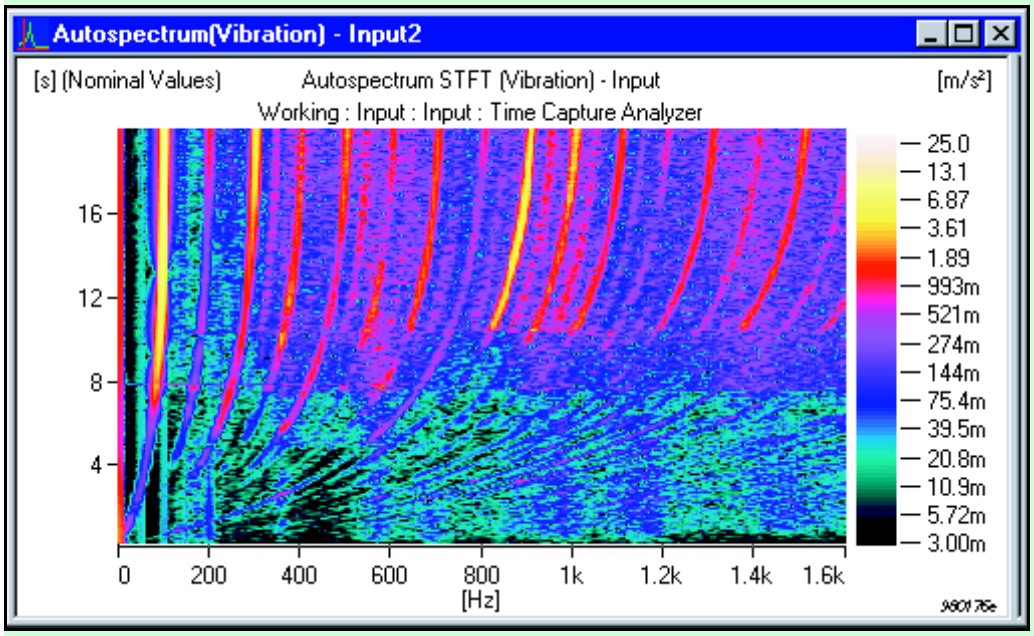
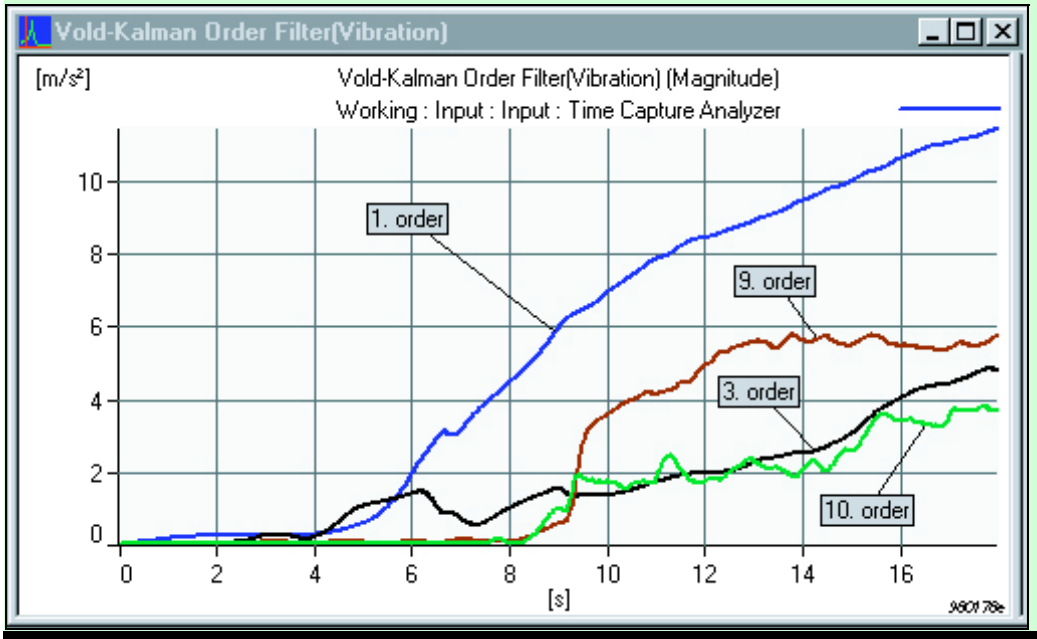
PRODUCT DATA

Vold-Kalman Order Tracking Filter — Type 7703
for PULSE, the Multi-analyzer System Type 3560





Vold-Kalman Order Tracking Filter Type 7703 allows high-performance tracking of harmonic responses, or orders, of periodic loads in mechanical and acoustical systems. This method allows the beat-free extraction of close and crossing orders in systems with multiple axles, and possesses a finer frequency and order resolution than conventional techniques. The tracking capabilities are independent of the rate of change of the rotational speed (slew rate).

7703

Brüel & Kjær

Uses and Features

USES:

- ❍ Amplitude and phase of first order for multiplane balancing and foundation diagnoses of industrial rotors
- ❍ Amplitude and phase for operating deflection shapes per order
- ❍ Separation of drive shaft orders from wheel orders in suspension tuning
- ❍ Isolation of order interaction phenomena in subjective sound quality studies
- ❍ Separation of sinusoids from broadband noise

FEATURES:

- ❍ Post-processing operations on any number of channels at any sampling rate
- ❍ Order extraction as phase assigned order or order waveform as a function of time
- ❍ Order extraction independent of the rate of change of rotational speed (slew rate)
- ❍ No phase bias in time domain waveform extraction
- ❍ Separation of interacting orders in multi-axle systems overcoming beat phenomena
- ❍ Ultra-fine tracking resolution in absolute bandwidth or constant percentage bandwidth
- ❍ 1-, 2- and 3-pole filter shapes
- ❍ RPM profile (RPM versus time) estimation using least squares cubic splines giving accurate instantaneous RPM
- ❍ Repair of RPM profile in cases of tacho signal defects
- ❍ Hinge points in RPM profile allowing for, for example, gear shifts
- ❍ Playback of order waveform through a sound card

Fundamentals of Order Tracking

Mechanical systems under periodic excitation, such as machines with one or more rotating shafts or reciprocating components, will, in vibration and noise measurements, respond with a superposition of sine waves. The frequencies of these sine waves are integer multiples of the fundamental of the involved excitation frequencies. The sine waves are called harmonics, or orders, of the respective excitations. As the periodic excitations change their frequency, the orders will change their frequencies in sympathy. From the excitation “point” in the machine to the measurement point, the sine waves are subjected to the transfer characteristics, the Frequency Response Function (FRF), of the structure, meaning that all the sine waves or orders have their amplitude and phase changed in accordance with the FRFs. When the excitation frequencies change, each individual order may see itself amplitude and phase modulated by the FRF. In non-linear structures the responses will still be harmonics of the excitations, just the non-linearity will generate higher harmonics. Mechanical looseness or rattling may generate subharmonics. Some machinery may have inherent modulation mecha-

nisms giving rise to orders that are not integers of the excitation frequencies but rather modulation products of the excitations.

It is often helpful to visualize an order as an amplitude (and phase) modulated radio signal. The underlying sine wave whose frequency is a multiple of the fundamental periodic phenomenon would be the carrier wave, while the slowly varying amplitude and phase function that modifies the carrier wave is the radio program. A radio receiver demodulates the signal by removing the carrier wave and playing the modulation function, also known as the (complex) envelope. Now, in mechanical systems, the carrier wave may continually change its frequency, making the orders similar to amplitude modulated spread spectrum radio signals.

The art of order tracking is to extract selected orders in terms of amplitude and phase, the phase assigned order, and the waveform it self, the order waveform. The order waveform and the phase assigned order are given as functions of time.

Phase Assigned Orders and Order Waveforms

A harmonic is a sine waveform whose instantaneous frequency is a constant multiple of that of an underlying periodic load. The amplitude and phase of the harmonic is a function of the load and the transfer characteristics of the system, and is called the phase assigned order. The output of the Vold-Kalman filter is the order waveform as a function of time. The filter is symmetric in time, such that there is no phase bias. The phase assigned order, i.e., amplitude and phase as a function of time, may also be generated from order waveform.

Capabilities

The Vold-Kalman tracking filter provides a very sharp single-pole filter shape for compatibility with first generation Kalman filtering, and 2- and 3-pole filters with flatter passband and improved selectivity of orders. Filter bandwidth is specified in absolute bandwidth or in constant percentage bandwidth.

The method allows for the simultaneous extraction of orders, also with respect to multiple axes, such that even close and crossing orders may be extracted without beating interactions.

The RPM estimation is performed with a least squares cubic spline curve fit with the possibility of automatic repair of RPM profiles in cases of defective tacho signals. The algorithm allows for sudden RPM changes experienced, for example, in engaging and disengaging the clutch and in gear shifts.

The steps in a Vold-Kalman order analysis procedure are as follows:

❍ Depending on the length of the time signal (see Requirements in the Specifications), use an FFT analyzer in Type 7700, Time Capture Type 7705 (Fig. 1) or Data Recorder Type 7701 to acquire the tacho signals and the response signals.

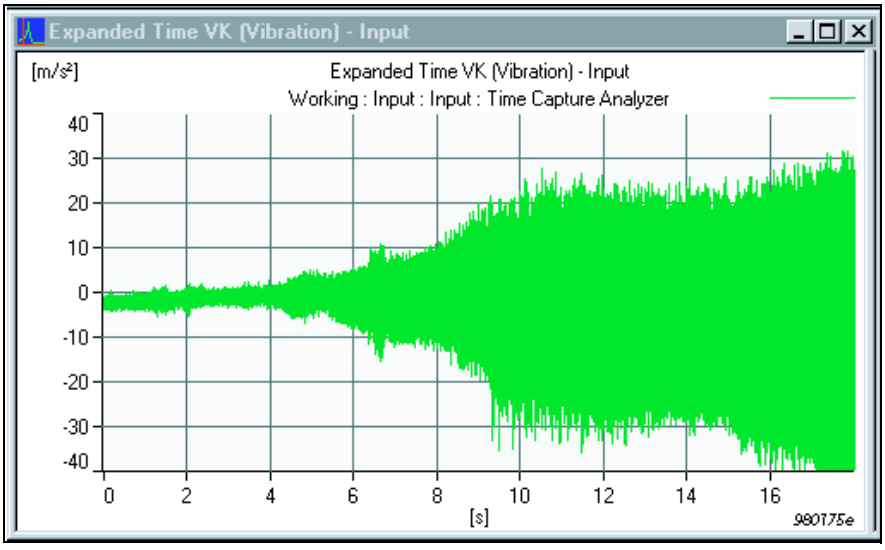


Fig. 1 The time history record of a vibration response from a fast run-up using Time Capture Type 7705

❍ Make waterfall and contour plots of the acquired data using FFT analysis. This gives an overview of the event to be analysed (Fig. 2).

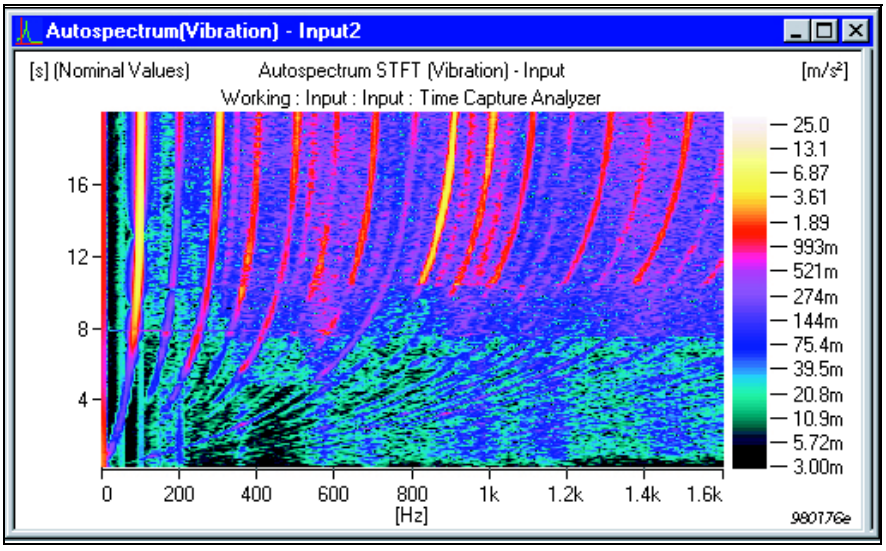


Fig. 2 Short-time Fourier Transform of the vibration signal of the run-up

❍ Select the part of the acquired time signal to be analysed.
❍ Estimate the RPM profile (Fig. 4).
❍ Use the Vold-Kalman filter to extract the selected phase assigned orders (Fig. 5) or the order waveforms (Fig. 6).

Fig. 3 Recorded tacho signal

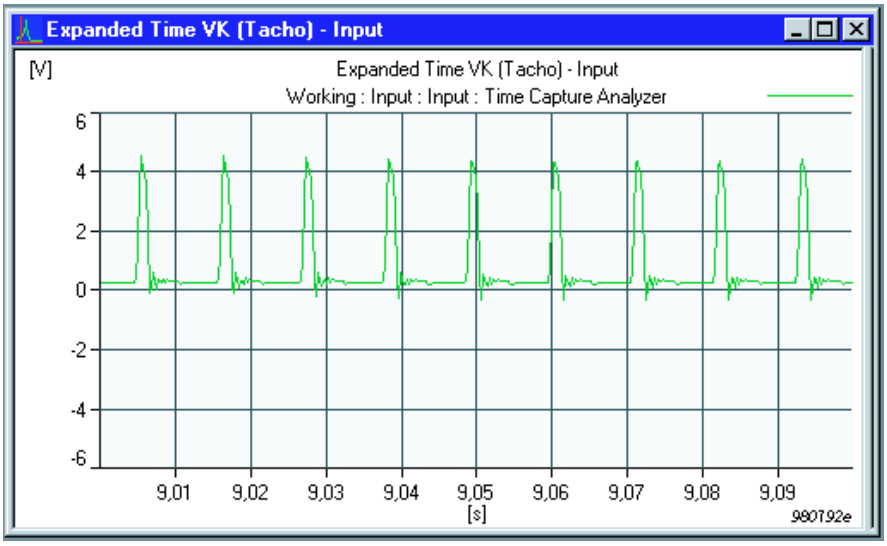


Fig. 4 RPM Profile (RPM as a function of time) estimated from a recorded tacho signal

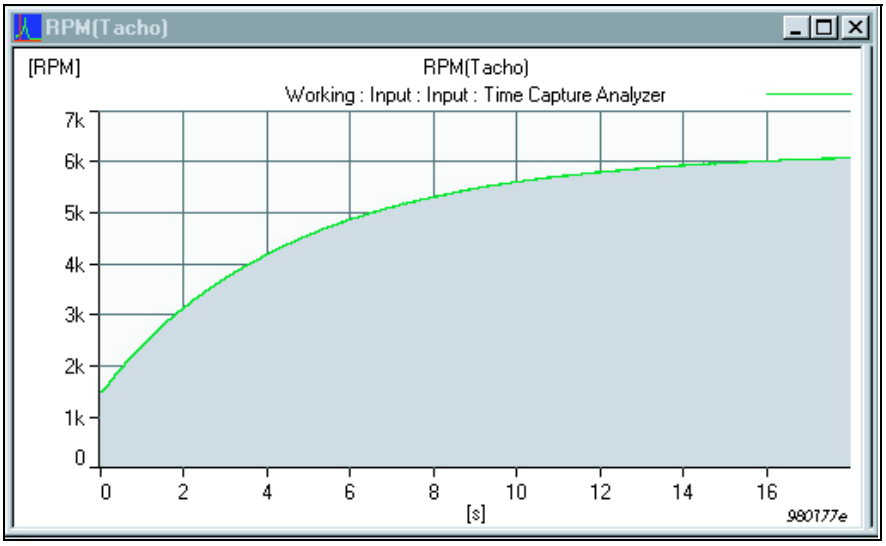
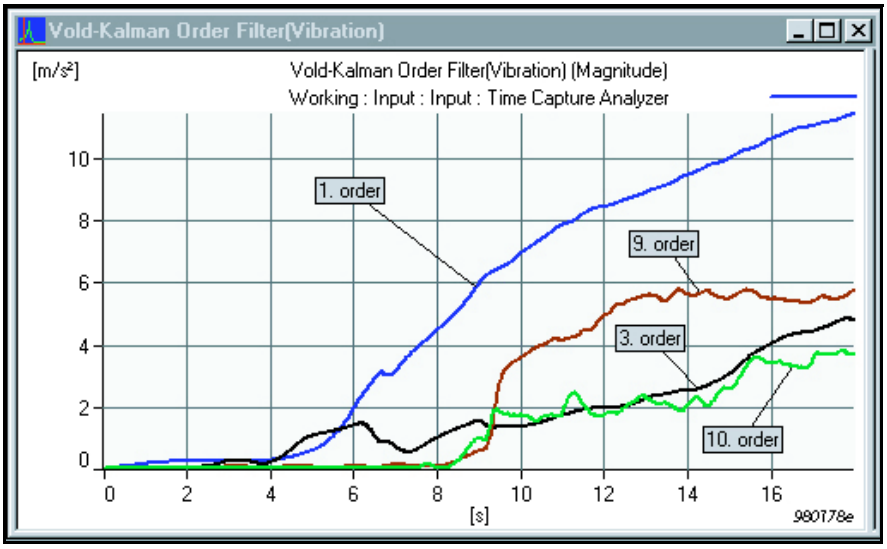


Fig. 5 Magnitude of selected (phase assigned) orders extracted using the Vold-Kalman Order Tracking Filter



All Previous Methods – Vold-Kalman Offers

- Beat-free decoupling of close and crossing orders
- Advanced tachometer signal processing including automatic wild point rejection

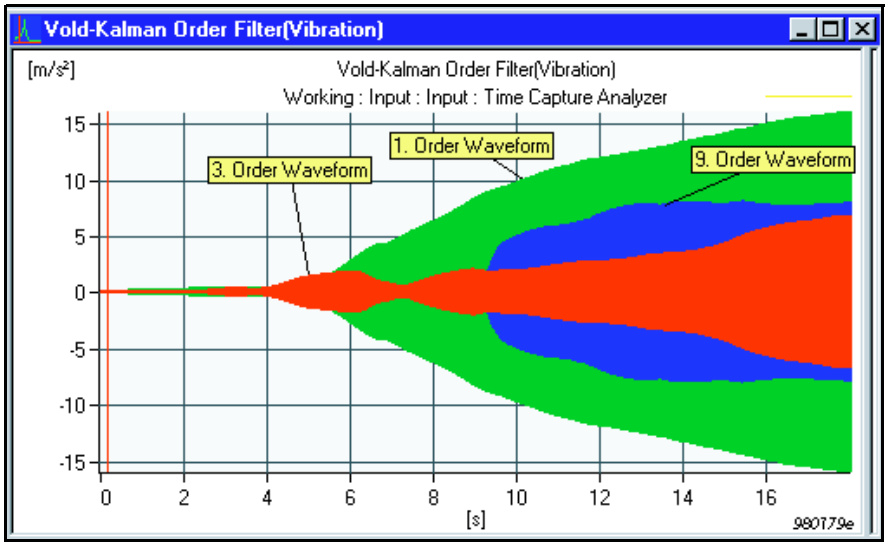
FFT-based Order Cuts – Vold-Kalman Offers

- Fine resolution in both the time and the frequency domain
- No slew rate limitation
- Order waveform
- No picket fence effect error (amplitude error)

Order Tracking – Vold-Kalman Offers

- Fine resolution in both the time and the frequency domain
- No slew rate limitation
- Order waveform

Fig. 6 Three order waveforms extracted by Vold-Kalman filtering of the run-up response signal



Digital Tracking Filters – Vold-Kalman Offers

- Much shorter transients
- No phase bias (for most digital filters)
- Order waveform and phase assigned orders
- No slew rate limitation

1st Generation Kalman Tracking Filters – Vold-Kalman Offers

- Filter bandwidth specified in Hz or %
- Multipole filters for flat passband and improved selectivity

Specifications 7703

Type 7703 is a LabShop Tool Pack for use with PULSE, the Multi-analyzer System Type 3560. The specifications below apply for PULSE LabShop version 4.1 or later

Requirements

- The PC Requirements for Multi-analyzer System Type 3560 must be fulfilled
- Noise and Vibration Analysis Type 7700 must be installed.
- The max. time record is 16 ksamples (e.g., T = 2 s for 3.2 kHz span) for Type 7700. Hence:
  Time Capture Type 7705 is strongly recommended for capturing of and selection in long time records
- The capture real-time channel × bandwidth product (ChBW) is typically 12 kHz, depending on the PC. Hence:
  Data Recorder Type 7701 (+ UL0112–00x Throughput-to-disk Option) is necessary if the real-time ChBW requirements typically exceeds 12 kHz, e.g., higher frequency and or more channels

Processing Functions

Type 7703 includes the following processes:
- Vold-Kalman RPM profile estimation from tacho signals – spline curve fit of RPM profile overcoming defects in the tacho signals
- Vold-Kalman Order filtering (phase-bias-free filtering conserving the phase properties of the signals)

Processing Control

Type 7703 allows control of calculations as follows:
- Tacho pulse detection controlled by tacho level, slope and hysteresis and number (real) of tacho pulses per revolution
- RPM profile curve fitting controlled by segmentation of, and allowance for, hinge or bend points in the profile. The RPM profile may be decimated to reduce the amount of output data
- Vold-Kalman order filtering based on one or more RPM profiles. The filtering is controlled by single-pole filters and 2- and 3-pole filters (flat response and better selectivity). For all filter types, the bandwidth (BW) can be set as a constant BW [Hz] or as a constant percentage BW [%] (of the order)

The outputs are one or more orders (order no. an integer or real) in terms of: order waveforms as function of time or phase assigned orders (amplitude and phase) as function of time. The phase assigned order output may be decimated to reduce the amount of output data

Display

Specifications are the same as for Multi-analyzer System Type 3560 with the following additions:

RPM TYPES:
- Raw RPM and spline fitted RPM profiles for verification of the correctness of the fit

ORDER TYPES:
- Order waveform as function of time
- Phase assigned order as a function of time

Vold-Kalman Order Tracking Properties

ORDER EXTRACTION:
Tracking: Tracks non-progressive RPM profiles including sudden RPM changes (e.g., gear shifts). Unlimited RPM change rate, acceleration
Filtering: Phase-bias-free filtering conserving the phase properties of the analysed signals
Order Decoupling: If more orders are extracted jointly, coupled – i.e., crossing or close orders – will be extracted decoupled and beat-free

RPM PROFILE SPLINE FITTING:
Segmentation and Hinge Points: The spline fit may be segmented and equipped with hinge points. Each segment accounts for a local RPM maximum or minimum; for a progressive RPM profile 8 – 10 segments yields a god fit. The hinge points allow for sudden RPM changes as introduced, for example, by a gear shift
Defective Tacho Pulses: If not to many, defective tacho pulses may be rejected still obtaining a good RPM profile.
Rejection: Up to xx% of possibly defective pulses

Ordering Information

Type 7703: Vold-Kalman Order Tracking Filter
A LabShop Tool pack for use with PULSE, the Multi-analyzer System Type 3560

Type 7700 Version 4.1 or later is required for Type 7703

Optional Accessories

FOR LONG TIME RECORDS:
Type 7705: Time Capture for capture of and selection in long time records
Type 7701: Data Recorder for capturing long time records using
UL 0112–00x: Throughput-to-disk Option

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