ELECTRONICS AND MECHANICS – A BALANCE ACT IN ERF-APPLICATIONS

LUCIEN JOHNSTON, MANFRED KRÄMER
HORST ROSENFELDT

Fludicon GmbH, Landwehrstr. 55, 64293 Darmstadt, Germany

A new high voltage amplifier/supply unit specifically for the demands of ERF applications and ER-fluid testing has been designed, developed and tested. This unit is now commercially available. The heart of the amplifier is a 60kHz clocked blocking oscillator (B.O.) type high voltage transformer operating in current-control-mode. Main attributes of this patented transformer are a low leakage inductance coupled with a reduced influence of the internal capacitance on the natural frequency of the transformer. The B.O. type transformer is fed by the rectified mains voltage (230V AC). Controlled switching of the transformer on the primary side and high voltage dependent forced discharge of the charging capacitor secondary-side via high voltage sink allow externally variable HV (0-6kV) modulation up to 1kHz which is independent of the load. For detailed ER-fluid investigation and exact mechatronic control, accurate load current and load voltage monitoring, flashover indication and minimal signal distortion were design feature requirements.

1 Introduction

From an applications point of view, the ER-effect allows the design and development of truly mechatronic systems. Electrical signals result in a direct alteration of mechanical properties. The response time of commercially available ER fluids can only be extrapolated from system signal- and response-times. All data points to ER reaction times of less than 1ms. To make full use of this dynamic reaction, one of the key areas of application development is hence the availability of a supply unit for the necessary electrical field of several kilovolts which allows for accurate modulation in excess of 1kHz.
From an ER-fluid research and development standpoint, detailed knowledge of the actual load current and load voltage in any given test-rig setup will allow for a better understanding of the internal electrical field conditions and dielectric properties of the fluid under scrutiny. An electrical breakdown (flashover) counter with internal shutdown and automatic ramp-up, overload safety and accurate signal amplification are necessary design features of a state-of-the-art, compact high voltage amplifier for ERF technology.

2 HV Amplifier/Supply Unit Design

The newly designed HV amplifier/supply unit is based on a blocking oscillator type high voltage transformer. High voltage modulation is realized by closed loop control. Variance comparison of set point and instantaneous HV value is used, in combination with the primary side current-mode-control, as feedback signal for switching the transformer, the oscillator of which is clocked at 60kHz.
Controlled on-off switching of the transformer primary-side and forced discharge of the charging capacitor via high voltage sink allow for a modulation of the output

voltage which is to a large degree independent of the ERF-load. The transformer is fed by the rectified mains voltage. In comparison with linear power amplifiers using four quadrant output stages, this amplifier design allows for a very compact size and attractive cost-performance ratio. As the load current is a function of the output voltage, power loss is kept to a minimum and a higher load current is available at a reduced output voltage.
One of the main design features of the amplifier is the galvanic separation of primary and secondary sides of the transformer. By ensuring separation of earthing lines on the primary and secondary side, the actual load current flowing through the ER-fluid between the electrodes can now be accurately measured. The use of opto-couplers between primary and secondary sides avoids distortion of the measurements by any equalizing currents.

3 Specifications

The following table gives a summary of the technical data of the amplifier.

Input signal (potentiometer or analogue)	0 – 6 V
Output voltage / current	0 – 6 kV / ≥ 20 mA
Mains supply	230 V AC
Max. output power	120 W
Monitors	Load current (1V/10mA) Load voltage (1V/kV)
Dimensions (width x height x depth)	257mm x 150mm x 256mm
Input impedance	40 kΩ
Response time (10%-90%)	0.4 ms (load 500kΩ//1nF)
Load capacitance	1 nF

Table 1: Specification summary

To allow for maximum flexibility in laboratory use or for field tests, the amplifier can be supplied as a benchtop unit (as shown in fig [1], or optionally inserted within a standard 19” rack. The compact dimensions allow for two RheCon amplifiers to be placed side-by-side within a single 19” rack. The size and also weight are important aspects to be taken into consideration when operating mobile ERF applications. For semi-active suspension systems utilizing four ERF dampers, for example, the units will fit comfortably within the boot or trunk of the test automobile – hence allowing for accurate control and measurement of all relevant parameters (control voltage, output voltage, output current…) under field conditions.

Fig. 1: Photo of RheCon – benchtop unit

4 Sample measurement

The dynamic response of the amplifier has been thoroughly tested. Varios wave forms (sine, triangle, step) at frequencies up to 1000 Hz were carried out and the response documented.

In figure [2], the following settings were used:

- Load condition: 500 kΩ/1nF
- Step function: 0-6 kV
- Frequency: 50 Hz
- Scaling: 5 ms /division (horizontal)
  2 kV/division (vertical)
- Upper curve: output voltage
  Lower curve: control voltage

As can be seen from the curves in figure [2], a very high slew rate has been realized (in this case, 6 kV/0.1 ms). Even allowing for a conservative response time of 0.3 ms, accurate modulation up to 1 kHz for a sine wave can be realized.

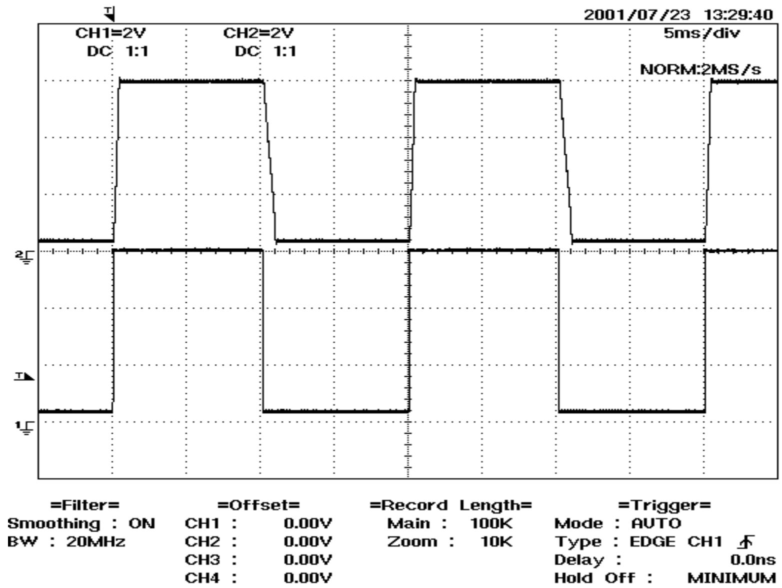

Fig. 2: Dynamic RheCon response

5 Summary

Industrial application of the ERF technology requires the ability to combine the three basic components ER-Fluid – Mechanics – Electronics to a functioning unit. With the development of a compact, dynamic, cost-effective, CE-compliant and accurate ERF-controller, a further step towards this goal has been taken. At the same time, minimal nonlinear distortion, the accurate measurement of the load current and flashover registration will allow the implementation of the same amplifier in a laboratory environment for ER-fluid research activities.

One of the areas of ERF technology which can now be investigated more thoroughly is the volume flow dependence of load currents flowing through activated ER-fluids. This so-called sensor effect, although previously observed, has yet to be quantified to an extent which will allow the integration of this sensor function within the control algorithm of the ERF application. The use of an ER-fluid as power transfer-, control- and sensor-medium will further enhance the advantages of this technology.