AC Magnetic Field

AC magnetic field is generated when an alternating current is passing through a coil. The AC current is a time-varying current and it is often sine-wave. Thus the magnetic is also time-varying. There are several techniques for generating high-frequency magnetic field as will discuss below. The magnetic field intensity or strength is depended on the alternating current. Therefore high-current is needed to produce high AC magnetic field.

An AC current driver such as the TS200 and the TS250 can output many amperes of current through an AC magnetic coil to produce the field. The TS20/TS250 can drive coils such an AC Helmholtz coil pair directly. This called the direct-drive method discuss below. High current can be driven through the coil as shown in Figure 1.
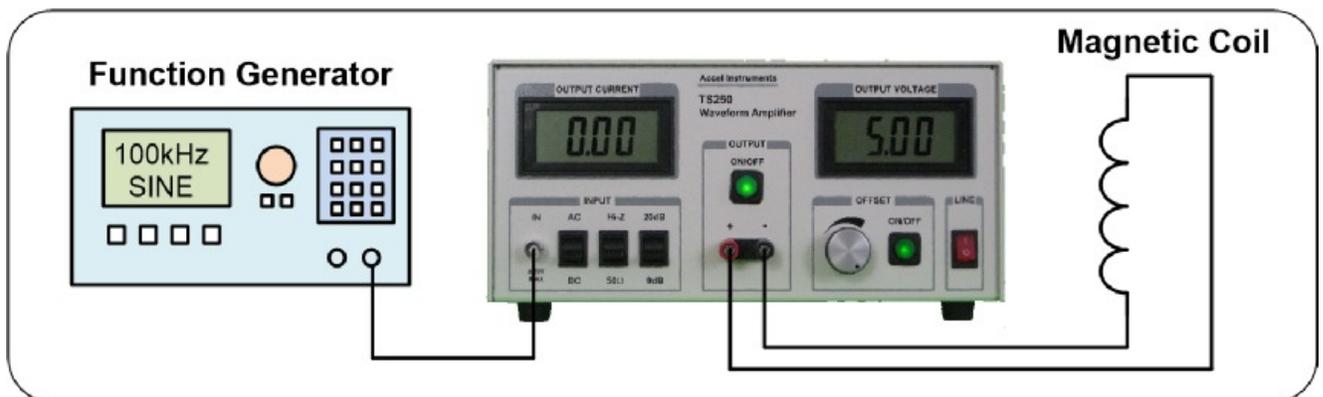
AC Magnetic Field Generation Diagram

Figure 1. The TS250 driver amplifies current and drives a magnetic coil to produce AC magnetic field.

AC Electromagnet Current and Impedance

AC electromagnet (magnetic coil) impedance is given in Equation-1. In Equation-1 the coil resistance is R and the reactance is jωL. For calculating the electromagnetic coil current, the impedance magnitude or the absolute value is used as in Equation-2. If the coil resistance is small compared to its reactance, resistance sometimes can be ignored. The current through the coil, I, is equal to the voltage, V, divided by its impedance, |Z|, as given in Equation-3.

$$Z = R + j\omega L \qquad \text{Equation-1}$$

$$|Z| = \sqrt{R^2 + (\omega L)^2} \qquad \text{Equation-2}$$

$$I = \frac{V}{|Z|} = \frac{V}{\sqrt{R^2 + (\omega L)^2}} \qquad \text{Equation-3}$$

Low Frequency Electromagnetic Field

At low frequency the magnetic coil impedance (Equation-2) is usually low, especially when the resistance is also a low value. High current can be obtained even with low voltage as given in Equation-3. For example, if a given Helmholtz coil resistance is 0.1 ohm and the reactance at 60Hz is 1 ohm, the absolute impedance is about 1 ohm. If 5A current is needed, a 5V driver is required. At low frequency, high current can be driven through the coil as shown in Figure 1.

High Frequency Magnetic Field

At high frequency on the other hand, the AC magnetic coil impedance is increase proportional to the frequency, ω. The magnetic coil impedance is often very large. Generally the reactance dominates the overall impedance. For example, an 1mH high-frequency solenoid coil at 10kHz will have a reactance of 62.8 ohm. If 5A current is needed, a 314V driver is required. Thus at high frequency, the coil current is decreased with increase in frequency (Equation-3). Advance resonant impedance-cancellation technique can be used to reduce the driver voltage.

Selecting an Alternating Magnetic Field Generator

The TS200 and the TS250 are high-current amplifier and drivers for generating AC or alternating magnetic field. They differentiate from other amplifier instruments in the market in that they are very high output current even at high AC frequencies. Table 1 lists the two (TS250/TS200) alternating magnetic coil drivers' output voltage and current range.

Table 1. AC Magnetic Field Driver Selection Guide

Model	Voltage Range	Peak Reactive Current (Note 1)	Peak Resistive Current (Note 2)
TS200-0A/B	-10V to + 10V	0 – 4.0A	0 – 5.0A
TS200-1B	-20V to + 20V	0 – 2.8A	0 – 3.8A
TS200-2B	-20V to + 45V	0 – 1.4A	0 – 2.0A
TS200-3B	-10V to + 70V	0 – 1.4A	0 – 2.0A
TS200-4A/B	0V to + 15V	0 – 3.5A	0 – 4.5A
TS200-5B	-40V to + 40V	0 – 1.4A	0 – 2.0A
TS250-0	-10V to + 10V	0 – 5.0A	0 – 6.0A
TS250-1	-20V to + 20V	0 – 3.1A	0 – 4.4A
TS250-2	-30V to + 30V	0 – 2.1A	0 – 3.0A
TS250-3	-40V to + 40V	0 – 1.7A	0 – 2.5A
TS250-4	-6V to + 15V	0 – 4.0A	0 – 5.0A
TS250-5	-6V to + 30V	0 – 2.1A	0 – 3.0A
TS250-6	-6V to + 45V	0 – 1.7A	0 – 2.5A
TS250-7	-6V to + 65V	0 – 2.1A	0 – 2.5A

Note 1. Magnetic coil is inductive that means its power is reactive. The TS250/TS200 output current is reduced for reactive power.

Note 2. Maximum resistive current is obtained at max voltage minus 1.0V. For example 9.0V for the TS250-0.

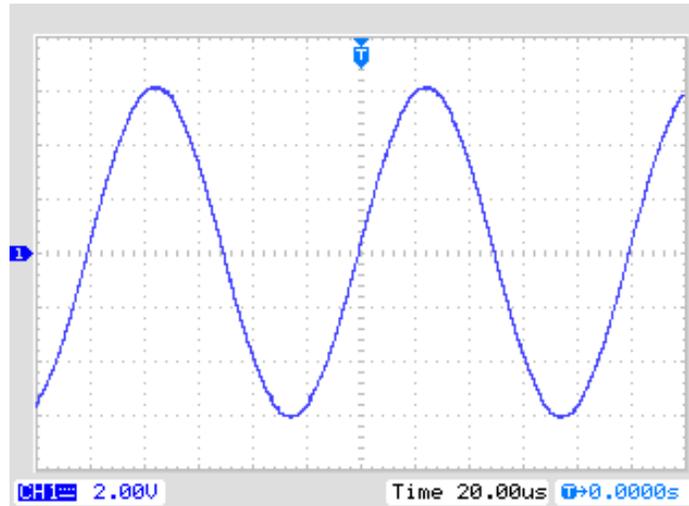## Alternating Magnetic Field Driver Waveform Examples

Figure 2. TS250-0 outputs 12App (+/-6A) current for generating alternating electromagnetic field. The TS250 output voltage is 12Vpp with 1 ohm load or 12App.

High-Current Amplifier Impedance Matching

Understand Reactive vs. Real Power

Magnetic coils are highly inductive. Their impedance is reactive which means the real part of the impedance is nearly zero (very low resistance) as discussed in Equation-1. Helmholtz coils for example, it does not dissipate real (thermal) power if its resistance is very small. It also means all real power (heat) is dissipated inside the AC magnetic coil driver. As a result there will be excess heating inside the high-current amplifier driver. The TS250 and TS200 can handle about 50 watt RMS reactive power.

Resistive Impedance Matching

A simple method to increase electromagnetic driver output current (and stronger AC magnetic field) is to make the coil more resistive. Adding a resistor in series with the coil as shown in Figure 3 will make the load more resistive. Use a resistor with resistance between 0.5Z to Z. Where Z is equal to the high-frequency coil's reactance or jωL. As an example, if the AC coil reactive impedance is 10j ohm at 1kHz, use a 5 ohm to 10 ohm series resistor. The combined impedance is given in Equation-4. At high current the series resistor can dissipate high power. The power dissipation of the series resistor is given in Equation-5. The resistor may be hot at high current. You must choose a power resistor that is rated for the power dissipation. For high frequency applications, select a non-inductive series resistor.

$$Z_{Total} = \sqrt{R^2 + (\omega L)^2}$$ Equation-4

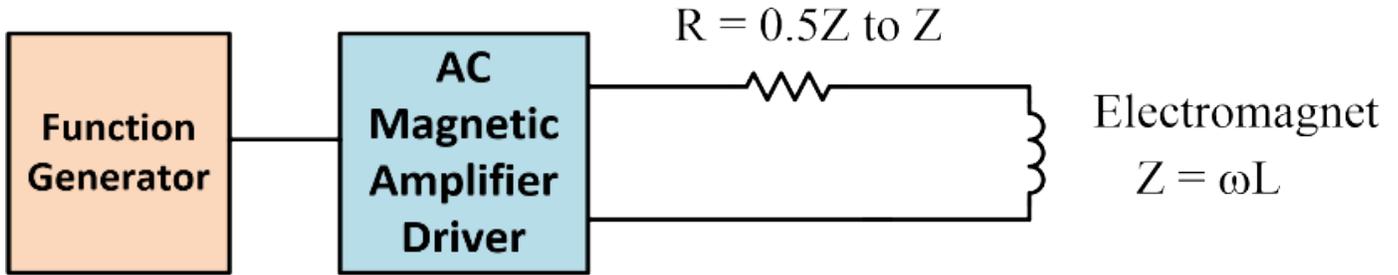$$P_{Dissipate} = (I_{RMS})^2 R$$ Equation-5

Figure 3. Impedance matching will increase the AC electromagnetic field driver output current.

Parallel AC Drivers For Higher Current

The TS250-0 high-current amplifier in Table-1 can output up to 6A peak current for producing AC electromagnetic field. Two or three TS250/TS200 can be paralleled connected to increase the AC magnetic driver output current. As shown in Figure 4, each coil power amplifier driver is connected to a small series isolation resistor. The resistance is typically between 0.25 ohm to 1 ohm. You can use the isolation resistor as impedance matching discussed above. Contact factory for more information on parallel connection and high output current driver.
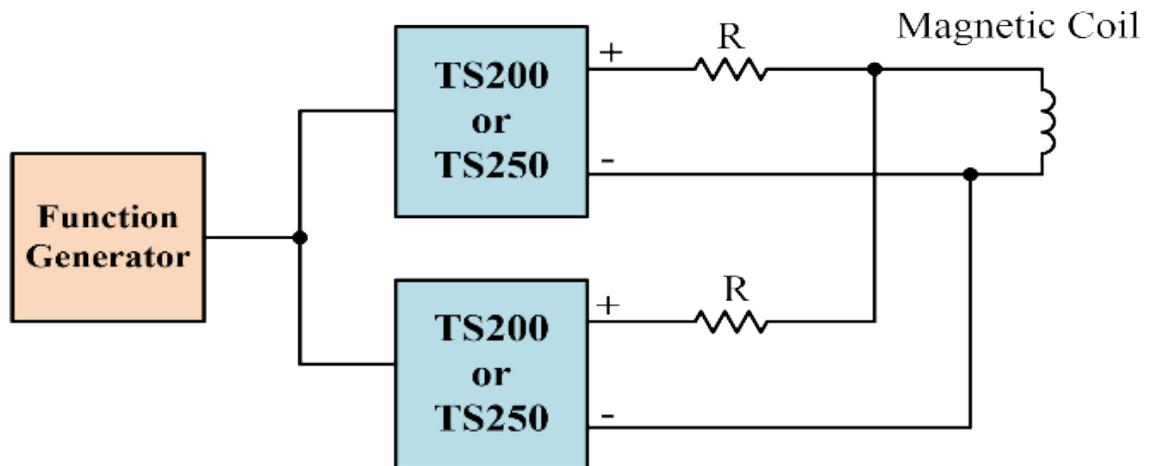

Figure 4. Connect two TS250 in parallel to increase the output current by 2x.