HUBERT
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Whitepaper No. 10

HUBERT Power Amplifiers and Electric System Voltage Ripple

MADE IN GERMANY

Revision 1.0

1 Introduction

The electric seat heater, the infotainment system and various other control units for engine electronics are typical components in modern motor vehicles. The operational safety of these electrical and electronic components is tested according to various standards and factory norms, such as **LV124, VDA 320, LV123** or **VW80300**.

A sinusoidal alternating voltage is also superimposed on the supply voltage of the vehicle electrical system to ensure that the test object is immune to interference from voltage ripple.
Depending on the standard, the frequency ranges are between 10 Hz and 200 kHz with amplitudes up to 32 V_{pp}. The classic DC power supplies are generally not suitable for this high requirement of fast signal processing.

A perfect task for the fast HUBERT 4-quadrant power amplifiers.

The following sections present examples of test setups and tests from the automotive factory standard VDA 320 and VW80300. The focus here is on the presentation of the transient characteristics and performance of the HUBERT 4-quadrant power amplifier, in particular on reactive loads. These include, for example, the "popular" ubiquitous DC-DC converters. The required number and definition of the test cycles as well as the evaluation of the device under test (DUT) are not part of the considerations.

The required voltage source is provided by a 6 kW HUBERT 4-quadrant amplifier system **HUBERT A1500-70-16** or two 4-quadrant amplifiers **HUBERT A1110-40-QE**, the test signals are generated by a standard arbitrary generator.

2 VDA 320 E-05

In this very popular test, the 4-quadrant power amplifier takes over the DC supply of the DUT and superimposes the required AC voltage.

The definition of the test voltage is:

U_{F1}= 6 V_{pp}, F1: 15 Hz – 30 kHz
U_{F2}= 2 V_{pp}, F2: 30 kHz – 200 kHz

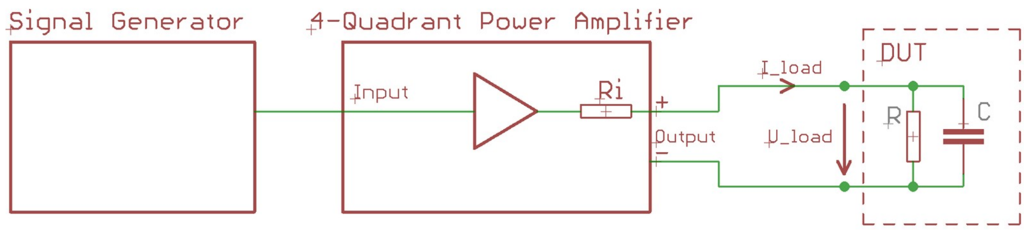

Figure 1: Test-Setup

Figure 1 shows the principle test setup with a reactive DUT, which in this example is realized by a typical equivalent circuit of capacitance and resistance.

The following operating parameters were selected as an example for this test:

Power Amplifier: **HUBERT A1500-70-16**
U_{dc} = 48 V, R_i = 50 mOhm, R = 1 Ohm, C = 7000 uF

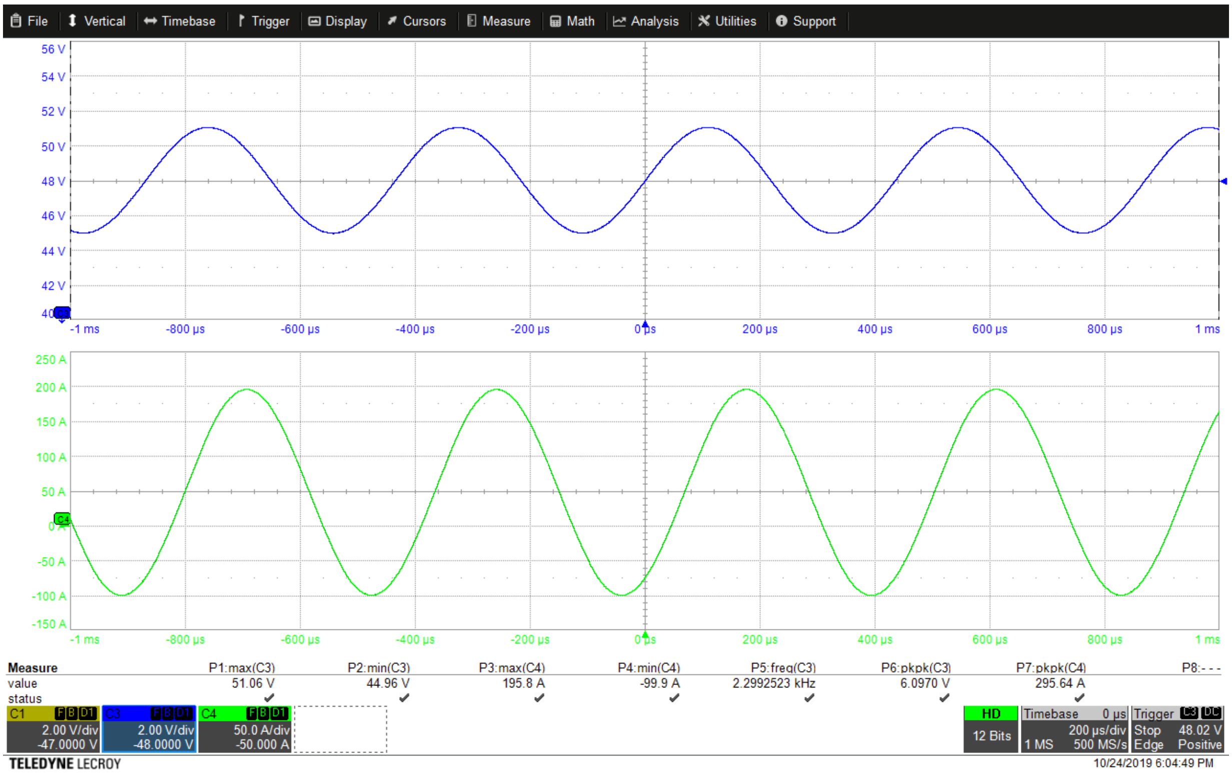

Figure 2: C3:U_mon; C4:I_mon

Figure 2 illustrates the performance requirements of the 4-quadrant amplifier system. On the one hand, high (ripple) source currents are required, here 200 A_p at 2.3 kHz. On the other hand, high currents (-100 A_p) at positive output voltage must be sinked. The performance data in the fourth quadrant are the focus here when dimensioning the amplifier system.

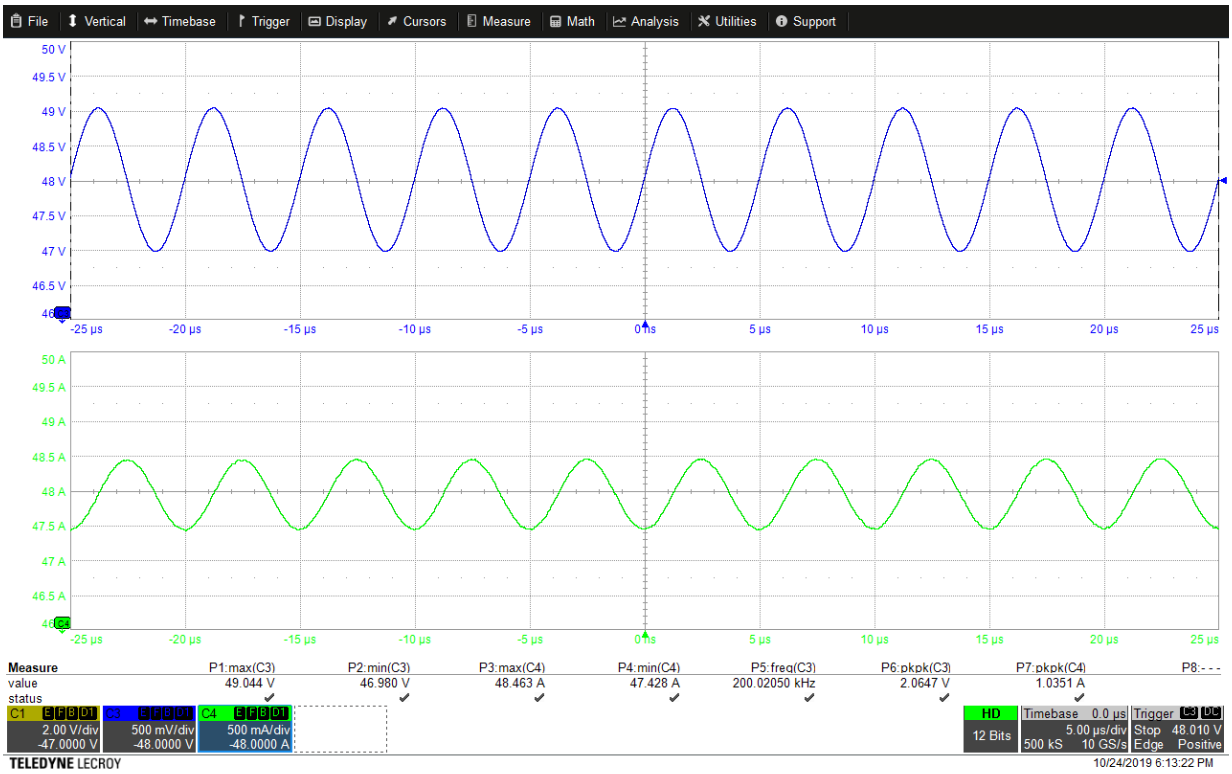

Figure 3: C3:U_mon; C4:I_mon

Figure 3 shows that even 200 kHz ripple voltage is not a hurdle for the amplifier system and provides valid results. Naturally, at this frequency the ripple currents are significantly lower due to e.g. line inductances and the ESR in the capacitance.

3 VW80300 EHV-09

The tests in the high-voltage range pose a particular challenge. Two possible test setups are presented in the next two sections. The required amplitudes of the superimposed alternating voltage are frequency-dependent, Table 1 gives an overview of the 450 V on-board power supply system.

Frequency	V_{HV}
10 Hz to 1 kHz	12 V_{pp}
1 kHz to 5 kHz	12 V_{pp} to 24 V_{pp} (frequency Log scale)
5 kHz to 40 kHz	24 V_{pp}
40 kHz to 50 kHz	24 V_{pp} to 8 V_{pp} (frequency Log scale)
50 kHz to 150 kHz	8 V_{pp}

Table 1

3.1 The Coupling Transformer

The classical method for the coupling of AC voltages is to use a transformer with high bandwidth and DC current carrying capacity which is fed by an AC amplifier. The HUBERT 4-quadrants amplifier is also used here as the driving force.

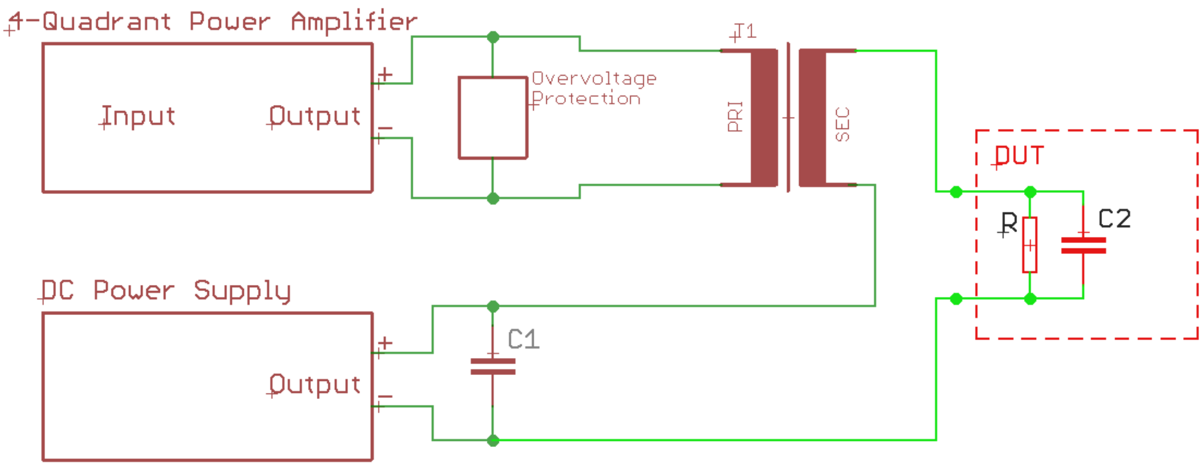

Figure 4: DC Source + AC Source + Coupling Transformer

The following operating parameters have been selected for the example:

Udc=400 V, C1=100 uF/1kV,
R=100 Ohm, C2=7,5 uF/1,2kV

Two different transformers were available:

The 'classic' T1-A: Ls=1 mH, Lp=4 mH, Imax= 50 Adc
The 'new one' T1-B: Ls=20 uH, Lp=80 uH, Imax= 50 Adc

4-quadrant power amplifier: **HUBERT A1110-16-E**

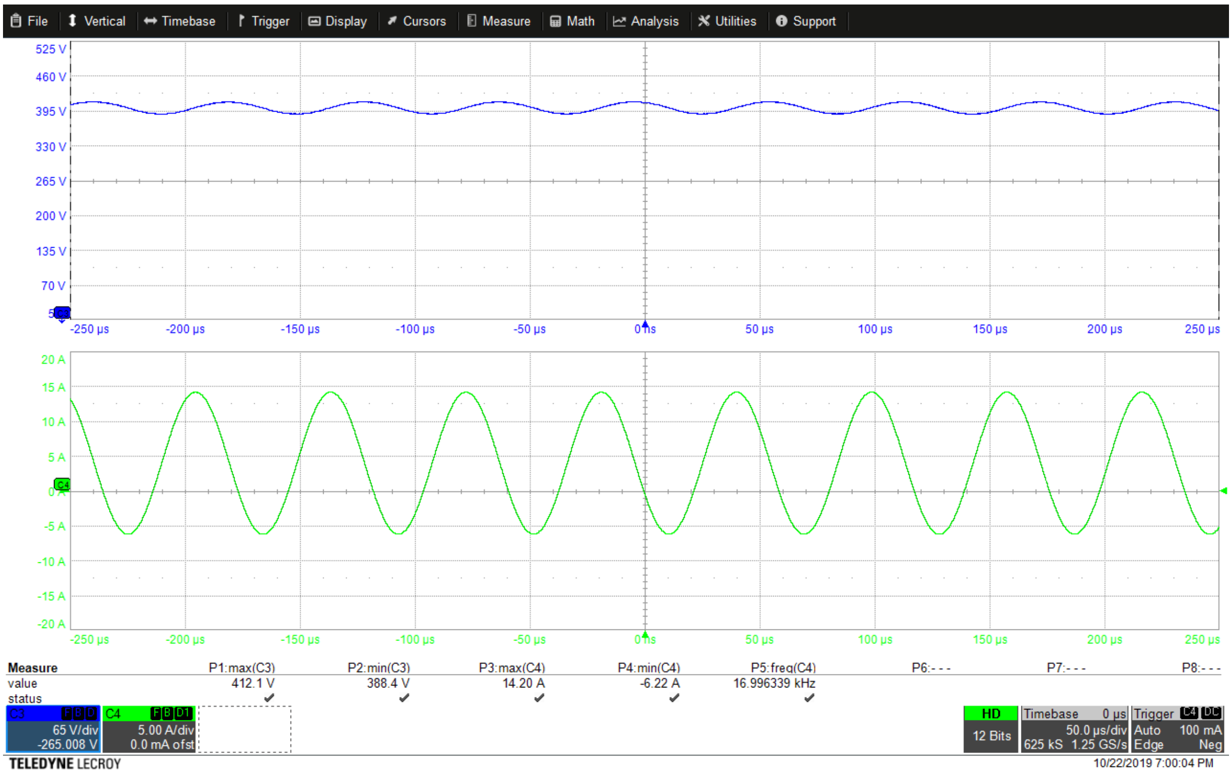

Figure 5: C3:U_load; C4:I_load; T1-A

Figure 5 shows the time courses of voltage and current at the load at 17 kHz. The required ripple voltage of 24 V_{pp} coupled in with transformer T1-A is achieved. As expected, the load current has a capacitive character (leading).

The 4-quadrant power amplifier operates on an inductive load. The performance data in all 4 quadrants must be taken into account when dimensioning (see also WP-1 Hubert 4-quadrant amplifier).

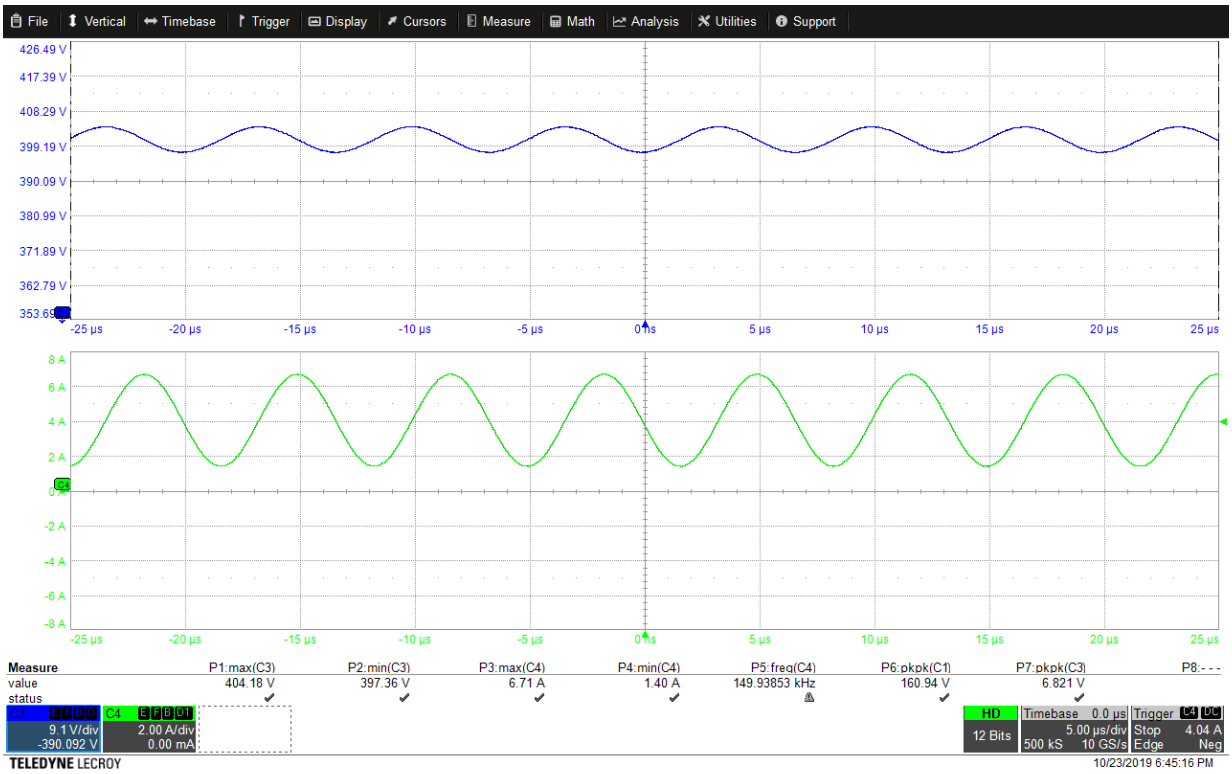

Figure 6: C3:U_load; C4:I_load; T1-A

At 150 kHz, however, the required ripple voltage of 8 V_{pp} is not achieved; the AC amplifier already delivers its maximum output voltage of 160 V_{pp}. This is where the typical transformer characteristics (e.g. frequency-dependent output impedance) come into play and have an unfavorable effect on signal processing. The current is inductive, also due to the entire cabling, and the test setup shows various frequency-dependent resonance points.

The voltage coupling in the upper frequency band with the transformer T1-B is much more successful.

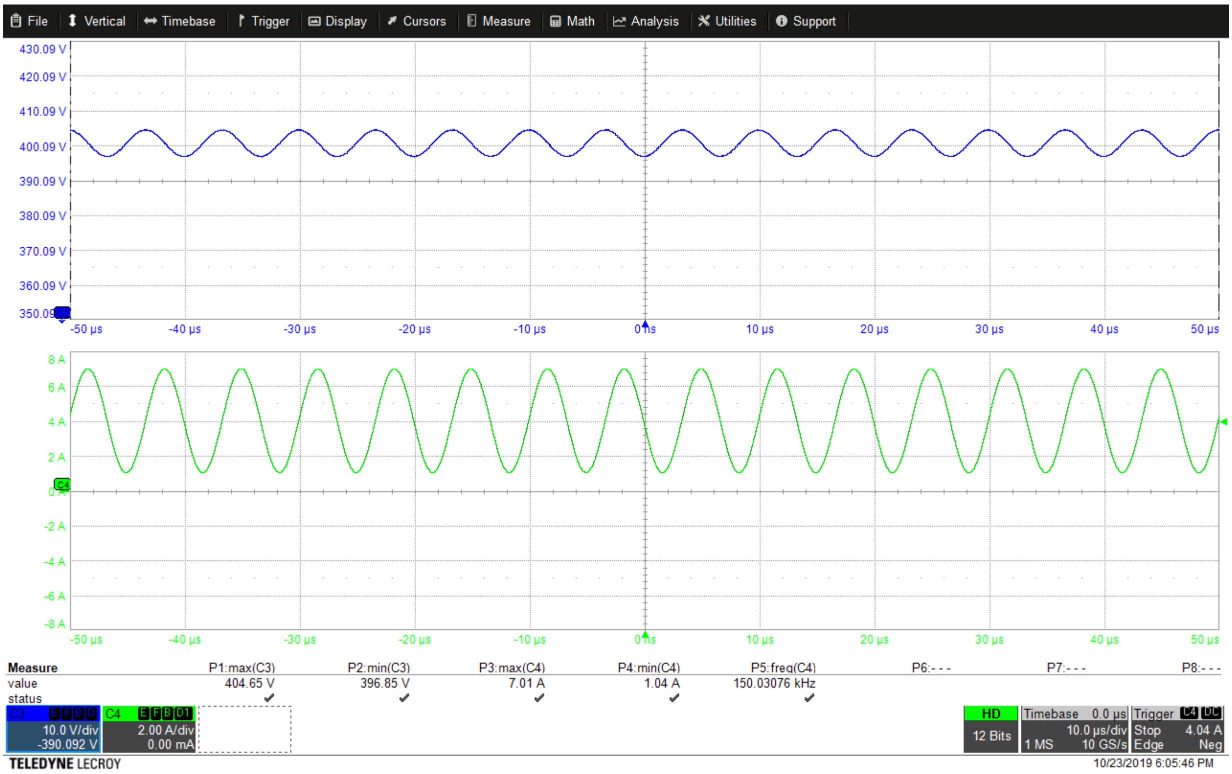

Figure 7: C3:U_load; C4:I_load; T1-B

Figure 7 shows that the required ripple voltage (8 V_{pp}) is achieved at 150 kHz and that the AC amplifier requires only 100 V_{pp} (Figure 8, C1).

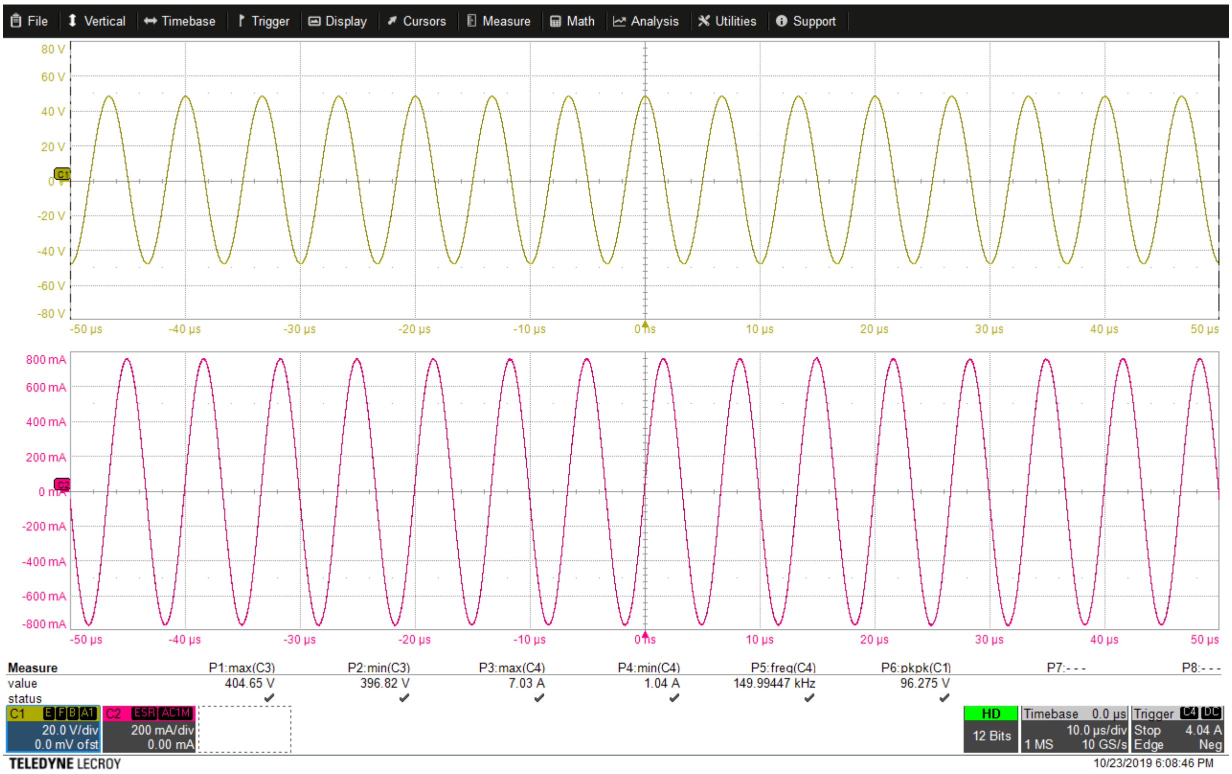

Figure 8: A1110-16-E, C1:U_mon; C4:I_mon; T1-B

Conclusion: The "2-way coupling transformer", with transformer T1-A for the frequency band from 15 Hz to approx. 5 kHz and transformer T1-B from 5 kHz to 150 kHz, is a proven approach for the successful coupling of broadband alternating voltage.

3.2 AC-Source und DC-Source in Series Connection

Another approach for coupling an alternating voltage into a high-voltage vehicle electrical system is the series connection of DC source and AC source.

Figure 9 shows the test setup: The DC source supplies the required DC voltage to a reactive DUT, also in this example, and the HUBERT power amplifier connected in series supplies the required AC voltage (AC source). For simplicity's sake, other networks listed in the supply lines according to the standard have been omitted. Important here is the galvanic isolation of the sources and protection against possible overvoltage at the output of the power amplifier. The capacitor C1 leads the ripple current past the DC power supply.

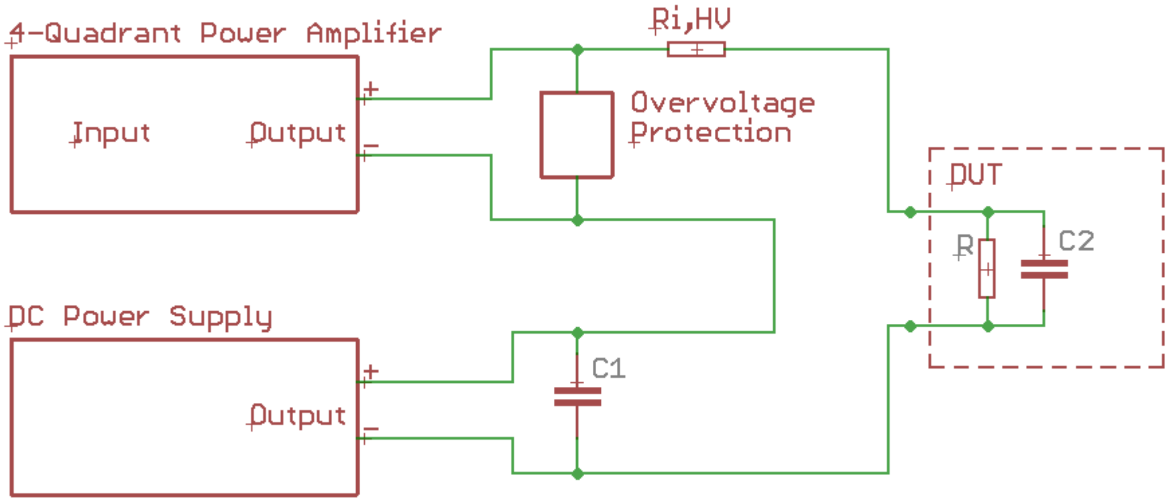

Figure 9: DC Source + AC Source

The following operating parameters have been selected for this example:

U_{dc}=400 V, C1=100 uF/1 kV,

R=100 Ohm, C2=7,5 uF/1,2 kV

4-quadrant power amplifier system: **HUBERT A1500-70-16**

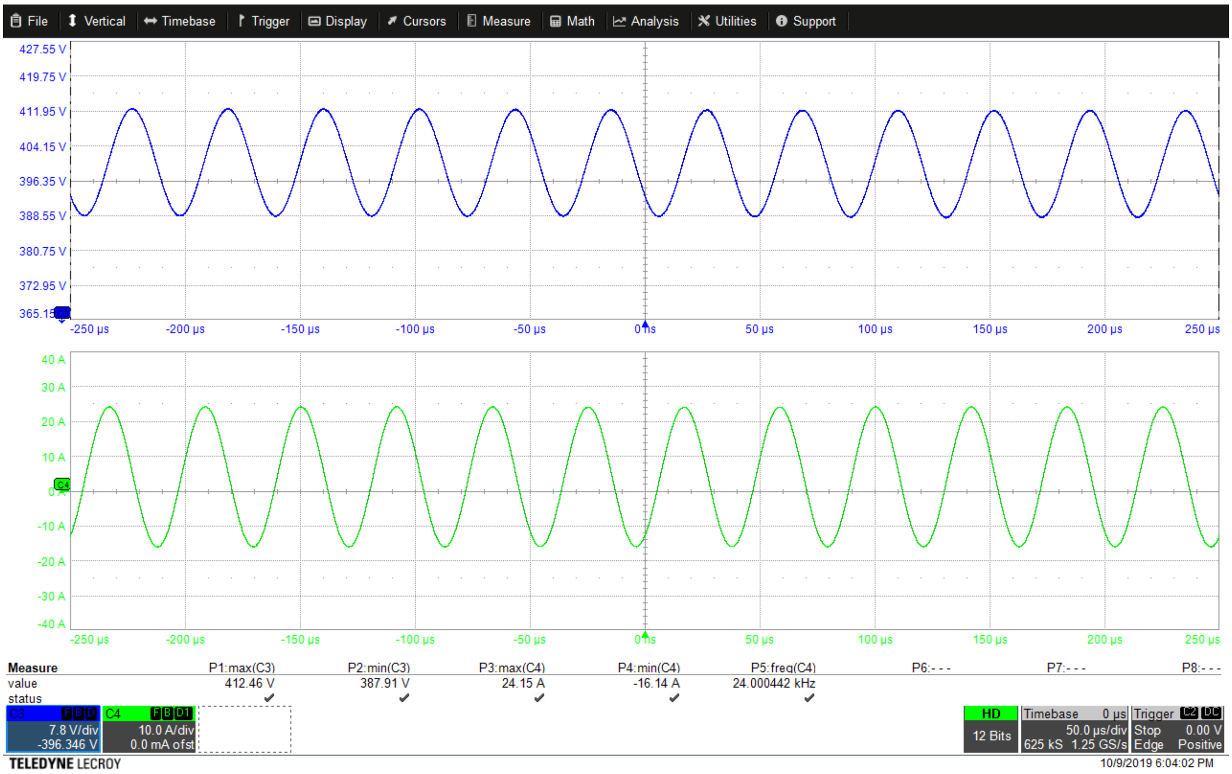

Figure 10: C3:U_load; C4:I_load;

Figure 10 shows the time course of voltage and current at the DUT at 24 kHz. The maximum ripple current was reached at this frequency. The polarity change of the load current is also significant here, which leads to a change of source and sink operation at the AC source. The performance of the power amplifier in the 4th quadrant (positive output voltage and negative output current) is required here.

In principle, the requirements for the 4-quadrant power amplifier are comparable to those in section 3.2. The only difference here is that a DC power supply is connected in series to increase the operating voltage of the DUT and the AC amplifier must therefore also carries the DC current. However, this time with lower output voltages. A closer look at the output current over output voltage diagram is absolutely necessary when dimensioning the amplifier system. The advantage of the series connection of DC and AC sources over the classic test setup with coupling transformer is their independence from the signal shape. Furthermore, the typical characteristics of transformers such as saturation, leakage inductance and frequency-dependent output impedance do not have to be taken into account.

Disadvantage: Galvanic isolation of the AC source and protection against overvoltage are essential.

4 Conclusion

For testing electrical and electronic components in motor vehicles, fast power sources are required to simulate the voltage ripple of the vehicle electrical system. The modulated interference signals place high demands on the performance of the test system.

Which amplifier model or amplifier system should be used (see also White Paper No. 6: More Voltage and Current) depends primarily on the required power, especially in the fourth quadrant, and on the required load current or ripple current.

It would be a pleasure for us to assist you with the design of your test station.

Do you have any questions about this or other applications?
We are happy to support you by telephone or e-mail.

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6 Document History

Revision	Date	Changelog
1.0	November 2019	Initial publication