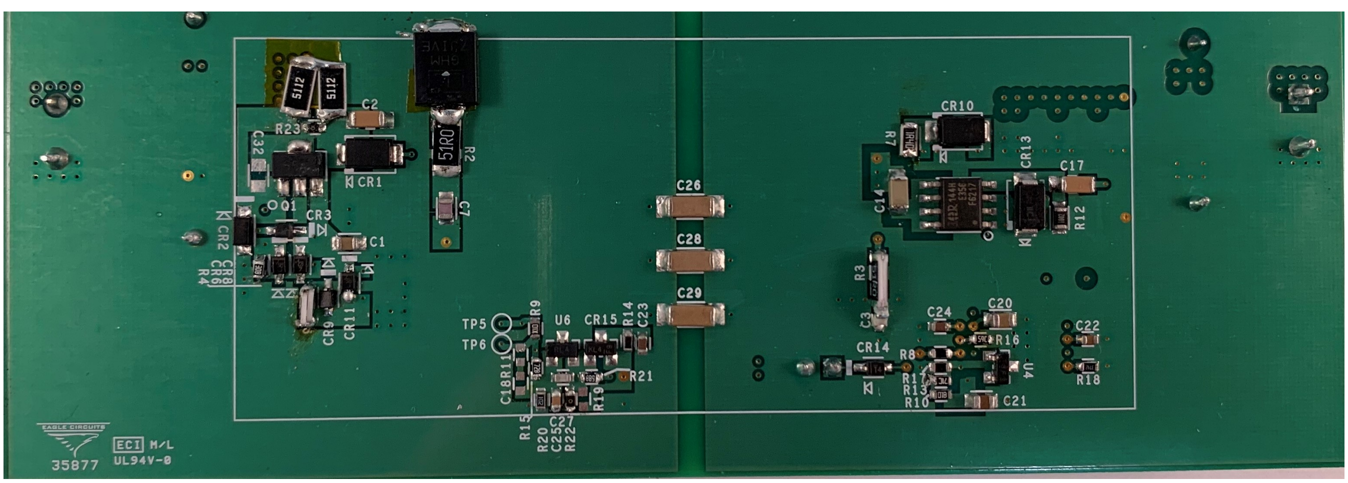
*Test Report: PMP22075*

# *High Efficiency 12-V/5-A Active-Clamp Forward With Wide Input Range 9-V to 60-V Reference Design*

## Description

This forward converter was designed for an isolated 60W intermediate bus voltage rail 12V. It features LM5026—100V active clamp current mode PWM controller.  A self-driven secondary rectifier with UCC27511 4A/8A driver was used for high efficiency. It is good for isolated supplies where high efficiency and hiccup protection are needed.



# 1 Test Prerequisites

## 1.1 Voltage and Current Requirements

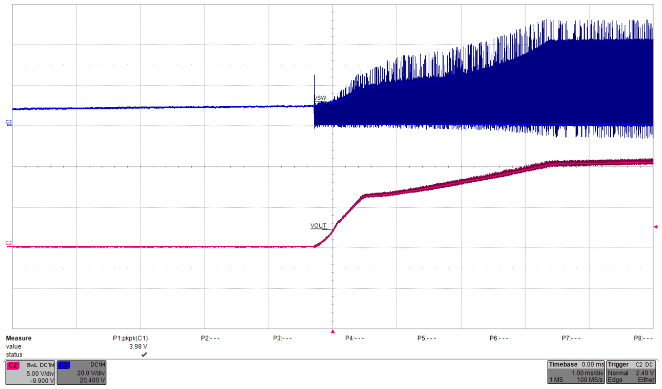
**Table 1. Voltage and Current Requirements**

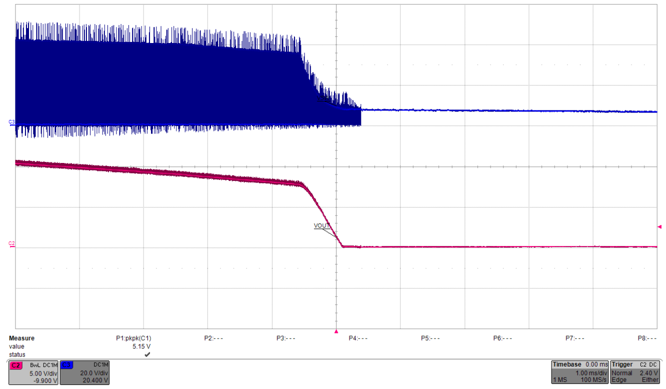
| PARAMETER | SPECIFICATIONS |
|---|---|
| Input voltage, Vin | 9V~60V |
| Output Voltage, Vo | 12V/5A |

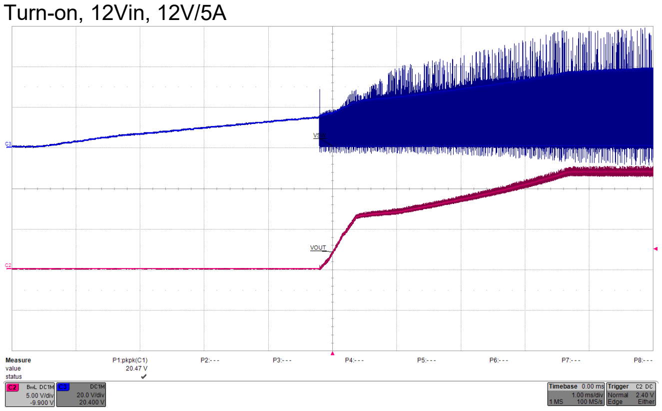
## 1.2 Required Equipment

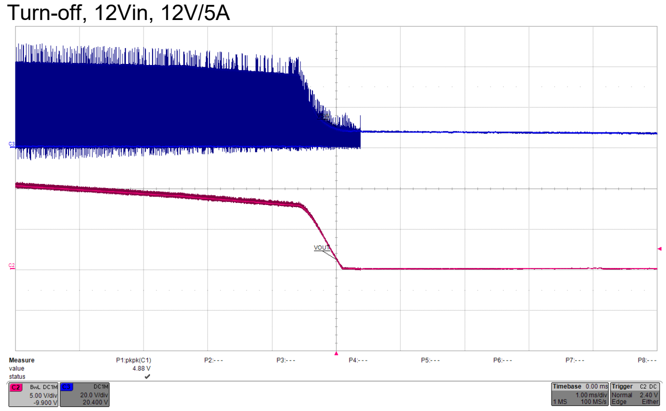
- Power Supply, 0~60V, 0~10A
- Load: 12V/5A

## 2 Startup and shutdown

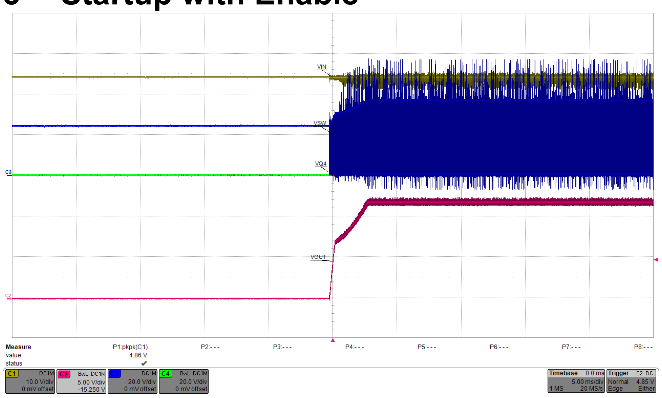

Turn-on, 12Vin, 12V/5A

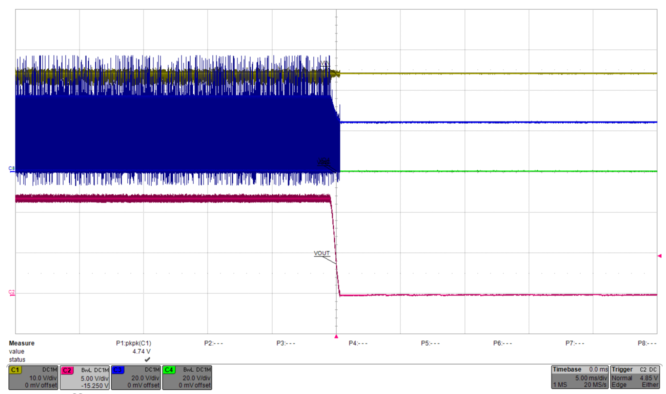

Turn-off, 12Vin, 12V/5A


Turn-on, 48Vin, 12V/5A

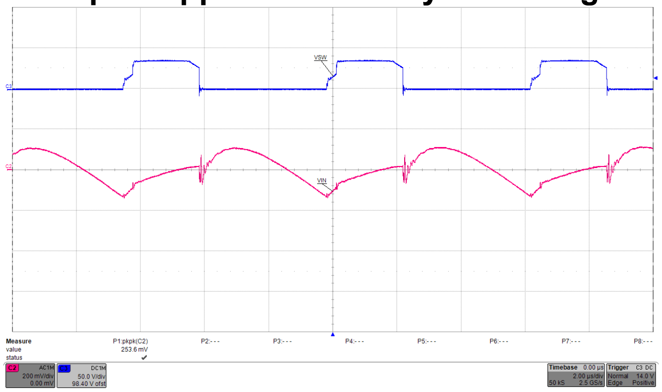

Turn-off, 48Vin, 12V/5A

## 3 Startup with Enable

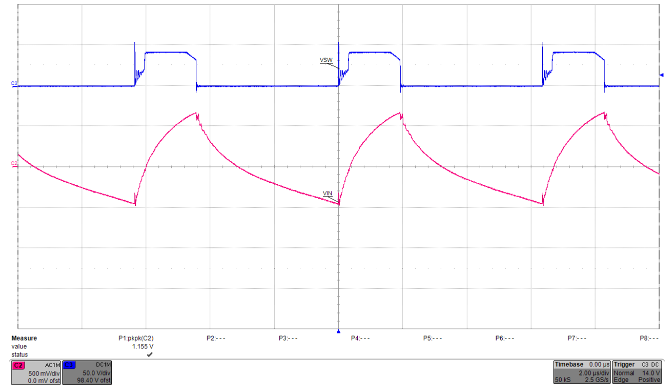

Turn-on, 24Vin


Turn-off, 24Vin

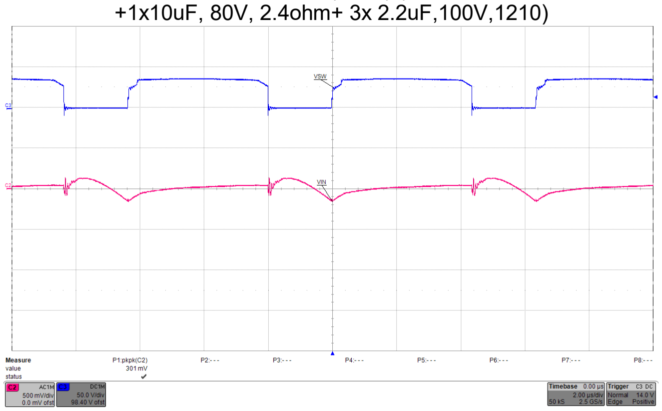
# 4 Input Ripple and Primary Switching Node



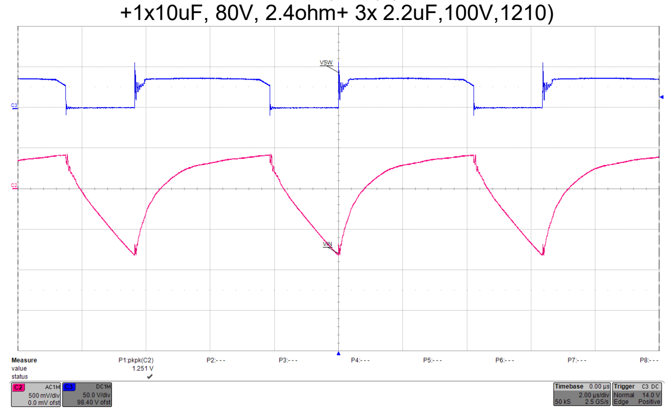
12Vin, 12Vout, 0A Load, 254mV (2.1%) (1x68uF, 100V, 320mohm +1x10uF, 80V, 2.4ohm+ 3x 2.2uF,100V,1210)



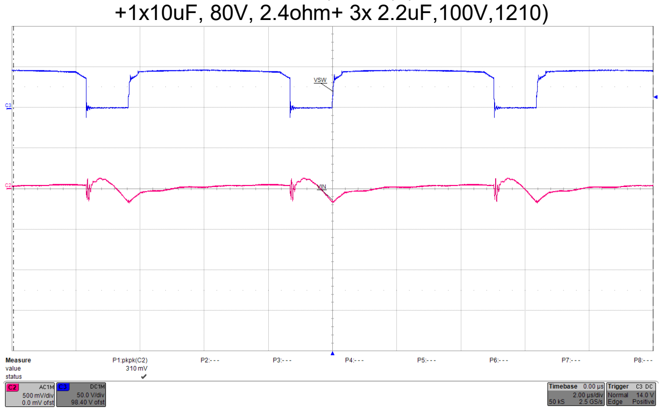
12Vin, 12Vout, 5A Load, 1.2V (10%) (1x68uF, 100V, 320mohm +1x10uF, 80V, 2.4ohm+ 3x 2.2uF,100V,1210)



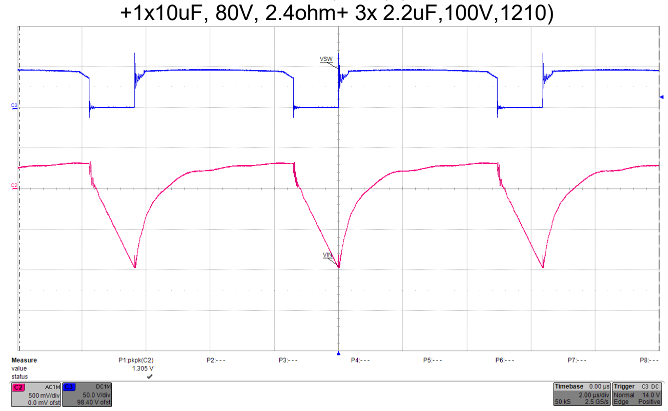
24Vin, 12Vout, 0A Load, 301mV (1.25%) (1x68uF, 100V, 320mohm +1x10uF, 80V, 2.4ohm+ 3x 2.2uF,100V,1210)



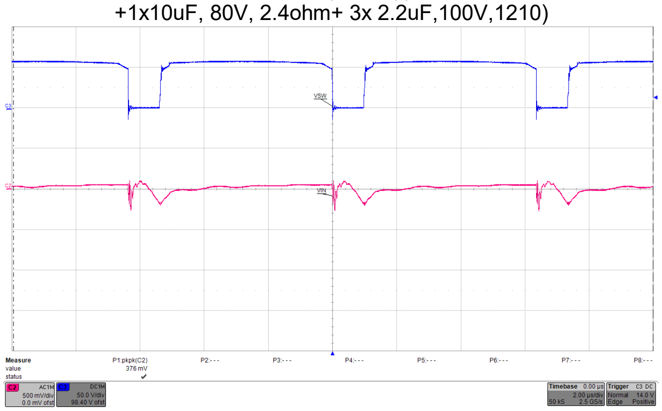
24Vin, 12Vout, 5A Load, 1.25V (5.2%) (1x68uF, 100V, 320mohm +1x10uF, 80V, 2.4ohm+ 3x 2.2uF,100V,1210)



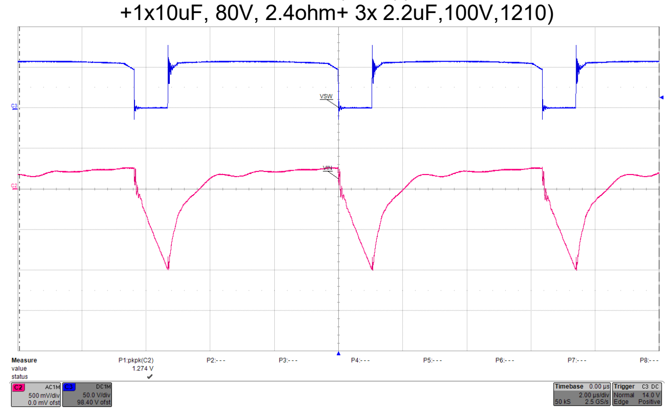
36Vin, 12Vout, 0A Load, 310mV (0.86%)(1x68uF, 100V, 320mohm +1x10uF, 80V, 2.4ohm+ 3x 2.2uF,100V,1210)



36Vin, 12Vout, 5A Load, 1.305V (3.6%)(1x68uF, 100V, 320mohm +1x10uF, 80V, 2.4ohm+ 3x 2.2uF,100V,1210)

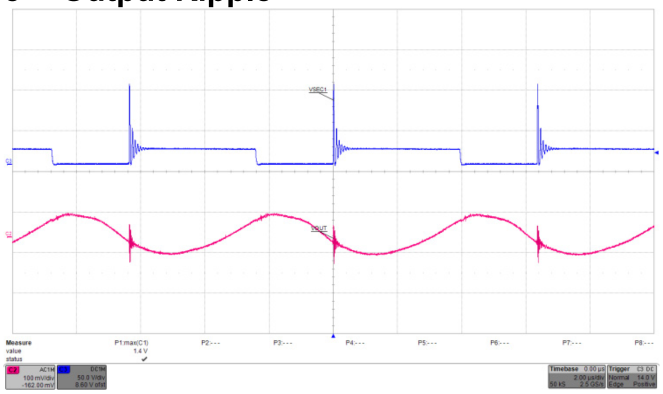


48Vin, 12Vout, 0A Load, 376mV (0.78%) (1x68uF, 100V, 320mohm +1x10uF, 80V, 2.4ohm+ 3x 2.2uF,100V,1210)

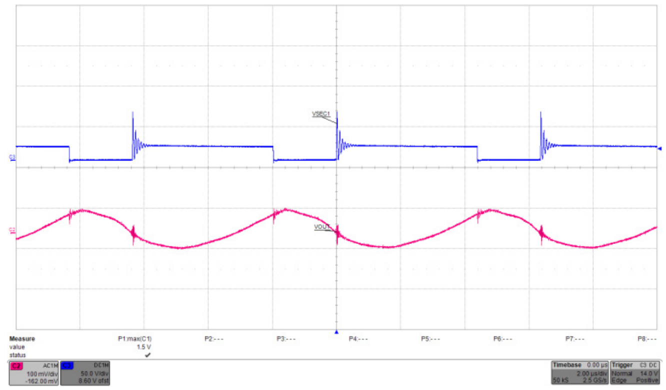


48Vin, 12Vout, 5A Load, 1.274V (2.65%) (1x68uF, 100V, 320mohm +1x10uF, 80V, 2.4ohm+ 3x 2.2uF,100V,1210)

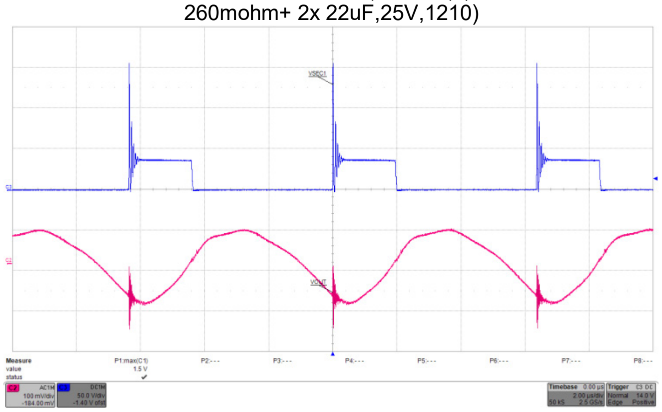
## 5 Output Ripple



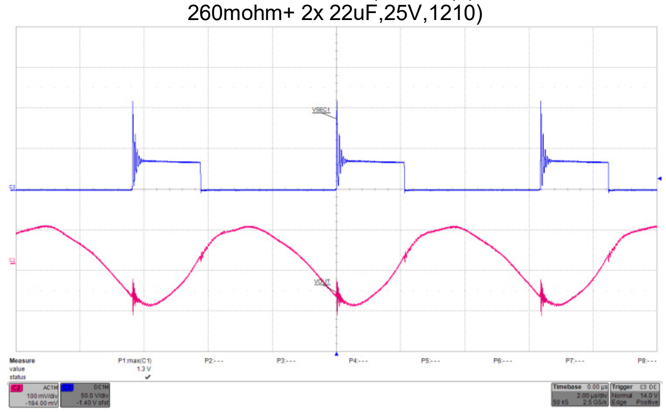
12Vin, 12Vout, 0A Load, 100mV (+/-0.5%) (1x100uF, 25V, 260mohm+ 2x 22uF,25V,1210)



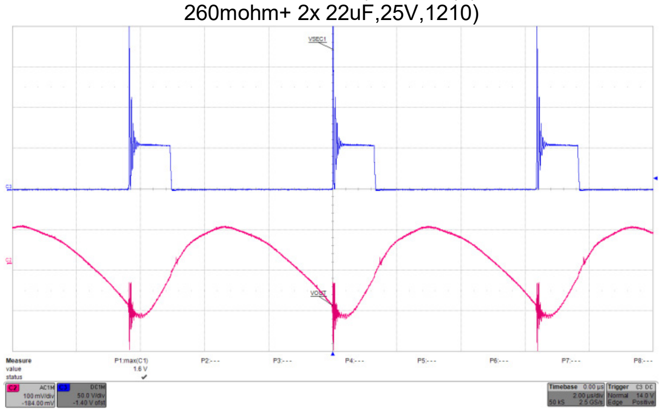
12Vin, 12Vout, 5A Load, 100mV (+/-0.5%) (1x100uF, 25V, 260mohm+ 2x 22uF,25V,1210)



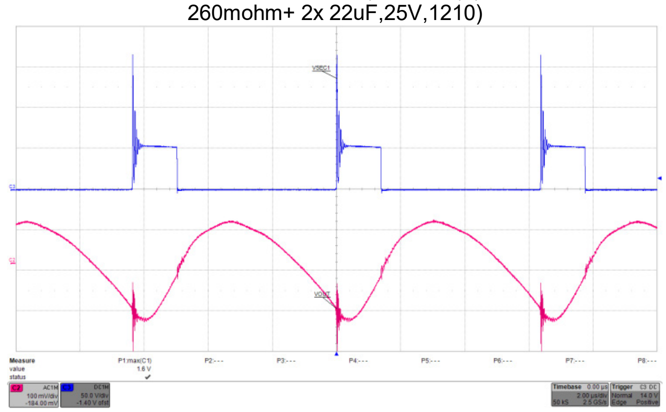
24Vin, 12Vout, 0A Load, 180mV (+/-0.75%) (1x100uF, 25V, 260mohm+ 2x 22uF,25V,1210)



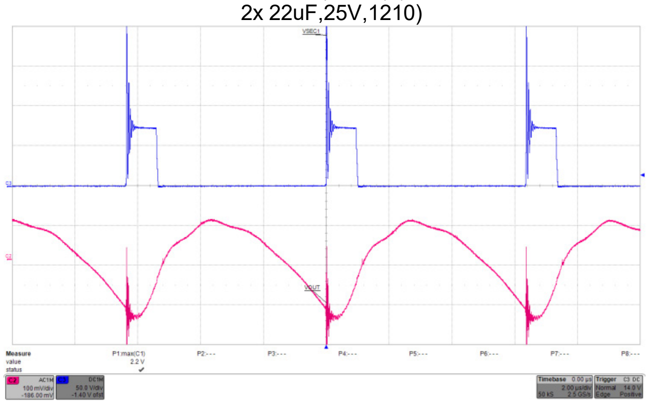
24Vin, 12Vout, 5A Load, 180mV (+/-0.75%) (1x100uF, 25V, 260mohm+ 2x 22uF,25V,1210)



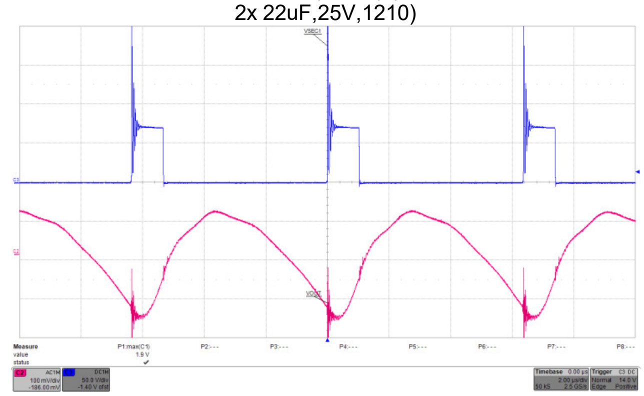
36Vin, 12Vout, 0A Load, 240mV (+/-1%) (1x100uF, 25V, 260mohm+ 2x 22uF,25V,1210)



36Vin, 12Vout, 5A Load, 240mV (+/-1%) (1x100uF, 25V, 260mohm+ 2x 22uF,25V,1210)

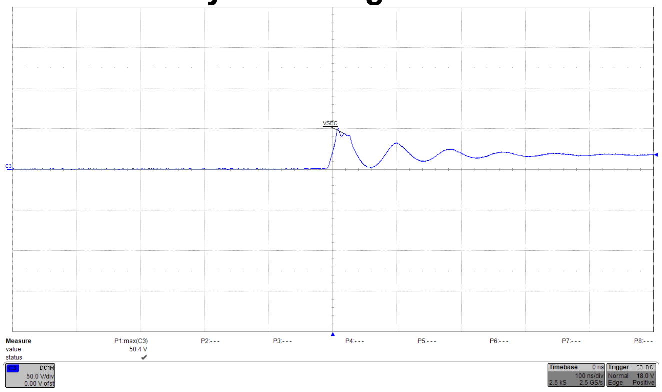


48Vin, 12Vout, 0A Load, 240mV (+/-1%) (1x100uF, 25V, 260mohm+2x 22uF,25V,1210)

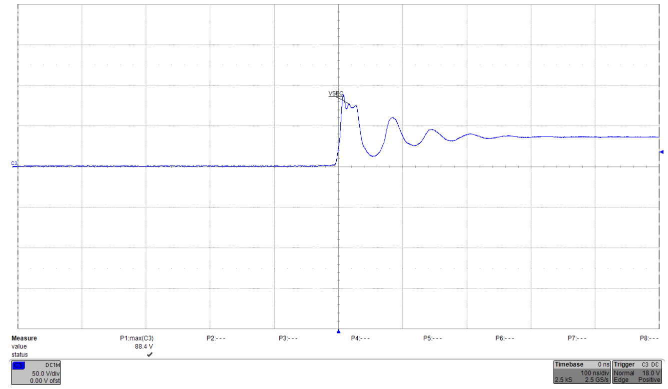


48Vin, 12Vout, 5A Load, 240mV (+/-1%) (1x100uF, 25V, 260mohm+2x 22uF,25V,1210)

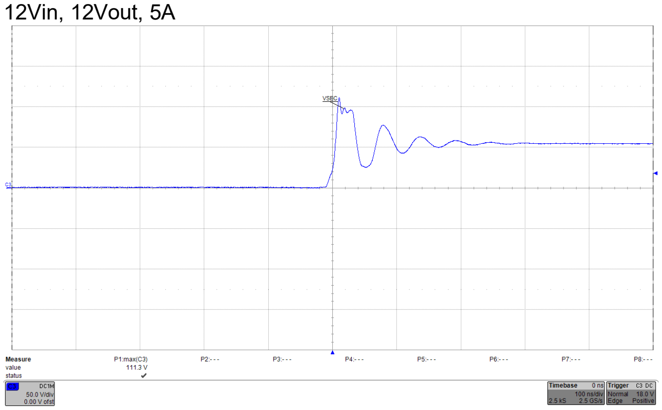
# 6 Secondary Switching Node



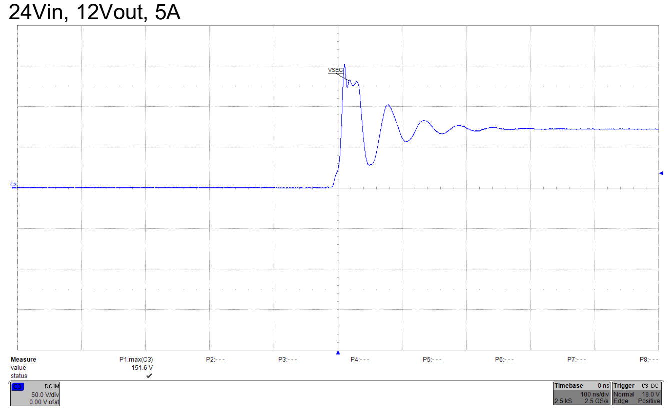
12Vin, 12Vout, 5A



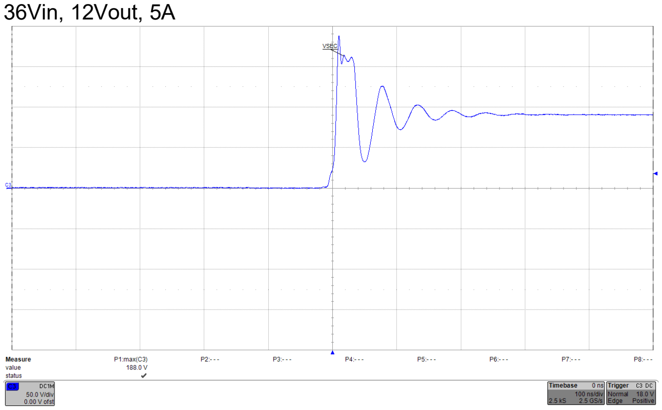
24Vin, 12Vout, 5A



36Vin, 12Vout, 5A

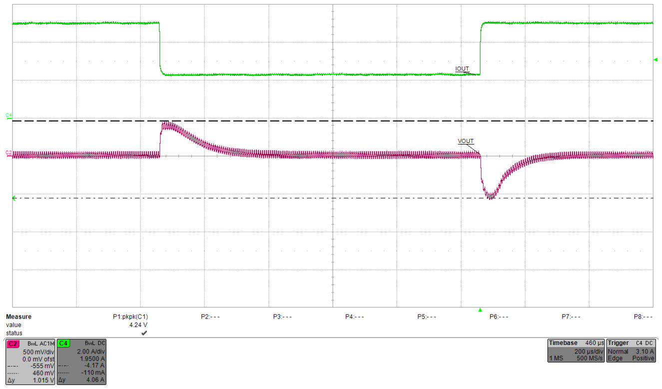


48Vin, 5A

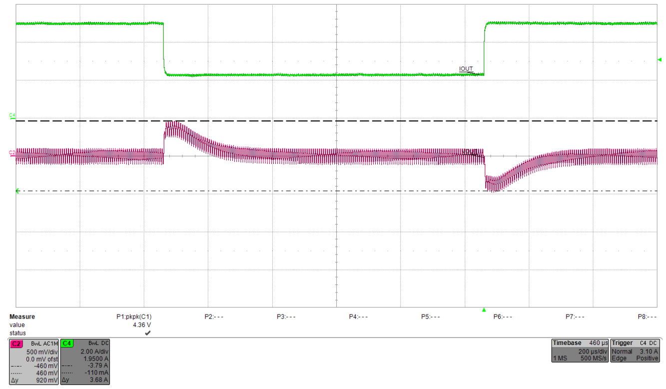


60Vin, 12Vout, 5A

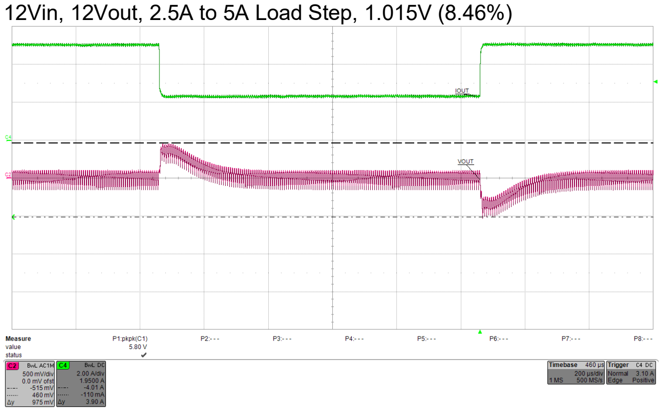
# 7 Transient



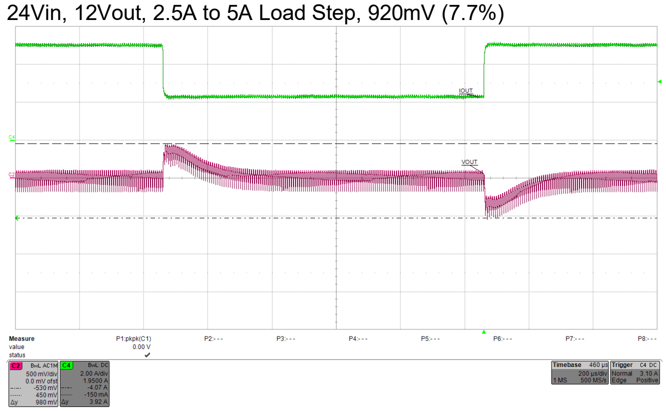
12Vin, 12Vout, 2.5A to 5A Load Step, 1.015V (8.46%)



24Vin, 12Vout, 2.5A to 5A Load Step, 920mV (7.7%)

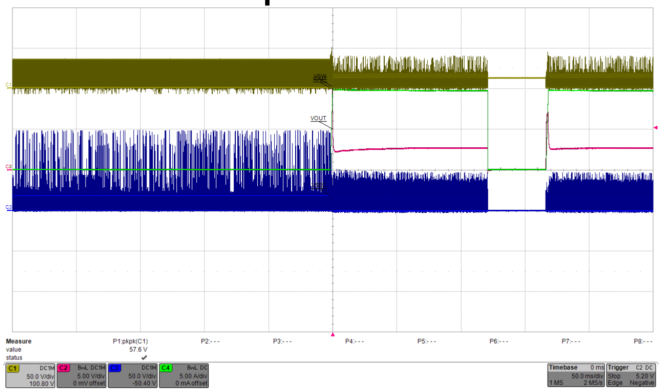


36Vin, 12Vout, 2.5A to 5A Load Step, 975mV (8.1%)

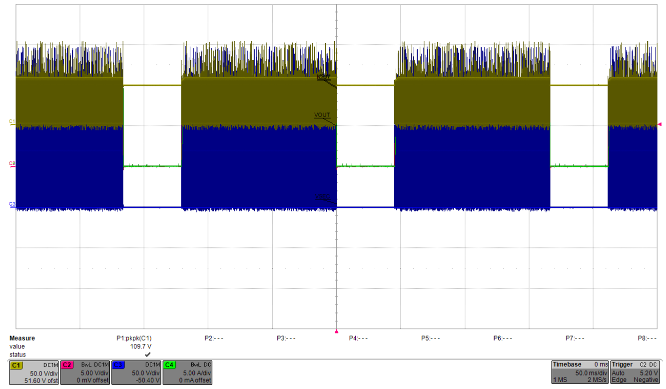


48Vin, 12Vout, 2.5A to 5A Load Step, 980mV (8.2%)

# 8 Over-current protection

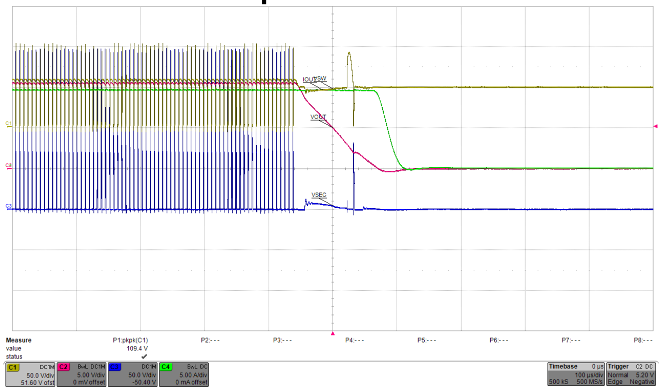


12Vin, Over-load applied, OCP=6.3A.

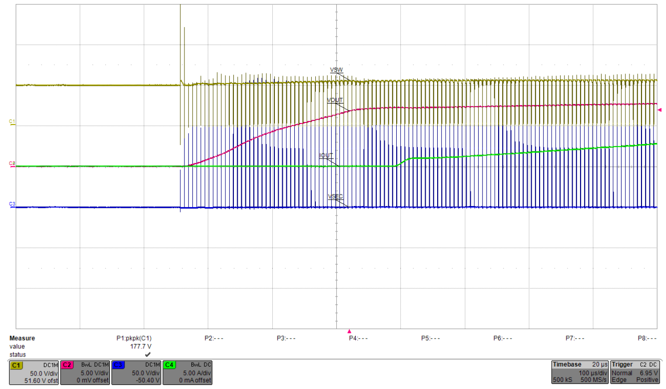


48Vin, Over-load applied, OCP=9.2A.

## 9 Short-circuit protection

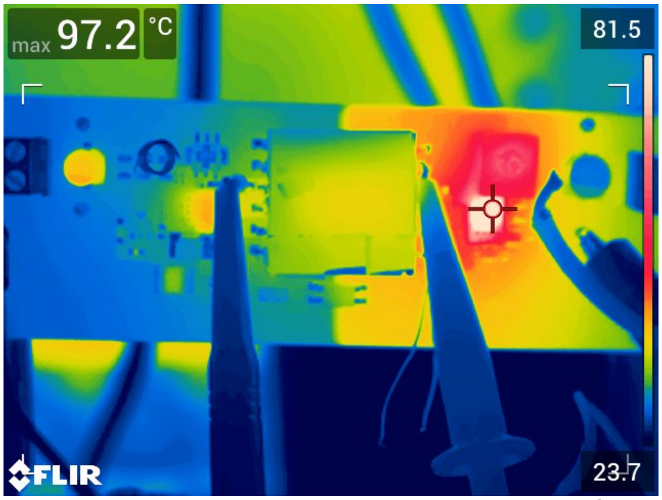


48Vin, 12Vout, Short circuit applied, SCP=9.2A.



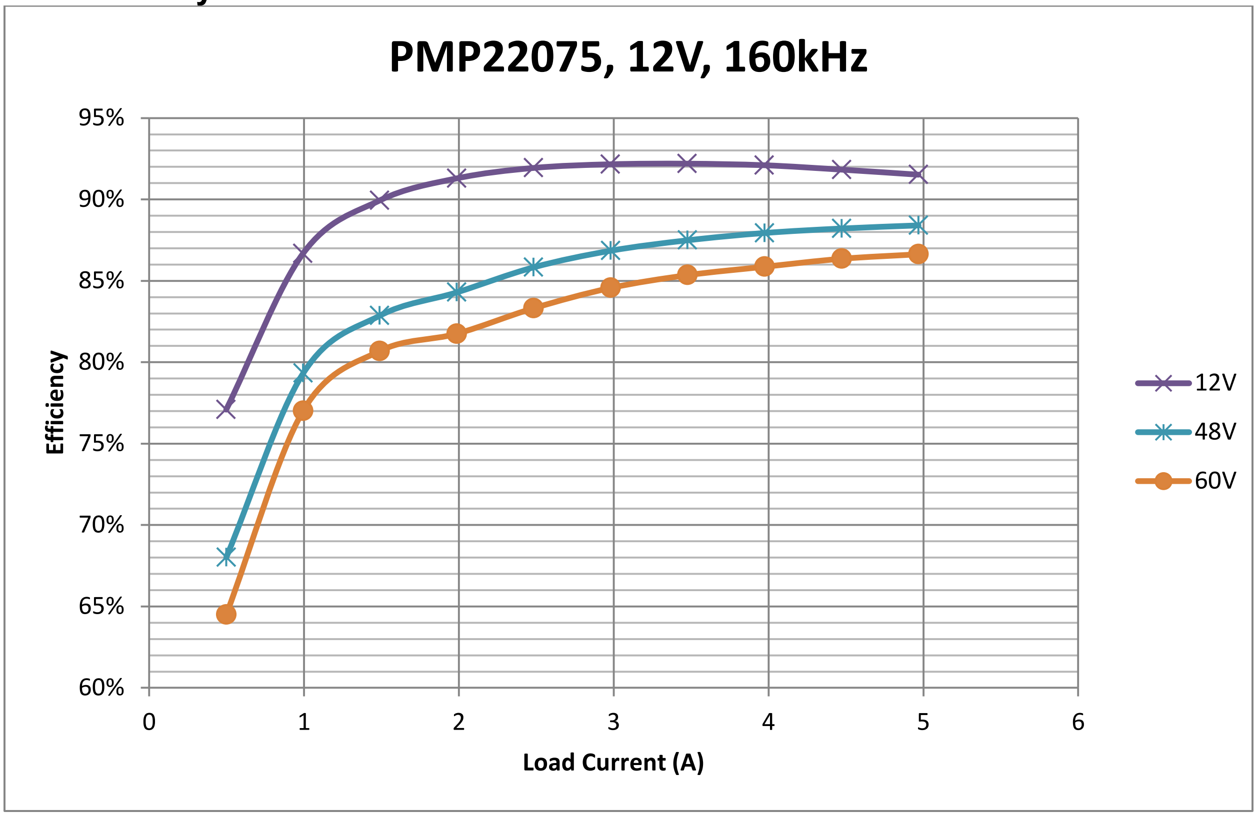
48Vin, 12Vout, Short circuit release

## 10 Short-circuit thermal




48Vin, 0Vout, 9.2A short circuit average current, $T_{FET(SEC)}$=97.2C

## 11 Efficiency




Test conditions: 12Vout, 160kHz.

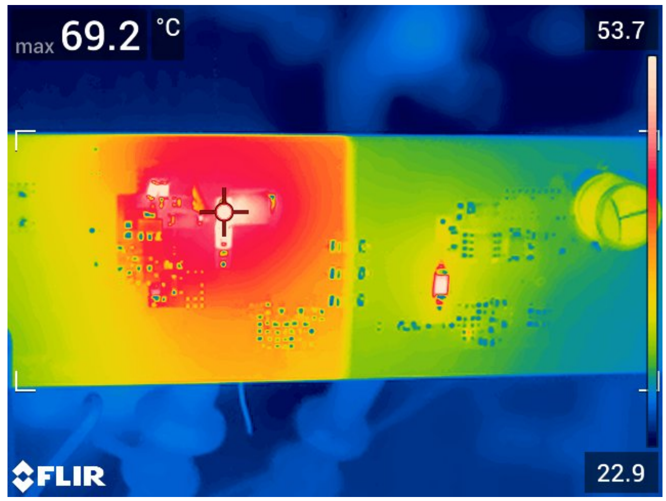
| Vin | Vout | Iin | Iout | eff | ploss |
|---|---|---|---|---|---|
| 9.011 | 10.579 | 0.193 | 0.016 | 9.8% | 1.57 |
| 9.009 | 10.460 | 0.746 | 0.497 | 77.3% | 1.52 |
| 9.007 | 10.365 | 1.317 | 0.993 | 86.8% | 1.57 |
| 9.005 | 10.280 | 1.892 | 1.488 | 89.8% | 1.74 |
| 9.003 | 10.193 | 2.469 | 1.985 | 91.0% | 2.00 |
| 9.001 | 10.109 | 3.047 | 2.481 | 91.5% | 2.35 |
| 8.999 | 10.037 | 3.630 | 2.979 | 91.5% | 2.76 |
| 8.997 | 9.952 | 4.209 | 3.475 | 91.3% | 3.29 |
| 8.996 | 9.853 | 4.780 | 3.973 | 91.0% | 3.86 |
| 8.994 | 9.762 | 5.353 | 4.471 | 90.7% | 4.50 |
| 8.992 | 9.680 | 5.925 | 4.968 | 90.2% | 5.20 |
| | | | | | |
| 12.001 | 11.842 | 0.160 | 0.016 | 9.9% | 1.73 |
| 11.999 | 11.844 | 0.637 | 0.497 | 77.1% | 1.75 |
| 11.998 | 11.846 | 1.132 | 0.993 | 86.7% | 1.81 |
| 11.996 | 11.846 | 1.634 | 1.489 | 89.9% | 1.97 |
| 11.994 | 11.846 | 2.148 | 1.986 | 91.3% | 2.24 |
| 11.992 | 11.847 | 2.667 | 2.482 | 91.9% | 2.58 |
| 11.991 | 11.847 | 3.194 | 2.979 | 92.2% | 3.00 |
| 11.989 | 11.847 | 3.725 | 3.475 | 92.2% | 3.49 |

| | | | | | |
|---|---|---|---|---|---|
| 11.987 | 11.847 | 4.264 | 3.974 | 92.1% | 4.04 |
| 11.985 | 11.847 | 4.814 | 4.472 | 91.8% | 4.71 |
| 11.984 | 11.847 | 5.367 | 4.968 | 91.5% | 5.45 |
| | | | | | |
| 24.003 | 11.852 | 0.136 | 0.016 | 5.9% | 3.08 |
| 24.003 | 11.852 | 0.375 | 0.498 | 65.6% | 3.10 |
| 24.002 | 11.851 | 0.621 | 0.994 | 79.0% | 3.12 |
| 24.001 | 11.850 | 0.867 | 1.489 | 84.8% | 3.16 |
| 24.000 | 11.850 | 1.119 | 1.986 | 87.7% | 3.31 |
| 23.999 | 11.849 | 1.374 | 2.482 | 89.2% | 3.56 |
| 23.998 | 11.849 | 1.634 | 2.980 | 90.0% | 3.91 |
| 23.997 | 11.848 | 1.895 | 3.476 | 90.6% | 4.29 |
| 23.996 | 11.848 | 2.160 | 3.974 | 90.8% | 4.76 |
| 23.996 | 11.847 | 2.428 | 4.472 | 90.9% | 5.29 |
| 23.995 | 11.846 | 2.699 | 4.968 | 90.9% | 5.90 |
| | | | | | |
| 36.028 | 11.851 | 0.068 | 0.015 | 7.4% | 2.28 |
| 36.028 | 11.851 | 0.232 | 0.497 | 70.5% | 2.46 |
| 36.027 | 11.851 | 0.403 | 0.993 | 81.1% | 2.75 |
| 36.027 | 11.851 | 0.576 | 1.489 | 85.1% | 3.10 |
| 36.026 | 11.851 | 0.751 | 1.986 | 87.0% | 3.50 |
| 36.026 | 11.851 | 0.924 | 2.482 | 88.3% | 3.89 |
| 36.025 | 11.851 | 1.100 | 2.980 | 89.1% | 4.31 |
| 36.024 | 11.850 | 1.276 | 3.476 | 89.6% | 4.78 |
| 36.024 | 11.849 | 1.455 | 3.974 | 89.9% | 5.31 |
| 36.023 | 11.848 | 1.634 | 4.472 | 90.0% | 5.89 |
| 36.023 | 11.848 | 1.816 | 4.969 | 90.0% | 6.53 |
| | | | | | |
| 48.027 | 11.852 | 0.060 | 0.016 | 6.6% | 2.69 |
| 48.026 | 11.852 | 0.181 | 0.498 | 68.0% | 2.78 |
| 48.026 | 11.852 | 0.309 | 0.994 | 79.3% | 3.07 |
| 48.025 | 11.851 | 0.443 | 1.489 | 82.9% | 3.65 |
| 48.025 | 11.850 | 0.582 | 1.987 | 84.3% | 4.39 |
| 48.024 | 11.850 | 0.714 | 2.483 | 85.8% | 4.86 |
| 48.024 | 11.849 | 0.847 | 2.980 | 86.8% | 5.35 |
| 48.023 | 11.849 | 0.980 | 3.477 | 87.5% | 5.89 |
| 48.023 | 11.847 | 1.115 | 3.974 | 87.9% | 6.46 |
| 48.023 | 11.847 | 1.251 | 4.472 | 88.2% | 7.08 |
| 48.022 | 11.846 | 1.386 | 4.969 | 88.4% | 7.72 |
| | | | | | |
| 60.030 | 11.850 | 0.056 | 0.015 | 5.5% | 3.15 |
| 60.029 | 11.851 | 0.152 | 0.498 | 64.5% | 3.25 |
| 60.029 | 11.850 | 0.255 | 0.994 | 77.0% | 3.52 |
| 60.029 | 11.850 | 0.364 | 1.489 | 80.7% | 4.22 |
| 60.029 | 11.849 | 0.480 | 1.987 | 81.8% | 5.25 |

| | | | | | |
|---|---|---|---|---|---|
| 60.028 | 11.848 | 0.588 | 2.483 | 83.3% | 5.89 |
| 60.028 | 11.848 | 0.696 | 2.980 | 84.6% | 6.45 |
| 60.027 | 11.847 | 0.804 | 3.477 | 85.3% | 7.07 |
| 60.027 | 11.847 | 0.914 | 3.974 | 85.9% | 7.75 |
| 60.026 | 11.845 | 1.022 | 4.473 | 86.4% | 8.37 |
| 60.026 | 11.844 | 1.132 | 4.969 | 86.6% | 9.08 |

## 12 Thermal

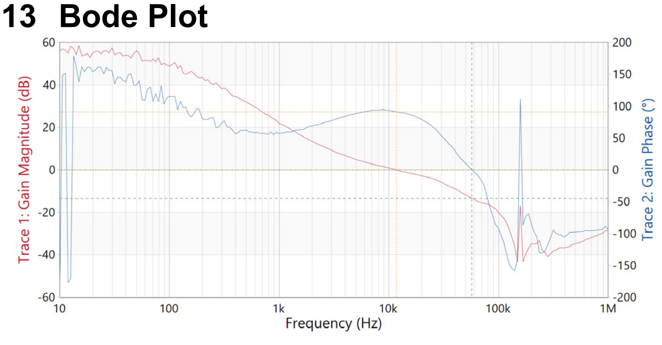
48Vin, 12V5A, $T_{FET(SEC)}$=60.8C Front view



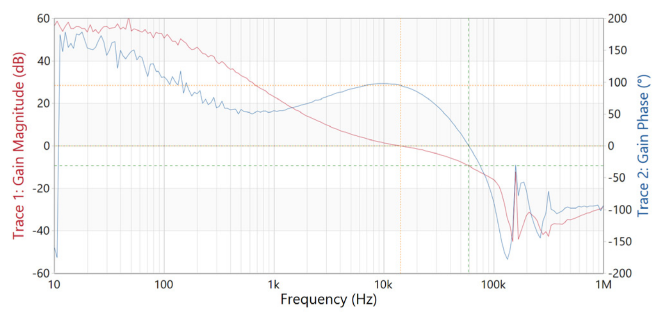
48Vin, 12V5A, Back view

Test conditions: 48Vin, 12V/5Aout, 160 kHz, Room Temperature, 200LFM. $T_{FET(SEC)}$=60.8C, $T_{XFMR}$=40C, $T_{FET(PRI)}$=39C.

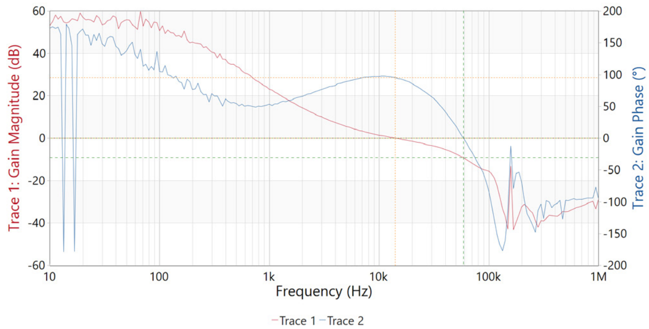
## 13 Bode Plot



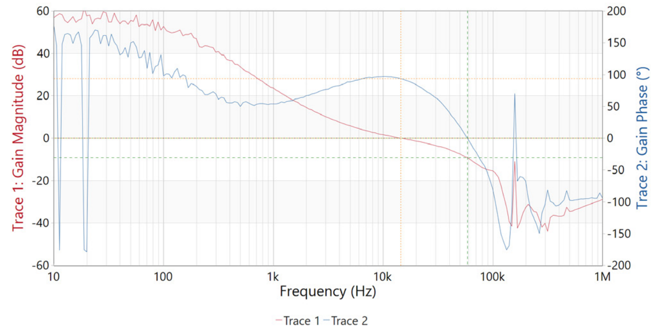
12Vin, 12Vout/5A, BW=11.7kHz, PM=91D, GM=13dB.



24Vin, 12V/5A, BW=14.2kHz, PM=95D, GM=9dB.




36Vin, 12Vout/5A, BW=14kHz, PM=95D, GM=9dB.




48Vin, 12Vout/5A, BW=14.5kHz, PM=94D, GM=9dB.

## IMPORTANT NOTICE AND DISCLAIMER