Ferrite vs. Pressed Powder-core Inductors

Which material is best? Why are powder core inductors so popular now?

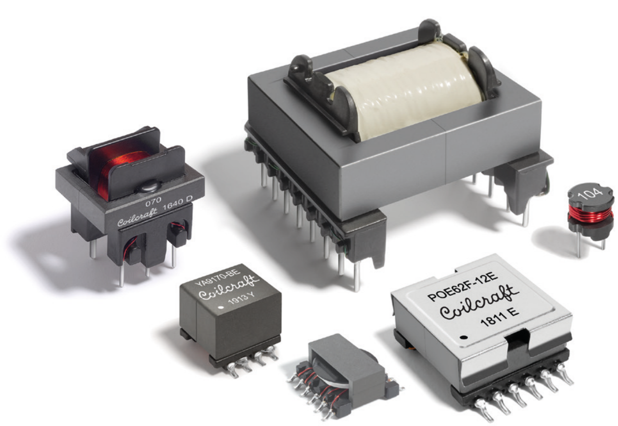
Introduction

Inductor and transformer cores are made from soft magnetic materials. “Soft” magnetic materials are easily magnetized and demagnetized, and a magnetic field is not present until these cores are excited by changing electric current in the windings (or “turns”) wrapped around them, creating an electromagnetic field. The term soft denotes the magnetic field is not permanent and disappears when the current stops. This is different from what we commonly call magnets. “Permanent” magnets are typically used to pick up, or attach things to, iron-containing (ferrous) metals (e.g. refrigerator magnets) and have a permanent magnetic field without windings or outside stimulus.

There are many varieties of soft magnetic materials. Almost all are based on a compound of iron. This article will discuss some key differences between ferrite cores and pressed-powder core (sometimes called composite) materials.

Ferrite Cores

Ferrite cores are crystalline ceramic iron-oxide compounds that are formed by high-temperature firing into hard, and sometimes brittle shapes. Ferrite cores are available in a wide variety of shapes, but the selection is somewhat limited because the cores are formed under very high pressure and temperature, making fine detail not feasible. Ferrite cores are used by winding wire on them to form transformers and inductors. Many inductors use ferrite cores, and they are particularly the material of choice for most transformer applications.



Ferrite cores:

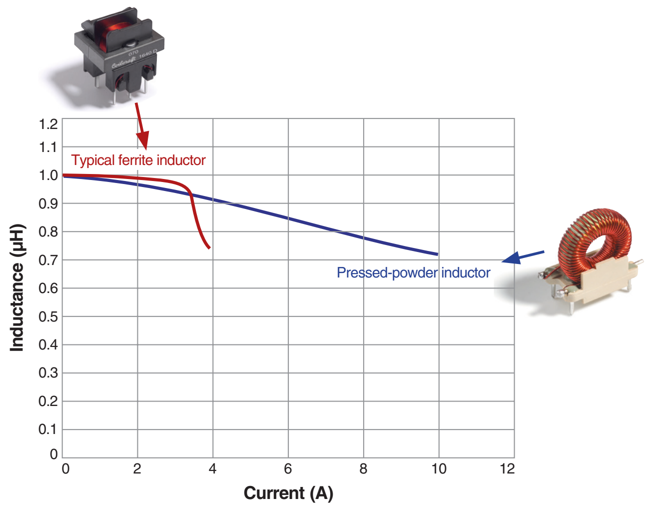
- Relatively high permeability
- Relatively low core loss at high flux density
- Limited shapes due to high temperature/pressure manufacturing

Pressed-Powder Cores

Pressed-powder cores are made from insulated iron-oxide particles which are pressed together to form solid core shapes. Compared to ferrite, pressed-powder cores are lower permeability but generally support higher current without saturation. In addition, saturation is “softer” such that inductance does not drop precipitously as with ferrite. Like ferrite, pressed-powder cores are available in a limited variety of shapes, with pressed powder most common in toroid shapes.

Pressed-powder

- Relatively low permeability
- Relatively high core loss at high flux density
- Soft saturation characteristics



Pressed-Powder Inductors

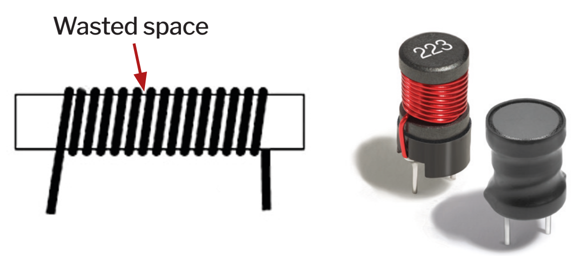
A particular use of pressed powder has become very popular in recent times. Pressed powder requires much less temperature to form than ferrite cores and therefore can be formed directly over windings without melting the copper wire or the insulation. This allows core material to fill all the space that was previously wasted in inductor windings. This has enabled some of the industry's most efficient and energy dense inductors. These inductors achieve very high current ratings and very low DC resistance (DCR) in a tiny overall size.

In addition to the efficient circuit performance, this method completely covers the windings with magnetic core material and achieves not only a robust and rugged design, but also one with excellent magnetic shielding to reduce the chance of radiated EMI emissions

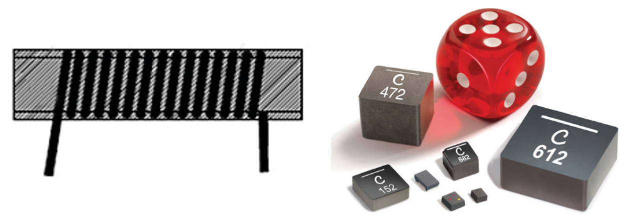
Pressed-powder Molded Inductors:

- High energy density for reduced size/greatest efficiency
- Soft saturation
- Resistant to high shock and vibration
- Full shielding for low EMI
- Minimized acoustical noise

Traditional winding on a ferrite or powder core



Pressed powder molded over a winding eliminates wasted air pockets, enabling reduced part size



Product Selection Examples using Coilcraft Design Tools

Coilcraft's inductor design tools are designed to find the top-performing parts for any set of operating conditions, enabling users to evaluate inductor performance without concern for the materials used or construction type. Those factors are reflected in the tool results so the user can focus on circuit performance while optimizing the use of off-the-shelf inductors. The following examples illustrate how pressed-powder composite inductors often, but not always, end up as the best solution from a size, saturation current, and low-loss / high-efficiency standpoint.

Example One:

For our first example, we'll look at the results in our [DC-DC Optimizer Tool] for a buck regulator operating at 800 kHz with 12 V input, 9 V, 0.75 A output, at 85°C ambient. The results below show that the XGL3530-682 pressed-powder inductor is smallest, with a higher Isat rating, and total losses far below the ferrite inductors.

Part Number (Check parts below to Analyze)	L nominal (µH)	L actual at Ipeak (µH)	L actual at IDC (µH)	I peak (A)	ΔIL%	CCM / DCM	Isat (A)	Irms (A)	DCR Typ @ 85°C (mΩ)	Total losses (mW)	Part temp. (°C)	Max Temp Rating (°C)	Length (mm)	Width (mm)	Height (mm)	Mount	Shielded	Core material
XGL3530-682 Sample Buy	6.8	6.1	6.4	1.1	91%	CCM	2.1	4.7	83.7	169	92°C	165°C	3.65	3.35	3.0	SM	Yes	Composite
1008PS-682 Sample Buy	6.8	6.4	6.7	1.1	85%	CCM	1.4	0.84	643	413	140°C	145°C	3.81	3.78	2.74	SM	Yes	Ferrite
LPS4012-682 Sample Buy	6.8	6.7	6.8	1.1	85%	CCM	1.2	0.88	377	221	115°C	125°C	4.1	4.1	1.2	SM	Yes	Ferrite
LPS4018-682 Sample Buy	6.8	6.7	6.8	1.1	86%	CCM	1.1	1.9	166	137	103°C	165°C	4.1	4.1	1.8	SM	Yes	Ferrite
XGL4020-682 Sample Buy	6.8	6.4	6.6	1.1	89%	CCM	3.4	5.4	78.3	142	90°C	165°C	4.3	4.3	2.1	SM	Yes	Composite

Example Two:

Our next example is a buck-boost regulator operating at 1 MHz with 9-12 V in and 5 V at 0.75 A output at 25°C ambient. Again, the composite XGL inductor is the smallest solution, with a higher Isat rating and total losses well below the larger ferrite inductors.

Part Number	L nominal (µH)	L actual at Ipeak (µH)	I peak (A)	ΔIL%	Isat (A)	Irms (A)	DCR Typ @ 25°C (mΩ)	Total losses (mW)	Part temp. (°C)	Max Temp Rating (°C)	Length (mm)	Width (mm)	Height (mm)	Shielded	Core material
XGL3530-562	5.6	4.7	1.5	55%	2.4	7.6	54.0	192	34°C	165°C	3.65	3.35	3.0	Yes	Composite
1008PS-562	5.6	3.7	1.6	62%	1.8	1.5	324	544	114°C	145°C	3.81	3.78	2.74	Yes	Ferrite
LPS4012-562	5.6	5.1	1.5	52%	1.6	1.7	234	341	73°C	125°C	4.1	4.1	1.2	Yes	Ferrite
XGL4020-562	5.6	5.1	1.5	53%	3.7	9.9	48.7	158	30°C	165°C	4.3	4.3	2.1	Yes	Composite
XGL4030-562	5.6	5.3	1.5	51%	4.2	10.3	31.5	120	30°C	165°C	4.3	4.3	3.1	Yes	Composite
XGL4025-562	5.6	5.2	1.5	52%	3.8	9.5	43.4	144	30°C	165°C	4.3	4.3	2.5	Yes	Composite

Example Three:

Our final example shows that there are exceptions to the idea that composite core (pressed-powder) inductors are always best. It is based on Texas Instruments reference design PMP21277 for a 12 V to 20.5 V / 7.5 A max continuous current boost application running at 250 kHz. While it is true that Coilcraft XAL pressed-powder parts give the smallest solution size, the total losses are higher than the ferrite core inductors in this case. The SER2918H ferrite-core inductor was selected by TI due to lower DCR, lower losses, and a much higher Isat rating.

Part Number	L nominal (µH)	L actual at Ipeak (µH)	L actual at IDC (µH)	I peak (A)	ΔIL%	CCM / DCM	Isat (A)	Irms (A)	DCR Typ @ 25°C (mΩ)	Total losses (mW)	Part temp. (°C)	Max Temp Rating (°C)	Length (mm)	Width (mm)	Height (mm)	Mount	Shielded	Core material
XAL1510-103	10.0	9.0	9.2	14.0	17%	CCM	26.3	41.2	6.8	1342	41°C	165°C	16.4	15.4	10.0	SM	Yes	Composite
XAL1010-103	10.0	7.5	7.8	14.2	20%	CCM	17.5	29.0	13.4	2802	60°C	165°C	11.8	10.5	10.0	SM	Yes	Composite
AGM2222-103	10.0	9.1	9.2	14.0	17%	CCM	37.0	55.9	2.1	479	35°C	165°C	23.0	23.0	23.0	TH	Yes	Powdered iron
AGP4233-103	10.0	10.0	10.0	13.9	16%	CCM	63.0	63.6	2.8	695	34°C	165°C	43.2	36.8	28.0	TH	Yes	Ferrite
SER2915L-103	10.0	9.0	9.3	14.0	17%	CCM	17.6	47.4	1.5	417	37°C	125°C	27.94	27.9	15.36	SM	Yes	Ferrite
SER2918H-103	10.0	9.9	9.9	13.9	16%	CCM	32.1	44.3	2.6	559	36°C	125°C	27.94	27.9	17.78	SM	Yes	Ferrite

Conclusion

There are a variety of core materials used in today's inductors and each will continue to have their place. Understanding the major core types can be helpful in identifying the best inductor for a particular application, but even more important is that datasheets have evolved and users now can use Coilcraft's suite of sophisticated tools like to better understand the available choices and optimize circuit performance.

Pressed-powder molded, magnetically-shielded inductors are often the popular choice because of many benefits, including small size, soft saturation, low loss, inherent robustness, low EMI, and minimized acoustical noise risk vs traditionally-wound, ferrite-based inductors. Using Coilcraft's selection and analysis tools to compare and analyze inductors simplifies and optimizes selection in terms of critical circuit performance parameters.