# Abstract:

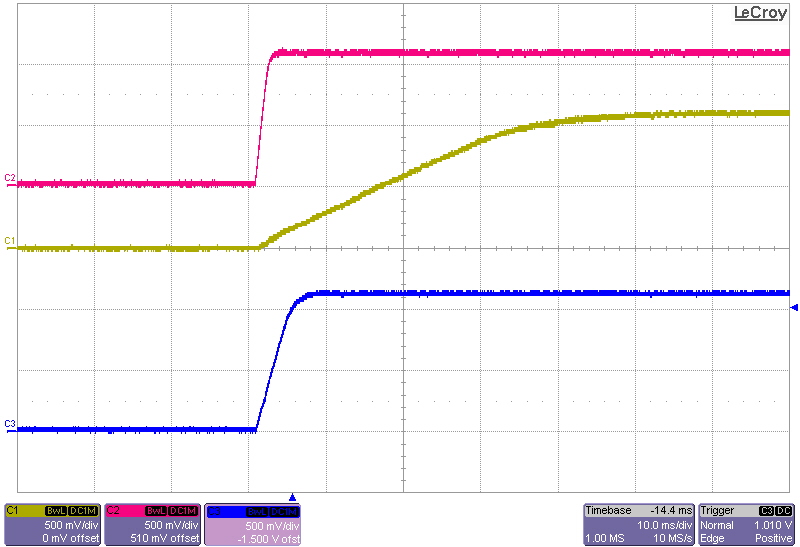
All the equations used to calculate component values in the PMP8275 design are located in the “Design Procedures” section of the various IC’s datasheets. The datasheet of the LM10011 details how to design the feedback network of the system.

# 1 Startup

Input voltage = 12V

Output voltage = 1.1V

Load current = 0A



C1: VOUT\_5A; C2:VOUT\_3A; C3:VOUT\_3A\_MODULE

# 2 Efficiency

The efficiency is shown in the figure below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| VIN | IVIN | ILOAD | VOUT | EFFI% |
| 4.500 | 0.002 | 0.005 | 0.977 | 54.852 |
| 4.500 | 0.030 | 0.118 | 0.975 | 84.307 |
| 4.500 | 0.055 | 0.218 | 0.970 | 85.637 |
| 4.500 | 0.130 | 0.518 | 0.970 | 85.926 |
| 4.500 | 0.197 | 0.769 | 0.970 | 84.028 |
| 4.500 | 0.269 | 1.019 | 0.970 | 81.688 |
| 4.500 | 0.345 | 1.269 | 0.970 | 79.315 |
| 4.500 | 0.426 | 1.519 | 0.970 | 76.869 |
| 4.500 | 0.513 | 1.769 | 0.970 | 74.416 |
| 4.500 | 0.605 | 2.020 | 0.970 | 71.972 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| VIN | IVIN | ILOAD | VOUT | EFFI% |
| 10.005 | 0.002 | 0.005 | 0.980 | 23.876 |
| 10.005 | 0.015 | 0.118 | 0.978 | 75.404 |
| 10.005 | 0.027 | 0.219 | 0.972 | 78.678 |
| 10.005 | 0.061 | 0.519 | 0.972 | 82.175 |
| 10.005 | 0.092 | 0.769 | 0.972 | 81.603 |
| 10.005 | 0.124 | 1.020 | 0.972 | 80.196 |
| 10.005 | 0.157 | 1.270 | 0.971 | 78.329 |
| 10.005 | 0.193 | 1.520 | 0.971 | 76.368 |
| 10.005 | 0.231 | 1.771 | 0.971 | 74.313 |
| 10.005 | 0.272 | 2.021 | 0.971 | 72.192 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| VIN | IVIN | ILOAD | VOUT | EFFI% |
| 14.505 | 0.002 | 0.004 | 0.980 | 14.480 |
| 14.505 | 0.012 | 0.119 | 0.979 | 69.276 |
| 14.505 | 0.020 | 0.220 | 0.975 | 73.521 |
| 14.505 | 0.044 | 0.520 | 0.973 | 78.867 |
| 14.505 | 0.065 | 0.770 | 0.973 | 78.904 |
| 14.505 | 0.088 | 1.020 | 0.973 | 77.923 |
| 14.505 | 0.112 | 1.271 | 0.973 | 76.360 |
| 14.505 | 0.137 | 1.521 | 0.972 | 74.577 |
| 14.505 | 0.163 | 1.770 | 0.972 | 72.587 |
| 14.505 | 0.192 | 2.021 | 0.972 | 70.590 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| VIN | IVIN | ILOAD | VOUT | EFFI% |
| 4.500 | 0.002 | 0.004 | 0.973 | 42.209 |
| 4.500 | 0.031 | 0.120 | 0.972 | 83.726 |
| 4.500 | 0.056 | 0.221 | 0.972 | 85.305 |
| 4.500 | 0.130 | 0.521 | 0.970 | 86.659 |
| 4.500 | 0.192 | 0.771 | 0.970 | 86.388 |
| 4.500 | 0.258 | 1.022 | 0.969 | 85.357 |
| 4.500 | 0.326 | 1.272 | 0.969 | 83.997 |
| 4.500 | 0.397 | 1.522 | 0.969 | 82.512 |
| 4.500 | 0.471 | 1.772 | 0.969 | 80.958 |
| 4.500 | 0.548 | 2.022 | 0.968 | 79.371 |
| 4.500 | 0.629 | 2.272 | 0.968 | 77.751 |
| 4.500 | 0.713 | 2.522 | 0.968 | 76.130 |
| 4.500 | 0.801 | 2.773 | 0.968 | 74.465 |
| 4.500 | 0.893 | 3.023 | 0.967 | 72.805 |
|  |  |  |  |  |
|  |  |  |  |  |
| VIN | IVIN | ILOAD | VOUT | EFFI% |
| 10.005 | 0.002 | 0.003 | 0.975 | 16.201 |
| 10.005 | 0.016 | 0.121 | 0.974 | 75.386 |
| 10.005 | 0.027 | 0.221 | 0.974 | 78.965 |
| 10.005 | 0.062 | 0.521 | 0.972 | 81.916 |
| 10.005 | 0.090 | 0.771 | 0.972 | 83.097 |
| 10.005 | 0.120 | 1.022 | 0.972 | 82.975 |
| 10.005 | 0.150 | 1.272 | 0.971 | 82.328 |
| 10.005 | 0.182 | 1.522 | 0.971 | 81.380 |
| 10.005 | 0.214 | 1.773 | 0.971 | 80.262 |
| 10.005 | 0.248 | 2.022 | 0.970 | 79.045 |
| 10.005 | 0.283 | 2.273 | 0.970 | 77.736 |
| 10.005 | 0.320 | 2.523 | 0.970 | 76.375 |
| 10.005 | 0.358 | 2.773 | 0.969 | 74.976 |
| 10.005 | 0.398 | 3.024 | 0.969 | 73.549 |
|  |  |  |  |  |
| VIN | IVIN | ILOAD | VOUT | EFFI% |
| 14.505 | 0.002 | 0.003 | 0.975 | 11.347 |
| 14.505 | 0.012 | 0.121 | 0.975 | 69.497 |
| 14.505 | 0.020 | 0.221 | 0.975 | 73.966 |
| 14.505 | 0.045 | 0.522 | 0.974 | 77.949 |
| 14.504 | 0.065 | 0.772 | 0.973 | 79.925 |
| 14.504 | 0.085 | 1.022 | 0.973 | 80.236 |
| 14.505 | 0.107 | 1.273 | 0.973 | 79.874 |
| 14.505 | 0.129 | 1.523 | 0.972 | 79.155 |
| 14.505 | 0.152 | 1.773 | 0.972 | 78.201 |
| 14.504 | 0.176 | 2.023 | 0.972 | 77.104 |
| 14.504 | 0.201 | 2.273 | 0.971 | 75.892 |
| 14.505 | 0.226 | 2.523 | 0.971 | 74.674 |
| 14.505 | 0.253 | 2.774 | 0.971 | 73.308 |
| 14.505 | 0.281 | 3.024 | 0.970 | 71.937 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| VIN | IVIN | ILOAD | VOUT | EFFI% |
| 4.500 | 0.002 | 0.003 | 0.979 | 35.718 |
| 4.500 | 0.032 | 0.122 | 0.978 | 82.829 |
| 4.500 | 0.057 | 0.222 | 0.978 | 84.303 |
| 4.500 | 0.130 | 0.522 | 0.974 | 86.797 |
| 4.500 | 0.192 | 0.773 | 0.974 | 87.020 |
| 4.500 | 0.257 | 1.023 | 0.974 | 86.364 |
| 4.500 | 0.323 | 1.273 | 0.974 | 85.425 |
| 4.500 | 0.391 | 1.523 | 0.974 | 84.320 |
| 4.500 | 0.462 | 1.773 | 0.974 | 83.154 |
| 4.500 | 0.534 | 2.024 | 0.974 | 81.966 |
| 4.500 | 0.610 | 2.273 | 0.974 | 80.712 |
| 4.500 | 0.687 | 2.524 | 0.974 | 79.476 |
| 4.500 | 0.767 | 2.774 | 0.973 | 78.220 |
| 4.500 | 0.850 | 3.025 | 0.973 | 76.987 |
| 4.500 | 0.935 | 3.275 | 0.973 | 75.732 |
| 4.500 | 1.023 | 3.524 | 0.973 | 74.467 |
| 4.500 | 1.114 | 3.774 | 0.973 | 73.220 |
| 4.500 | 1.209 | 4.025 | 0.973 | 71.968 |
|  |  |  |  |  |
|  |  |  |  |  |
| VIN | IVIN | ILOAD | VOUT | EFFI% |
| 10.005 | 0.002 | 0.003 | 0.980 | 12.963 |
| 10.005 | 0.016 | 0.122 | 0.979 | 73.661 |
| 10.005 | 0.028 | 0.222 | 0.979 | 76.928 |
| 10.005 | 0.063 | 0.522 | 0.975 | 80.429 |
| 10.005 | 0.092 | 0.773 | 0.975 | 82.118 |
| 10.005 | 0.121 | 1.023 | 0.975 | 82.449 |
| 10.005 | 0.151 | 1.273 | 0.975 | 82.164 |
| 10.005 | 0.182 | 1.523 | 0.975 | 81.521 |
| 10.005 | 0.214 | 1.773 | 0.974 | 80.687 |
| 10.005 | 0.247 | 2.024 | 0.974 | 79.802 |
| 10.005 | 0.281 | 2.274 | 0.974 | 78.820 |
| 10.005 | 0.316 | 2.524 | 0.974 | 77.790 |
| 10.005 | 0.352 | 2.774 | 0.974 | 76.715 |
| 10.005 | 0.389 | 3.025 | 0.974 | 75.644 |
| 10.005 | 0.428 | 3.275 | 0.974 | 74.509 |
| 10.005 | 0.467 | 3.525 | 0.973 | 73.393 |
| 10.005 | 0.508 | 3.775 | 0.973 | 72.262 |
| 10.005 | 0.550 | 4.025 | 0.973 | 71.111 |
|  |  |  |  |  |
| VIN | IVIN | ILOAD | VOUT | EFFI% |
| 14.505 | 0.002 | 0.003 | 0.980 | 10.007 |
| 14.505 | 0.012 | 0.122 | 0.979 | 67.745 |
| 14.504 | 0.021 | 0.223 | 0.979 | 71.845 |
| 14.505 | 0.046 | 0.523 | 0.976 | 76.102 |
| 14.504 | 0.067 | 0.774 | 0.976 | 78.212 |
| 14.504 | 0.087 | 1.024 | 0.976 | 78.972 |
| 14.505 | 0.108 | 1.274 | 0.976 | 79.014 |
| 14.505 | 0.131 | 1.524 | 0.976 | 78.550 |
| 14.504 | 0.153 | 1.774 | 0.976 | 77.974 |
| 14.505 | 0.176 | 2.024 | 0.975 | 77.161 |
| 14.504 | 0.200 | 2.274 | 0.975 | 76.295 |
| 14.505 | 0.225 | 2.525 | 0.975 | 75.315 |
| 14.505 | 0.251 | 2.775 | 0.975 | 74.304 |
| 14.504 | 0.277 | 3.025 | 0.975 | 73.255 |
| 14.505 | 0.305 | 3.275 | 0.974 | 72.198 |
| 14.504 | 0.333 | 3.525 | 0.974 | 71.122 |
| 14.505 | 0.362 | 3.775 | 0.974 | 70.020 |
| 14.505 | 0.392 | 4.025 | 0.974 | 68.869 |

# 3 Load Regulation (DC Accuracy with LM10011)

The max error that can be tolerated in terms of Vout on the DSP was given to be 5%. The goal of the design was to keep the DC error to a max 2.5%, in order to allow for room to compensate for the AC error.

There are 4 main contributors to the final error seen on the output. They are: the error caused by the LM10011, feedback voltage error, the error of resistors in the feedback network, and the load regulation error from the IC. If the compilation of these errors are more than the targeted 2.5%, they can be decreased by using higher precision resistors(.1% or .5%), choosing an IC to minimize the feedback voltage error, as well as the load regulation error.

The expected output voltage, in the tables below, was based off the 6 bit-VCNTL pin specifications listed in the C6657 data manual. It also shows the total %DC error seen on the various outputs of the PMP8319 at different LM10011 codes compared to the expected voltages. The data was taken at no-load as well as full load. Please note that all three ICs on the design cannot output less than their Vref(0.765V). The C6657 Data Manual states that it will never request for a voltage below 0.85V, well within the range of all 3 output voltage ranges. The feedback resistors were precise to 1%.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | LM10011 Code | Expected output voltage | Vout\_act (no load) | %ERROR (No load) | Vout\_act (full load) | %ERROR (Full load) |
| VIDA,B,C=0 | N/A | N/A | N/A | N/A | N/A | N/A |
| VIDA=1 | N/A | N/A | N/A | N/A | N/A | N/A |
| VIDB=1 | 18 | 0.8150 | 0.82 | 0.613 | 0.8120 | 0.368 |
| VIDA,B=1 | 27 | 0.8730 | 0.878 | 0.573 | 0.8690 | 0.458 |
| VIDC=1 | 36 | 0.9300 | 0.935 | 0.538 | 0.9260 | 0.430 |
| VIDB,C=1 | 54 | 1.0460 | 1.05 | 0.382 | 1.0410 | 0.478 |
| VIDA,B,C=1 | 63 | 1.1030 | 1.107 | 0.363 | 1.0980 | 0.453 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | LM10011 Code | Expected output voltage | Vout\_act (no load) | %ERROR (No load) | Vout\_act (full load) | %ERROR (Full load) |
| VIDA,B,C=0 | N/A | N/A | N/A | N/A | N/A | N/A |
| VIDA=1 | N/A | N/A | N/A | N/A | N/A | N/A |
| VIDB=1 | 18 | 0.8150 | 0.815 | 0.000 | 0.8090 | 0.736 |
| VIDA,B=1 | 27 | 0.8730 | 0.879 | 0.687 | 0.8730 | 0.000 |
| VIDC=1 | 36 | 0.9300 | 0.93 | 0.000 | 0.9240 | 0.645 |
| VIDB,C=1 | 54 | 1.0460 | 1.045 | 0.096 | 1.0390 | 0.669 |
| VIDA,B,C=1 | 63 | 1.1030 | 1.102 | 0.091 | 1.0970 | 0.544 |

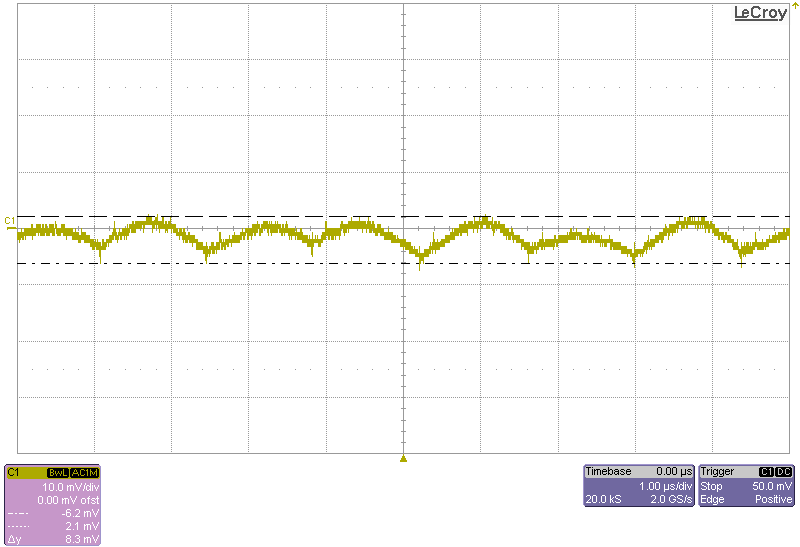
|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | LM10011 Code | Expected output voltage | Vout\_act (no load) | %ERROR (No load) | Vout\_act (full load) | %ERROR (Full load) |
| VIDA,B,C=0 | N/A | N/A | N/A | N/A | N/A | N/A |
| VIDA=1 | N/A | N/A | N/A | N/A | N/A | N/A |
| VIDB=1 | 18 | 0.8150 | 0.82 | 0.613 | 0.8140 | 0.123 |
| VIDA,B=1 | 27 | 0.8730 | 0.877 | 0.458 | 0.8720 | 0.115 |
| VIDC=1 | 36 | 0.9300 | 0.935 | 0.538 | 0.9290 | 0.108 |
| VIDB,C=1 | 54 | 1.0460 | 1.049 | 0.287 | 1.0430 | 0.287 |
| VIDA,B,C=1 | 63 | 1.1030 | 1.106 | 0.272 | 1.1000 | 0.272 |

# 4 Output Voltage Ripple

Input voltage = 10V

Output voltage = 1V

Load current = 2A

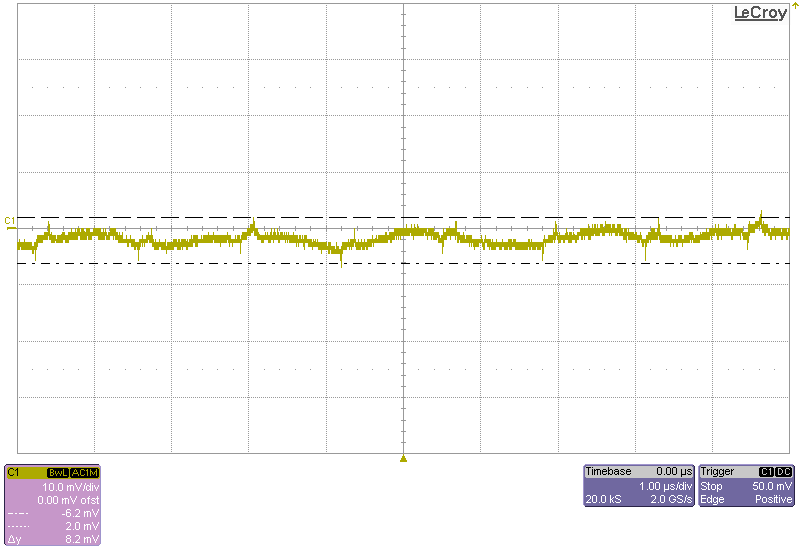


C1: VOUT\_2A

Input voltage = 10V

Output voltage = 1V

Load current = 3A

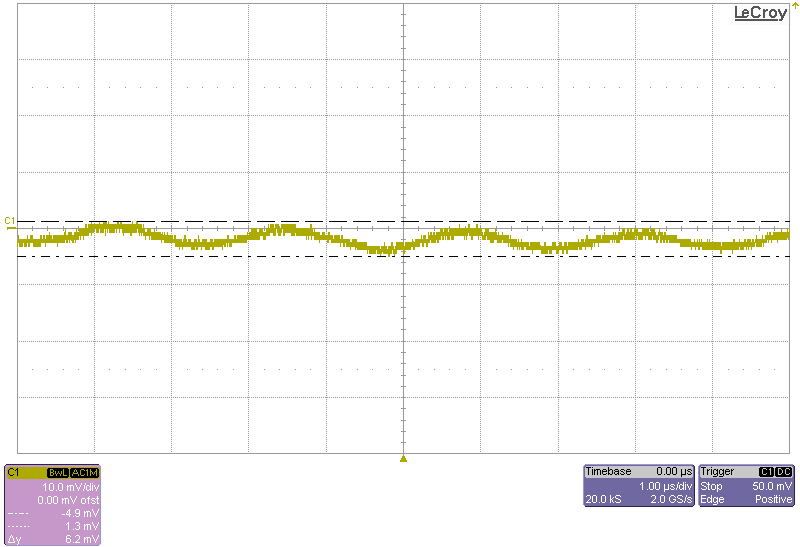


C1: VOUT\_3A

Input voltage = 10V

Output voltage = 1V

Load current = 4A

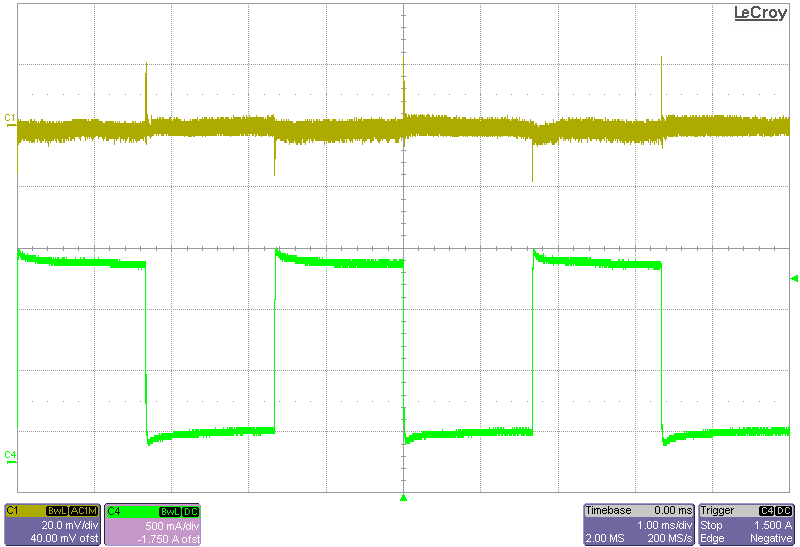


C1: VOUT\_4A

# 5 Load Transients

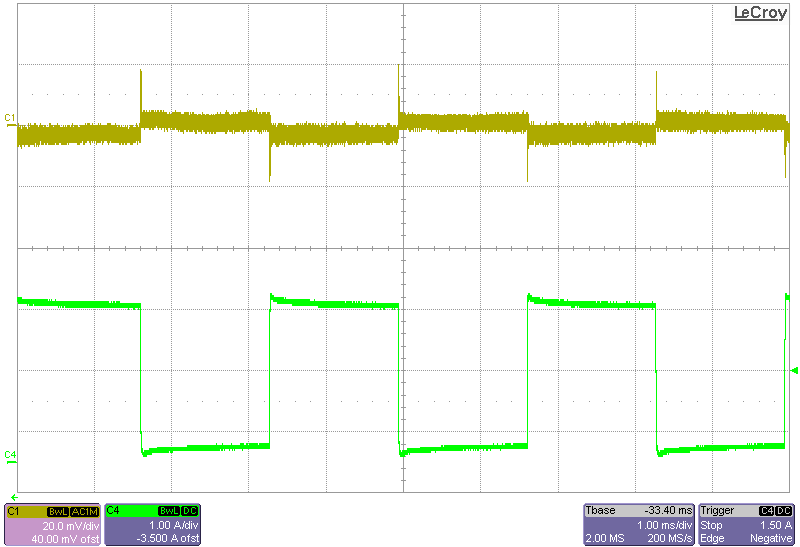
Channel 1 : Vout\_2A (AC coupled)

Channel 4 : Load current



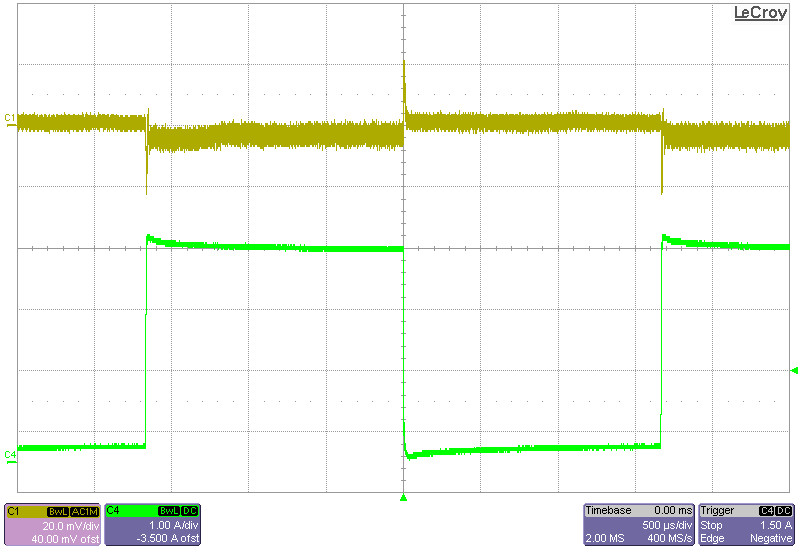
Channel 1 : Vout\_3A (AC coupled)

Channel 4 : Load current



Channel 1 : Vout\_3A (AC coupled)

Channel 4 : Load current



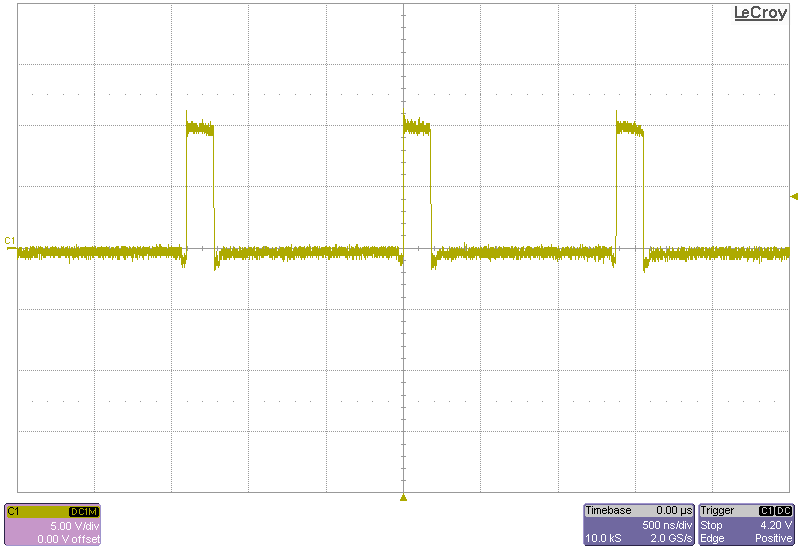
# 6 Switch Node Waveforms

The following figures show the full bandwidth switch node waveforms at:

Input voltage = 10V

Output voltage = 1V

Load current = 2A (full BW)

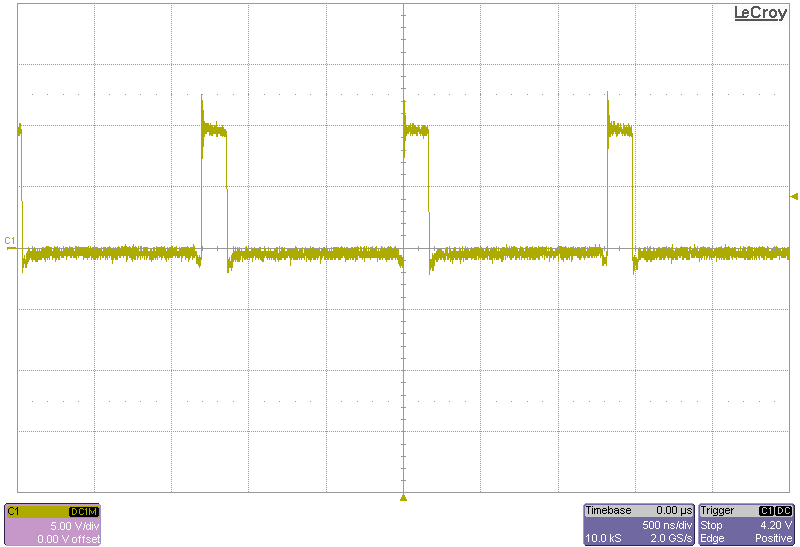


C1: VOUT\_2A

Input voltage = 10V

Output voltage = 1V

Load current = 3A (full BW)

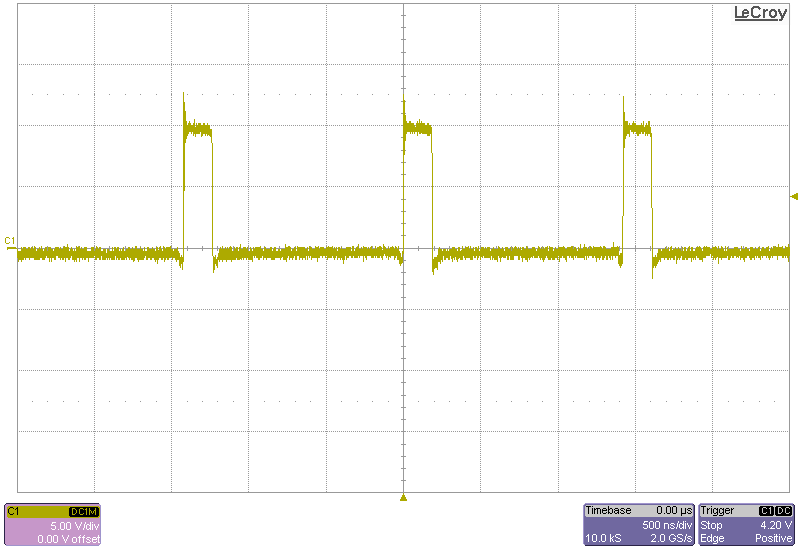


C1: VOUT\_3A

Input voltage = 10V

Output voltage = 1V

Load current = 4A (full BW)



C1: VOUT\_4A

**7 Control Loop Frequency Response**

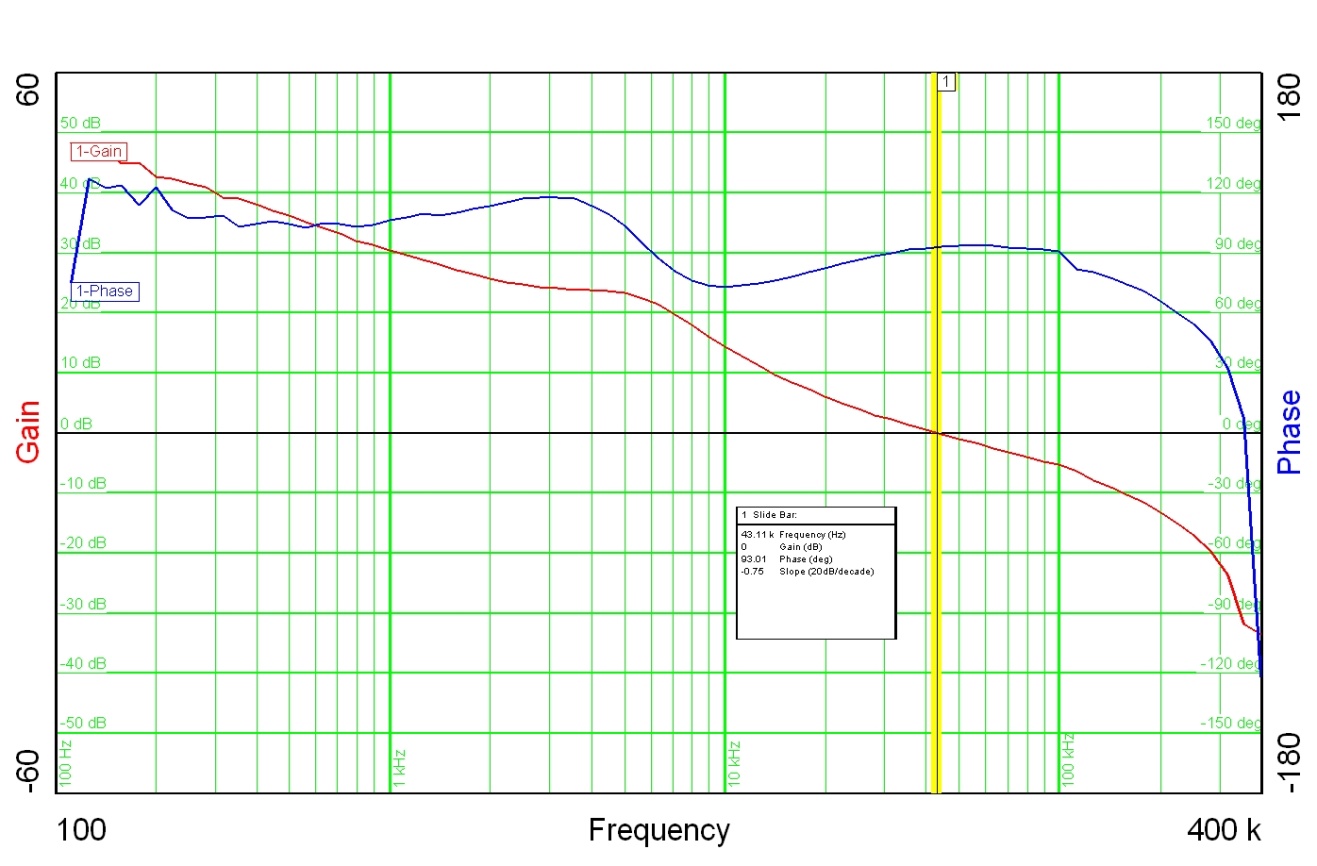
Input voltage = 10VDC

Output voltage = 1V

Load current = 25A

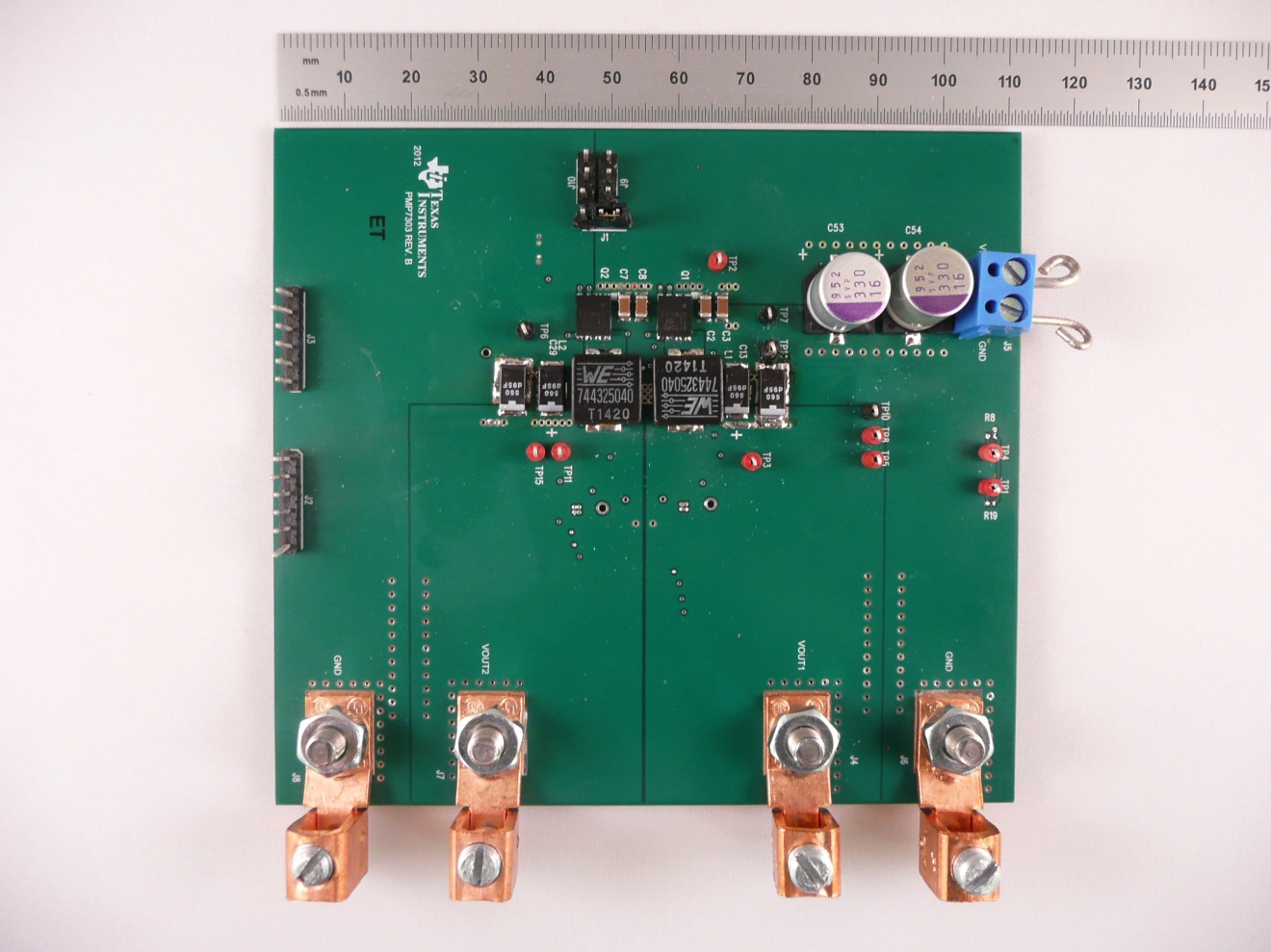
Phase margin = 93.01°

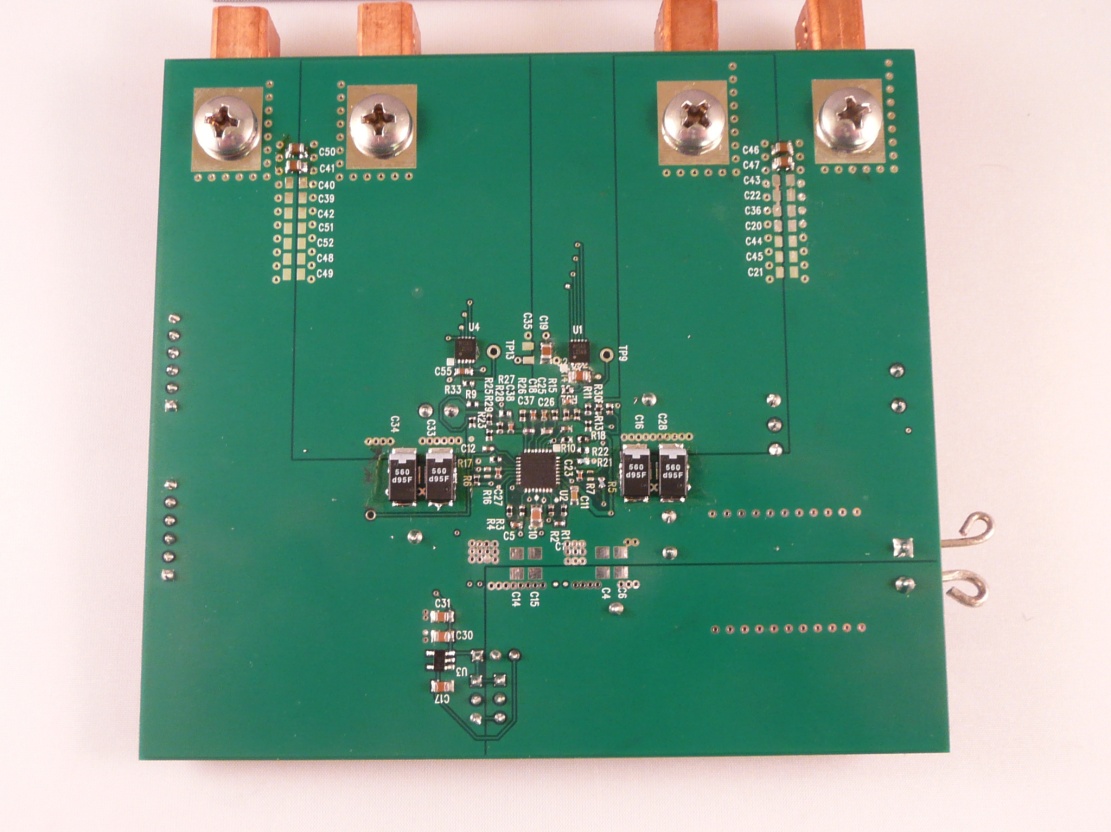
Bandwidth = 43.11kHz



**8 Photo**

The images below show the top and bottom view, respectively, of the PMP7303 REVB prototype board.





**9 Thermal Analysis**

The images below show the infrared images (top and bottom, respectively) taken from the FlexCam after 10min at full load (1V@25A). Input voltage = 10 VDC.

