Test Data
For PMP10596
01/22/2015

TEXAS INSTRUMENTS

Overview

The PMP10596 reference design is a LED driver based on SIMPLE SWITCHER® LM46002 buck regulator. The driver board takes 24V +/-25% input voltage, and supplies700mA output current to drive up to 4 LEDs in series. The LM46002 is a 60V, 2A synchronous buck regulator with integrated FETs, and in this design, it is configured as a high efficiency constant current converter. It is accomplished by using the voltage across a current sense resistor as the feedback signal. To reduce the sense resistor power loss, a 2V voltage reference is used to bias the FB pin via a resistor network, and, as a result, the equivalent feedback reference voltage becomes 0.35V, lower than the 1V feedback of the LM46002. The reference board employs 3 dimming schemes, which allows the output current to be adjusted via the potentiometer, an analog voltage or a PWM signal. It offers easy and flexible control to dim the LED brightness. The design also adds output overvoltage protection from LED open-circuit failure.

Power Specification

Vin range:	18V – 30V, 24V (nominal)
Output current:	700mA max (constant current)
Output voltage:	15.2V (nominal, with 4x LED string)
Switching Frequency:	500 kHz

Reference Board

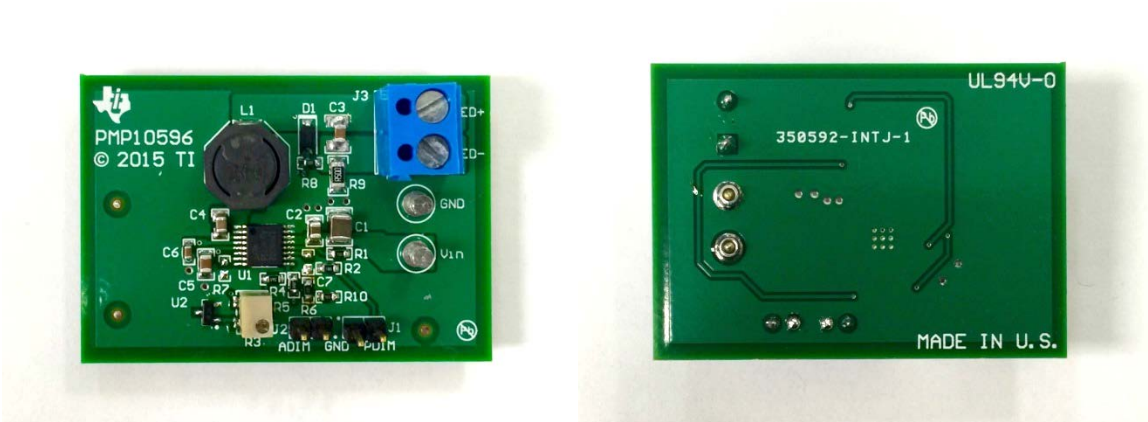

Figure 1 Board photos

The board size is 50x35 mm, and the component area is about 21x27 mm.

Board Configuration and Test Setup

The positive and return of the input supply should be connected to the Vin and GND test point respectively on the board. The LED string should be connected to J3, LED+ to the LED anode and LED- to the LED cathode.

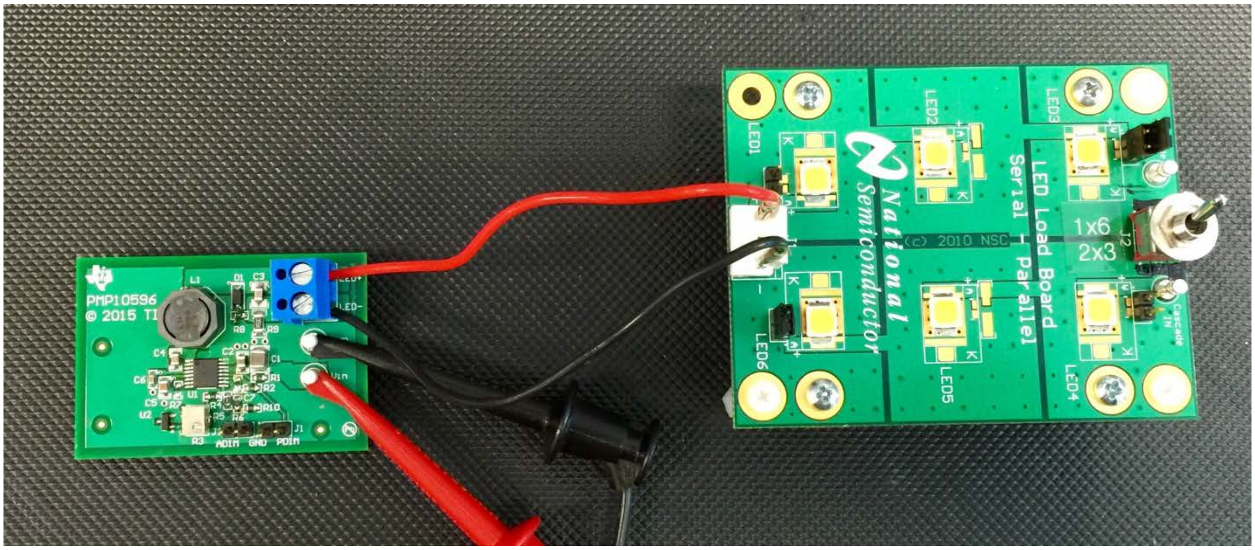

Figure 2 Test setup

LED Dimming:

The PMP10596 board provides 3 dimming methods.

1. R3 potentiometer: Tuning R3 can set the output current level. It will change the pull-up voltage of R4 from 2V to 3.2V (Vcc), and it affects FB pin voltage and therefore can adjust the output current from full scale 700mA to 0A. Turning the knob clockwise can increase the output current, and turning it counterclockwise lowers the current.
2. Analog voltage dimming: Applying an analog voltage signal to the connector J2, from ADIM to GND, can dim the output LED current. The voltage from 0V to 1V will vary the output current from 700mA to 0A. The board is designed that the connector J2 can be left open or shorted by jumper, and the output current will be slightly less than 700mA (about 680mA) when left open.
3. PWM dimming: The third dimming method is to inject a PWM voltage signal to the connector J1, from PDIM to GND. As J1 is connected to the EN pin of the LM46002, the PWM signal will turn on and off the converter. The PWM signal should have a voltage level >2.5V to be above the enable threshold, and a frequency 100Hz - 150Hz. The human eyes cannot detect the LED blinking when the frequency is faster than 100Hz, and the eyes will average out the brightness and see it as a dimmed light. But the LM46002 has an internal soft start timer of 4.2ms, the PWM frequency cannot be higher than 150Hz, otherwise the LED driver will not have enough time to recover and supply current within one cycle. The dimming level can be adjusted by the duty cycle

of the PWM signal. Due to the soft start, the PWM method doesn't provide the fine granularity as the other two methods.

The reference board was tested using a LED test board as shown in Figure 2. The LED board has 6 Cree XLamp MX-6 LEDs (MX6AWT-A1-0000-000BE5), and can be configured flexibly as one or multiple LEDs in series connection.

Efficiency

The efficiency measurement was taken at 18V, 24V and 30V inputs when driving different number of LEDs. For 4x LEDs, the peak efficiency is about 94%.

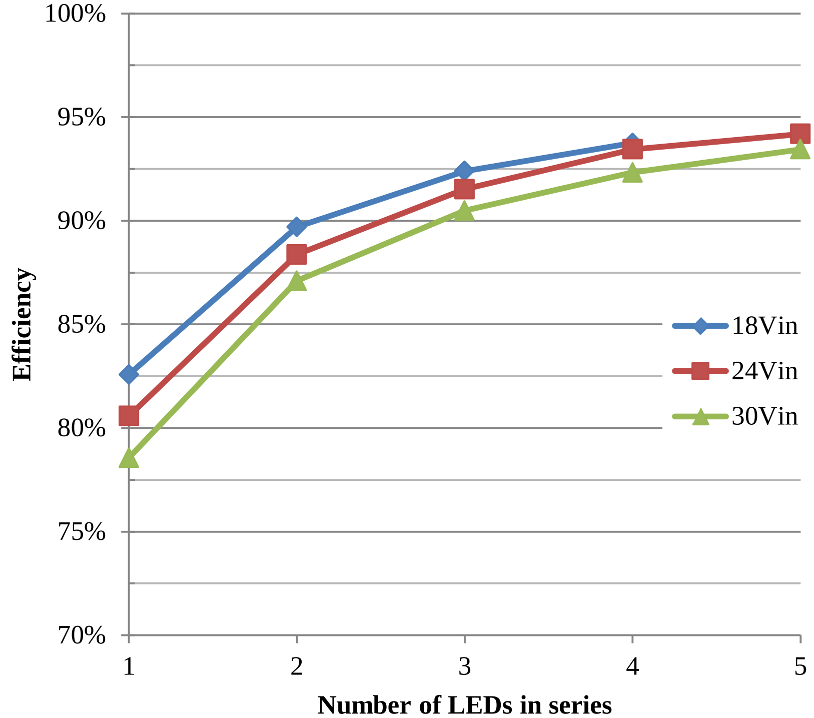

Figure 3 Power efficiency at 700mA output

Thermal

The thermal image was taken at 23°C room temperature, no air flow. The board was operating at 24V input, 700mA output, driving 4x LEDs.

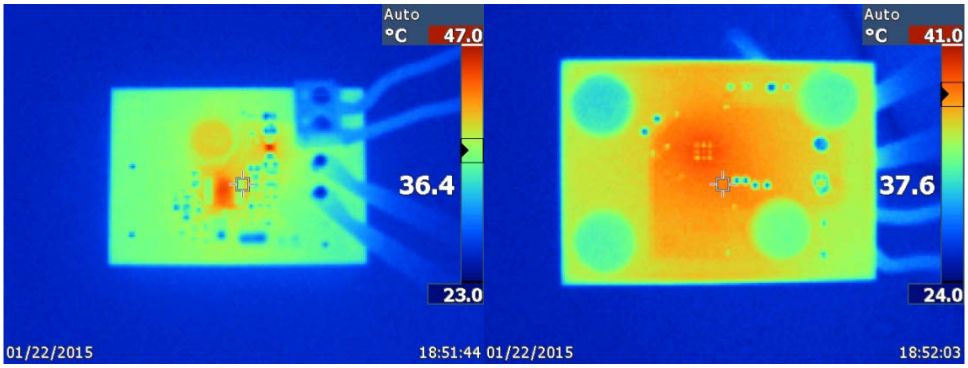

Figure 4 Board thermal images

Dimming

The board was tested at 24V input, driving 4x LEDs. The analog voltage dimming result is shown in Figure 5.

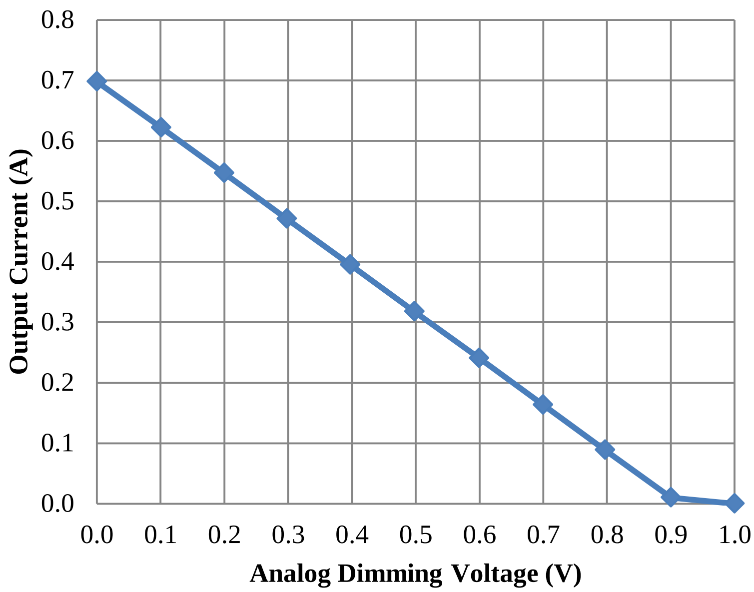

Figure 5 Analog dimming voltage vs. output current

The PWM dimming was tested by injecting a 100Hz, 5V PWM pulse to J1 connector. By varying the duty cycle the average output current changed accordingly. The test waveforms shown were at 70% and 90% duty cycle. Ch1 (yellow) is the PWM signal, and Ch4 (magenta) is the output current.

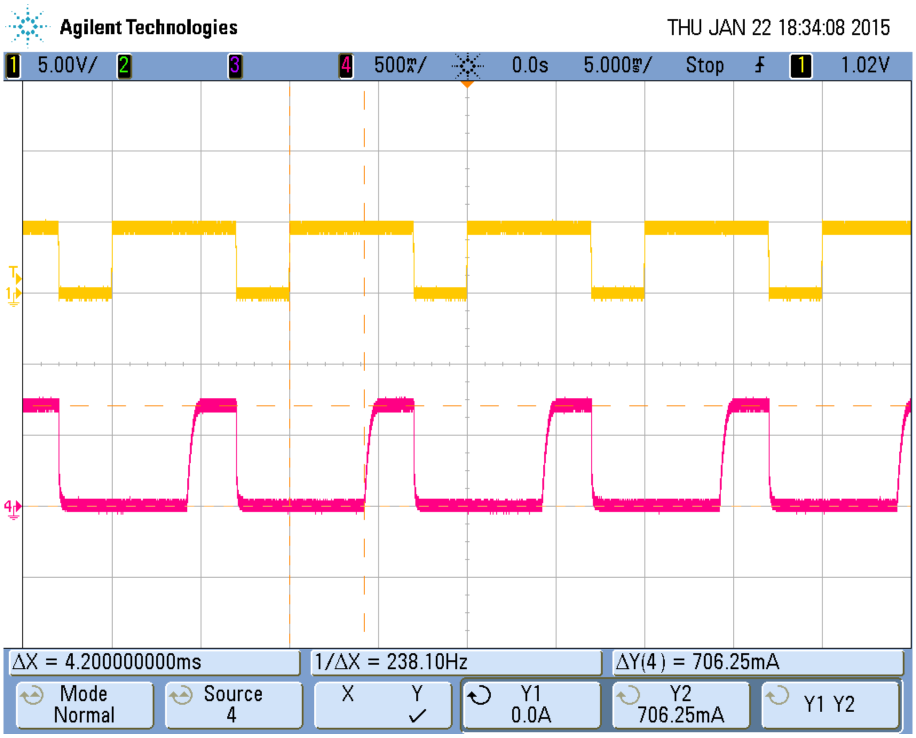

Figure 6 PWM at 70% duty cycle, average output current at 0.08A

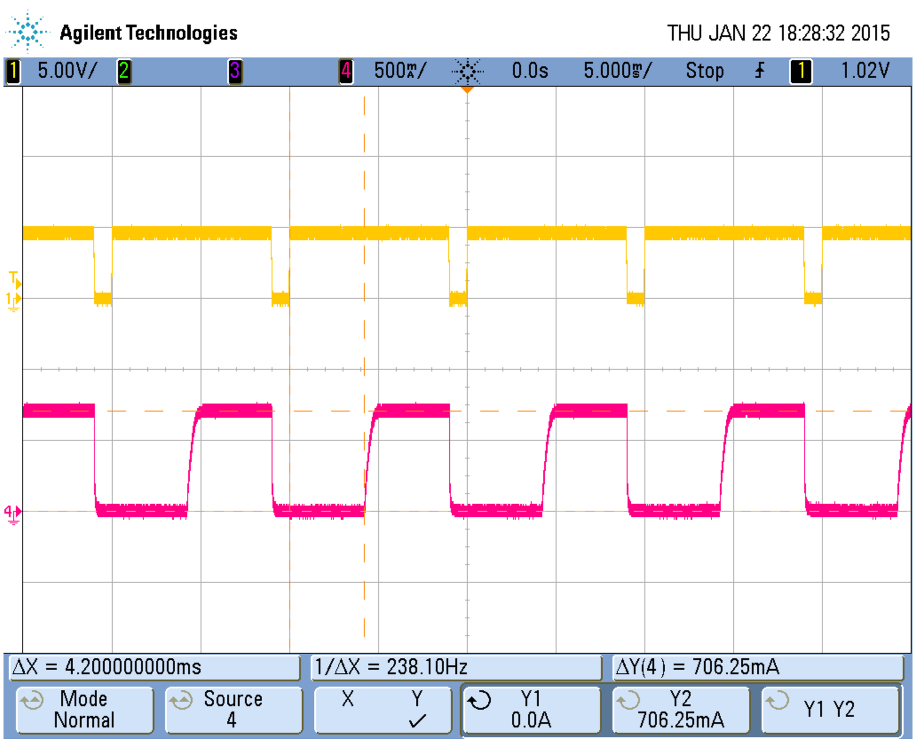

Figure 7 PWM at 90% duty cycle, average output current at 0.32A

Start Up

Ch1 (yellow) is the input voltage, Ch2 (green) is the switch node voltage, and Ch4 (magenta) is the output current.

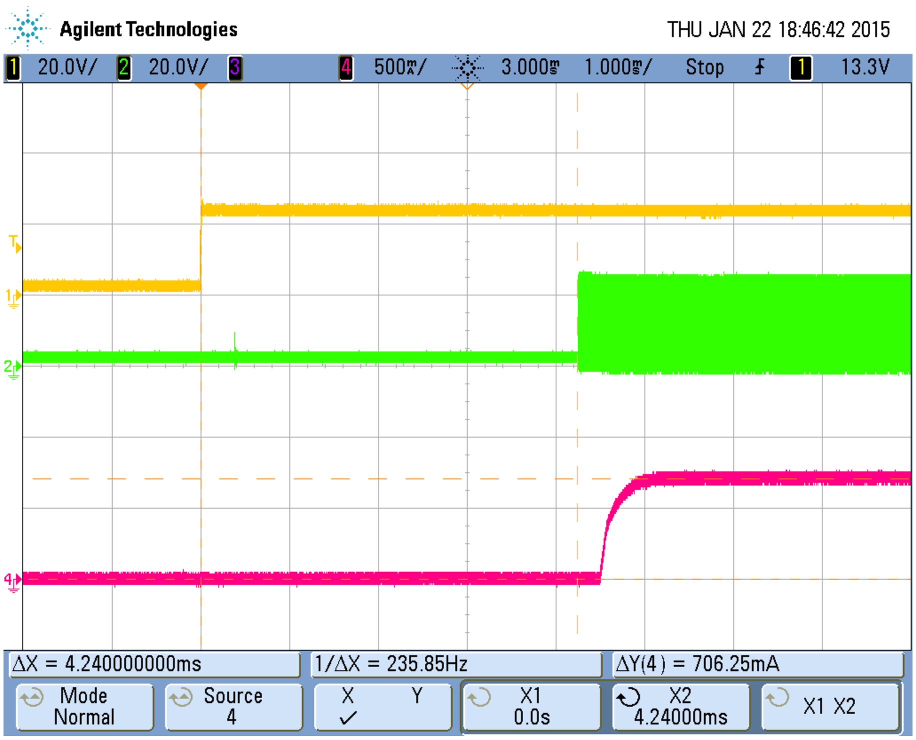

Figure 8 Start up at 24Vin, 700mA, 4x LEDs

Switching Waveforms

Ch1 (yellow) is the switch node voltage.

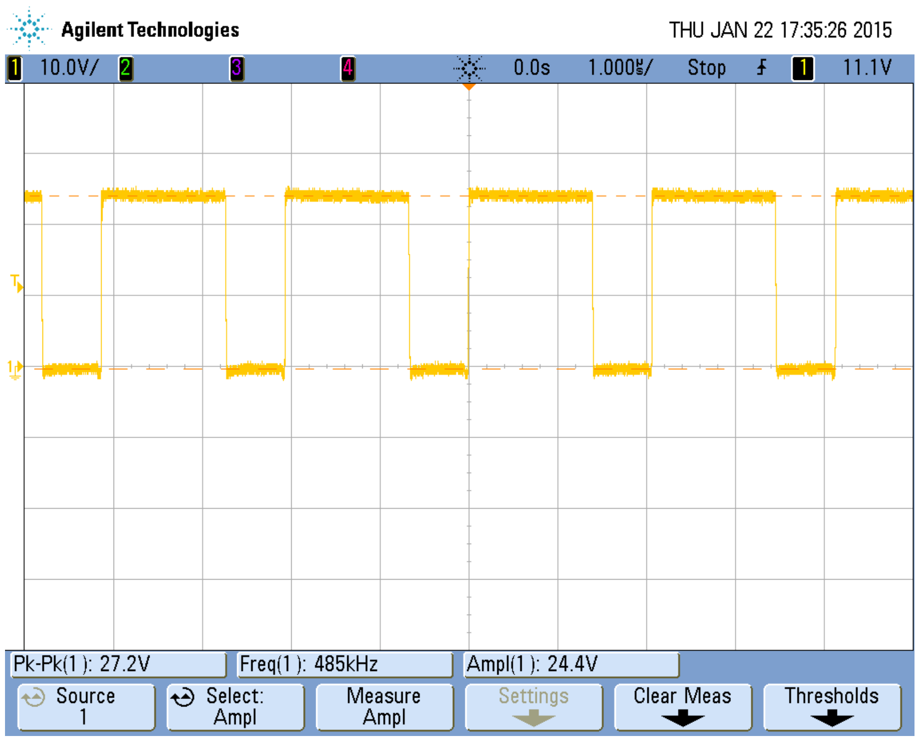

Figure 9 Switching waveform at 24Vin, 700mA, 4x LEDs

Load Transient

The load transient was tested by applying a 500mV square voltage signal to the ADIM connector. It stepped the output current from 300mA to 700mA. Ch1 (yellow) is the LED+ to LED- output voltage in AC mode, and Ch4 (magenta) is the output current.

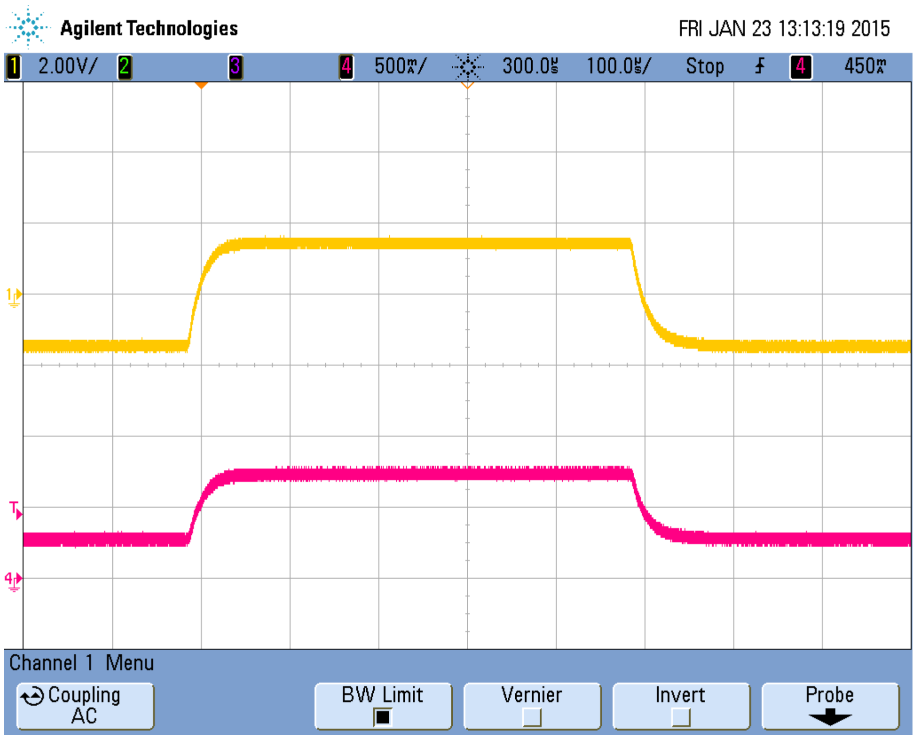

Figure 10 Output load transient at 24Vin, 4x LEDs

Output and Input Ripples

The output/input ripples were measured directly at the output/input capacitors. Ch1 (yellow) is output/input voltage ripple in AC mode, and Ch4 (magenta) is the output current.

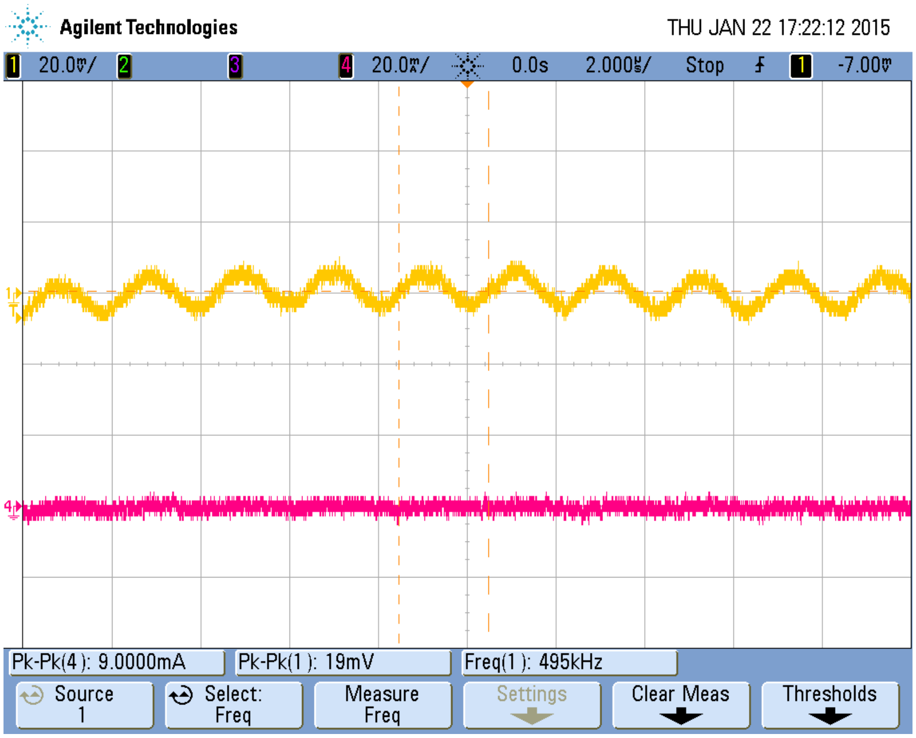

Figure 11 Output ripple at 24Vin, 700mA, 4x LEDs

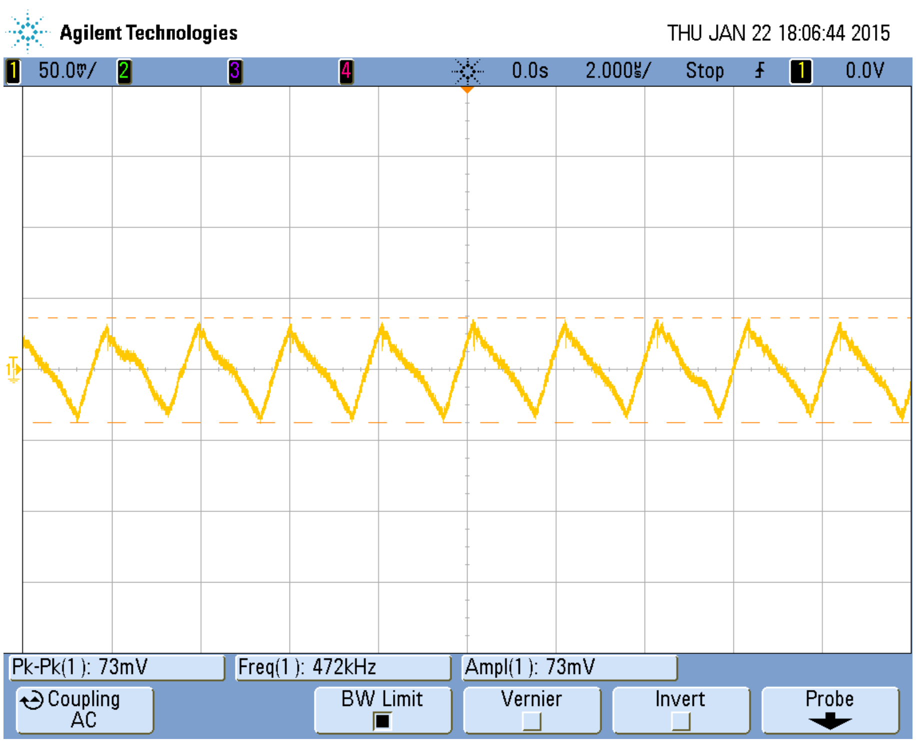

Figure 12 Input ripple at 24Vin, 700mA, 4x LEDs

Open Circuit and Short Circuit Test

The open circuit was tested at 30V input, 700mA, 4x LEDs condition, and the connected wire from the reference board to the LED board was pulled open in a sudden. Because of the Zener diode, the board entered OVP and the LED+ voltage was clamped to about 20V. Figure 13 shows the transition from normal operation to open circuit, and Figure 14 shows the steady state open circuit operation. Ch1 (yellow) is the LED+ voltage, Ch2 (green) is the switch node voltage, and Ch4 (magenta) is the output current.

Figure 13 Open circuit test from 700mA output operation

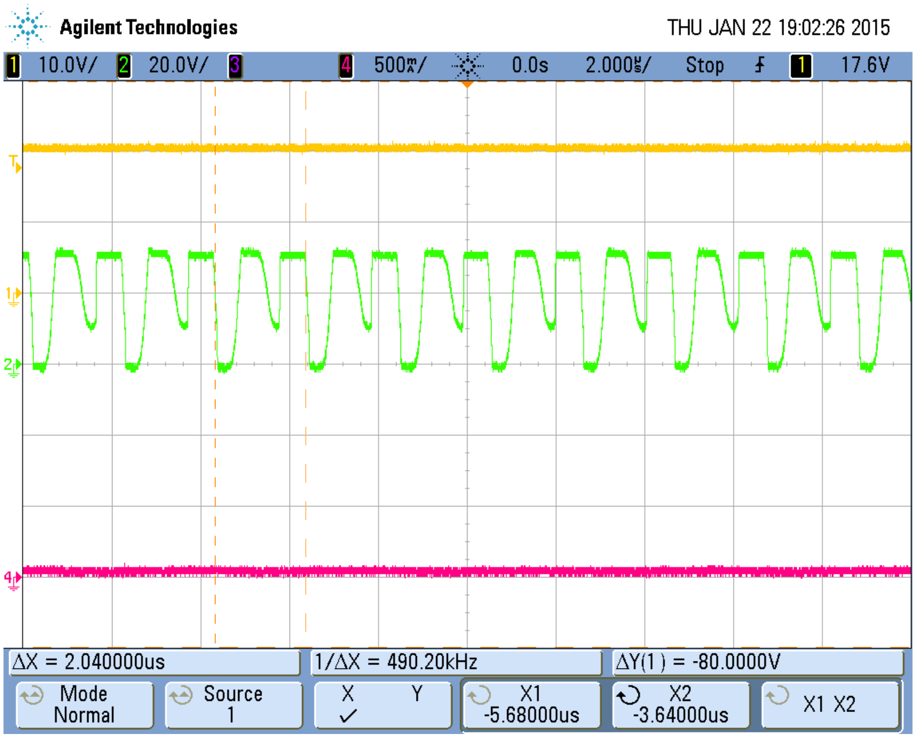

Figure 14 Open circuit operation at 30Vin

The short circuit was tested by shorting LED+ and LED- together while operating at 24V input, 700mA, and 4x LEDs condition. Since the reference board is configured as a constant current output, the short circuit current will always be limited at 700mA level. Ch1 (yellow) is the LED+ voltage, Ch2 (green) is the switch node voltage, and Ch4 (magenta) is the input current.

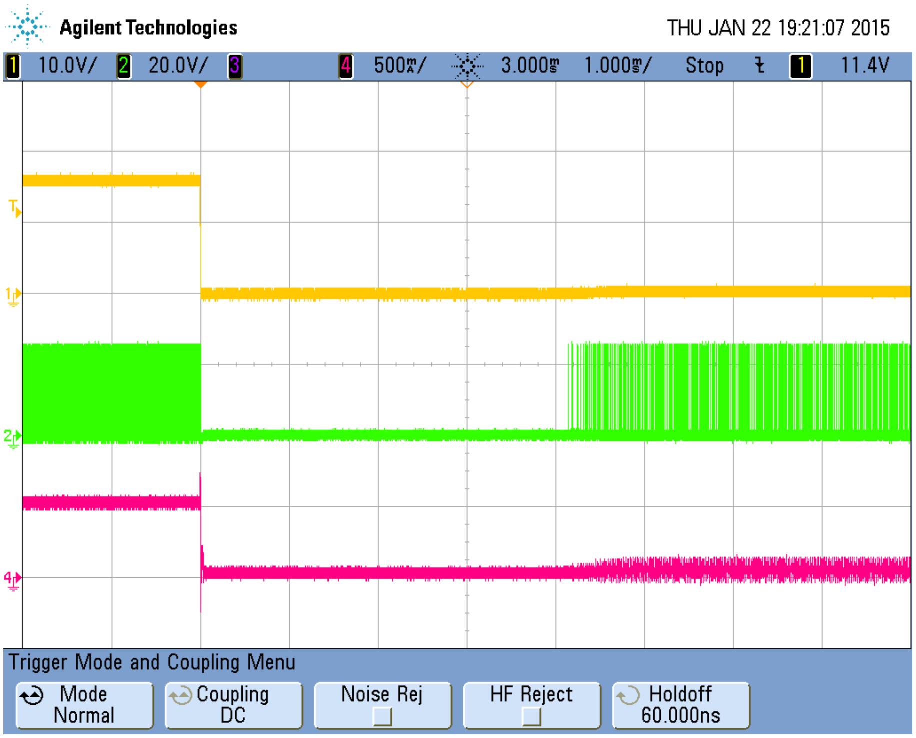

Figure 15 Short circuit test from 24Vin, 700mA, 4x LEDs

Closed Loop Response

The closed loop gain was measured by injecting a small AC signal across R8, and probed the signal using a network analyzer (AP 200). The result shows a 56 kHz bandwidth and 67 degree phase margin.

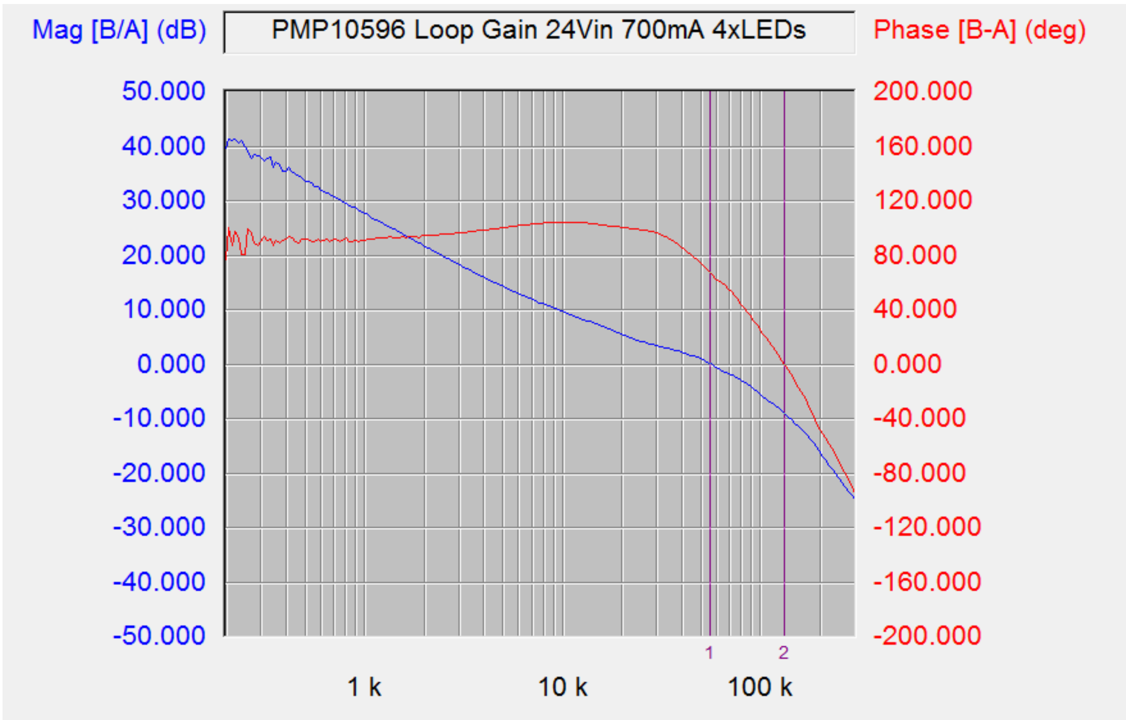

Figure 16 Closed loop response at 24Vin, 700mA, 4x LEDs

Appendix: Efficiency Test Data

#LED	Vin (V)	Iin (A)	Vout (V)	Iout (A)	Efficiency
1	18.062	0.197	4.207	0.699	82.6%
2	18.086	0.348	8.068	0.700	89.7%
3	18.010	0.501	11.895	0.700	92.4%
4	17.926	0.647	15.558	0.698	93.8%
1	24.085	0.151	4.202	0.699	80.6%
2	24.028	0.265	8.062	0.699	88.4%
3	24.058	0.375	11.815	0.699	91.5%
4	24.014	0.488	15.670	0.699	93.4%
5	24.044	0.601	19.460	0.699	94.2%
1	30.099	0.124	4.200	0.699	78.6%
2	30.053	0.215	8.060	0.698	87.1%
3	30.098	0.303	11.823	0.698	90.5%
4	30.056	0.389	15.496	0.697	92.3%
5	30.105	0.480	19.353	0.698	93.4%