HUBERT
amp up your process

White Paper No. 5
Driving coils

Introduction

Many areas of research and development or of industrial measuring and test engineering require the use of magnetic fields. Generally, coils of most varied designs and types with fix inductivity are implemented for these purposes. An example is what is referred to as Helmholtz coil, which is encountered in various EMC-relevant standards.

The HUBERT amplifier range is the “driving” force for generation of a magnetic field. It provides the required coil current.
Prior to operation of alternating-current systems it is helpful to understand some correlation aspects of current and voltage at this amplifier load. This topic is explained in the chapters below.

Alternating-current behavior

The ideal coil with inductivity L is an inductive reactance XL, i.e. an inductance. It impedance is increased with increasing frequency and the sine wave current lags behind the coil voltage by 90°.

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

However, the real coil is loss-loaded, which can be demonstrated by means of a series connection with an effective resistance RL. The impedance ZL of the real coil is calculated from:

$$|Z_L| = \sqrt{R_L^2 + X_L^2}$$

For the phase angle between current and voltage it follows:

$$\phi = \arctan(X_L / R_L)$$

In Figure 1 the impedance and phase characteristic of the HUBERT field coil RL120 (suitable for tests acc. to MIL-STD-461) is illustrated in the frequency range between 10 Hz – 200 kHz.

Its major electrical data are:
DC resistance: 40 mOhm ; Inductivity: 86 uH; Nominal current: 16 A

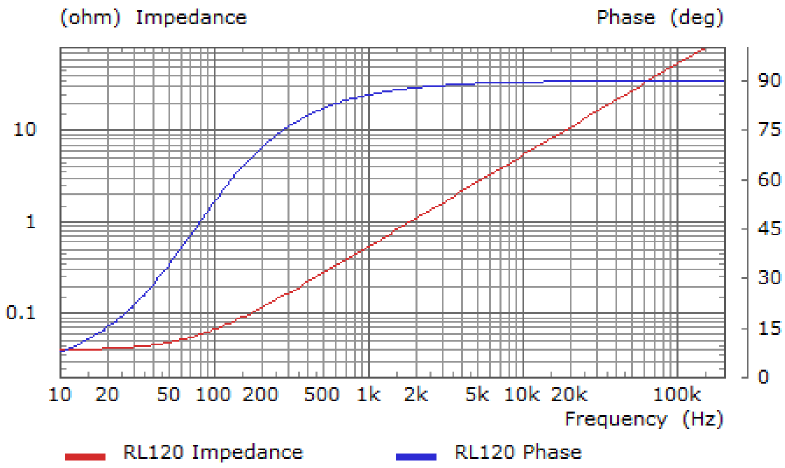

Figure 1: Impedance and Phase Response RL120

Amplifier with coil

Which consequences result for operation of a power amplifier with a reactive load? The interaction is explained below using the example of a HUBERT 4-quasrant amplifier A1110-16-E and the coil RL120.

The objective: maximum current (I_{out} = 27 A_p) through the coil in a frequency range of 10 Hz – 150 kHz. As explained before, the load is not frequency-dependent. Therefore, the level of the input voltage must be readjusted in a voltage amplifier for obtaining a constant output current.

The current amplifier provides another option for actuation (see also White Paper No. 2: Amplification of voltage or current?).

For the current considerations, the losses in the supply cables and plugged connections are neglected for reasons of simplification.

Stage 1

With a frequency of 10 Hz the inductive proportion of the impedance is very low.

$$|Z_L| = \sqrt{R_L^2 + X_L^2} \sim 40\, mOhm$$

For the amplifier this load is quasi a “short circuit” and therefore, the low operating voltage shall be selected in the sense of dissipation power. In this way, maximum output voltage of U_{out_max} = 25 V_p is achieved with I_{out} = 27 A_p. From this follows the maximum impedance of Z_{L_max} = 0.926 Ohm, which is reached at approx. 1.7 kHz (Figure 1).
Time to switch over.

Stage 2

With frequencies from 1.7 kHz the device is switched to medium operating voltage. In this stage U_{out_max} = 50 V_p at I_{out} = 27 A_p and thus Z_{L_max} = 1.85 Ohm. The stage objective is reached at a frequency of approx. 3.4 kHz.

On this occasion: take a look at the performance of the amplifier.

Figure 2 illustrates the time-based characteristics of the voltage and current output variables at a signal frequency of 3.4 kHz and medium operating voltage. The lagging current is a great challenge for the amplifier with regard to its capability of being operated as source and as sink. With an output voltage of U_{out} = 0 V the maximum current flows into the coils and generates high dissipation power in the amplifier (here: operating voltage * output current; see also White Paper No.1 HUBERT Power amplifiers).

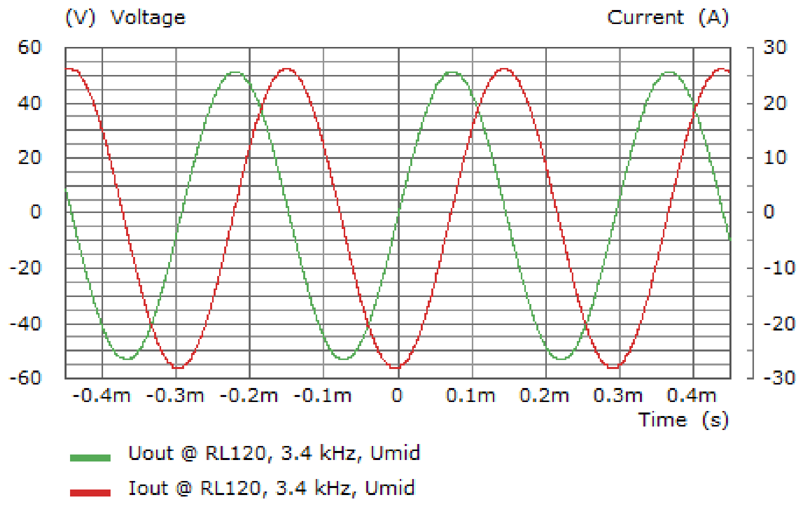

Figure 2: A1110-16-E Output Voltage and Current

Stage 3

For the last section, high operating voltage is selected from 3.4 kHz with U_{out_max} = 75 V_p. Now, the current is not the only limiting factor any more but also the maximum output voltage. At 150 kHz the impedance is

$$|Z_L| = \sqrt{R_L^2 + X_L^2} \sim 81\, Ohm$$

and with U_{out_max} = 75 V_p a maximum output current I_{out}=0.926 A_p is obtained.

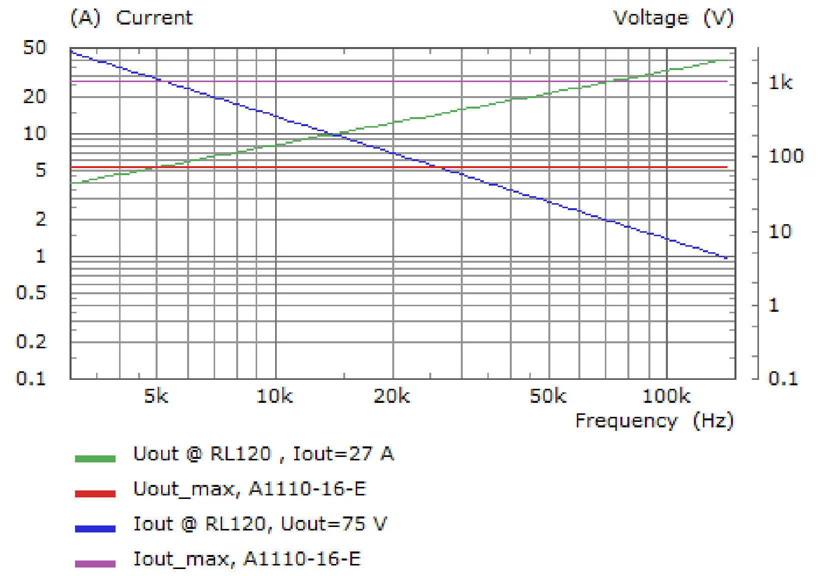

Figure 3: A1110-16-E Output Voltage and Current @ RL120 over Frequency

Figure 3 reveals the relationships with regard to the required and feasible output variables of the power amplifier within a frequency range of 3 kHz -150 kHz. From approx. 4.9 kHz the maximum output voltage is no longer sufficient for the required current and thus the current is decreased with increasing frequency.

Conclusion and outlook

In its capacity as complex load, a coil provides a power amplifier with an entire range of options from “quasi” short-circuit to “quasi” idle in extreme cases. With increasing frequency the output voltage required for constant current is also increased. The phase shift between voltage and current of almost 90° must be taken into account when selecting the required amplifier.

Higher output voltages can be realized through:

- series connection of several amplifiers
- set-up of series resonance circuits

Contact us - we will be happy to provide a solution for your application!

Dr. Hubert GmbH
Universitätsstraße 142
44799 BOCHUM
GERMANY
Tel. +49 234 970569-0
Fax. +49 234 970569-29
sales@drhubert.de
www.drhubert.de