HBK
HOTTINGER BRÜEL & KJÆR

2022 eDrive User Group Meeting

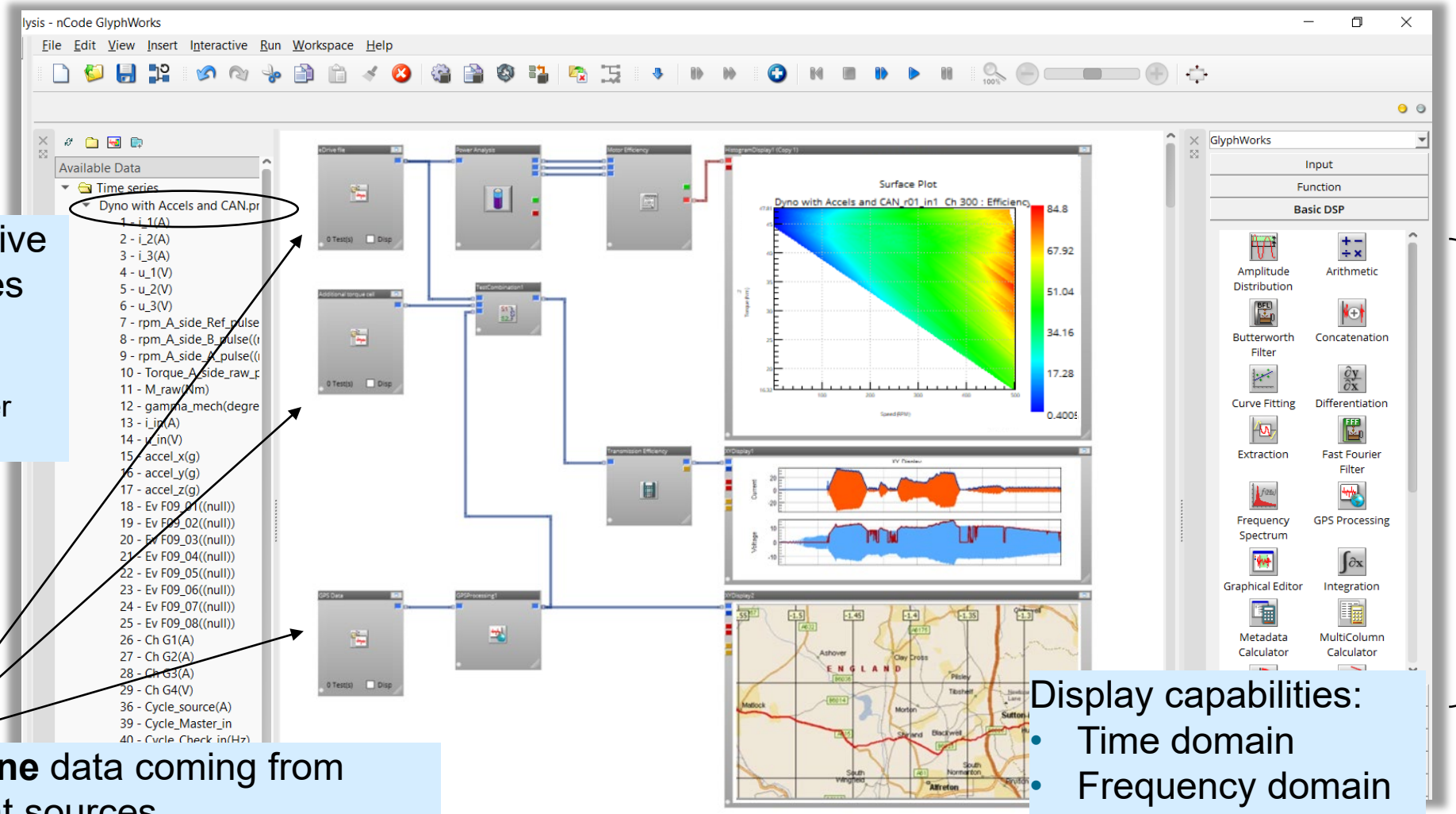
Digital signal processing techniques to identify faults and maximize efficiency in EVs

Kurt Munson
HBK

HBM

Brüel & Kjær

nCode GlyphWorks for post-processing measured data



Reads eDrive (PNRF) files natively
But also
CSV and other formats

Combine data coming from different sources
(e.g. PNRF, MDF4, BKC, etc.)
Also, easy to **compare** different tests

Wide range of **post-processing** functions including

- anomalies
- harmonic filtering
- statistics
- classification
- **power analysis**

Display capabilities:

- Time domain
- Frequency domain
- Histograms
- 3D scatter plots
- **Surface plot**

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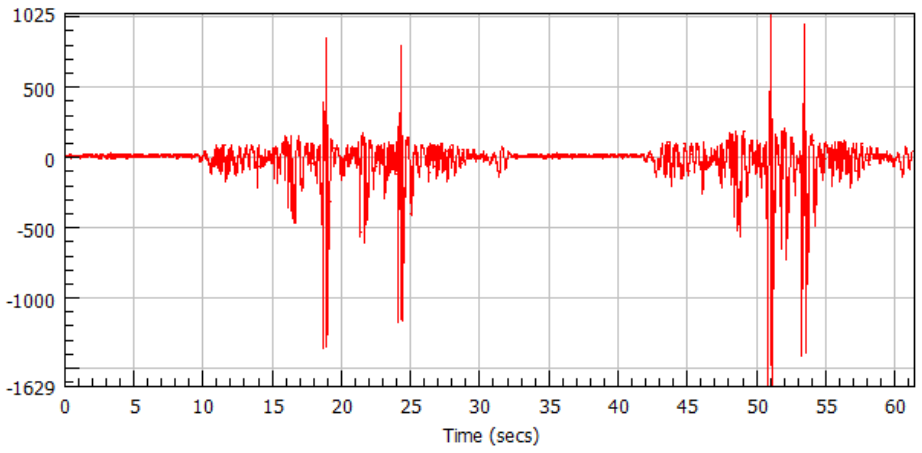
Agenda

1. Introduction to digital signal processing (DSP)
2. Using DSP to calculate EV powertrain efficiency
3. Using DSP to identify EV faults
4. Questions at any time!

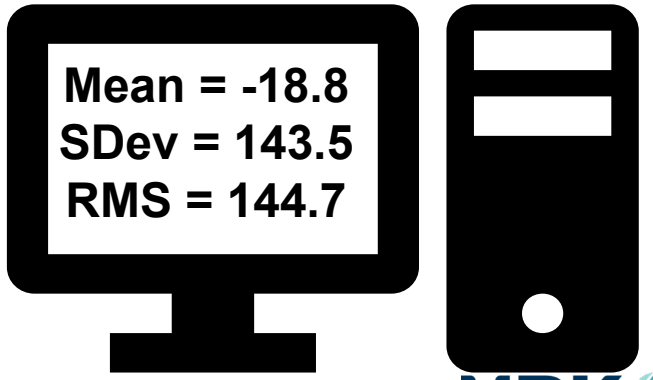
What is Digital Signal Processing?

- The time-varying signal is made up of discrete points through time
- ***DSP*** is the manipulation and transformation of this data through computational processing

voltage
current
acceleration
speed
etc.



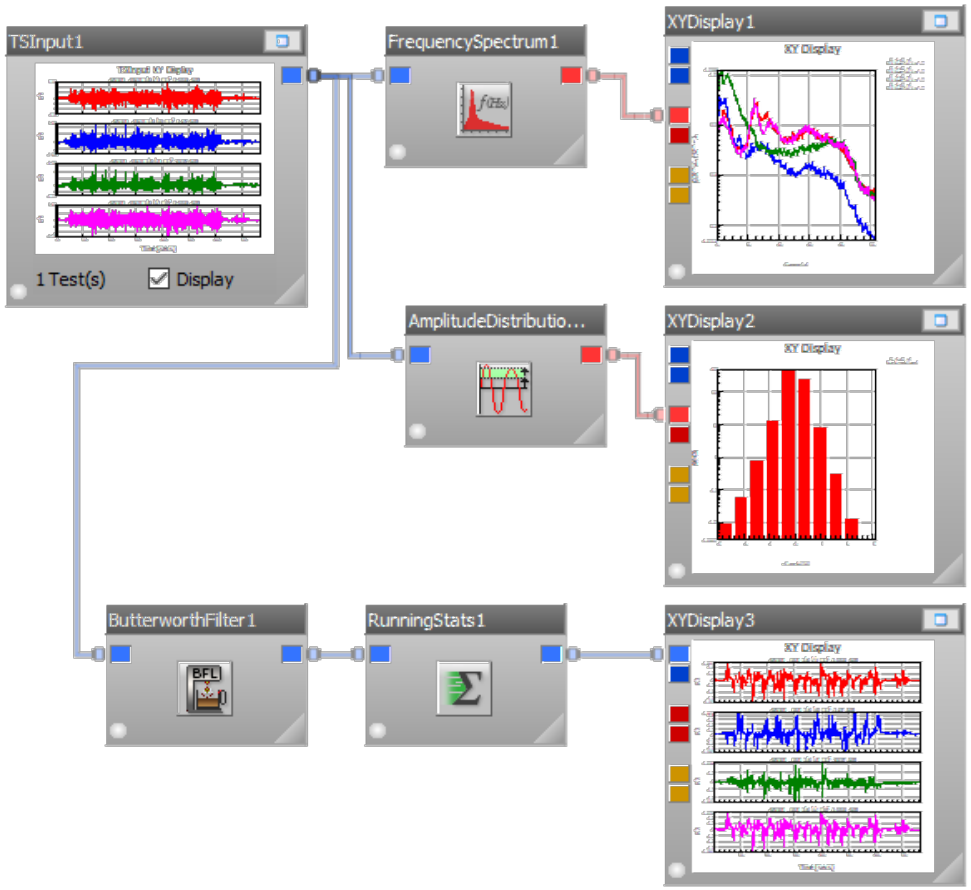
Time (s)	9 RF_SHK_LD LB
0.00000	15.91
0.00200	14.52
0.00400	11.14
0.00600	9.348
0.00800	6.613
0.01000	4.177
0.01200	4.177
0.01400	4.724
0.01600	5.768
0.01800	7.409
0.02000	10.14
0.02200	12.08
0.02400	13.28
0.02600	14.67
0.02800	15.22
0.03000	16.46
0.03200	16.56



nCode software for DSP

- Intuitive, graphical interface for standardized analysis of measured data
- Contains wide range of DSP and vibration analysis tools
- Natively supports 40+ binary files types
- Save and easily distribute and update processes

GlyphWorks



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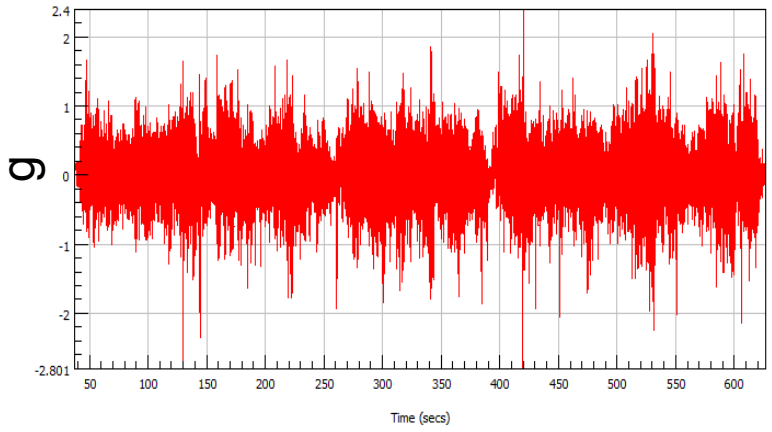
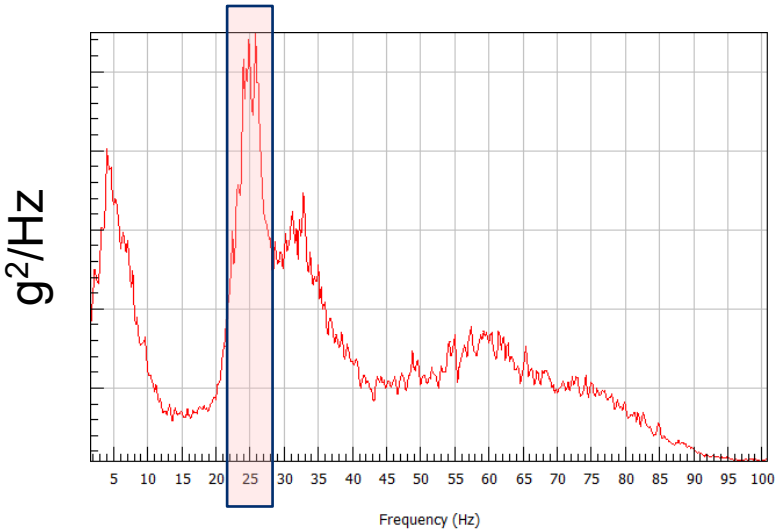
The frequency domain

- What frequencies are present in my signal?

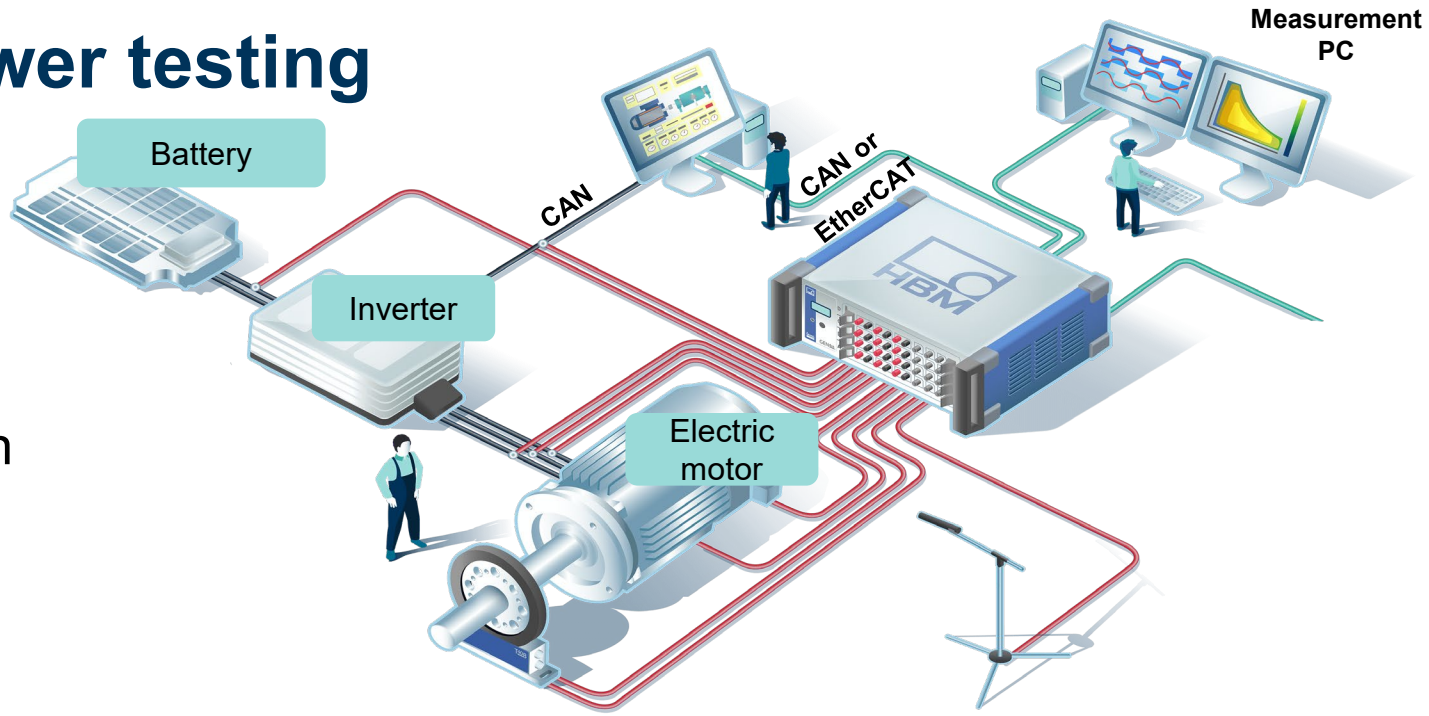


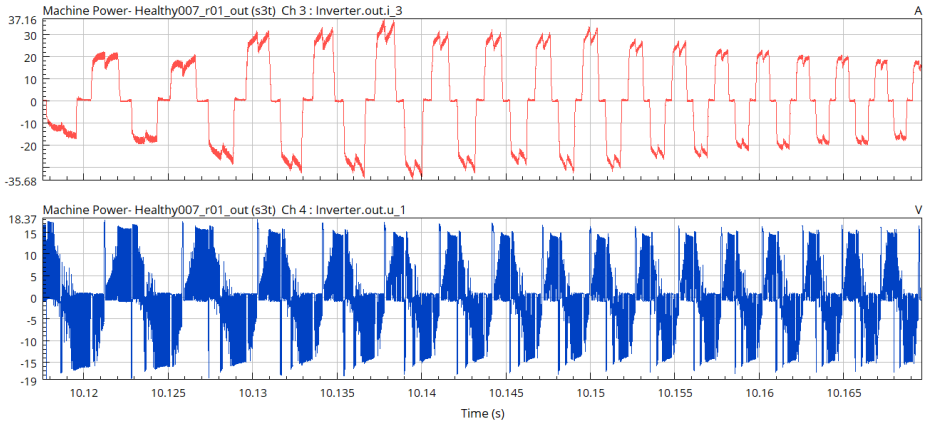
Fourier Transform



HBM eDrive for electric power testing

- Simple and accurate measurement of electro-mechanical signals
- All channels recorded at up to 2 million samples per second
- Highly accurate
- Transient power measurements
- Direct import to nCode GlyphWorks!





The value of DSP in a nutshell…

Assess performance

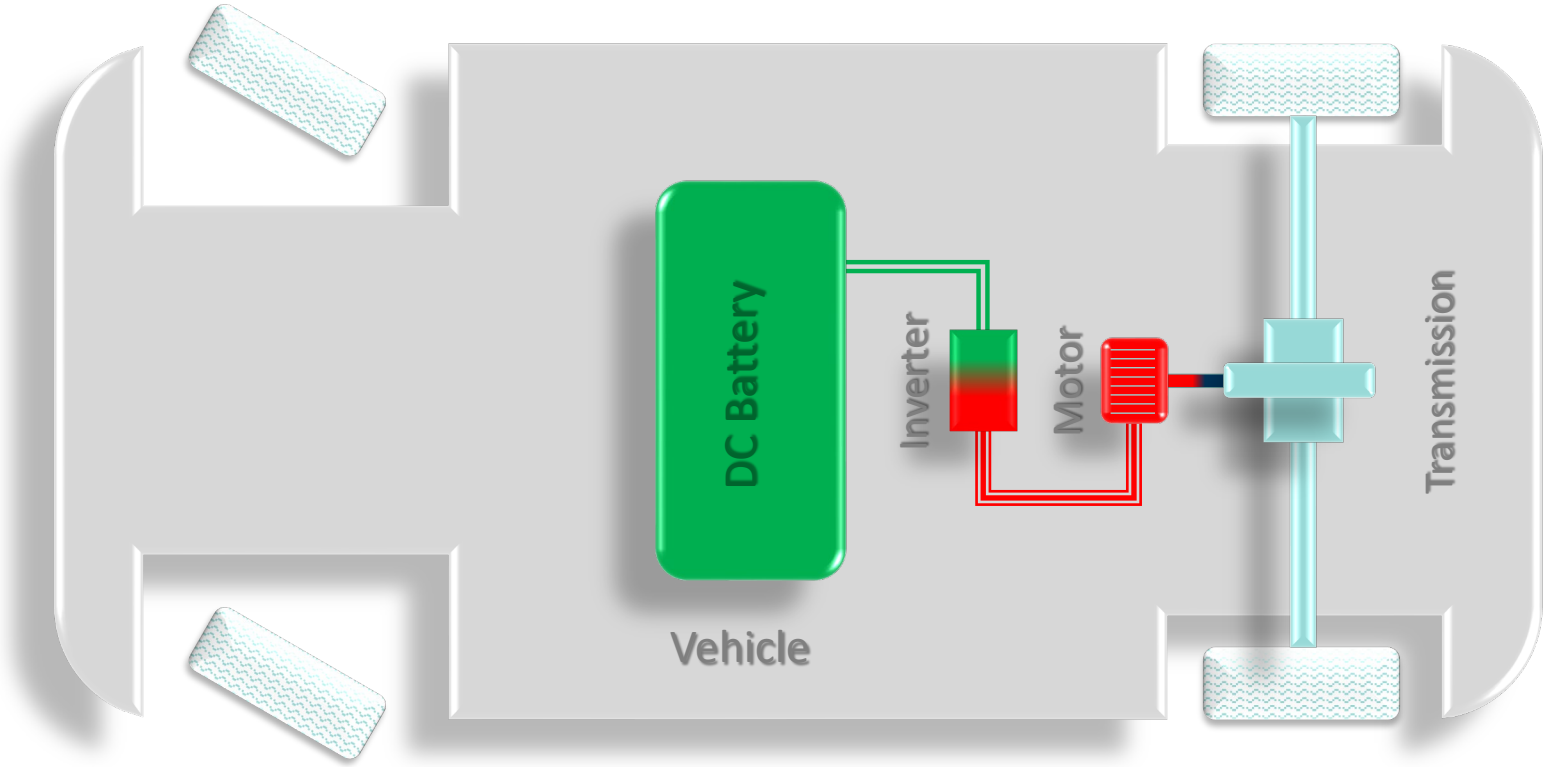
Identify faults

nCode GlyphWorks enables EV engineers to:

- **Analyse** the huge quantities of measured electric time series data.
- **Quantify** power, efficiency, and durability.
- **Compare** designs, configurations, control strategies or materials.

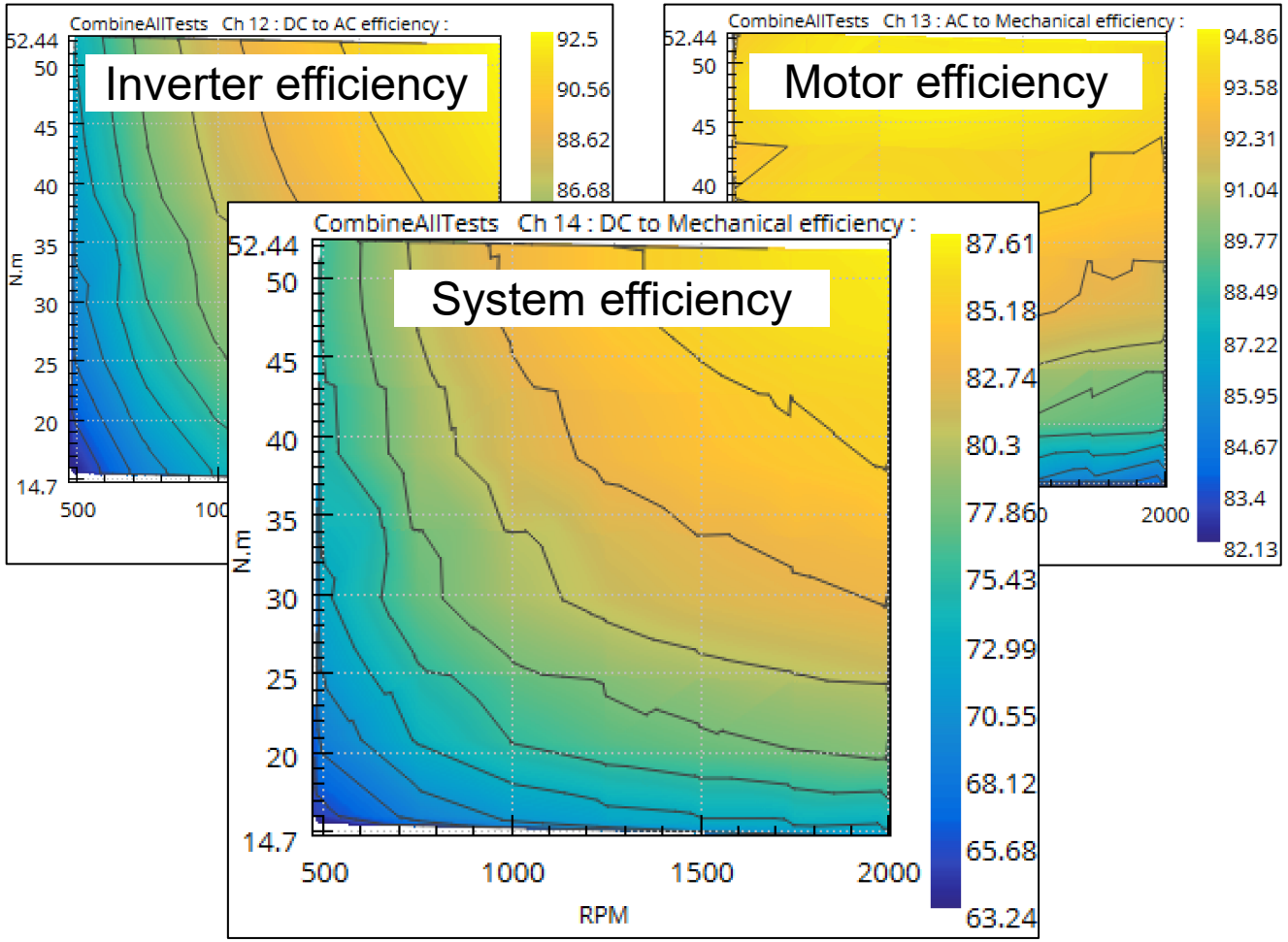
Efficiency of an Electric Vehicle

Energy conversion & efficiency losses



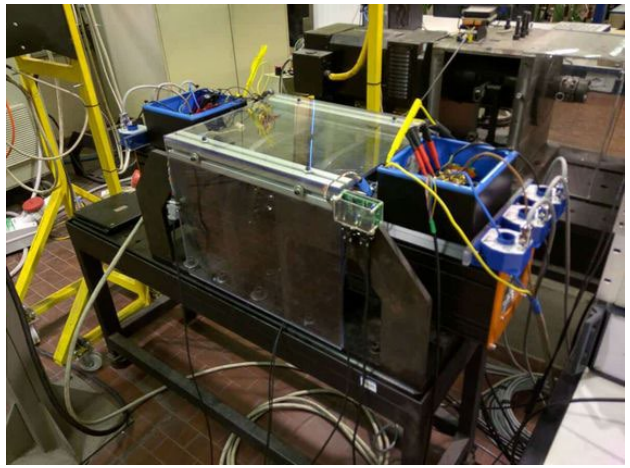
- Battery DC
- Inverter DC-AC
- Motor AC
- Transmission

Efficiency of an Electric Vehicle



EV efficiency and performance analysis

What is the optimum gear ratio for the gearbox?



- An electric motor test rig made of:
  - motor under test + controller
  - dynamometer
  - sensors and recorder
- Data acquisition
  - Operate the machine through 35 torque and speed combinations
  - Record a 1 sec snapshot of data for each torque/speed condition
- Post-data acquisition analysis
  - Analyze all 35 runs: 10+ million data points in total per channel (35s @ 0.5MHz), 10 channels in total
  - Produce an efficiency map

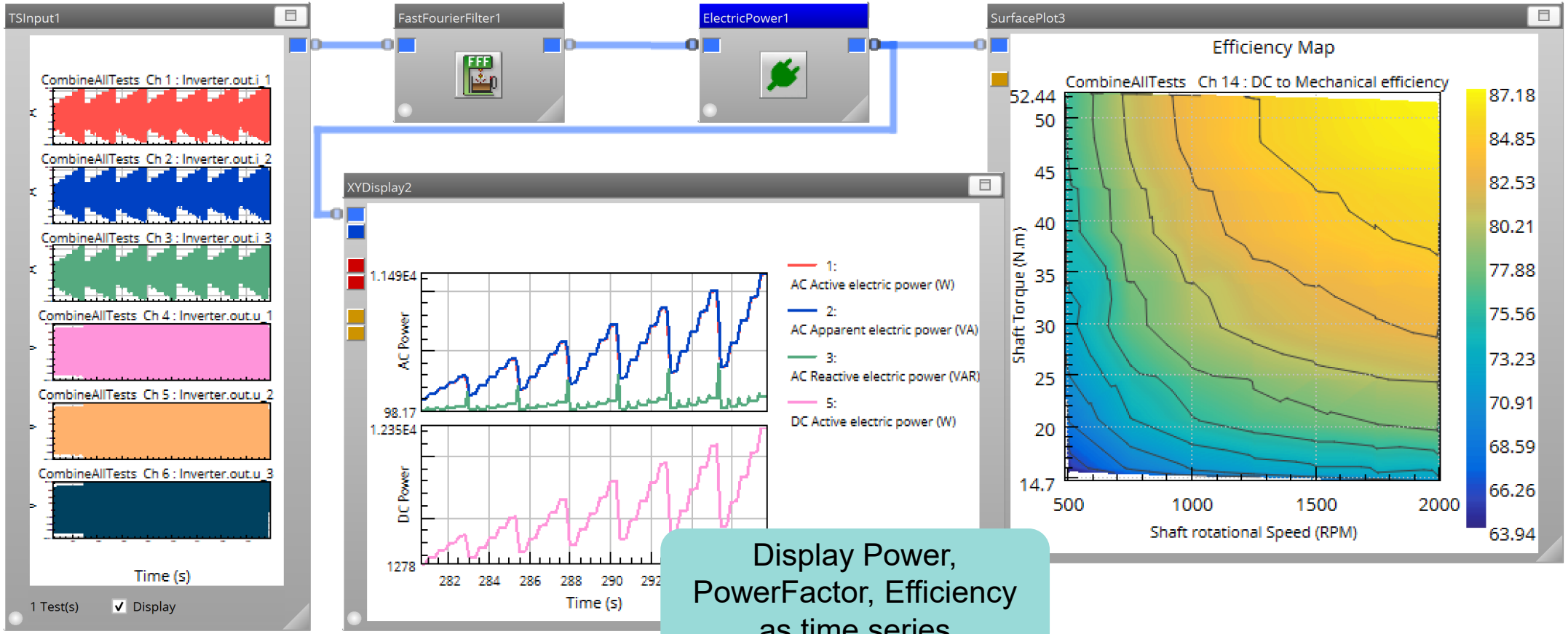
Software demonstration: nCode GlyphWorks for efficiency analysis

Input file(s)

(Optional) Lowpass filter to remove harmonics

Calculate Power and Efficiency

Display Efficiency Map



Display Power, PowerFactor, Efficiency as time series

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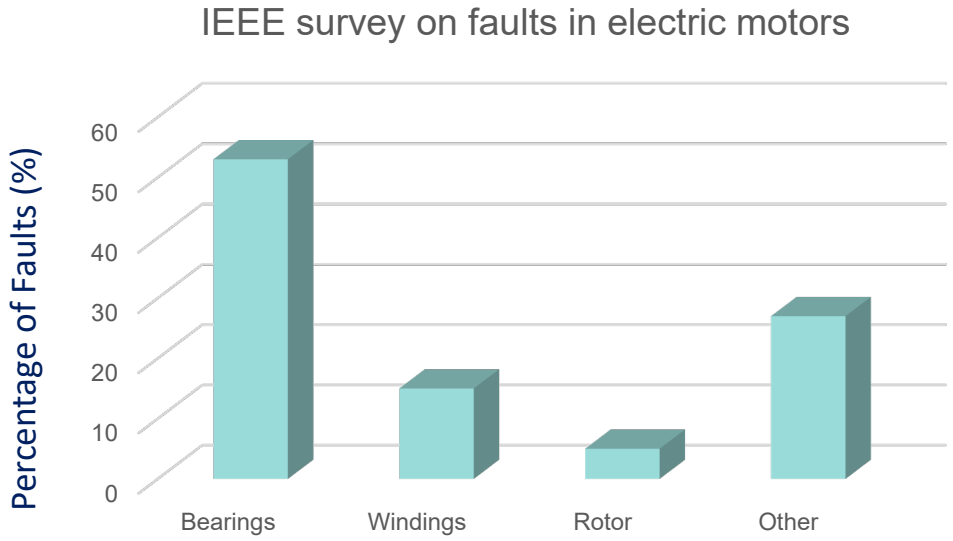
Faults in electric motors



Thorsen and Dalva, "A Survey of Faults on Induction Motors" IEEE Transactions on Industry Applications

Fault location	Causes	Consequences
Bearings	• Misalignment, imbalance, etc. • Current passing through bearing	• Vibration • Loss of efficiency
Windings	• Interturn shorts due to excessive heat and current	• Vibration • Fire
Rotor	• Demagnetization due to heat	• Loss of efficiency • Torque ripple • Vibration

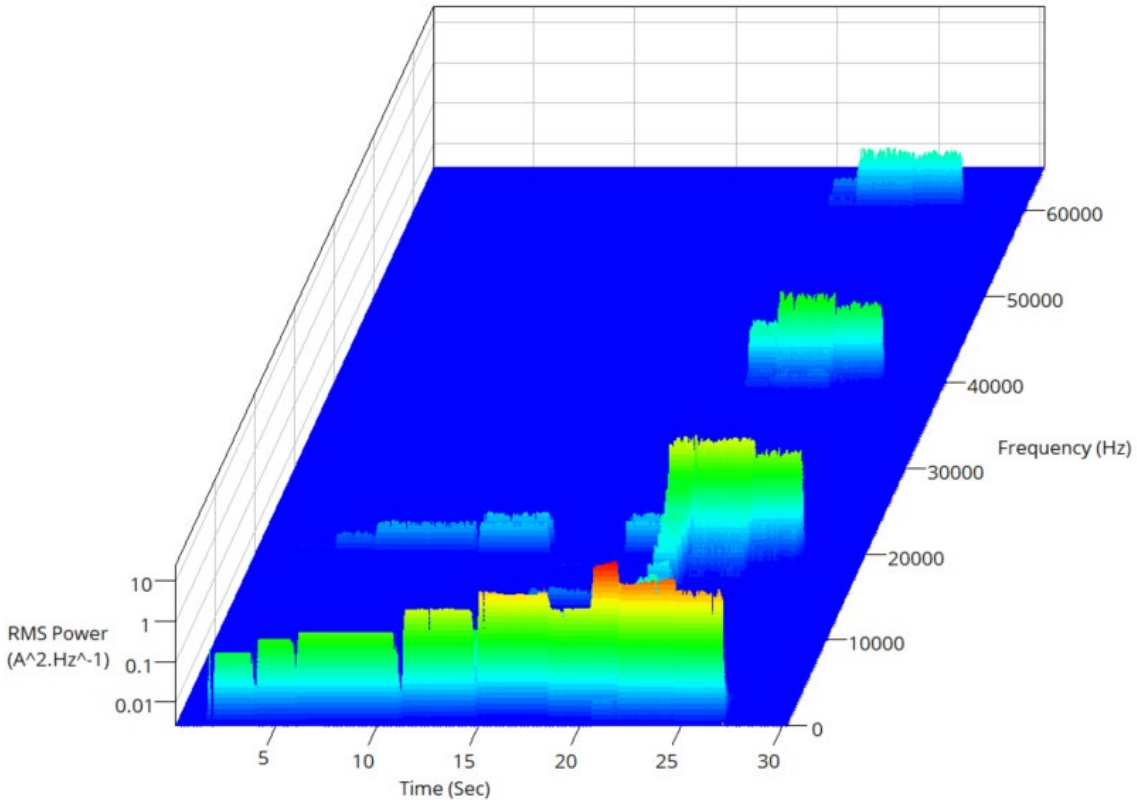
To observe the early signs of premature durability failure, we need to:

- Reduce large data sets to key metrics like statistics, histograms, and spectra
- Use analysis techniques to identify changes from the expected behavior

Identifying electric motor faults

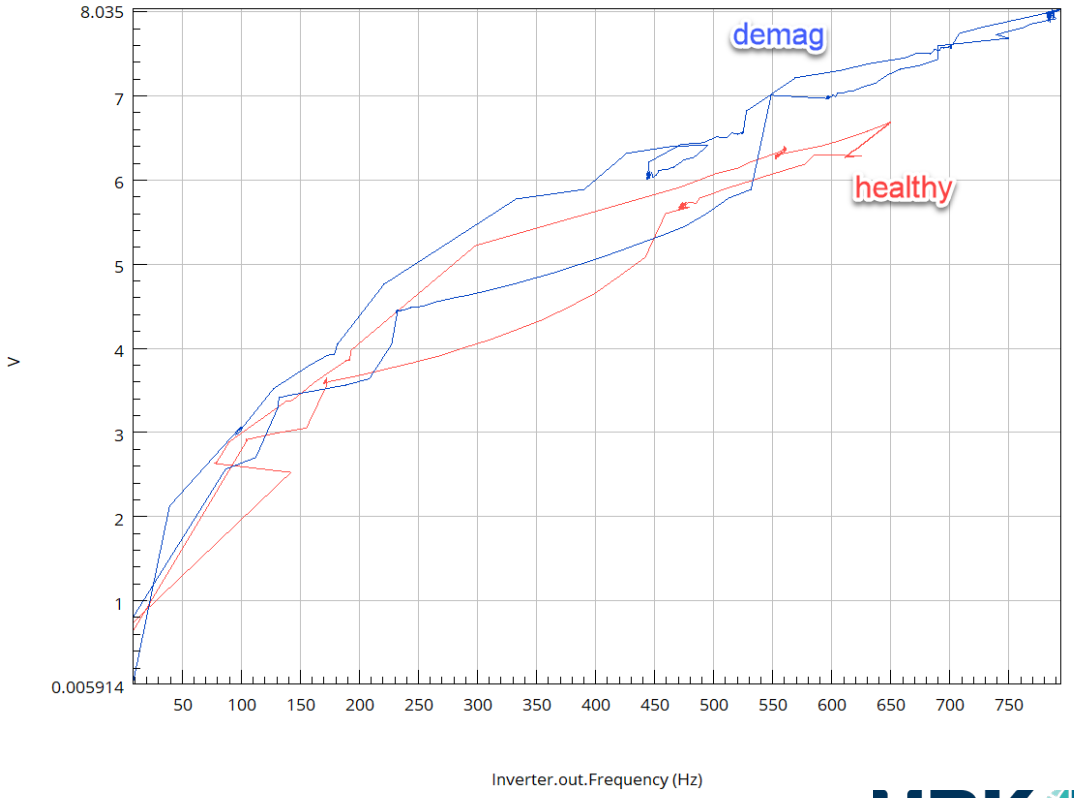
Interturn shorts

- Identified by increased harmonic content and vibration



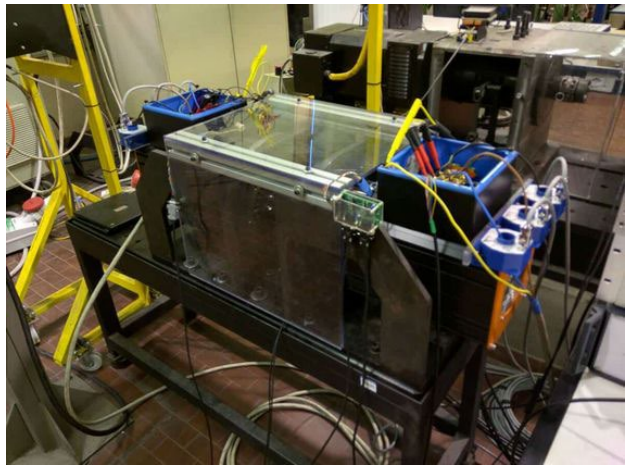
Demagnetization due to heat

- Loss of efficiency shown by higher voltage requirement for a given speed and torque



Identifying EV motor faults

What's causing loss of performance?



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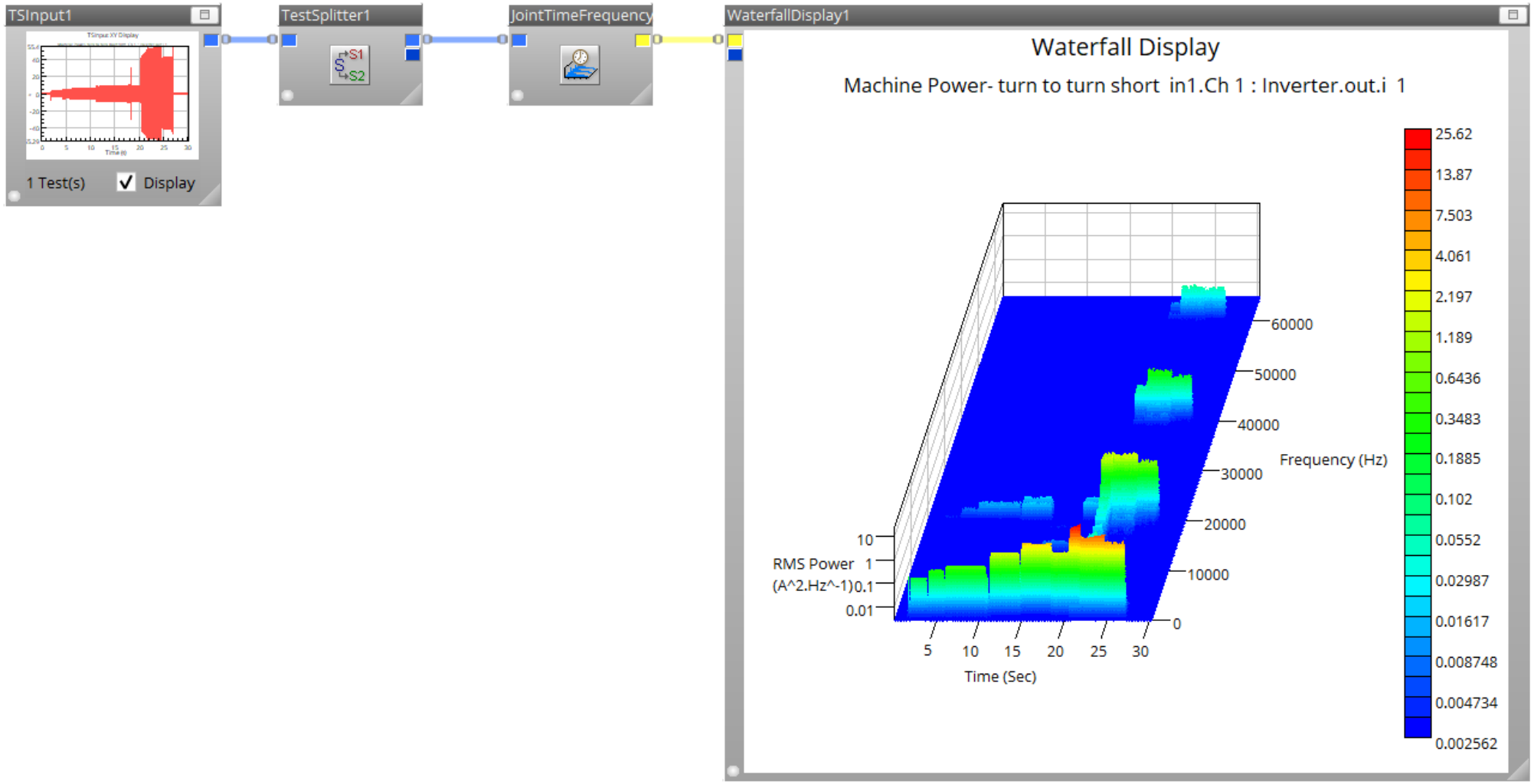
- Post-Data Acquisition Analysis
  - Analyze all 35 runs: 10+ million data points in total per channel (35s @ 0.5MHz), 10 channels in total
  - Identify faults and their sources

Software demonstration: nCode GlyphWorks for fault detection



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Thank You

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