*Test Report: PMP21783*

# 60-W Ultra-Wide Range Power Supply Reference Design

TEXAS INSTRUMENTS

**Description**

This reference design provides a 12-Vdc, 5-Vdc, and 3.3-Vdc output from an ultra-wide range of both AC and DC inputs. A universal 85 – 265-Vac input can be applied to the input of the valley-switching flyback. For DC inputs ranging from 24 – 150 Vdc, a boost is designed to create a 150-V bus voltage that is fed to the flyback. If the input is 150 – 250 Vdc the boost does not switch to improve efficiency while still powering the flyback and other down stream converters.



**Figure 1.** Board Top

# 1 Test Prerequisites

## 1.1 Voltage and Current Requirements

| PARAMETER | SPECIFICATIONS |
| --- | --- |
| Input Voltage Range (J1) | 24 – 250 Vdc |
| Input Voltage Range (J2) | 85 – 265 Vac |
| Output Voltage 1 | 12 Vdc |
| Output Current 1 | 3.25 A |
| Output Voltage 2 | 5 Vdc |
| Output Current 2 | 3 A |
| Output Voltage 3 | 3.3 Vdc |
| Output Current 3 | 3 A |
| UCC28742 Switching Frequency | 70 kHz-80 kHz |
| LM5022Switching Frequency | 200 kHz +/- 15% |
| TPS54302 Switching Frequency | 400 kHz +/- 27.5% |

# 2 Testing and Results

## 2.1 Efficiency Graphs
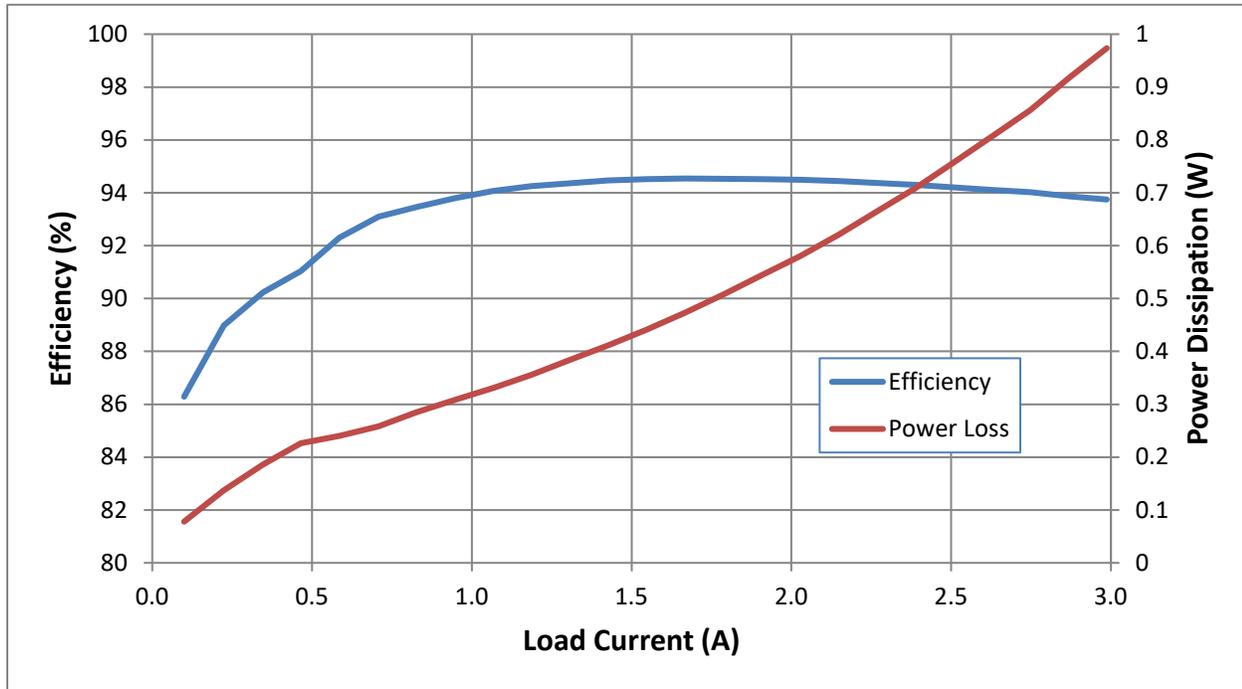


**Figure 2**. Efficiency for U6 buck converter with 12 Vdc input and 5 Vdc output.
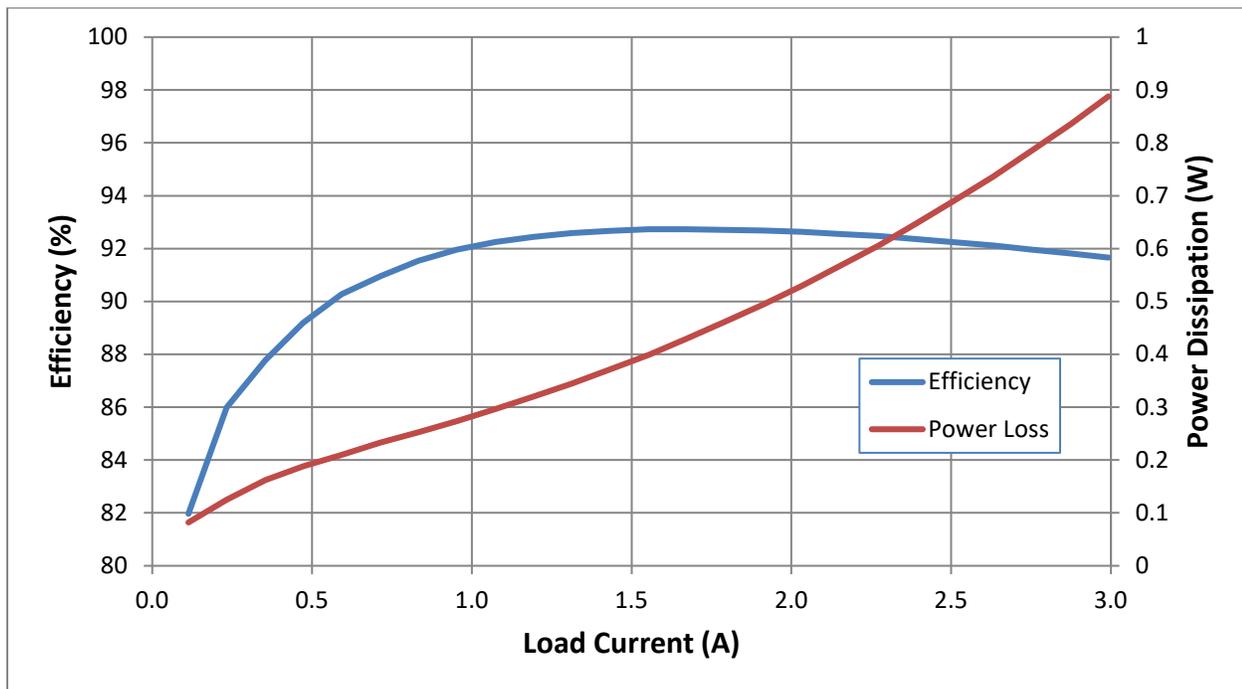


**Figure 3.** Efficiency for U7 buck converter with 12 Vdc input and 3.3 Vdc output.

*60-W Ultra-Wide Range Power Supply Reference Design*
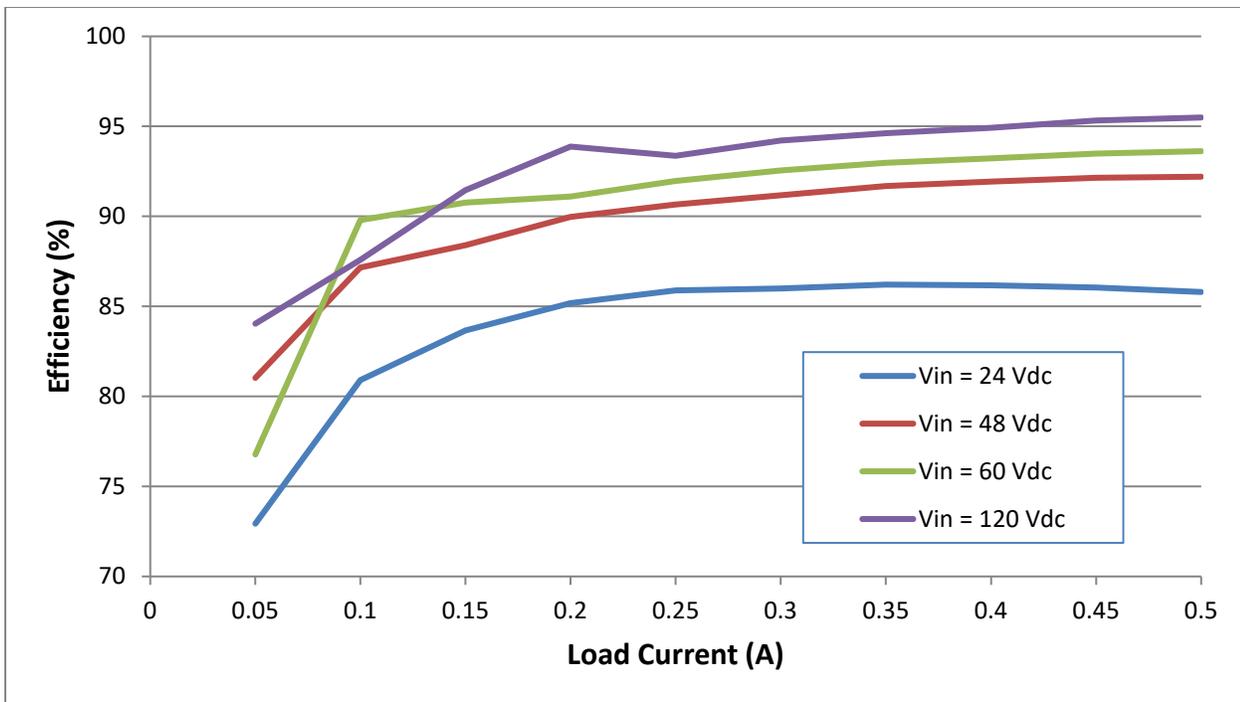
**Figure 4.** Efficiency for U1 boost converter with 150 Vdc output
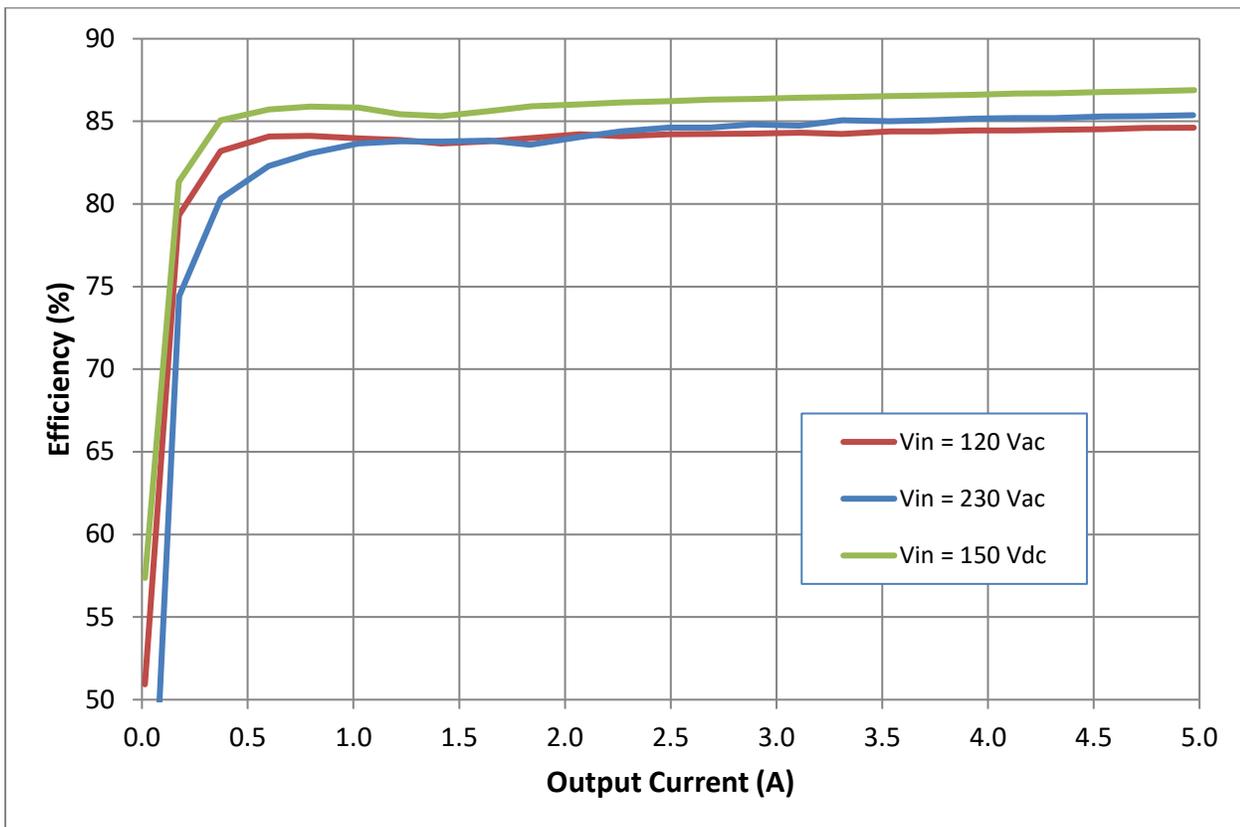


**Figure 5.** Efficiency for U4 flyback converter with 12 Vdc output

## 2.2 Efficiency Data

| | Input Voltage (V) | Input Current (A) | Input Power (W) | Output Voltage (V) | Output Current (A) | Output Power (W) | Efficiency (%) | Power Loss (W) |
|---|---|---|---|---|---|---|---|---|
| **12V** | 11.999 | 0.047 | 0.569 | 4.926 | 0.100 | 0.491 | 86.286 | 0.469 |
| | 11.999 | 0.362 | 4.350 | 4.922 | 0.826 | 4.065 | 93.458 | 3.524 |
| | 11.999 | 0.671 | 8.046 | 4.916 | 1.547 | 7.605 | 94.518 | 6.499 |
| | 11.999 | 0.983 | 11.792 | 4.909 | 2.267 | 11.128 | 94.366 | 9.526 |
| | 11.999 | 1.298 | 15.575 | 4.888 | 2.987 | 14.602 | 93.750 | 12.588 |

**Figure 6.** Efficiency data for U6 buck converter at light load, one quarter load, half load, third quarter load, and full load

| | Input Voltage (V) | Input Current (A) | Input Power (W) | Output Voltage (V) | Output Current (A) | Output Power (W) | Efficiency (%) | Power Loss (W) |
|---|---|---|---|---|---|---|---|---|
| **12V** | 11.999 | 0.038 | 0.455 | 3.291 | 0.113 | 0.373 | 86.286 | 0.341 |
| | 11.999 | 0.249 | 2.988 | 3.285 | 0.833 | 2.735 | 93.458 | 2.155 |
| | 11.999 | 0.458 | 5.490 | 3.278 | 1.553 | 5.091 | 94.518 | 3.937 |
| | 11.999 | 0.670 | 8.037 | 3.271 | 2.272 | 7.432 | 94.366 | 5.765 |
| | 11.999 | 0.887 | 10.639 | 3.259 | 2.992 | 9.752 | 93.750 | 7.647 |

**Figure 7.** Efficiency data for U7 buck converter at light load, one quarter load, half load, third quarter load, and full load

| | Input Voltage (V) | Input Current (A) | Input Power (W) | Output Voltage (V) | Output Current (A) | Output Power (W) | Efficiency (%) | Power Loss (W) |
|---|---|---|---|---|---|---|---|---|
| **24 Vin** | 24.189 | 0.423 | 10.232 | 149.246 | 0.050 | 7.462 | 72.931 | 2.770 |
| | 24.090 | 1.111 | 26.764 | 149.282 | 0.150 | 22.392 | 83.666 | 4.372 |
| | 24.090 | 1.804 | 43.458 | 149.296 | 0.250 | 37.324 | 85.885 | 6.134 |
| | 24.090 | 2.517 | 60.635 | 149.352 | 0.350 | 52.273 | 86.210 | 8.361 |
| | 24.090 | 3.614 | 87.061 | 149.388 | 0.500 | 74.694 | 85.795 | 12.367 |
| **48 Vin** | 48.000 | 0.192 | 9.216 | 149.350 | 0.050 | 7.468 | 81.028 | 1.749 |
| | 48.000 | 0.528 | 25.344 | 149.361 | 0.150 | 22.404 | 88.400 | 2.940 |
| | 48.000 | 0.858 | 41.184 | 149.360 | 0.250 | 37.340 | 90.666 | 3.844 |
| | 48.000 | 1.188 | 57.024 | 149.371 | 0.350 | 52.280 | 91.680 | 4.744 |
| | 48.000 | 1.688 | 81.024 | 149.413 | 0.500 | 74.707 | 92.203 | 6.318 |
| **60 Vin** | 60.029 | 0.162 | 9.725 | 149.323 | 0.050 | 7.466 | 76.775 | 2.259 |
| | 60.029 | 0.411 | 24.672 | 149.295 | 0.150 | 22.394 | 90.768 | 2.278 |
| | 60.029 | 0.676 | 40.580 | 149.279 | 0.250 | 37.320 | 91.967 | 3.260 |
| | 60.029 | 0.936 | 56.187 | 149.269 | 0.350 | 52.244 | 92.982 | 3.943 |
| | 60.029 | 1.328 | 79.719 | 149.266 | 0.500 | 74.633 | 93.621 | 5.086 |
| **120 Vin** | 120.020 | 0.074 | 8.881 | 149.277 | 0.050 | 7.464 | 84.038 | 1.418 |
| | 120.020 | 0.204 | 24.484 | 149.278 | 0.150 | 22.392 | 91.454 | 2.092 |
| | 120.020 | 0.333 | 39.967 | 149.270 | 0.250 | 37.318 | 93.372 | 2.649 |
| | 120.020 | 0.460 | 55.209 | 149.252 | 0.350 | 52.238 | 94.619 | 2.971 |
| | 120.020 | 0.651 | 78.133 | 149.220 | 0.500 | 74.610 | 95.491 | 3.523 |

**Figure 8.** Efficiency data for U1 boost converter at light load, one quarter load, half load, third quarter load, and full load for different input ranges

| | Input Voltage (V) | Input Current (A) | Input Power (W) | Output Voltage (V) | Output Current (A) | Output Power (W) | Efficiency (%) | Power Loss (W) |
|---|---|---|---|---|---|---|---|---|
| **150 VDCin** | 150.049 | 0.002 | 0.304 | 12.016 | 0.015 | 0.175 | 57.366 | 0.130 |
| | 149.999 | 0.114 | 17.142 | 12.007 | 1.220 | 14.645 | 85.436 | 2.496 |
| | 149.939 | 0.232 | 34.712 | 12.001 | 2.494 | 29.931 | 86.228 | 4.781 |
| | 149.883 | 0.345 | 51.756 | 11.999 | 3.734 | 44.804 | 86.567 | 6.952 |
| | 149.828 | 0.458 | 68.689 | 11.997 | 4.975 | 59.683 | 86.888 | 9.006 |
| | Input Voltage (Vrms) | Input Current (Arms) | Input Power (W) | Output Voltage (V) | Output Current (A) | Output Power (W) | Efficiency (%) | Power Loss (W) |
| **230 VACin** | 230.120 | 0.016 | 0.510 | 12.026 | 0.013 | 0.161 | 31.559 | 0.349 |
| | 230.100 | 0.216 | 17.500 | 12.017 | 1.220 | 14.665 | 83.802 | 2.835 |
| | 230.060 | 0.414 | 35.360 | 12.009 | 2.492 | 29.925 | 84.628 | 5.435 |
| | 230.060 | 0.596 | 52.662 | 12.007 | 3.731 | 44.796 | 85.063 | 7.866 |
| | 230.010 | 0.756 | 69.896 | 12.007 | 4.970 | 59.672 | 85.373 | 10.224 |
| **120 VACin** | 120.180 | 0.012 | 0.328 | 12.020 | 0.014 | 0.167 | 50.928 | 0.161 |
| | 120.130 | 0.363 | 17.472 | 12.010 | 1.220 | 14.655 | 83.878 | 2.817 |
| | 120.080 | 0.647 | 35.542 | 12.004 | 2.494 | 29.933 | 84.218 | 5.609 |
| | 120.040 | 0.882 | 53.091 | 12.001 | 3.733 | 44.802 | 84.387 | 8.289 |
| | 119.980 | 1.106 | 70.517 | 11.999 | 4.973 | 59.669 | 84.617 | 10.848 |

**Figure 9.** Efficiency data for U4 flyback converter at light load, one quarter load, half load, third quarter load, and full load for different input ranges

## 2.3 Bode Plot

All Bode Measurements were made with full load conditions, unless noted otherwise
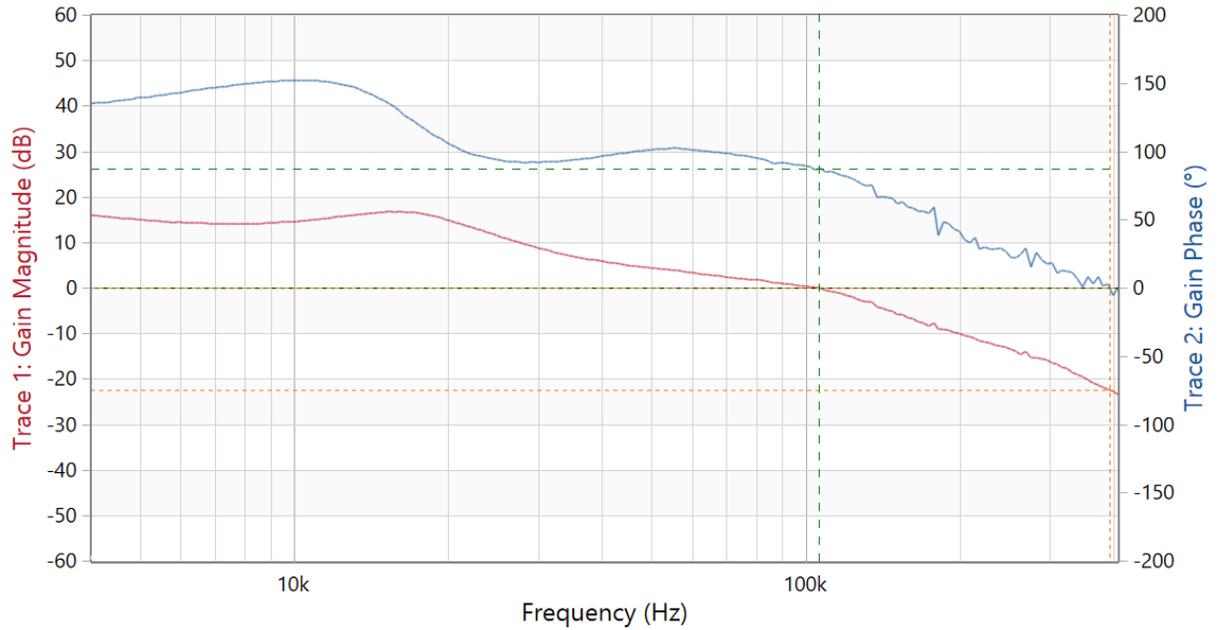


**Figure 10.** Bode plot for U6 buck converter

| Vout (V) | Load (A) | Bandwidth (kHz) | Phase Margin (°) |
|---|---|---|---|
| 5 | 3 | 106.232 | 87.394 |
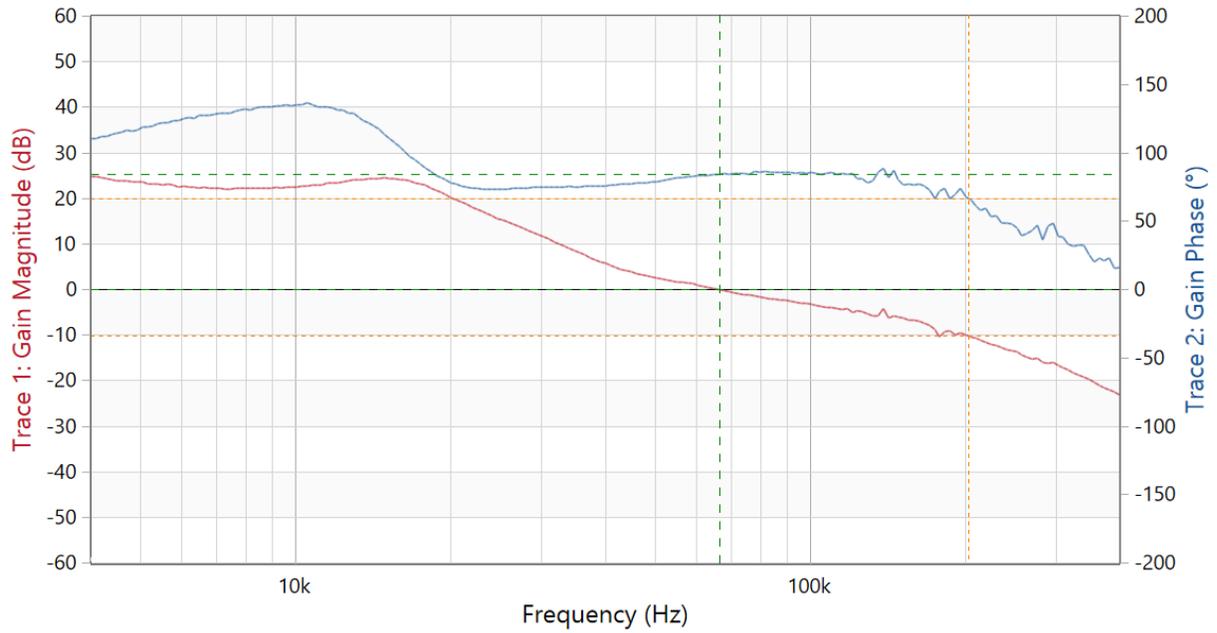
**Figure 11.** Bode plot for U7 buck converter

| Vout (V) | Load (A) | Bandwidth (kHz) | Phase Margin (°) |
|----------|----------|-----------------|------------------|
| 3.3 | 3 | 66.66 | 84.312 |
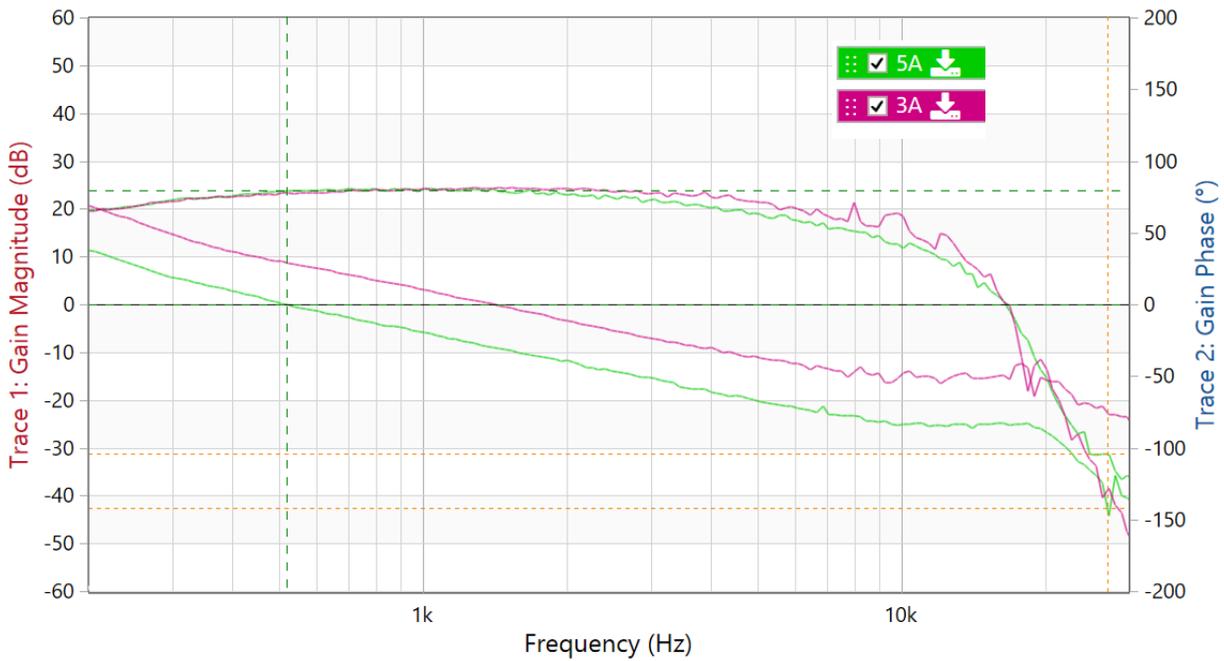
**Figure 12.** Bode plot for U4 flyback converter. 3 A is typical load condition, 5 A is peak load condition

| Vout (V) | Load (A) | Bandwidth (kHz) | Phase Margin (°) |
|---|---|---|---|
| 12 | 3 | 1.423 | 81.356 |
| 12 | 5 | 0.519 | 79.285 |

### 2.4 Thermal Image

All thermal images are taken after a 10 minute soak with no airflow.
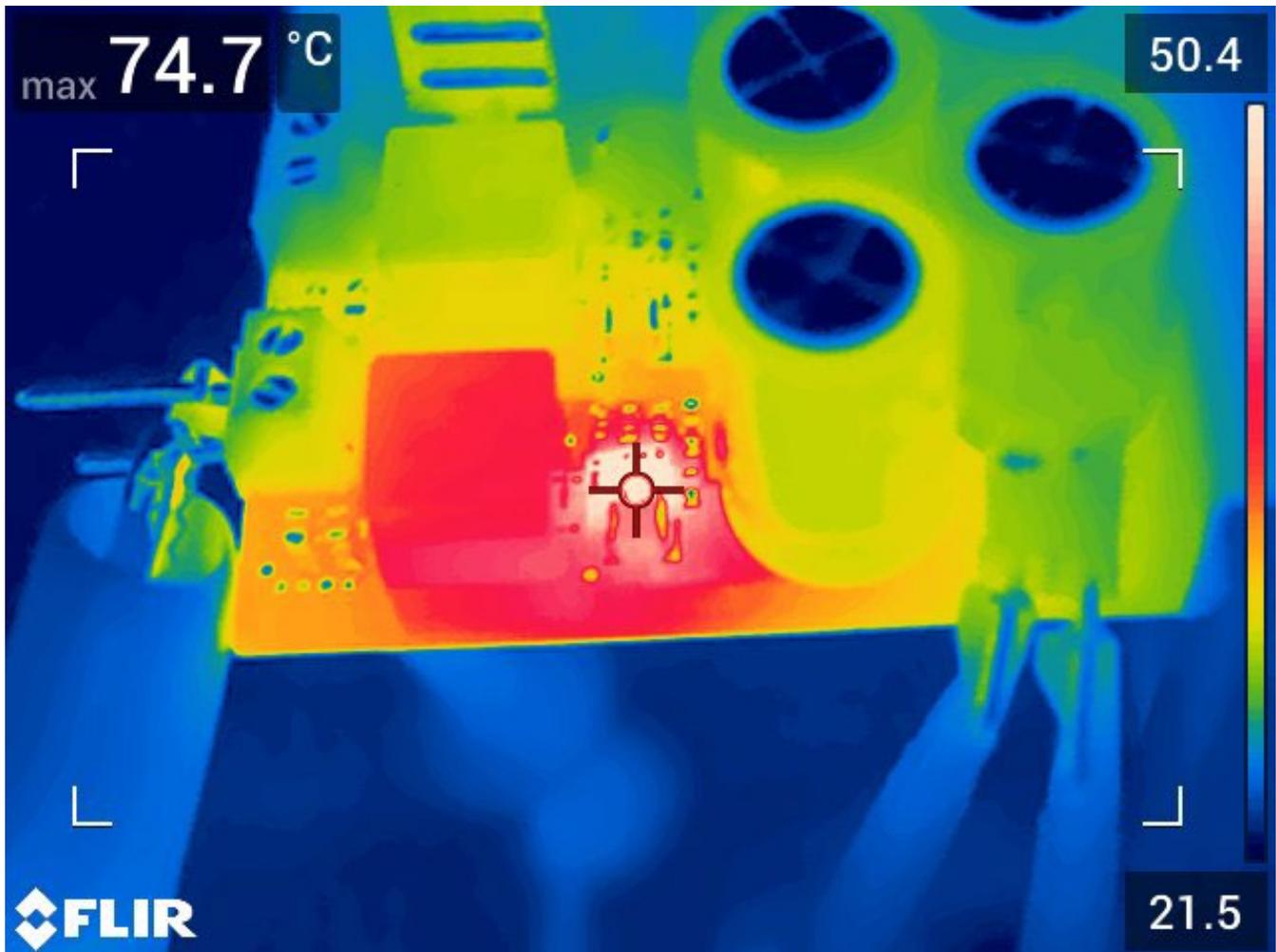


**Figure 13.** U6 converter after 10 minute thermal soak at 3 A load, 12 Vdc input and 5 Vdc outpu.
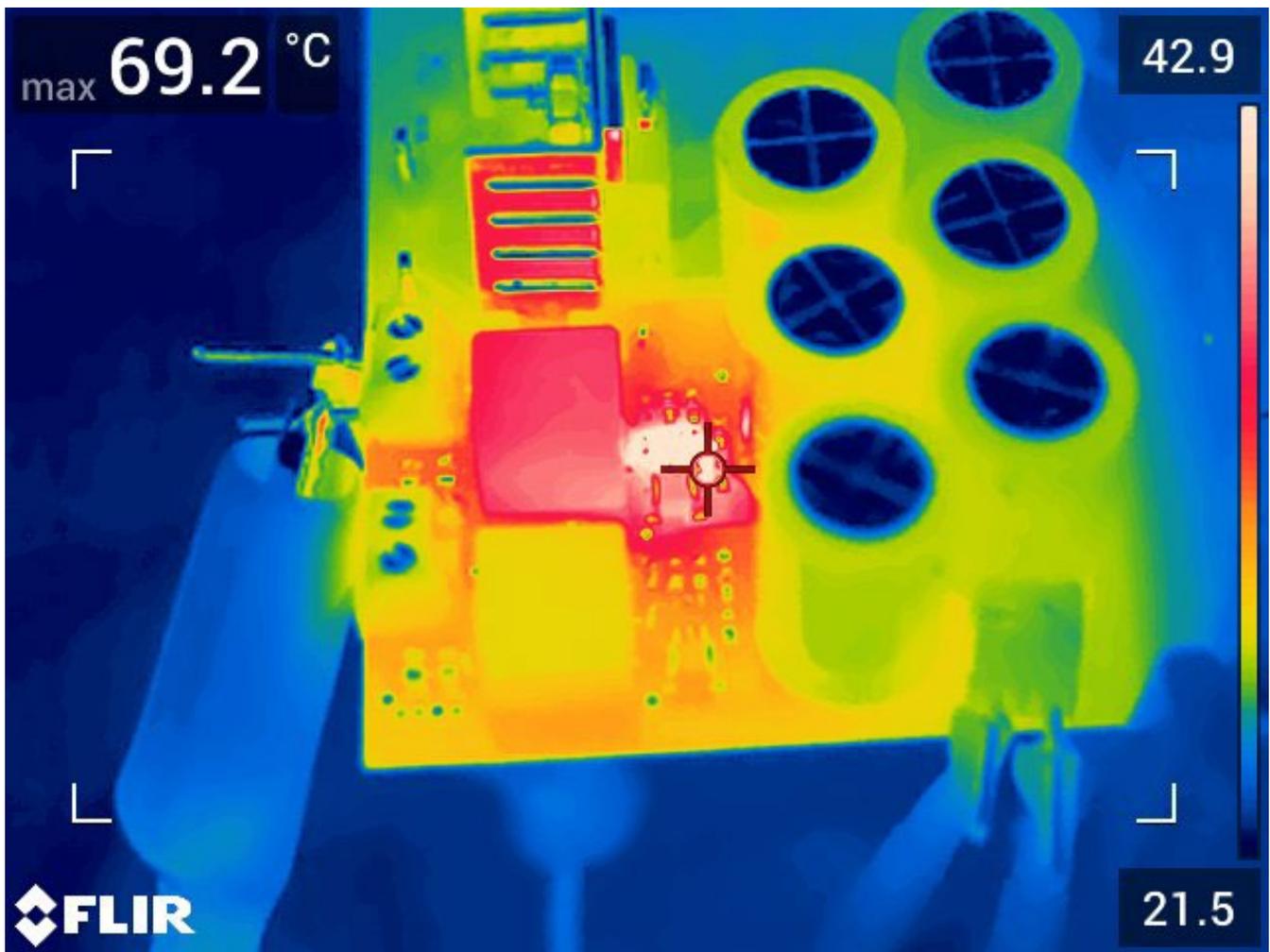
**Figure 14.** U7 converter after 10 minute thermal soak at 3 A load, 12 Vdc input and 3.3 Vdc output
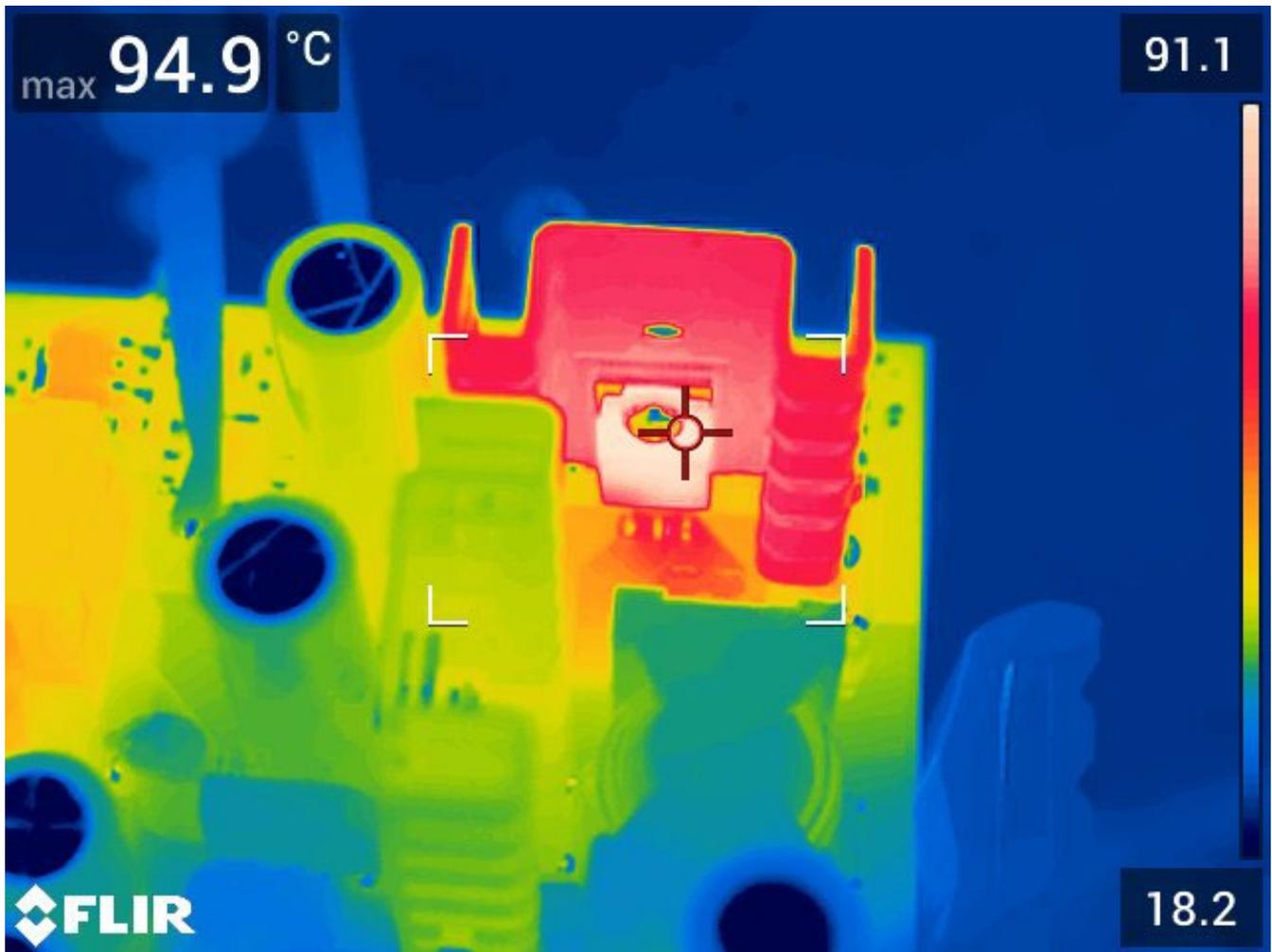
**Figure 15.** Q2 for LM5022 boost converter after 10 minute thermal soak at 24 Vdc input, loaded with 3.25 A on 12 Vdc rail
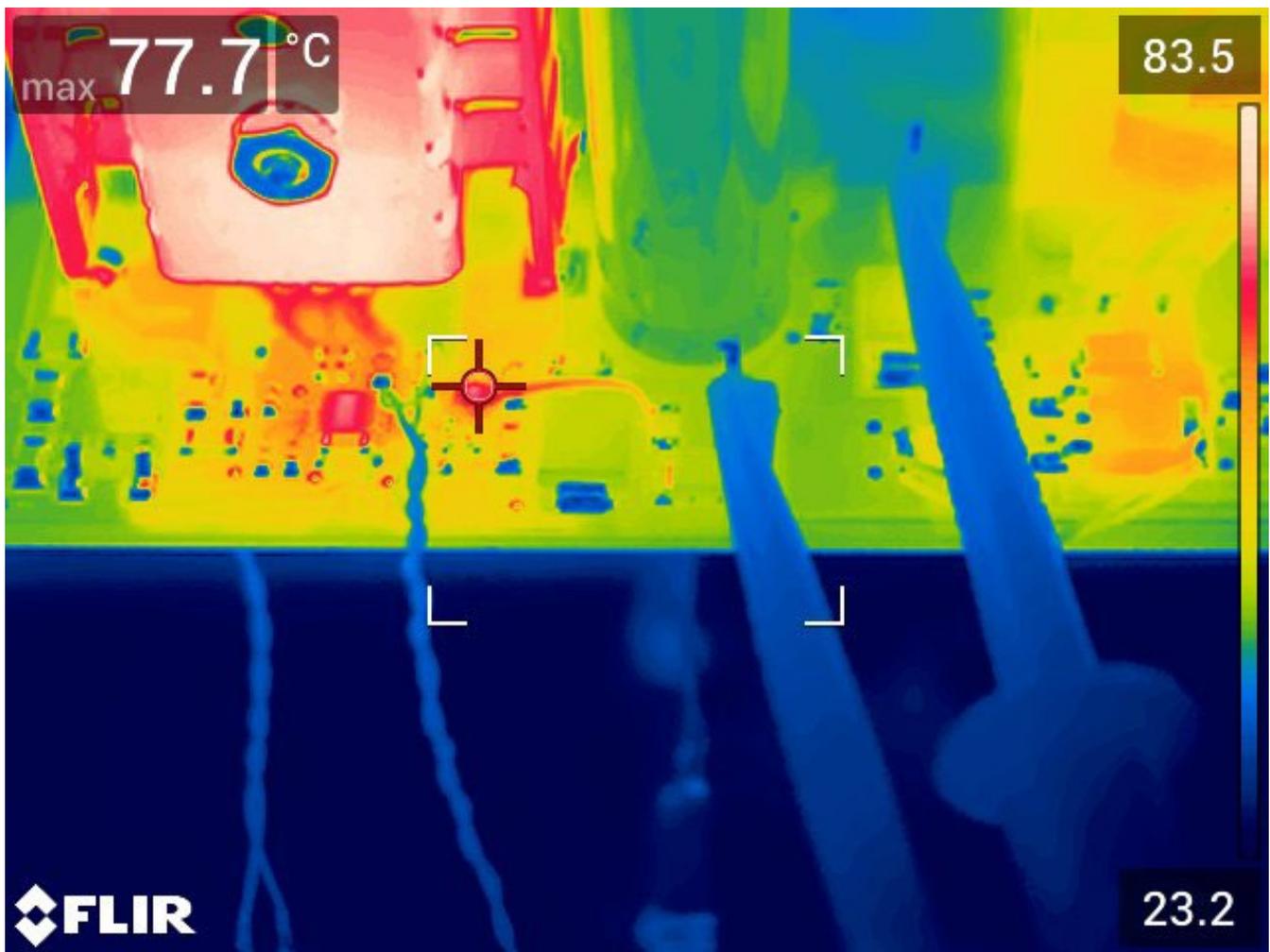
**Figure 16.** Regulator for VCC of LM5022 after 10 minute thermal soak at 24 Vdc input, loaded with 3.25 A on 12 Vdc rail
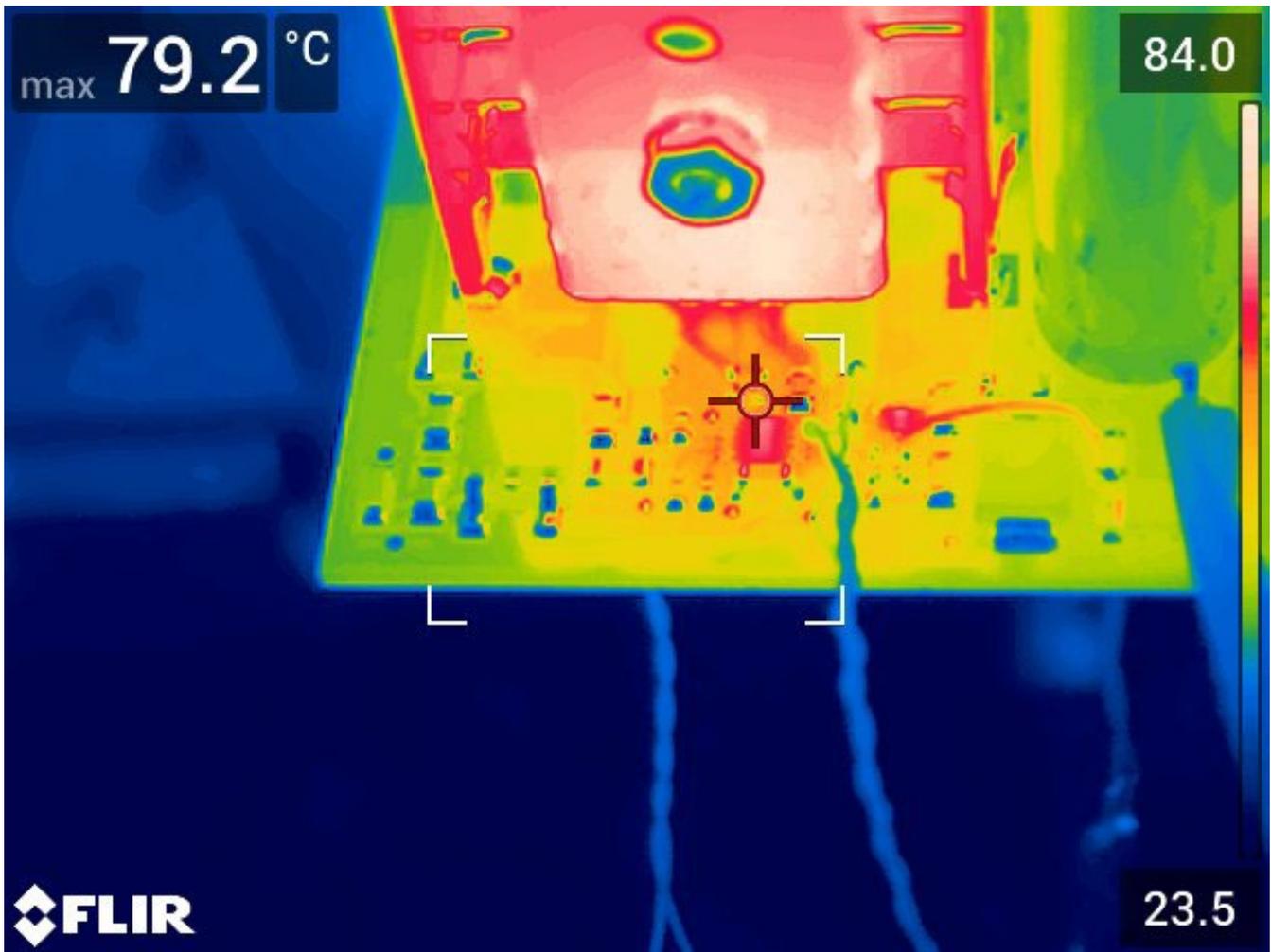
**Figure 17.** U1 LM5022 after 10 minute thermal soak at 24 Vdc input, loaded with 3.25 A on 12 Vdc rail
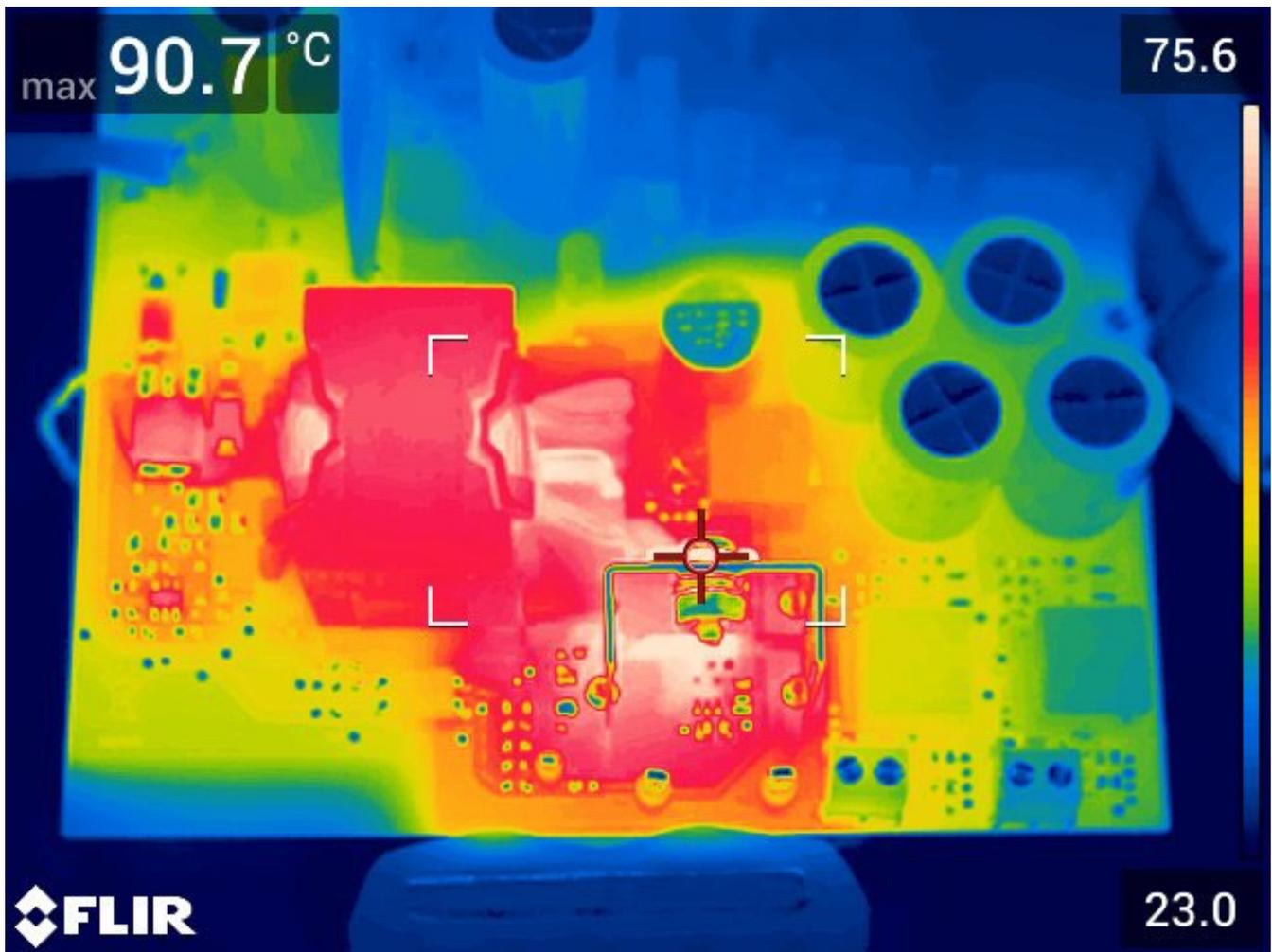
**Figure 18.** Top of board, only U4 flyback is on, after 10 minute thermal soak at 150 Vdc input, loaded with 5 A on 12 Vdc rail
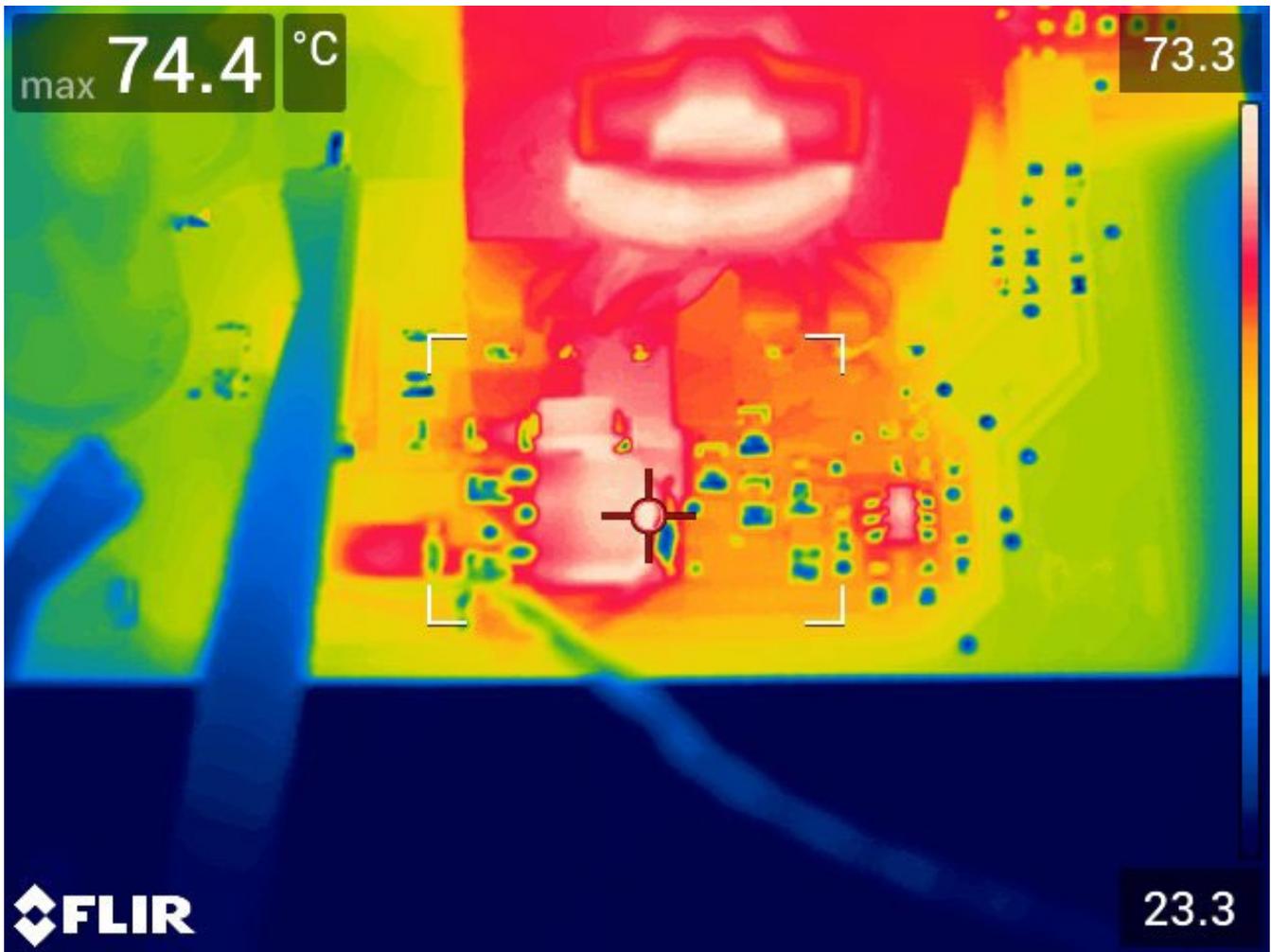
**Figure 19.** Q4 for UCC28742 flyback after 10 minute thermal soak at 150 Vdc input, loaded with 5 A on 12 Vdc rail
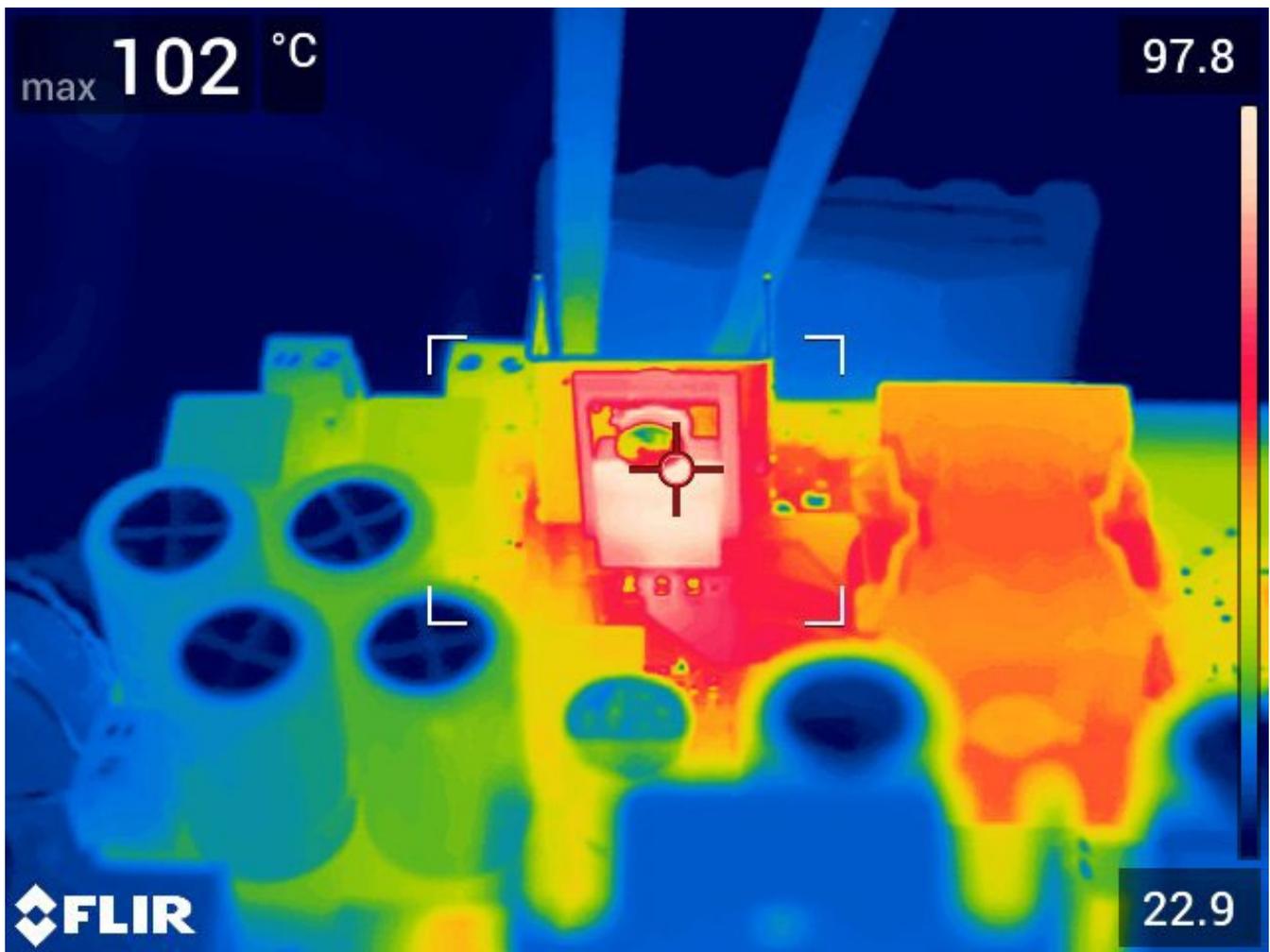
**Figure 20.** Q3 for flyback after 10 minute thermal soak at 150 Vdc input, loaded with 5 A on 12 Vdc rail

# 3 Waveforms

## 3.1 Switching
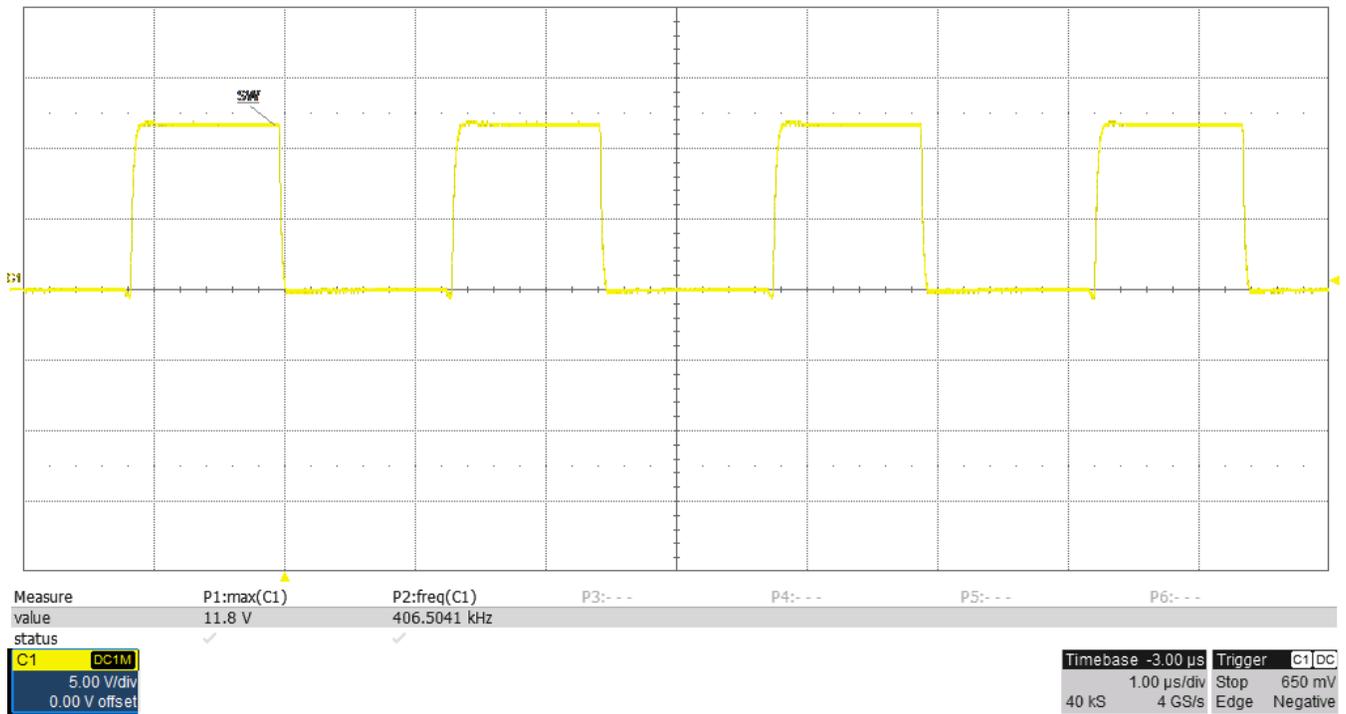


**Figure 21.** Switch node for U6 buck converter at 3 A load, 12 Vdc input and 5 Vdc output
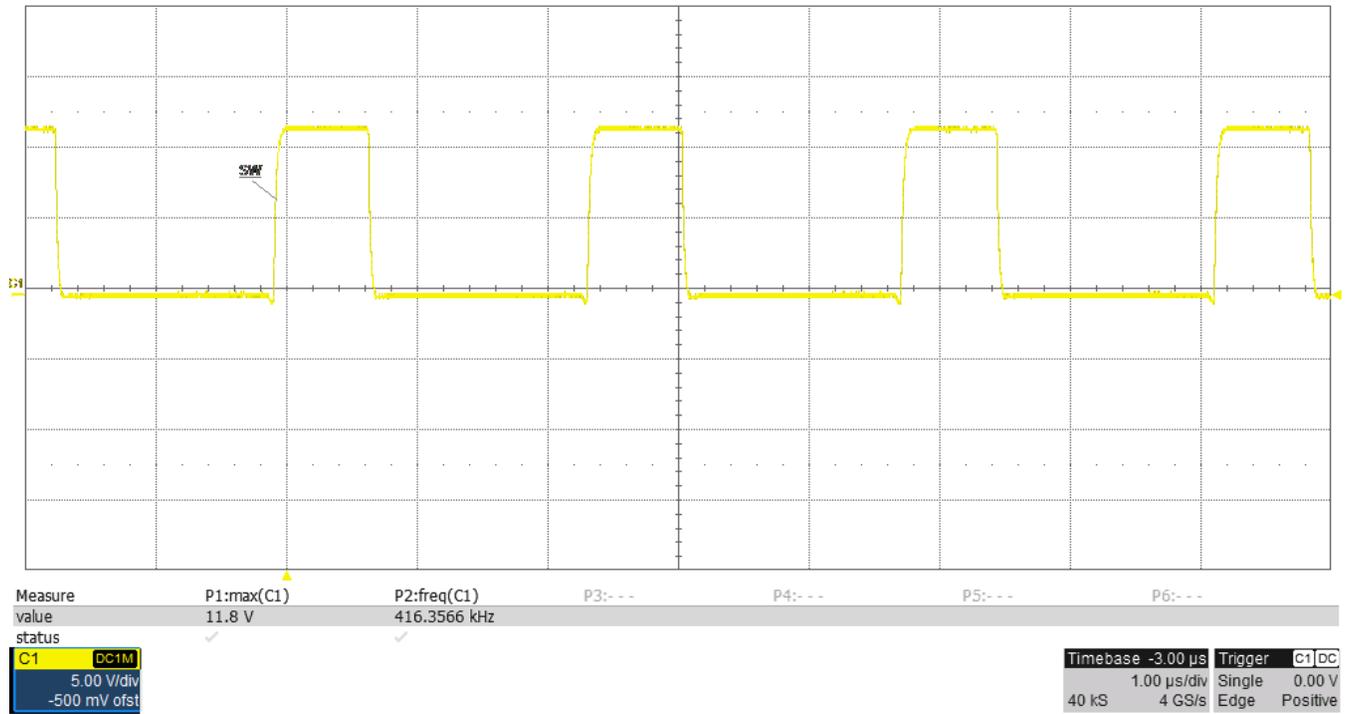
**Figure 22.** Switch node for U7 buck converter at 3 A load, 12 Vdc input and 3.3 Vdc output

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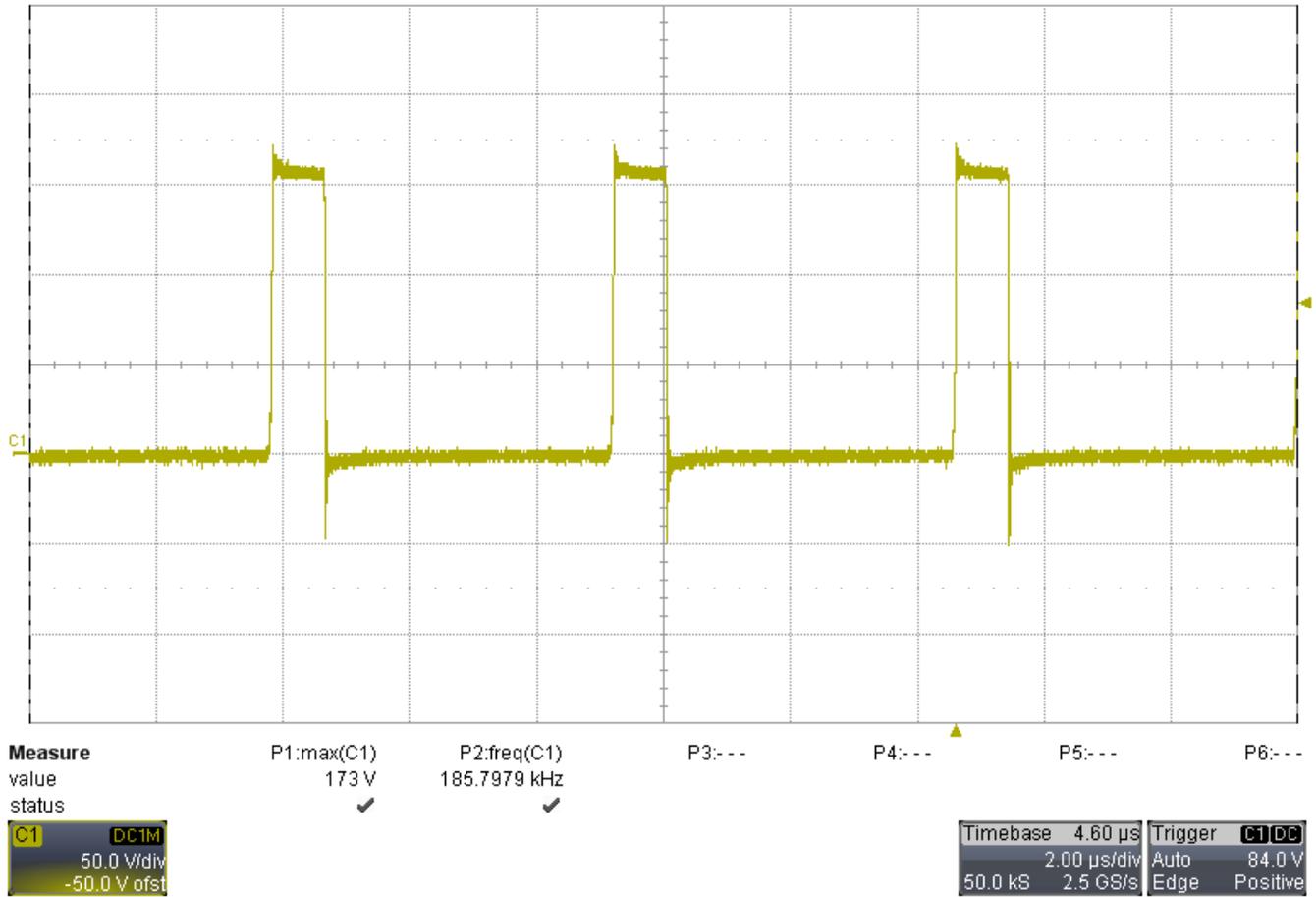
**Figure 23.** Switch Node for the LM5022 boost converter at full load on the 12 Vdc rail with 24 Vdc input
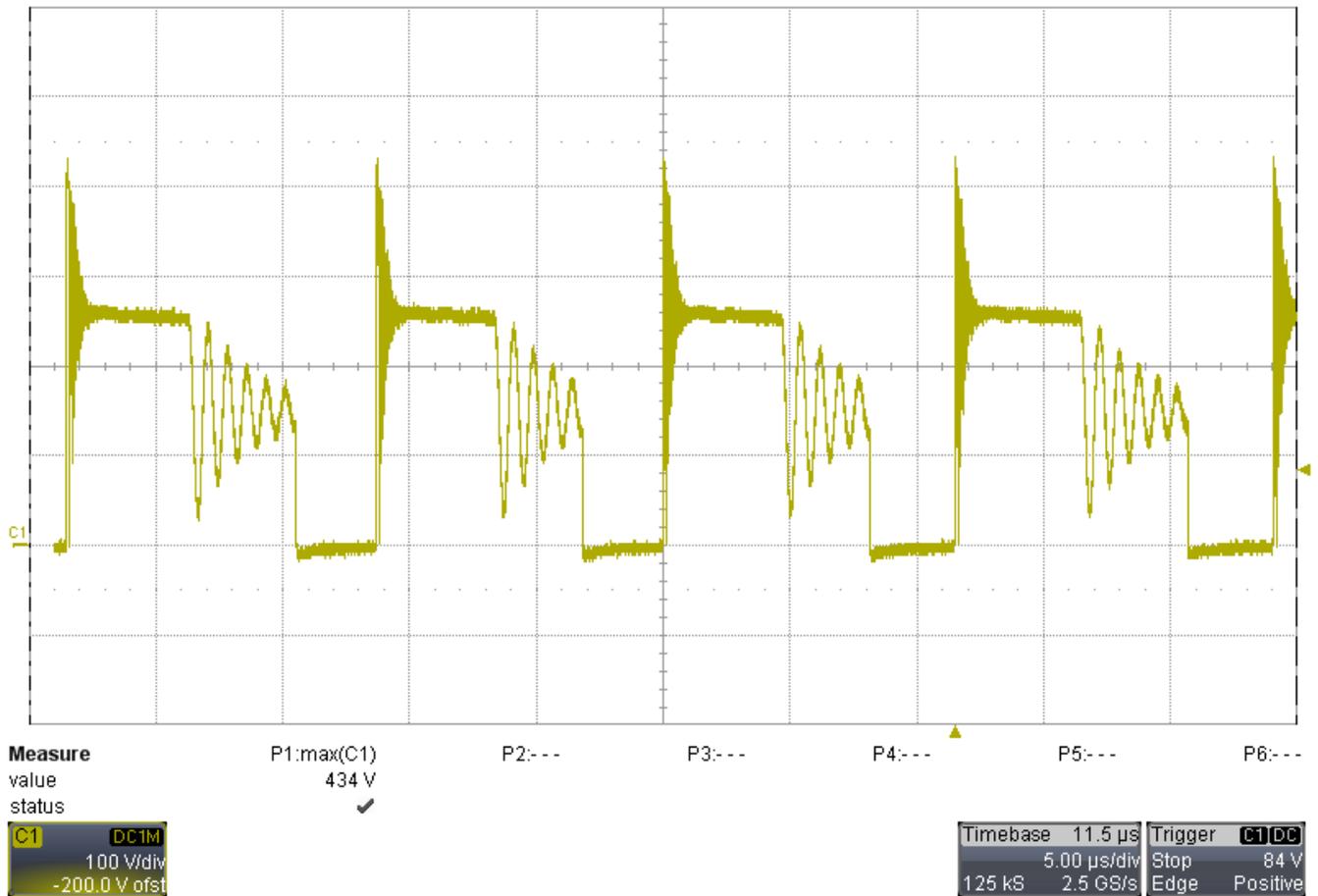
**Figure 24.** Switch node for the U4 flyback with 150 Vdc input, and 5 A on the 12 Vdc rail
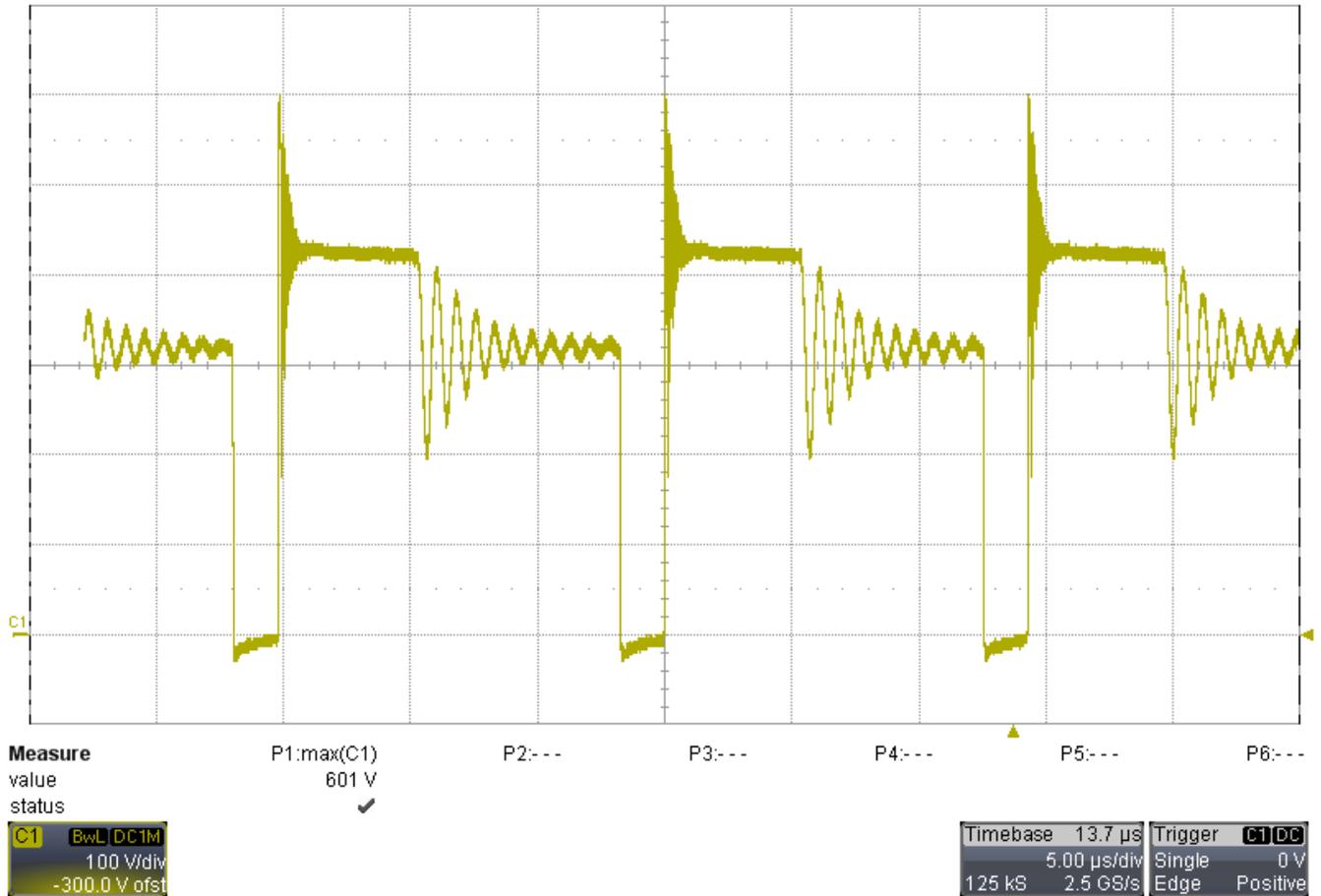
**Figure 25.** Switch node for the U4 flyback with 230 Vac input, and 5 A on the 12 Vdc rail

## 3.2 Output Voltage Ripple

Measurements were taken using the tip and barrel method across the output caps for each rail when at full load.
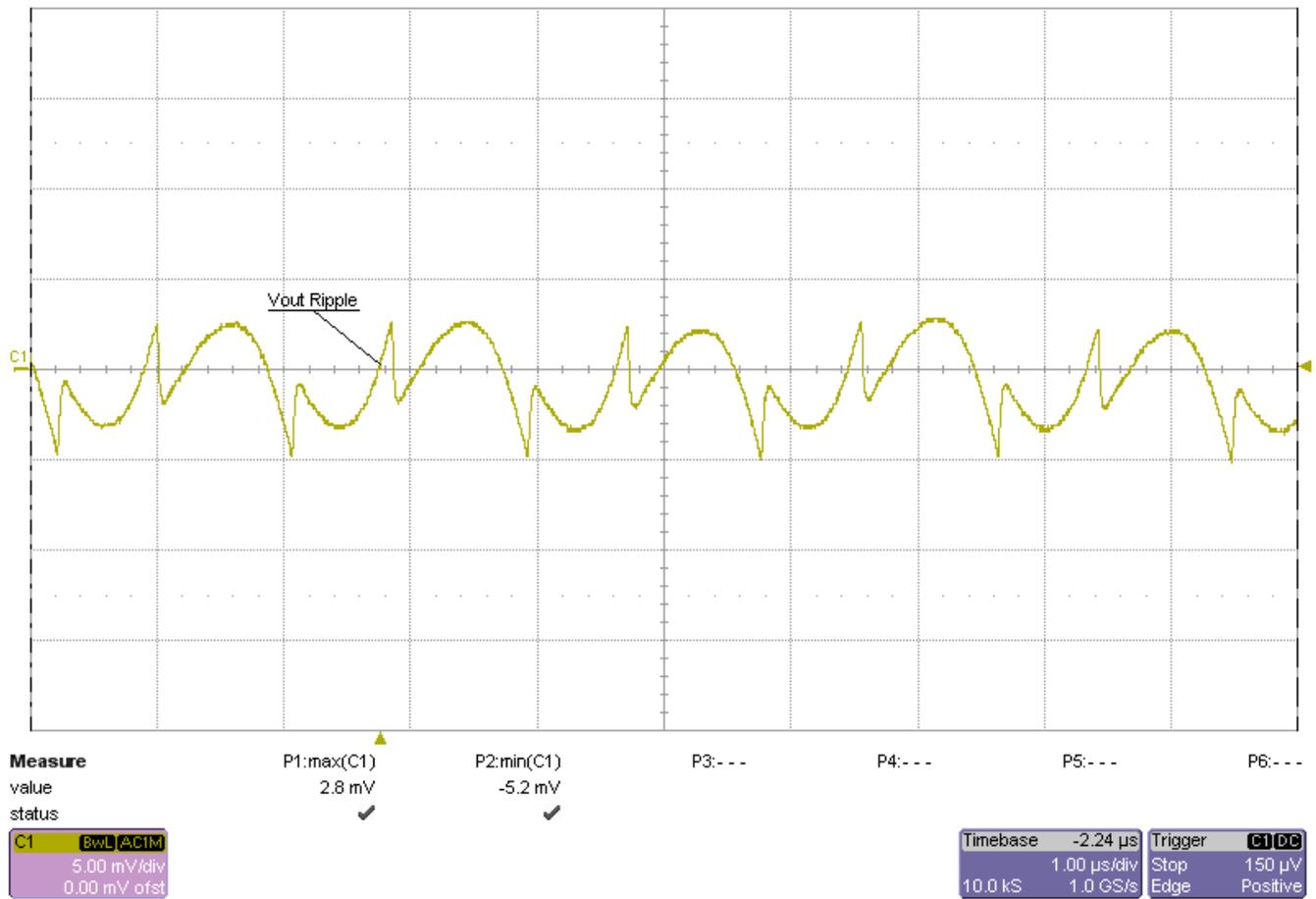


**Figure 26.** Output ripple of U6 converter at 3 A load, 12 Vdc input and 5 Vdc output
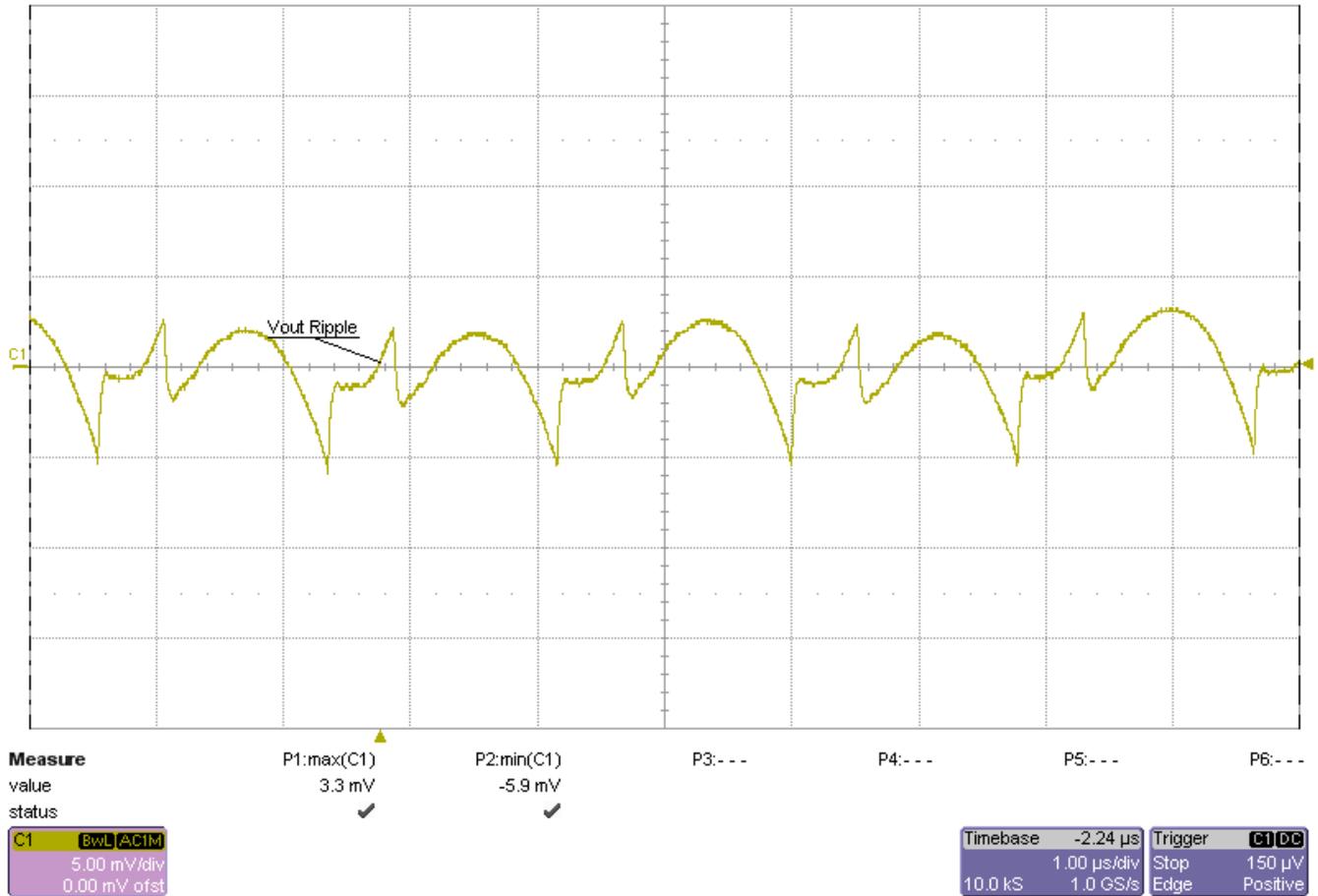
**Figure 27.** Output ripple of U7 converter at 3 A load, 12 Vdc input and 3.3 Vdc output
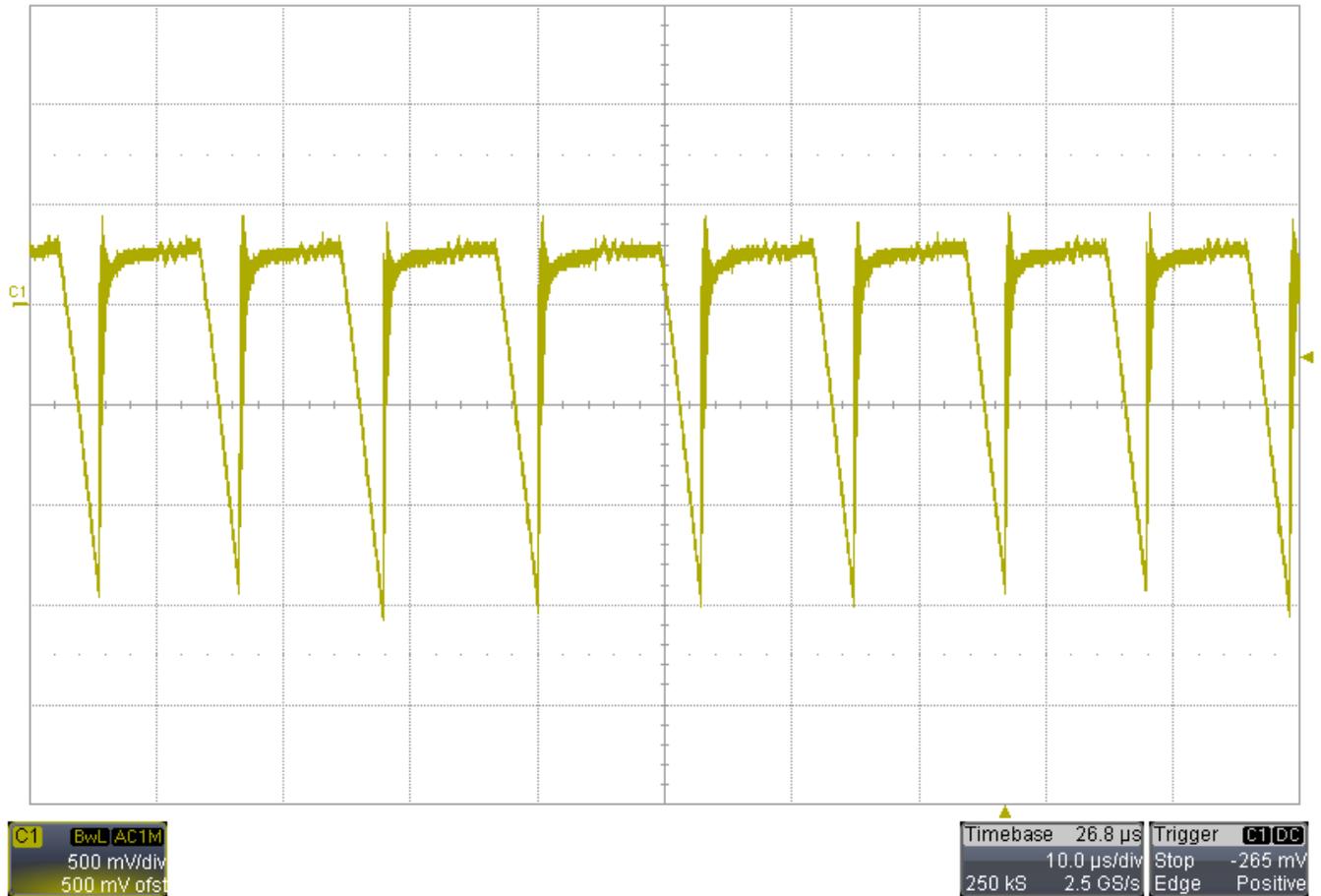
**Figure 28.** Output ripple for U1 boost converter with 24 Vdc input and 3.25 A load on the 12 Vdc rail
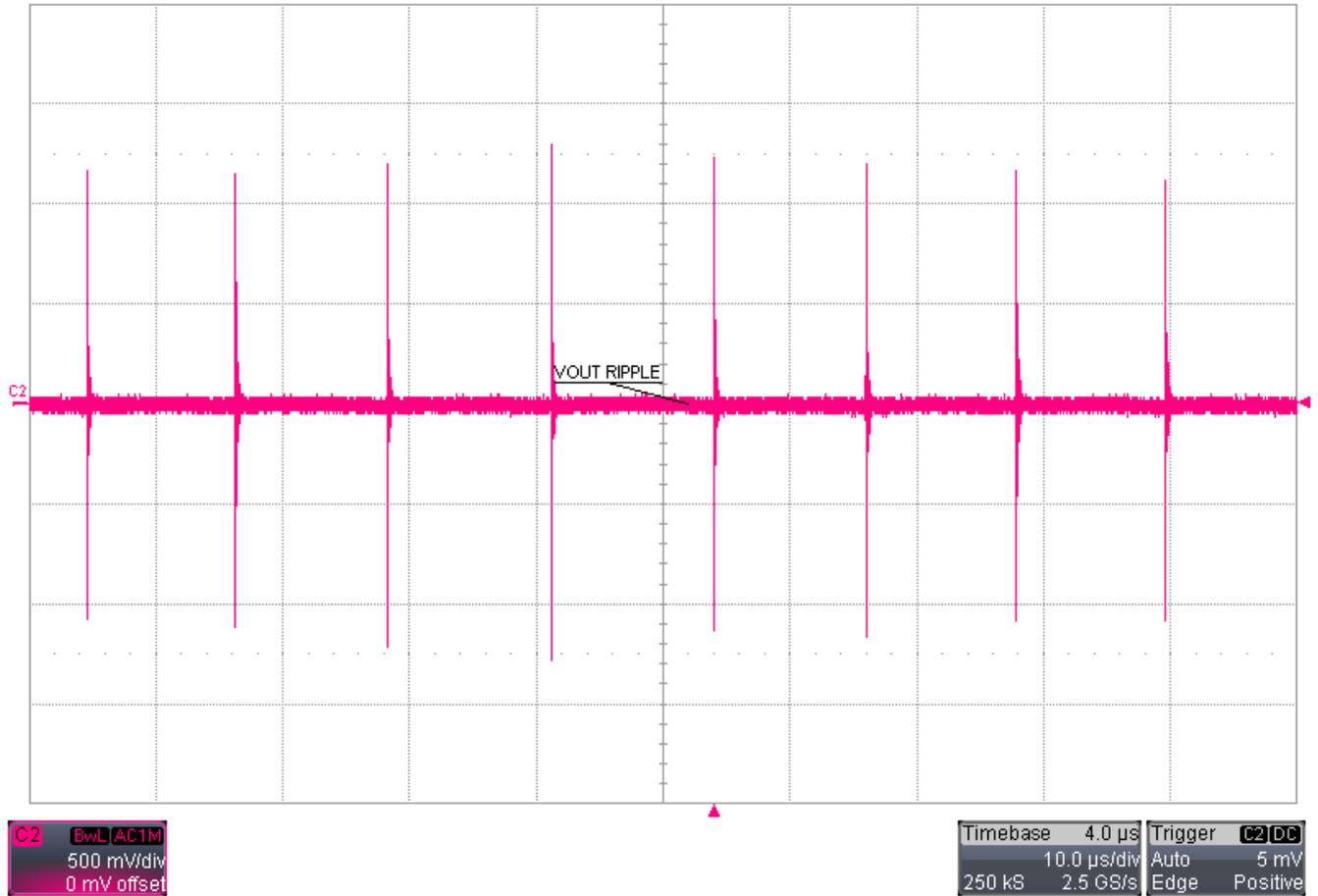
**Figure 29.** Output voltage for U4 flyback at 5 A load and 150 Vdc input
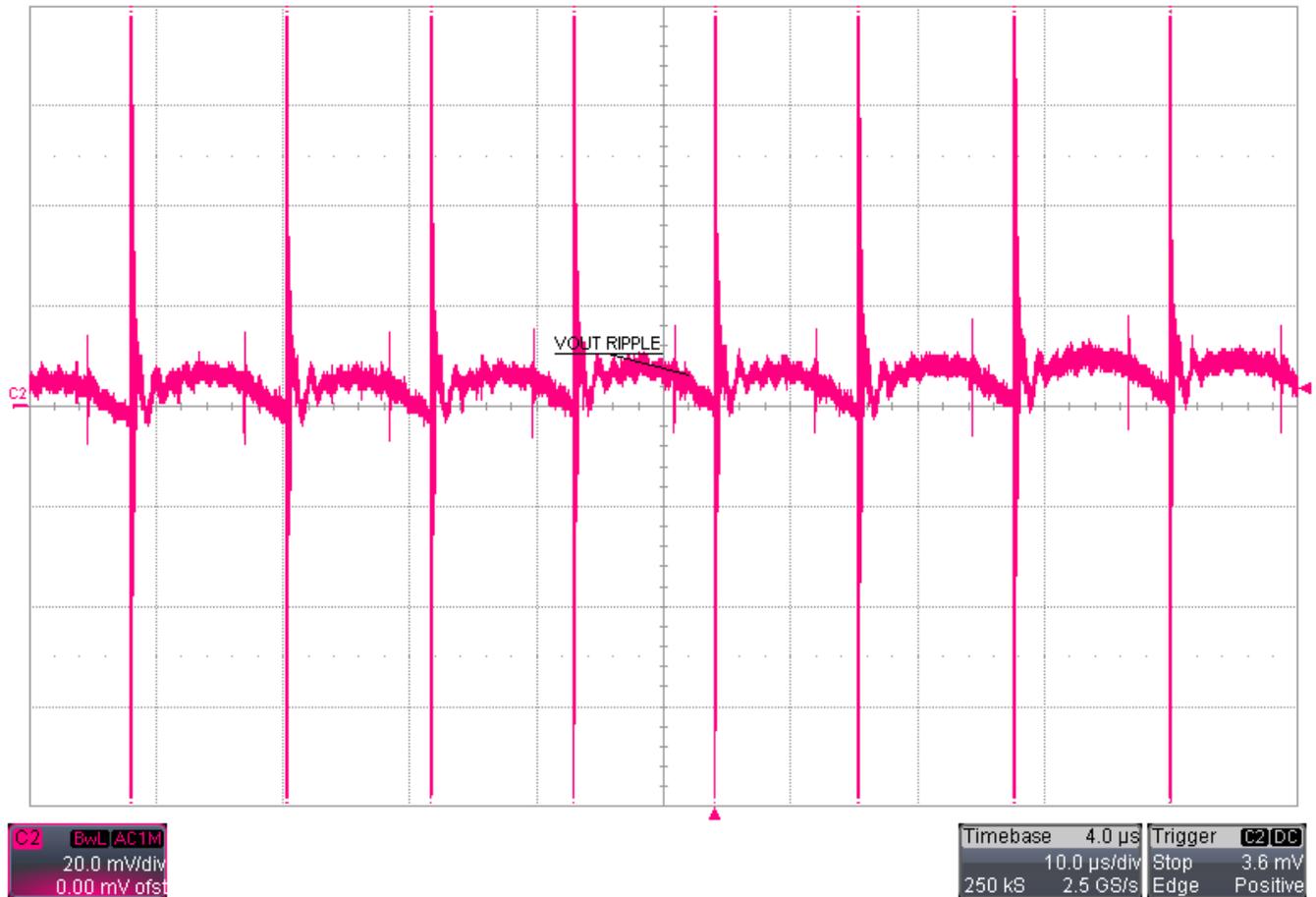
**Figure 30.** Output voltage for U4 flyback at 5 A load and 150 Vdc input. Voltage per division is increased for close up view of ripple

# LOAD TRANSIENTS
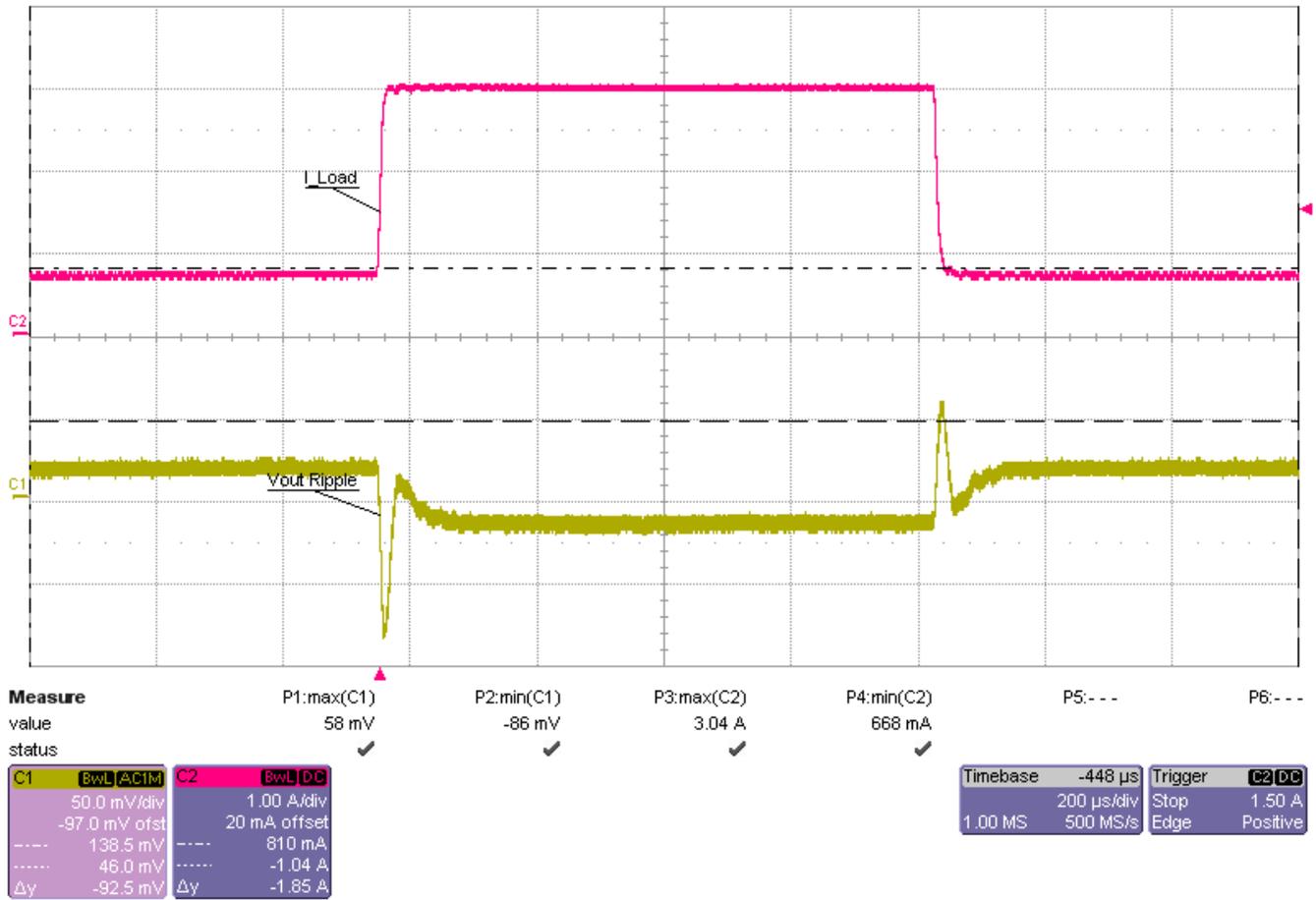


**Figure 31.** Load transient response for U6 buck converter at 3 A load, 12 Vdc input and 5 Vdc output
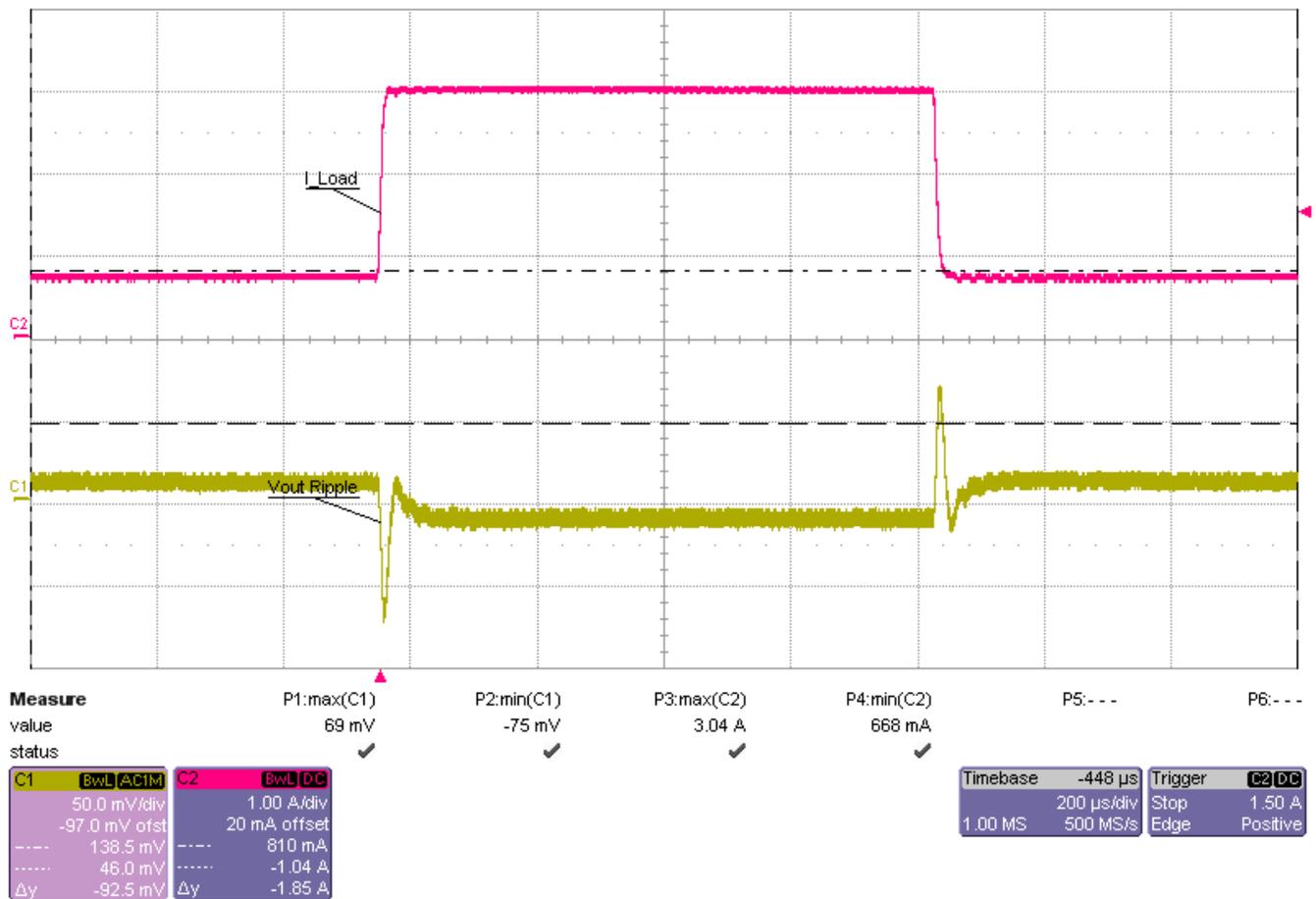
**Figure 32.** Load transient response for U7 buck converter at 3 A load, 12 Vdc input and 3.3 Vdc output
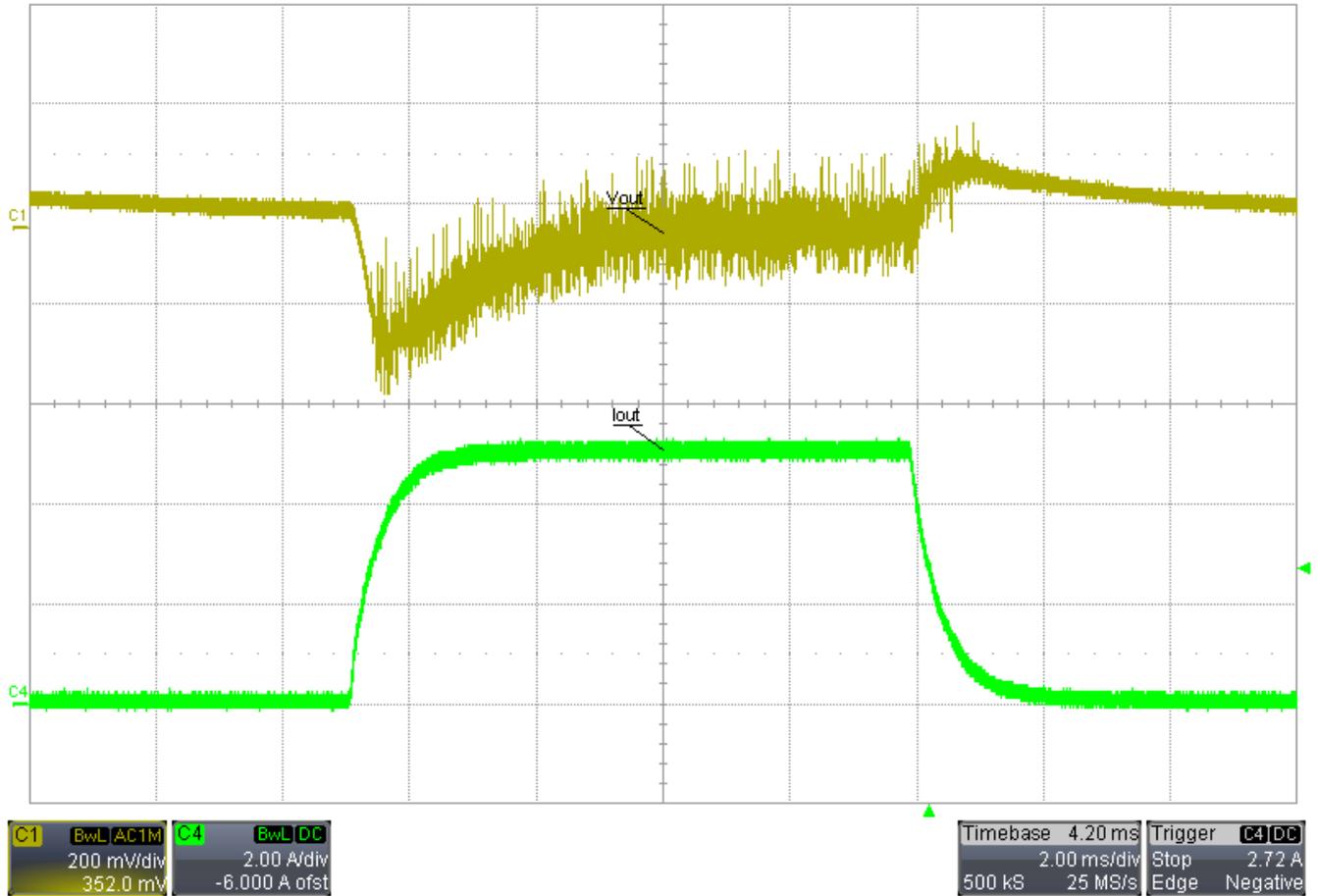
**Figure 33.** U4 flyback Load transient response**,** with load transient between 0 A and 5 A

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