Application Note

Analysis and Improvement of Using Boost Converter to Generate the Negative and Positive Voltage Rails

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ABSTRACT

Many TFT-LCD panels require negative voltage rail and positive voltage rail to power the amplifiers from the 12-V or 5-V power supply. *Generating Negative and Positive Voltage Rail With Boost Converter TLV61048*, application note used TLV61048 device and referred to *Design for a Discrete Charge Pump*, application note to demonstrate an example to generate the negative voltage rail and positive voltage rail. For asynchronous boot converter, the forward diode can help reduce the gap between positive voltage rail and negative voltage rail and for synchronous boost converter, due to MOSFET integration, the forward voltage drop is very low, but it also can use a diode to minimize the gap. But the diode cannot effectively reduce the voltage gap through the full load current range. This application note demonstrates using the resistor to effectively reduce the gap. The application can also design a calculator to simplify the design procedure. The components based on the asynchronous boost converter using the Boost Converter± Quick Calculator available for download from the TPS61377 product folder. Last, the document shows an example using TPS61377 and shows the precaution for the schematic design and layout design.

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Trademarks

1 Introduction

Section 2 analyzes the original design from Generating Negative and Positive Voltage Rail With Boost Converter TLV61048 and then using the formula to describe main side effect. To reduce the side effect, the section also provides a design. Section 3 uses *Boost Converter± Quick Calculator* to design a circuit in specific condition. Section 4 demonstrates the schematic example and layout example for the application.

2 Analysis of Dual Polarity Voltage Rails Design With Boost Converter

Figure 2-1 shows the typical circuit of dual polarity voltage rails design with asynchronous boost converter. The image uses the RCHG, CCHG, D2 and D3 to achieve the negative voltage rail.

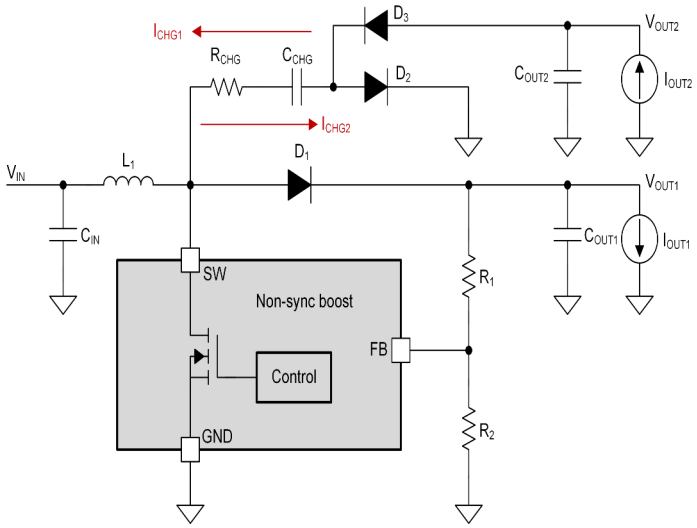

Figure 2-1. Typical Circuit of Dual Polarity Voltage Rails Design With Asynchronous Boost Converter

2.1 Analysis of Factors Affecting Negative Voltage Rail

Negative voltage rail DC voltage can be estimated through Equation 1. The negative voltage rail can have a gap comparing with positive voltage rail. Main factors causing negative voltage gap are RCHG and forward voltage of D2 and D3.

$$-V_{OUT2} = (V_{OUT1} + V_{D1}) - (I_{CHG1} + I_{CHG2}) \times R_{CHG} - V_{D2} - V_{D3} \quad (1)$$

$$I_{CHG1} = \frac{1}{D} \times I_{OUT2} \quad (2)$$

$$I_{CHG2} = \frac{1}{1-D} \times I_{OUT2} \quad (3)$$

But forward voltage of D1 helps the voltage gap. Normally, selecting higher forward voltage of D1 to cover the gap is the common method and the higher forward voltage can help the gap in full load, but in light load condition, the higher forward voltage can generate the extra voltage on the negative voltage rail if we select higher forward voltage of D1.

$$\text{Negative voltage drop} = \frac{1}{D(1-D)} \times I_{OUT2} \times R_{CHG} + V_{D2} + V_{D3} - V_{D1} \quad (4)$$

2.2 Improvement of Gap Between Negative Voltage Rail and Positive Voltage Rail

Figure 2-2 shows the improvement. To select appropriate R3 and forward voltage of D1 can improve the gap. The negative voltage rail formula can be edited as Equation 5. For best practice have the design meet Equation 6 to reduce the gap. To reduce the gap in full load current range, the commendation is to design to eliminate the forward voltage drop. And can simplify the Equation 7 to Equation 8.

$$-V_{OUT2} = \left(V_{OUT1} + V_{D1} + \frac{I_{OUT1}}{1-D} \times R_3\right) - (I_{CHG1} + I_{CHG2}) \times R_{CHG} - V_{D2} - V_{D3} \quad (5)$$

$$V_{D1} + \frac{I_{OUT1}}{1-D} \times R_3 = \frac{1}{D(1-D)} \times I_{OUT2} \times R_{CHG} + V_{D2} + V_{D3} \quad (6)$$

$$I_{OUT1} \times R_3 = \frac{1}{D} \times I_{OUT2} \times R_{CHG} \quad (7)$$

$$R_3 = \frac{1}{D} \times R_{CHG} \times \frac{I_{OUT2}}{I_{OUT1}} \quad (8)$$

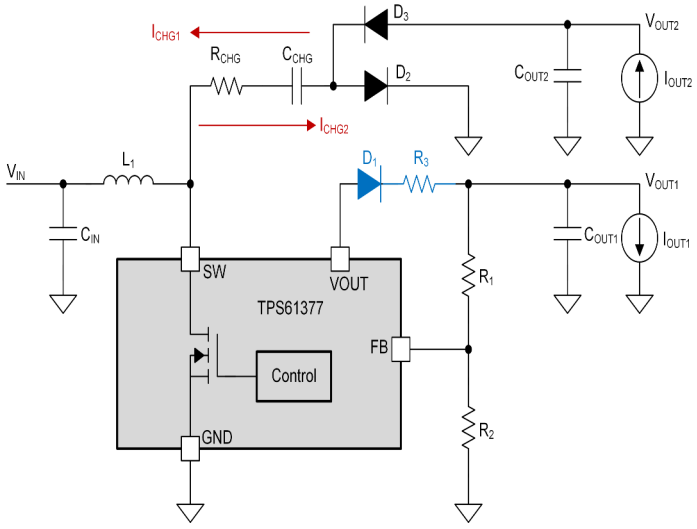

Figure 2-2. Improvement of Voltage Gap Between Negative Voltage Rail and Positive Voltage Rail

3 Boost Converter ± Quick Calculator Design

Table 3-1 shows the example of the test condition.

Table 3-1. Test Condition Example

Test condition	
Input voltage	12V
Output voltage	± 19V
Output load	± 100mA

And the application note uses TPS61377 to achieve the design. The switching frequency is 650kHz. Table 3-2 shows the preliminary results.

Table 3-2. I/O Condition in Boost Converter ± Quick Calculator Design

I/O condition			
System Parameters	**Value**	**Unit**	**Remark**
Vin(typ)	12	V	Typical input voltage
VOUT1	19	V	Positive power rail voltage
VOUT2	-19	V	Negative power rail voltage
Fsw	650	kHz	Switching frequency
IOUT1	0.1	A	Load current of positive voltage rail
IOUT2	0.1	A	Load current of negative voltage rail
Efficiency	90	%	Estimated value, used 90% as default
Ripple of VCOUT2	0.19	V	1% of VOUT
CCHG	0.81	µF	Recommended CCHG that achieve desired Vout ripple
RCHG	0.32733	Ω	Recommended RCHG, by using Ts = RCHG × CCHG

Table 3-3 shows the components selection. The forward voltage of D2 and D3 are better to select the smaller to minimize the power loss of the architecture. In the previous section, the recommendation is to forward voltage of D1 and R3. For the power loss of R3 needs be carefully designed.

Table 3-3. Components Selection in Boost Converter ± Quick Calculator Design

Components selection			
System Parameters	**Value**	**Unit**	**Remark**
CCHG	4.70	µF	Real CCHG, suggest > recommended value for derating
RCHG	1	Ω	Real RCHG, suggest >= 1Ω && recommended value, use 1Ω as first
VD2	0.35	V	Real forward voltage of VD2, smaller is good
VD3	0.35	V	Real forward voltage of VD3, smaller is good
VD1	0.7	V	Recommended forward voltage of VD1=VD2+VD3
VD1	0.7	V	Real forward voltage of VD1
R3	2.32	Ω	Recommended R3 by using real VD1
R3	2.32	Ω	Real VD1 resistor
PR3	0.0408	W	Average power of R3

Table 3-4 shows the calculation result after inputting the I/O condition and Component selection. Original gap means that the architecture without using R3 and D1. After R3, the gap can be effectively reduced.

Table 3-4. Calculation Result in Boost Converter ± Quick Calculator Design

Calculation result			
System Parameters	**Value**	**Unit**	**Remark**
D	0.43		Duty cycle of boost converter
Ts	1.54	µs	Duty time
Ton	0.66	µs	Duty on time
ICHG1	0.23	A	Averaged ICHG1
ICHG2	0.18	A	Averaged ICHG2
ΔVCHG	0.033	V	Ripple of the CCHG
VCHG	19.17	V	DC voltage of the CCHG
Original -VCOUT2	18.59	V	Original negative voltage rail
Original Gap	0.41	V	Original gap
Output capacitance	0.4603	µF	Cout need for VOUT1
Optimized -VCOUT2	19.0005	V	Optimized negative voltage rail
PRCHG	0.0408	W	Power of RCHG
Optimized Gap	-0.0005	V	Optimized gap

4 Demo and Test

4.1 Simulation Results

Simulation uses the Table 4-1 test parameters to analyze the function of R3 in Figure 4-1.

Table 4-1. Test Parameters

Test parameters	
Input voltage	12V
Output voltage	± 19V
Output load	± 500mA

Table 4-2 shows the gap between with using R3 and without using R3. R3 can effectively eliminate the DC offset using the architecture.

Table 4-2. Gap With and Without Using R3

IOUT1/2 (A)	R3=2.32ohm, Gap(V)	R3 = 0ohm, Gap(V)
0	0.0000	0.0000
0.1	-0.0005	0.41
0.2	-0.0010	0.82
0.3	-0.0015	1.22
0.4	-0.0021	1.63
0.5	-0.0024	2.04

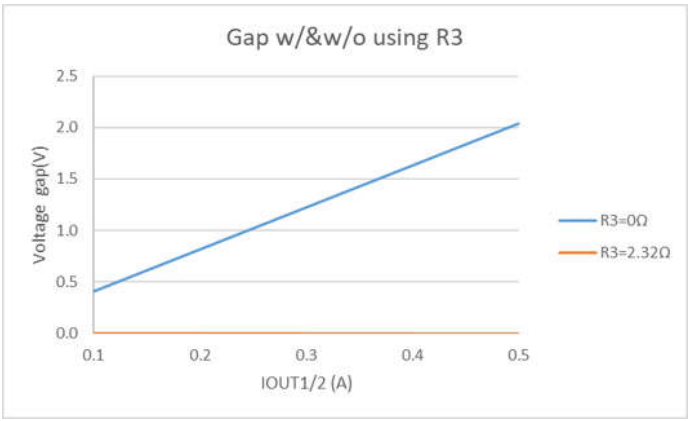

Figure 4-1. Gap With and Without Using R3

4.2 Demo Board Example

Figure 4-2, Figure 4-3, and Figure 4-4 demonstrate a schematic and two-layered layout example using TPS61377 to achieve Table 4-1 requirements. To minimize the output power loop, the recommendation is to add 1μF capacitor on VOUT pin to GND like C14 showing in the schematic.

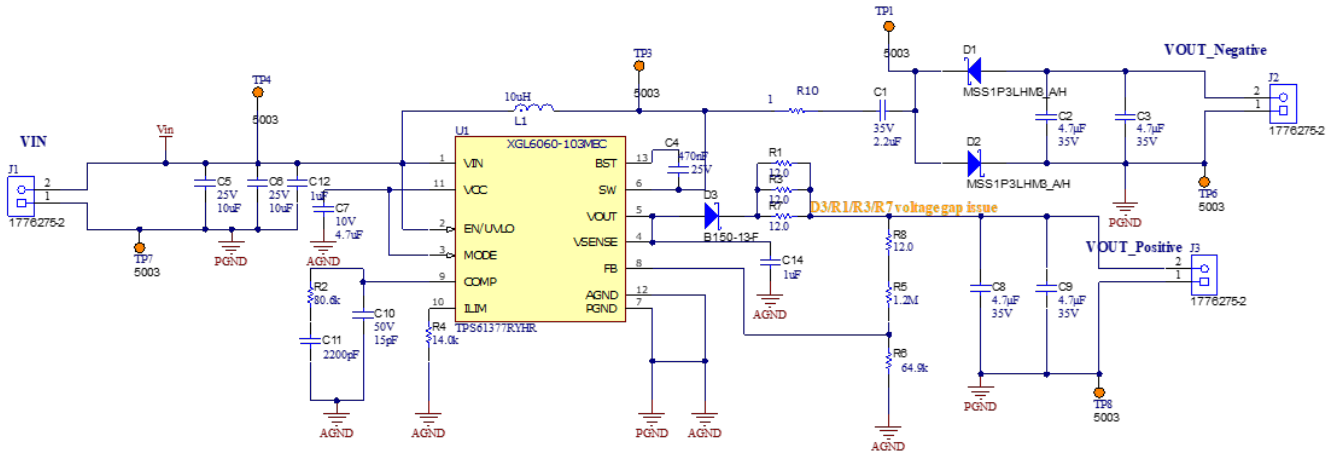

Figure 4-2. TPS61377 Schematic

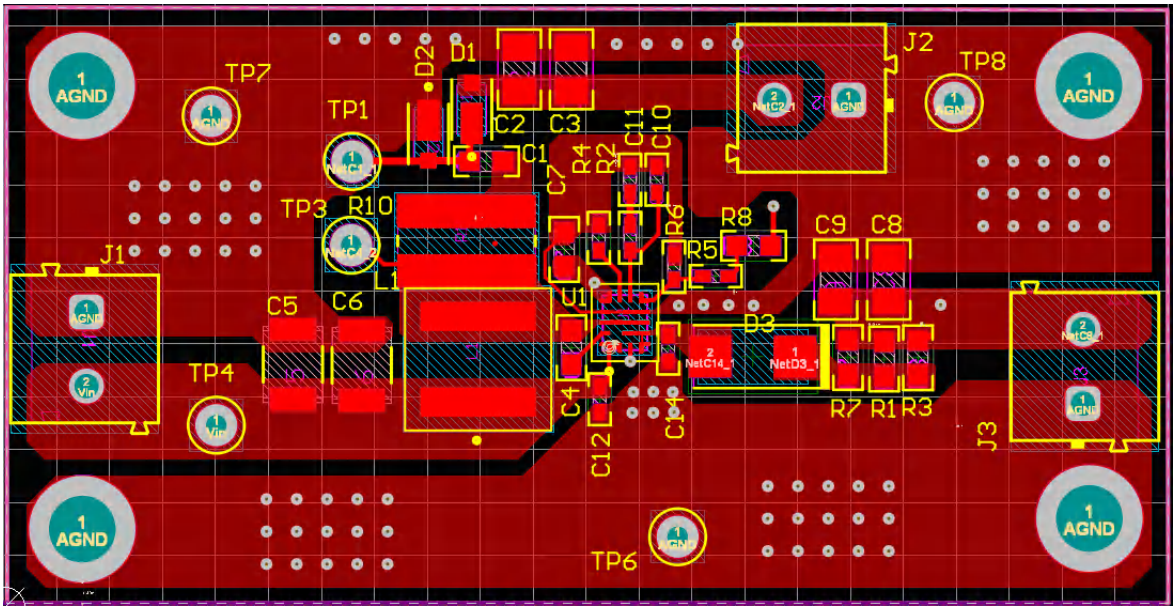

Figure 4-3. TPS61377 Layout (Top)

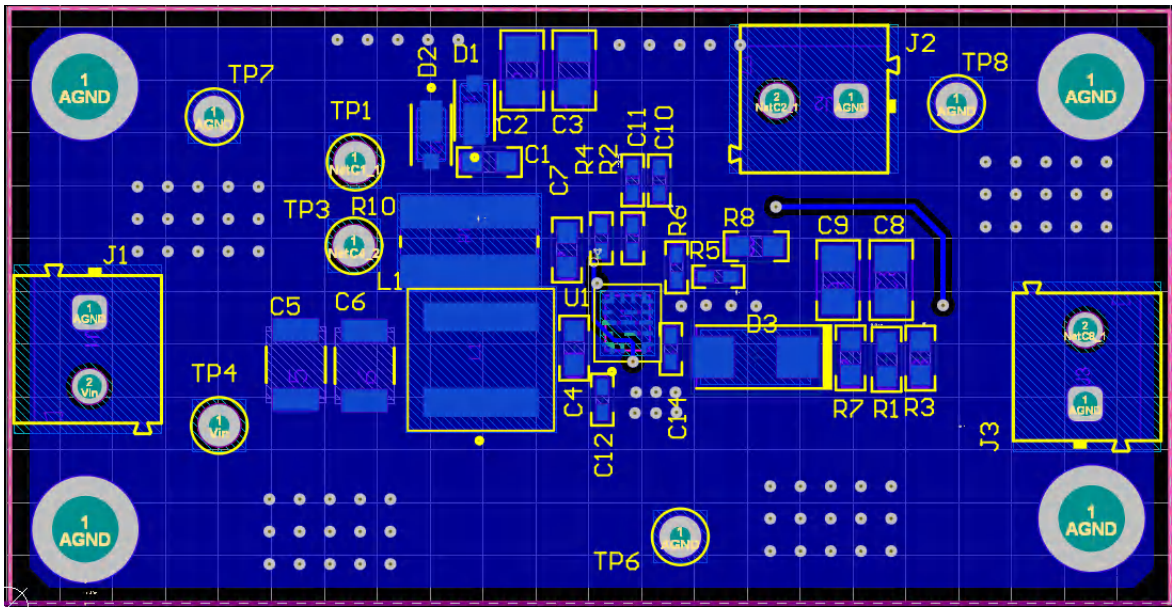

Figure 4-4. TPS61377 Layout (Bottom)

5 Summary

This application note shows the method to eliminate the DC offset issuing using charge pump circuit with traditional boost converter. But the method is not recommended to use in high power rating application because the method needs to select high power rating charge resistor and the method can cause higher power loss, cost, and size. The Boost Converter ± Quick Calculator can be used to evaluate the resistors power rating need to do further design and complete assessment in advance.

6 References

- Texas Instruments, *Design for a Discrete Charge Pump*, application note.
- Texas Instruments, *Generating Negative and Positive Voltage Rail With Boost Converter TLV61048*, application note.

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