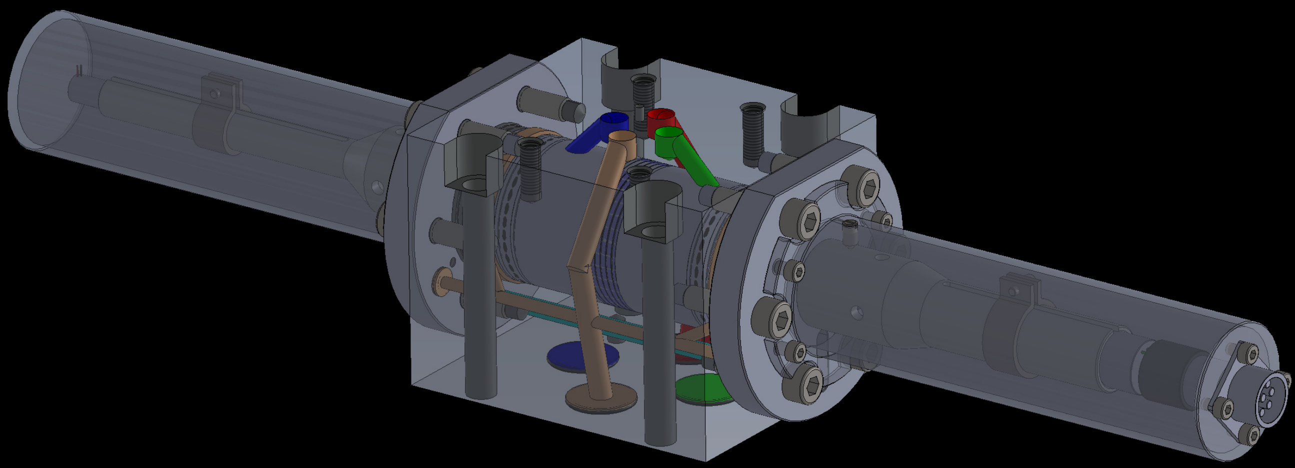

ValveExpert

VX-FRC-2.x

Test Equipment for Servo–
and Proportional Valves

Frequency Response Cylinder
ValveExpert VX-FRC-2.x

Revision: January 2014

Sort Description

shashkov@dietzautomation.com
www.dietzautomation.com

Frequency Response Analysis

One of the main dynamical characteristics of a servovalve is the *Frequency Response*. This is the relationship between no-load control flow and harmonic (sinus-type) input signal. Frequency response expressed by the amplitude ratio and phase angle which are constructed for harmonic signals from a specific frequency range. Definition of the amplitude ratio and phase lag, based on the Fourier method, is given below. Let $x(t)$ be a control flow or spool position signal corresponding to input signal $u(t) = A\sin(\omega t)$. Here $\omega = 2\pi f$ and A - frequency and amplitude of the test signal $u(t)$. We will assume that a servovalve is a stable dynamical system. In this case, after some transition time Δt, the output signal $x(t)$ will be a periodic function with the same frequency ω and can be represented by the following Fourier series

$$x(t) = \sum_{k=0}^{\infty} R_k(\omega)\sin(k\omega t + \phi_k(\omega)).$$

For any k, the amplitude $R_k(\omega)$ and initial phase $\phi_k(\omega)$ expressed by the formulas

$$R_k(\omega) = |K_k(i\omega)|\,, \phi_k(\omega) = \arg\left(K_k(i\omega)\right),$$

$$K_k(i\omega) = \frac{\omega}{2\pi}\int_{\Delta t}^{\Delta t + 2\pi/\omega} x(t)e^{-ik\omega t}dt.$$

Graph of the function $R_1(\omega)/R_1(0)$ represents the normalized *Amplitude Ratio* of the valve.[1] Graphical representation of the function $\phi_1(\omega)$ is the *Phase Lag*. Main parameters of frequency response analysis are *Natural frequency* and -3dB point. Examples of phase lag and amplitude ratio are shown below on Figure 1 and Figure 2. Note that valve frequency response may vary with the input amplitude, temperature, supply pressure, and other operating conditions. Note also, that for linear dynamical systems $K_1(i\omega) \equiv K(i\omega)$ and $K_k(i\omega) \equiv 0$, $k = 2, 3, \ldots, \infty$.

Step Response Analysis

Another very important dynamical characteristic of a servovalve is a response for a step-type control signal. The main parameters of such a test are *Rise Time* and *Overshoot*. These parameters for positive and negative steps are demonstrated on Figure 3.

Frequency Response Cylinder

In order to test frequency response parameters, test stands series ValveExpert can be equipped with frequency response cylinders ValveExpert VX-FRC-2.x (see Figure 4). The frequency response cylinder is laid out to be installed between the servovalve to be tested and the main manifold of the test stand ValveExpert. The position and velocity transducers of the cylinder will be connected to the test-stand with a single connector mounted on the piston. The mounting port pattern of the cylinder corresponds to the norm ISO 10372-06-05-0-92 which is basically used by all test stands series ValveExpert.[2] The output pattern of the cylinder ValveExpert VX-FRC-2.x corresponds to norm ISO 10372-04-04-0-92 and it allows mount directly the Moog 76x series valves or similar.

[1] $R_1(0)$ is a formal notation for $R_1(\omega_0)$, where ω_0 is small enough. Usually ω_0 is 5-10Hz.
[2] This standard is used for Moog 72 series servovalves.

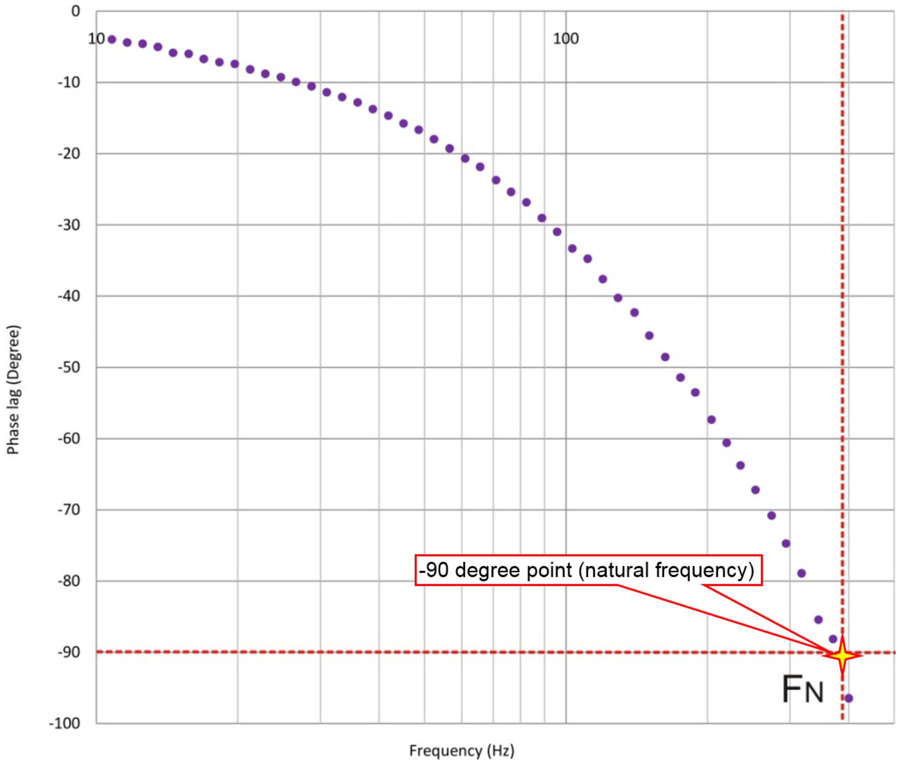

Figure 1: Phase-lag characteristics

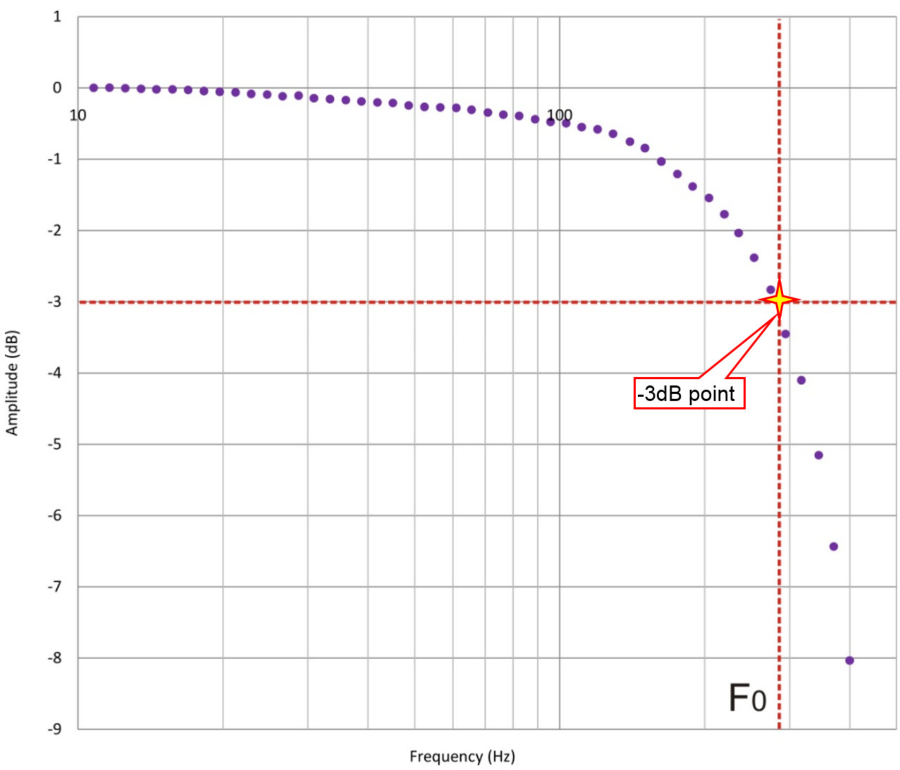

Figure 2: Amplitude ratio characteristics

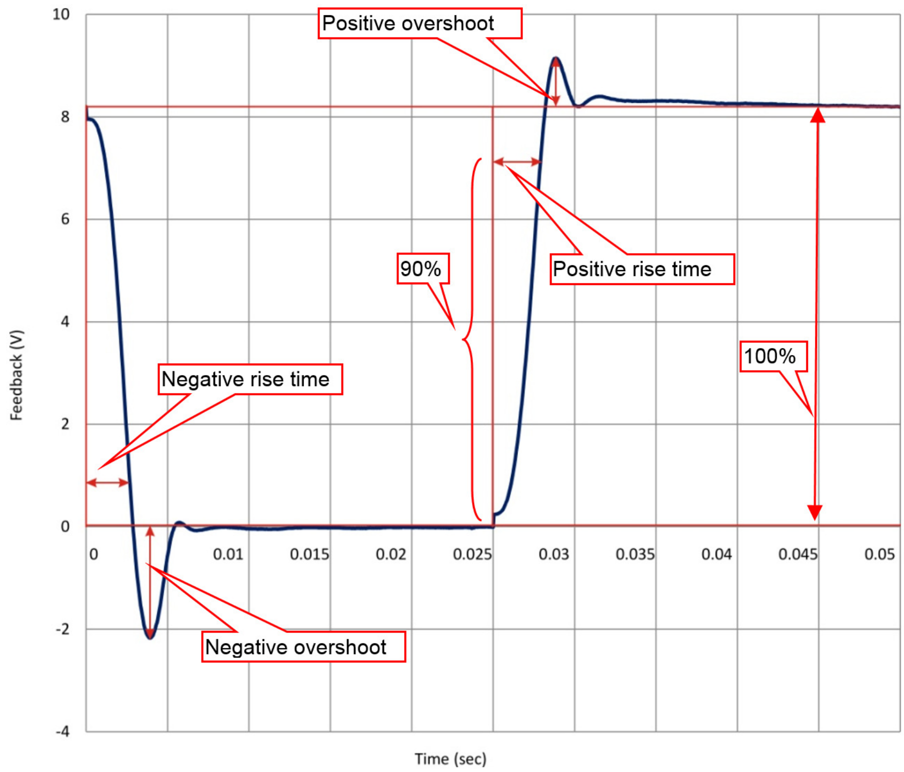

Figure 3: Step response analysis

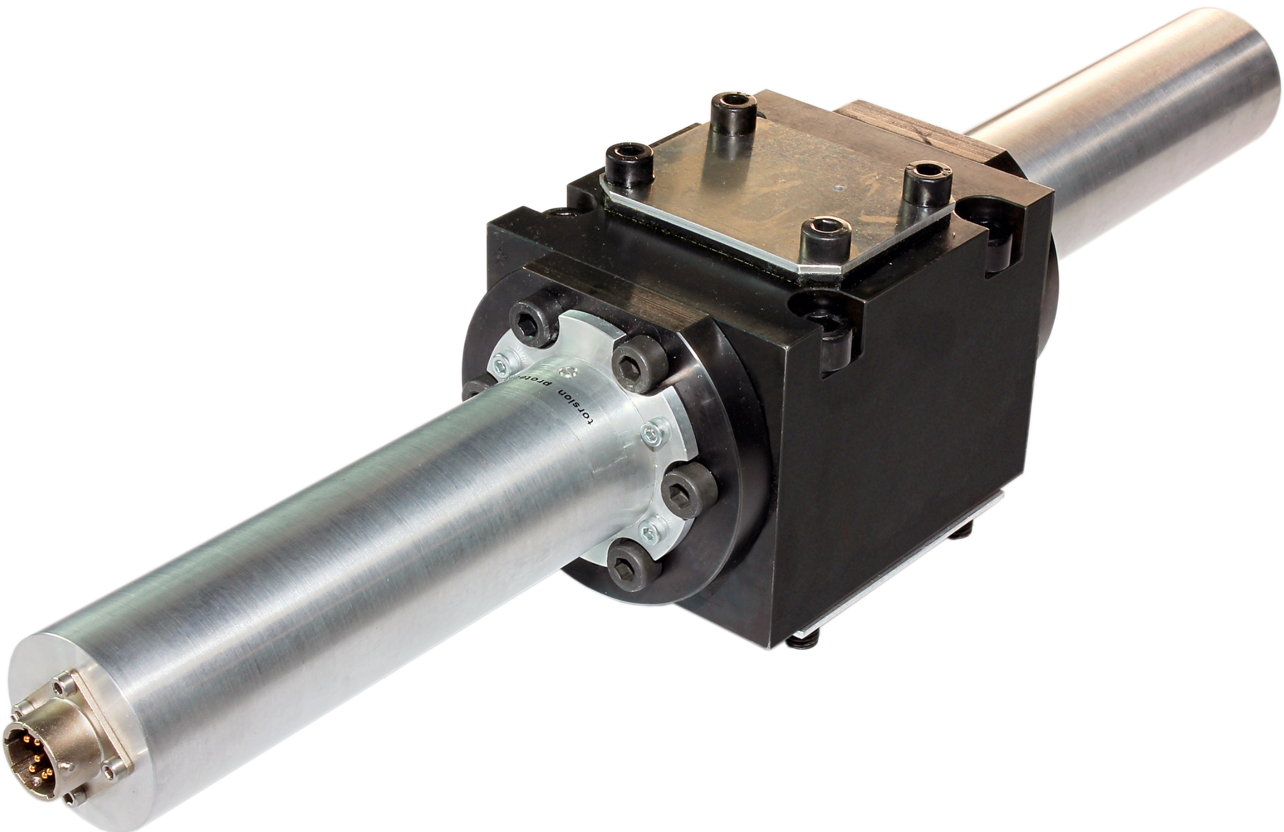

Figure 4: Frequency Response Cylinder ValveExpert VX-FRC-2.x

Specifications

Piston

- Piston diameter: $50mm$
- Rod diameter: $12mm$
- Effective piston area: $1850m^2$
- Total effective stroke: $30mm$ ($\pm15mm$)
- The piston seals[3] are O-rings.[4]
- Bottom side port pattern: ISO 10372-06-05-0-92 (see Figure 5)
- Tom side port pattern: ISO 10372-04-04-0-92 (see Figure 5)

Position Transducer

- Type: DC-DT LVDT
- Supply voltage: $6VDC$ to $30VDC$
- Output at full extension: $14VDC$ with $24VDC$ supply
- Non linearity: $\pm0.5\%$ of full scale

Velocity Transducer

- Electrical impedance: $2500R$, $0.065H$
- Output sensitivity: $4mV/mm/sec$
- Frequency response: $1500Hz$ (with load $> 250K$)
- Non linearity: $\pm0.5\%$ of full scale

Software ValveExpert

Software ValveExpert supports detailed analysis of the dynamical characteristics. The basic analysis may include:

- Natural frequency (Frequency at 90° phase lag)
- Natural amplitude (Amplitude damping at the natural frequency)
- $-3dB$ point (Frequency at $-3dB$ amplitude damping)

[3] There are versions for mineral oil, Skydrol type media, calibration fluid MIL-PRF-7024, or red oil MIL-H-5606.

[4] The piston is not frictionless. However with the larger piston area together with the high pressure gain of the servovalves, this friction is negligible.

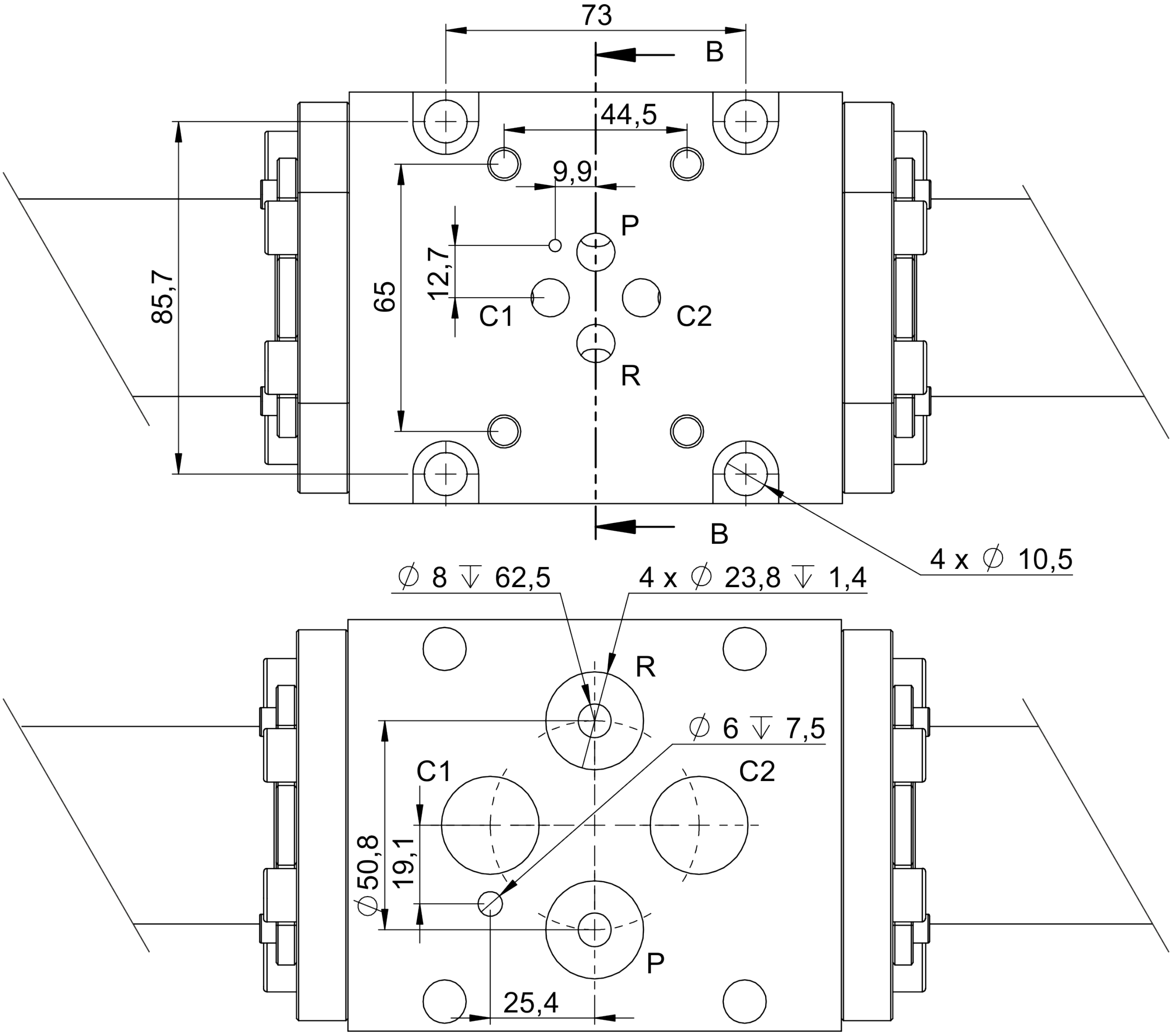

Figure 5: Mounting patterns of the Cylinder ValveExpert VX-FRC-2.x

- Best linear dynamical model and the transfer function
- Step response of the dynamical model
- Rise time
- Overshoot
- Saturation time

The results of the dynamical test give basic data for the modeling, mathematical analysis and computer simulations. Figure 6 shows an example of the test results.

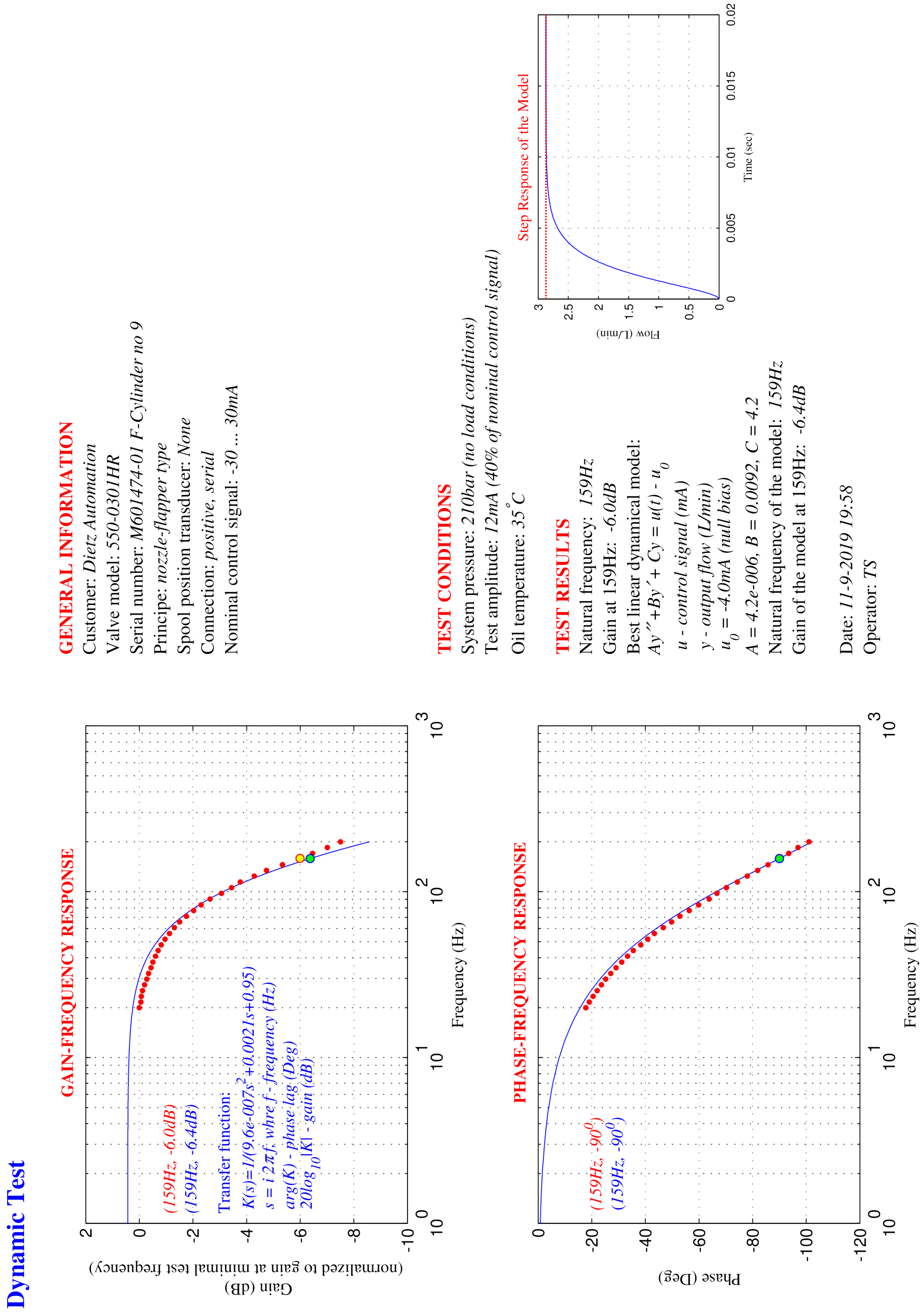

Figure 6: Results of the dynamical test with the Frequency Response Cylinder ValveExpert VX-FRC-2.x

DIETZ automation GmbH
Auf Maien 17
66538 Neunkirchen
Germany
office: +49 6821 8691762
cell: +49 1522 8712097
shashkov@dietzautomation.com
www.dietzautomation.com

USt. ID Nr.: 219 401 070
Geschäftsführer: Dr. Mikhail Shashkov
Handelsregister: AG Saarbrücken HRB 12729

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