Loss Analysis and Measurement of High Frequency Power Inductors

Nowadays, there has been a trend towards increasing the efficiency and minimizing the size of power electronic converters. However, inductors are still one of the bottlenecks, occupying relatively large space area and dissipating noticeable power loss. Achieving optimum design of these components with minimum loss indeed requires a profound understanding of the high frequency loss distribution in these components. This thesis presents a comprehensive study of power loss dissipation in the core material and the winding of high frequency power inductors. Different approaches have been studied for the loss analysis of inductor winding loss and inductor core loss.

In the inductor winding loss analysis, due to the high complexity of mathematical analysis and FEM modelling, measurement approaches are more practical and reliable. One common and straightforward approach is to use the commercial impedance analyzers for measuring the ac resistance of the high frequency inductors. It has been demonstrated that the ac resistance measurement of high efficiency inductors (small ac resistance of a high impedance inductor) is outside the capability of the equipment for performing an accurate measurement.

In the core loss measurement, the B-H loop measurement method as the very common method for measuring the loss of the magnetic cores is very sensitive to phase shift error. Particularly for low permeability cores, phase shift error dominantly influences the accuracy of the loss measurement process.

This thesis presents a new simple and practical method for measuring the ac resistance of the high frequency power inductors. Due to the high frequency measurement, parasitic impedances of the measurement setup are carefully studied. Experimental results show substantial improvement in the ac resistance of two sample high efficiency inductors compared to Agilent4294A performance. Moreover, the experimental results are in a good agreement with the 2D numerical results from COMSOL Multiphysics simulation.

Moreover, the performance of the B-H loop measurement method for the loss measurement of powder magnetic cores is discussed. It is analytically demonstrated that this method is very susceptible to phase shift error. A simple compensation method is proposed for loss measurement of powder magnetic cores excited with sinusoidal waveforms. The compensated loss measurement results are accurate compared to the estimated loss values from the datasheet.