LC filter with improved high-frequency attenuation

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Keywords

- *LC filter*
- *Harmonics*
- *T-type filter*

Introduction

This application note describes an improved T-type LC filter that can be used to further attenuate harmonics if a standard Pi-type filter (such as the one used in many of Chipcon's development kits) is not sufficient. This T-type filter provides much better stop-band attenuation than a Pi-type filter due to improved insulation between input and output. Measured results for a filter for operation in the 915 MHz band are also presented.

Harmonics

When designing an RF power amplifier, there is always a trade-off between linearity and efficiency. Since power amplifiers used in low-power radio systems must be efficient to keep power consumption down, the power amplifiers used are usually non-linear, and they will therefore introduce harmonic distortion.

Regional regulations define the maximum harmonic power levels that are allowed. If the output harmonic levels are too high, some form of filter must be inserted after the power amplifier to reduce the harmonics to sufficiently low levels. Please see [3] for more information about regulations.

Pi-type RF filter

The filter used for attenuating harmonics on most of Chipcon's development kits is a Pi-type (two shunt capacitors, one series inductor) filter. This filter is a 3 dB ripple Chebychev low-pass LC-filter consisting of L71, C71 and C72. The filter is designed for 50 Ω termination impedance. The design equations are provided below. The exact values must be found through measurements to account for parasitic capacitances.

$$\omega_C \approx \omega_{RF} \cdot \left(\frac{1}{1-0.1333} \right) \qquad L = \frac{35.6}{\omega_C} \qquad C = \frac{0.067}{\omega_C}$$

where $\omega_c = 2 \cdot \Pi \cdot f_c$, where f_c is the cut-off frequency. $\omega_{RF} = 2 \cdot \Pi \cdot f_{RF}$, where f_{RF} is the transmitted RF frequency .

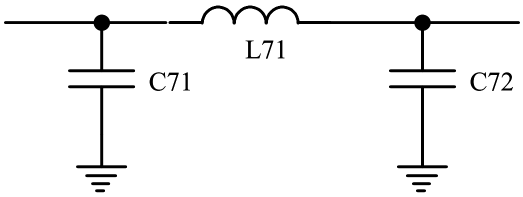

Figure 1 Pi-type LC filter

This filter provides good performance with a minimum of component cost, since inductors are usually more expensive than capacitors. However, in some cases the above filter configuration does not provide sufficient attenuation of harmonics. This is because there is only one series component and there may be too much coupling between the input and the output of the filter.

T-type RF filter

The improved version of the filter solves this problem by using two series components. This filter is of a T-type with two series inductors and one shunt capacitor. It provides greatly improved stop-band attenuation compared to the Pi-type filter. The coupling between the input and output is significantly reduced because two series components are used.

A slight disadvantage of this filter is that it is more sensitive to parasitic shunt capacitance. The component values must be fine-tuned to account for the PCB layout paracitics.

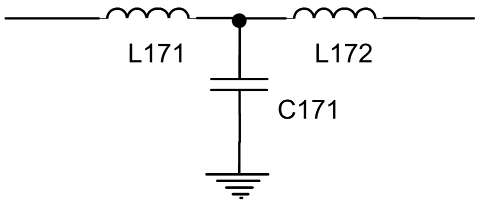

Figure 2 T-type LC filter

The easiest way to calculate component values is to use filter design software such as [1]. It is also possible to transform a Pi-type circuit to a T-type circuit by using the following equations [2]:

$$Z_{L171} = \frac{Z_{L71} \cdot Z_{C71}}{Z_{C72} + Z_{C71} + Z_{L71}}$$

$$Z_{C171} = \frac{Z_{C72} \cdot Z_{C71}}{Z_{C72} + Z_{C71} + Z_{L71}}$$

$$Z_{L172} = \frac{Z_{C72} \cdot Z_{L71}}{Z_{C72} + Z_{C71} + Z_{L71}}$$

Practical results

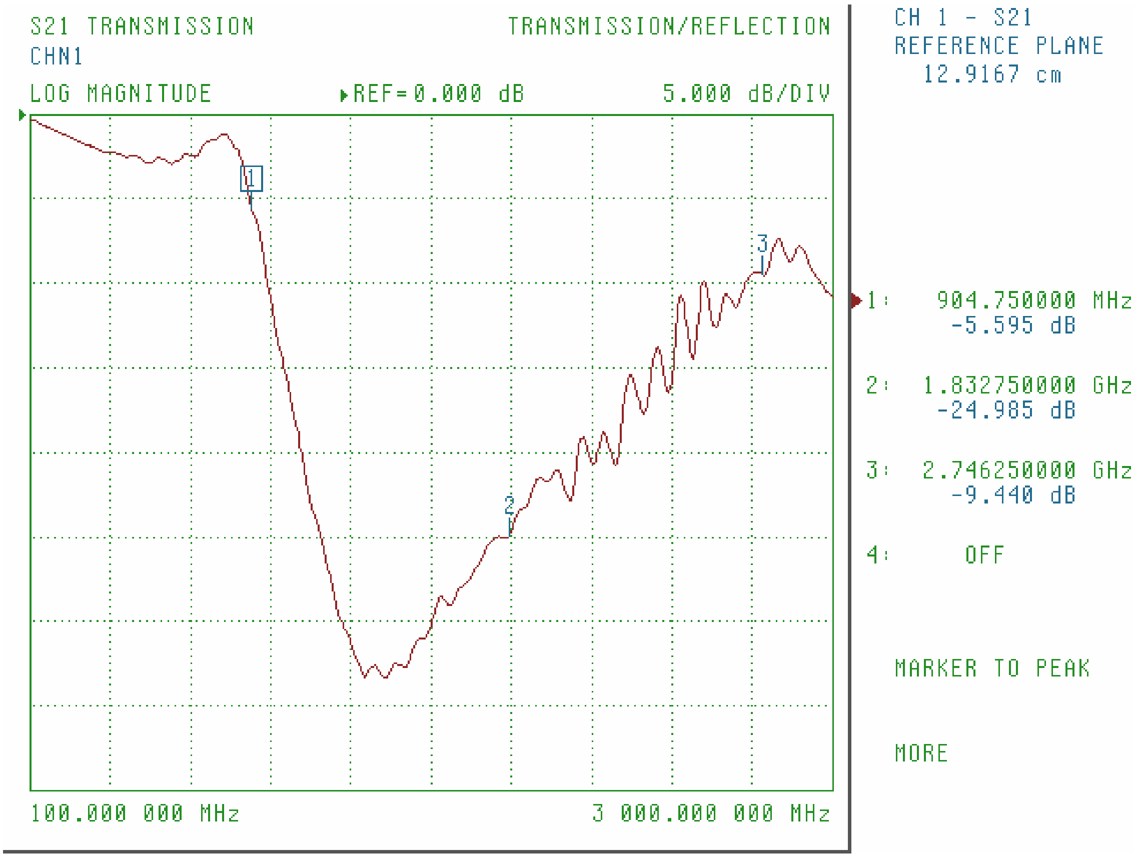

Figure 3 Frequency response of Pi-type filter

Figure 3 shows the frequency response of a low-pass Pi-type LC filter designed for use at 868/915 MHz. The component values for this filter are C71=8.2 pF, C72=8.2 pF and L71=3.3 nH. The main problem with this filter is that higher frequencies couple from the input to the output, resulting in a notch characteristic. This is mainly due to PCB layout parasitic capacitance.

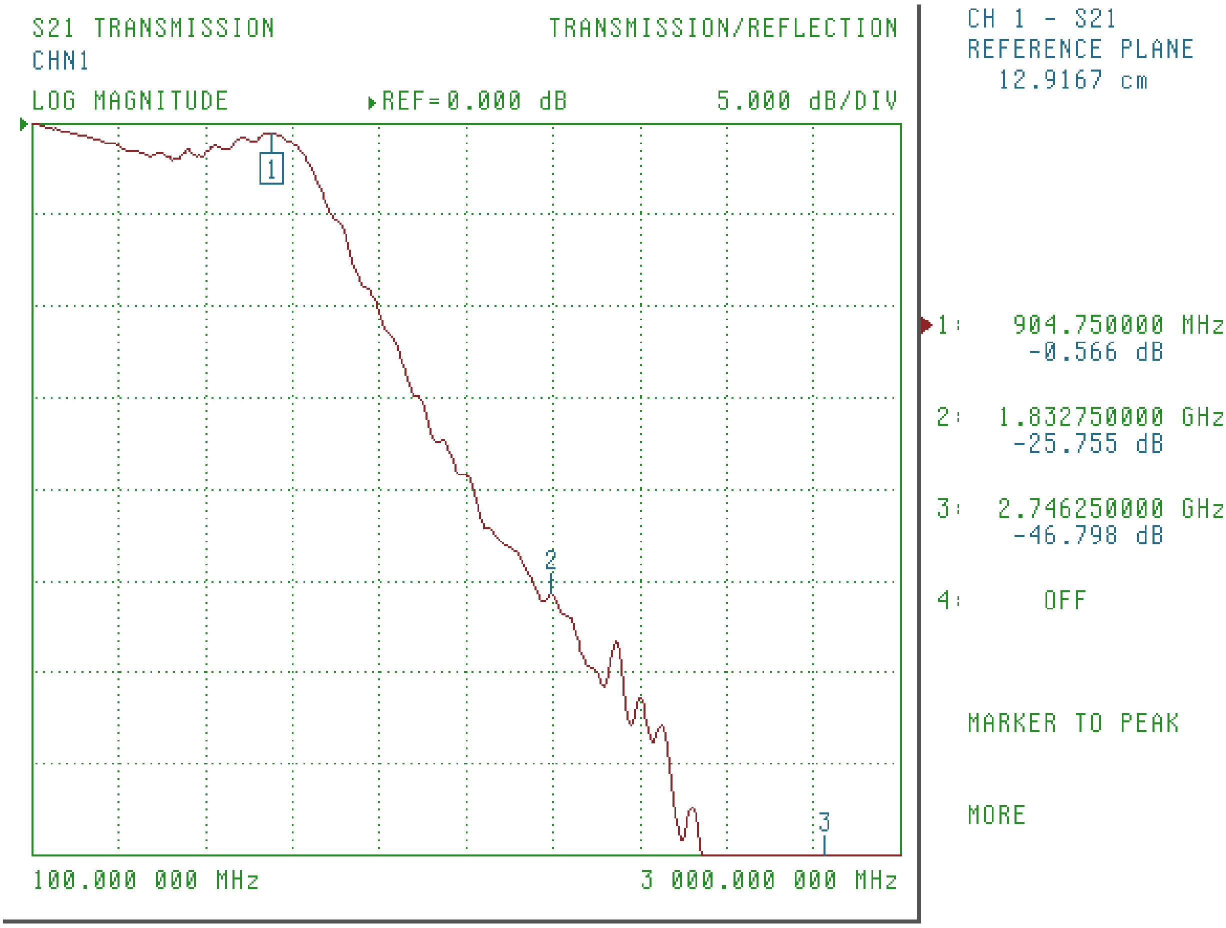

Figure 4 Frequency response of T-type filter

As can be clearly seen in Figure 4, the frequency response of the T-type filter is much better in terms of suppressing higher frequencies. The component values for this filter are L171=15 nH, L172=15 nH and C171=2.2 pF. These values differ somewhat from the calculated values (L171=16 nH, L172=16 nH, C171=3.2 pF). This is due to PCB layout paracitics.

References

Cited references

[1] HyDesign Ltd, *RFSim99*. 1999. Downloadable from http://membres.lycos.fr/f1rhr/tech1/RFSIM99/RFSim99.htm or http://rf.rfglobalnet.com/software_modeling/software/2/710.htm

[2] P. Vizmuller, *RF Design Guide*. Artec House, 1995.

[3] Chipcon, *AN001: SRD Regulations*. Downloadable from http://www.chipcon.com

Document History

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1.0		Initial release.

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