Test Report: PMP40909

3.3-V to 4.2-V Input, 12-V, 60-W Peak Output Power Boost Converter Reference Design

Description

This reference design demonstrates two methods that connect two TPS61288 devices in parallel to support high-output power. One method is to connect the VIN, VOUT, FB and COMP pin together directly. Because the two devices share the same voltage on the COMP pin, the inductor peak current of the two devices is closed at the typical condition. However, considering the process variation at the worst condition, the output current of one device can only be 50% of the other device. Thus, the maximum average power of this method is approximately 30 W from 3.3-V to 4.2-V input, but the peak output power can be 60 W for dozens of milliseconds. The other method uses an amplifier and two current-sensing resistors to maintain the current balance between two ICs. The amplifier compares the output voltage differential of two ICs, and then adjusts the voltage of one device to keep the two VOUT pins similar. The current of the two ICs is closed to each other. See the *Power Sharing Between Two Parallel, Four-Switch Buck-Boost Converters* application report for the details of this method. The average output power can be up to 40 W using this method.

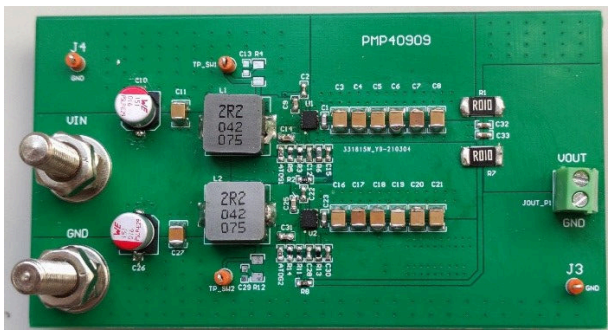
Bench test results of these two solutions are found in this test report. Detailed schematics, layouts, and BOMs are found the in the reference design folder.

Features

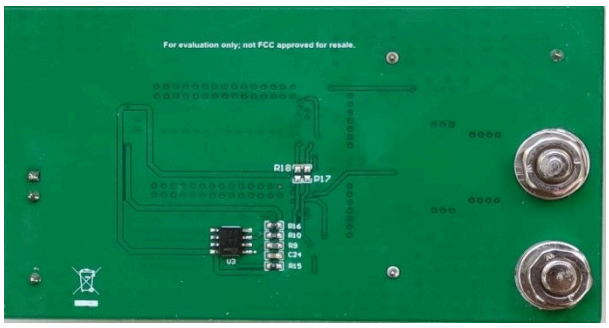
- Input voltage range: 3.3 V to 4.2 V
- Output voltage: 12 V
- Output current: 5 A
- Dual phase in parallel

Applications

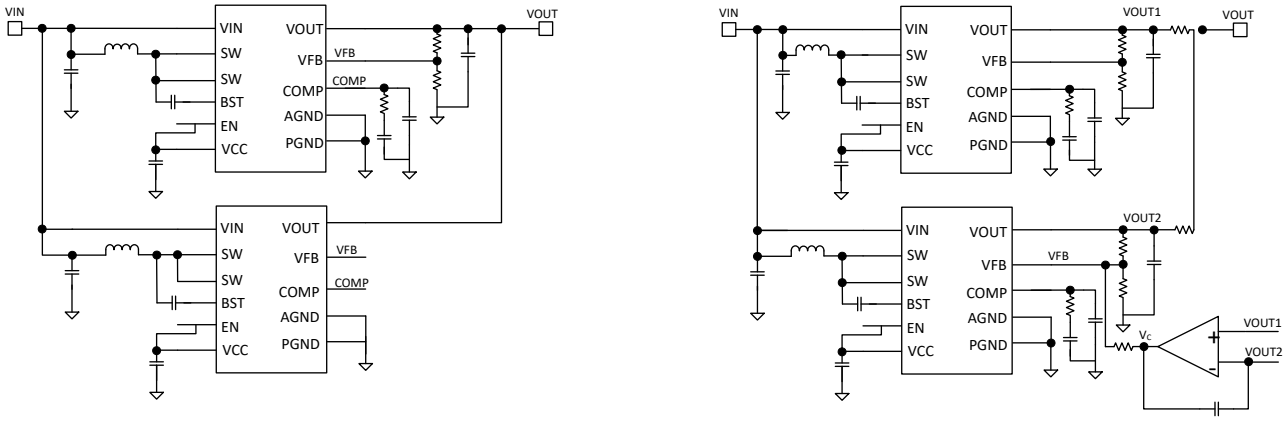
- Bluetooth® speaker
- Source driver of LCD display



Board Image (Top View)



Board Image (Bottom View)



Simplified Schematic Without and With a Current-Sharing Circuit

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
Input voltage	3.3 to 4.2 Vdc
Output voltage	12 Vdc
Output current	5 A

1.2 Required Equipment

- Multimeter (current): Agilent 34401A
- Multimeter (voltage): Agilent 34401A
- DC Source: Chroma 62012P-80-60
- E-Load: Chroma 6312A module
- Oscilloscope: Tektronix DPO3054
- Electrical Thermography: Fluke Ti125

1.3 Dimensions

The board dimensions are 110 mm (length) × 55 mm (width) × 32 mm (height).

2 Testing and Results

2.1 Efficiency Graphs

Figure 2-1 and Figure 2-2 show the efficiency of both methods from 0.1 A to 5 V at 12-V output.

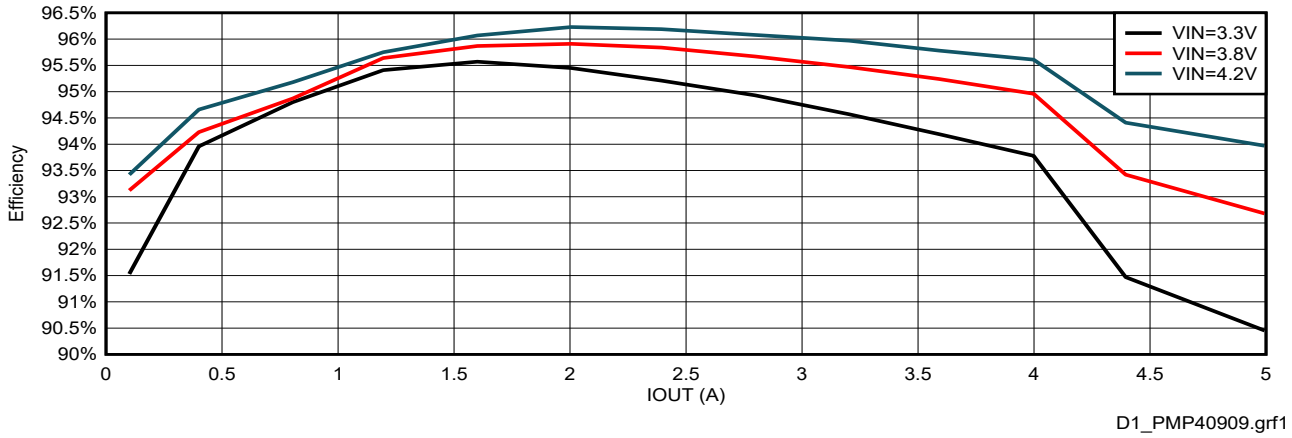


Figure 2-1. Efficiency Without Current Sharing

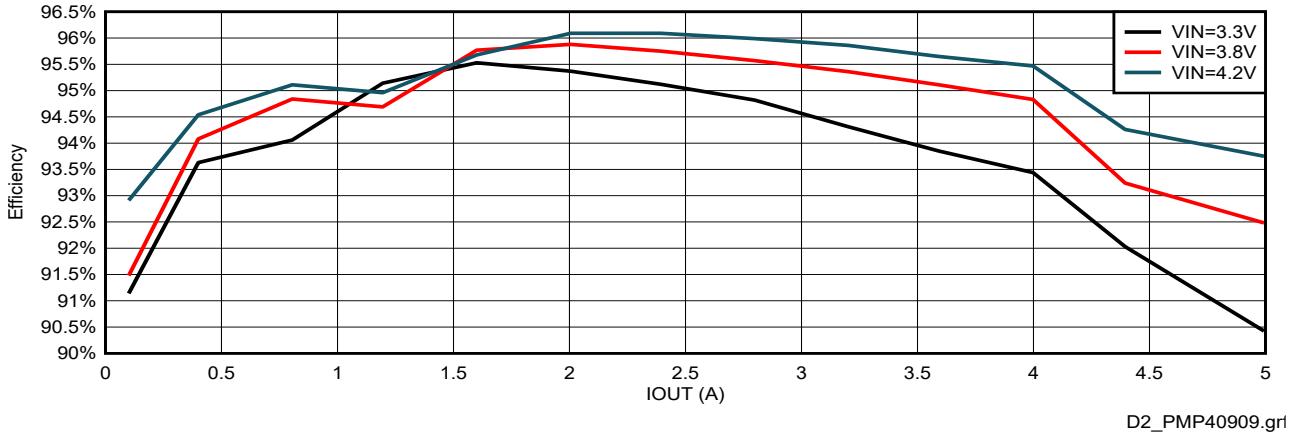


Figure 2-2. Efficiency With Current Sharing

2.2 Efficiency Data

Table 2-1 details the efficiency data without a current-sharing circuit.

Table 2-1. Efficiency Data Without Current-Sharing Circuit

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	Efficiency (%)
3.2937	0.397	1.3083	11.9758	0.100	1.1974	91.53%
3.3000	1.545	5.0985	11.9772	0.400	4.7905	93.96%
3.2999	3.079	10.1604	11.9704	0.805	9.6322	94.80%
3.2997	4.542	14.9871	11.9687	1.195	14.2986	95.41%
3.2995	6.071	20.0314	11.9674	1.600	19.1438	95.57%
3.2996	7.617	25.1327	11.9671	2.005	23.9900	95.45%
3.2995	9.118	30.0852	11.9664	2.394	28.6443	95.21%
3.2995	10.689	35.2681	11.9660	2.798	33.4783	94.93%
3.2993	12.283	40.5258	11.9661	3.203	38.3249	94.57%
3.2993	13.831	45.6320	11.9659	3.592	42.9798	94.19%
3.2992	15.461	51.0087	11.9661	3.998	47.8379	93.78%
3.2250	17.845	57.5501	11.9770	4.395	52.6389	91.47%
3.2130	20.591	66.1589	11.9800	4.995	59.8401	90.45%
3.7950	0.339	1.2860	11.9764	0.100	1.1974	93.12%
3.8001	1.338	5.0845	11.9785	0.400	4.7909	94.23%
3.8000	2.672	10.1535	11.9704	0.805	9.6322	94.87%
3.7997	3.935	14.9520	11.9698	1.195	14.2999	95.64%
3.7997	5.253	19.9599	11.9691	1.599	19.1352	95.87%
3.7995	6.581	25.0048	11.9683	2.004	23.9811	95.91%
3.7994	7.867	29.8899	11.9678	2.394	28.6477	95.84%
3.7995	9.211	34.9973	11.9674	2.798	33.4821	95.67%
3.7994	10.566	40.1448	11.9670	3.203	38.3276	95.47%
3.7994	11.882	45.1441	11.9670	3.593	42.9948	95.24%
3.7993	13.261	50.3830	11.9671	3.998	47.8419	94.96%
3.7400	15.061	56.3281	11.9730	4.395	52.6213	93.42%
3.7330	17.288	64.5361	11.9740	4.995	59.8101	92.68%
4.1957	0.305	1.2818	11.9766	0.100	1.1974	93.42%
4.2001	1.205	5.0611	11.9786	0.400	4.7910	94.66%
4.1999	2.409	10.1176	11.9816	0.804	9.6299	95.18%
4.1999	3.556	14.9347	11.9703	1.195	14.3005	95.75%
4.1998	4.743	19.9195	11.9697	1.599	19.1362	96.07%
4.1997	5.937	24.9337	11.9692	2.005	23.9942	96.23%
4.1995	7.092	29.7831	11.9685	2.394	28.6492	96.19%
4.1995	8.296	34.8391	11.9678	2.797	33.4720	96.08%
4.1994	9.511	39.9401	11.9677	3.203	38.3300	95.97%
4.1994	10.687	44.8794	11.9677	3.592	42.9862	95.78%
4.1993	11.916	50.0394	11.9674	3.998	47.8430	95.61%
4.1460	13.441	55.7264	11.9710	4.395	52.6125	94.41%
4.1360	15.383	63.6241	11.9700	4.995	59.7902	93.97%

Table 2-2 shows the efficiency data with an external amplifier current-sharing circuit.

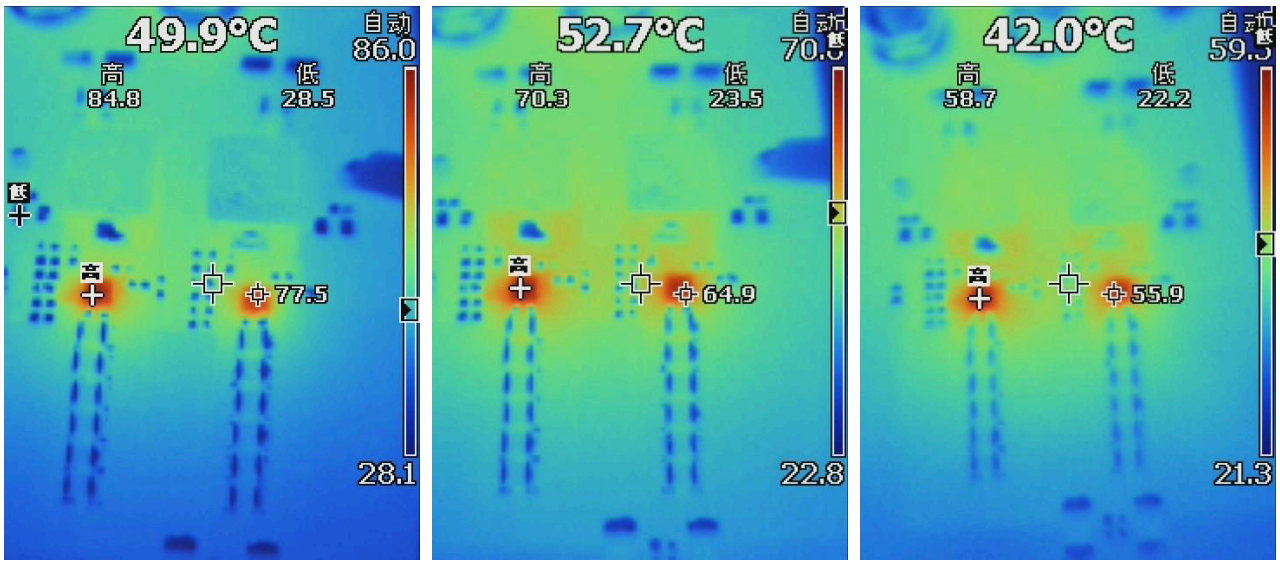
Table 2-2. Efficiency Data With External Amplifier Current-Sharing Circuit

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	Efficiency (%)
3.2936	0.400	1.3190	12.0238	0.100	1.2022	91.14%
3.3000	1.556	5.1348	12.0208	0.400	4.8079	93.63%
3.2998	3.111	10.2658	12.0139	0.804	9.6559	94.06%
3.2997	4.573	15.0896	12.0165	1.195	14.3557	95.14%
3.2995	6.099	20.1239	12.0173	1.600	19.2237	95.53%
3.2995	7.655	25.2574	12.0154	2.005	24.0869	95.37%
3.2995	9.162	30.2301	12.0131	2.394	28.7560	95.12%
3.2995	10.743	35.4461	12.0129	2.798	33.6094	94.82%
3.2994	12.368	40.8065	12.0119	3.204	38.4829	94.31%
3.2993	13.933	45.9691	12.0113	3.592	43.1427	93.85%
3.2992	15.574	51.3821	12.0099	3.998	48.0129	93.44%
3.2210	17.816	57.3853	12.0160	4.395	52.8103	92.03%
3.2190	20.680	66.5689	12.0510	4.995	60.1947	90.42%
3.7947	0.346	1.3143	12.0255	0.100	1.2024	91.48%
3.8000	1.345	5.1110	12.0218	0.400	4.8082	94.08%
3.7999	2.686	10.2066	12.0164	0.806	9.6804	94.84%
3.7998	3.989	15.1575	12.0133	1.195	14.3519	94.69%
3.7996	5.279	20.0583	12.0152	1.599	19.2089	95.77%
3.7996	6.611	25.1190	12.0142	2.005	24.0843	95.88%
3.7995	7.904	30.0315	12.0126	2.394	28.7549	95.75%
3.7995	9.254	35.1602	12.0110	2.798	33.6041	95.57%
3.7995	10.616	40.3356	12.0095	3.203	38.4638	95.36%
3.7994	11.936	45.3496	12.0079	3.592	43.1304	95.11%
3.7993	13.323	50.6183	12.0075	3.998	48.0032	94.83%
3.7290	15.226	56.7778	12.0450	4.395	52.9378	93.24%
3.7170	17.506	65.0698	12.0470	4.995	60.1748	92.48%
4.1956	0.308	1.2941	12.0256	0.100	1.2024	92.91%
4.2001	1.211	5.0863	12.0221	0.400	4.8084	94.54%
4.2000	2.421	10.1681	12.0184	0.805	9.6708	95.11%
4.1999	3.598	15.1112	12.0119	1.195	14.3502	94.96%
4.1997	4.783	20.0871	12.0142	1.600	19.2187	95.68%
4.1996	5.965	25.0508	12.0131	2.004	24.0710	96.09%
4.1996	7.125	29.9220	12.0114	2.394	28.7519	96.09%
4.1994	8.335	35.0023	12.0096	2.798	33.6002	95.99%
4.1994	9.553	40.1169	12.0076	3.203	38.4577	95.86%
4.1994	10.737	45.0894	12.0066	3.592	43.1260	95.65%
4.1994	11.971	50.2709	12.0052	3.998	47.9944	95.47%
4.1380	13.561	56.1154	12.0350	4.395	52.8938	94.26%
4.1290	15.528	64.1151	12.0340	4.995	60.1098	93.75%

2.3 Thermal Images

The thermal performance is measured in four-layer PCB. The PCB has 1-oz copper for the outer layer, and 0.5-oz copper for the inner layer. Better thermal performance can be achieved with thicker copper PCB.

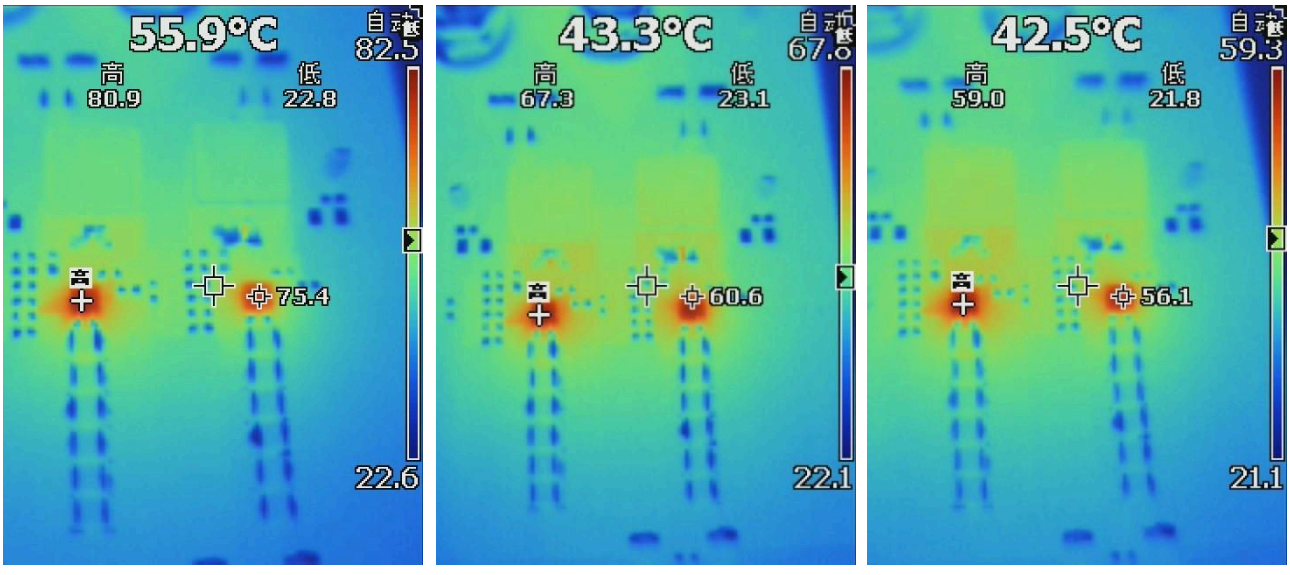
The three thermal images in Figure 2-3 illustrate the thermal conditions without current-sharing current at input voltages of 3.3 V, 3.8 V, and 4.2 V. For typical conditions, the current through the two devices is close to each other even though there is no specialized current-sharing circuit. The thermal performance at 4.2-V input is much better, this means the output power capability at 4.2-V input is more than 40 W.



T_A = 25.0°C, 3.3-V Input, 40-W Load | T_A = 25.0°C, 3.8-V Input, 40-W Load | T_A = 25.0°C, 4.2-V Input, 40-W Load

Figure 2-3. Thermal Images Without Current Sharing

The three thermal images in Figure 2-4 illustrate the thermal conditions with an external amplifier current-sharing current.



T_A = 25.0°C, 3.3-V Input, 40-W Load | T_A = 25.0°C, 3.8-V Input, 40-W Load | T_A = 25.0°C, 4.2-V Input, 40-W Load

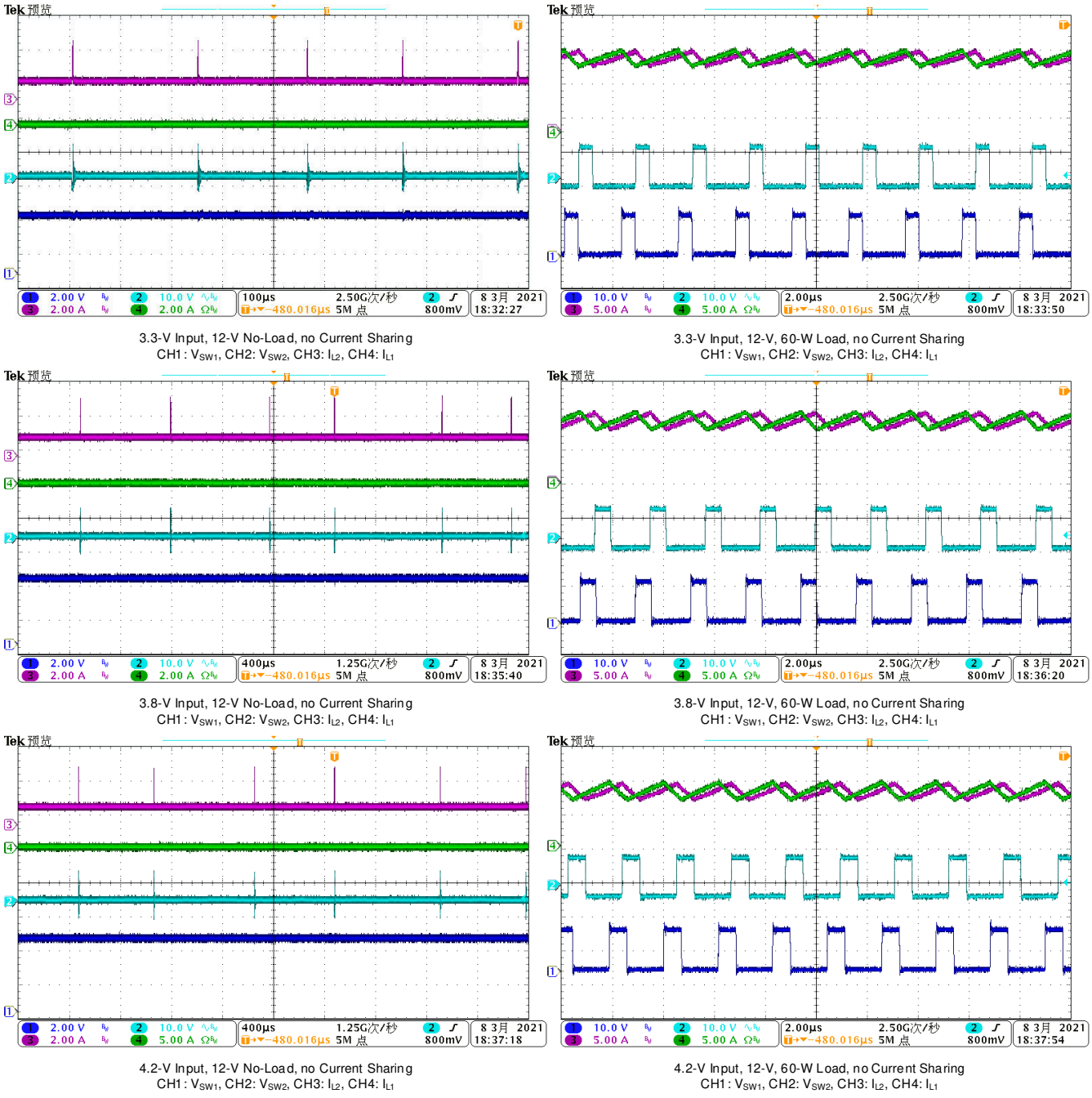
Figure 2-4. Thermal Images With Current Sharing

3 Waveforms

3.1 Switching

The waveforms of switching nodes at no-load and full-load conditions are shown in this section.

The waveforms in Figure 3-1 are the switching waveforms without a current-sharing circuit.



3.3-V Input, 12-V No-Load, no Current Sharing
CH1 : V_{SW1}, CH2: V_{SW2}, CH3: I_{L2}, CH4: I_{L1}

3.3-V Input, 12-V, 60-W Load, no Current Sharing
CH1 : V_{SW1}, CH2: V_{SW2}, CH3: I_{L2}, CH4: I_{L1}

3.8-V Input, 12-V No-Load, no Current Sharing
CH1 : V_{SW1}, CH2: V_{SW2}, CH3: I_{L2}, CH4: I_{L1}

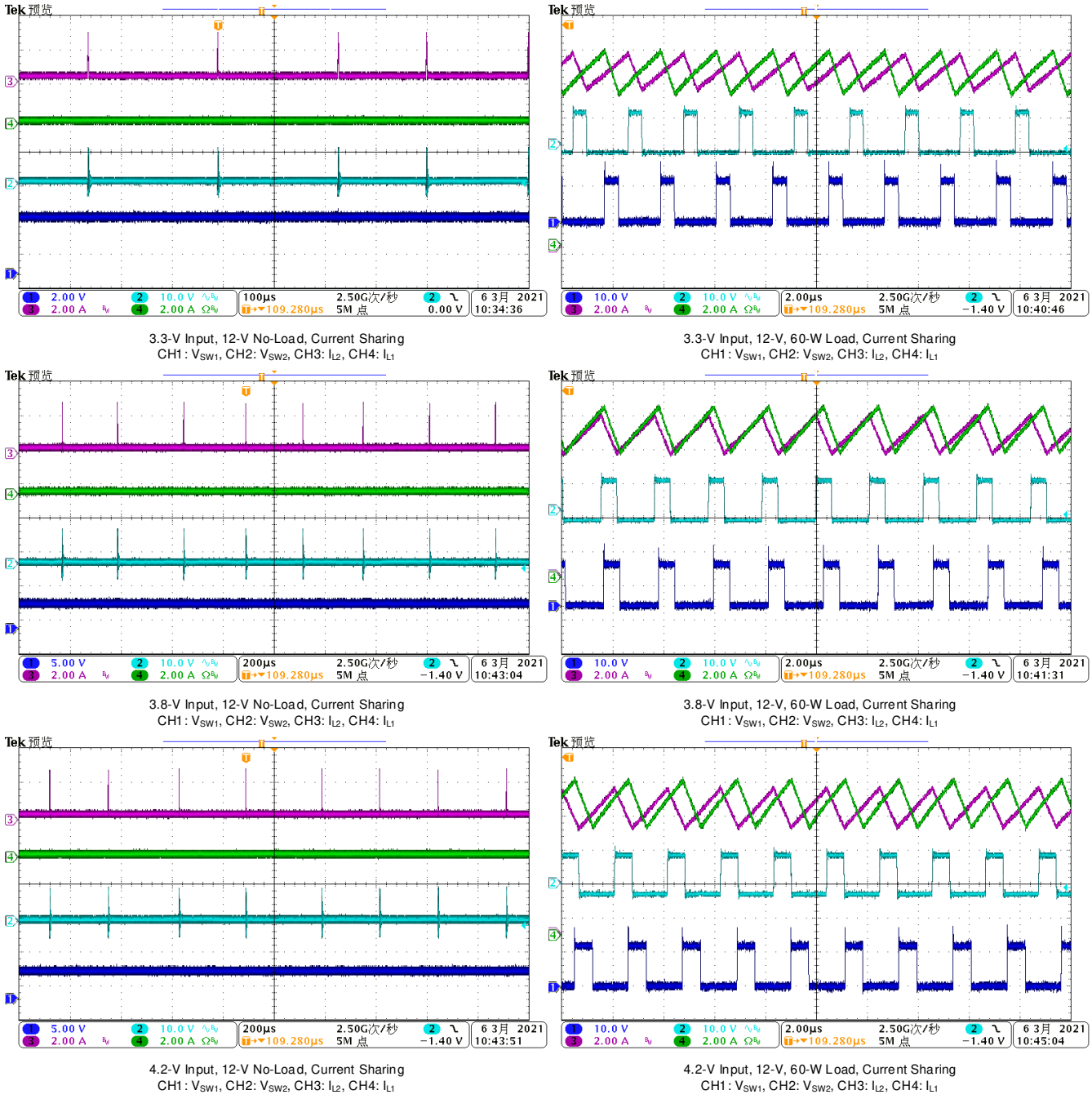
3.8-V Input, 12-V, 60-W Load, no Current Sharing
CH1 : V_{SW1}, CH2: V_{SW2}, CH3: I_{L2}, CH4: I_{L1}

4.2-V Input, 12-V No-Load, no Current Sharing
CH1 : V_{SW1}, CH2: V_{SW2}, CH3: I_{L2}, CH4: I_{L1}

4.2-V Input, 12-V, 60-W Load, no Current Sharing
CH1 : V_{SW1}, CH2: V_{SW2}, CH3: I_{L2}, CH4: I_{L1}

Figure 3-1. Switching Waveforms Without Current Sharing

The waveforms in Figure 3-2 are the switching waveforms with an external amplifier current-sharing circuit.



3.3-V Input, 12-V No-Load, Current Sharing
CH1 : V_{SW1}, CH2: V_{SW2}, CH3: I_{L2}, CH4: I_{L1}

3.3-V Input, 12-V, 60-W Load, Current Sharing
CH1 : V_{SW1}, CH2: V_{SW2}, CH3: I_{L2}, CH4: I_{L1}

3.8-V Input, 12-V No-Load, Current Sharing
CH1 : V_{SW1}, CH2: V_{SW2}, CH3: I_{L2}, CH4: I_{L1}

3.8-V Input, 12-V, 60-W Load, Current Sharing
CH1 : V_{SW1}, CH2: V_{SW2}, CH3: I_{L2}, CH4: I_{L1}

4.2-V Input, 12-V No-Load, Current Sharing
CH1 : V_{SW1}, CH2: V_{SW2}, CH3: I_{L2}, CH4: I_{L1}

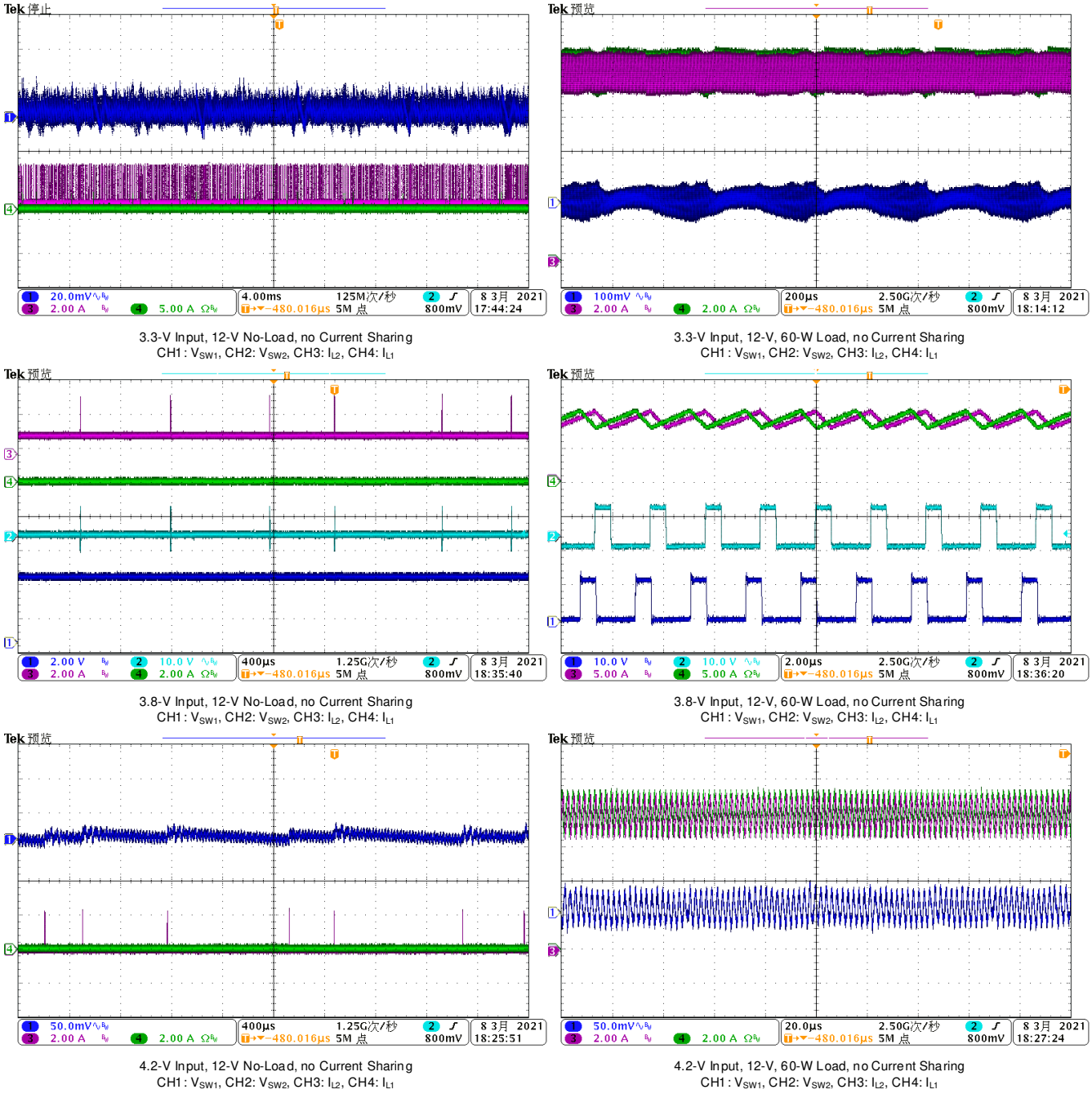
4.2-V Input, 12-V, 60-W Load, Current Sharing
CH1 : V_{SW1}, CH2: V_{SW2}, CH3: I_{L2}, CH4: I_{L1}

Figure 3-2. Switching Waveforms With Current Sharing

3.2 Output Voltage Ripple

The waveforms of output AC ripples at no-load and full-load conditions are shown in this section.

The images in Figure 3-3 are the output voltage-ripple waveforms without a current-sharing circuit.



3.3-V Input, 12-V No-Load, no Current Sharing
CH1 : V_{SW1}, CH2: V_{SW2}, CH3: I_{L2}, CH4: I_{L1}

3.3-V Input, 12-V, 60-W Load, no Current Sharing
CH1 : V_{SW1}, CH2: V_{SW2}, CH3: I_{L2}, CH4: I_{L1}

3.8-V Input, 12-V No-Load, no Current Sharing
CH1 : V_{SW1}, CH2: V_{SW2}, CH3: I_{L2}, CH4: I_{L1}

3.8-V Input, 12-V, 60-W Load, no Current Sharing
CH1 : V_{SW1}, CH2: V_{SW2}, CH3: I_{L2}, CH4: I_{L1}

4.2-V Input, 12-V No-Load, no Current Sharing
CH1 : V_{SW1}, CH2: V_{SW2}, CH3: I_{L2}, CH4: I_{L1}

4.2-V Input, 12-V, 60-W Load, no Current Sharing
CH1 : V_{SW1}, CH2: V_{SW2}, CH3: I_{L2}, CH4: I_{L1}

Figure 3-3. Output Voltage-Ripple Waveforms Without Current Sharing

The images in Figure 3-4 are the output voltage-ripple waveforms with an external amplifier current-sharing circuit.

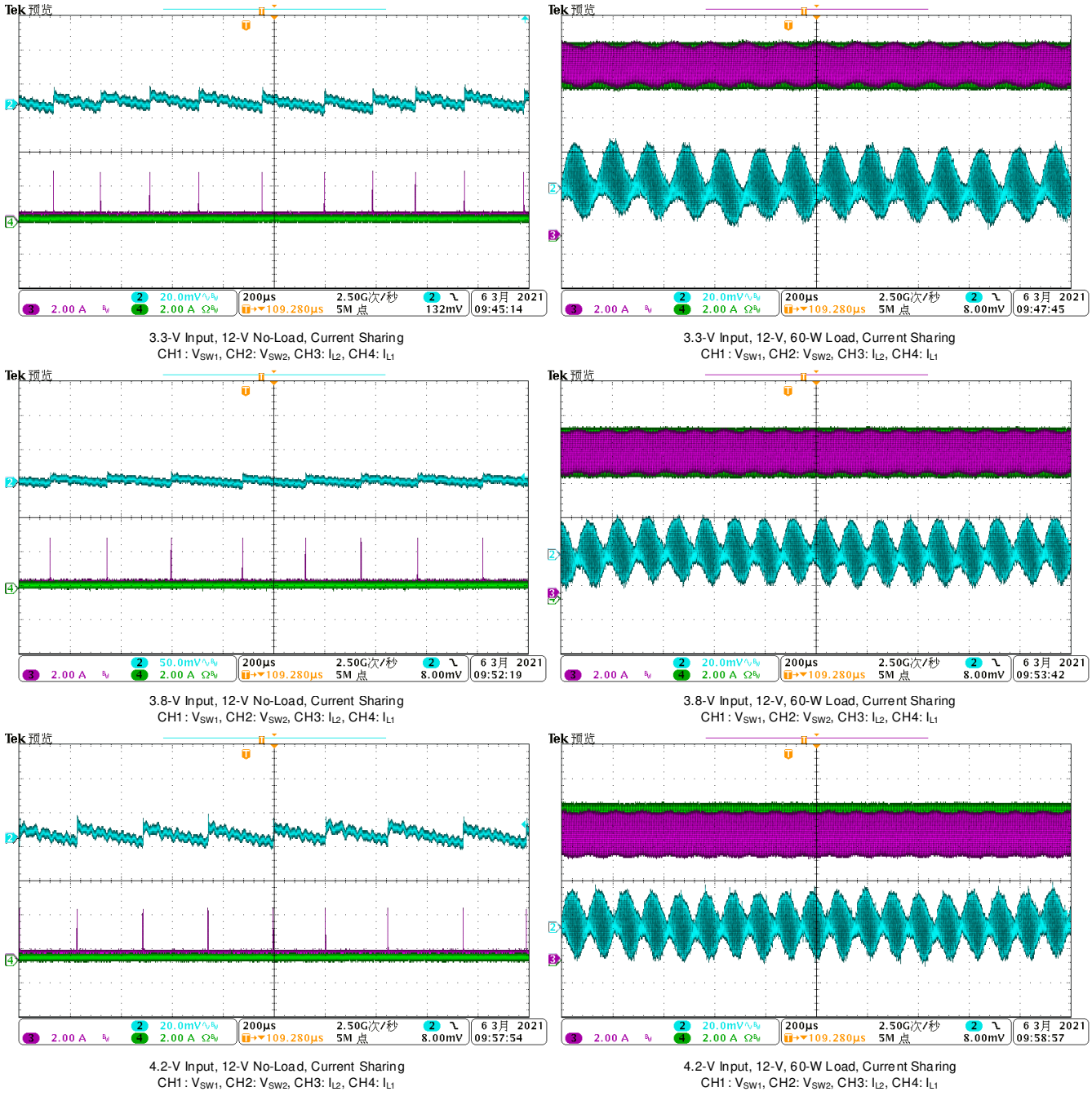
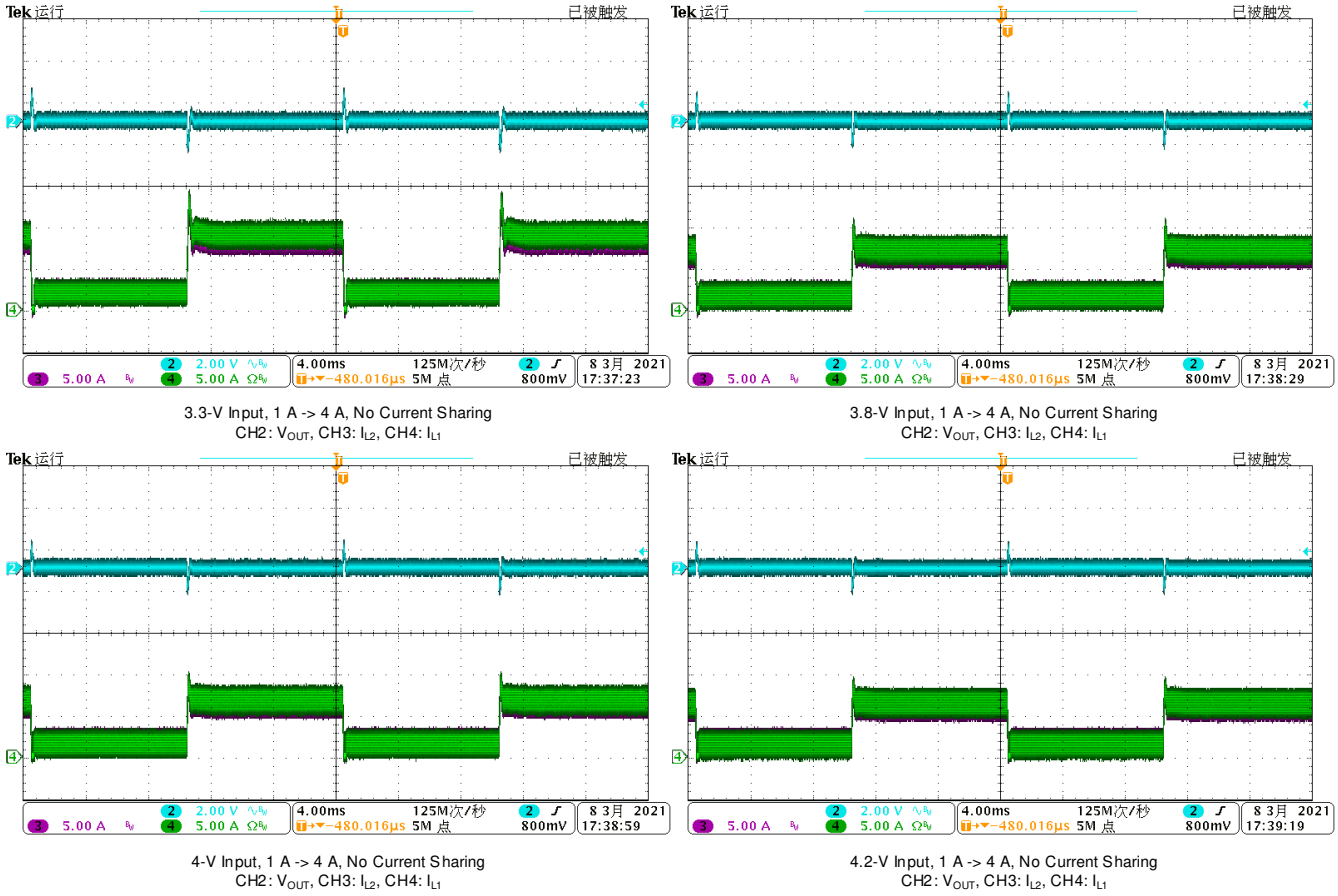


Figure 3-4. Output Voltage-Ripple Waveforms With Current Sharing

3.3 Load Transients

The waveforms of output AC ripples at a load transient from 20% to 80% loading with a slew rate of 0.4 A/µs are shown in this section.

The waveforms in Figure 3-5 are the load-transient waveforms without a current-sharing circuit.



3.3-V Input, 1 A -> 4 A, No Current Sharing
CH2: V_{OUT}, CH3: I_{L2}, CH4: I_{L1}

3.8-V Input, 1 A -> 4 A, No Current Sharing
CH2: V_{OUT}, CH3: I_{L2}, CH4: I_{L1}

4-V Input, 1 A -> 4 A, No Current Sharing
CH2: V_{OUT}, CH3: I_{L2}, CH4: I_{L1}

4.2-V Input, 1 A -> 4 A, No Current Sharing
CH2: V_{OUT}, CH3: I_{L2}, CH4: I_{L1}

Figure 3-5. Load-Transient Waveforms Without Current Sharing

The waveforms in Figure 3-6 are the load-transient waveforms with an external amplifier current-sharing circuit.

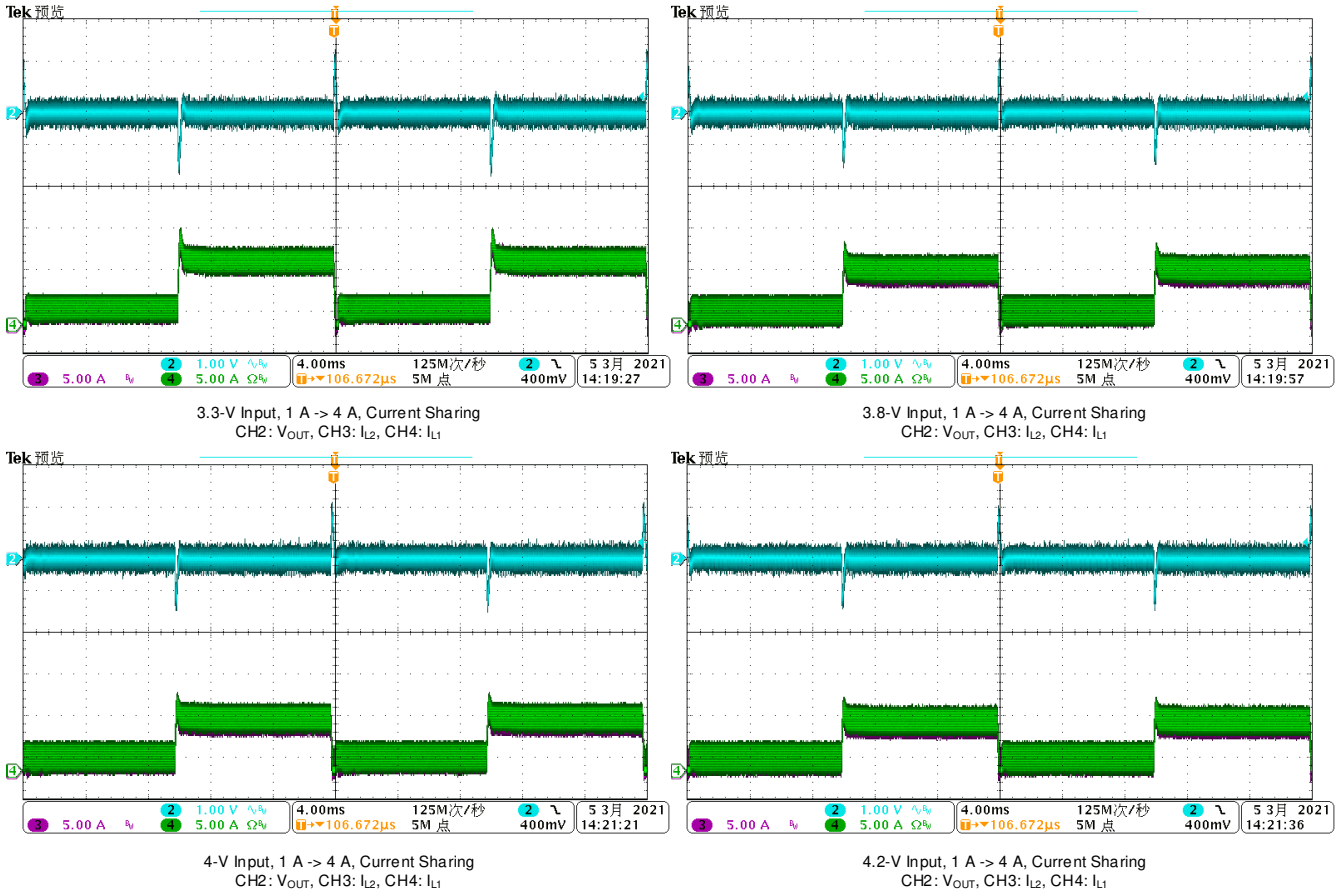
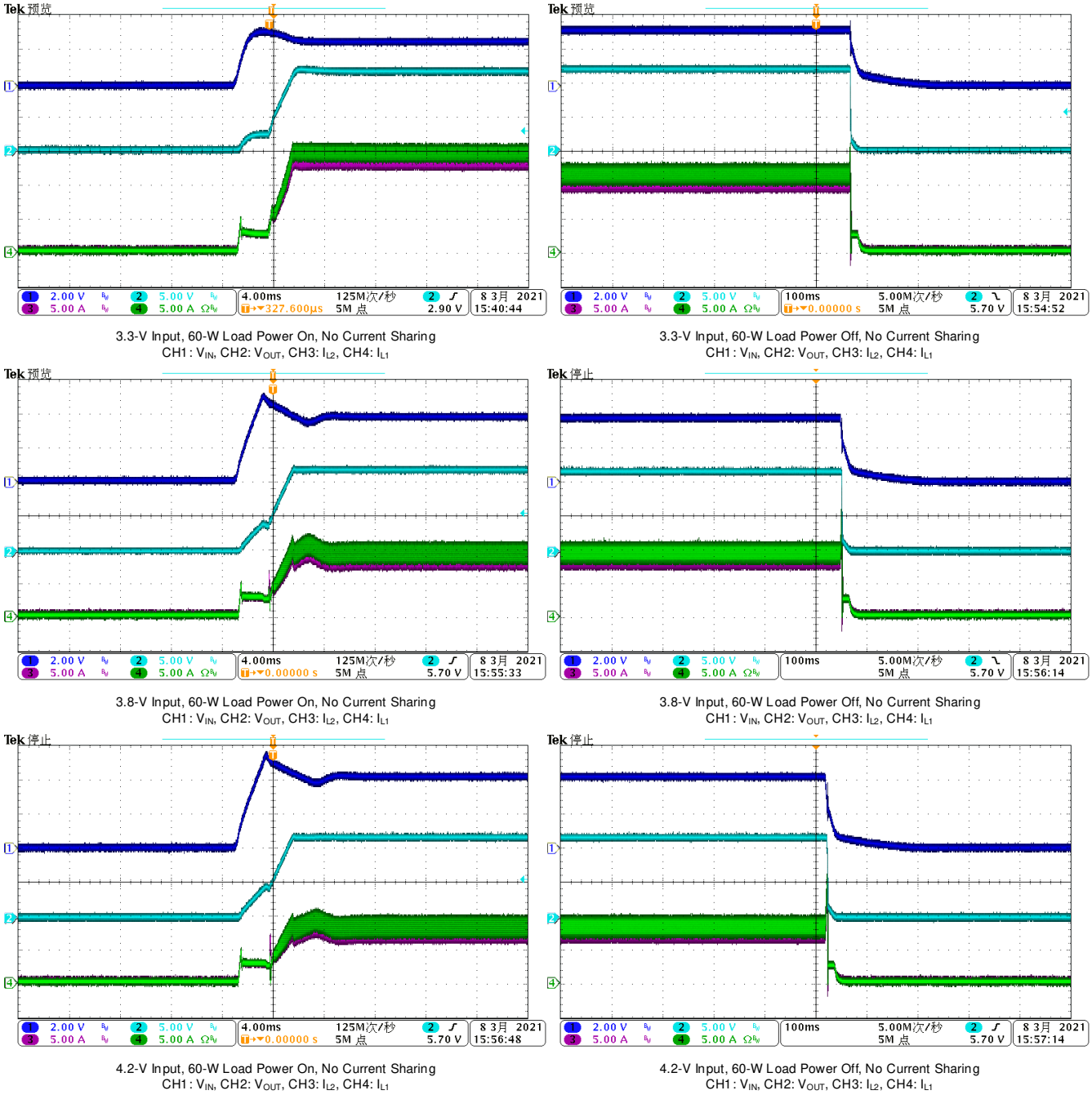


Figure 3-6. Load-Transient Waveforms With Current Sharing

3.4 Power On, Power Off

The waveforms of system power on and off with full load outputs are shown in this section.

The waveforms in Figure 3-7 are the power on and power off waveforms without a current-sharing circuit.



3.3-V Input, 60-W Load Power On, No Current Sharing
CH1 : V_{IN}, CH2: V_{OUT}, CH3: I_{L2}, CH4: I_{L1}

3.3-V Input, 60-W Load Power Off, No Current Sharing
CH1 : V_{IN}, CH2: V_{OUT}, CH3: I_{L2}, CH4: I_{L1}

3.8-V Input, 60-W Load Power On, No Current Sharing
CH1 : V_{IN}, CH2: V_{OUT}, CH3: I_{L2}, CH4: I_{L1}

3.8-V Input, 60-W Load Power Off, No Current Sharing
CH1 : V_{IN}, CH2: V_{OUT}, CH3: I_{L2}, CH4: I_{L1}

4.2-V Input, 60-W Load Power On, No Current Sharing
CH1 : V_{IN}, CH2: V_{OUT}, CH3: I_{L2}, CH4: I_{L1}

4.2-V Input, 60-W Load Power Off, No Current Sharing
CH1 : V_{IN}, CH2: V_{OUT}, CH3: I_{L2}, CH4: I_{L1}

Figure 3-7. Power On and Power Off Waveforms Without Current Sharing

The waveforms in Figure 3-8 are the power on and power off waveforms with an external amplifier current-sharing circuit.

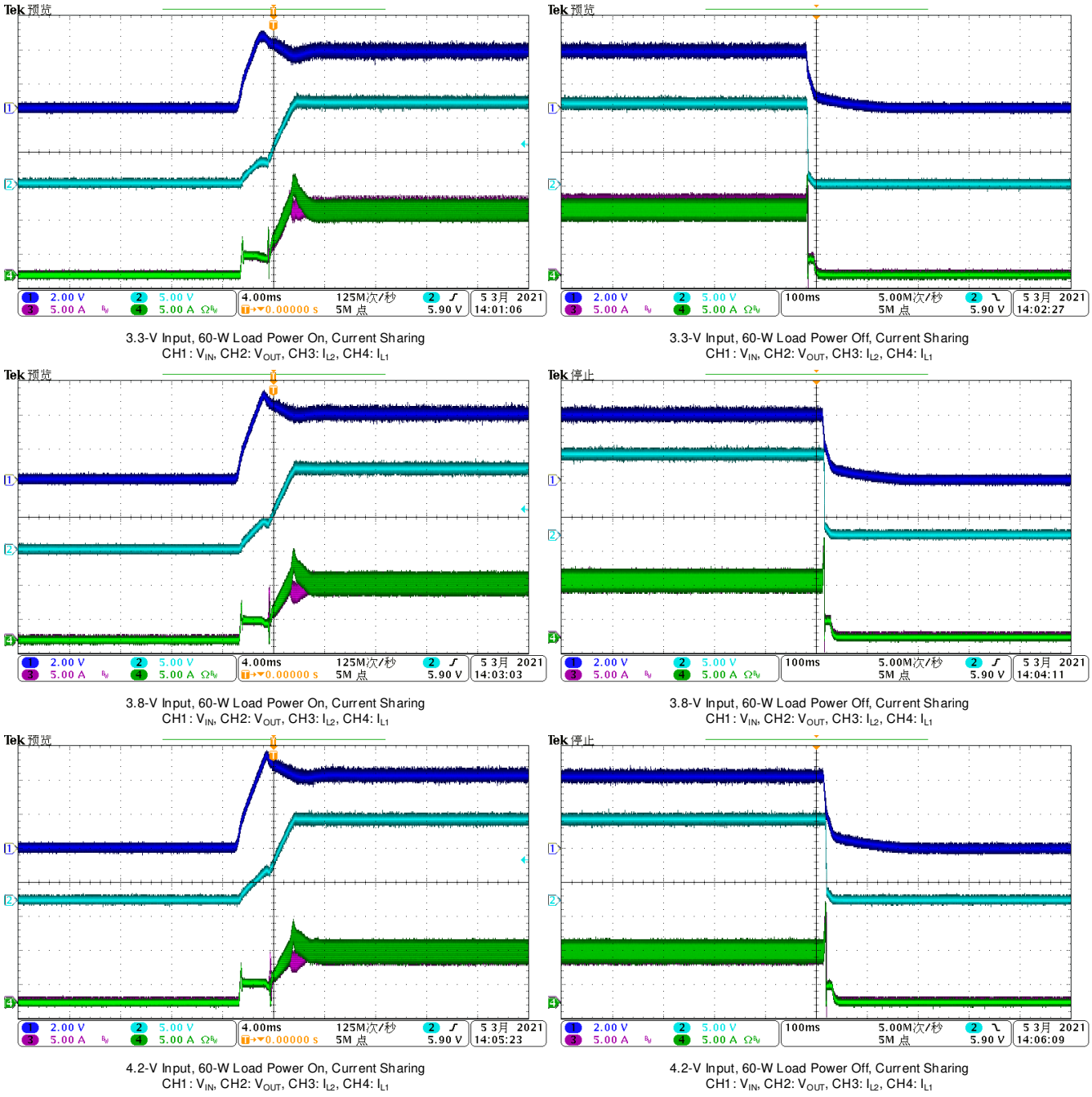


Figure 3-8. Power On/Off Waveforms With Current Sharing

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