

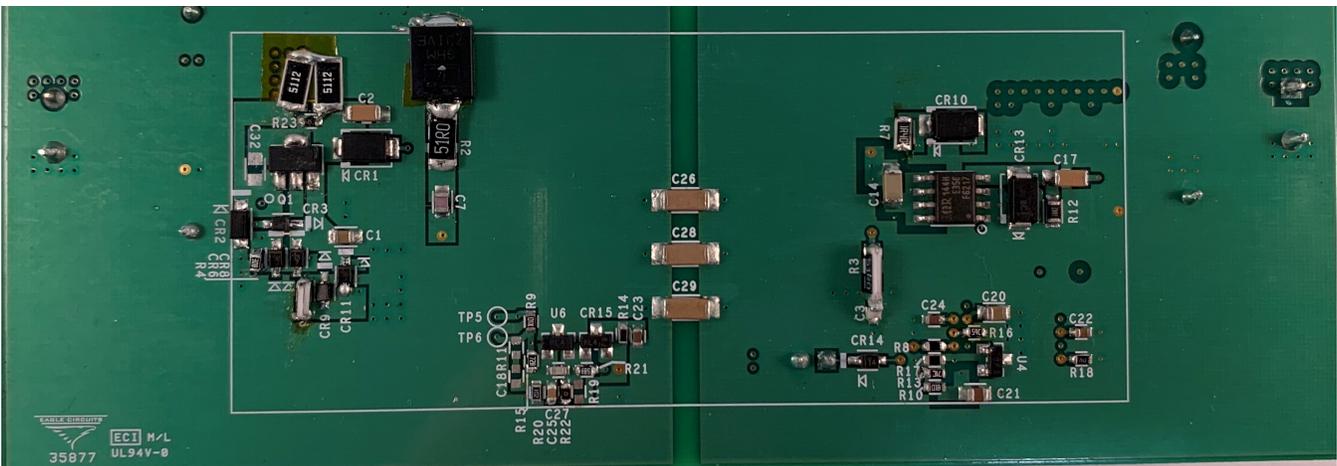
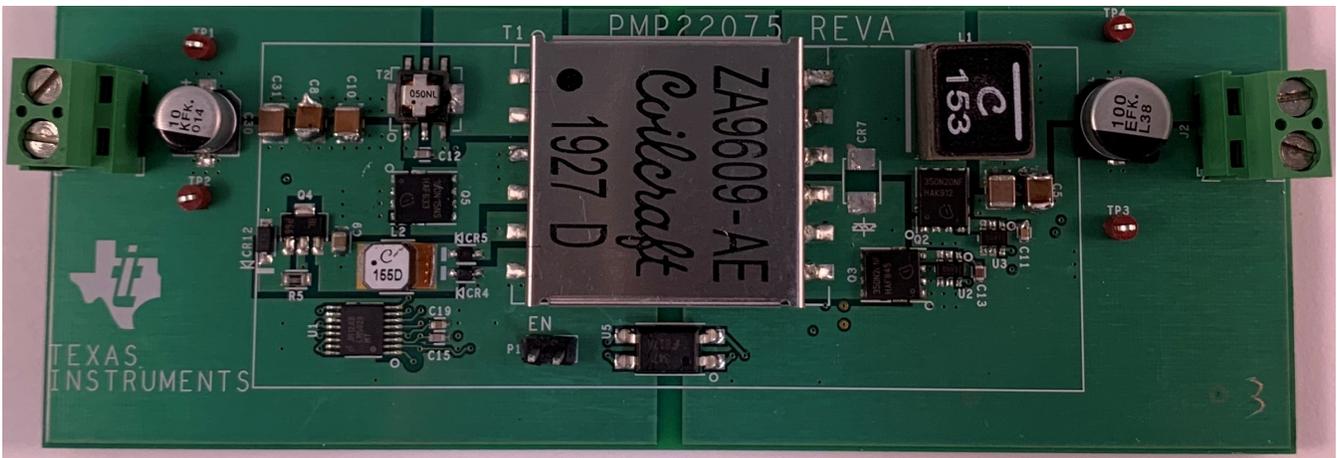
Test Report: PMP22075

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.



An IMPORTANT NOTICE at the end of this TI reference design addresses authorized use, intellectual property matters and other important disclaimers and information.

1 Test Prerequisites

1.1 Voltage and Current Requirements

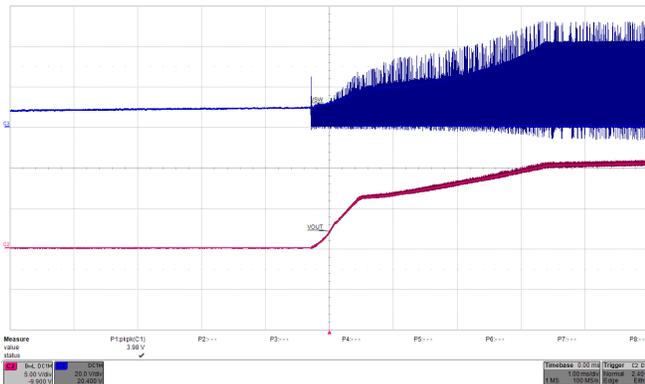
Table 1. Voltage and Current Requirements

| PARAMETER | SPECIFICATIONS |
|-------------------------|----------------|
| Input voltage, V_{in} | 9V~60V |
| Output Voltage, V_o | 12V/5A |

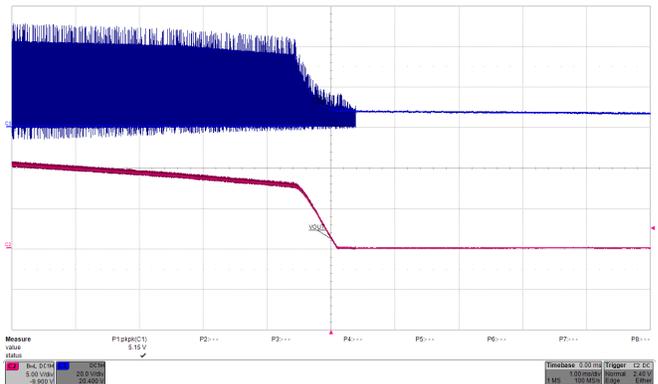
1.2 Required Equipment

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

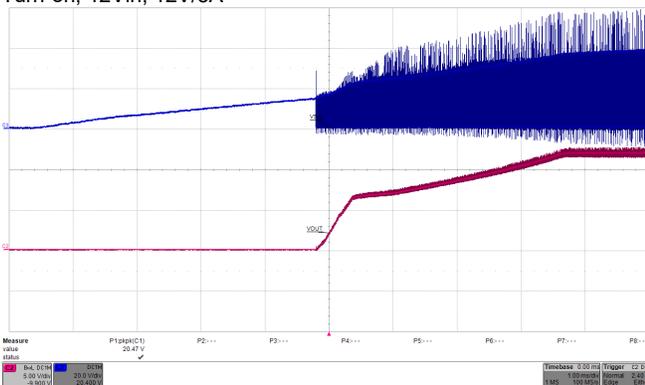
2 Startup and shutdown



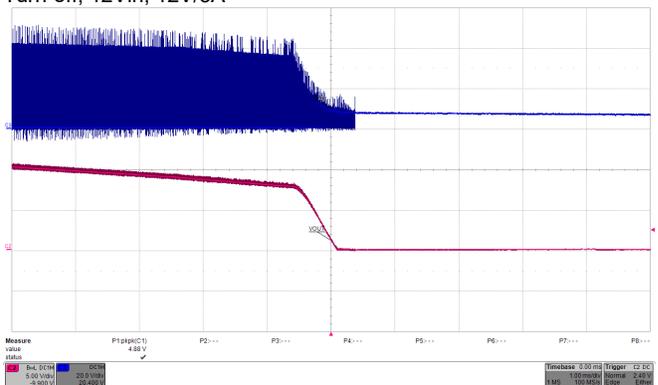
Turn-on, 12Vin, 12V/5A



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

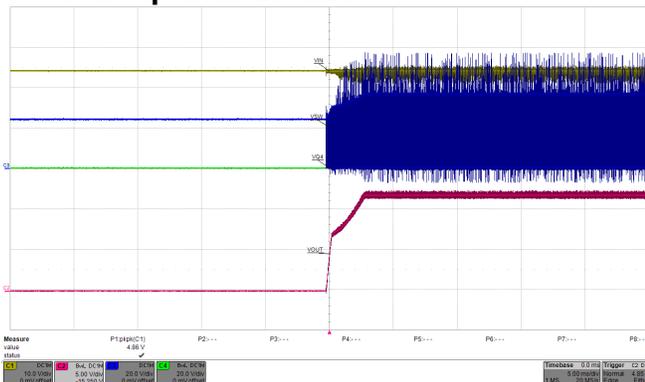


Turn-on, 48Vin, 12V/5A

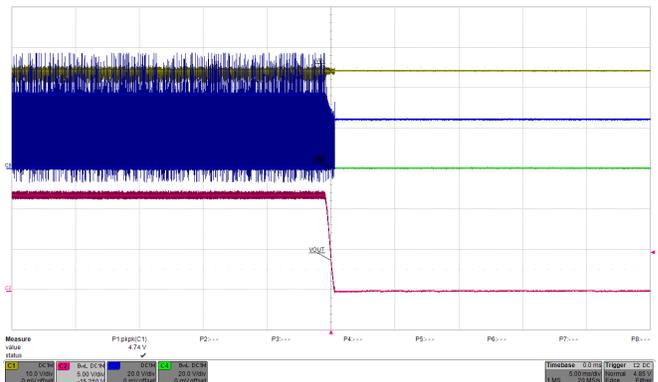


Turn-off, 48Vin, 12V/5A

3 Startup with Enable

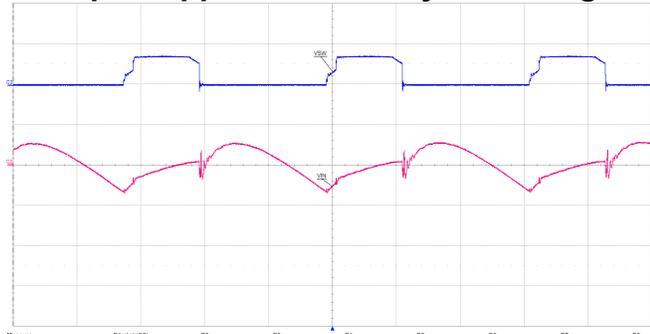


Turn-on, 24Vin

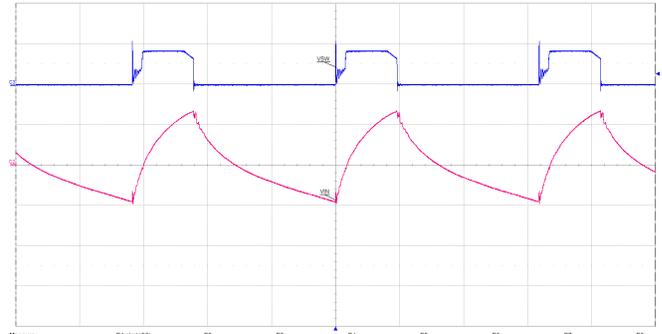


Turn-off, 24Vin

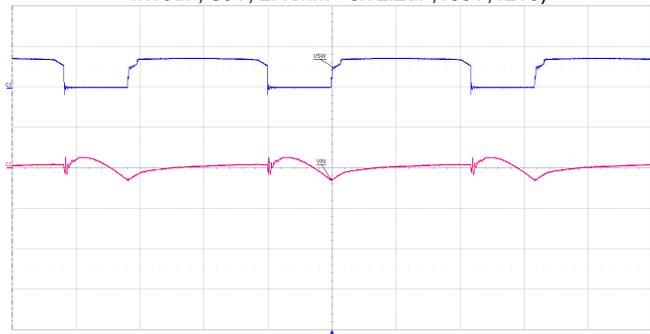
4 Input Ripple and Primary Switching Node



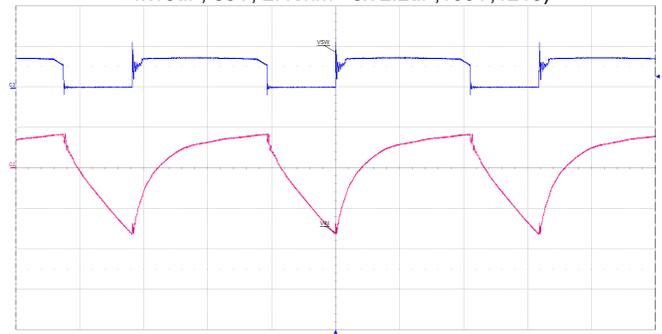
12Vin, 12Vout, 0A Load, 253mV (2.1%) (1x68uF, 100V, 320mohm +1x10uF, 80V, 2.4ohm+ 3x 2.2uF,100V,1210)



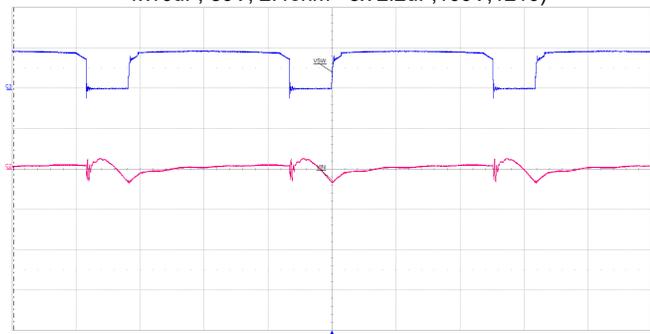
12Vin, 12Vout, 5A Load, 1.2V (10%) (1x68uF, 100V, 320mohm +1x10uF, 80V, 2.4ohm+ 3x 2.2uF,100V,1210)



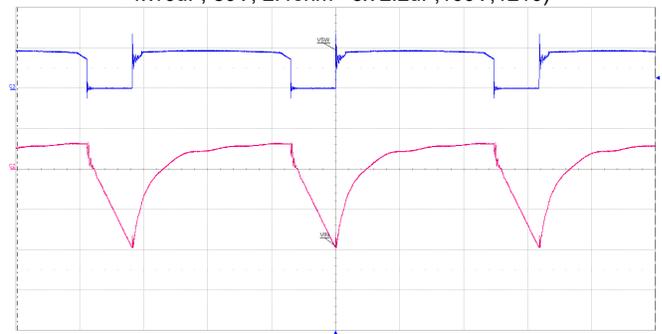
24Vin, 12Vout, 0A Load, 301mV (1.25%) (1x68uF, 100V, 320mohm +1x10uF, 80V, 2.4ohm+ 3x 2.2uF,100V,1210)



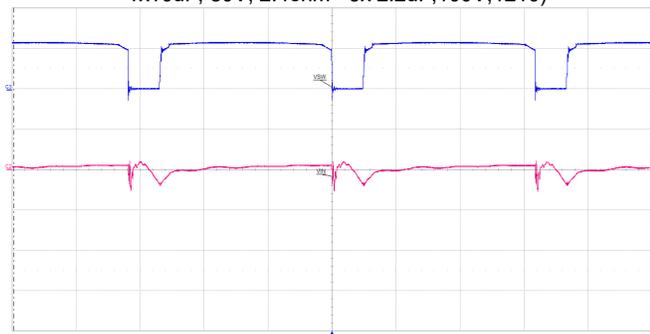
24Vin, 12Vout, 5A Load, 1.25V (5.2%) (1x68uF, 100V, 320mohm +1x10uF, 80V, 2.4ohm+ 3x 2.2uF,100V,1210)



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)

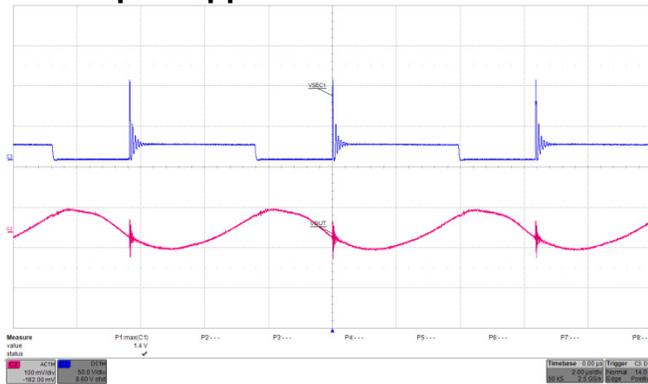


48Vin, 12Vout, 0A Load, 376mV (0.78%) (1x68uF, 100V, 320mohm +1x10uF, 80V, 2.4ohm+ 3x 2.2uF,100V,1210)

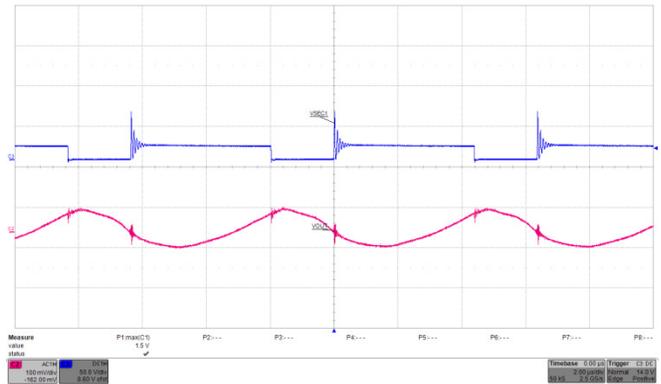


48Vin, 12Vout, 5A Load, 1.274V (2.65%) (1x68uF, 100V, 320mohm +1x10uF, 80V, 2.4ohm+ 3x 2.2uF,100V,1210)

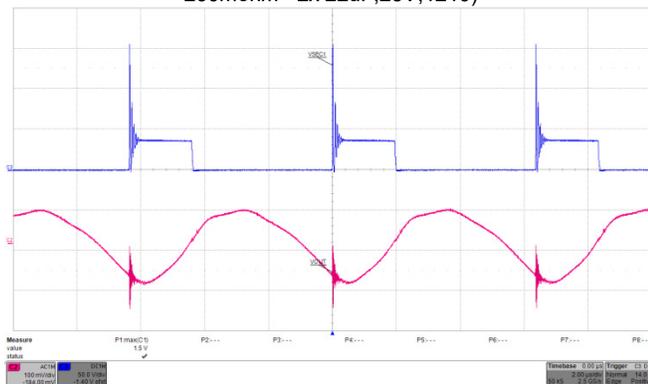
5 Output Ripple



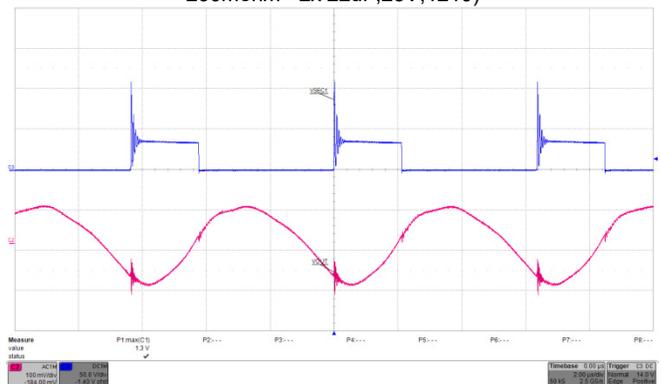
12Vin, 12Vout, 0A Load, 100mV (+/-0.5%) (1x100uF, 25V, 260mohm+ 2x 22uF,25V,1210)



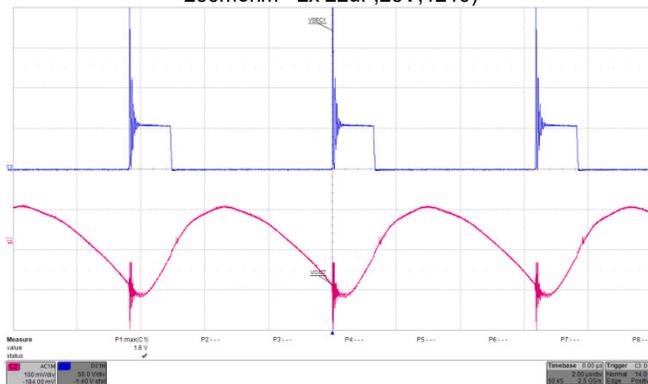
12Vin, 12Vout, 5A Load, 100mV (+/-0.5%) (1x100uF, 25V, 260mohm+ 2x 22uF,25V,1210)



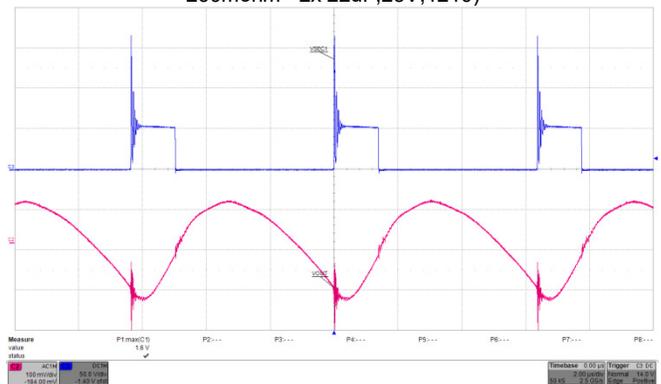
24Vin, 12Vout, 0A Load, 180mV (+/-0.75%) (1x100uF, 25V, 260mohm+ 2x 22uF,25V,1210)



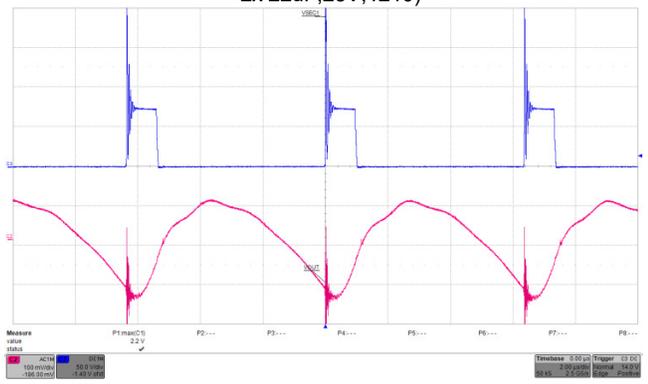
24Vin, 12Vout, 5A Load, 180mV (+/-0.75%) (1x100uF, 25V, 260mohm+ 2x 22uF,25V,1210)



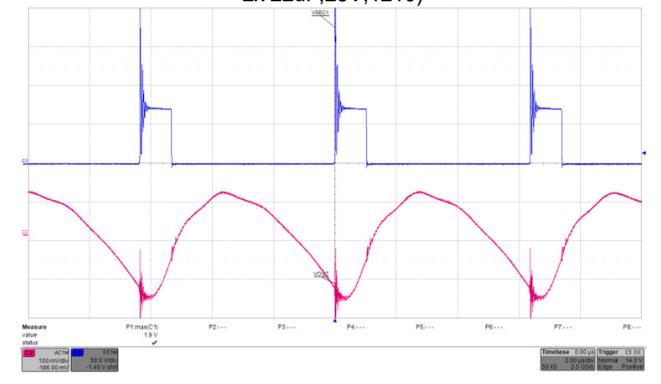
36Vin, 12Vout, 0A Load, 240mV (+/-1%) (1x100uF, 25V, 260mohm+ 2x 22uF,25V,1210)



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

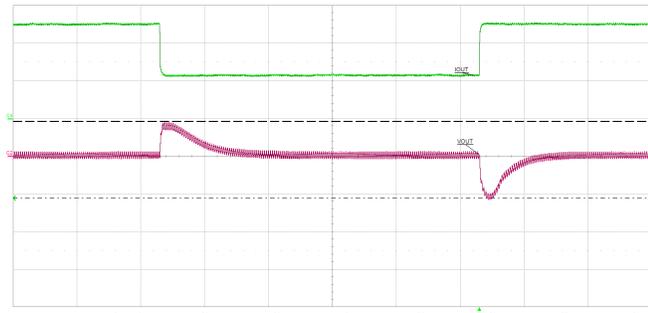


48Vin, 12Vout, 0A Load, 240mV (+/-1%) (1x100uF, 25V, 260mohm+ 2x 22uF,25V,1210)

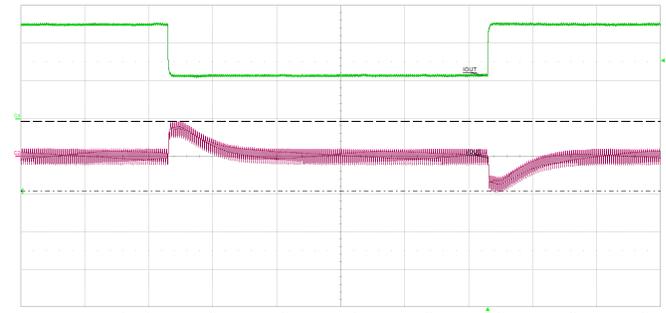
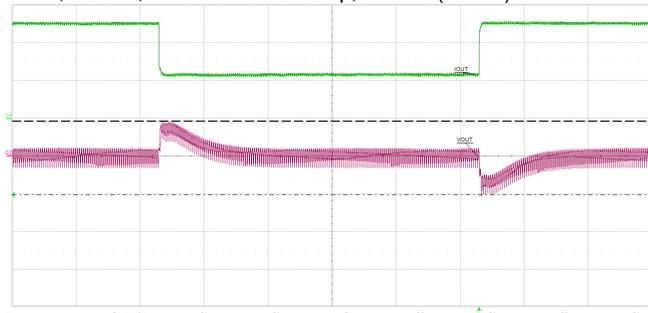


48Vin, 12Vout, 5A Load, 240mV (+/-1%) (1x100uF, 25V, 260mohm+ 2x 22uF,25V,1210)

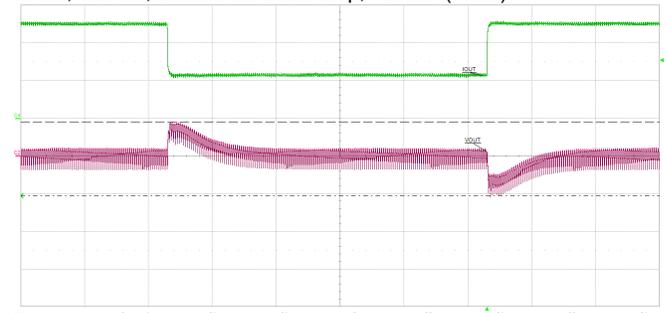
7 Transient



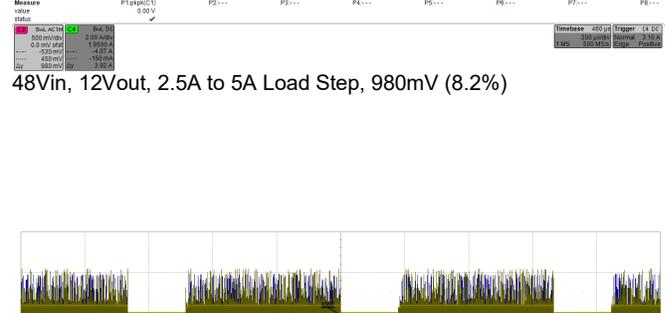
12Vin, 12Vout, 2.5A to 5A Load Step, 1.015V (8.46%)



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

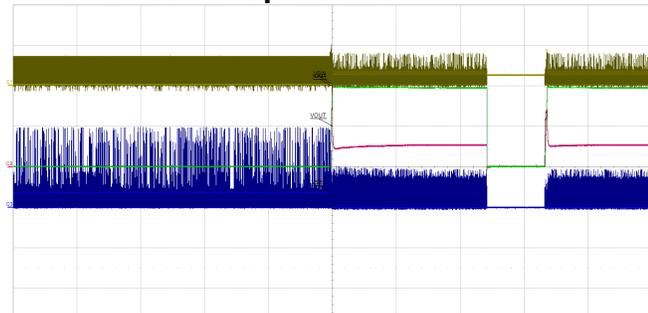


36Vin, 12Vout, 2.5A to 5A Load Step, 975mV (8.1%)

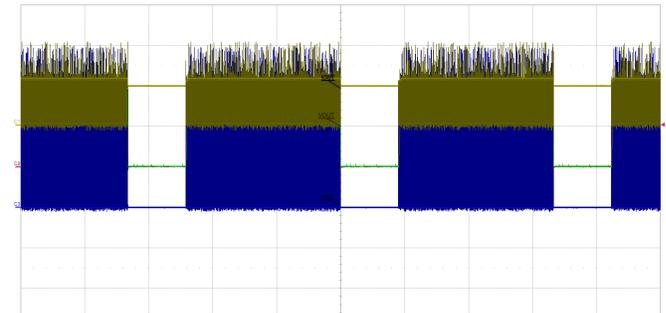


48Vin, 12Vout, 2.5A to 5A Load Step, 980mV (8.2%)

8 Over-current protection



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

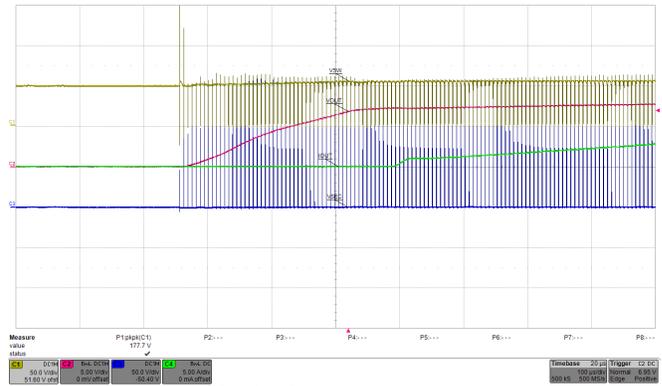


48Vin, Over-load applied, OCP=9.2A.

9 Short-circuit protection

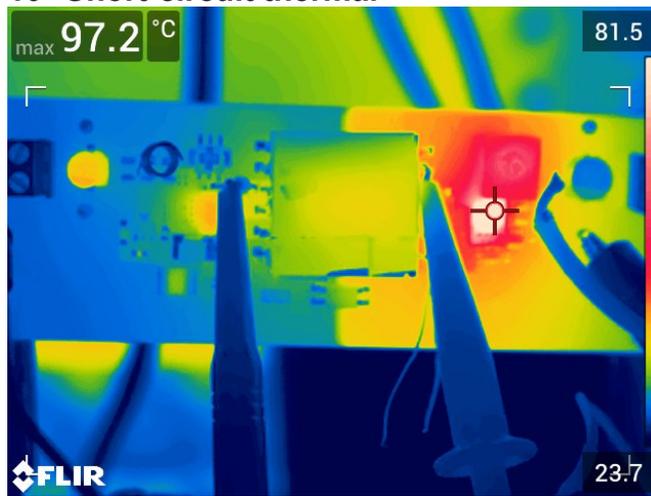


48Vin, 12Vout, Short circuit applied, SCP=9.2A.



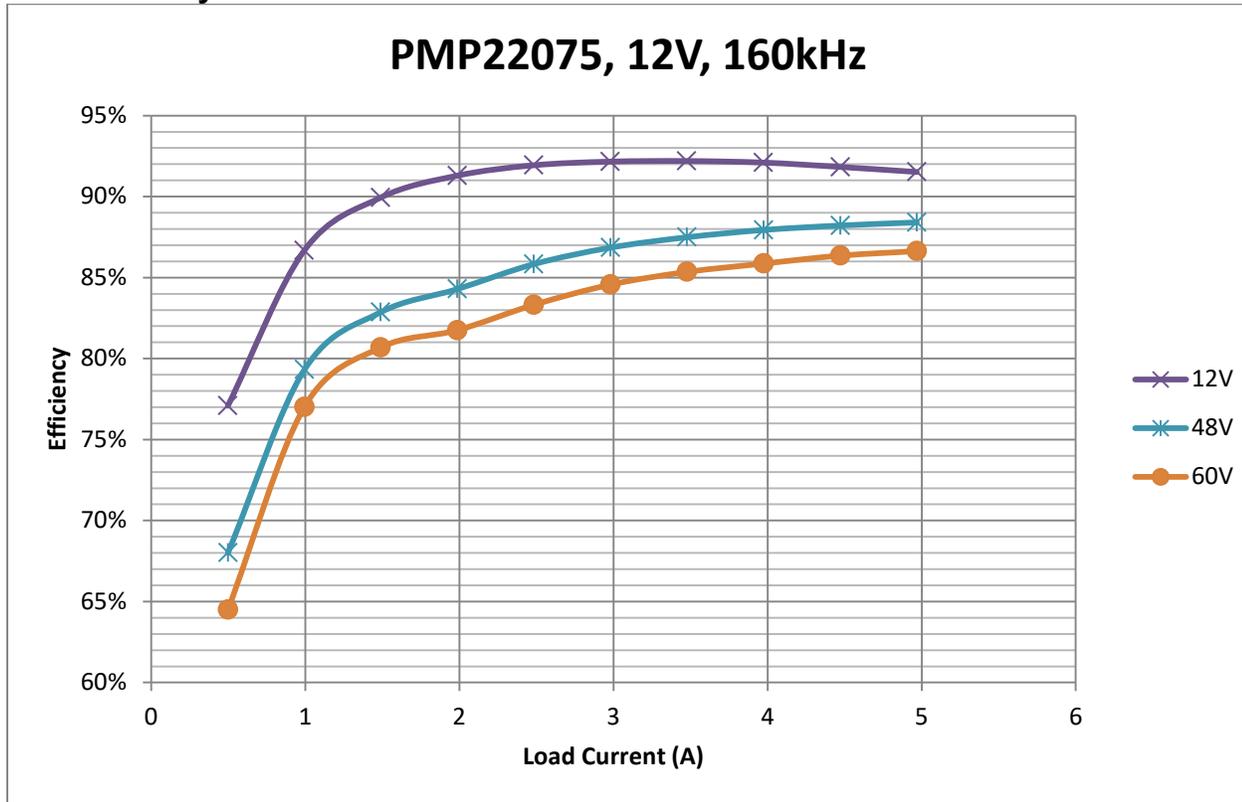
48Vin, 12Vout, Short circuit release

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 |

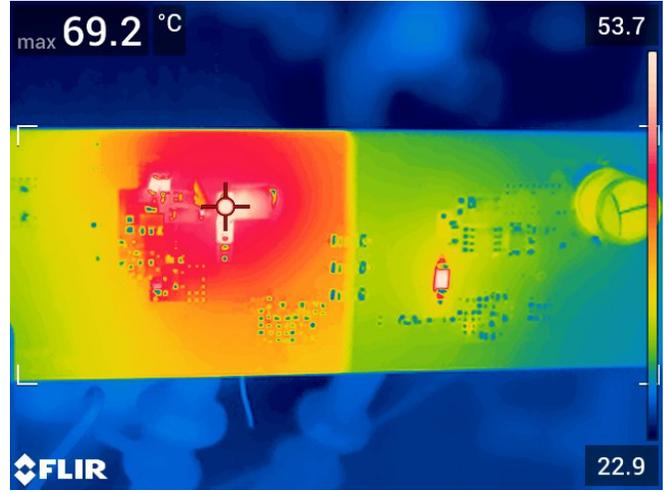
| | | | | | |
|--------|--------|-------|-------|-------|------|
| 11.987 | 11.847 | 4.264 | 3.974 | 92.1% | 4.04 |
| 11.985 | 11.847 | 4.814 | 4.472 | 91.8% | 4.71 |
| 11.984 | 11.847 | 5.367 | 4.968 | 91.5% | 5.45 |
| | | | | | |
| 24.003 | 11.852 | 0.136 | 0.016 | 5.9% | 3.08 |
| 24.003 | 11.852 | 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



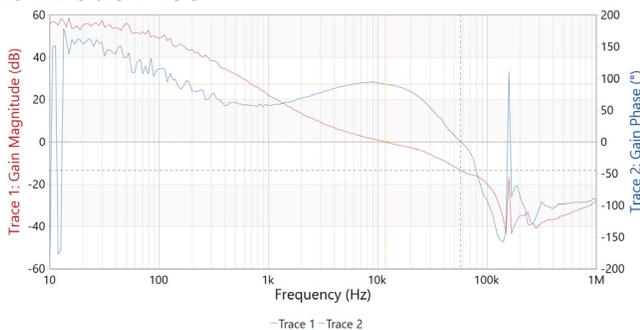
48Vin, 12V5A, $T_{FET(SEC)}=60.8C$ Front view



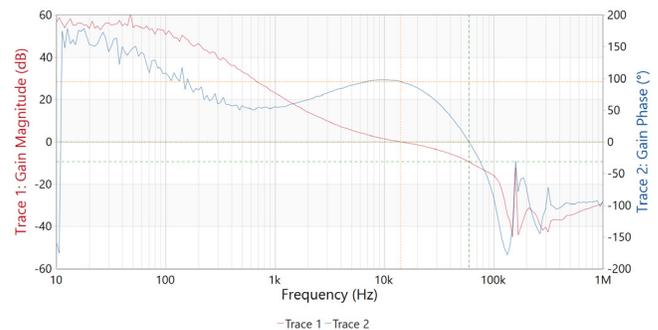
48Vin, 12V5A, Back view

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

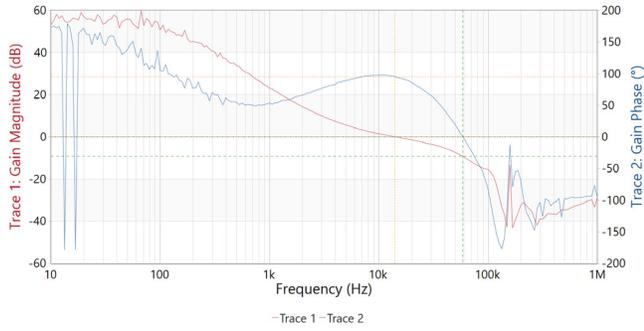
13 Bode Plot



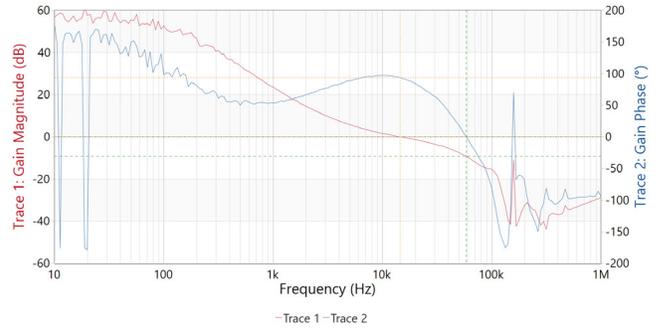
12Vin, 12Vout/5A, BW=11.7kHz, PM=91D, GM=13dB.



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.

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