mini Ring-Core-Calculator Version 1.3 (2000-2015)

Help File of mini RK by DL5SWB † & DG0KW

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The Program Files:

1. minirk13.exe the Calculator
2. minirk13_d.pdf German Help-File
3. minirk13_e.pdf English Help-File
4. minirk13_f.pdf French Help-File

Copy all files in **one** directory of your choice or use the more comfortable setup.exe!
The program is tested under Windows 9x, ME, 2000, XP and W7.

Tested under Linux:

- LINUX SuSe 9.0 with Wine20050524
- Ubuntu 14.04.3 LTS und VirtualBox V 5.0.4 r 102546

mini Software from DL5SWB & DG0KW for a mini Price
Freeware for Radio Amateurs

General

The program used to calculate inductors (coils) and their number of turns on toroids, ferrite sleeves and air coils. These find their use for baluns, Ununs, bandpass filters, low pass filters, resonant circuits, and more. The data of the cores in the program are integrated.

Who needs such a calculator? - Radio amateurs, who are still home brewing.

You need a certain inductance and looking for the corresponding number of turns.
Well, looking for the A_L-Value in a table (But where I've seen it last time?) - and found it.

But what about the formula? Again searching.

Not found or if you did, which units to use?

Is a T50-2 red or yellow?

This program has all these answers and even more.

Usage

Input fields have **green** background, selection fields a **yellow** one and result fields are **white**.



Placing the cursor a while on some fields and labels you will get short hints.

The program starts in German and remembers the locale then carried out for the next program start.

You can use whatever you want, comma or point. An automatic conversion is done. The units can be between the English dimensions (English, United States) inch, foot and AWG (American Wire Gauge = American Wire Gauge) and metric measurements mm, cm, m switched. In menu "Units" one can switch back to metric and compare the results.
Entering or even changing a value you will note, that the program is updating the results immediately. So you can compare different variants easily and quickly.

After all values are entered is started by clicking on the button



to calculate.

Appearing "xxx" in result fields means: There are invalid values. This is among other things to prevent a division by zero.

Pressing F1 the corresponding help topic is shown.

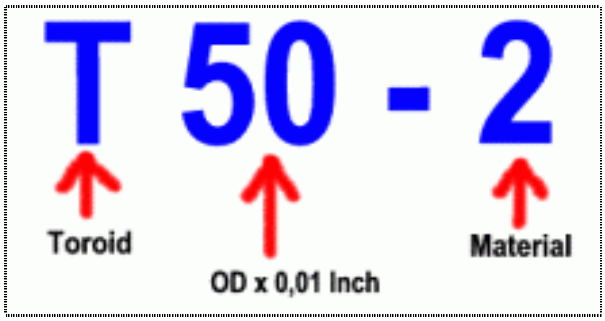
In menu "Tools" you will find some additional useful helping tools around the ring core.

Note

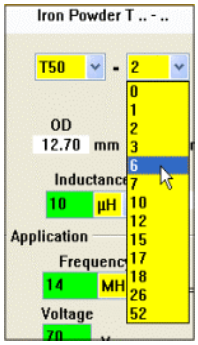
Exact calculation of inductors isn't as easy as it seems to be. Manufacturers specify AL-values of ring cores often with a tolerance up to 30%. The permeability depends upon the frequency, the temperature and the magnetic flux. The shape influences the inductance of an air core.
Due to conversion of units additional rounding failures might occur.
Interpreting the results you should this always bring to mind.

Iron Powder Cores (AMIDON)

Core Number



T means toroid (ring core). The following figures are representing the outer diameter in 0,01 inch. The figure(s) after the dash indicating the mixture of material and therewith the usable frequency range, indicated by the color of the core. Through both list fields

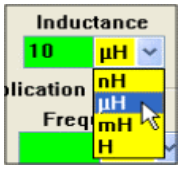


the desired core can be selected. Unfortunately, not all combinations are manufactured or available in this program. In this case a hint is displayed.

After selection all necessary data are displayed.

Calculations

Enter the needed inductance. The unit is preset to µH, but can changed using the list box.



On entering or also on changing these values the number of turns will be calculated immediately by this formula:

$$N = \sqrt{\frac{L}{A_L}}$$

Each pass of the wire through the center of the core counts as one turn.

The physical dimensions limit the maximal diameter of wire. Applying this diameter (minus tolerance) the entire winding can be wound single layered on the core. If you get a very thin wire, try the calculation again with a greater core size. The job of the computer is to compute and so he should deliver the length of wire as well. If you have ever threaded a 2-m long wire through a toroid, although 75 cm were sufficient, you will appreciate it. But don't forget to add terminating lead length to the calculated length.

Application

This part provides additional information on the behavior of the core under applied frequency and voltage.
Transformer applications require an inductive resistance X_L of the winding

$$X_L = 2 \times \pi \times f \times L$$

which should be at least four times greater than the resistance to be transformed.
Entering the working frequency provides a quick overview.

Magnetic Calculations

The following calculations should be considered as a guide only and some are only available for iron powder cores. The Bmax figures apply to both iron powder and ferrite cores over the 0.1 – 30 MHz range. Some manufactures provide ferrite core loss data and that is included in the calculations where it is available. Published data by manufactures is often not available.

The maximum magnetic flux is a function of frequency using a table of Bmax(f) given by the manufacturer. Other values are interpolated within the range of 100 kHz and 30 MHz.Bmax should not be exceeded in any applications. The formula for magnetic flux incorporates several parameters and is shown below:

$$\hat{B} = \frac{U_{rms} \times \sqrt{2}}{\omega \times A_e \times N}$$

Where B is the peak flux density, Urms is the applied voltage, Ae is the cross sectional area, N is the number of turns and

$$\omega = 2 \times \pi \times f$$

The second limiting factor is the temperature rise caused by the core loss.
To get the core loss per volume [mW/cm³] we have to use this complex formula:

$$P = \frac{f}{\underbrace{\frac{a}{B^3} + \frac{b}{B^{2.3}} + \frac{c}{B^{1.65}}}_{hysteresis\ loss}} + \underbrace{d \times f^2 \times B^2}_{eddy\text{-}current\ loss}$$

Where a, b, c, d are material characteristics, f the applied frequency and B the magnetic flux. The first term is representing the hysteresis loss, while the second is the amount of the eddy-current loss. Both are shown in the status bar for information purposes.

The absolute core loss Ploss [W] is:

$$P_{loss} = P \times V$$

Finally we can determine the temperature rise [℃] by:

$$t = \left(\frac{P_{loss}}{A_{surface}} \right)^{0.833}$$

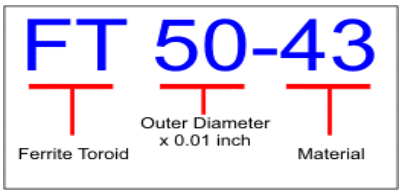
This is an approximation for cores in free standing air and for 100% duty cycle. Intermittent operation will reduce the temperature rise. In all cases the final temperature of the core should not exceed about 50 ℃ – warm to touch but not very hot . Copper losses in the winding are not calculated and, if significant, will increase the temperature rise.

The bottom line

Another problem: You have wound 17 turns onto a T68-3 long time ago and not marked the inductance nowhere. The bottom part will help you. X_L will be calculated using the same working frequency as above.

Ferrite Cores (AMIDON)

Core Number



Unfortunately these cores have no color code. After purchasing you should mark them using your own code.

Calculations

This page has the same structure as that for Iron Powder Cores (AMIDON). The frequency ranges are provided separately for resonant, transformer and choke applications.

Magnetic Calculations

The following calculations should be considered as a guide only and some are only available for iron powder cores. The Bmax figures apply to both iron powder and ferrite cores over the 0.1 – 30 MHz range. Some manufactures provide ferrite core loss data and that is included in the calculations where it is available. Published data by manufactures is often not available.

The core loss calculation [mW/cm³] is based on the STEINMETZ relationship:

$$P = a \times f^{c} \times B^{d}$$

where a, c and d are the material coefficients available for F, H, J, K and W.
It is accurate only over limited ranges of frequency and flux density.

The absolute core loss Ploss [W] is:

$$P_{loss} = P \times V$$

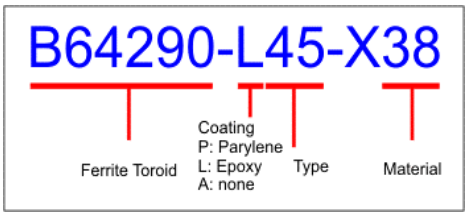
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Ring Cores from EPCOS

Ordering Code



The example shows type R16 (OD = 16 mm) with material T38.

Selection

The selection is done by core size (physical dimensions) and by material. Since the data are available, the ordering code is displayed.

Calculations

The same as in Iron Powder Cores (AMIDON)
Magnetic calculations are not available.

Ring Cores from Ferroxcube (Philips)

Type number



T	core type	T = Toroid
N	coating	N = Polyamide (Nylon) X = Epoxy C = Parylene C L = Lacquer (Polyurethane)
10/6/4	core size	outer / inner / height: 10,6 x 5,2 x 4,4 mm³
4A11	material	color code = pink

Calculations

The same as in Iron Powder Cores (AMIDON)
Magnetic calculations are not available.

Notes

The 3C85 (red) material, often found in part lists for LF applications in amateur radio projects, is obsolete and substituted by the lower loss material 3C90 (dark blue). Following sizes of 3C85 are still in the programs database: TN14/9/5, TN19/11/15, TN25/15/10, TX42/26/13 and TL58/41/18. For others use Unknown Cores.

Ring Cores from WE (WÜRTH ELEKTRONIK)

From the large number of available cores [1] were only a small number of out-selected cores of which are data for a calculation available, be taken. In these cores is ferrite toroidal cores and to ferrite sleeves.

Type number

For identification of the cores the article number is used.

Calculations

The same as in Iron Powder Cores (AMIDON)
Magnetic calculations are not available.

Note: the core material 4W620 roughly equivalent to the material of 43 AMIDON

Information and sources:

The cores are available directly from [1]. Some of the cores can be rela-hen also at [2] and [3]. Note: The name used in [2] is shown in square brackets.

[1] Würth Elektronik GmbH & Co.KG, www.we-online.de
[2] DARC Verlag GmbH, Lindenallee 6, D-34225 Baunatal, www.darcverlag.de
[3] DG0SA, www.dg0sa.de/ —► Balun

Unknown Cores or the Program doesn't know them

A lot of ring cores, used by radio amateurs, are available in this program. Should we miss a type, there are several options:

a) We are waiting for an update.

This will take a lot of time!

b) We can pick up the data from a catalogue.

Type in the AL-value from the datasheet into the edit field! Note the unit carefully. In literature you will find different units for AL such as:

µH / (100 N)²	=	0,1 nH / N²
µH / (1000 N)²	=	0,001 nH / N²
mH / (1000 N)²	=	nH / N²

The unit nH means the same as nH / N².
The list field allows the selection of the proper unit. For calculations it's important, that the number of turns is squared. Note the brackets in conversion table above.

c) We have no data, but an inductance meter and a caliper.

In Tools-menu we click on "AL and Permeability" and fill in the measured values. On page "Unknown Cores" click on button "Copy AL from Tool" to copy these calculated values. In the same way you can copy the physical dimensions for calculations of length and maximal diameter of wire.

Air Cores

Although air cores are no ring cores, those shouldn't be missed in this program. Many radio amateurs occupying with construction of linear amplifiers, low pass filters and match boxes, which could hardly be done without air cores.
The exact formula for the inductance of an air core involves elliptic integrals, which cannot be solved. For practical purposes an approximation is always used.

The inductance of an infinite long solenoid is given by:

$$L = N^2 \times \mu_0 \times \mu_r \times \frac{A}{l}$$

$$\mu_0 = 4 \times \pi \times 10^{-7} \text{ H/m}$$

$$\mu_r = 1 \qquad \text{for air}$$

with a circle cross section

$$L = N^2 \times \mu_0 \times \underbrace{\frac{\pi \times D^2}{4}}_{area} \times \frac{1}{l}$$

For real solenoids a correction factor K has to be introduced, which depends only on the shape of the core (diameter and length):

$$L = N^2 \times \mu_0 \times \frac{\pi}{4} \times D \times \frac{D}{l} \times K$$

A good approximation for long solenoids, which can easy used on pocket calculators, provides following well-known formula:

$$L = N^2 \times \frac{D^2}{101{,}6 \times l + 45{,}72 \times D} \underbrace{\frac{\mu H}{cm}}_{units}$$

An accuracy of better 1% is stated. This is a good value for amateur purposes.

In this program the correction factor is calculated by an approximation, which yields results, just as well for short coils.

A special case is the Inductance of a Straight Wire, which can be calculated as well:

The formula is with skin effect:

$$L = 2 \times l \times \left(\ln\left(\frac{4 \times l}{D} \right) - 1 \right) \underbrace{\frac{nH}{cm}}_{units}$$

Without skin effect:

$$L = 2 \times l \times \left(\ln\left(\frac{4 \times l}{D} \right) - 1 + \frac{\mu_r}{4} \right) \underbrace{\frac{nH}{cm}}_{units}$$

For sufficiently high frequencies (skin effects) the inductance is 50 nH per meter lower because the internal inductance goes to zero.
The above formulae are based on the assumption that the diameter is much less than the length, otherwise the result becomes negative or zero.

From version 1.2.1 this more complex equation is used, which gives better accuracy with short and thick wires.

$$L = \frac{\mu_0 \times l}{2 \times \pi} \times \left[\ln\left(\frac{2 \times l}{D} + \sqrt{1 + \left(\frac{2 \times l}{D} \right)^2} \right) - \sqrt{1 + \left(\frac{D}{2 \times l} \right)^2} + \frac{D}{2 \times l} + \frac{\mu_r}{4} \right]$$

Tools

The menu "Tools" contains a few helping tools for additional calculations, which can be executed in an own window simultaneously.

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Determining AL and Permeability µi

a) Calculating AL-Value

Required is the measurement of inductances. We wind a few (at least 10, otherwise we will lose accuracy) probe turns on a ring core and measure the inductance.
The AL-value is given by:

$$A_L = \frac{L}{N^2}$$

The result is provided in the most common unit nH/N². This value can be copied to Unknown Cores for additional calculations.

b) Calculating Permeability µi

The AL-value from a) and the physical dimensions of the core deliver the initial permeability (only valid for very low field strength).
The magnetic characteristics effective length l_e and effective area A_e are computed by the physical dimensions.
Unfortunately, the permeability is not a constant, but depends upon the temperature, the frequency and the magnetic flux. As material parameter it can be used to determine an unknown core material.

$$\mu_i = \frac{A_L \times l_e}{\mu_0 \times A_e}$$

The quantities le and Ae are encapsulated in core factor.

$$\Sigma(l/A) = \frac{l_e}{A_e}$$

$$\mu_i = \frac{A_L}{\mu_0} \times \Sigma(l/A)$$

$$\mu_0 = 4 \times \pi \times 10^{-7}\ \mathrm{H/m}$$

Because flux has a tendency to concentrate on the inside corners we'll use a formula which reflects this. The effective length is calculated as:

$$l_e = \pi \times D_o \times \frac{\ln\left(\frac{D_o}{D_i}\right)}{\frac{D_o}{D_i} - 1}$$

The effective area is calculated as:

$$A_e = h \times \frac{D_o}{2} \times \frac{\ln^2\left(\frac{D_o}{D_i}\right)}{\frac{D_a}{D_i} - 1}$$

The dimensions of the core are in mm and can be copied to Unknown Cores for additional calculations, if necessary. If the thickness of coating can be estimated, it should be used; otherwise we get an additional failure of the magnetic characteristics and μ_i, particularly for small ring cores.

AL determine from Permeability

If the permeability is known, then the AL-value can be determined therefrom. The input and the calculation done as described above.

Resonant Circuits

This is an easy-to-use tool for calculating the components of a resonant circuit. Troublesome conversion of units isn't to do anymore. Let the computer do it!

Following formulae do the calculations:

$$f = \frac{1}{2 \times \pi \times \sqrt{L \times C}}$$

$$C = \frac{1}{4 \times \pi^2 \times f^2 \times L}$$

$$L = \frac{1}{4 \times \pi^2 \times f^2 \times C}$$

Cu Calculating Cu Resistance

In constructing air core coils in mH range it is useful to know the resistance of the copper winding wire.

$$R = \rho \times \frac{l}{A} = \rho \times \frac{4 \times l}{\pi \times D^2}$$

resistivity of copper @ 20 ℃:

$$\rho = 0.0175 \frac{\Omega\, mm^2}{m} \text{ or } 1.75 \times 10^{-8}\ \Omega\, m$$

The dependence of copper resistance on temperature can be calculated. The preset temperature of 20 ℃ can be changed.

$$R = R_{20} \times \left(1 + \alpha \times \left(t - 20\right)\right)$$

Temperature coefficient of copper: α = 0.0038 1/K

The input is limited from –200 ℃ to 250 ℃, becaus e within this range the relation between resistance and temperature can be considered as approximately linear.

m in ft Metric Conversion

This tool was added on suggestion of US amateurs. It might be also helpful for others. In technical articles in US literature still non-metric units are used.

a) Conversion of length units

The conversion factors:

1 inch = 2.54 cm
1 foot = 12 inch = 30.48 cm
1 yard = 3 feet = 91.44 cm

The conversion works in both directions.

b) Conversion from AWG to mm

The AWG system (American Wire Gauge) for characterizing copper wires was introduced in 1857. Each diameter has a number (#): 0000, 000, 00, 0, 1 ... 40. Number 0000 is defined as having a diameter of 0.46 inch and #36 has a diameter of 0.005 inch. The other numbers are more or less geometrically defined between these points. The sizes correspond to the number of steps when manufacturing copper wire. For practical purposes the following relations are of special interest.

A decrease by

- 3 AWG-numbers, for example from #13 to #10, doubles the area and halves the resistance,
- 6 AWG-numbers doubles the diameter,
- 10 AWG-numbers increases the area by a factor of 10 and reduces the resistance by a factor of 10.

In the list box all AWG-numbers are selectable. Additional the associated diameter in inch is displayed and the value in mm is calculated.

c) Conversion from °F to °C

This conversion is only a supplement when considering temperature depending values.

$$t_{\circ C} = (t_{\circ F} - 32) \times \frac{5}{9}$$

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This software is freeware.

The distribution is permitted **only completely** (minirk13.exe, minirk13_d.pdf, minirk13_e.pdf minirk13_f.pdf) **and free of charge**.

Disclaimer

This program you get without any guarantee of function, error-free, or fitness for any particular purpose. The user will apply this software at his own risk. In no case the author will be responsible for any damage.

Known Problems

The program doesn't check, if the values you enter making sense in the real world. In case you get, for example, a maximal diameter of 0.0 mm or a number of turns of 10000, which isn't displayed completely by the way, then the limits are obviously exceeded. In worse case an error message like "Overflow…" appears. However, you can continue after pressing OK. The most common mistakes and incorrect entries are however intercepted by the program.

The last word

Do you miss any calculation, did you find a bug or do you think this program could be more comfortable, then feel free and send information to the author.

mailto:dg0kw@darc.de

We will see what we can do.

Stralsund, in June 2015 Klaus Warsow, DG0KW

History

Version 1.0 (2000-06):

- Developed as rapid assistant for own home brew projects under Windows 3.1. First published in issue 11/2000 of the German Amateur Radio Magazine "FUNKAMATEUR“.

Version 1.0a (2000-11):

- Entering a point won't cause an error message any longer.
- The point is converted to a comma and vice versa.

Version 1.1 (2002-06):

- "Iron Powder Cores (AMIDON)": Added T 520 and Material "18".
- "Ferrite (AMIDON)": Added some core sizes and materials F, H, K, W.
- "Ferroxcube (Philips)": Added ring cores completely.
- "Unknown Cores": Now calculations with any AL are possible or copy from before calculated in 'Tool'.
- "Air Cores": Calculation of short coils is done with the same accuracy as for long ones (new approximation).
- Added "Inductance of a Straight Wire".
- Added Tools for determining AL and initial permeability, calculation of resonant circuits and calculation of copper resistance in dependence of temperature.
- Updated the program on Windows 9x.
- Help files reworked.
- Program and Help additional in English.
- Many little changes.

Version 1.1.1 (2003-03):

- "Ferrite (AMIDON)": Corrected AL-value of FT50B-43 and FT82-43.

Version 1.1.2 (2003-05):

- Added calculation in inch, foot and AWG in order to make the life easier for US users.
- Some little cosmetics.

Version 1.1.3 (2005-05):

- Added calculation for magnetic flux B and Bmax (0.1 – 30 MHz).
- Added calculation for temperature rise (iron powder and some ferrite cores).
- The calculated number of turns is an integer value.
- The max diameter is now calculated correctly. (Thanks to Peter, ZL2AYX)
- Some little cosmetics.

Version 1.2 (2005-06):

- Program and Help additional in French. (Thanks to François, F5ANN)

Version 1.2.1 (2006-03):

- "Inductance of straight wire": Using a more complex formula with better accuracy for short wires.

(2014-01) Wilfried Burmeister, DL5SWB †

- Adoption of the program to continue through DG0KW

Version 1.3.0 (2015-06):

- Implementation of the program in a different programming environment
- In four languages, in addition Italian
- Expansion to additional toroids
- Another tool has been added
- Creation of a simple print function
- Help files now in PDF format
- The accuracy of the calculations could be slightly increased

Version 1.3.1 (2015-12):

- Help-File additional in Italian. (Thanks to Franco, I2FHW)
- Program and Help additional in Czech. (Thanks to Jara, CB ?)