

## ***The Magnetic Agnostic Structure (Part 1): A Proposed Language For Describing And Documenting Magnetic Components***

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Although my major was electronics, my main experience before coming to power electronics and magnetics was in software. Yes, I was a programmer. And after some years, I became a magnetics software modeler or a programmer of magnetics—I am not sure which.

It might be my background in software and digital electronics, but one of the more shocking things I discovered about power electronics is the contrast in its tools: the latest technologies can be used together with the most archaic program.

I have seen designs done with the newest GaN modules, top-notch PCB design, buried vias, several ounces in internal layers, and several thousand dollars per prototype... and still the versioning system is a series of files call "board1.brd," "board2.brd," "boardfinal.brd," "boardfinal2.brd," etc.; all in a folder in a computer, or a shared directory in the company's network. Ring any bells?

This system of record keeping is concerning. I am not so much worried about the risk to that project if the hard disk is damaged. That can be salvaged in most cases. The real problem here is the damage you are doing to the project legacy. Will you remember enough about those files to reuse the project in a couple of years? Will the next engineer be able to decipher or even find your files, after you have left the company? That's the real risk.

And because this article is about magnetics, I want to focus a bit more on them. Do you remember, dear reader, any structure that you followed to store the information about any magnetic you have designed? Did you put any thought into its maintainability or scalability?

In this article I'll discuss the shortcomings I see in the way engineers document their magnetic component designs, and propose a new language for doing so which I am calling the Magnetic Agnostic Structure or MAS for short. Throughout this discussion I will refer to MAS, alternately as a format, structure or language—in this context they mean the same thing.

In introducing MAS, I'll explain how I arrived at my proposed format for defining magnetic components, and its various uses. Delving further, I'll provide a high-level description of how the magnetic component (the "magnetic") is defined as a whole, and then go into much more detail on how the core can be defined in this format.

### ***The Spreadsheet Approach—What's Wrong With It?***

Many engineers use Excel as their magnetics database: they put the name of the core shape in one column, the material in another one, the gap length, the number of turns in the primary, the gauge of the wire, etc. all in individual columns. Sound familiar?

That approach works at the beginning. But then they start adding their designs there, keeping the versions or the internal reference in another column. They track how many were manufactured. Then there is a case where they might need Litz, so they add another column for the number of strands.

A distributed gap? Just add another column. A spacer used in another design? Another column. A customized core? That means several columns—things start to get complicated. A multi-secondary transformer? That multiplies several columns. And all this without even getting into how the magnetic is wound. So imagine what a monstrous spreadsheet it can become after a few years.

What's more, this is just for one person or team. If we broaden the comparison to different companies, where each one follows a different style of recordkeeping, the entropy grows.

Imagine you are a manufacturer and just got the order to assemble a transformer, or an engineer that is trying to reproduce the application note, and get a specification with many steps, including the following:

**"Step 42) Wind 5 turns of 5 filar 5 strands 0.05 wire"**

What should you do?

One interpretation, especially if you come from the high-frequency world, is that you take 5 Litz wires of 5 strands, each one of diameter 0.05 mm, twist them together in a bundle, and then give 5 turns of that.

Another interpretation, if you are used to Simplis MDM, or PI Expert, is that you grab the same Litz wires of 5 strands as before, but in this case you give 25 turns, and connect them in parallels of five.

But it gets better. Imagine that you are a Unitrode fan, and know their handbooks by heart. Then you would be getting 5 solid wires of 0.05 mm, twisting them together in a bundle, and then giving 25 turns, and connecting 5 of them in parallel (Yes, in some books from Unitrode strand is used as parallel).

OK, enough complaining about the state of things. I think all this could be improved or standardized, by having a common language that can *unambiguously describe a magnetic component*. This has been my project for the last few months.

The aim of this project is to provide a format that can be written and understood by any human; that can be shared, copied, *versioned*, and *stored* efficiently; that can be read by different software tools and produce an equal result, be they analytical tools, circuit simulators, finite element or CAD software. This would be a format that can automatically produce a technical drawing, a 3D model, a temperature estimation, a magnetic field plot, or a list of assembly steps, without leaving a detail to interpretation.

Difficult? Yes. Possible? Absolutely.

What I am going to present is not a final version of that, it is a draft, which can be improved. I will reiterate it at the end, but the objective of this article is *start* a discussion and form a working group, so that many minds can write, review and clash ideas on how to have the best language.

### ***A First-Pass Attempt***

This first prototype I called "Magnetic Agnostic Structure," because it defines a magnetic independently of its kind or application, and because being an engineer, I like puns. This term's acronym is MAS, which means "more" or "plus" in my mother tongue, Spanish.

I would like to start with some clarifications—or "design decisions"—I made along the way, and explain why I made them. I also think they are a nice way of introducing the reasoning behind the MAS format.

Without an application, a magnetic component is just a piece of iron with copper wires around it. The excitation defines the magnetic as much as the construction: the same component can be used as a transformer in an LLC or as an inductor in a flyback. Some coupled inductors can be used as common-mode chokes.

Of course, the performance is not going to be the same, as normally one component is optimized for an application, but that is beside the point. What I want to highlight is that the operating point (excitation and circuit conditions) is as important as the construction, and they must be equally defined.

For that reason, I opted for my specification to cover both, but separately, and I called them *inputs* and *magnetic*. One input can excite many magnetics, and one magnetic can work with many different inputs.

Another design decision I made was to support indirection (also called dereferencing). This is a fancy term used mainly in programming, but the use is a logical one as follows:

When a property needs to be defined (let's say the shape of the core) the property can be defined directly in the document (by including all the data about that shape: dimensions, family, etc.) or just by a name (say, for example, we are using shape ETD 49). Of course, in the second case, that reference needs to be defined somewhere accessible (in a manufacturer datasheet, in a standard, or in another database).

This indirection might be weird, but we will clarify it with further examples later. But why would I want to do that? Well, because it allows us to use components that already exist (RM 12, TDK N87, Litz 800x0.1, etc.) together with custom definitions (a custom shape, a custom wire, or a custom material). It even allows us to define and reuse our custom components. It allows us to create a *scalable system*.

The last decision I made was selecting the format of the files. It needs to be a structured format that is readable and editable easily by a human; that can be processed by a generic software; and that can be stored in a database, downloaded, or even printed. Ideally, it should be one that can enforce certain templates, in order to maintain the format itself.

I decided to go with JSON (JavaScript Object Notation, pronounced "Jason" like the name) because it supports lists (used for listing the different windings in a magnetic) and dictionaries (a key-value part, for example: "shape": "ETD49"). Also, it has no strange reserved words (words limited to certain prescribed uses like "start" or "end") so it is really easy to read. Plus it is supported by any programming language and software, and it can be efficiently stored in most modern databases.

But my favorite part—it has a declarative language (called JSON Schema<sup>[1]</sup>) that defines the structure of a given JSON. So it is possible to establish that a JSON defining a core must have a material and a shape, or otherwise it is wrong.

Now we have some foundational steps: we are able to define inputs and magnetics, we can define custom parts, name them, and reuse them; and we can define rules to enforce our format. It sounds like a good start to me.

### **Call For Professionals**

The objective of this article is not to set in stone a format for others to adopt and follow. Nothing could be further from my mind.

Instead, the Magnetic Agnostic Structure outlined here should be considered as a first draft version. It serves as a starting point that describes the idea and can be improved by a group of professionals from manufacturers, companies and academia.

And that is the real reason for the article, dear reader. If after reading it you are as enthusiastic as I am about the idea of having a common language for magnetics, something that can grow even into other parts of power electronics, something that allows us to really exchange information in a way that none is lost, that is easy to understand and comfortable to use; get in contact with me at the email below,<sup>[2]</sup> as we are creating a discussion group to start working in a real common language.

But to provide the basis for future collaborative discussions, in the text that follows I will lay out my approach to using the MAS to define the magnetic component (aka "the magnetic") and the core. Given the space required to describe the cores, I will save my discussion of wires, windings, and inputs, for parts 2 and 3 of this article series.

### **The Magnetic**

As noted above, I am going to separate into different specifications (and therefore files or entries in the database, or fields) anything that has to do with input to the system (operating points and requirements) from the physical system itself (the magnetic component). This first section describes how a magnetic can be described.

It is a common practice of magnetics manufacturers to decouple cores (including gaps) and windings, having collections of compatible cores and wound bobbins, which allows creating a multitude of different magnetics by combining them (see the table).

I have followed the same principle for separating the different parts of the magnetic component, choosing to define the core and winding as two (almost) independent objects. Cores and windings can be defined by themselves and linked together, supporting even having magnetic cores with more than one winding window, and placing different windings in each one.

#### **Name**

This name references the magnetic component and can be used to refer to it. This field can contain any valid string of characters, and can hold the manufacturer's reference or a description of a custom magnetic.

Table. List of inductors using the same core. The different number of turns can be inferred from the increase in inductance and dc resistance of successive entries in the table. (Source: Data for Würth Elektronik's WE-PD SMT Power Inductor)<sup>[3]</sup>

L ( $\mu$ H)	I <sub>R</sub> (A)	I <sub>SAT</sub> (A)	R <sub>DC</sub> (m $\Omega$ )	R <sub>DC max.</sub> (m $\Omega$ )	f <sub>res</sub> (MHz)	Size	Version	Design Kit
0.47	23.5	34	1.7	3	120	1280	Standard	744770
0.75	17	27	3.2	5	110	1280	Standard	744770
1.5	16.5	19	3.2	5	42	1280	Standard	744770
2.4	11.5	15	6.3	9	41	1280	Standard	744770
3.5	10.2	12.5	8	11	37.5	1280	Standard	744770
4.7	9.5	11	9	12	31.2	1280	Standard	744770
5.6	8.7	10	10.5	13.5	24	1280	Standard	744770
6.1	8.5	9.5	11	14	25	1280	Standard	744770
7.6	8.4	8.5	11.5	15	21.3	1280	Standard	744770
10	7	7.5	15	20	18	1280	Standard	744770
12	6.2	6.5	16	21	16	1280	Standard	744770

## Core

This section of the structure (or field, to reuse that term) must completely define the magnetic core used in our magnetic component. It must support commercial off-the-shelf (COTS) cores as well as customized ones. With the information in this section any user or software must be able to identify and buy the core from a distributor, create a 3D model for simulation, or be able to manufacture it.

In order to achieve this, the information is grouped in three levels or descriptions, each one independent from the others. Ideally any level/description must be able to describe the core, and all the information of the core can be extracted from any of them.

This description has three parts:

- **Functional description:** The most commonly used in core datasheets, this information describes the core from the functional point of view: shape, material, number of stacks, etc. Practical for humans.
- **Processed description:** Here the processed information is kept. Things like the dimensions of the columns, the winding windows, or the effective parameters of the shape are stored here. Practical for analytical models.
- **Geometrical description:** This is the information of the core related to its geometry and relative position. Data about which pieces make the core, including ferrite pieces, spacers, or column chunks for distributed gaps, along with all their relative positions, rotations, and machining. Practical for CAD models.

More information about each one will be provided in each section of the structure.

## Name

This name references the core and can be used to refer to it from any number of magnetic components. This field can contain any valid string of characters, and can hold the manufacturer's reference or a description of a custom core.

## Manufacturer Info

Optional field for COTS cores, compiling the information about the manufacturer and possible distributors.

- Reference: Reference name given by the manufacturer.
- Relative Cost (optional): Relative cost compared with other cores.
- Distributors: List of elements, where each element represents one distributor (including the manufacturer itself, if they also provide direct sales) and offer, containing the following fields:
  - Reference: Reference given by the distributor
  - URL (optional): If sold online, the URL to the product
  - Cost: Absolute cost of the core in dollars by the distributor.

## Functional Description

This level describes the core in a way mainly thought for humans, defining the core with the values used by most power engineers.

I decided to break down the specification in part following the common use in the industry. A core manufacturer has a list of materials they use to create their cores (ferrites, iron powder, nanocrystalline, etc.) and then uses those materials to create a core with a given shape (RM8, PQ40/40, T25), and then it might machine some gapping into some column (that is, the leg or pole of a core). Additionally, some of these shapes can be stacked to create larger cores.

**Shape.** This field has two possible definitions, a text reference to which shape is used, or the proper definition of the shape, according to the dimensions described in DIN EN 62317. It must be clarified that in the case of pieces designed to go in sets, like most non-toroidal cores, the specification described here is for just *one piece*, not the whole set.

It was mentioned before, but in the first case, just the name of the shape, the information must be stored somewhere accessible. A common setup that complies with this condition is having a database with all the shapes defined by the DIN EN 62317 standard.

Basically, this allows us to create a collection of shapes in only one place and just use references to these shapes in our designs, so any human or software can easily look up any data regarding that shape just by knowing its name (see the figure).

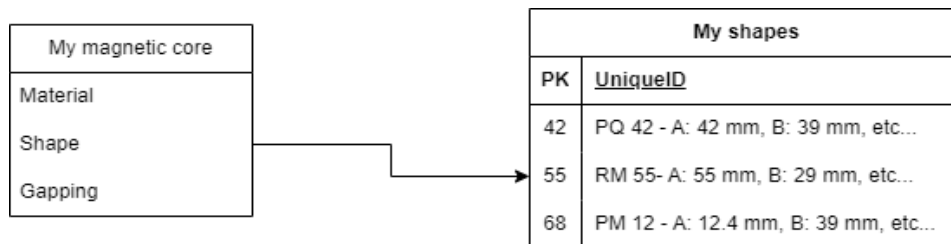


Figure. Core shapes can be defined in a separate database and then referred to when specifying designs using the MAS format.

The fields needed to describe a shape are:

- Name: Name of the shape, (for example, ETD 49/25/16)
- Aliases: Other names this shape can have (such as ETD 49)
- Type: Indicates if the shape is standard or custom.
- Family: Family of the shape, as written in the DIN EN 62317 standard (RM, PQ, etc.)
- Magnetic Circuit: Indicates if the magnetic is closed (as it is the case for toroids or UT cores) or open (PQ, RM, U, etc.). Open magnetic circuit shapes are usually used in sets of two to make a closed circuit.
- Family Subtype: When several forms are possible for a shape, this field represents the index of that subtype (e.g.: PM has two subtypes: 1 and 2)
- Dimensions: Dictionary/map holding the different dimensions of the shape, according to DIN EN 62317. It can contain different values due to tolerances, with variables for minimum, nominal and maximum dimensions.

The following is an example for RM 12/17:

```
{
  "name": "RM 12/17",
  "aliases": ["RM 12LP"],
  "type": "standard",
  "family": "rm",
  "magneticCircuit": "open",
  "familySubtype": "3",
  "dimensions": {
    "A": {"minimum": 0.03610, "maximum": 0.03740},
    "B": {"minimum": 0.00830, "maximum": 0.00840},
    "C": {"minimum": 0.01560, "maximum": 0.01610},
    "D": {"minimum": 0.00450, "maximum": 0.00475},
    "E": {"minimum": 0.02500, "maximum": 0.02600},
    "F": {"minimum": 0.01230, "maximum": 0.01280},
    "G": {"minimum": 0.01290},
    "H": {"minimum": 0.00540, "maximum": 0.00560},
    "J": {"minimum": 0.02870, "maximum": 0.02980},
    "R": {"maximum": 0.00030}
  }
}
```

The whole JSON Schema with the complete definition can be found in reference [4]:

All data for (to the best of my knowledge) all standard shapes can be found in reference [5].

**Number of stacks.** Integer number defining how many cores are stacked along the z axis (C dimension according to DIN EN 62317).

**Material.** As the shape field, the material field can hold either a text reference to which material is used, or the actual definition of the material.

For the case of the definition, the following fields are defined, although, in contrast with the previous field, many are optional or support different types of data. This design might look unnecessarily complex, but it was a way of having one structure for all the different materials used in power magnetics, along with the different methods used by different manufacturers. More information will be provided in each individual parameter:

- Name: Name of the material, as defined by the manufacturer (for example 3C94)
- Family: Family to which the material belongs, as defined by the manufacturer (for example 3C, High Flux)
- Manufacturer Info: Dictionary/map with the information about the manufacturer, including name, status of the material, internal reference, or cost.
- Type: Indicates if the shape is commercial or custom.
- Curie temperature: The temperature at which the material loses its ferromagnetism.
- Material composition: Type of the material, which can be one of the following:
  - Ferrite
  - Iron powder
  - Nanocrystalline
  - Amorphous
  - Electrical steel
- Saturation: List of points defining the saturation at different temperatures. Each point must have its magnetic flux density, magnetic field strength, and temperature values.
- Permeability: Dictionary/map containing all the different possible permeabilities, of which the only mandatory parameter is the initial permeability. Each permeability can be defined in two ways, either

with a list of points or with an individual point. Each point is defined by a value as a minimum, but can carry more data, including temperature, magnetic field dc bias, frequency (which is commonly used for ferrites), or even modifier equations (as it is common for iron powder materials). With this definition we can cover all from individual values, to temperature graphs, or equations.

- Volumetric losses: This is a list of possible methods for calculating the volumetric losses of the material. The options are:
  - Steinmetz coefficients: List of ranges defined by a minimum and maximum frequency, including the coefficients k, alpha and beta (and optionally ct0, ct1, and ct2, for temperature dependance) for calculating the volumetric losses for any method derived from Steinmetz.
  - Roshen coefficients: Values for calculating the volumetric losses according to Roshen's method. The needed values are normally provided by the manufacturer: remanence, coercive force, and resistivity, at optionally some reference volumetric losses.
  - List of measured volumetric loss points, each defining the excitation B field, its temperature, its measured value and the measuring method. It can be used for different statistical methods, from simple interpolation to artificial intelligence training.
- BH cycle (optional): List of points defining the BH cycle. Each point must have its magnetic flux density, magnetic field strength, and temperature values.

The following example is for Ferroxcube 3C94:

```
{
  "type": "commercial",
  "curieTemperature": 220,
  "materialComposition": "ferrite",
  "name": "3C94",
  "family": "3C",
  "manufacturerInfo": {"name": "Ferroxcube"},
  "permeability": {"initial": [{"value": 1438.0, "temperature": -40.0,
"frequency": 10000.0}, {"value": 1523.0, "temperature": -30.0, "frequency":
10000.0}, {"value": 1650.0, "temperature": -20.0, "frequency": 10000.0}, {"value":
1776.0, "temperature": -10.0, "frequency": 10000.0}, {"value": 1914.0,
"temperature": 0.0, "frequency": 10000.0}, {"value": 2078.0, "temperature": 10.0,
"frequency": 10000.0}, {"value": 2250.0, "temperature": 20.0, "frequency":
10000.0}, {"value": 2474.0, "temperature": 30.0, "frequency": 10000.0}, {"value":
2696.0, "temperature": 40.0, "frequency": 10000.0}, {"value": 2926.0,
"temperature": 50.0, "frequency": 10000.0}, {"value": 3171.0, "temperature": 60.0,
"frequency": 10000.0}, {"value": 3423.0, "temperature": 70.0, "frequency":
10000.0}, {"value": 3613.0, "temperature": 80.0, "frequency": 10000.0}, {"value":
3786.0, "temperature": 90.0, "frequency": 10000.0}, {"value": 3924.0,
"temperature": 100.0, "frequency": 10000.0}, {"value": 4039.0, "temperature":
110.0, "frequency": 10000.0}, {"value": 4005.0, "temperature": 120.0, "frequency":
10000.0}, {"value": 3952.0, "temperature": 130.0, "frequency": 10000.0}, {"value":
3912.0, "temperature": 140.0, "frequency": 10000.0}, {"value": 3773.0,
"temperature": 150.0, "frequency": 10000.0}, {"value": 3795.0, "temperature":
160.0, "frequency": 10000.0}, {"value": 3850.0, "temperature": 170.0, "frequency":
10000.0}, {"value": 3934.0, "temperature": 180.0, "frequency": 10000.0}]}},
  "saturation": [{"magneticFluxDensity": 0.34167244027867405, "magneticField":
73, "temperature": 100.0}, {"magneticFluxDensity": 0.38505343517127105,
"magneticField": 80, "temperature": 25.0}],
  "volumetricLosses": {
    "default": [
      {
        "method": "roshen",
        "remanence": [{"magneticFluxDensity": 0.07894755435464,
```

```

"magneticField": 0, "temperature": 100.0}, {"magneticFluxDensity":
0.162273628313529, "magneticField": 0, "temperature": 25.0}],
      "coerciveForce": [{"magneticFluxDensity": 0,
"magneticField": 10.078443393042846, "temperature": 100.0},
{"magneticFluxDensity": 0, "magneticField": 15.964913844705038, "temperature":
25.0}],
      "resistivity": [{"value": 10, "temperature": -20},
{"value": 7, "temperature": 0}, {"value": 4, "temperature": 20}, {"value": 2,
"temperature": 50}, {"value": 1, "temperature": 100}]
    },
    {
      "method": "steinmetz",
      "ranges": [
        {"alpha": 1.419999968, "beta": 2.884999936, "ct0":
1.972776047, "ct1": 0.022263625000000002, "ct2": 0.00012535900000000002,
"minimumFrequency": 1, "maximumFrequency": 150000, "k": 3.530102481},
        {"alpha": 2.124999953, "beta": 2.70499994, "ct0":
2.1613195, "ct1": 0.023272995, "ct2": 0.00011659800000000001, "minimumFrequency":
150000, "maximumFrequency": 400000, "k": 0.000588}
      ]
    }
  ]
}

```

The whole JSON Schema with the complete definition can be found in reference [6]. All data for the most commonly used (and growing list of) materials can be found in reference [7].

**Gapping.** This field defines a list with all the different gaps that can exist in a magnetic core. In order to simplify the use of the common cases, while allowing complex ones, each of the gaps in the list can be defined with as little information as its length (and a centered standard subtractive gap will be assumed), while allowing many other fields to be included. These fields would modify its type, or its vertical or horizontal placement. Additionally, some processed information can be included in order to completely define the behavior of the gap, especially its fringing effect.

- Length: Length of the gap along the path of the magnetic flux.
- Type: Type of the gap, especially used in how the 3D models and drawings are created. It can be:
  - Residual: the residual gap existing between two imperfect parallel surfaces.
  - Additive: a gap created by adding an object between the pieces of the core, usually known as spacer.
  - Subtractive: a gap that is created by removing or grinding away part of the material of the core. Most common gaps are of this type.
- Coordinates: Vector of 3 with the X, Y and Z dimensions of the center of the gap, referred to the center of the winding column.
- Shape: Shape of the column where the gap is. It can be one of the following:
  - Oblong
  - Round
  - Rectangular
  - Irregular
- Distance closest normal surface: Distance to the closest normal distance, usually the top or bottom part of the winding window.
- Distance closest parallel surface: Distance to the closest normal distance, usually the opposite side of the winding window.
- Area: Geometrical area of the gap.



- Section dimensions: Dimension of the section of the column that is normal to the flux, where the gap starts or ends.

The number of elements in the list of gaps can be less than, equal to, or greater than the number of columns. If no coordinates are provided, the gaps can implicitly define some common cases:

- Empty list: Residual gaps in columns.
- One element: One grinded subtractive gap in the winding column (central column for most shapes).
- As many elements as columns, all with equal length: A spacer additive gap in all columns.
- More gaps than columns: Distributed gaps in the central column.

Example of simple gapping, one grinded gap in the center, residual in the lateral legs:

```
"gapping": [
  {
    "type": "additive",
    "length": 0.001
  },
  {
    "type": "residual",
    "length": 0.00001
  },
  {
    "type": "residual",
    "length": 0.00001
  }
]
```

The whole JSON Schema with the complete definition can be found in reference [8].

### Processed Description

This level or description holds the processed data from the core. This is detailed data that is useful for working with the core, but it does not define its shape, instead it is a consequence of the shape.

The opposite step, from processed to functional, is done when selecting a magnetic core depending on the input excitations (for example, the area-product or energy methods). We implicitly define the winding window and the central column, and from that date we choose the shape that is closer to them.

**Dimensions.** The width (x axis or A dimension according to DIN EN 62317), the height (y axis or B dimension according to DIN EN 62317), and the depth of the core (z axis or C dimension according to DIN EN 62317).

**Columns.** List of elements, where each one represents one of the columns of the magnetic core, and has the following variables:

- Type: Central or lateral.
- Shape: Shape of the column. It can be one of the following:
  - Oblong
  - Round
  - Rectangular
  - Irregular.
- Area: Area of the section column, normal to the magnetic flux direction.
- Width, depth, height: The dimensions of the column.
- Coordinates: Vector of 3 with the X, Y and Z dimensions of the center of the gap, referred to the center of the winding column.

**Winding windows.** List of elements, where each one represents one of the winding windows of the magnetic core. In most cases there will be only one, although the structure is thought to support any possible combination of cores with multiple winding windows. Each element has the following variables:

- Type: It can be either:
  - Rectangular, for concentric cores
  - Radial, for toroids.
- Width/angle: Horizontal width of the winding window (x axis or A dimension according to DIN EN 62317). Angle in radians in the case of toroids.
- Height/radial height: Vertical height of the winding window (y axis or B dimension according to DIN EN 62317). In the case of toroids, the radial height from the surface of the toroid towards its center.
- Area: Area of the winding window.
- Coordinates: The coordinates of the center of the winding window, referred to the center of the main column. In the case of half-sets, the center will be in the top point, where it would join another half-set.

**Effective parameters.** The field contains the effective parameters as defined in DIN IEC 60205. They are:

- Effective length: Equivalent length that the magnetic flux travels through the core.
- Effective area: Equivalent section that the magnetic flux traverses, because the shape of the core is not uniform and its section changes along the path.
- Minimum area: Minimum area seen by the magnetic flux along its path.
- Effective volume: This is the product of the effective length by the effective area, and represents the equivalent volume that is magnetized by the field.

## Geometrical Description

This level or description holds all the information of the core from a geometrical point of view, ready to be processed by software that need a 2D/3D representation to work with the magnetic component, as is the case in finite element simulation.

All the parts of the magnetic core are described here, including its shape, position, rotation, machining operations, and material. In contrast with the functional description, the gaps are not explicitly defined here as entities, but implicitly with the separation between pieces and the machining processes (for example, grinding) done.

Each of the parts must have the following fields:

- Type: Type of part, it can be one of following:
  - Half set: If it is one piece of a core set, like most concentric cores (for example, one piece of an RM12).
  - Toroid: Toroidal piece.
  - Plate: Similar to a half-set, but only the plate part, without the columns. (for example, I pieces to create EI sets).
  - Sheet: Thin sheet used in laminated cores.
  - Closed: One-piece cores that are not toroidal, like UT cores.
  - Spacer: Rectangular piece, usually of insulating material, that is used to separate cores and create gaps in all legs.
  - Chunk: Piece of material without a predefined shape, commonly used to create distributed gaps.
- Material: Material of the part. It can be one of the materials defined before, or an insulation material, like Teflon or plastic.
- Shape: Shape of the part. It can be one of the shapes defined before, or a basic shape like a rectangle or a cylinder.
- Coordinates: The coordinates of the piece.
- Rotation: The rotation of the piece
- Machining: List of machining steps that must be applied to the piece, including its length and coordinate.

## More To Come

In this article, I have made the case for why a new language is needed for defining magnetic components and their elements—cores, windings and excitations—in a way that may be usable to power engineers, magnetics manufacturers and other interested parties. This format is meant to replace the ad hoc methods currently used by power engineers to define and document a magnetic component.

Here in part 1, I have outlined my initial attempt at developing such a system, which I have dubbed the Magnetic Agnostic Structure or MAS, and presented my proposed structure for defining the magnetic component as a whole (the “magnetic”) and the core. In the upcoming parts 2 and 3 of this series, I will present my proposals for defining the other elements of a magnetic component design including wires, windings, and inputs (excitations).

As noted previously, these proposals are only intended as starting points for developing a standardized methodology of defining and documenting magnetic component designs through the collaboration of engineers in industry and academia.

## References

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## About The Author



*Alfonso Martínez is a software and electronics engineer, and creator of OpenMagnetics and AutoPlanar. He has more than 14 years of technical experience spread between the electronic engineering and computer science fields. Being among these two worlds he decided to start bringing the best of the software world to the power electronics world: the open-source philosophy.*

*He created OpenMagnetics as a path to tearing down the paywalls and giving every engineer in the world access to the best tools, knowledge, and latest simulation models.*

*From 2018 to 2022 he worked as CTO at Frenetic, where he was responsible for developing its online AI-based tool for designing magnetic components. Prior to this, Alfonso cofounded the start-up Swarm64 in Berlin, where he created an FPGA-based architecture to optimize the performance of databases. That company was acquired by ServiceNow. And previously he developed hardware and firmware in the field of the Internet of Things at a startup in Madrid. Alfonso holds an MSc in industrial engineering from the Polytechnic University of Madrid.*

For more on magnetics design, see these [How2Power Design Guide search results](#).