

CASE STUDY

United States of America

TI Group Automotive Systems LLC Noise and Vibration Testing on Fuel Pumps

Automotive

PULSE, Transducers

TI Automotive is a tier-one supplier of fluid storage and delivery systems for fuel, brake, powertrain and air-conditioning applications. This total systems capability, combined with advanced technology and a global presence, makes TI Automotive a leading supplier to automotive manufacturers around the world.

The TI Automotive Global Test Group facility at Caro, Michigan uses two PULSE™ systems for noise and vibration testing of its complete fuel storage and delivery systems, and components.



Leading Global Tier-one Supplier

TI Automotive is a leading global tier-one supplier of fluid storage and delivery systems. Over half of the 52 million cars that are built worldwide rely on TI Automotive brake, fuel and powertrain technology. Change, Progress and Innovation – these are the three words that are the driving force behind the TI Automotive business philosophy. Whether delivering complete systems or state-of-the-art components, TI Automotive satisfies the most stringent customer requirements anywhere in the world.

The company employs some 20 000 people at over 150 facilities in 29 countries across Europe, North America, Latin America and Asia Pacific.

TI Automotive has strengthened its applications engineering teams, invested in state-of-the-art technology and built a network of “Just-In-Time” satellite assembly facilities around the world. These capabilities, together with an extensive product range, offer automotive manufacturers complete brake, fuel and powertrain fluid storage and delivery solutions.

Quality

TI Automotive's customers not only set themselves tough quality standards – they also expect the same from their supply partners. TI Automotive is dedicated to becoming a globally preferred supplier by achieving total customer satisfaction. Its commitment to quality is demonstrated around the world – its sites are certified to a variety of international quality system standards including ISO 9000, VDA 6.1, EAQF, QS 9000 and the latest TS 16949.

Global Test Group

TI Automotive's Global Test Group supports the company's world-class components and systems with its laboratories all over the world. Primary facilities are located in Auburn Hills and Caro, Michigan and Rastatt in Germany. There are additional 'satellite' engineering laboratories in Connecticut (USA), France, Germany, Brazil and Japan.

Extensive testing is conducted on all fuel and brake, HVAC, fuel storage and delivery components and systems, using state-of-the-art facilities – from fuel lines through to complete fuel system and vehicle testing, to ensure conformance to the latest regulations. Many of TI Automotive's test labs have been granted ISO 17025 accreditation. This highly regarded and stringent quality system ensures that the company's testing is repeatable and reliable with equipment traceable to National Standards and conducted by qualified personnel. Its in-house testing capabilities give TI Automotive the 'edge' in helping its customers get to market faster and more reliably than its competitors.

Fuel Storage and Delivery Systems

From Filler Pipe to Fuel Rail

TI Automotive provides a comprehensive product line of fuel storage and delivery components, integrated into total solutions that address automotive OEM requirements. TI develops and validates systems that meet the constantly changing regulatory requirements, targeting customer needs for a competitively priced, high-value systems solution.

*Fig. 1
TI Automotive
Systems
manufactures a
range of electric
fuel pumps for the
automotive
industry*

The product range includes:

- Turbine and Gerotor fuel pumps
- Emission compliant tank designs
- Integrated fuel delivery modules
- Fill and Vapour control valves
- Electronic control modules
- Fill pipes



TI Automotive's fuel delivery module assemblies incorporate fuel pumps, reservoirs, fuel filters, level senders and pressure control devices. Some 1 million fuel pumps are manufactured each year of which about 295 000 pumps are manufactured at the Caro facility by 220 employees. The latest production technologies are used, including a Brüel & Kjær based production test system that ensures consistent quality products and high productivity.

Test Facilities

*Fig. 2
The NVH
characteristics of a
car's electric fuel
pump are analysed
in the hemi-
anechoic chamber*



The NVH test laboratory at Caro was built about 12 years ago. TI Automotive's policy is to continually expand and upgrade its test facilities. The hemi-anechoic room is large enough to accommodate a complete vehicle. Smaller anechoic chambers are available for testing components.

The test lab is not only used to test fuel delivery products made at the Caro plant. It also tests products from TI Automotive's production sites from around the world. Testing requirements are continually growing and TI Automotive's OEM customers are demanding increased levels

of test data, and specifications and regulations around the world that relate to fuel delivery systems are constantly increasing.

Testing Expertise

There's a wealth of sound and vibration expertise at Caro – continued demonstration of TI Automotive's commitment to thoroughly testing its products.

*Fig. 3
Left to right:
Kirk Doane, Eric
Netkowski and
Brian Kukla*



Kirk Doane is a Test Engineer, Release Engineering. Kirk has a Bachelor's degree in computer science and avionics. He's worked at TI Automotive for 15 years. Kirk explains, "I am really the NVH lab's customer. I'm the 'interface' between R&D and the test lab – it's my job to ensure that all our products meet their high specifications before being put into production".

Kirk continues, "I was closely involved in the decision to buy PULSE. Brüel & Kjær's reputation was an important factor in our decision. We wanted an analyzer of high quality and reliability, that was easy and intuitive to use, and it was clear that a PC-based platform was the way to go".

Eric Netkowski is a Senior Technician, Global Test Group, in the NVH Laboratory. Eric has a degree in mechanical engineering and is currently working towards another degree. Eric says, "I have worked at TI Automotive for over 2 years. My work is concerned with testing complete fuel delivery systems in vehicles, testing components and off-site testing at our OEM customers". Eric continues, "Caro is an ideal location as we

are strategically placed to serve the major automotive manufacturers around the Detroit area”.

Brian Kukla is also a Senior Technician, Global Test Group, in the NVH Laboratory. Brian has worked at TI Automotive for 2 years and is currently studying for a degree in his specialised fields of fluid systems and electronics. Brian explains, “My prime responsibilities are to ensure that we get reliable and consistent test data, to ensure the use of ‘best practices’ in our data acquisition, and to develop our electronics and IT resources that we use in the NVH lab”.

PULSE

*Fig. 4
Brian Kukla works
with PULSE inside
the hemi-anechoic
chamber*



Kirk says, “TI Automotive has used Brüel & Kjær products for more than 15 years, and they have proved themselves to be completely reliable. So, we bought our first 8-channel PULSE analyzer 2½ years ago”. He continues, “This was quickly followed by a 4-channel portable PULSE system. It’s very useful when we make tests at our customers’ premises. We also use it with a laptop PC for in-car testing, either at a test track or on public roads, and of course we can take the complete data acquisition system to any of our production facilities – it very compact and versatile”.

Eric explains, “Temperature and atmospheric pressure have significant effects on the performance of fuel delivery systems. We can take a complete vehicle to a testing facility in Arizona, and we take our PULSE system with us”.

Brüel & Kjær Microphones are used exclusively. TI Automotive also uses a range of accelerometers, both single axis and triaxial. Eric continues, “We use Brüel & Kjær Calibrators – a Type 4294 for the accelerometers and a Type 4231 for the microphones, and we calibrate the transducers before every test”.

Kirk adds, “We get excellent back-up, service and support from Brüel & Kjær’s office in Livonia (Detroit). If a component requires calibration, then we get the loan of a replacement while it’s away, so we can keep on testing”.

Brian says, “PULSE is really easy to use. We developed our own templates for routine, repetitive tests and the TEDS (Transducer Electronic Data Sheet) facility built into the transducers reduces the setup time and the risk of a mistake being made”.

TEDS and IEEE1451.4 Support

The IEEE 1451 Smart Transducer Interface Standards describe an open, common, network-independent communication standard for Smart transducers. The IEEE 1451.4 defines a Mixed Mode Interface for analogue transducers with analogue and digital operating modes. A Transducer Electronic Data Sheet (TEDS) is added to a traditional two-wire, constant current excited transducer containing a FET amplifier. The TEDS contains a minimum of pertinent data stored in a physically small memory device, as

required by tiny sensors. Access to the data in the TEDS template is available via a TEDS Editor Kit or by Control Software Packages for conditioning amplifiers that support IEEE 1451.4 (i.e., NEXUS, Oasis and 16-channel Conditioning Amplifier Type 2694) or by PULSE.

The advantages of a system containing TEDS include:

- Elimination of cabling and connection errors
- Identification and specification using digital communication
- “Plug and play” technology for acoustic and vibration testing
- Reduction of setup time
- Simplification of calibration databases

Testing

Brian says, “As a major tier-one supplier, we work very closely with our customers who are the world’s major automotive companies. Our products range from individual components, to modules, sub-assemblies – right through to complete solutions”. Brian continues, “This means that we make systematic tests on everything from a single item to a full prototype or production vehicle”.

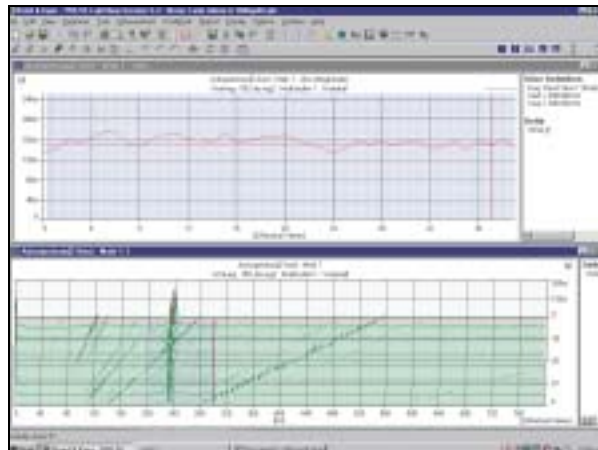
Tests must be repeated using a wide variety of fuels, including diesel. Brian says, “For example, the gasoline available in Brazil is different to gasoline in Europe”.

The test data from the NVH Laboratory is:

- R & D – TI Automotive uses the test data extensively in R & D applications on new product development
- End-of-line production testing
- Batch testing – to check the quality and reliability of its existing products
- Benchmark testing of competitors products
- Durability testing (e.g., vibration, pressure pulse, flow)

Brian continues, “We sometimes develop the NVH specifications for our fluid delivery systems ourselves but, in most instances, we work closely with our customers. We have very open relationships with the automotive manufacturers and this is the way we like to work”.

*Fig. 5
A waterfall display
with slice showing
pump resonance*

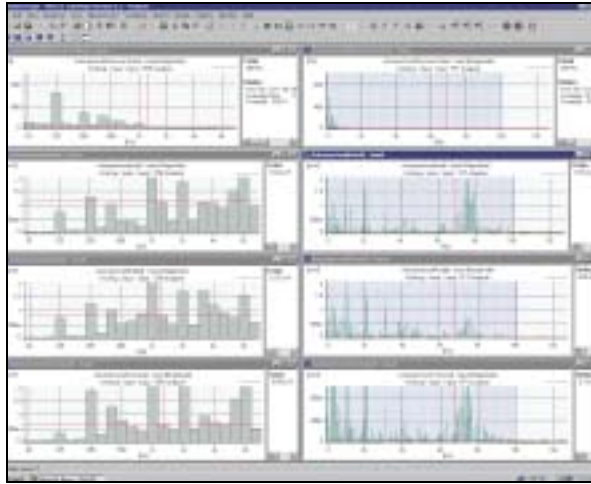


Typical Tests

Low-frequency humming was noticed on a fuel pump. Using a small anechoic chamber, PULSE was set-up with one microphone and one accelerometer. The pump was run at voltage steps from minimum to maximum. Using a waterfall plot in the PULSE display, the resonance frequency of the pump could be identified. A slice was extracted and this showed that the resonance frequency did not vary with changes in the pumps operating voltage.

An average measurement takes about 10 minutes. In this example, the pump was run using 40 voltage steps from 9 to 15 volts. This is the normal operating range. For a typical measurement 4 to 6 channels are used.

Fig. 6
1/3-octave CPB analysis of a pump's pressure pulse and its axial, radial and torsional properties



Brian says, “The fuel pump must be operating for the engine to run, so reliability is vital and we have to consider all operating circumstances. We have developed in-house software to monitor the current drawn by the fuel pump. We use the 8th order of the FFT (500 to 600 Hz) to calculate the engine RPM and it’s accurate to within 8 rpm. The pump power supply voltage is very accurate and it’s controlled through the RS-232 port of the PC. Our pumps typically use 4 to 8 amps”. He continues, “The frequencies of interest are from about 70 Hz up to 10 kHz but most of our analysis is below

3.2 kHz. We know that pump regulators can generate broadband noise between 200 to 400 Hz so we make sure that this does not affect the accuracy of our measurements”.

Pump noise is measured on a complete vehicle that is placed in the hemi-anechoic room. Generally, two microphones are used – one is placed by the driver’s headrest while the second is located close to a passenger’s headrest in the rear of the car. Tests are made with both the vehicle engine running at idling speed and also with only the fuel pump running. Eric says, “At 30 dB(A) the noise from the pump is just noticeable. We normally see 31 to 35 dB(A) on our pumps and we don’t want to see noise figures above this level”.

Eric continues, “Examples of other types of tests include the use of an accelerometer connected to PULSE to check the natural resonance frequency of a fuel tank, or to check if there is a vibration hotspot. We also use a modal hammer and accelerometers to check the resonances of a complete vehicle. These frequencies can resonate with components in our fuel delivery systems. When we have acquired accurate data, then we can either change the design of our product or suggest possible changes that could be made to the vehicle. Again, this is where the very close relationship with manufacturers is a real benefit”.

Sometimes it’s necessary to get a subjective opinion when comparing different sounds. The sound is recorded as a wave file and played to a jury of TI Automotive’s employees who work in areas other than NVH testing. “It’s useful to have the results of our objective analysis confirmed by human ears”, says Brian.

Accreditation

In the near future, the NVH Laboratory at Caro will be accredited to A2LA. The preparation work is well under way. When granted, the TI Automotive NVH lab will join a select club of about 20 NVH laboratories in the USA that have been granted this prestigious A2LA accreditation.

Reporting and Data Handling

Test data is archived on CD-ROM. Reports are made using the Microsoft® Office suite (Word and Excel). The reports are placed on the database enabling R & D, production departments, etc., all over the world to access the test results. Data from a previous test is often accessed for a comparison with a new test.

Eric says, “One of things that I especially like about PULSE is the data export facility to the Microsoft® Office suite. It’s easy, quick and effective. We used to run on Windows NT® – now we use Windows® 2000”.

The Future

Fig. 7
Left to right: Eric Netkowski, Brian Kukla and Kirk Doane work in TI Automotive's NVH laboratory



Kirk concludes, “PULSE has been a real benefit in our NVH testing. We sure made the right decision and knowing that the data is accurate and repeatable not only gives us confidence but also our customers. The need for testing is constantly increasing and there’s no doubt that we’ll invest in further Brüel & Kjær solutions”.

Key Facts

- TI Automotive is a leading global tier-one supplier of fluid storage and delivery systems
- The company employs some 20 000 people at over 150 facilities in 29 countries across Europe, North America, Latin America and Asia Pacific
- TI Automotive's Global Test Group supports the company's components and systems with its laboratories all over the world – a primary facilities is at Caro, Michigan
- The fuel storage and delivery product range includes turbine and Gerotor fuel pumps, tanks, fill and vapour control valves, electronic control modules, fill pipes
- TI Automotive has used Brüel & Kjær products for more than 15 years
- Two Brüel & Kjær PULSE systems are used in the NVH Testing Laboratory at Caro
- TI Automotive uses Brüel & Kjær Accelerometers, Microphones and Calibrators
- TI Automotive gets excellent back-up, service and support from Brüel & Kjær's office in Detroit
- “PULSE is really easy to use”
- Accurate and repeatable data gives confidence to TI Automotive and its customers