Linear Regulator Series, Switching Regulator Series

Suppression Method of Switching Noise Using Linear Regulator and Low Pass Filter

Switching regulators contain ripple and switching noise in their output voltage. Therefore, they are inappropriate as a power supply for applications, such as sensors, that require a precise input voltage. General countermeasures include connecting a linear regulator to the output of a switching regulator to suppress the ripple and switching noise. However, under various conditions including a load, it may be difficult to suppress the ripple and switching noise, and the switching noise may be propagated. As an additional countermeasure, it is effective to connect a low pass filter to the output of a switching regulator, and then connect them as the power supply to a linear regulator.

This application note describes the method and result of the ripple and switching noise suppression using a linear regulator and a low pass filter.

Generation of ripple and switching noise and suppression method

Although the switching regulators generate ripple and switching noise, the noise can be suppressed by connecting a linear regulator to the output according to the PSRR (Power Supply Rejection Ratio).

However, the PSRR decreases at high frequencies due to limited frequency characteristics of linear regulators. Since the switching frequency is high, ranging from several hundred kHz to several MHz, the switching noise is superimposed on the output of the linear regulator (Figure 1).

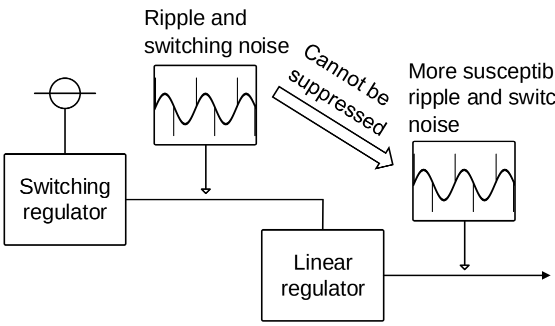

Figure 1. The PSRR decreases at high frequencies due to limited frequency characteristics of linear regulators

When the switching noise is superimposed on the output, the precision requirement for the sensor input may not be adequate.

To increase the PSRR in a high frequency region, connect a low pass filter to the output of a switching regulator to suppress high frequencies. Although frequencies still remain in the low region, these frequencies can be suppressed with the linear regulator, resulting in suppressed output (Figure 2).

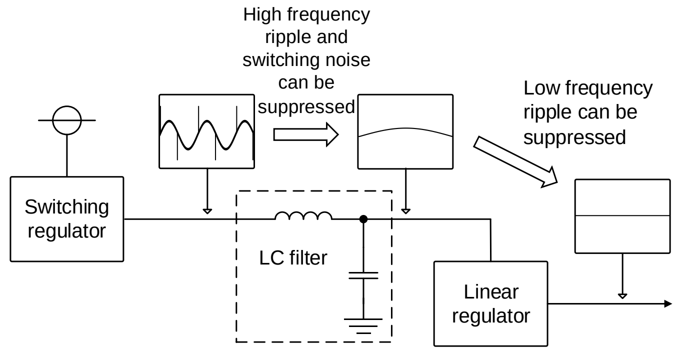

Figure 2. Suppression of switching noise with low pass filter

Measurement method for PSRR of linear regulator

This section describes the PSRR characteristics of linear regulators. The suppression rate of the switching noise is determined according to the characteristics. The higher the gain of the PSRR, the higher the suppression rate. The measurement circuit for the PSRR is shown in Figure 3. Input the OSC of the FRA (FRA5087, NF) into the bipolar amplifier (HSA4101, NF) to superimpose the AC ripple component. Then, input the output (DC offset 5 V, ripple 20 mV) into the linear regulator. Perform the measurement under the conditions of the output load (PLZ334W, KIKUSUI) at 1 mA, 10 mA, and 100 mA. The IC used here is BU29JA2MNVX-C (VIN 5.0 V, VOUT 2.9 V).

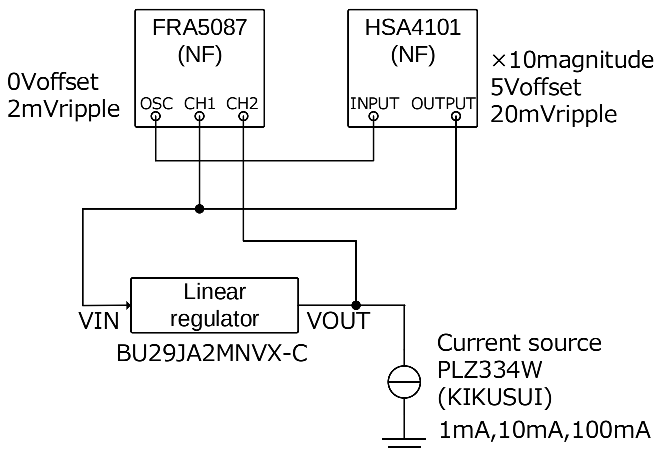

Figure 3. Measurement method for PSRR

In this application note, BD9D300MUV is used as the switching regulator. When its output is used as the power supply for BU29JA2MNVX-C, it can be seen that the PSRR is low near the switching frequency (1.25 MHz) (Figure 4). In addition, the PSRR decreases as the output load increases, suggesting that the switching noise is propagated. Therefore, to compensate for the frequency characteristics of the linear regulator, it is necessary to insert a low pass filter between the switching regulator output and the linear regulator. In this application note, an LC filter is used as the low pass filter (Figure 5).

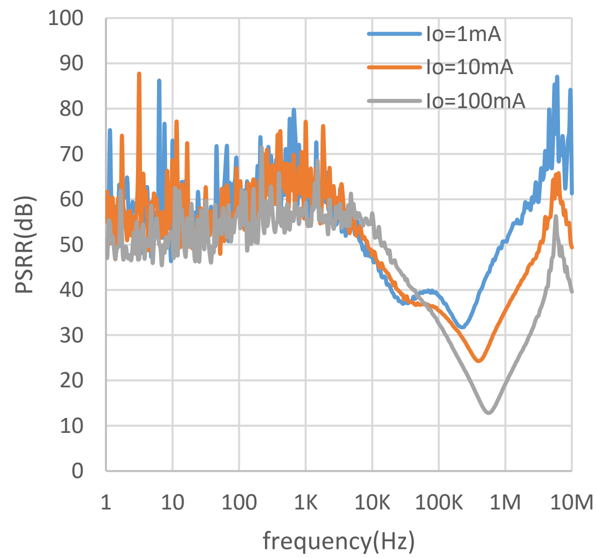

Figure 4. PSRR characteristics of BU29JA2MNVX-C

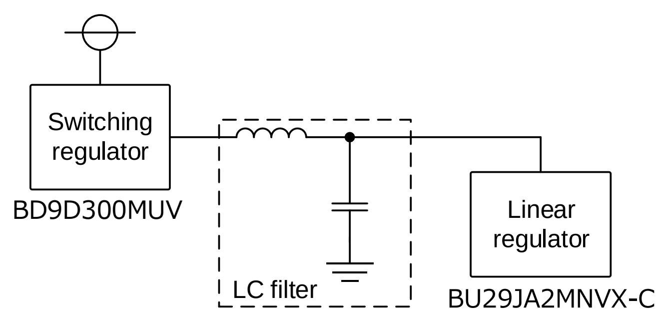

Figure 5. Insertion position of LC filter

Constant design for low pass filter

When a low pass filter is required, use of simulation is convenient and helpful for designing the filter. If a free SPICE model is made public, you can use a simulator to perform detailed checks.

Perform a simulation using LQH2MCN470K02 (Murata) with L = 47 μH (series resistance DCR = 5Ω) and GRM188B31A106KE69 (Murata) with C = 10 μF as the parts (Figures 6 and 7). The constants used in this application note is an example. It is necessary to use the coil (rated current and DCR) and the capacitor that are suitable for actual specifications.

In Figure 6, for example, the maximum current is set to 100 mA and VOUT is allowed to drop to 0.5 V relative to VIN. In addition, the rated current of the coil used is 120 mA.

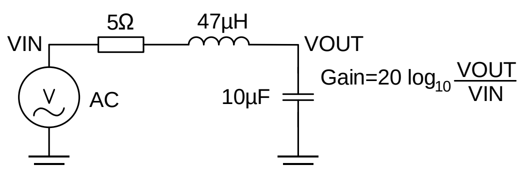

Figure 6. Image of frequency characteristics measurement for low pass filter

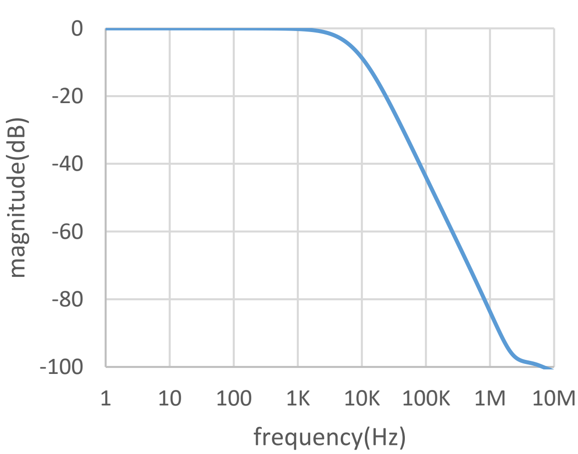

Figure 7. Frequency characteristics of low pass filter

The cutoff frequency is 7.35 kHz according to $1/(2\pi\sqrt{LC})$. Since the frequency response is -23 dB near 30 kHz where the PSRR is decreased and -70 dB near 500 kHz, it can be expected that the PSRR can be improved (Figure 7).

PSRR including low pass filter

Figure 8 shows a measurement circuit including a low pass filter. As described above, measure the PSRR characteristics when the output load is 1 mA, 10 mA, and 100 mA. The results of PSRR measurement under each output load condition are shown in Figure 9.

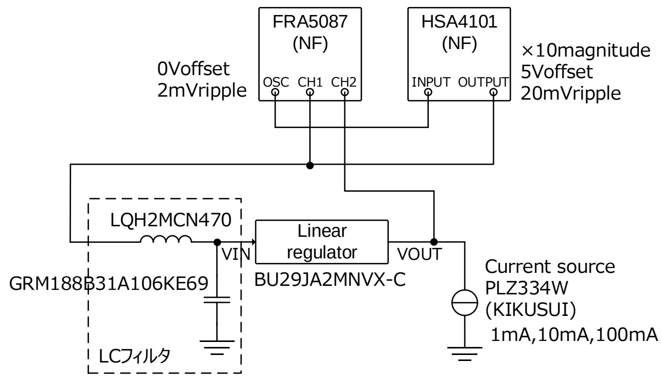

Figure 8. PSRR measurement circuit for linear regulator including low pass filter

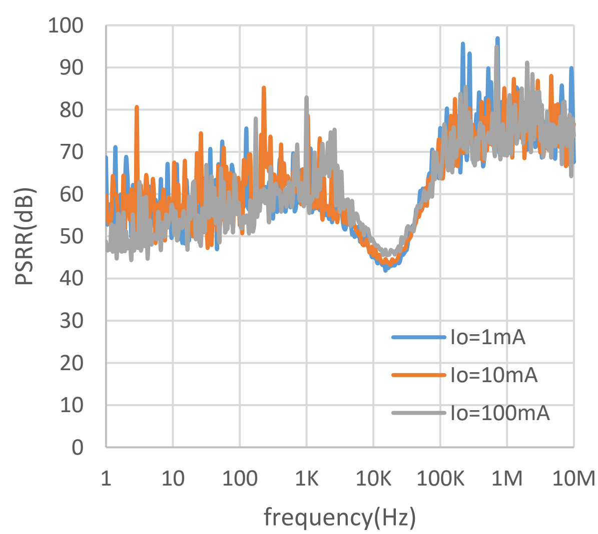

Figure 9. PSRR of linear regulator including low pass filter

Since the PSRR exceeds 60 dB under all load conditions with the switching frequency of BD9D300MUV at 1.25 MHz, the switching noise is suppressed with the low pass filter.

Circuit design preventing switching noise propagation

First, check the magnitude of the switching noise of the switching regulator. The switching regulator is connected with the power supply (6643A, HEWLETT PACKARD). Separate the switching noise of the switching regulator (BD9D300MUV) using a DC block (PSPL5501A, Tektronix) and input the signal into the spectrum analyzer (N9020A, Agilent Technologies) to perform a component analysis. The result of the analysis shows occurrence of peaks at multiples of the switching frequency (Figures 10 and 11).

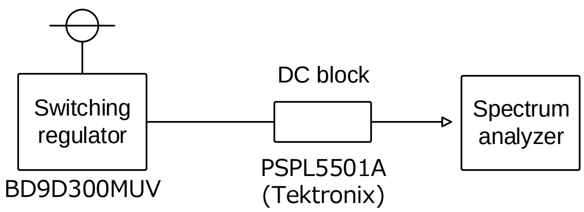

Figure 10. Method for signal analysis of switching noise

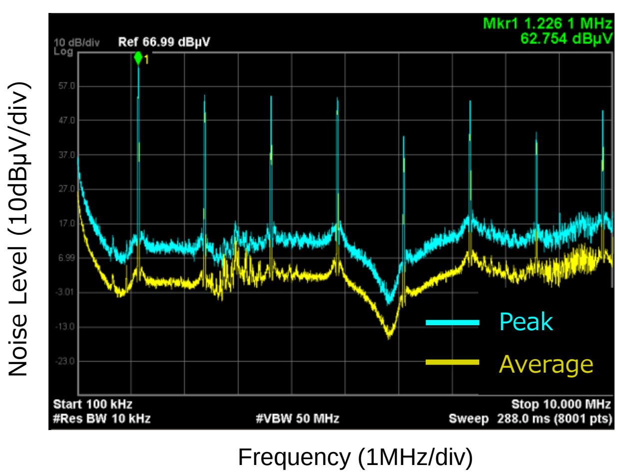

Figure 11. Result of signal analysis of switching noise

Next, connect a low pass filter to the output of the switching regulator, and connect the linear regulator to the low pass filter. Connect the DC block to the output of the linear regulator and input the output signal into the spectrum analyzer to perform a component analysis (Figures 12 and 13).

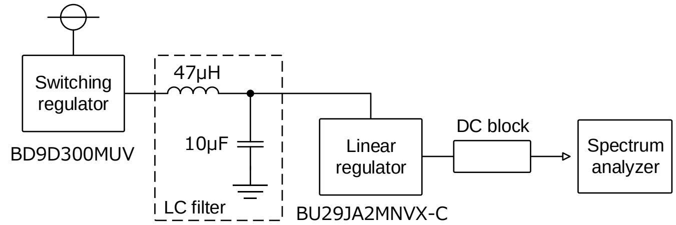

Figure 12. Switching noise suppression circuit with linear regulator and low pass filter

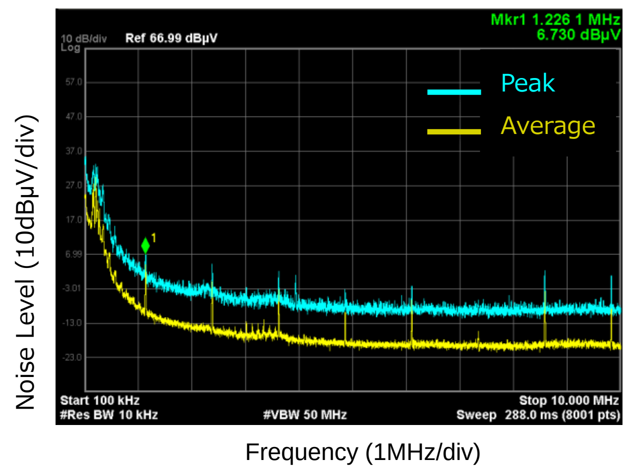

Figure 13. Results of signal analysis of switching noise reduction

It can be confirmed that the switching noise is suppressed with this circuit (Figure 14).

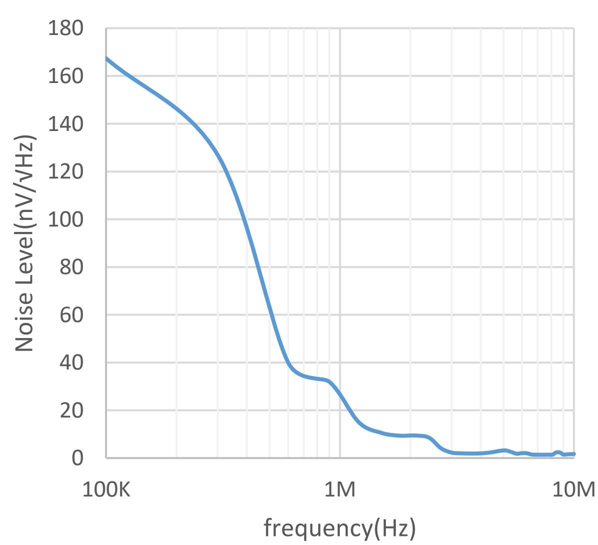

Figure 14. Results of switching noise suppression with linear regulator and low pass filter

Summary

When the output of a switching regulator is used as the power supply for a linear regulator, the switching noise that cannot be suppressed may be superimposed on the output. To suppress this noise, it is effective to insert a low pass filter between the switching regulator and the linear regulator. This application note provided an example of the circuit and summarized the experimental results.

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