Helmholtz Coils Driver

Helmholtz coils, named after the German physicist Hermann von Helmholtz, is consisted of two identical electromagnetic coils place in parallel and aligned their centers in the same axis like a mirror image as shown in Figure 1. When electrical current pass through the coils in the same direction, it creates a highly uniform magnetic field in a 3-dimension region of space inside the coils. Helmholtz coils are often used for cancel background (earth's) magnetic field, measurements, probe calibration, and magnetic field for susceptibility testing of electronic equipment.

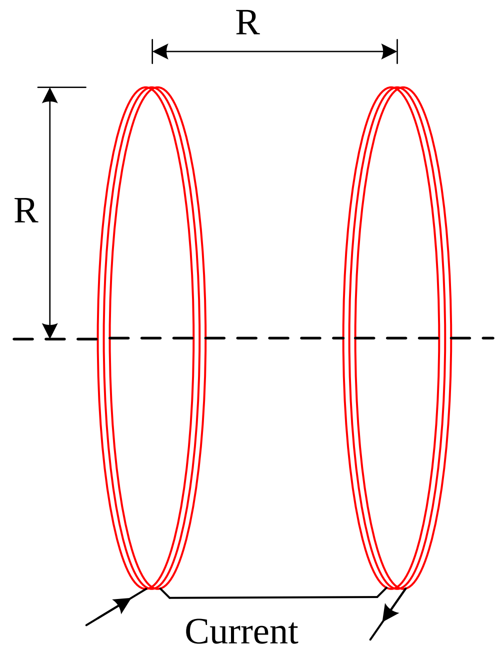

Figure 1. Helmholtz coils is consisted a pair of coils with radius R and separated by a distance equal to R.

Coils Construction

Because the two magnetic coils are designed to be identical, uniform magnetic field is achieved when the coil radius is equal to the separation distance. The two coils are connected in series such that identical current is feeding both coils will create two identical magnetic fields. The two added fields achieved uniform magnetic field in a cylindrical volume of space in the center between the two parallel coils. This cylindrical-shape region of space uniform field is approximately equal to 25% of coil radius (*R*) and a length equal to 50% of the spacing between the two coils. Helmholtz coils are available in 1, 2, or 3 axes. Multiple axis magnetic coils generate magnetic fields in any direction in the three-dimension space inside the Helmholtz coils.

Helmholtz coil magnetic field equation is given below.

$$B = \frac{0.8991 \times 1010^{-6} nI}{R} \qquad \text{Eq. 1}$$

B = field in Tesla
n = number of turns in a coil
I = current in amperes
R = coil radius in meters

Helmholtz Coils Model

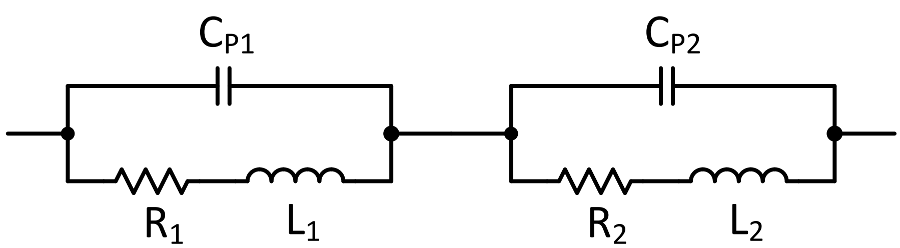

Figure 2. Helmholtz coils are modeled as two LCR circuits connected in series.

A pair of Helmholtz coils can be model as shown in Figure 2. Each coil can be modeled as a parasitic resistor in series with an ideal inductor. The parasitic resistor resistance is generally small. There is also a parasitic capacitor parallel to the inductor and resistor in series. The parasitic capacitance and inductor formed a self-resonant frequency.

Although the coils are designed to be as closely match as possible, but some small variations between them are expected. Each coil has its own series resistance and parasitic capacitance. The parasitic capacitance and the coil inductance formed a self-resonant frequency. As a rule-of-thumb the testing frequency should be well below (less than one-fifth) the self-resonant frequency.

Driving Helmholtz Coils

If the magnetic field experiment is low frequency or the coils are low inductance or both, the Helmholtz coils may be driven directly using a high-current waveform amplifier/driver such as the TS200 and TS250. Because of low frequency or low inductance, the coil's impedance is low enough it can be driven by an amplifier directly as shown in Figure 3.

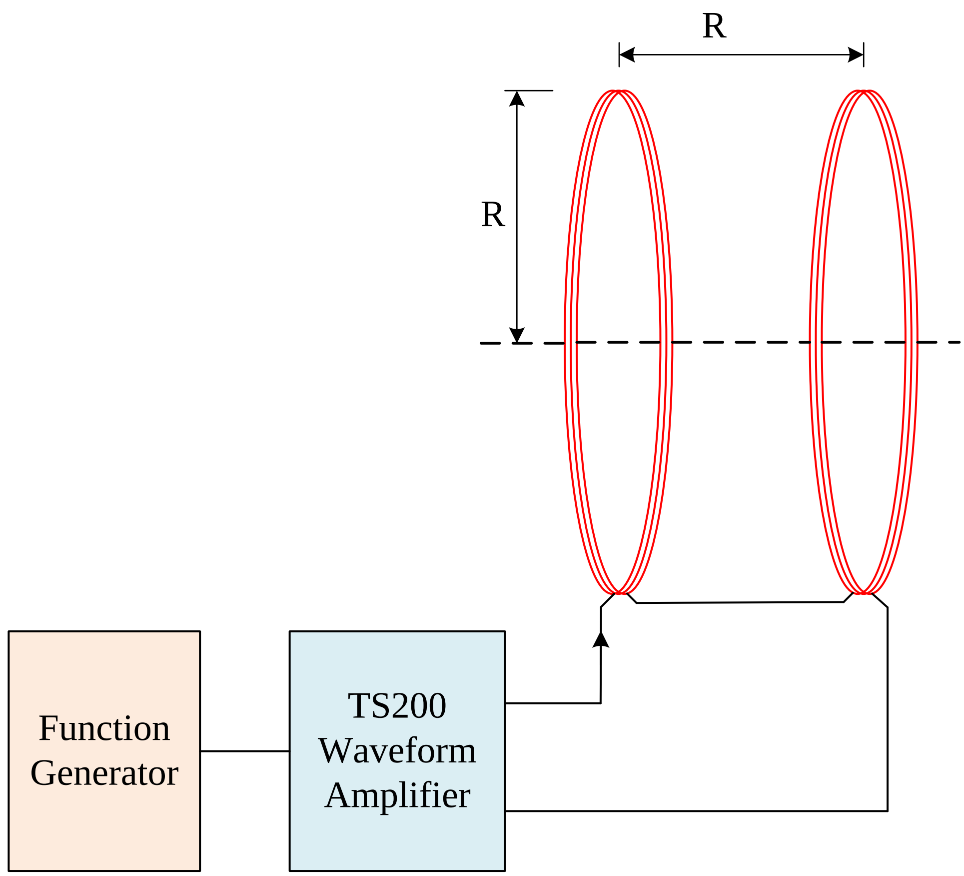

Figure 3. Waveform amplifier directly drives the Helmholtz coils.

Use Equation 1 to calculate the coil current for a desired magnetic field. Then use Equation 2 to calculate the maximum voltage. The maximum voltage is when the current and frequency are both at maximum. The next step is to find a function generator amplifier that can deliver the current and voltage at the maximum frequency. Table 1 shows the amplifier selection.

$$V = I|Z| = I\sqrt{R^2 + (\omega L)^2} \qquad \text{Eq. 2}$$

Z is the coils impedance
R are the coils resistance, $R = R_1 + R_2$
L are the coils inductance, $L = L_1 + L_2$
I is the peak current
ω is the angular frequency, $\omega = 2\pi f$

Select an Amplifier

After calculating the current and voltage from equation 1 and 2 discussed above, use Table 1 to select a high-current amplifier model.

Table 1. Waveform Amplifier Selection Guide

Waveform Amplifier	Voltage Range	Max Peak Current	RMS Current
TS200-0A/B	-10 to +10V	5.0A	5A
TS200-1B	-20V to +20V	3.8A	2.7A
TS200-5B	-40V to +40V	2.0A	1.4A
TS250-0	-10 to +10V	6.0A	5.0A
TS250-1	-20V to +20V	4.4A	3.1A
TS250-2	-30V to +30V	3.0A	2.1A
TS250-3	-40V to +40V	2.5A	1.7A

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