PMP15036 Test Results

System Description

The traditional fixed power supply audio PA has been well established for many years. The shortage of this fixed power supply PA is that when the input audio signal's peak to average ratio is high, the conversion efficiency will be low. Because during the periods of the peaks, the PA requires a full voltage to be able to deliver the required power without running into distortion, but during the periods of lower signal amplitude, this full voltage is not required and keeping high power supply voltage means unnecessary power is dissipated.

For the portable blue tooth speaker, the battery lasts time is of upmost important. In most of the working time, the blue tooth speaker works in the low music volume condition. Therefore, if we can set the supply voltage of the PA low when the music volume is low, the supply voltage of the PA high when the music volume is high, then the conversion efficiency of the blue tooth speaker can be greatly improved. And the lasts time of the battery will be much longer.

TPS61178 is a high efficiency 20V synchronous boost converter. It could isolate the output from the input side when shutdown. So it can help to reduce the battery loss when the PA is not working.

TPS3128D2 is a stereo efficiency, digital power amplifier. TPS3128D2 has low idle power loss and helps to extend the battery life of the Bluetooth/wireless speakers.
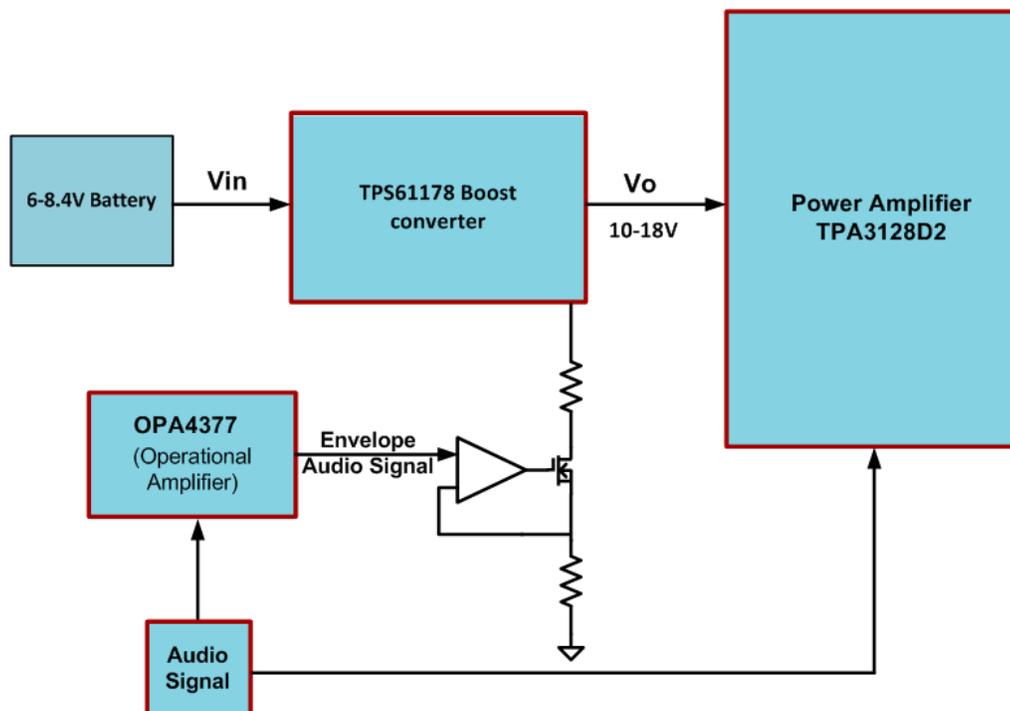

Figure 1. Block Diagram of the PMP15036

The block diagram of this reference design is shown in Figure 1. This reference design delivers an envelope-tracking power supply circuit for the PA TPA3128D2 with boost converter TPS61178. The objective of envelope-tracking is to improve the efficiency of PA in the full range of the output power. By adding an audio envelope signal to the FB pin, the TPS61178's output voltage can change in accordance with the envelope of the audio signal. Thus the PA can always operate at high-efficiency in the whole output power range.

Table 1 gives out the TPS61178 output voltage in corresponding to the different amplitude audio signal. When the audio signal is 0mV, the output voltage of TPS61178 is 10V. When the audio signal is 400mV, the output voltage of TPS61178 is 18V, which is the highest value in this TI design.

Table 1. Performance Specification

Audio Signal _ peak(mV)	Output Voltage(V) (Typical)
0	10
50	11
100	12
150	13
200	14
250	15
300	16
350	17
400	18

Design Theory

Figure 2.1 shows the boost converter part schematic of the TI design PMP15036. Operational amplifier U2A detects the audio signal from the right channel. Operational amplifier U2B detects the audio signal from the left channel. The output of U2A and U2B is connected together by D2 and D4.So only the audio signal with higher volume could pass through. The operational amplifier U2D , diode D3, resistor R13, R15, capacitor C18 forms the envelope tracking circuit. It samples out the peak envelope waveforms of the input audio signal. Operational amplifier U2C, mosfet Q3 and resistor R16 convert the envelope voltage signal to an envelope current signal. This envelope current signal makes the output voltage of the TPS61178 changes in accordance with the amplitude of the input audio signal.

When the input audio signal is 0V, the output of the envelope-tracking circuit is 0V. So the current flowing through Q3 is 0A. The output voltage $V_{o(min)}$ is determined by R3 and R5. A standard low side resistor R5 of 57.6kΩ is selected. The high side resistors R3 can be calculated by the following equation:

$$\frac{V_{o(\min)} - V_{FB}}{R3} = \frac{V_{FB}}{R5}$$

(1)

Where

- V_{FB} is the TPS61178's feedback regulation voltage (V_{FB}=1.198V).

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- $V_{O(min)}$ is the boost converter's minimum output voltage, which is defined as 10V in this TI design.

So R3=422 kΩ.

When the input audio signal is at its maximum amplitude of 400 mV, the output voltage of the envelope-tracking circuit is 800mV. The current flowing through Q3 reaches its maximum value. The output voltage of TPS61178 also reaches its maximum value 18V. The maximum current flowing through Q3 ($I_{Q3(max)}$) can be calculated as:

$$I_{Q3(\max)} = \frac{(V_{o(\max)} - V_{FB})}{R3} - \frac{V_{FB}}{R5} = 19.02uA \qquad (2)$$

So the resistors R16 can be calculated by the following equation:

$$R16 = \frac{V_{envelop(\max)}}{I_{Q3(\max)}} \approx 42.2k\Omega \qquad (3)$$

Where

- $V_{envelop(max)}$= 800mV(two times of the maximum amplitude of the input audio signal).

The design theory of this test report mainly focus on the envelope tracking circuit calculate. For the power stage and compensation network calculate, please refer to the TPS61178 datasheet.

Figure 2.2 shows the power amplifier part schematic of the TI design PMP15036. TPS3128D2 is a class-D amplifier with low idle loss. The gain of the TPA3128D2 is set at 32DB (31DB - 33DB) in this TI design. So when the peak amplitude of the input audio signal is 400mV, the output voltage can reach 16V(17.86V at worst case). For the other key components selection, please refer to the TPA3128D2 datasheet.
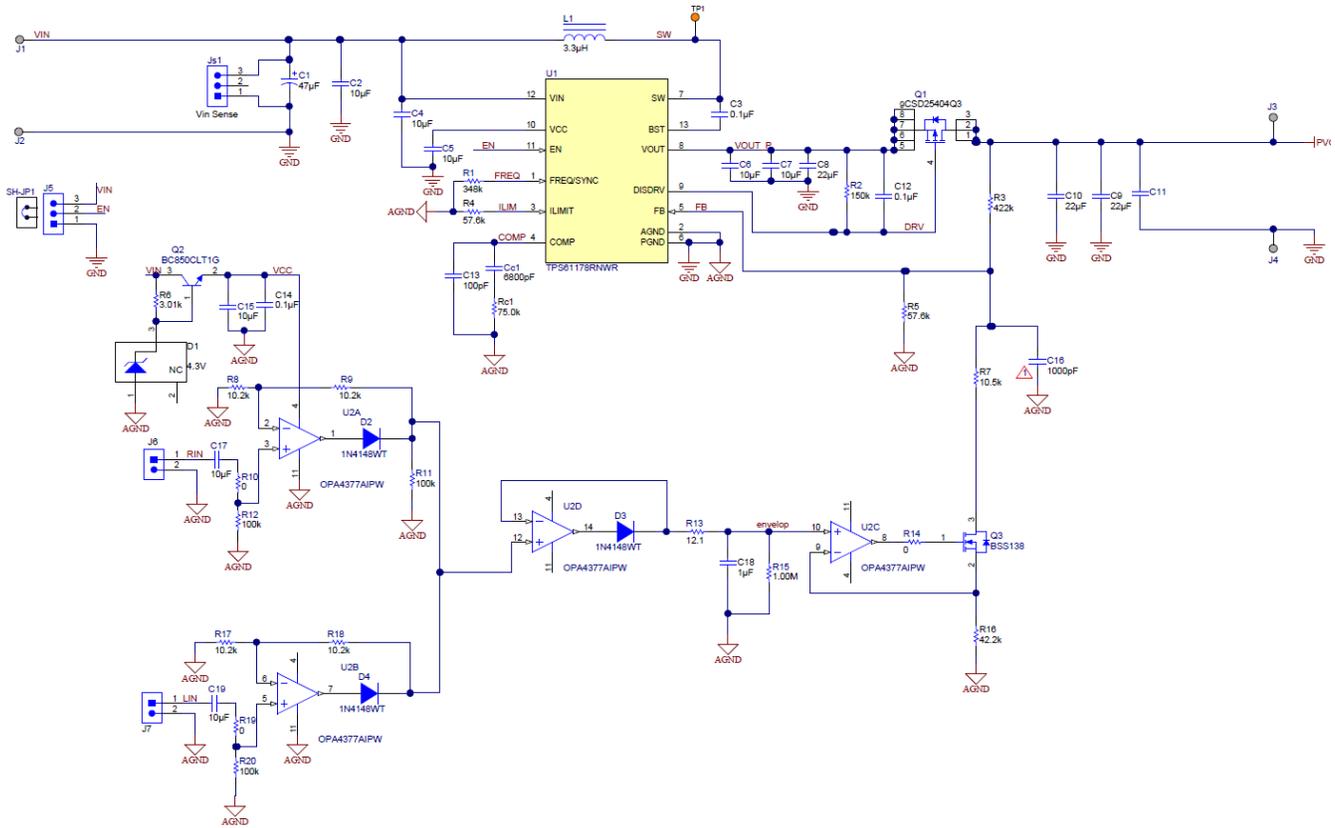
Figure 2.1 Schematic of the PMP15036 (Boost Converter)
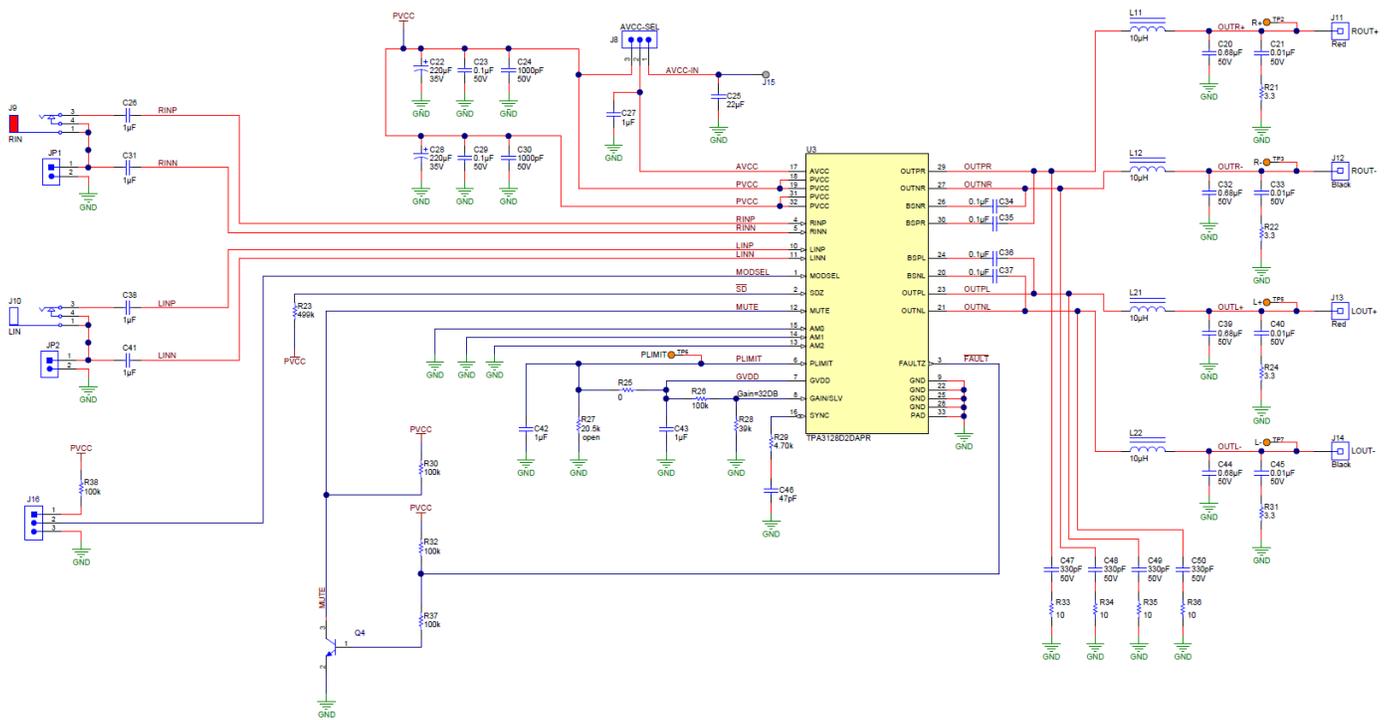
Figure 2.2 Schematic of the PMP15036 (Power Amplifier)

Test Result

Figure 3 shows the output voltage of the boost converter TPS61178 versus the amplitude of the input audio signal. The output voltage rises linearly with the increase of the audio signal.
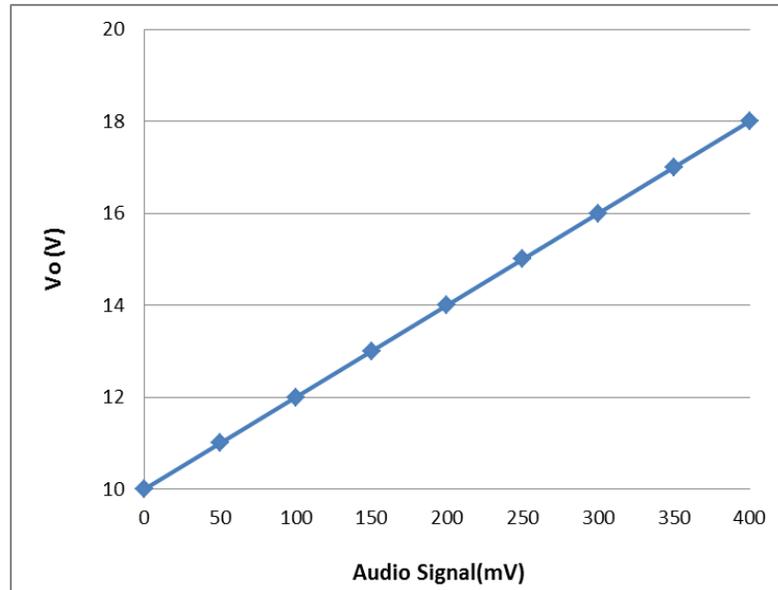

Figure 3 V_O VS. Audio Signal

Figure 4.1, Figure 4.2 , Figure 4.3 and Figure 4.4 show the output voltage transition of the boost converter TPS61178 from $V_{O(min)}$ to $V_{O(max)}$ when the input audio signal steps up from 0mV to 400mV (V_{in}=7.2V, R_{load}=8 ohm).The TPS61178's output voltage rises up from the lowest value to the highest value within around 1.5ms at this big audio signal step. The TI design PMP15036 uses two 220-uF electrolytic capacitors at the TPS61178's output side, which act as the decoupling capacitor of the TPA3128D2. If changing the two 220-uF electrolytic capacitor to two 100-uF electrolytic capacitors, the TPS61178's output voltage can rise from $V_{O(min)}$ to $V_{O(max)}$ within 1ms in the worst case conditions, which can meet most of the applications at the customer side.
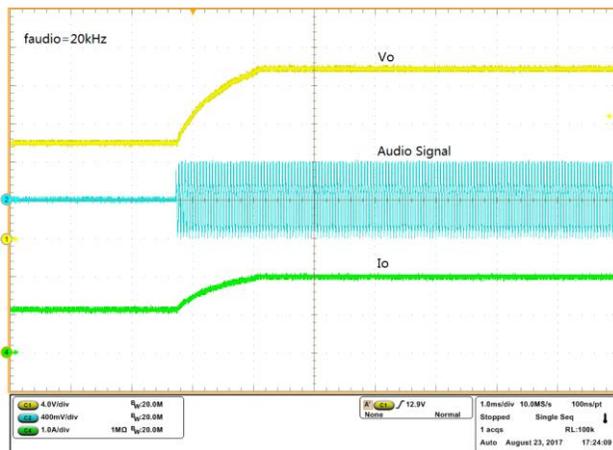
Figure 4.1 Output Voltage Transition at f_{audio}=20kHz
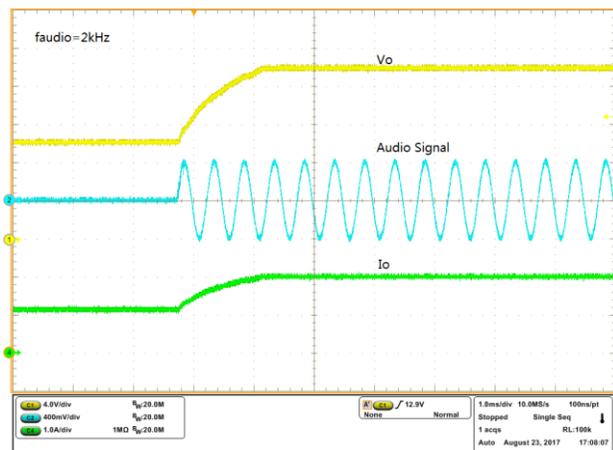
Figure 4.2 Output Voltage Transition at f_{audio}=2kHz
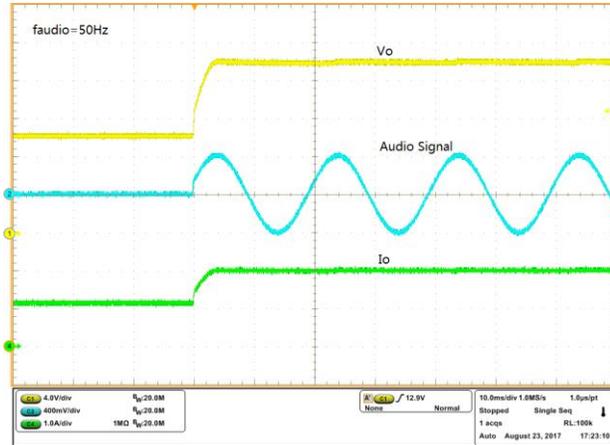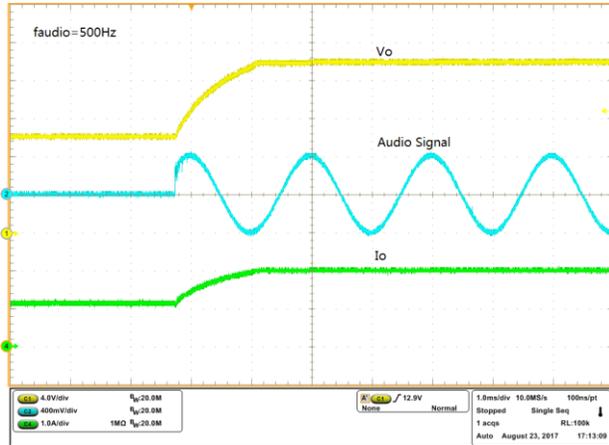
Figure 4.3 Output Voltage Transition at f_{audio}=500Hz   Figure 4.4 Output Voltage Transition at f_{audio}=50Hz

Figure 5 shows the waveforms of the input audio signal and the output voltage of the TPS61178 while playing music. The output voltage of the TPS61178 changes in accordance with the change of the input audio signal.
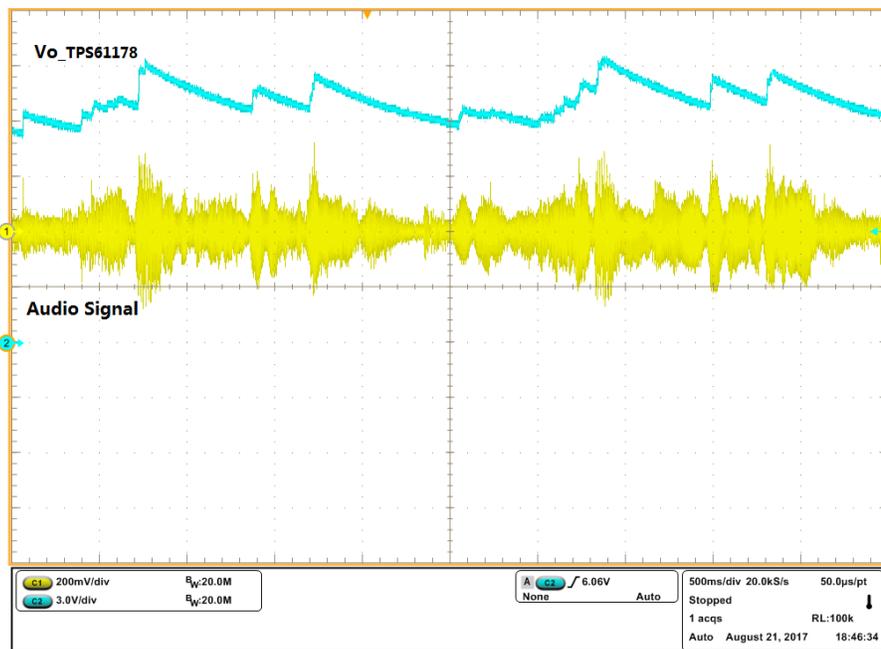

Figure 5 Output Voltages of the TPS61178 while Playing Music

Figure 6 shows the efficiency comparison result of the TI design PMP15036 envelop tracking solution with the traditional fixed supply voltage solution. With the TI design PMP15036, the conversion efficiency at the low music volume can be greatly improved. The efficiency is more than 20% higher than that of the fixed supply voltage solution. In most of the real application conditions, the music volume is low or medium, so with the TI design PMP15036 solution, the battery lifetime can be greatly prolonged.
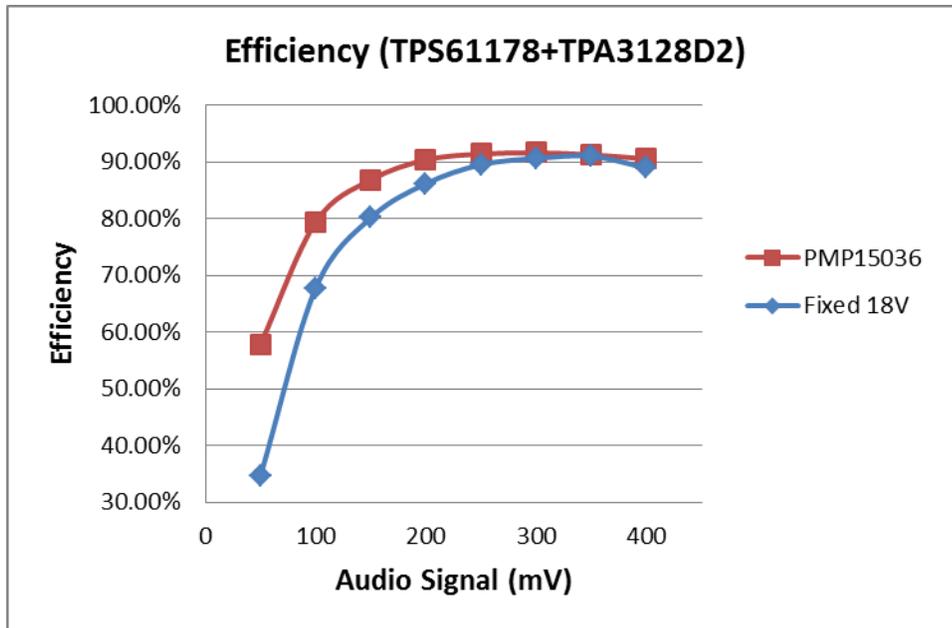
Figure 6 Efficiency Comparison Result (Vin=7.2V, Ro=4 ohm)

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