Test Report: PMP31054

LLC Converter With Air-Core Transformer Reference Design (Anti-Tampering for E-Meter Applications)

Description

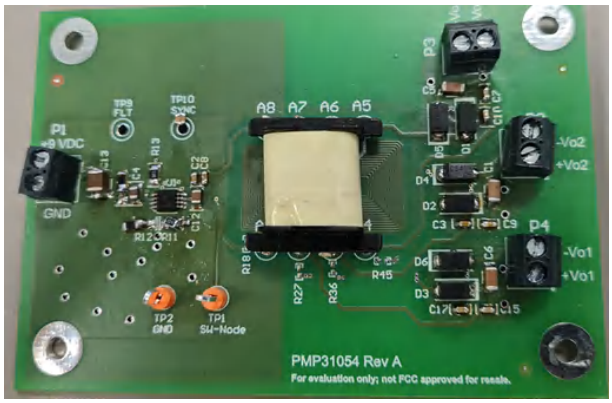
This reference design features an LLC converter controlled by the UCC25800-Q1 (open-loop LLC transformer driver for isolated bias supplies), operating with 9 V, generating three output voltages of 9.0 V with a maximum load current of 50 mA each. An air core transformer was used to avoid the core saturation in the presence of a strong external magnetic field.

Features

- Supplies three isolated outputs, each 9 V, 50 mA from single 9-V source
- Coreless transformer cannot saturate because of external static magnetic field
- Low input-output inter-winding capacitance thanks to resonant topology
- Open loop converter: no feedback compensation
- Possibility to use coreless transformer or printed windings on the PCB

Applications

- Electricity meter



Top View

Tilted View

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
V_{IN}	9 V
V_{OUT1}	9.0 V
V_{OUT2}	9.0 V
V_{OUT3}	9.0 V
I_{OUT1}	50 mA
I_{OUT2}	50 mA
I_{OUT3}	50 mA

1.2 Considerations

- To simplify the measurement process, the three output rails were shorted together. This report considers a single output voltage of 9.0 V, 150 mA.
- Transformer structure: the three secondary windings were wired together to provide a high symmetrical structure.

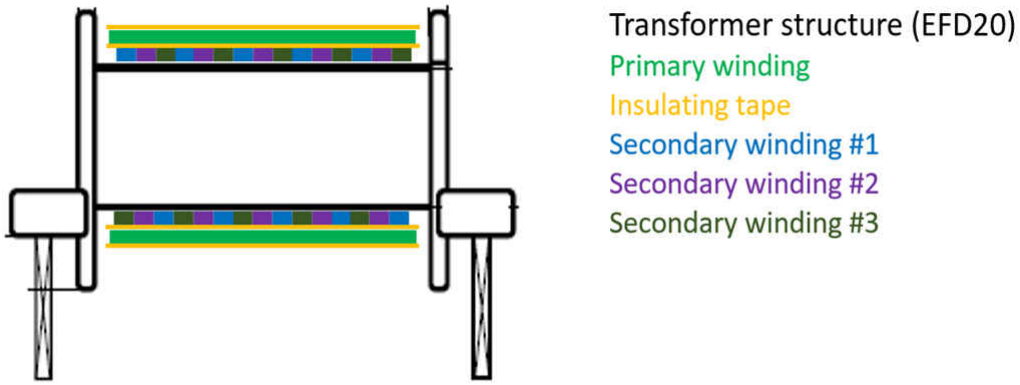


Figure 1-1. Transformer Structure

- Number of turns: primary winding (Np): 32, secondary windings (Ns): 36 (Coated copper wire, V 180 Ø, 0.20 mm)
- Measured inductance of primary winding: 5.9 µH (magnetizing), 1.59 µH (leakage)
- Measured inductance of secondary winding: 2.16 µH (leakage)

1.3 Dimensions

The size of the board is 89 mm × 61.4 mm. The 4-layer board has 35-µm copper thickness on each layer.

2 Testing and Results

2.1 Efficiency Graphs 9 V_{IN}

Efficiency is shown in the following figure.

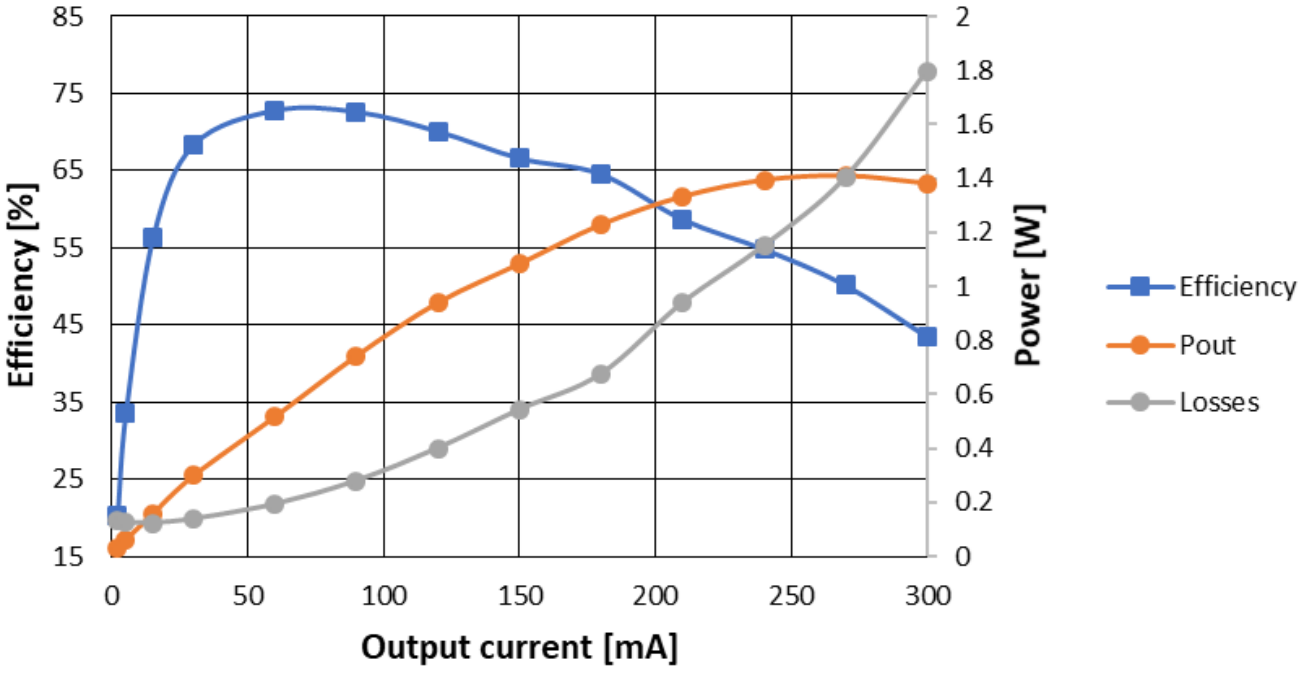


Figure 2-1. PMP31054 Efficiency Graph

2.2 Efficiency Data

Efficiency data is shown in the following table.

Input Voltage (V)	Input Current (mA)	Power (W)	Output Voltage (V)	Output Current (mA)	Output Power (W)	Losses (W)	Efficiency (%)
9.0	18.2	0.16	16.67	2.0	0.03	0.13	20.3
9.1	20.9	0.19	12.93	4.9	0.06	0.13	33.5
9.0	31.3	0.28	10.56	15.0	0.16	0.12	56.2
9.1	48.4	0.44	9.98	30.0	0.30	0.14	68.4
9.0	79.4	0.71	8.70	59.5	0.52	0.19	72.8
9.0	113.2	1.02	8.23	90.2	0.74	0.28	72.6
9.0	148.4	1.34	7.73	121.5	0.94	0.40	70.1
9.0	181.0	1.63	7.20	150.4	1.08	0.54	66.6
9.1	210.0	1.90	6.79	180.9	1.23	0.67	64.5
9.1	250.0	2.27	6.32	210.6	1.33	0.94	58.7
9.1	280.0	2.54	5.77	241.5	1.39	1.15	54.8
9.1	310.0	2.81	5.24	269.1	1.41	1.40	50.1
9.1	350.0	3.18	4.60	300.3	1.38	1.80	43.5

2.3 Output Voltage Regulation (9 V_{IN})

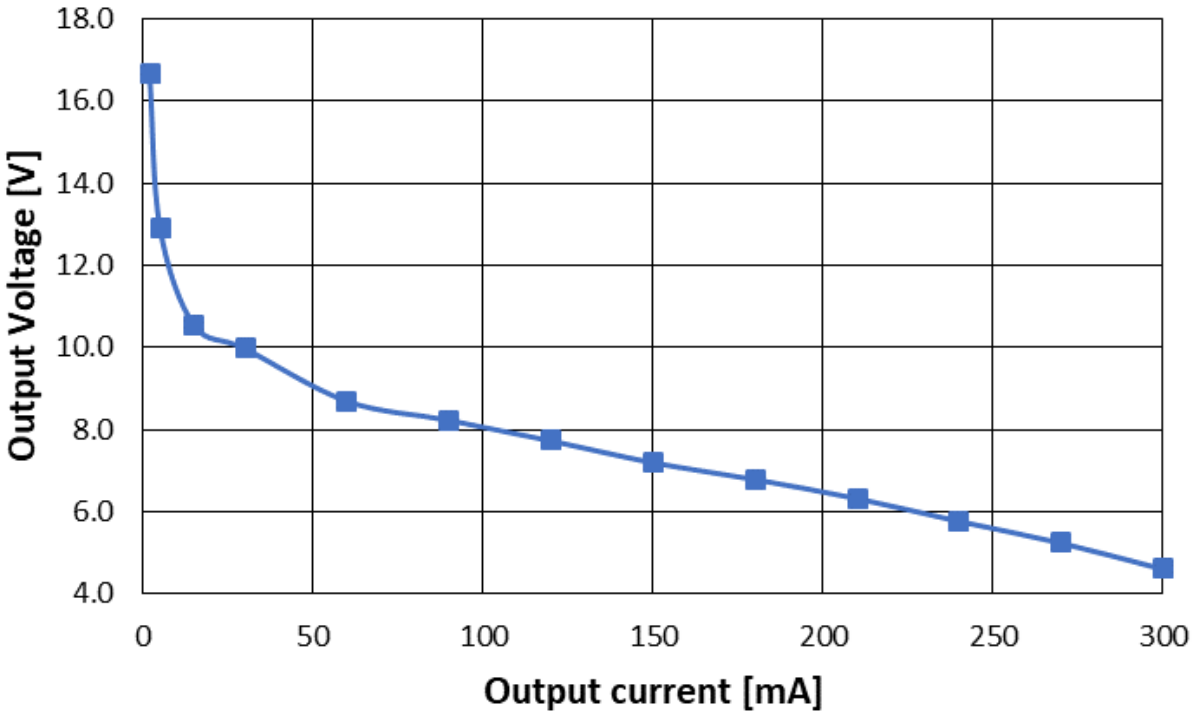


Figure 2-2. V_{OUT} Regulation

2.4 Thermal Images

Figure 2-3 shows the thermal image for a 150-mA load current.

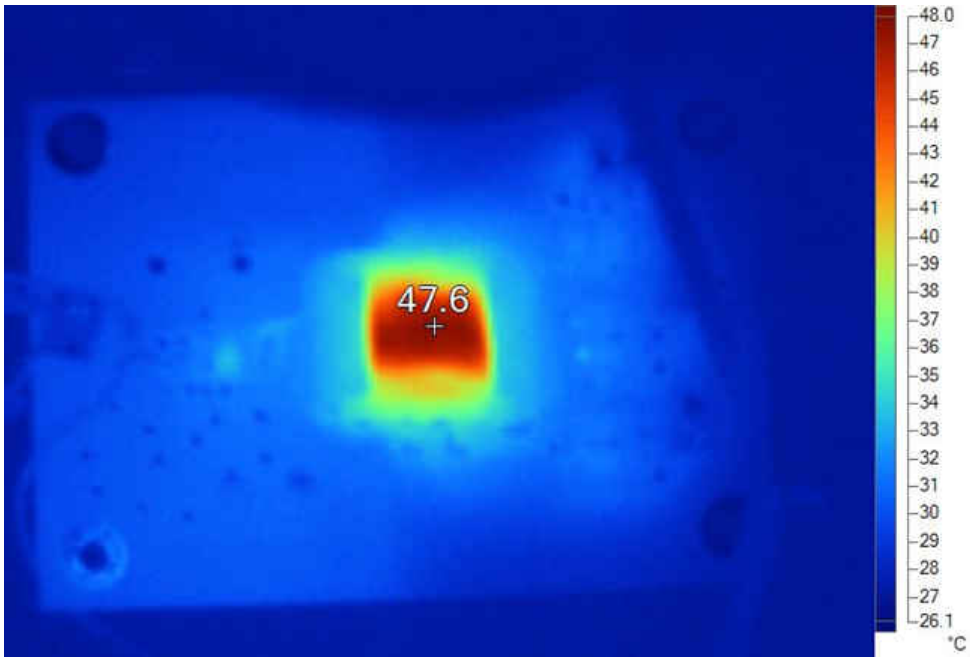


Figure 2-3. Thermal Image at 9 V_{IN} and 150-mA Load Current

Figure 2-4 shows the thermal image for a 150-mA load current.

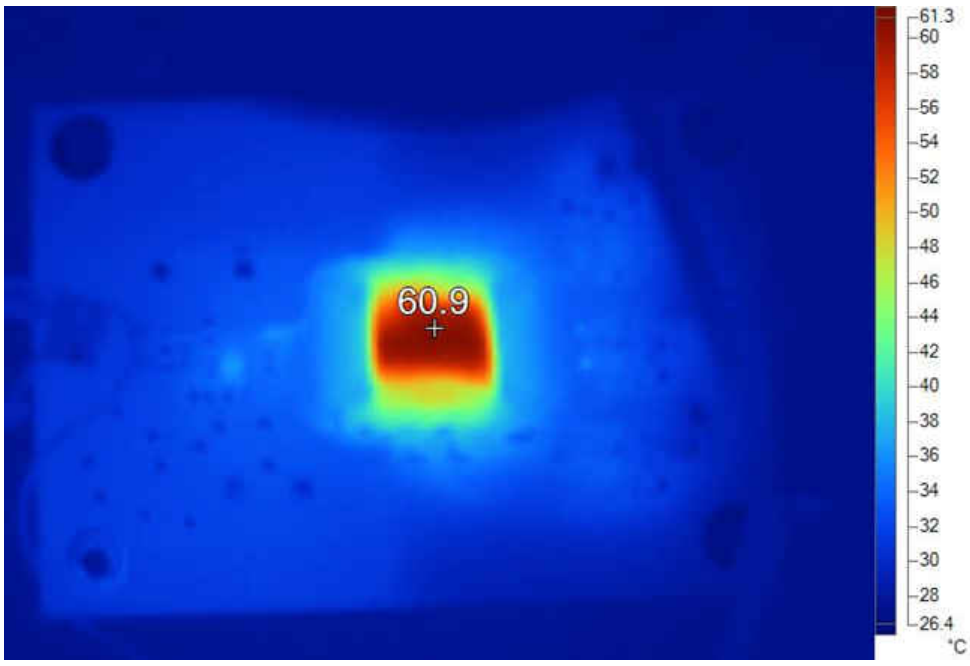


Figure 2-4. Thermal Image at 9 V_{IN} and 200-mA Load Current

3 Waveforms

3.1 Switching

Switching behavior is shown in the following figures.

3.1.1 Primary Side

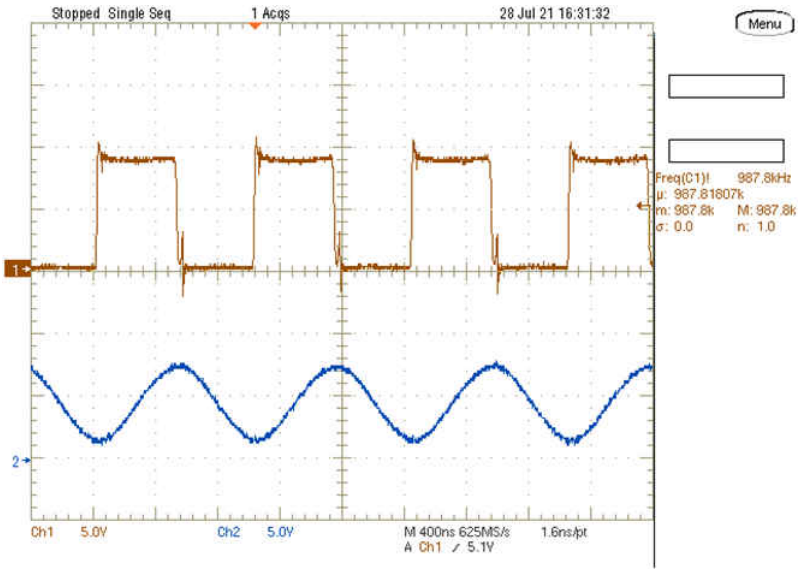


Figure 3-1. Switching Waveforms on Primary Side

- Ch1: Switching node (**A1** to GND) at 9 V_{IN} and 150-mA load current [scale: 5.0 V / div, 400 ns / div]
- Ch2: **A8** to GND at 9 V_{IN} and 150-mA load current [scale: 5.0 V /div, 400 ns / div]

3.1.2 Secondary Side

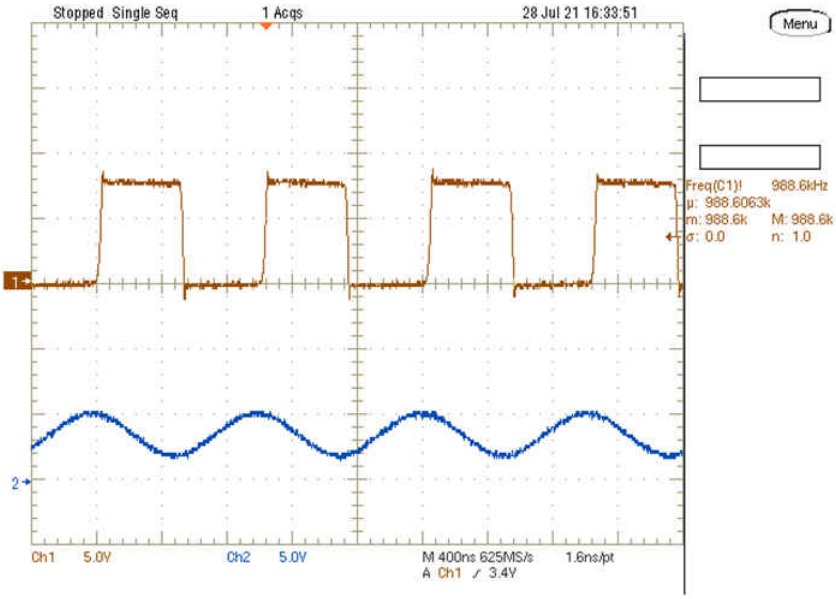


Figure 3-2. Switching Waveforms on Secondary Side

- Ch1: **A6** to $-V_o2$ at 9 V_{IN} and 150-mA load current [scale: 5.0 V / div, 400 ns / div]
- **A3** to $-V_o2$ at 9 V_{IN} and 150-mA load current [scale: 5.0 V / div, 400 ns / div]

3.2 Output Voltage Ripple

Output voltage ripple is shown in the following figure.

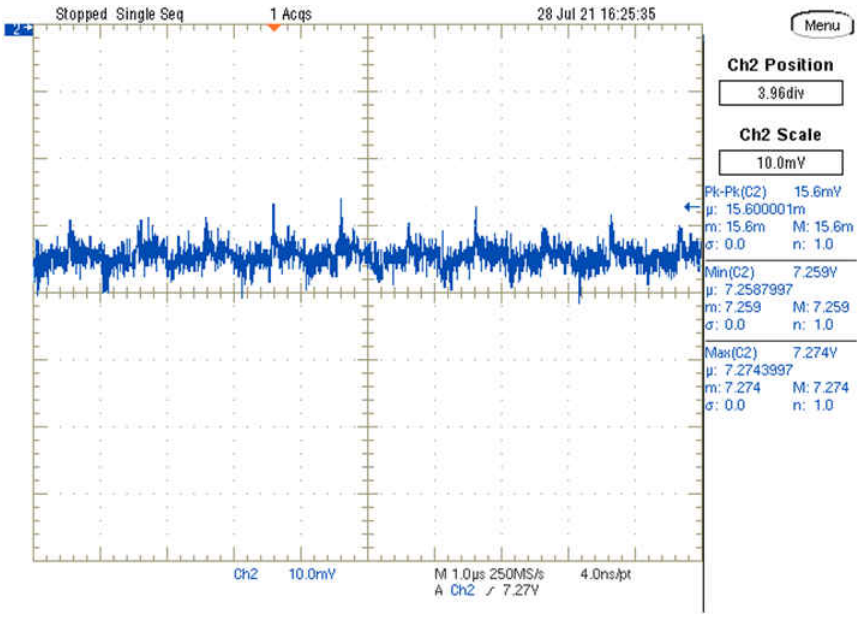


Figure 3-3. Output Voltage Ripple

- Ch2: 9 V_{IN}, 150-mA load, 15.6-mV peak-peak-ripple [scale: 10 mV / div, 1.0 µs /div]

3.3 Start-Up Sequence

Start-up behavior is shown in the following figure.

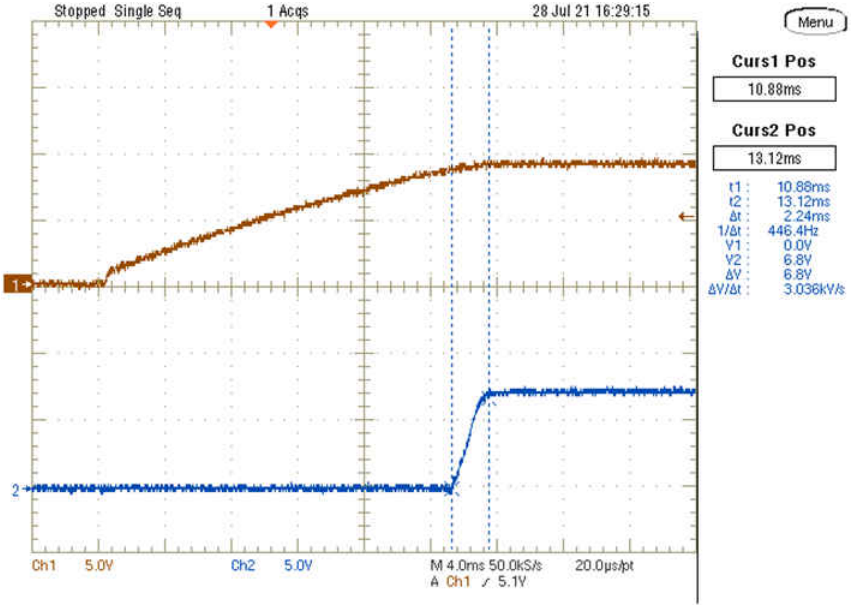


Figure 3-4. Start-Up Waveform

- Ch1: Input voltage at 9 V_{IN} [scale: 5 V / div, 4.0 ms / div]
- Ch2: Output voltage at 9 V_{IN} and 150-mA load current [scale: 5 V / div, 4.0 ms / div]

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