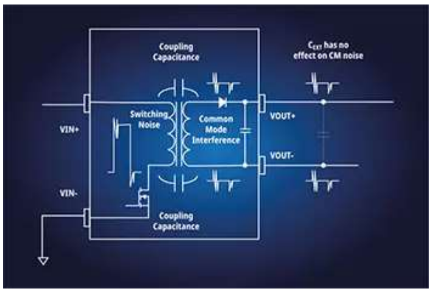
Very low noise filter for isolated DC/DC converters

Mar 4, 2019



All isolated DC/DC converters contain switching elements which generate electrical noise. The parasitic inductances and capacitances associated with a power switching transistor driving a high inductive load such as a transformer mean that switching resonances are unavoidable. A simple DC/DC converter operating at a moderate switching frequency of a few hundred Kilohertz can have a noise signature ranging up to 20 MHz.

Such high frequency interference insinuates itself throughout the converter, jumping from track to track and from input to output via the coupling capacitances within components. In addition, the pulsating energy flow from input to output causes an output ripple and a reflected input ripple current to flow. This pulsating current causes lower frequency voltages to be generated in any inductive elements such as wires, lengths of PCB track, vias or pins. Although the input and output voltage ripple can be reduced by adding additional input and output capacitance, the common mode noise levels are harder to filter because they appear across both ends of the input or output so are not “seen” by the filter (Fig. 1)

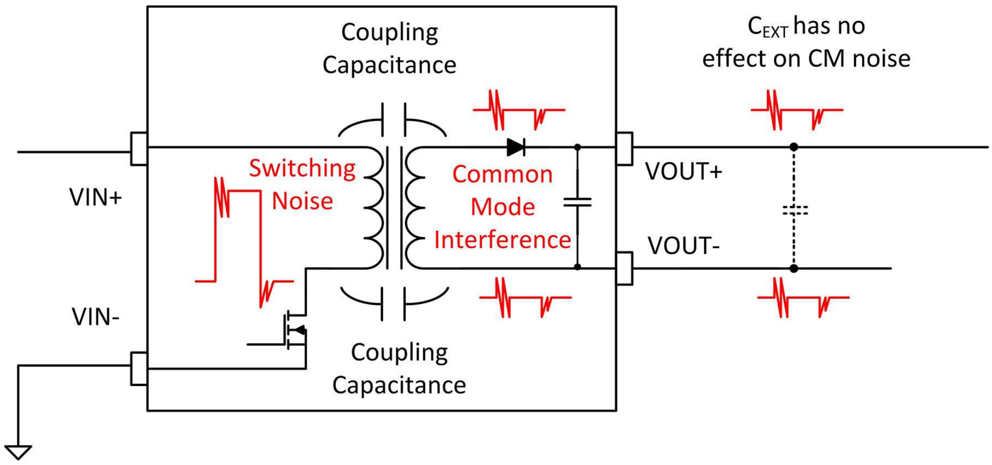


Fig.1: Common Mode Noise in a DC/DC converter (from DC/DC Book of Knowledge[1])

To cr[illegible] a very low ripple and noise output power supply, three separate filters, each handling a different part of the interference spectrum are need[illegible]

1: Output ripple filter. This filter reduces the pulsating output ripple caused by the regular transfer of power across the transformer. Each switching cycle will create a pulse of current that needs to be absorbed by the output capacitor. In between the power transfer cycles, the output capacitor has to supply the load by itself. The voltage on the output capacitor rises and falls with every switching cycle with a characteristic sawtooth shape (fig. 2).

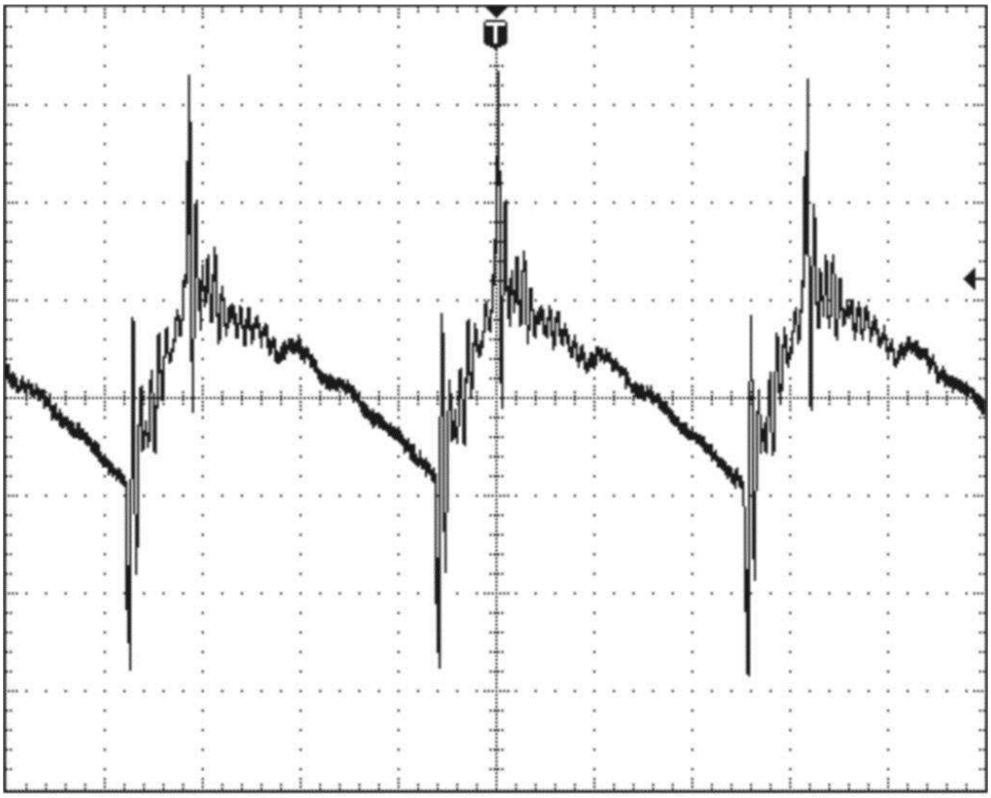


Fig. 2: Typical Output Ripple and Noise Waveform for a DC/DC converter

Superimposed on top of this sawtooth waveform is the high frequency switching noise caused by resonant effects each time the power transistor switches on (Vce drops rapidly) or off (Vce rises rapidly). The high frequency noise is thus synchronised with the peaks and troughs of the switching cycle.

2: Input ripple filter. Each time the power transistor switches on, the input current rises rapidly. Each time it switches off, it falls rapidly. There is some common mode noise superimposed on this ripple current which the input capacitors cannot filter out, but generally the noise levels on the input side are lower than on the output because the main power supply is low impedance source which absorbs a lot of the high frequency noise.

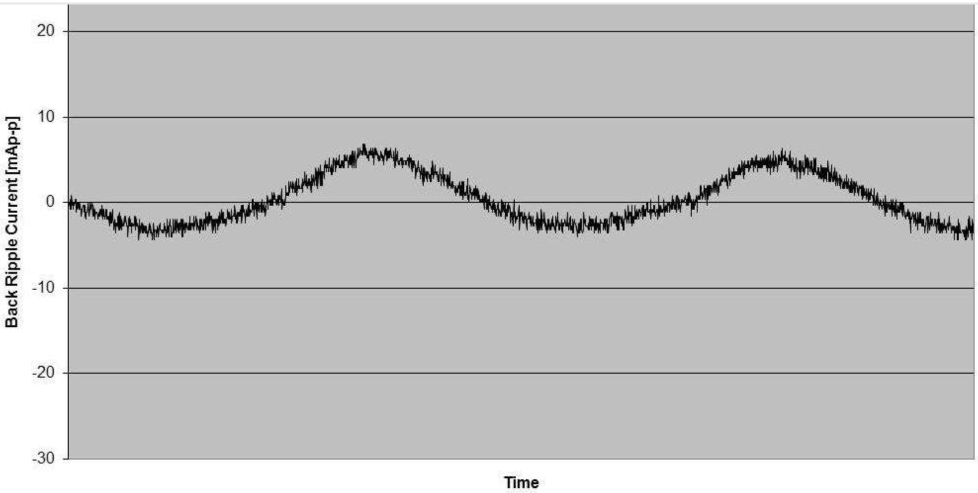


Fig. 3: Reflected Ripple Current

3. The transformer behaves like a high impedance source between input and output. Therefore the switching noise can easily bridge across the transformer through the coupling capacitance between the windings. This noise can be reduced by providing a low impedance path back from the output to the input by adding a capacitor across the isolation gap.

We set ourselves the task of creating an isolated power supply with an output ripple and noise of less than 5mVp-p. Such smooth supplies are needed in highly sensitive amplifier circuits measuring very small signals or in high resolution signal processing applications such as 24-bit A-to-D converters.

We used a R1ZX-0505 DC/DC converter which has an output regulated with an on-board linear regulator. This gives an already low noise output of typically 30mVp-p.

The first step was to add a 2nF capacitor from –Vout to +Vin. Compared to the 100pF coupling capacitance of the transformer, the 2nF capacitor provides a much lower impedance return path. This single component reduced the output noise significantly but had little effect on the input or output ripple.

The second step was to add capacitors across the input and output pins. Two 10µF MLCCs were connected in parallel to reduce the effective ESR and placed across both the input and output. The result was a much reduced input and output ripple, but the common mode noise was still strongly visible on the output. Fig. 4 shows the output waveform.

It seemed that all we needed now to do would be to filter out these high frequency switching spikes. However, they were not easy to get rid of because they were due to common mode interference and adding more capacitance or LC filters did not have any effect.

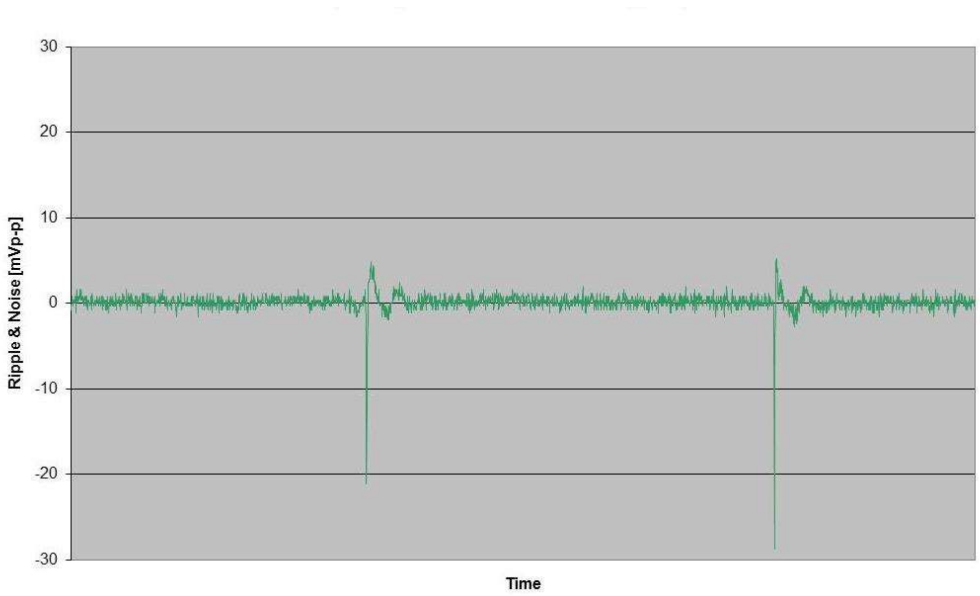
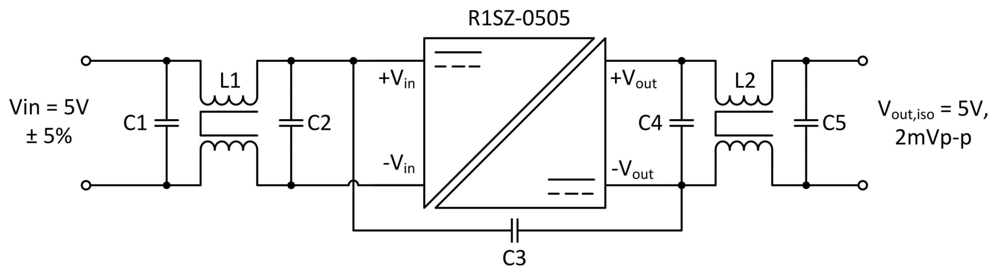


Fig 4: Output waveform with input and output ripple suppression capacitors.

We turned to our common mode sample box and tried different combinations of common mode inductors until we found the optimum solution. On the input, a 50µH choke was needed in a pi-filter format with another pair of capacitors. Even with the high CMRR of a linear regulator, the input ripple still needed to be kept tightly under control. A similar common mode Pi-filter was placed on the output, but a smaller 10µH choke was found to be sufficient (figs 5 and 6)



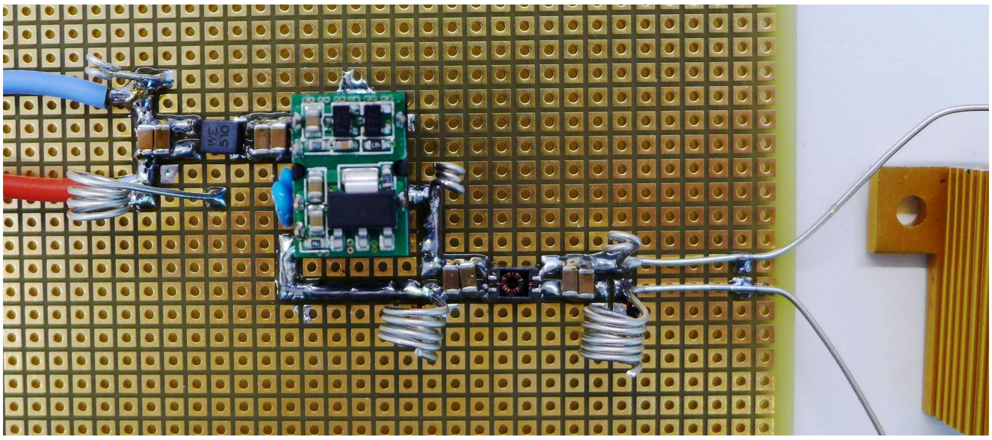
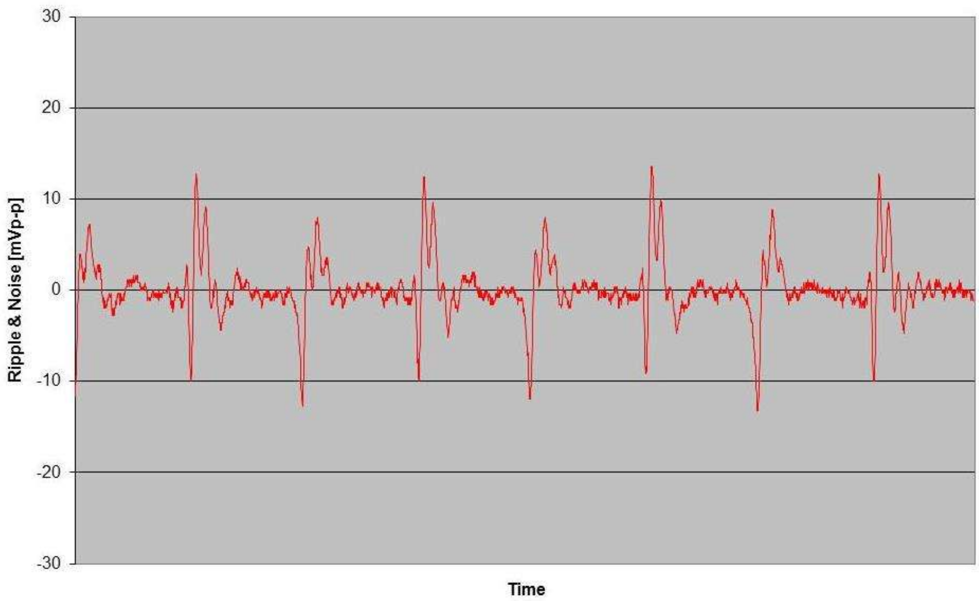


Fig 5: The full filter design

Unfiltered Output (C3 fitted only)



Filtered Output (with common mode chokes)

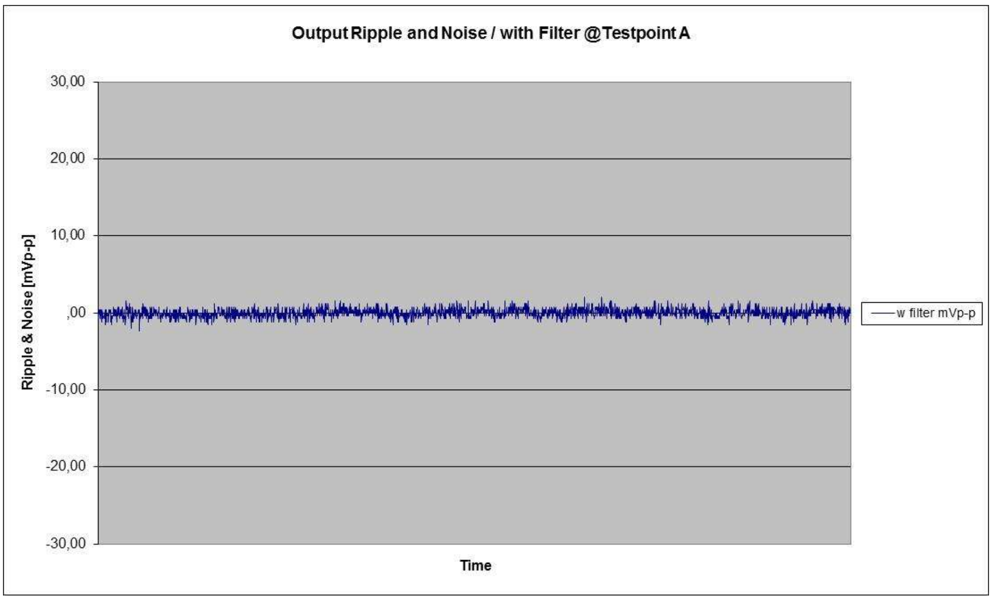


Fig 6: Before and after output waveforms (same scale)

Conclusion: With the common mode filters, the output ripple and noise under full load was measured at around 2mVp-p. Changing any of the component values made this figure worse, so this is the minimum value. The full filter may seem complex, but is necessary to combat all of the different interference sources to get an excellent low noise supply (-68dB) and as the required components are small, very little extra board space is required.

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1, please refer to the **DC/DC Book of Knowledge**,

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