# eKIT – PLATO Add-on for Measurement & Analysis of eMotor & Resolver Characteristics

## eMotor & resolver characteristics

As eMotors with attached resolvers are now a common, integral part of automtove ePowetrain assemblies, it is paramount that key electrical characteristics are assessed in the manufacturing/assembly process to ensure reliable and efficient operation in-service.

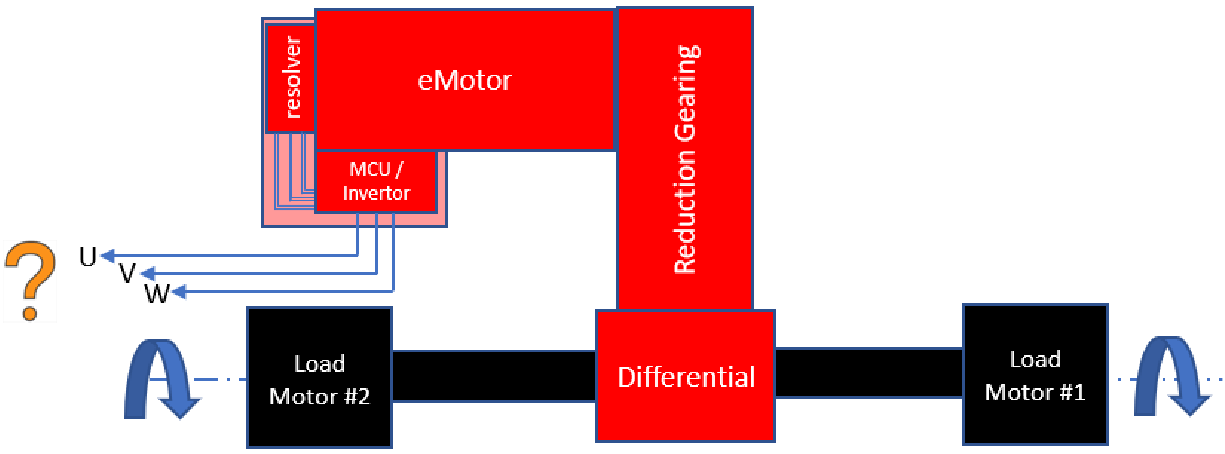
The **eKIT** add-on for the PLATO NVH measurment and analysis system currently supports testing of the following items/characteristics:

- back-EMF analysis to determine:
  - build/winding quality
  - electrical perfomance (output/RPM)
- resolver analysis to determine:
  - offset angle relative to eMotor
  - transformation ratio

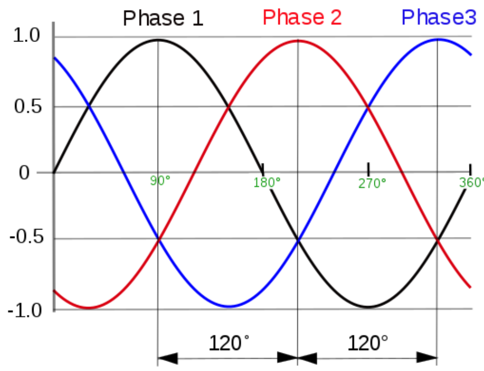
Verifying eMotor & resolver characteristics in the factory ensures reliable and efficient operation in-service

## Back-EMF testing

eMotor winding, general build quality and electrcial power output capability are most readily assessed by rotating the eMotor using an external motor (or motors) to generate back-EMF. When the eMotor is being tested as part of a 2-in-1 or 3-in-1 ePowertrain assembly, it is usual to back-drive the eMotor using the test machine´s output motor(s).



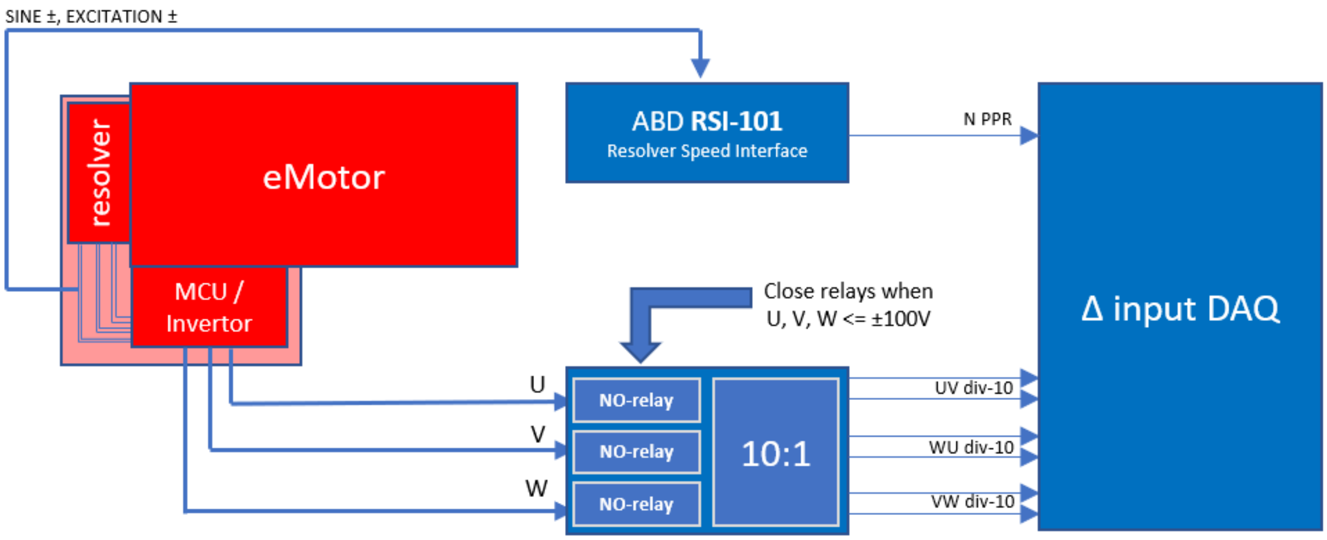
A perfectly manufactured eMotor will genate perfectly sinusoidal voltage outputs on each of the three phases. The peak-to-peak amplitude at a gven rotation speed (rpm) provides a measure of electro-mechanical efficiency, and any deviations from perfectly formed sinusoidal waveforms provides information on general build and winding quality.




PLATO uses a differential input analogue DAQ-card to measure the voltage differences across each of the phases. And, because the voltages being measured typically exceeed the operational envelope of the DAQ-hardware (±10V), 10:1 potential dividers are used between the eMotor outputs and the DAQ-inputs. Further, to safeguard against the possibility that the voltages may rise above ±100V, the potential divider module (the ABD, now NVHI **IPD-101**) also includes normally-open (NO) relays that are only closed by the system when the rotational speed of the eMotor is confirmed as being below a defined RPM value.


An eMotor speed reference signal is also required to allow the analysis to be synchronised to rotational speed (RPM). This is provided by the ABD, now **RSI-101** (resolver speed interface) module which takes resolver signals (SINE± and EXCITATION±) and converts them into a N-PPR pulsetrain signal that can be sampled as a speed reference signal.


Testing typically takes place with the eMotor rotating at a fixed speed in the range 1000-2000 RPM. The voltage differences across each of the eMotor windings are sampled simultaneously with the N PPR (pulse-per-revolution) signal. Analysis then proceeds to calculate the peak-to-peak voltage values of each of the three phase differences together with an order spectrum for each voltage phase difference.




Isolated Potential Divider

The screen-shot below is typical of that presented at test time showing order spectra for each phase difference together with peak-to-peak (PtP) voltages (including PtP normalised by the rotational speed i.e. V/Hz). If any tested feature for each phase fails a user-defined pass/fail limit the background to the order spectrum spectrum is colour-coded red.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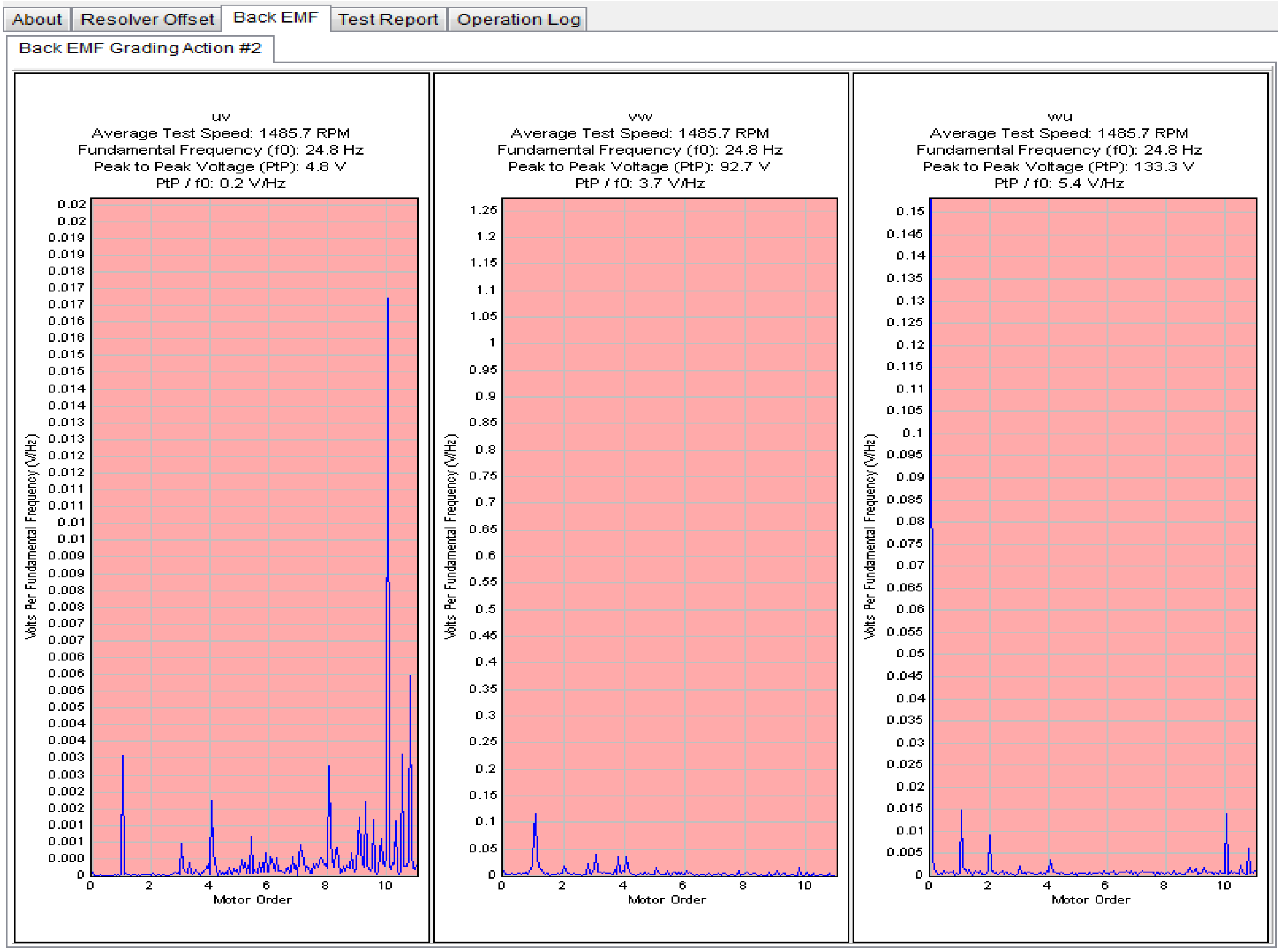
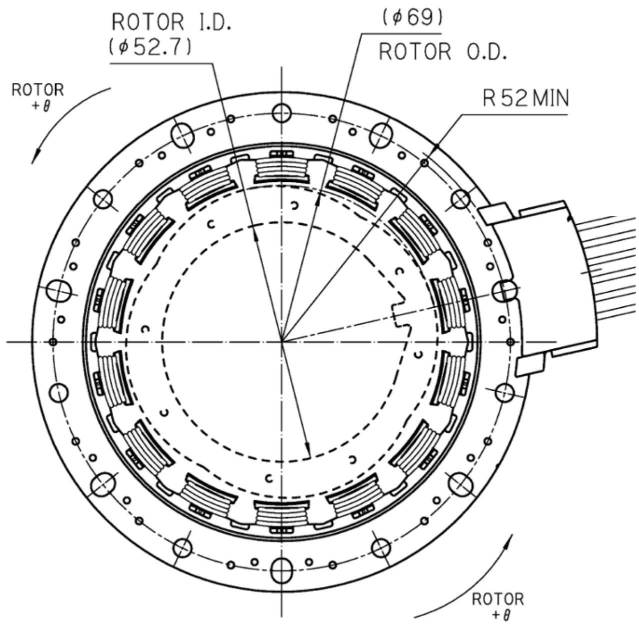



Results are then summarised in the usual PLATO html-format test report and, if required, transmitted to the test machine controller (PLC) via OPC for display on the machine´s HMI etc. By default, pass/fail limits may be placed on the fundamental rotation order plus harmonics thereof up to x10. Excessive harmonic levels can be an indication of poor winding quality. Red/green shading provides a clear indication of features that have passed/failed.

TEST STAGE RESULTS:Back EMF Measure

**MOTOR BACK EMF**

| PARAMETER NAME | Thermal Coeff [mT] | Fund Freq [f0] | Measurement | Value (V) | Value/f0 (V/Hz) |
|---|---|---|---|---|---|
| uv | 1.0000 | 24.7617 | Peak to Peak | 4.7623 | 0.1923 |
| | | | Fund x1 Amp | 0.0892 | 0.0036 |
| | | | Fund x2 Amp | 0.0115 | 0.0005 |
| | | | Fund x3 Amp | 0.0335 | 0.0014 |
| | | | Fund x4 Amp | 0.0314 | 0.0013 |
| | | | Fund x5 Amp | 0.0228 | 0.0009 |
| | | | Fund x6 Amp | 0.0050 | 0.0002 |
| | | | Fund x7 Amp | 0.0575 | 0.0023 |
| | | | Fund x8 Amp | 0.2200 | 0.0089 |
| | | | Fund x9 Amp | 0.3141 | 0.0127 |
| | | | Fund x10 Amp | 0.3472 | 0.0140 |



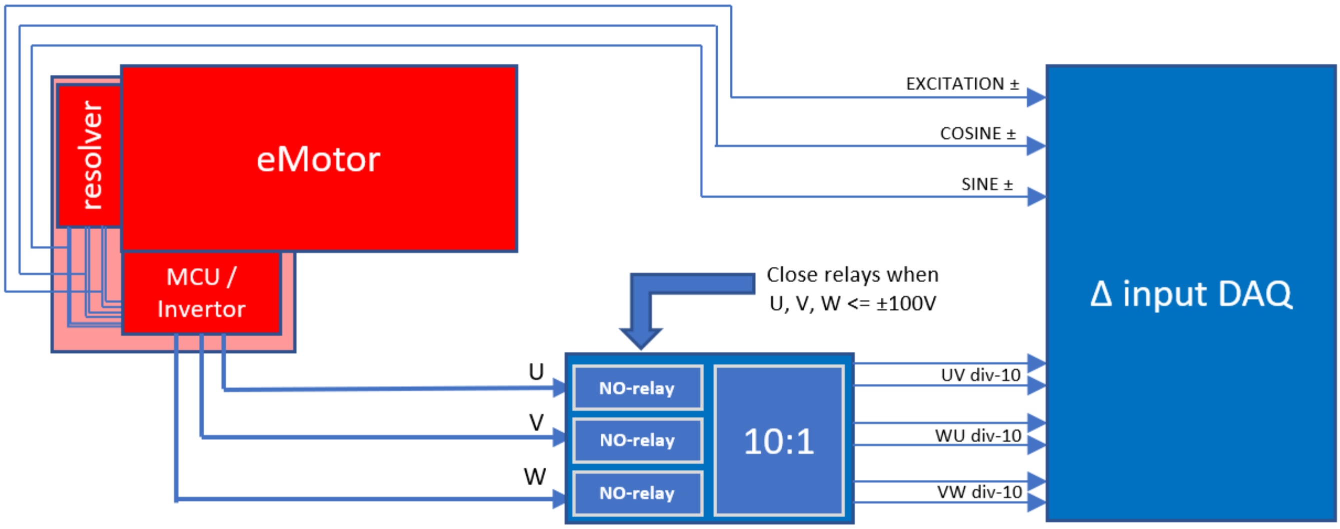

## Resolver offset angle and transformation ratio testing

Resolver modules are fitted to ePowertrain assemblies to provide precise angular feedback to the eMotor controller (MCU/invertor) to promote optimised and efficient operation of the eMotor. However, resolver modules are typically supplied with an angular tolerance that relates electrical output zero-degrees to physical (geometric) zero-degrees. So, when the resolver is mechanically fitted to an eMotor it is important to know the offset angle (difference in zero-degrees) between the resolver´s output and zero-degrees of the eMotor.

Zero-degrees of the eMotor can be determined by measuring and analysisng the (near) sinusoidal back-EMF waveforms generated when the eMotor is rotated. The voltage measurement set-up (using an isolated voltage attenuator) is therefore very similar to that used for back-EMF testing.

Zero-degrees output from the resolver can be determined by measuring and analysing the raw resolver signals (SINE, COSINE and EXCITATION). Intercepting the raw resolver signals is paramount to avoid other potential angular offsets that might be introduced by hardware such as resolver-to-digital convertors.

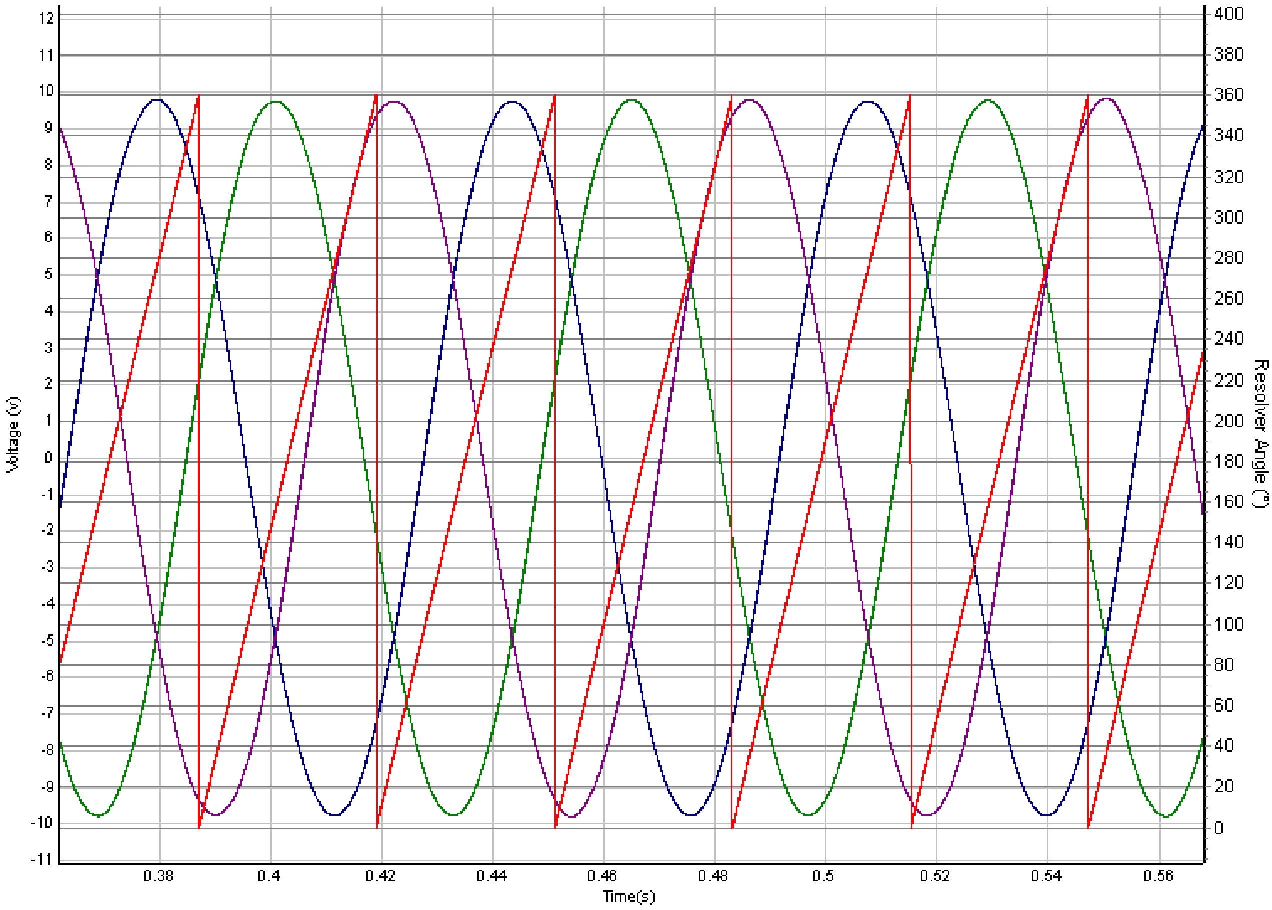
Resolver transformation ratio is a measure of resolver output signal strength. All transformer based devices output signals whose amplitudes are smaller than the amplitudes of the input (excitation) signal. Transformation ratio is simply the (output/input) value for each of the resolver outputs (SINE and COSINE).




Isolated Potential Divider

Testing typically takes place with the eMotor rotating at a fixed speed in the range 250-1000 RPM. The voltage differences across each of the eMotor windings are sampled simultaneously with the raw resolver signals. Analysis then proceeds to calculate the resolver offset angle and the transformation ratios for each resolver outut.

The screen-shot below is typical of that presented at test time showing measured voltages for each phase difference together with the calculated resolver anagle.




Results are then summarised in the usual PLATO html-format test report and, if required, transmitted to the test machine controller (PLC) via OPC for display on the machine´s HMI etc. Pass/fail limits may be placed on the offset angle and each of the two transformation ratios. Red/green shading provides a clear indication of features that have passed/failed.

TEST STAGE RESULTS:Resolver Offset Measure

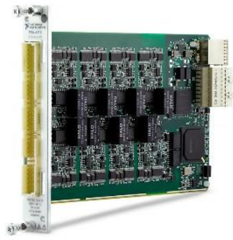
**RESOLVER CHARACTERISTICS**

| PARAMETER NAME | MIN (°) | MEAN (°) | MAX (°) | SINE XFORM RATIO | COSINE XFORM RATIO | PASS/FAIL |
|---|---|---|---|---|---|---|
| Parameter #1 | 22.7817 | 23.6664 | 24.1291 | 0.2859 | 0.2857 | PASS |

## Channel counts and DAQ-hardware

An 8-channel, differential analogue input DAQ-system is typically required to perform all the tests outlined above.

### 8-channel system

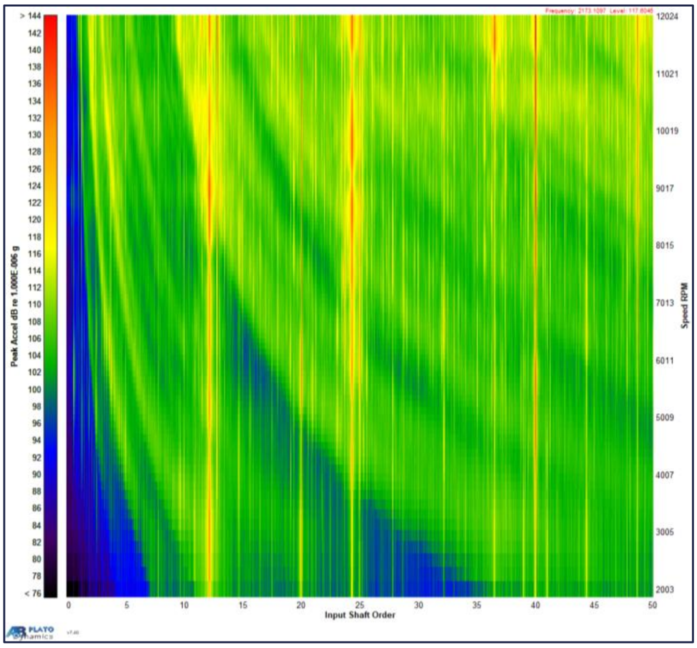
| Channel | Measuring | Recommended DAQ-hardware |
|---|---|---|
| 1 | UV back-EMF (div-10 via IPD-101) | National Instruments **PXIe-4310** plug-in, differential input DAQ-card, 400kHz/channel. Other options, including a plug-in PCI-express card are available – contact NVH International for more information.  |
| 2 | WU back-EMF (div-10 via IPD-101) | |
| 3 | VW back-EMF (div-10 via IPD-101) | |
| 4 | | |
| 5 | Resolver – EXCITATION | |
| 6 | Resolver – SINE | |
| 7* | Resolver – COSINE | |
| 8* | eMotor N PPR (via RSI-101) | |

## PLATO – "one stop shop"

PLATO from NVH International is a PC-based, multi-channel hardware/software system solution, primarily designed for measuring noise/ vibration ("NVH") signatures from rotating machines such as automotive powertrain assemblies.

Adding eKIT to an ePowertrain NVH test system therefore allows NVH testing and eMotor/resolver characteristics/performance testing to be conducted by the same test station if required.

(Please refer to separate datasheets for overviews of the generic PLATO NVH measurement & analysis system and its application to ePowertrains).




## Pedigree

Many vendors can supply NVH measurement & analysis systems, but PLATO from NVH International is designed, developed and supported by engineers who:

- liaise with ePowertrain engineers, daily, worldwide
- understand ePowertrain designs
- understand the manufacturing processes involved
- have first-hand experience of where manufacturing can go wrong and how this translates into noise/vibration output

Please ask for a copy of our PLATO installation reference list.

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