Application Report
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Reducing Output Ripple Voltage of TPS61070 During PFM-Mode Operation

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ABSTRACT

This application report presents a possible solution to reduce the output ripple voltage of the TPS61070 during PFM-mode operation, and primarily focuses on modifying the feedback loop response and how that affects the output ripple voltage for Bluetooth™ headset application with a single-cell alkaline battery.

Contents

List of Figures

1 Introduction

The battery life for Bluetooth™ headset primarily depends on the power consumption of the Bluetooth chipset, as well as the efficiency of the dc/dc converter. Due to the unique current pulses drawing from the Bluetooth chipset at a different operating mode, it places a stringent requirement on the dc/dc converter to achieve high efficiency throughout the operating conditions.

Achieving high converter efficiency (>85%) during talk mode is not difficult as the average current drawn is between 20 mA and ~30 mA. However, during sniff-mode (or standby-mode) operation, the system draws low current (µA) most of the time, with repetitive current pulses of 20 mA to ~ 30 mA periodically. In order to achieve high converter efficiency, power safe-mode (or pulse frequency modulation) operation is required to improve the converter efficiency to greater than 75%.

During power safe-mode operation, the converter only operates when the output voltage trips below a lower set threshold voltage, ramping up the output voltage with several pulses until the output voltage exceeds the upper set threshold voltage, and the converter enters the power safe-mode operation again. The output ripple voltage of this power safe-mode operation, therefore, is much higher than fixed frequency operation, and could easily exceed 50 mV. This violates the ripple voltage requirement of the Bluetooth chipset and might cause abnormal current drawn by the chipset.

Figure 1 shows this phenomenon in the actual circuit with our TPS61070 converter boosting from a single-cell alkaline battery to 1.8 V during sniff-mode operation. The pulse-frequency modulation (PFM) ripple voltage of > 40 mV causes the system to draw extra current.

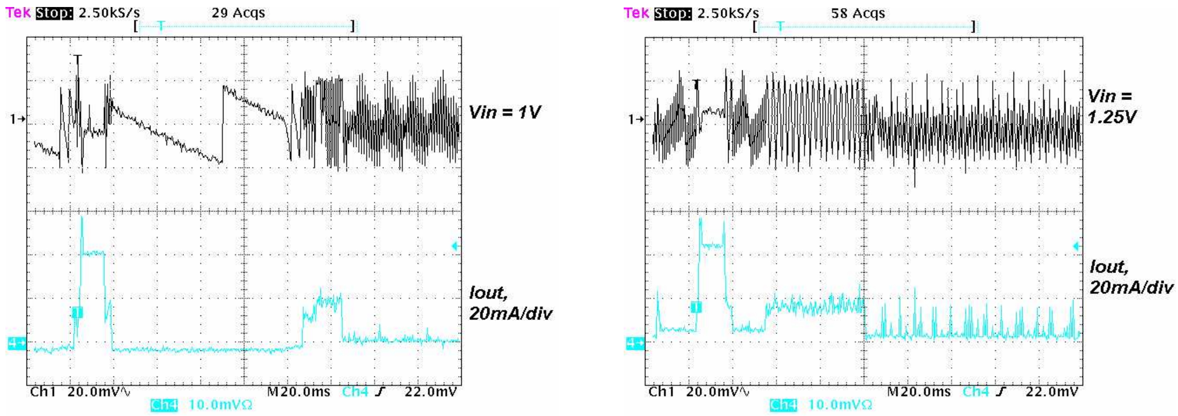


Figure 1. High Ripple Voltage Causes the Bluetooth Chipset to Draw Excessive Current During Sniff-Mode Operation

Bluetooth is a trademark of Bluetooth SIG, Inc..

2 Experiment

TPS61070EVM evaluation module (EVM) was used in this experiment with slight modification to find a practical solution of reducing the PFM ripple voltage for such an application. Figure 2 shows the schematic for this evaluation. Figure 3 shows the screen captures of the output ripple voltage before any modification of the EVM, with inductor value of 4.7 µH and output capacitor of 2 × 4.7 µF. The left image of Figure 3 shows the ripple voltage when no load is connected at the output, and the right image of Figure 3 shows the ripple voltage when periodic current pulses are drawn to the load to simulate the sniff-mode operation of a Bluetooth headset.

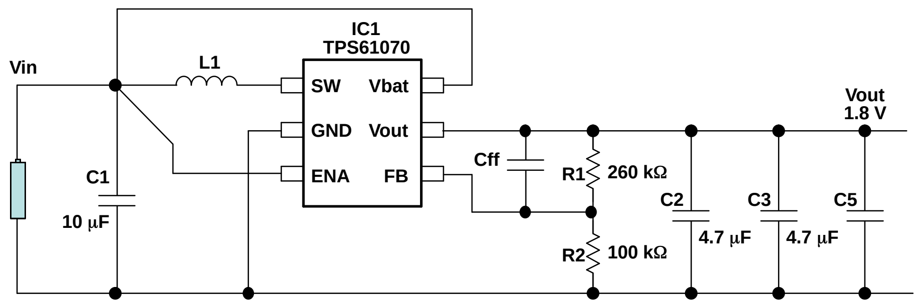


Figure 2. Test Circuit of TPS61070 for Single-Cell Alkaline Battery to 1.8-V Output

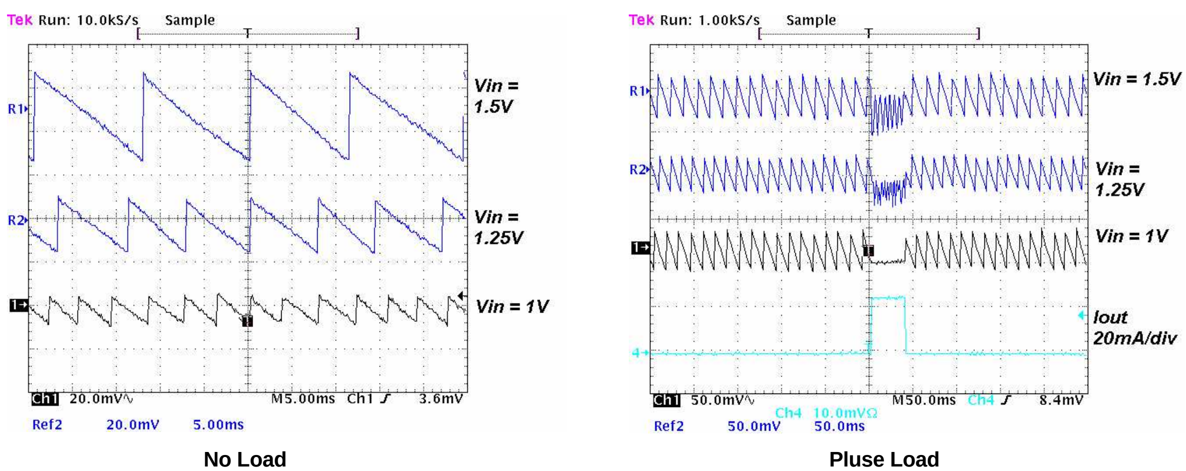
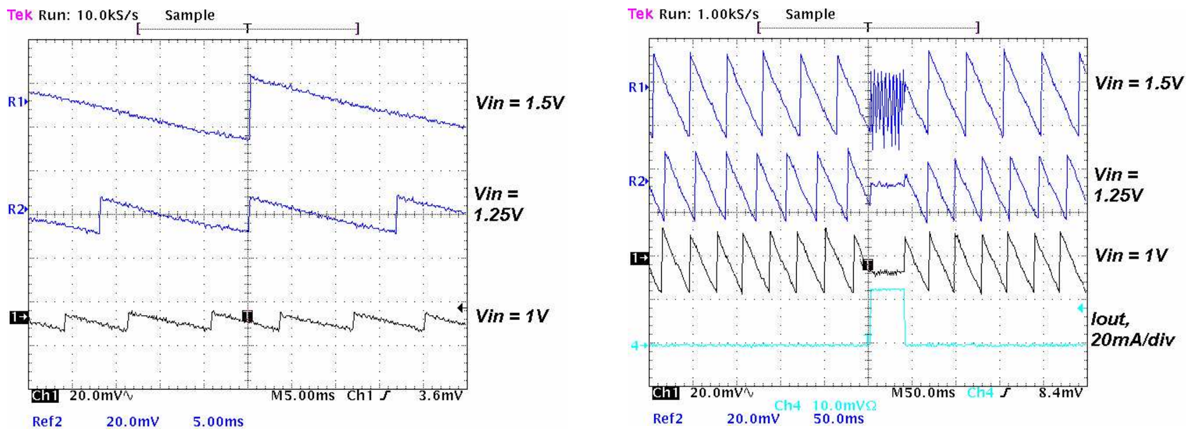


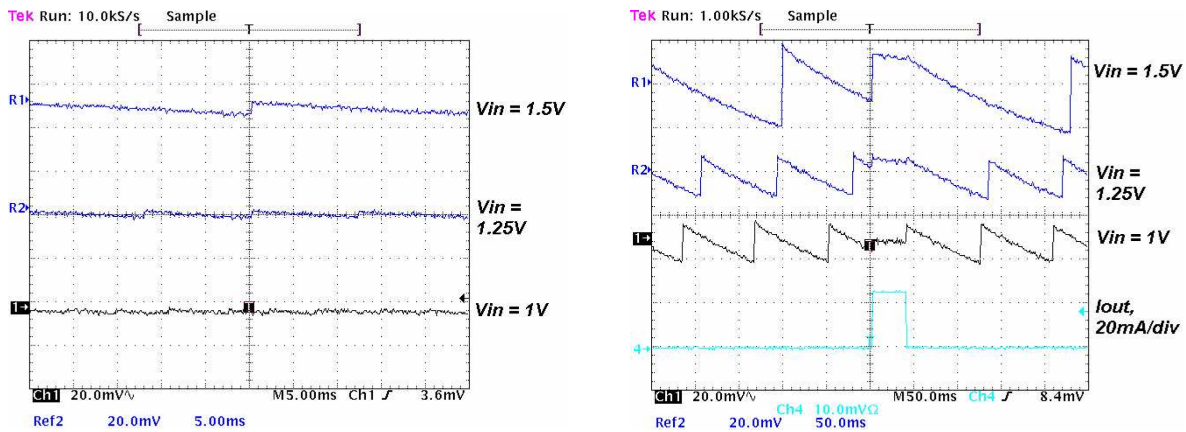
Figure 3. Output Ripple Voltage During PFM-Mode Operation With Original EVM Setup of 4.7-µH Inductor and 2 × 4.7-µF Output Capacitors (Note the change of voltage scale on the right to accommodate the waveforms.)

Although adding an output capacitor to the circuit improved the ripple voltage at no-load steady state, it did not improve the ripple voltage during periodic pulse current-mode operation (simulated sniff-mode operation). Figure 4 and Figure 5 show the ripple voltage after adding a 22-µF output capacitor and 120-µF output capacitor, respectively.



No Load Pluse Load

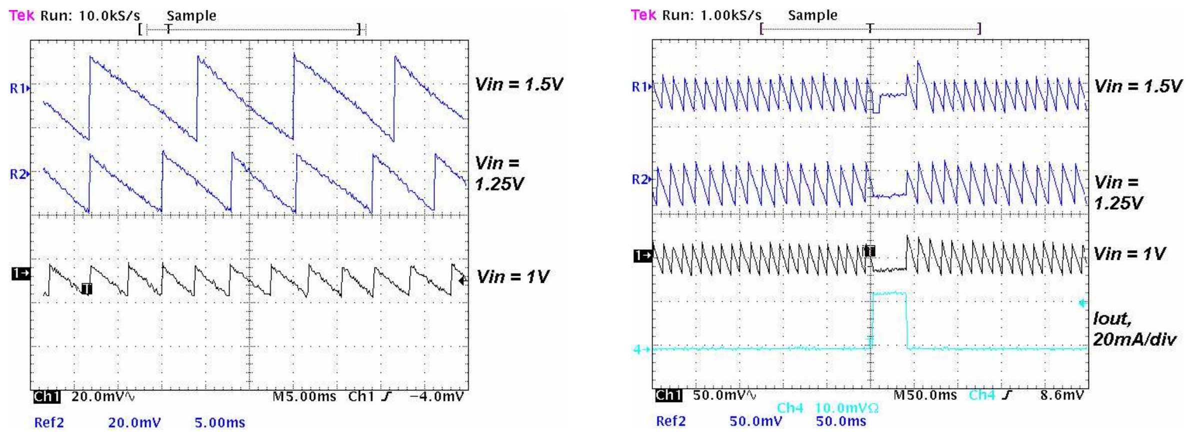
Figure 4. Output Ripple Voltage During PFM-Mode Operation With Additional 22-µF Output Capacitor (C5)



No Load Pluse Load

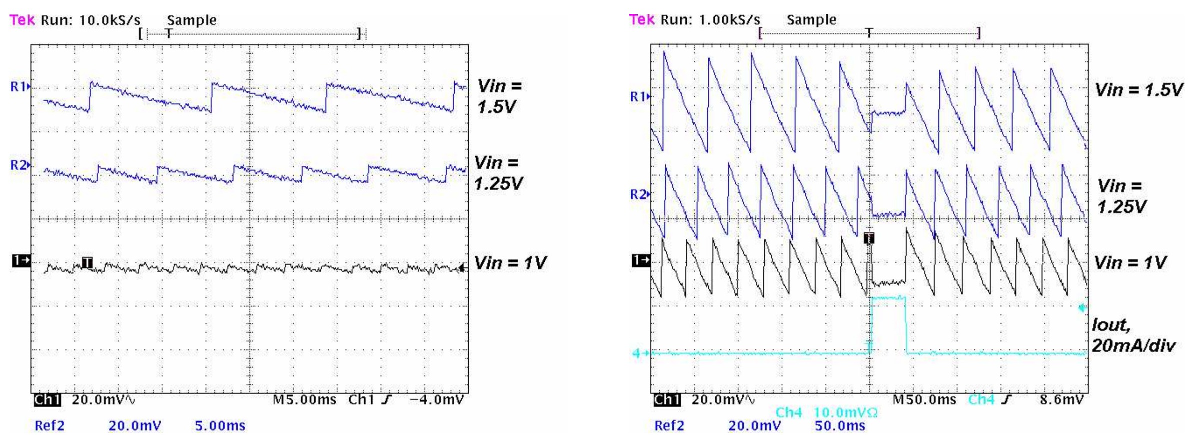
Figure 5. Output Ripple Voltage During PFM-Mode Operation With Additional 120-µF Output Capacitor (C5)

Increasing the inductance from 4.7 µH to 10 µH also did not improve the ripple voltage during the pulse load. Figure 6 shows the output ripple voltage with 2 × 4.7-µF output capacitors. Figure 7 and Figure 8 show the ripple voltage with the addition of 22-µF and 120-µF output capacitors, respectively



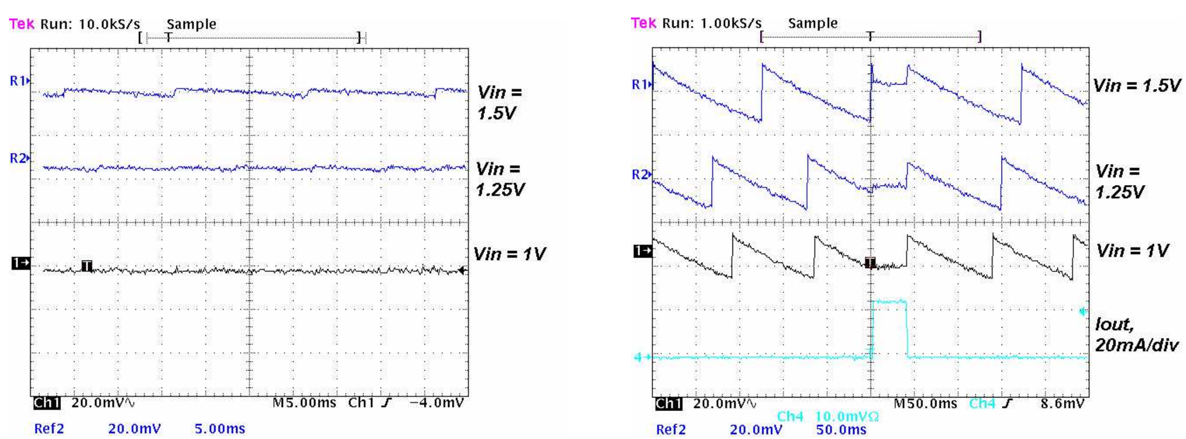
No Load | Pluse Load

Figure 6. Output Ripple Voltage During PFM-Mode Operation With 10-μH Inductance, 2 × 4.7-μF Output Capacitor (Note the change of voltage scale on the right to accommodate the waveforms.)



No Load | Pluse Load

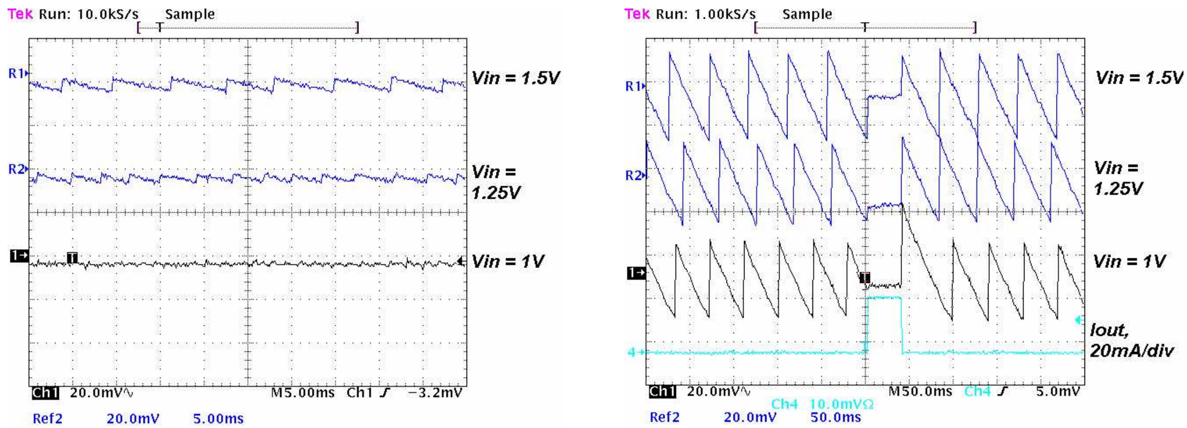
Figure 7. Output Ripple Voltage During PFM-Mode Operation With 10-μH Inductance, 2 × 4.7-μF + Additional 22-μF (C5) Output Capacitor



No Load | Pluse Load

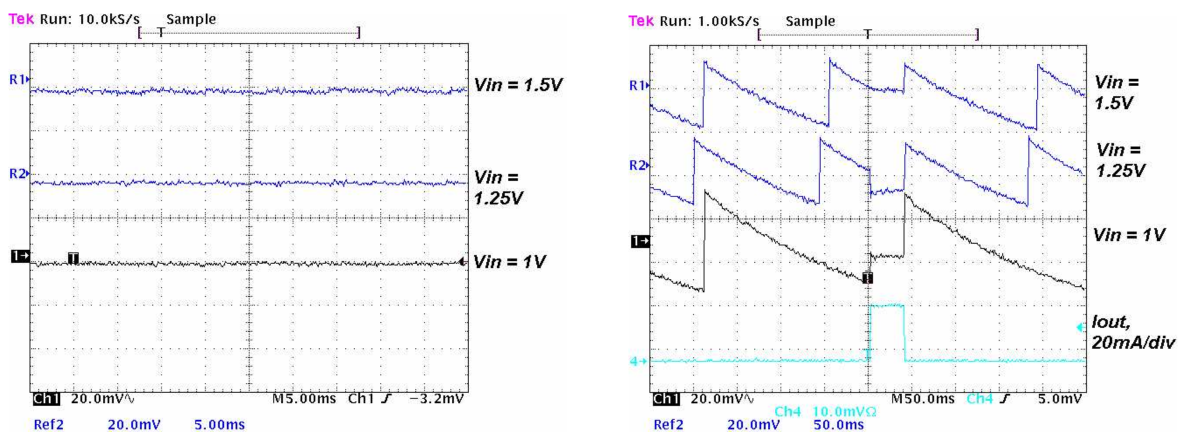
Figure 8. Output Ripple Voltage During PFM-Mode Operation With 10-μH Inductance, 2 × 4.7-μF + Additional 120-μF(C5) Output Capacitor

Increasing the inductance to 22 µH did not improve the ripple voltage at pulse load operation. It actually caused increases of output ripple voltage, especially at lower input, as shown in Figure 9 and Figure 10.



No Load | Pluse Load

Figure 9. Output Ripple Voltage During PFM-Mode Operation With 22-µH Inductance, 2 × 4.7-µF + 22-µF (C5) Output Capacitor



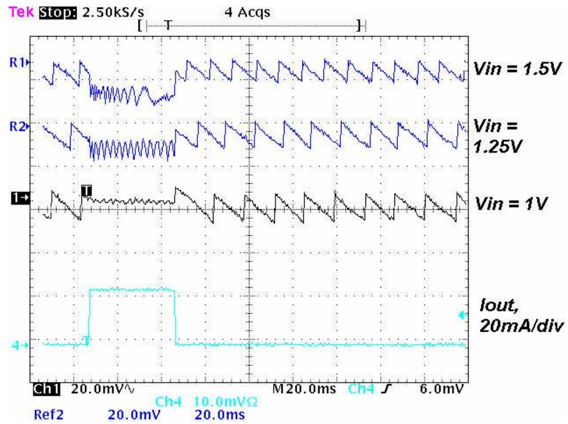
No Load | Pluse Load

Figure 10. Output Ripple Voltage During PFM-Mode Operation With 22-µH Inductance, 2 × 4.7-µF + 120-µF (C5) Output Capacitor

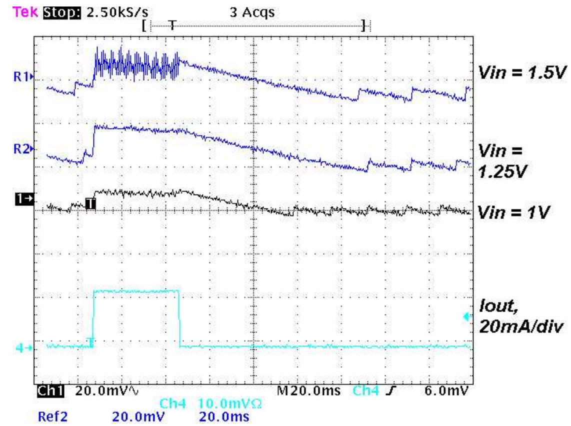
The preceding test results show that simply increasing the inductance or output capacitance could not improve the output ripple voltage significantly during pulse load operation (unless one increased the output capacitance to the range of few thousand microfarads, which is impractical in this application).

At light- to no-load operation, when the inductor current reduces to zero, power safe-mode (PFM) operation occurs, and the output voltage is monitored and regulated by the comparator. The trip point of the comparator and the rate of voltage change at the FB pin determine the output PFM ripple voltage. Adding a feedforward capacitor (Cff) at the feedback path allows more high-frequency content to be coupled into the FB pin and also increases the rate of voltage change. This should reduce the PFM ripple voltage.

With the addition of a 1-nF feedforward capacitor (Cff), the output ripple voltage has improved significantly. Figure 11 shows the screen captured with 4.7-µH inductance with different output capacitance. Figure 12 and Figure 13 show the output ripple voltage with 10-nF and 100-nF feedforward capacitors, respectively.

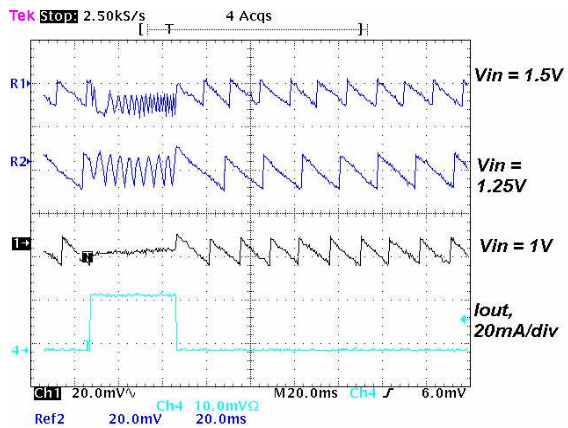


2 x 4.7 μF + 22 μF

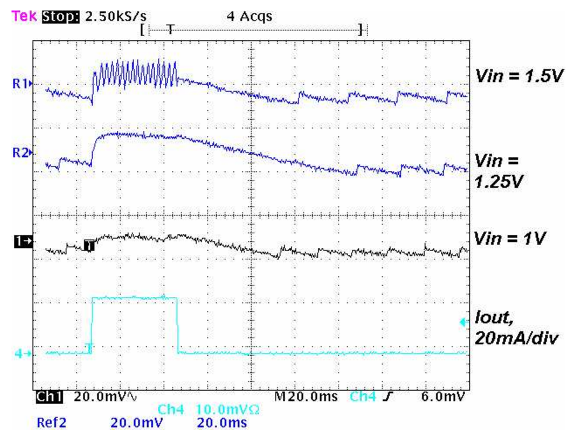


2 x 4.7 μF + 120 μF

Figure 11. Output Ripple Voltage During PFM-Mode Operation With 1-nF Feedforward Capacitor (Cff), 4.7-μH Inductor, and With Different Output Capacitors

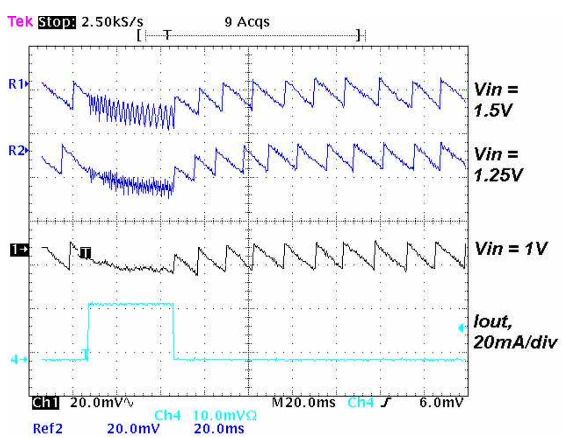


2 x 4.7 μF + 22 μF

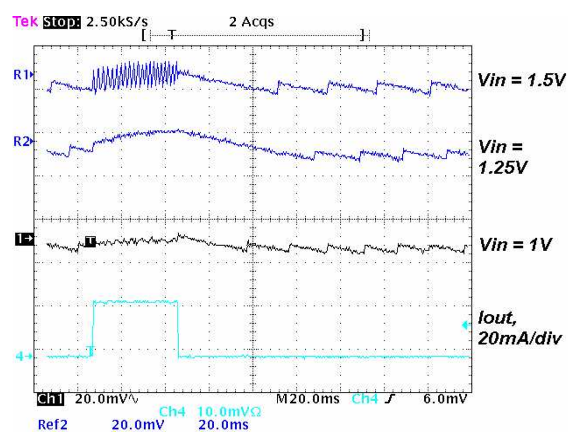


2 x 4.7 μF + 120 μF

Figure 12. Output Ripple Voltage During PFM-Mode Operation With 10-nF Feedforward Capacitor (Cff), 4.7-μH Inductor, and With Different Output Capacitors



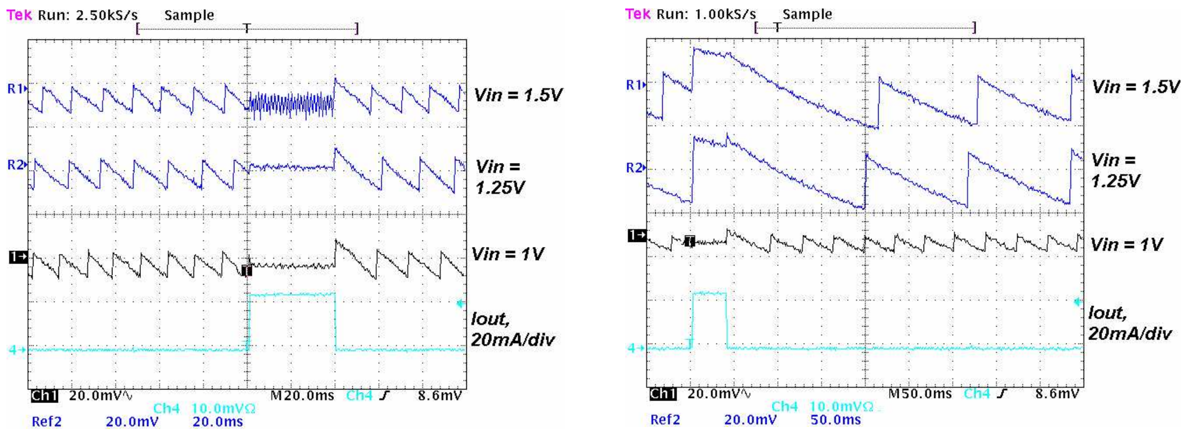
2 x 4.7 μF + 22 μF



2 x 4.7 μF + 120 μF

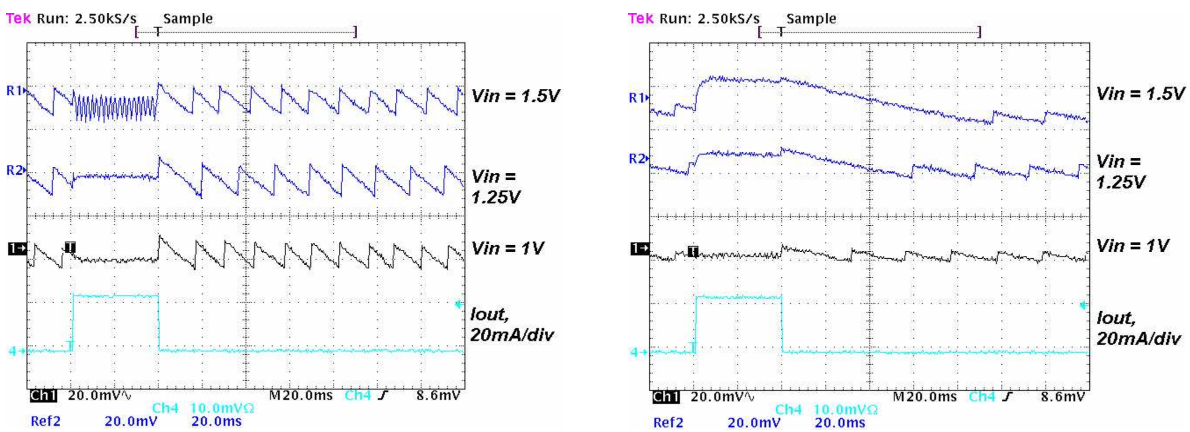
Figure 13. Output Ripple Voltage During PFM-Mode Operation With 100-nF Feedforward Capacitor (Cff), 4.7-μH Inductor, and With Different Output Capacitors

Increasing the inductance from 4.7 µH to 10 µH did not show much improvement on the ripple voltage. Figure 14 to Figure 16 show the screens captured with 1-nF, 10-nF, and 100-nF feedforward capacitors, respectively.



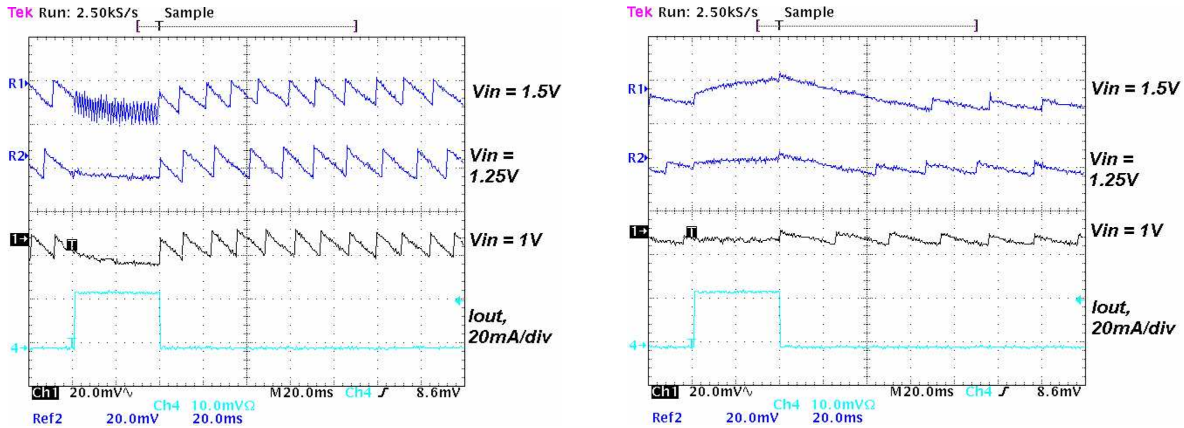
2 x 4.7 µF + 22 µF **2 x 4.7 µF + 120 µF**

Figure 14. Output Ripple Voltage During PFM-Mode Operation With 1-nF Feedforward Capacitor (Cff), 10-µH Inductor, and With Different Output Capacitors



2 x 4.7 µF + 22 µF **2 x 4.7 µF + 120 µF**

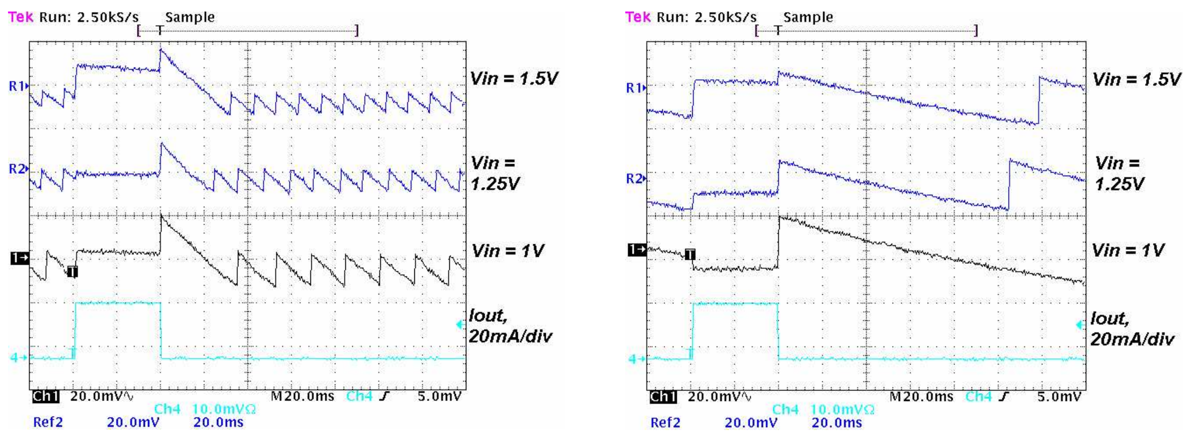
Figure 15. Output Ripple Voltage During PFM-Mode Operation With 10-nF Feedforward Capacitor (Cff), 10-µH Inductor, and With Different Output Capacitors



2 x 4.7 µF + 22 µF **2 x 4.7 µF + 120 µF**

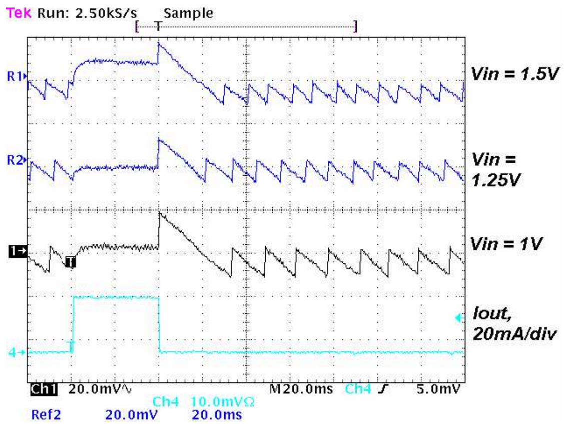
Figure 16. Output Ripple Voltage During PFM-Mode Operation With 100-nF Feedforward Capacitor (Cff), 10-µH Inductor, and With Different Output Capacitors

Increasing the inductance to 22 µH causes the ripple voltage during the transition from pulse load to no load to increase significantly. Figure 17 to Figure 19 show the screen captured with 1-nF, 10-nF, and 100-nF feedforward capacitors, respectively.

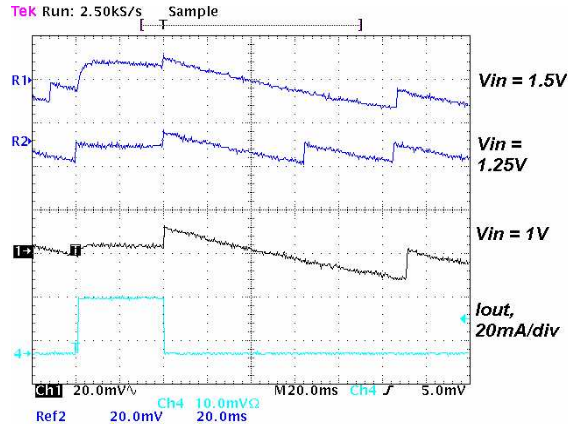


2 x 4.7 µF + 22 µF **2 x 4.7 µF + 120 µF**

Figure 17. Output Ripple Voltage During PFM-Mode Operation With 1-nF Feedforward Capacitor (Cff), 22-µH Inductor, and With Different Output Capacitors

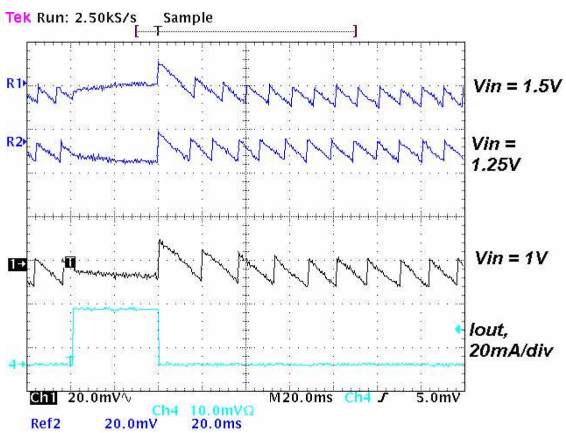


2 x 4.7 µF + 22 µF

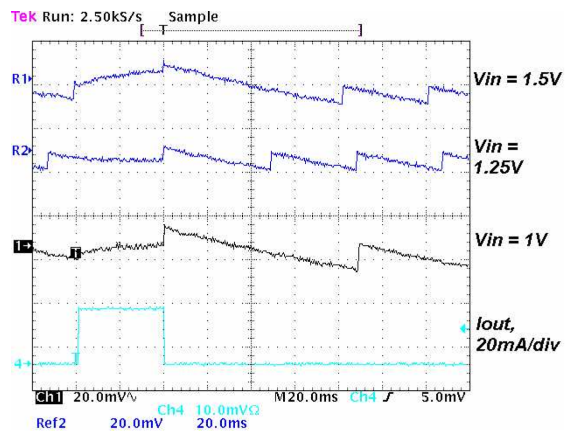


2 x 4.7 µF + 120 µF

Figure 18. Output Ripple Voltage During PFM-Mode Operation With 10-nF Feedforward Capacitor (Cff), 22-µH Inductor, and With Different Output Capacitors



2 x 4.7 µF + 22 µF



2 x 4.7 µF + 120 µF

Figure 19. Output Ripple Voltage During PFM-Mode Operation With 100-nF Feedforward Capacitor (Cff), 22-µH Inductor, and With Different Output Capacitors

3 Summary

From the preceding test results, with a reasonable output capacitor value (greater than 22 µF) and inductance value of 4.7 µH to 10 µH, adding a feedforward capacitor from 1 nF to 100 nF could significantly reduce the output ripple voltage.

Figure 20 and Figure 21 show the screen capture of the ripple voltage and current waveform from the actual Bluetooth headset during sniff-mode operation. It confirms that this is a practical solution to reduce the output ripple voltage in the Bluetooth headset by adding the feedforward capacitor at the feedback loop.

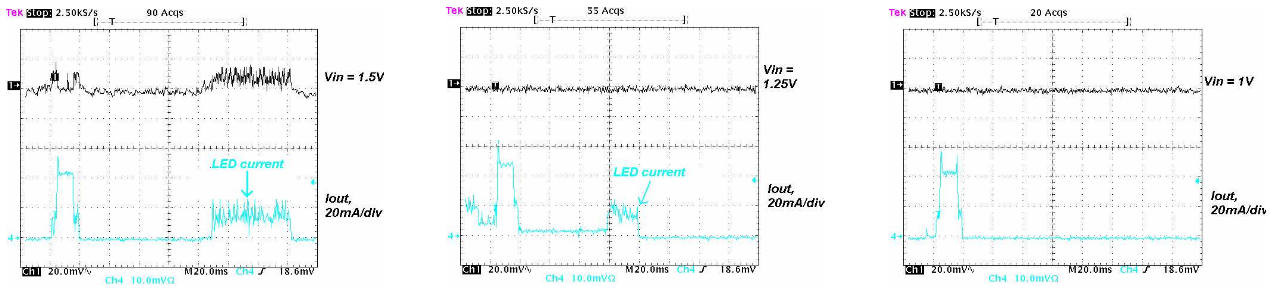


Figure 20. Output Ripple Voltage and Current Waveform From TPS61070 During Sniff-Mode Operation of Bluetooth Headset With 1-nF Feedforward Capacitor (Cff) and With 2 × 22-μF Output Capacitors

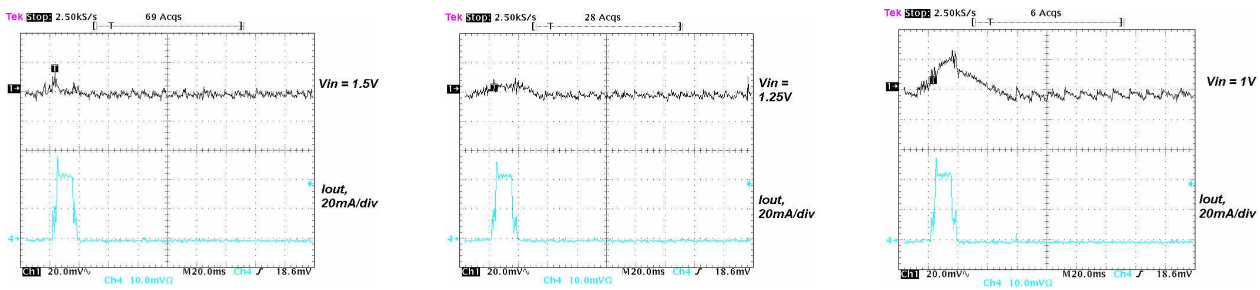


Figure 21. Output Ripple Voltage and Current Waveform From TPS61070 During Sniff-Mode Operation of Bluetooth Headset With 10-nF Feedforward Capacitor (Cff) and With 2 × 22-μF Output Capacitors

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