
# QuickApp Toroid Design

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# Abstract


- Ferrite and iron powder toroids are often used to create custom inductors and transformers in radio frequency (RF) applications.
- The finger-friendly eightolives QuickApp Toroid tool helps relate the key parameters in toroid design.

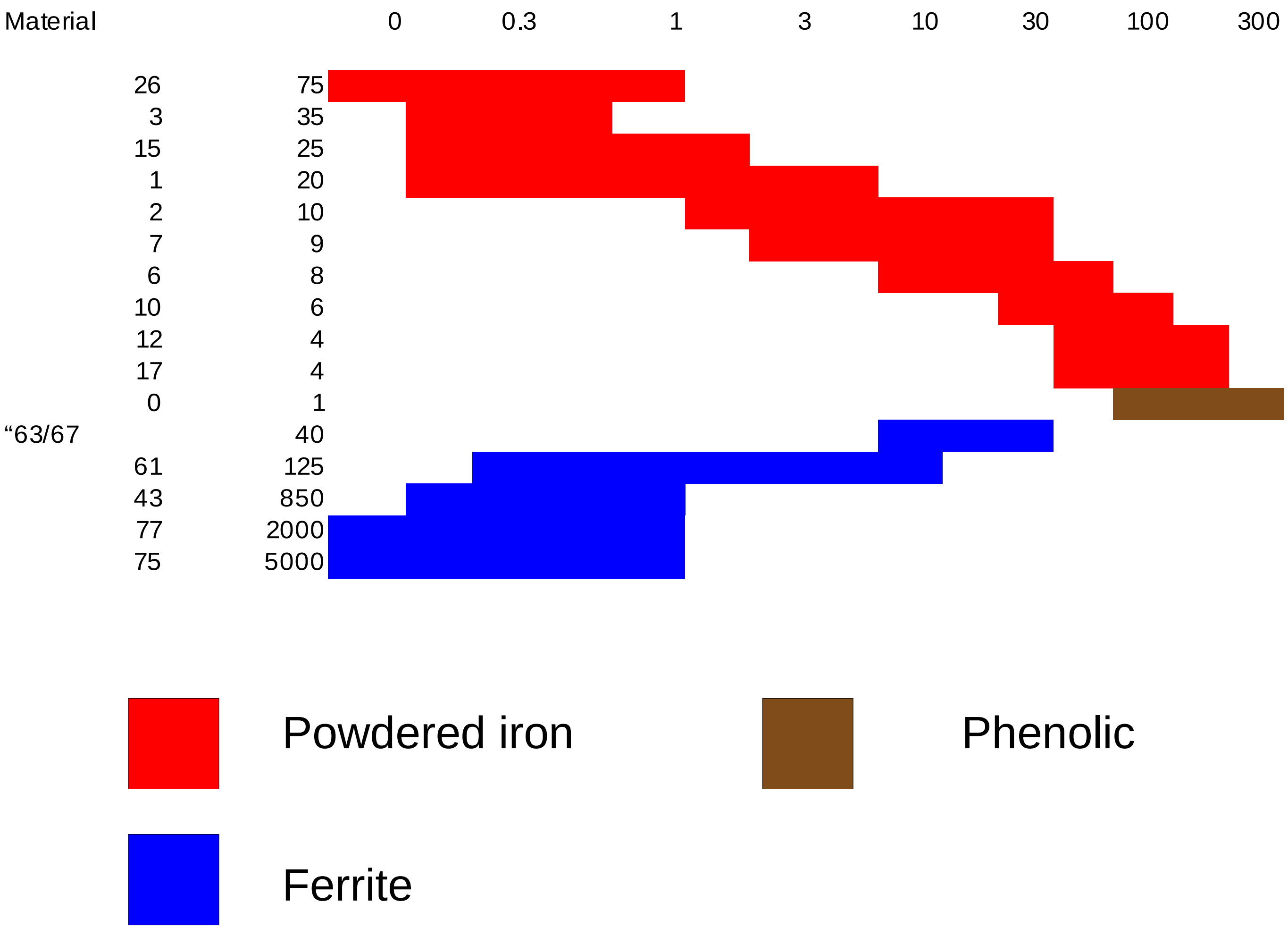
# Toroids

- Toroids are made of various magnetic materials with different properties. Major categories are:
  - Powdered iron cores
  - Ferrites
- The inductance varies as a function of the materials magnetic constant (µ), number of turns of wire, toroid core physical dimensions
- The performance is effective over a frequency range

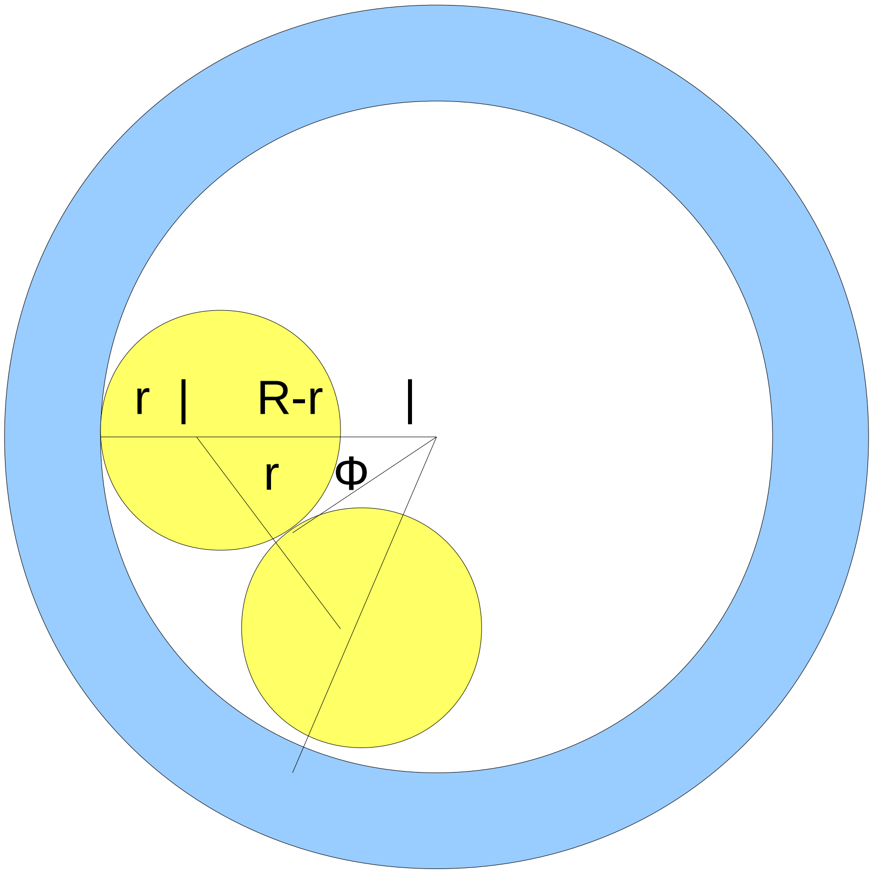
# Limiting Factors

- The maximum number of turns is a function of wire size and toroid inner diameter
- Wire size and turns add resistance which dissipates power and lowers the inductor's Q
- Saturation flux limits relate to overheating
- More than a single layer of windings can cause additional unwanted resonances

# Frequency Ranges For Resonance



# Maximum Single Layer Turns




R = core inner radius

r = wire outer radius

$\Phi = \operatorname{asin}(r / (R-r))$

$N_{max} < \pi / \Phi$

When $r < R$

# Temperature Rise

- Temperature rise is caused by loss in the winding and loss in the core
- Temp Rise = (Pdiss(mW) / SurfaceArea) **.833
  - Still Air estimate
- We recommend design for a 25 degree C rise max
- Wire loss is determined by current and wire size
- Core losses are more difficult to estimate
  - Insufficient data on many materials
  - Losses vary due to several parameters

# Estimating Flux Density

- Maximum flux density
- Faraday's Law
  - V = 4.44 F N Ae Bpeak = Math.sqrt(2) * PI F N Ae Bp
- In the Toroid Tool you specify coil current Irms
  - Ipeak = Math.sqrt(2) Irms
  - E = L di/dt = L * Math.sqrt(2) * Irms * 2 * PI * F
- Equating the two:
  - Bpeak = 2 * Irms * L / ( N * Ae)

# Inductance

- Inductance is calculated using the manufacturer provided factors
- In general
  - L = μ $\mu_0$ h/(2* PI) * ln(b/a) * N**2

    where

    – μ is permeability of the core material

    – $\mu_0$ is 4 * PI * 10**-7

    – H is core height

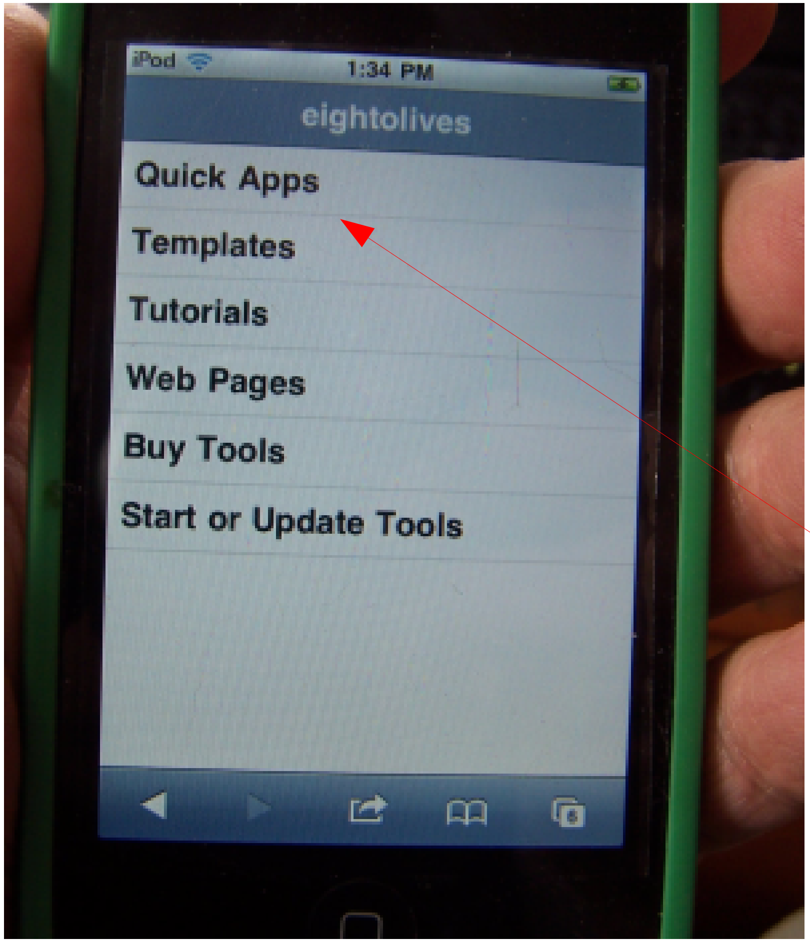
    – B outside radius

    – A inside radius

    – N number of turns of wire

# Start at:

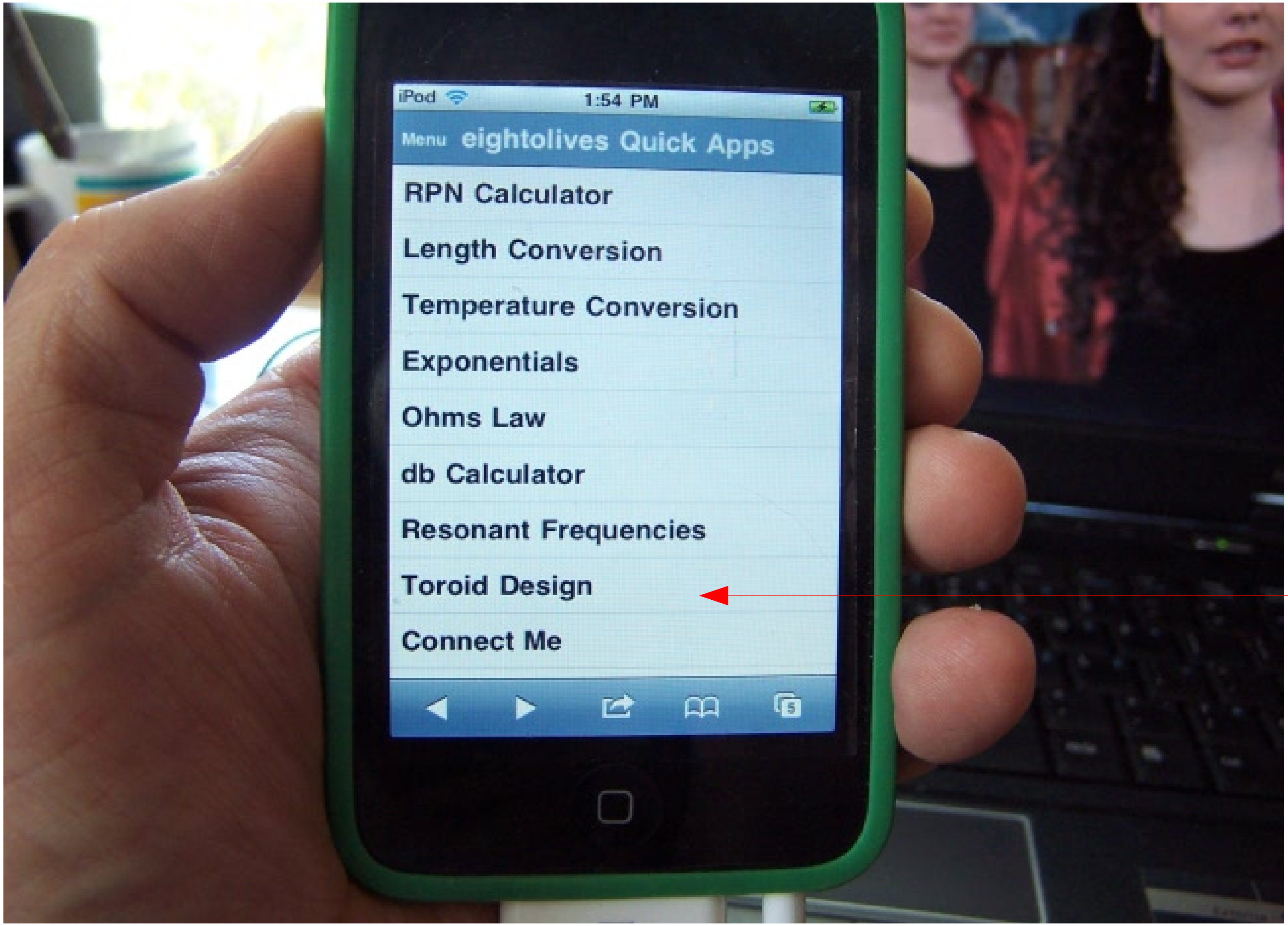
http://www.eightolives.com/docs/Mobile/navigate/navigate.htm




- or start from the eightolives.com Home Page and click “QuickApps”
- The main menu lets you select the QuickApps menu or other eightolives resources

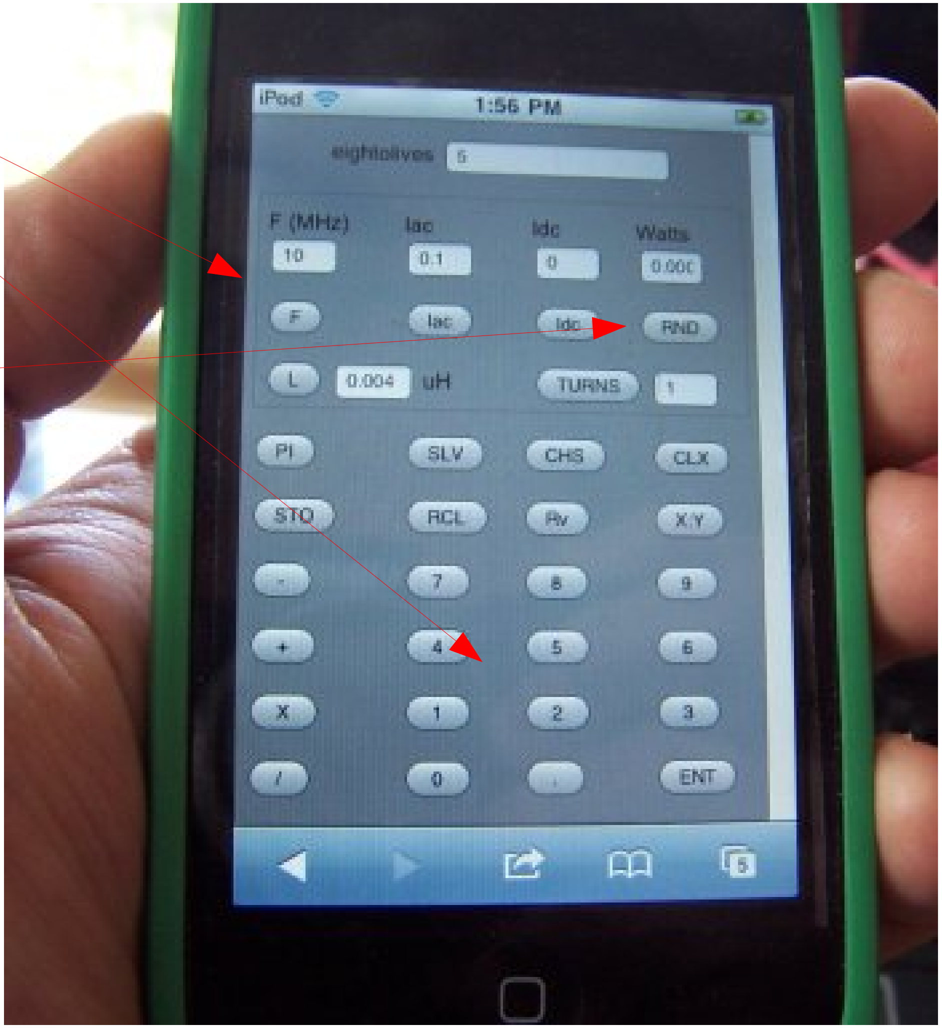
Hint: Bookmark the link to this menu.

# Then Pick the Toroid Tool



Enter numbers then press the F, Iac, Idc, L or TURNS buttons.

RND rounds the TURNS entry.



Scroll down for the Core Size, Material and Wire Size selectors.

The Design Report is in the bottom text area.

# Using the Toroid Tool

- Select material, core and wire size from the drop down selectors
- Enter numbers using the buttons and then press the L or TURNS button
  - The other parameter is calculated
  - Use the RND key to round the number of turns
- Entering values for AC RMS current (IAC) or DC current (IDC) will estimate power dissipation
- A Design Report is presented in the text area at the bottom of the tool display.

# Generated Design Report

Inductor T-37-2 - Specifies the part designation

Inductance = 1.024 uH - Specifies the inductance

Number of Turns = 16 - The number of turns of wire needed

Max single layer turns` = 23 - The max number of single layer turns possible for the core and wire size

Wire size = 24 - The wire size used assumes triple enamel insulation

Wire resistance = 0.03 ohms - An estimate of the wire resistance

Wire length = 17.40 in - An estimate of the length of wire needed.

Wire capacity = 0.57 A cont - The max current rating for the wire.

Iac = 0.01 A rms - Your estimate of inductor rms AC current.

Idc = 0 A - Your estimate of inductor DC current.

Permeability u = 10 - The permeability of the selected core material

Design frequency = 28 MHz - The intended design operating frequency.

Frequency range = 2 - 30 MHz - The manufacturer's recommended range for resonance applications.

Impedance = 180.15ohms - The estimated impedance of the inductor at the design frequency.

Estimated Q* = 4839.32 - The estimated unloaded Q of the inductor.

Estimated flux density* = 1.80 gauss - The estimated ideal flux density for the given conditions.

Est. Core Loss* = 7.71 mW/cm**3 - The estimate core loss parameter.

Wire Loss* = 0.00 Watts - The estimated power loss due to the wire used.

Core Loss* = 0.00 Watts – The estimated ideal loss in the core.

Calculated Voltage = 2.52 Volts – The estimated equivalent max voltage across the inductor given the current specs.

Power dissipation* = 0.00 Watts - Estimated total power dissipation of the inductor.

Temp rise still air* = 1.80 C - Estimated still air temperature rise after a long operating period.

Maximum flux density* = 29.85 gauss - An estimate of the flux density for the specified conditions.

* indicates a rough approximation

# Reality Check

- Some of the estimates made are based on ideal circumstances and may not reflect reality
- Core saturation limiting effects are not considered in the computations
  - This makes core power losses and temperature rise unrealistic at higher values.
  - It means that additional investigation is required if they are too high
- Max flux estimates are derated for design freqency

# Reality Check

- Things to verify in your design:
  - The required number of turns < max possible turns
  - Iac + Idc < Wire capacity current
  - Design frequency is compatible with mfg recommendation
  - Estimated flux density is less than the estimated Max flux density and always less than ~1000
  - The Calculated Voltage is realistic for your system
  - The still air temperature rise is less than 25 C or you may need heat sinking or moving air

# Reality Check

- Modify Wire Size, Core Size and Material until you get an acceptable design solution
- Variations in manufactured core material and construction may yield inductance variation of +/- 10 to +/- 20%

# Hints

- Bookmark the menu page so can easily access the tools
- Calculations automatically occur on data entry solving for a likely parameter. To specify the parameter to solve, press the parameter button then press the SLV button

# For more information

- http://www.micrometals.com
- https://www.amidoncorp.com/
- http://www.palomar-engineers.com/
- Check the QuickApps Overview for more info on the other apps from the tutorials page at: http://www.eightolives.com/tutorials.htm
- Review bug reports and status from the QuickApps home page at: http://www.eightolives.com/docs/Mobile/index.htm