Ripple Blocker™ for Power Supply Output Noise Attenuation
“Silence is Golden”

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Global Positioning System (GPS), cellular phone and image sensors all require a low noise power supply in the RF section. In GPS applications, the receiver is highly sensitive and may need to decode very low power signals in the order of -160 dBW [1]. Power supply noise reduces the GPS signal acquisition time and position accuracy. In a cellular phone, supply noise can also cause dropped calls and reduce signal strength, problems consumers no longer tolerate in this advanced application. Image sensors benefit with improved signal-to-noise ratio for higher image quality. In these noise sensitive systems, additional power supply filtering is required to meet these stringent design requirements.

Power supply filtering requirements have traditionally been met by utilizing an LC filter on the output. The purpose of the filter is to reduce the switching regulator’s ripple voltage. With proper circuit design and printed circuit board (PCB) layout, the output ripple of a buck regulator is typically 1 percent of the output voltage. For example, a 2.5V output can have 25mV of output ripple. The LC filter is designed to attenuate the switching regulator output ripple. A simple output filter can reduce this noise anywhere from a factor of ten (20dB) to one hundred (40dB). The high frequency “spikes” which may be superimposed on the ripple are attenuated even more [2].

To get sufficient suppression with a single pole LC filter, a low cut-off frequency is required resulting in a large value inductor and capacitor which can be quite large in size. In portable applications, a semiconductor switch is also required to save power, increasing the PCB board area. Micrel has developed its Ripple Blocker™ technology (patent pending) to enable a single-chip solution which combines both the filter and switch into one part. This reduces the PCB footprint by up to 65 percent, providing excellent performance in minimal board area as shown in Figure 1. In this article, we will show the performance of Micrel's new Ripple Blocker™ technology. In addition, we will discuss how Ripple Blocker technology can also be applied to a Low Dropout Linear regulator (LDO) to achieve unmatched Power Supply Rejection Ratio (PSRR) performance from DC to 10MHz.

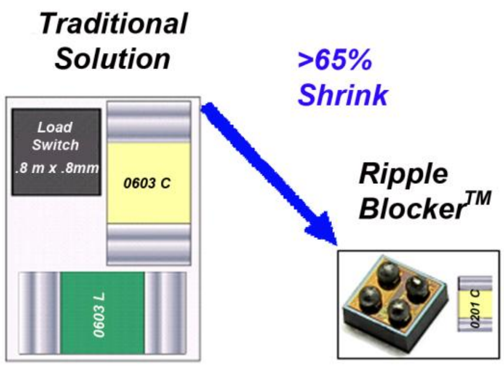

Figure 1. MIC94300 Board Room Reduction.

Micrel's MIC94300 Ripple-Blocker™ simplifies the filter design by integrating a load switch in conjunction with an active filter circuit to provide a clean output voltage. The load switch is controlled by an active-high enable. Forcing the enable low turns off the load switch and sends it into a near "zero" off-mode current state. When enabled, the load switch is operated in its saturation region to maintain optimum performance. This results in approximately 170mV fixed voltage drop between the input and output voltage. The MIC94300 is fully protected from damage due to fault conditions, offering linear current limiting and thermal shutdown.

A MIC94300 Ripple Blocker™ attenuation factor is about 1000 (60dB) from 30kHz to 10MHz. This is a 10 times improvement over the LC filter at the switching frequency. Figure 2 shows the power supply rejection ratio (PSRR) versus frequency of the MIC94300. The internal active filter passes DC and blocks any AC components with a frequency beyond 1kHz. A third order filter provides a steep roll-off so that most of the attenuation is available from 30kHz to 10MHz. This means that virtually all switching regulator output ripple components will be reduced by about 60dB.

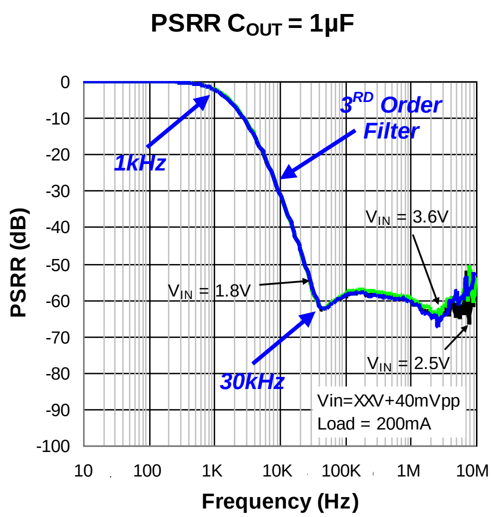

Figure 2. MIC94300 PSSR Performance.

A low 170mV drop is maintained over various loads, optimizing power efficiency. Most available LDOs will not maintain this level of power supply rejection (PSRR) for such a small voltage drop over such wide bandwidth while only consuming 100µA of ground current.

Figure 3 shows a typical application circuit. It consists of a MIC23155 synchronous buck switching regulator and a MIC94300 Ripple Blocker™. The buck regulator steps down the 5V input to 2.5V. The regulator's switching action creates the output ripple that appears on the output capacitor C1. The magnitude of the output ripple depends upon the inductor ripple current, the output capacitance value and its effective series resistance (ESR). Trace A in Figure 4 shows a 25mV peak-to-peak ripple measured across the output capacitor C1 and Trace B shows a spectral plot of the same signal. The fundamental frequency of 314kHz is the switching frequency of the buck regulator. The harmonics are multiples of the switching frequency.

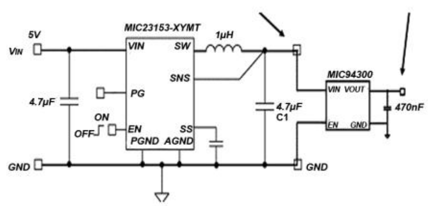

Figure 3. Typical Application Circuit.

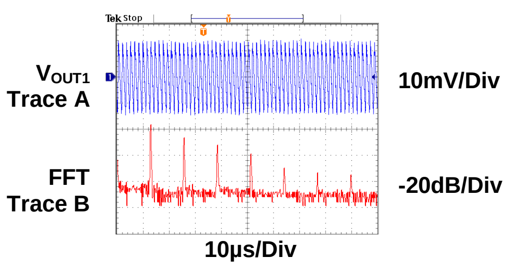

Figure 4. DC-DC Converter Output.

The ripple at the output of the MIC94300 Ripple Blocker™ is near "zero" (see Figure 5) trace A. Trace B shows that the switching harmonics have been virtually eliminated by Micrel's MIC94300 solution.

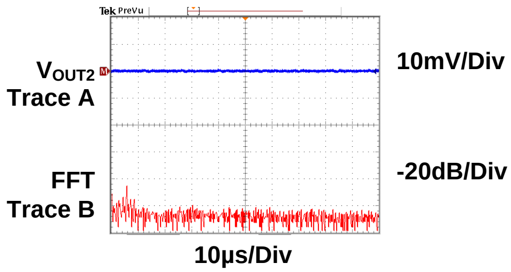

Figure 5. Ripple Blocker™ Output.

Figure 6 shows the functional block diagram of the MIC94300. The MIC94300 combines the low $R_{DS(ON)}$ of a current limit switch with the PSRR capability of an LDO. First, the LDO maintains a fixed voltage drop of 170mV that is independent of load current. The voltage drop is set by an internal 170mV voltage referenced to the input voltage. A low-pass filter passes the DC and blocks the AC component of the input voltage. The filtered signal is provided as a reference to the LDO so the output will follow the DC of the input but rejects any AC signal. The use of and NMOS as a pass device provides an extremely low dropout as used in current limit switches.

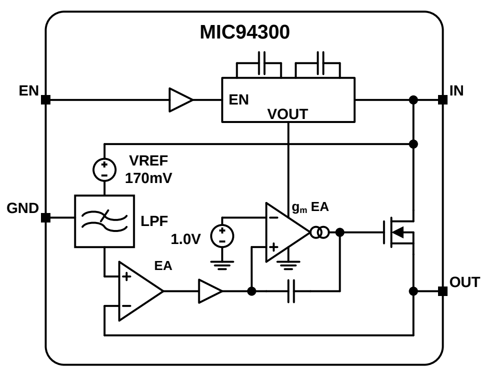

Figure 6. MIC94300 Ripple Blocker™ Diagram.

Micrel's Ripple Blocker™ technology can also be applied to low dropout linear regulators (LDOs) to produce fixed output voltage with high PSRR from DC to 10MHz. Figure 7 illustrates the performance of the MIC94310 Ripple Blocker™ LDO. The block diagram is shown in Figure 8. Here the output voltage is regulated like a basic LDO regulator where the output voltage is set by a resistor divider network connected between the output and ground.

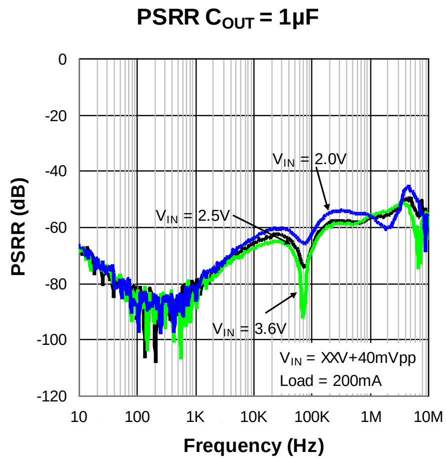

Figure 7. MIC94310 Ripple Blocker™ PSRR

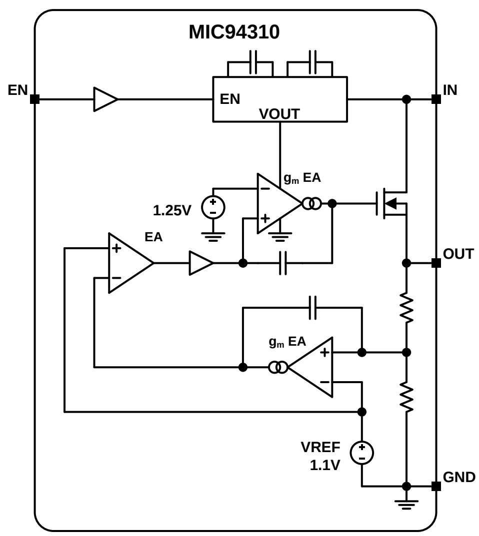

Figure 8. MIC94310 Ripple Blocker™ LDO Diagram.

Standard P-Channel LDOs have high PSRR at DC but will start losing ripple rejection above 10kHz, as shown in Figure 9. This roll-off is caused by the gain-bandwidth limit of the error amplifier. The MIC94310 does not have this limitation because it uses an NMOS pass device. This NMOS is configured as a source follower and has intrinsically good PSRR due to its low output impedance. This means that a smaller loop gain is needed to achieve the same PSRR when using a PMOS as a pass device. Therefore, at higher frequencies where the loop gain drops, an NMOS pass device can still maintain a good PSRR. The MIC94310 surpasses the performance of a standard LDO at frequencies from 60kHz to 10MHz. This makes the MIC94310 a perfect choice to use as a regulator with a switching regulator input voltage whose fundamental switching frequency is typically in the 500kHz to 3MHz range.

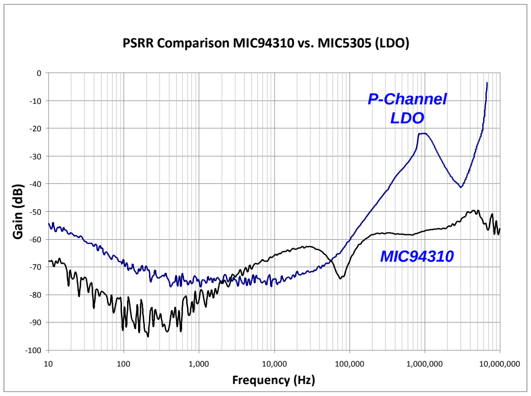

Figure 9. Standard LDO PSRR Vs Ripple Blocker PSRR.

Micrel's Ripple Blocker™ technology provides a simple, space saving and low cost solution for reducing power supply noise. The technology offers substantial noise reduction due to about a 60dB PSRR performance up to 10MHz. The Ripple Blocker™ family of devices is easy to use and improves the signal-to-noise ratio in a number of leading edge noise sensitive applications.

1. Wikipedia, "High Sensitivity GPS"
2. Nelson,Carl, "LT1070 Design Manual," Linear Technology Corporation, Application Note 19.