Low-Loss Molding Inductor Analysis

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Abstract—Molding inductors are a crucial component of many electronic devices and circuits, where they are used for energy storage, filtering, and power conversion applications.

However, inductors exhibit loss due to various mechanisms, such as hysteresis, eddy current, and resistive losses. The use of low-loss materials for inductor cores can significantly reduce these losses and improve the overall performance of the inductor. This paper will discuss the design and selection of low-loss materials for inductor applications.

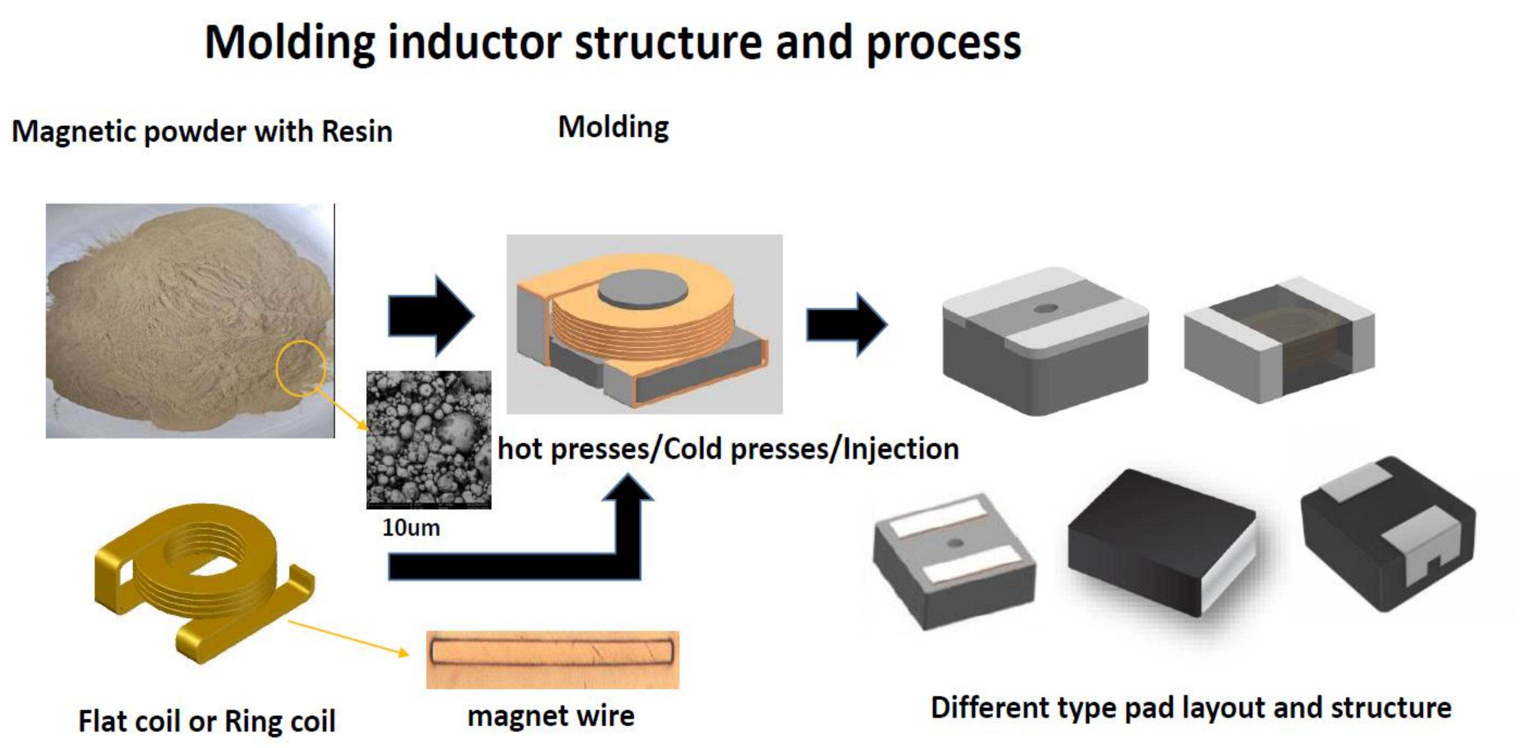

Fig. 1. Molding process

Types of Low-Loss Materials

Powdered Iron: Powdered iron is a magnetic material with high permeability and low core loss. It is commonly used in inductor cores for high-frequency applications, such as RF filters and telecommunication equipment.

Carbonyl: A class of metallic materials that are produced by the decomposition of metal carbonyls, Carbonyl materials also have high magnetic permeability and low coercivity, which make them useful for magnetic applications, such as inductors and transformers

Nanocrystalline Materials: Nanocrystalline materials are magnetic materials with a fine-grained microstructure, which results in high permeability and more low core loss. They are commonly used in inductor cores for power electronics, high-frequency applications, and renewable energy systems.

The magnetic materials properties comparisons of nanocrystalline, Iron, alloys, and Carbonyl are listed in Table I.

Comparison of magnetic materials properties

Series	SRP4018HEX-R68M	SRP4020FA-R68M	SRP4021HMT-R68M	SRP4021HMCT-R68M	SRP4020TA-R68M	SRP4020GA-R68M
Figures						
Powder	Nanocrystal	Alloy	Alloy	Alloy+ Carbonyl	Carbonyl	Alloy
Wire	Flat wire	Flat wire	Round wire	Round wire	Round wire	Flat wire
Feature	Low DCR/ACR Low AC/DC loss	High Irms High operating Temperature AECQ grade	Low cost Easy process	Low cost Easy process	High SRF High operating Temperature AECQ grade	High work voltage High reliability AECQ grade
Current - Saturation (Isat)	11A	11.6A	9.5A	11A	10A	14A
Current Rating (Irms)	11.8A	12A	11A	11A	7A	10A
DC Resistance	5.6mOhm Max	8.2mOhm Max	8.8mOhm Max	9.9mOhm Max	19mOhm Max	6.5mOhm Max
Operating Temperature	-55°C ~ 125°C	-55°C ~ 155°C	-40°C ~ 125°C	-40°C ~ 125°C	-55°C ~ 150°C	-40°C ~ 125°C
Valume	33.6 mm^3	35.3 mm^3	36.2 mm^3	36.2 mm^3	36.1 mm^3	33.6 mm^3
Process	Special Hot pressure molding	Hot pressure molding	Hot pressure molding	Hot pressure molding	Cold pressure molding	Injection molding
Cost	$$$$$	$$$	$$	$$	$	$$$$

Use MADMIX under test to be a part of a buck converter, it is possible to obtain an accurate inductor model, it can split AC-loss and DC-loss at the same time.

To further test the 6 different molding inductors with expected input and current, achieve total loss from different frequencies.

The measured molding inductor of the nanocrystal material-based inductors are shown in Fig. 2 and Fig. 2.1.

It can separate Pac/Pdc loss and Core/Winding loss so that we can be easier to get the correct data we want.

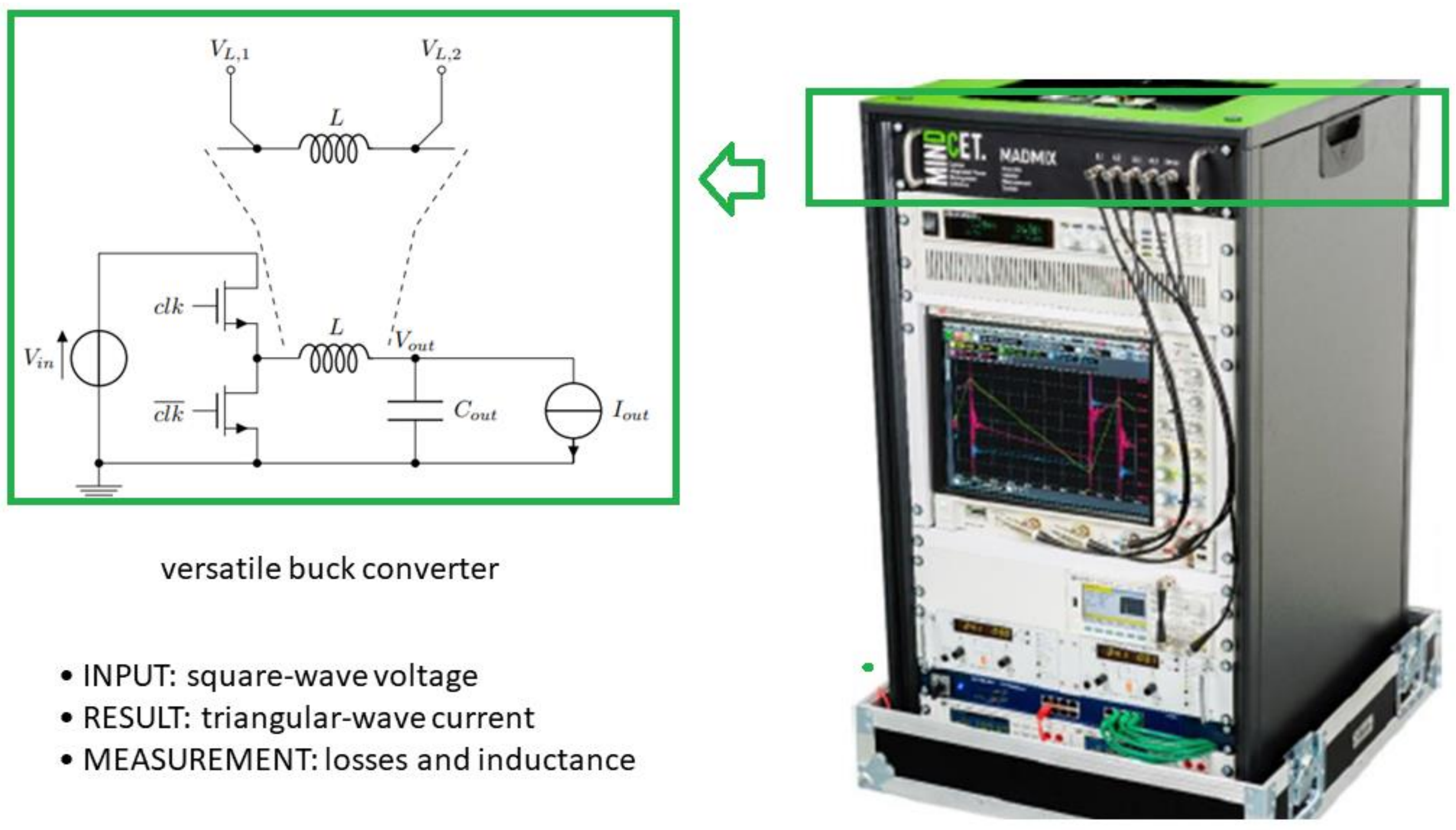

Figure 2: The MADMIX contains a buck converter in which the inductor L is the device under test.

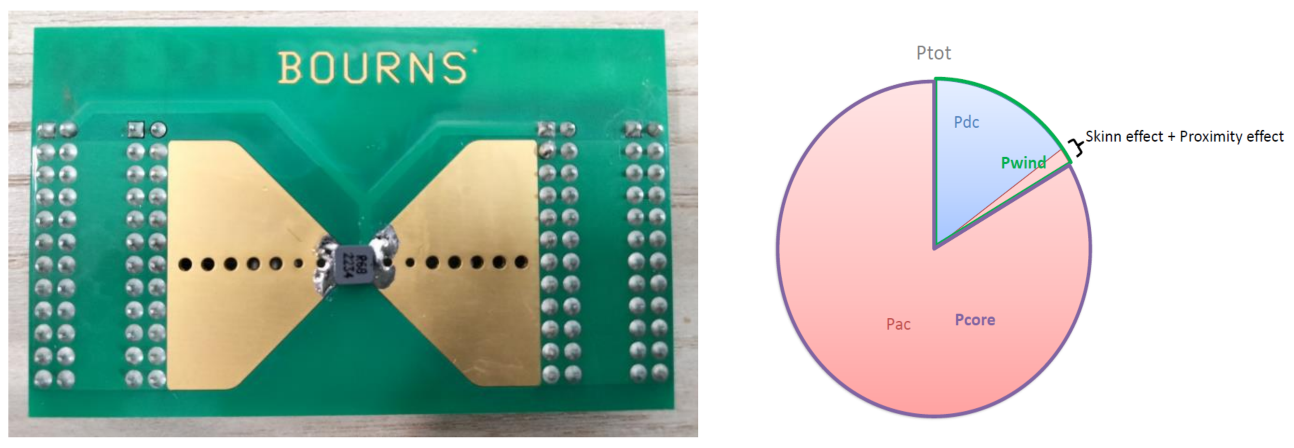

Figure 2.1: DUT sample and Power loss definitions (Pac+Pdc=Ptotal loss=Pcore+Pwind).

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Experimental results of core loss

As shown in Fig. 3, At 500 kHz, it can be found that the SRP4020GA-R68M (Iron) presents the highest core loss of 0.285W and SRP4020TA-R68M (Carbonyl) has 0.13 W loss, whereas the SRP4018HEX-R68M (nanocrystalline powder) inductors present the lowest core loss of 0.051 W.

In Fig. 4 in a different frequency 100kHz~1Mhz, we can see SRP4018HEX-R68M (nanocrystalline powder) inductors has the lowest core loss

Fig. 5, and Fig. 6 show in the different I-ripple currents that the SRP4018HEX-R68M (nanocrystalline powder) is also the lowest loss.

Nanocrystalline, Iron and Carbonyl inductors will depend on wire, binder, and powder particles in different frequencies and have some changes

When the frequency changes from 100 to 1000 kHz.

The nanocrystalline powder inductors have shown significantly fewer losses than Iron, Carbonyl.

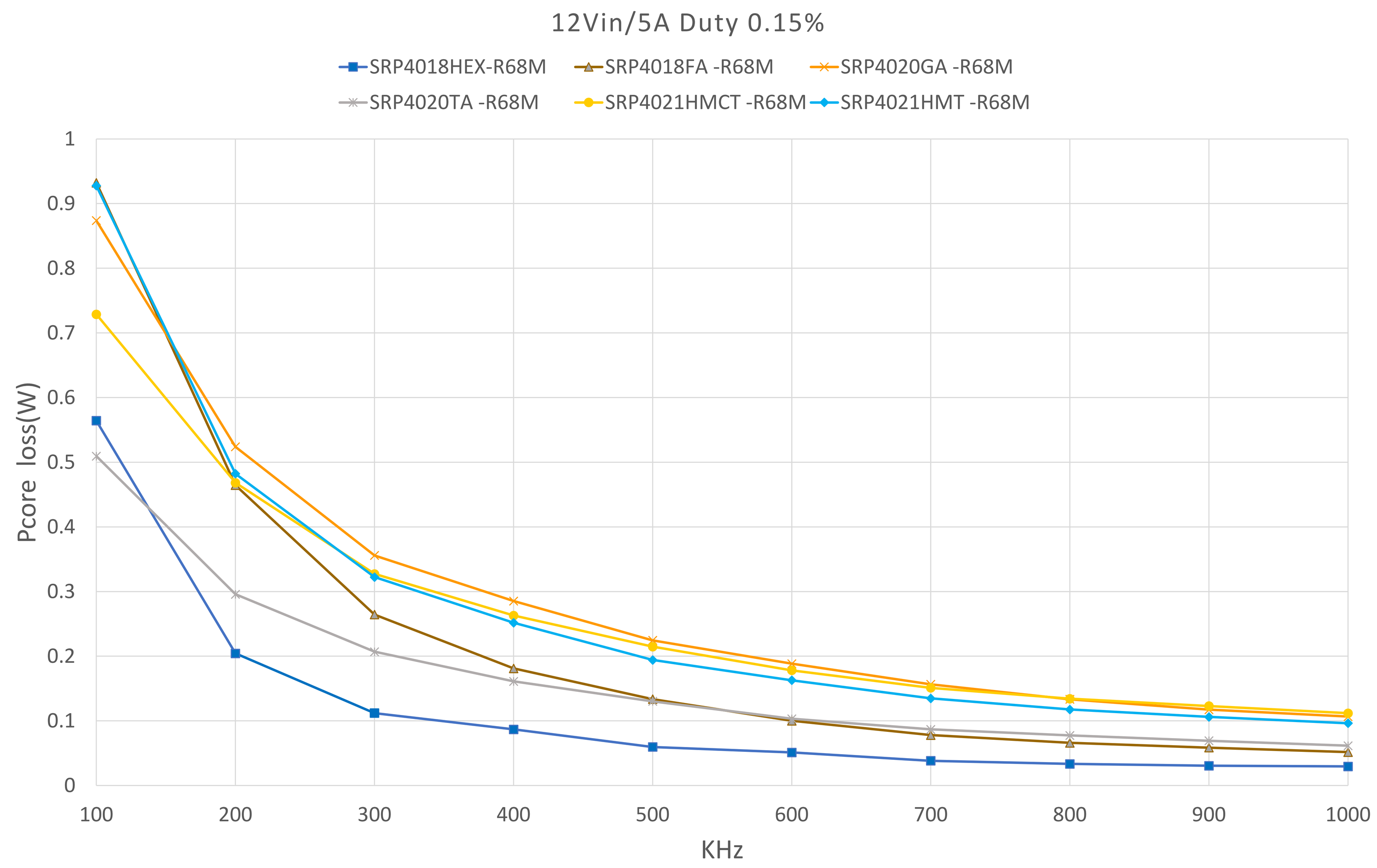


Fig.3 . Measured core loss at different operating frequencies when the peak-to-peak value of triangle current is 5 A from the MADMIX tester.

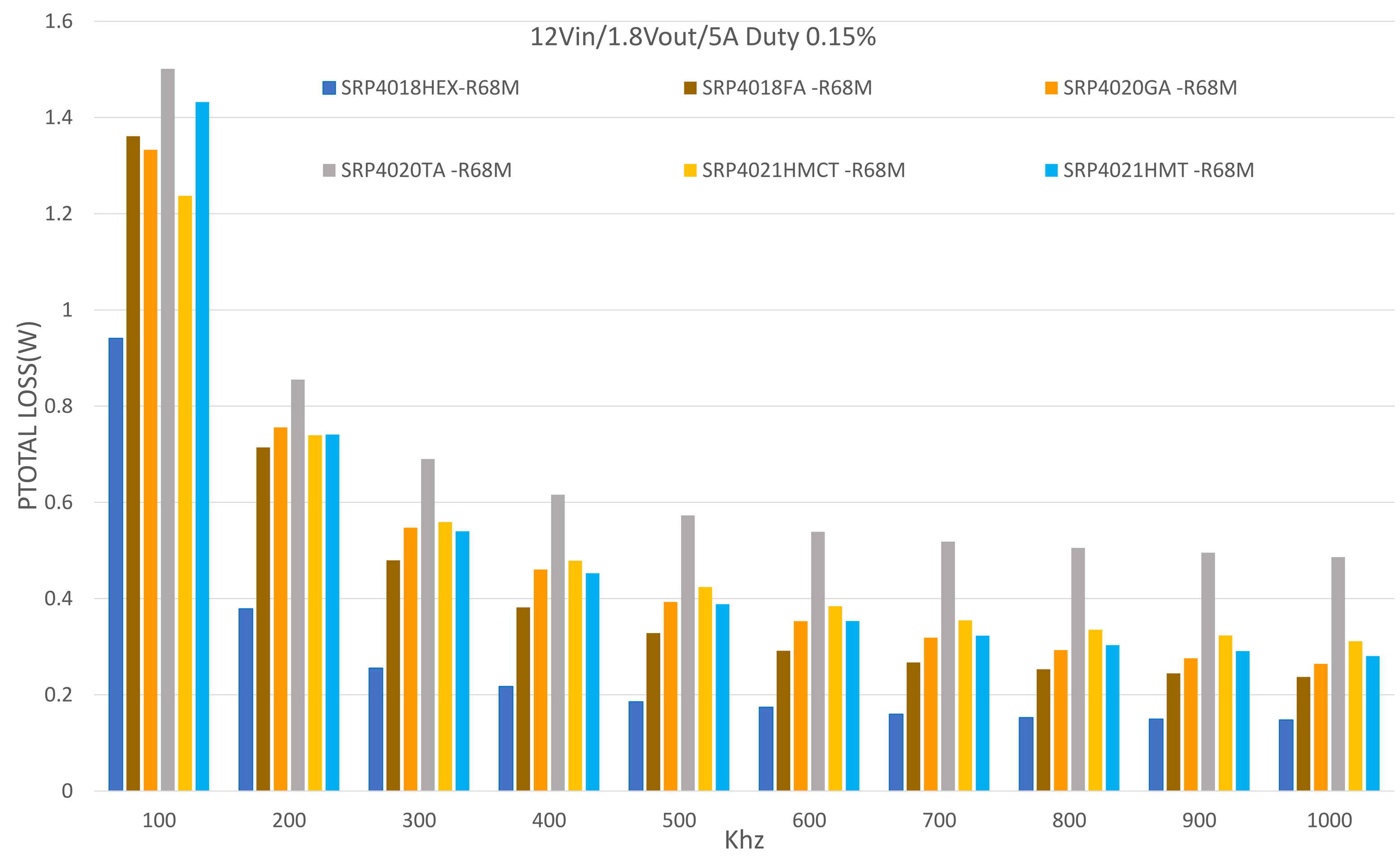
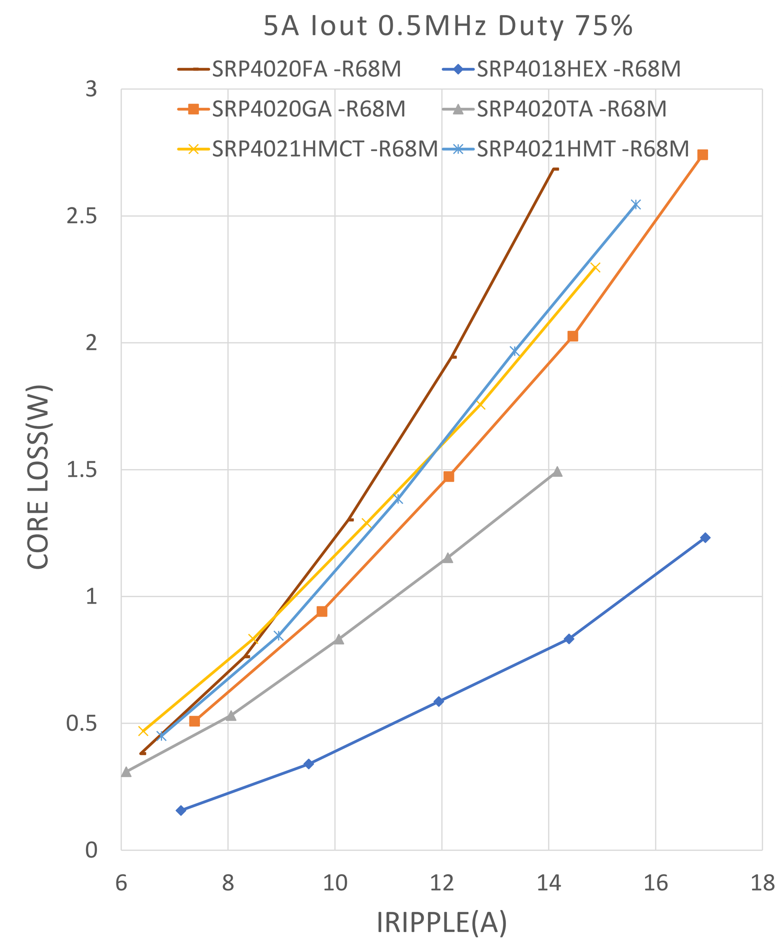


Fig. 4. Measured total loss at different operating frequencies when the peak-to-peak value of triangle current is 5 A from the MADMIX tester.

Thus, it can be concluded that the nanocrystalline powder, Fig. 7 has the best performance with the lowest core loss when the operating frequency is high. The nanocrystalline has the lowest core loss, which is better than Iron and Carbonyl at high-frequency operation, the nanocrystalline powder is competitive in high-frequency and high-power applications.



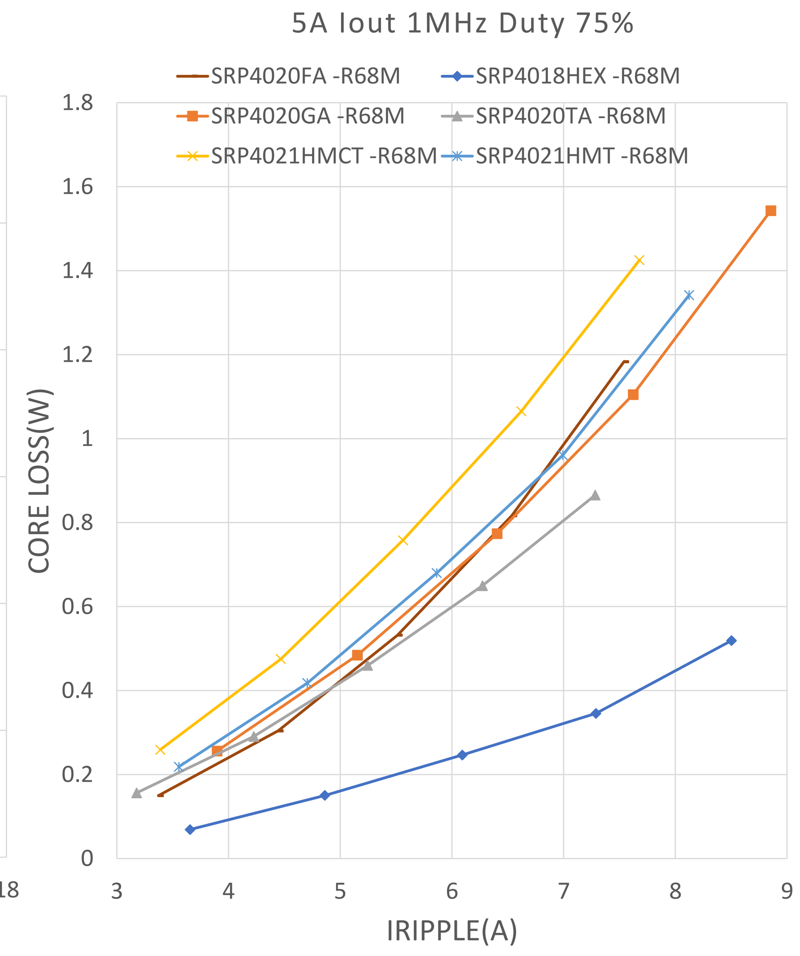


Fig. 5 Fig. 6. Measured core loss of different inductors at different I ripple values when the operating frequency are 500kHZ &1000 kHz.

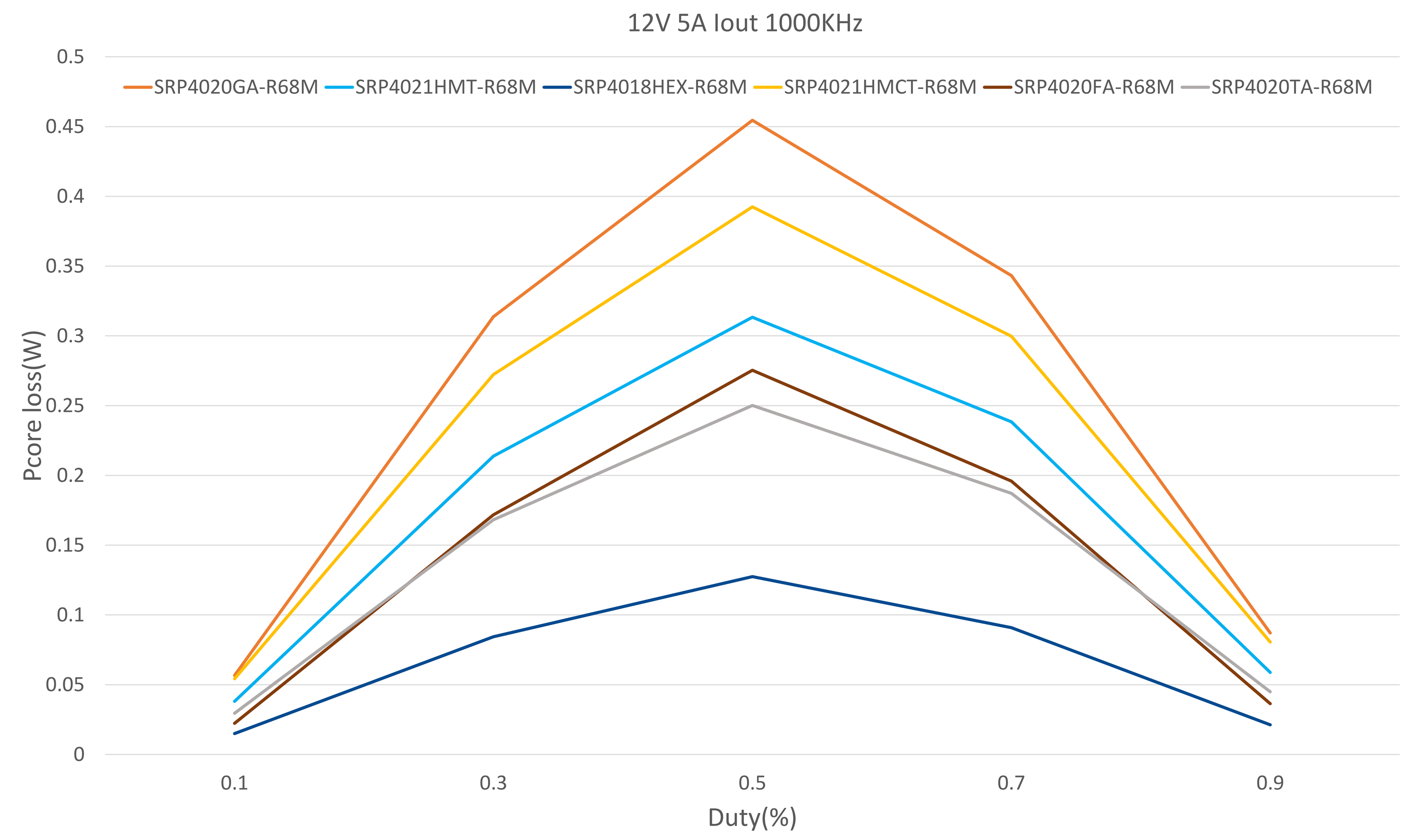


Fig. 7. Measured core loss of different inductors at different duty cycle when the operating frequency is 1000 kHz.

Conclusion

Low-loss materials are essential for future inductor applications and are critical to continue improving converter power density. The selection of low-loss materials depends on the operating frequency, magnetic field strength, and temperature. Ferrites, powdered iron, carbonyl, amorphous, and nanocrystalline materials are commonly used for inductor cores or molding inductors. The design considerations for low-loss materials include permeability, saturation flux density, core loss, and temperature stability. Nanocrystalline core structures exhibit an improved performance over traditional molded inductor materials.