Vector Measurement Solution
HV Measurement with vMeasure exp

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Vector Measurement Solutions

Vector and CSM Partnership

**VECTOR**
- Industry leader in automotive tools and software engineering

**CSM**
- German manufacturer of outstanding measurement technology for data acquisition
- Specialist for distributed measurements in mobile applications
- 100,000 modules in use today

Partners since 2015
Vector Measurement Solution: The Best of 2 Worlds

- **Measurement Hardware**
  - CSM Mini Modules
  - CSM EtherCAT Modules
  - CSM High-Voltage Modules

- **Measurement Software**
  - Measurement Software: vMeasure exp
  - Data Analysis Software: vSignalyzer
  - Data Mining and Data Management (Cloud/Enterprise): vMDM
  - High-End Data Loggers: vMeasure log

- **ECU Access Interfaces**
  - The tools from Vector and CSM allow all automotive technology to connect seamlessly

- **Bus Interfaces**
  - Measure signals from all automotive busses synchronously: CAN, LIN, CAN-FD, FlexRay, Ethernet
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CAN MiniModules

- **Measurement** modules for the acquisition of a variety of physical signals
  - Temperature (Type K / J / T, RTD100 / RTD1000)
  - Voltage
  - Pressure
  - Current
  - Acceleration (ICP)
  - Strain
  - Distance
  - Frequency, period, PWM, revolution, pulse duration, pause duration, event counting, ...

- **Output** modules to generate signals based on CAN values: Voltage, frequency, PWM
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CAN MiniModules - Key Features Overview

- Designed for distributed measurements in the engine compartment
  - extremely compact and robust
  - for environmental conditions IP65 / IP67
  - for operating temperatures from -40 °C to +125 °C

- Very good accuracy over the entire temperature range

- Galvanically isolated inputs up to 500 V DC:
  - channel / channel, channel / CAN and CAN / power supply

- Wide power supply range: 5.5 V to 60 V
  - for cars, trucks, 48 V on-board supply systems, even during cranking
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Housing Versions

CS – Case Small
CL – Case Large
SCS – Slide Case Small
SCL – Slide Case Large
TCL – Tough Case Large
Beyond CAN – The Ethernet Approach

- Generally recording of measured values ≥10 kHz
- Measurement of many channels with 500 Hz and more?
- Accurate time-synchronous detection
  - Of all physical measured variables
  - Of physical variables and
  - ECU variables
- Distant measuring points
EtherCAT Protocol for Measurement Modules

- Ethernet-based fieldbus system developed by Beckhoff Automation
- Standard Ethernet (IEEE 802.3) without modifications
- Short data update times (100 µs), Ethernet packets or frames
- 90 % bus load possible, 100 Mbit/s

**Benefits:**
- Precise time synchronization between all signals
- Huge number of signals at moderate speed
- Support of high data rates – up to 1 MHz/channel
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High Speed Measurement

- Sampling rate per channel up to 1000 kHz
- Time synchronization signal to signal better 1μs
High Channel Count

- Analysis of fatigue (stress) points
- Distances over 300 m on one crane
- > 1,000 strain gauges on one crane
Measurement Setup for ECAT- & CAN-Modules

- ECAT
- ECAT
- ... 
- THMM
- ADMM
- LCANc, DashCANc
- HV THMM
- PTMM, CNTMM, OUTMM

vMeasure Exp, CANape

XCP on Ethernet

CSM XCP-Gateway

EtherCAT
CSM High Voltage Measurement Modules

HV MiniModules CAN and EtherCAT®
- For mobile use - extremely compact, very robust and precise
- For installation close to the sensors
- IP 67, -40 °C to +100 °C

HV modules for rack mounting
- Ideal for high channel counts
- As precise as the HV MiniModules
- Use the same modules in test benches and in vehicles
- IP 65, -40 °C to +85 °C
Safe Measurement in High Voltage Environments

High-Voltage Measurement Application

Battery testing in vehicles as well as in test stands at Daimler, BMW, Audi, Porsche, VW

- Using our HV Test Bench Modules
- Thin-film PT-elements between cells
- Thermocouples type K
- Humidity
- Strain
- Vibration, shock
- Pressure
- Cell voltages
Use Case: Temperature, Humidity and Pressure Measurements in Batteries

**Use Case**
- Monitoring temperature balancing of each cell
- During charging, discharging, recuperation, cold start, etc.
- Verifying the BMS, heating and cooling system
- Detection of unwanted humidity and pressure inside the battery

**Challenge**
- Typ. 60, up to 100 temperature sensors per battery (400 V battery)
- Testing both in the lab and on the road

**Solution**
- HV measurement technology from CSM including also IEPE and Strain gauge
- PT100/PT1000 RTD sensors, foils ≤0.6 mm
- Mechanically robust to apply between battery cells

**Advantages**
- Robust, scalable and decentralized measurement
- Same equipment in lab and on the road when mounted in a rack
- Synchronous recording of all signals with vMeasure exp, also from control units or vehicle buses
HV Thermocouple Cable
System Overview

Vector Measurement Solution

HV CAN Modules

CAN MiniModules

Exhaust Gas Measurement

CSM data logger

Vector data logger

vMeasure log

vMeasure exp

XCP-Gateway

ECAT MiniModules

HV Breakout-Modules

HV ECAT MiniModules

CAN

EtherCAT®
CSM High Voltage Measurement Modules

**HV ADMM 4 HS**
- 4 analog inputs with reinforced insulation
- Measurement data rate up to 1 MHz per channel
- Measurement range adjustable per channel
- Type XW: up to ±1,000 V (extended up to ±2,000 V)
- Type OW: up to ±90 V
- Precise synchronization (modules & channels)
  - Important for calculation of electrical power, etc.
HV Breakout Modules (BM)

- For in-vehicle testing
- For dynamometer measurements
- Safe measurement of voltages up to 2 kV
- Safe measurement of currents up to 1.4 kA
- CAN and ECAT output, up to 1 MHz
vMeasure exp

- vMeasure exp is a flexible measurement software solution for reliable acquisition and efficient evaluation of measurement data.
- vMeasure exp supports
  - CAN-based measurement hardware
  - XCP on Ethernet based measurement hardware
  - DAIO interface for the individual support of other measurement hardware
  - Audio, video and GPS devices via USB
  - ECU interface with protocol XCP on CAN, LIN, FlexRay and Ethernet
- Signal acquisition on automotive bus systems and via OBD-II
- Intuitive configuration of the connected CSM measurement hardware
- Various options for visualization of measurement values
- Storage of the measurement data in standardized ASAM MDF format
Live Demo
Vector Measurement Solution

Fast HV Automotive Measurement

1. E-Motor
2. HV Battery
3. Power Electronics
4. HV Distributor
5. Compressor
6. Quickcharge Unit
7. OnBoard Charger
8. PTC Heater
9. DC/DC Converter
Today's questions

- **Overall EV validation, verification and compliance**
  - As an OEM, how can I guarantee that the overall system works? Is it robust?
  - What is the effect of high current pulses and peaks in real driving scenarios?
  - How does a component modify the DC quality worst case?
  - How do 2 e-motors interact on the power lines in real driving scenarios?
  - How does the HV network behave in real driving conditions? In accidents? Under water?
  - How big are the currents on the shielding of the HV cables and is guaranteed that they don’t burn?

- **Optimization**
  - Which Vehicle Control Unit algorithm and which inverter function increases the efficiency and with that, the range? 2% better efficiency can result in 4% more range!
  - What effect have new technologies for heating and cooling on increase in range?
  - What is the effect of new semiconductor materials (Siliziumcarbid, Galliumnitrid) in power electronics, on board chargers or DC/DC converters?
  - What temperatures are present in real-life in the windings of the e-motor, in the power electronics, in cables and plugs and under which conditions?
Conclusion

Challenge

- Electric engines are an established technology. Little surprises.
- The battery is crucial both for range, weight and safety
- The by far biggest complexity comes with
  - Dynamic effects on the power line that all consumers share
  - Fast switching of power electronics
  - Induced currents, the resulting distortions and temperatures
  - Sophisticated control mechanisms of the ECUs

Consequences

- You need analog measurements (temperatures, pressure, strain,...)
- You need high-speed measurements of currents and voltages (at least 1 MS/s)
- You need many of these high-speed measurement points (between all components)
- You need the capability to analyze efficiency, peak-to-peak, deviation etc. during runtime. Not as post processing
- You need ECU measurement and Bus Signal measurement on the same timeline. Absolute time-synchronous
Analog Measurement Modules from CSM
- Mobile measurement of physical values
- Robust and reliable

- High Voltage Measurement Modules from CSM
  - HV safe measurement of physical values
  - High voltage and current measurement @ 1MS/s
  - Completely synchronous across many channels

- Bus and ECU Measurement Interfaces from Vector
  - Measure values from all automotive bus systems
  - Measure values from inside the ECU

- Software: vMeasure or CANape
  - Collect all data from all sources synchronously with >2GB/s
  - Precise online calculation of P, S, Q, λ, peak-to-peak, FFT, ...
  - Use calculated values for triggering or further online analysis
Use Case
- Check voltage ripples (LV123 regulations)
- Validate DC quality

Challenge
- High channel count of signals with 1 MS/s
- Direct feedback to the test driver necessary
- Need for complex mathematical operations as trigger conditions
- High accuracy and absolutely synchronous to ECU measurements

Solution
- HV measurement technology, 1 MS/s per channel
- Synchronous data acquisition and recording with vMeasure log
- Online calculation of derivatives*, FFT*, VW 80303 criteria with vMeasure exp
- Triggering on all measured and calculated quantities

Advantages
- Efficient and reliable validation with instant feedback
- Synchronous recording of CAN, CAN FD, FlexRay, Ethernet and ECU signals

* planned
Feature Set Vector eMobilityAnalyzer

**DC Analyzer**

- Voltage and current
  - DC component $U$ and $I$
  - RMS voltage and current (true RMS, no gaps)
  - Peak-to-peak values
- Power
  - Active power
  - Electrical work
  - Total input charge flow (Ah)
  - Total output power flow (kWh)
  - Efficiency $P_{\text{out}} / P_{\text{in}}$

All calculated signals take input signals up to 1 MS/s and are available for synchronous recording, triggering and as input for further calculations or evaluations.
Use Case
- Recording power during drive testing
- Highly accurate and absolutely synchronous

Challenge
- Detection U, I with 1 MS/s necessary
- Precise determination of the electric frequency
- Triggering on calculated power quantities

Solution
- HV measurement technology from CSM, 1 MS/s per channel
- Data collection and recording with vMeasure log
- Fast and accurate determination of electric frequency
- Online calculation with vMeasure exp ePowerAnalyzer functions

Advantages
- Fast and flexible determination of efficiency
- Synchronous recording of CAN, CAN FD, FlexRay, Ethernet and ECU signals
Complex Power in AC

- Power in AC is a complex number. It looks like a triangle.
3 Phase Power-Analyzer

- Power
  - Active, apparent and reactive power
  - Instant power for all phases, electrical work (kWh)
  - Power factor $\lambda$
- Voltage and current
  - RMS voltage, RMS current
  - Current phase frequency
- Y-$\Delta$ transformation
- $d/q$ transformation: $I_a$, $I_\beta$, $I_d$, $I_q$

All calculated signals take input signals up to 1 MS/s each and are available for synchronous recording, triggering and as input for further calculations or evaluations.
Challenges of the software:

- Calculation of power requires $T$
- Need for immediate calculation instead of long integration period
  - $T$ is also input for many formulas
  - Results can be part of trigger conditions
    - Very fast and predictive algorithm needed
- Signal has a lot of noise
  - Algorithm has to deal with multiple zero-crossings
  - Simple detection ($if > 0$) is not sufficient and and ends up in noisy calculation results
- Vector vMeasure and vMeasure log can calculate dozens of zero crossings and formulas on multiple 1 MS/s channels simultaneously and is perfectly time synchronous to ECU and bus data
- Functionality is available as eMobilityAnalyzer function library in vMeasure and CANape
- Function Library can be extended by customer or Vector

$$\text{Power} = \sqrt{\frac{1}{T} \int_0^T (U(t) \cdot I(t))^2 \, dt}$$
For more information about Vector and our products please visit

www.vector.com

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