Measurement and Development of Low AC power loss multi layer inductor

~Today and Future~

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Development of Multi Layer Power Inductor

Market requirement of power inductor for mobile device

- High converting efficiency on Power supply
- Small
- Low Leak Noise

Solution

Combining FDK unique technology

- Ferrite technology
- Fine printing technology
- CAE technology

We are optimizing multi layer inductor for DC DC converter and introducing it quickly to the market.
Classification of General Power Inductor

Structure (cross section schematic draw)

<table>
<thead>
<tr>
<th>Cu coil</th>
<th>Ferrite</th>
<th>Ag coil</th>
<th>Ferrite</th>
<th>Cu coil</th>
<th>Metal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire Wounded</td>
<td></td>
<td>Multi Layer</td>
<td></td>
<td>Metal Molded</td>
<td></td>
</tr>
</tbody>
</table>

Comparison of the characteristic

<table>
<thead>
<tr>
<th>Structure</th>
<th>Magnetic Material</th>
<th>Leak Noise</th>
<th>miniaturize</th>
<th>Frequency properties</th>
<th>Efficiency Low DC</th>
<th>Efficiency High DC</th>
<th>DC Bias Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire Wound</td>
<td>Ferrite</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Multi Layer</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Metal Molded</td>
<td>Metal</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
Feature of Multi Layer Power Inductor(1)

Low Leakage Flux (Simulation Result)

Multi Layer: 3.2 * 2.6 * 1.0mm, 10uH

Winding: 2.8 * 2.6 * 1.0mm, 10uH

Wire Wounded

MAGNETIC FLUX DENSITY [mT at 0.2A]
Miniaturize (including thickness)

<table>
<thead>
<tr>
<th>Package Size</th>
<th>Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2x2.5</td>
<td>H:1.2mm</td>
</tr>
<tr>
<td>2.5x2.0</td>
<td>H:1.0mm</td>
</tr>
<tr>
<td>2.0x1.6</td>
<td></td>
</tr>
<tr>
<td>2.0x1.2</td>
<td></td>
</tr>
<tr>
<td>1.6x0.8</td>
<td>H:0.5mm</td>
</tr>
</tbody>
</table>

- Smallest package size: 1.6x0.8mm
- Lowest profile: 0.5mm
High converting efficiency

**Efficiency**
Buck, 2MHz, PWM, Vin=3.6V, Vout=1.8V

![Efficiency graph](image)

RDC of Multi layer and wire wounded is same as 0.11Ohm.

**Usage in power supply**

![Usage diagram](image)
Efficiency & Inductor Characteristic

Efficiency
Buck, 2MHz, PWM, Vin=3.6V, Vout=1.8V

\[ \text{Efficiency(\%)} = 100 - (\text{Switching Loss(\%) + Inductor Loss(\%)}) \]

Inductor Loss = AC Power Loss + DC Power Loss
(AV Resistance) (DC Resistance)

http://WWW.fdk.com
Method of reducing AC power loss

Magnetic Material

Optimizing
- Material composition
- Sintering condition
- And more

Low AC Power Loss Material

Inner Structure of inductor

About inner structure
Optimizing the shape of coil pattern, coil thickness, other dimension by CAE technology.

Reducing AC power loss
Reduction of AC power loss (Material)

Material A: Original magnetic material
Material B: New material for higher frequency

![Reduction of AC power loss](chart.png)

**Fig. SEM image of ferrite material**
Reduction of AC power loss (Structure)

Type A: Before optimizing inner structure, applied magnetic material A
Type B: Optimizing inner structure, applied magnetic material A
Type C: Same structure as type B, applied magnetic material B

ACR: Type A > Type B > Type C
AC power loss measurement based on actual usage

General at Measure
<20mA rms

Measurement:
Agilent 4284A(Irm 10mA)

On Actual usage
>20mA rms

Measurement:
Oscilloscope

Sw

I_L

I_L=58mA_rms

How to measure by large amplitude?
How much is AC resistance at power supply working on?

*I_out=at 200mA
# ACR Measurement by BH Analyzer

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Amplitude</th>
<th>Measurement method</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH analyzer (SY-8232 Iwatsu)</td>
<td>&lt;10MHz</td>
<td>&gt;1Ap-p</td>
</tr>
<tr>
<td>Impedance analyzer (4284A Agilent)</td>
<td>&lt;110MHz</td>
<td>&lt;20mArms</td>
</tr>
</tbody>
</table>

\[ Z_{x}(ACR) = \frac{V_1}{I} \]
Ex. Measurement Result
System: SY-8232 Iwatsu, IL=60mA rms, Frequency=1~6MHz

At 3MHz

<table>
<thead>
<tr>
<th></th>
<th>10mA rms</th>
<th>60mA rms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A</td>
<td>2.4 ohm</td>
<td>4.1 ohm</td>
</tr>
<tr>
<td>Type B</td>
<td>1.3 ohm</td>
<td>1.4 ohm</td>
</tr>
<tr>
<td>Type C</td>
<td>0.6 ohm</td>
<td>1.2 ohm</td>
</tr>
</tbody>
</table>
Loss Analysis Applying ACR by BH Analyzer

Inductor Loss:
AC loss = ACR x I(L)^2
DC loss = DCR x I(load)^2
Direction of development to the future

- Corresponding to higher switching frequency (over 6MHz)
  Starting development new magnetic material

- Smaller
  1608 size inductor has been achieved.
  Starting development for 1005.

- Thinner
  0.5mm thickness has been achieved.
  Starting development less than 0.3mm.
Next Multi layer Power inductor (small and efficiency)

Size, Inductance (μH)

2004~ 2006~ 2010~ 2012~

Frequency (MHz)

Magnetic Material1 (<3MHz)
Magnetic Material2 (<6MHz)
Magnetic Material3 (>6MHz)

Smaller and smaller
Higher efficiency

Achieved

Next target

http://WWW.fdk.com
Next Multi layer Power inductor

Thinner and Thinner (0.3mm)

Package Size: 2.0*1.2mm

0.5mm

1.6*0.8mm

0.3mm

Top
0.8mm

1.6mm

Bottom
Summary

- Introducing Multi Layer power inductor
- How to improving AC resistance
- AC power loss measurement based on power supply usage
- Next development (smaller, thinner, for higher frequency)
Thank you for listening!

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