

Real-Time OS with Intel® Core™ i7 Processors Enables High-Performance Automotive Test Systems

White Paper

Automotive Design
Simulation & Testing



AVL uses a multi-core Intel® processor platform to partition resources with TenAsys, INtime* for Windows, a real-time operating system with an easy-to-use Microsoft Windows* human interface.

The automotive industry is challenged to maintain a difficult balance between competing requirements: fuel efficiency, emissions, drivability, reliability, and cost efficiency. Tightened regulations have forced vehicle manufacturers to develop new technologies such as hybrid powertrains. These factors contribute to the increasing complexity of vehicle designs and produce the need for more sophisticated testing methods during the development process to ensure that design goals are met.

As testing becomes more complex, test systems need to process and control an increasing amount of data in real time, requiring substantial compute power and advanced interfaces to set up the tests, all of which must operate in real time. In addition, a significant amount of time and money can be saved by integrating simulation models instead of real vehicle components, creating more significant compute demands.

Test system manufacturers such as AVL List GmbH need to build flexibility and high performance into their products to meet this challenge. AVL uses a multi-core Intel® processor platform that run on a single system to partition resources between an easy-to-use Microsoft Windows*-based human interface and a real-time operating system, which provides the performance and deterministic response needed to run simulations of new vehicle hardware in real time.

AVL's solution includes the TenAsys INtime* real-time operating system, which was developed to support working with Windows-based systems to obtain maximum performance from an Intel® architecture platform.

Contents

| | |
|--|---|
| Test Applications Define Requirements | 3 |
| Application Needs Demand Multiple Operating Systems..... | 4 |
| Extending Analysis Capabilities with Mathematical Modeling | 4 |
| Using Simulation to Test CO ₂ Emissions Reduction Techniques..... | 5 |
| Pushing the Performance Envelope | 6 |
| Real-Time at the Core | 6 |
| Conclusion | 7 |

Test Applications Define Requirements

To test and qualify modern drivetrains, sophisticated test beds must be developed with the capability of testing overall system performance, as is done in endurance and emissions testing. But tests must also be executed on individual subsystems to ensure that they perform correctly. For example, electric motor testing and driveline testing. Modern test beds are computerized and capable of running tests in a stand-alone configuration or from a central control environment. The software that controls these systems must have the flexibility to adapt to the integration of system functions while managing the test environment in a seamless fashion.

The PUMA Open* automation system from AVL List GmbH, headquartered in Graz, Austria, was designed with this goal in mind. AVL is one of the world’s largest privately owned companies for the development, simulation, and testing technology of powertrains (hybrid, combustion engines, transmission, electric drive, batteries, and software) for passenger cars, trucks, and large engines. Due to its open system architecture, PUMA Open supports a broad array of AVL test components as well as third-party pieces if required, making all kinds of tests possible. PUMA Open coordinates the flow of all data, including sending instructions to set up the test bed and test sequencing, acquiring data, processing test data, and archiving test results. The system facilitates the execution of complex tests under the same conditions repeatedly, helping to ensure the quality and traceability of the results across many test units (UUTs) for certification purposes.

Figure 1 shows a test bed configuration consisting of the AVL PUMA Open automation platform with interfaces to the engine and load unit of the test bed and all participating devices and subsystems. Typical examples are measuring equipment for fuel consumption and emission benches, data acquisition modules with sensors for temperature and pressure, and media conditioning units. For special testing tasks, further system interfaces are used, for example, for Engine Control Unit (ECU) optimization with AVL CAMEO*, driveability evaluation with AVL drive systems, or combustion measurement with AVL IndiCom.*

A typical automated test running under the control of PUMA might consist of measuring the response of the drivetrain under a simulated load with the simulated atmospheric conditions that a vehicle is likely to encounter in the real world, such as driving uphill or downhill, accelerating, using an automatic or manual transmission, and so forth.

During testing, data must be captured from the ECU as input parameters such as load and throttle settings are varied. Information on parameters governed by the conditioning units – for example, water level, intake air quality, oil level, and fuel quality, is also input into the system. Precisely maintaining the time phasing of all inputs is critical to proper operation of the tests. To accomplish this, the data acquisition programs run on a real-time operating system that applies digital time stamps to the inputs and outputs. Test run execution, control, and simulation must also run in real time.

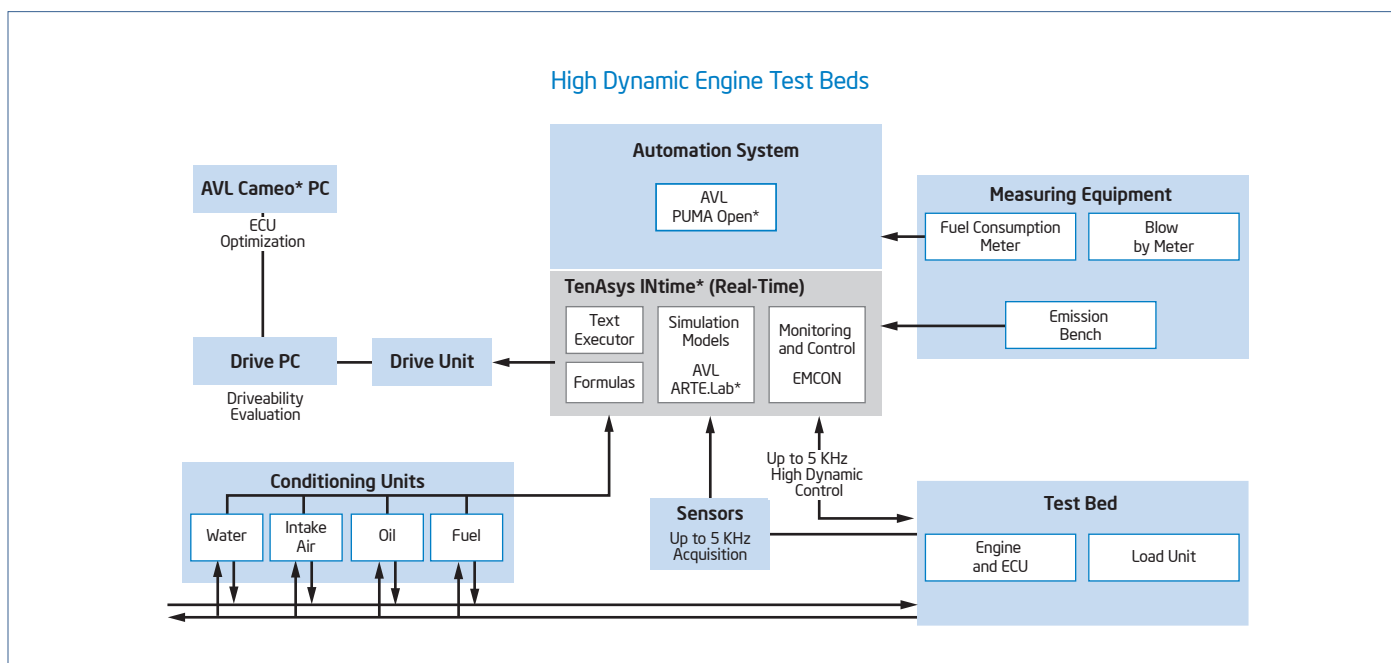


Figure 1. Typical test bed configuration.

Application Needs Demand Multiple Operating Systems

The AVL system uses Windows for implementing sophisticated operator interface controls (see Figure 2), but even running on the fastest processor, Windows by itself is incapable of guaranteeing that a signal from an outside device will be handled in a predictable amount of time. Therefore, establishing a cause-and-effect relationship between a combination of testing stimuli and the response of the system would be difficult or impossible if Windows were the only OS in the system.

AVL needed to supplement Windows with a real-time operating system (RTOS) that could run alongside Windows on the same computer, enabling Windows applications software to run while enabling the system to respond in real time to external events. Separate computer boxes could have been used for real-time and Windows processing in the test system, but this approach would have imposed cost and performance penalties compared to the single-hardware platform, dual-OS approach.

The RTOS that AVL uses for the PUMA Open system is TenAsys INtime. INtime is designed to ensure that real-time tasks are handled independently and not impacted by Windows task scheduling. The software does this by restricting the processing environment that Windows can control.

When run on the newest generation of multi-core processors, the AVL PUMA Open system uses an Intel Core i7 processor, INtime partitions real-time, and Windows tasks to run on separate cores, helping to ensure maximum performance for all software components of the system.

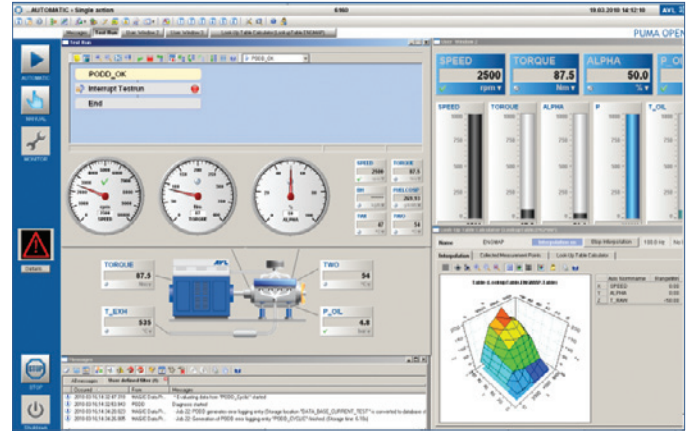


Figure 2. Operator interface controls are implemented using Windows.

Extending Analysis Capabilities with Mathematical Modeling

AVL's PUMA Open system can be used to predict the behaviors of certain components with the help of mathematical modeling. To do this, AVL offers an open simulation environment called ARTE.Lab* that uses MATLAB*/Simulink* software by The MathWorks for modeling of powertrain components (for example, engine and transmission), seamlessly integrating the models into the real-time environment of the AVL test bed. As shown in Figure 3, the simulation model is developed with AVL ARTE.Lab Studio SDK and MATLAB/Simulink and then compiled for the execution in INtime, resulting in a real-time application (.rta) that can be tested on the development PC and then transferred to the PUMA Open workstation to be executed in real time under the INtime RTOS on the test bed.

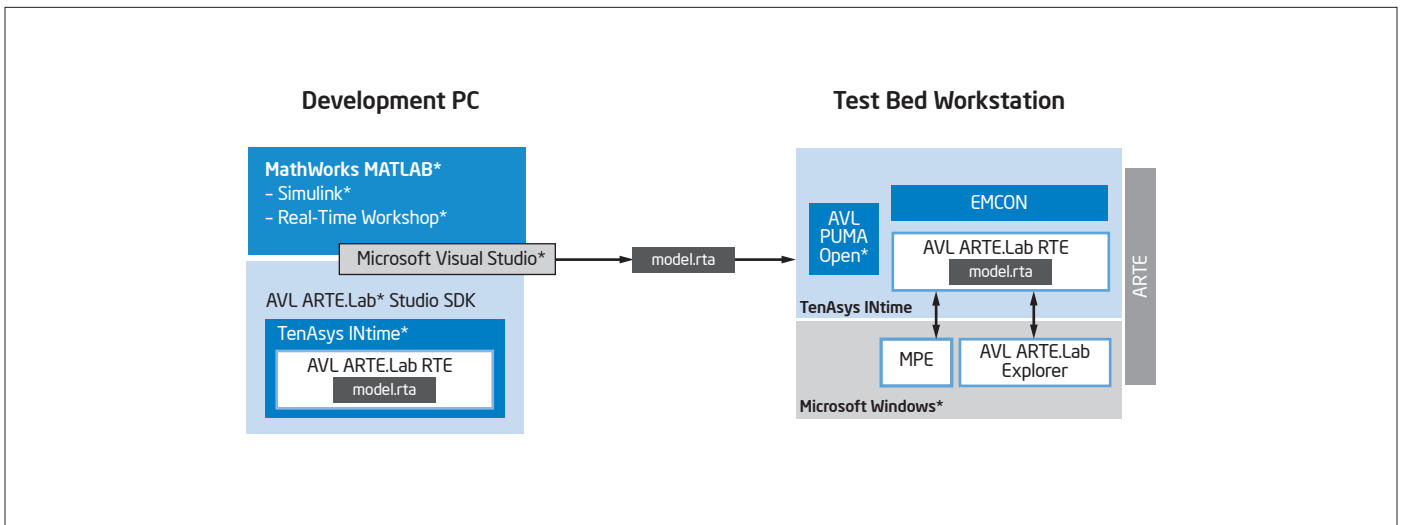


Figure 3. Simulink model is integrated into the AVL test bed.

This capability is particularly useful in monitoring and circumventing failure situations that potentially pose safety hazards. For instance, the monitoring and reaction of the automotive system to oscillations of the transmission shaft linking the engine to the load system (dynamometer).

Because the increasing complexity of engines and their control units leads to a higher probability of unpredictable malfunctions, the unexpected behavior of the unit being tested can excite the test bed's shaft connection. AVL's online shaft monitoring offers a solution to protect the shaft connection by detecting shaft overload caused by undesired oscillations, protecting the engine and dynamometer system. The need to respond to such conditions without delay underscores the requirement for software simulation and for running the Simulink-based ARTE.Lab algorithms on the RTOS. Figure 4 shows the real-time detection of a shaft overload condition during a simulated drivetrain test on an engine test bed.

Software modeling enables reliable monitoring during all states of operation, such as steady-state and transient as well as during engine start and stop. In manual and automatic (unattended) test bed operation, the state of critical systems in relation to the shaft load is detected in real time and can be stopped when oscillatory instabilities occur. Oscillatory instabilities might be caused by situations such as misfiring in one or more combustion chambers or operation at high idle.

Using Simulation to Test CO₂ Emissions Reduction Techniques

An effective way of reducing CO₂ emission is to stop the engine when the vehicle is at a standstill and idling, and then restarting it when the vehicle can move again. Manufacturers have been testing larger starter motors as well as experimenting with belt-driven starter/generators to assist the restarting, in an effort to implement a scheme whereby the motor is switched off automatically after the vehicle has been idling for a predefined period. Stopping and restarting the motor several times during the course of a journey means that the starter motor must be able to operate in the region of 10 to 50 times more frequently than normal. This in turn means that special starter motor and battery systems need to be developed and tested.

AVL has developed the means of simulating the engine load as seen by a starter with a simulation model in MATLAB/Simulink, which runs on the PUMA Open system using ARTE.Lab. The behavior of the starter/generator model can easily be optimized by modifying model parameters online on the engine test bed to arrive at the optimal fuel consumption. As a result, many more alternative configurations can be evaluated much more quickly at a lower testing cost than if real hardware was being used. Figure 5 shows how Simulink can produce realistic modeling of a starter motor when comparing an engine start process with a real starter motor (black) with one using a Simulink model for the simulation of the starter motor (red).

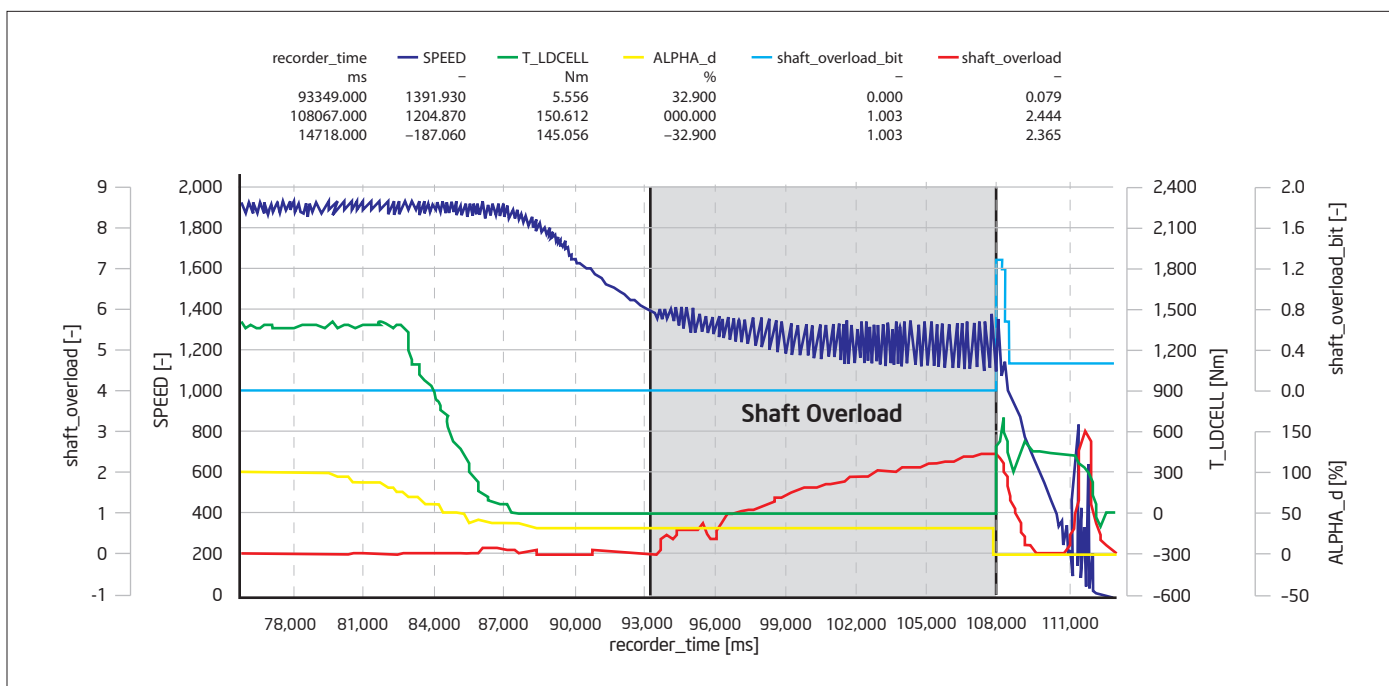


Figure 4. Simulated drivetrain test detects shaft overload in real time.

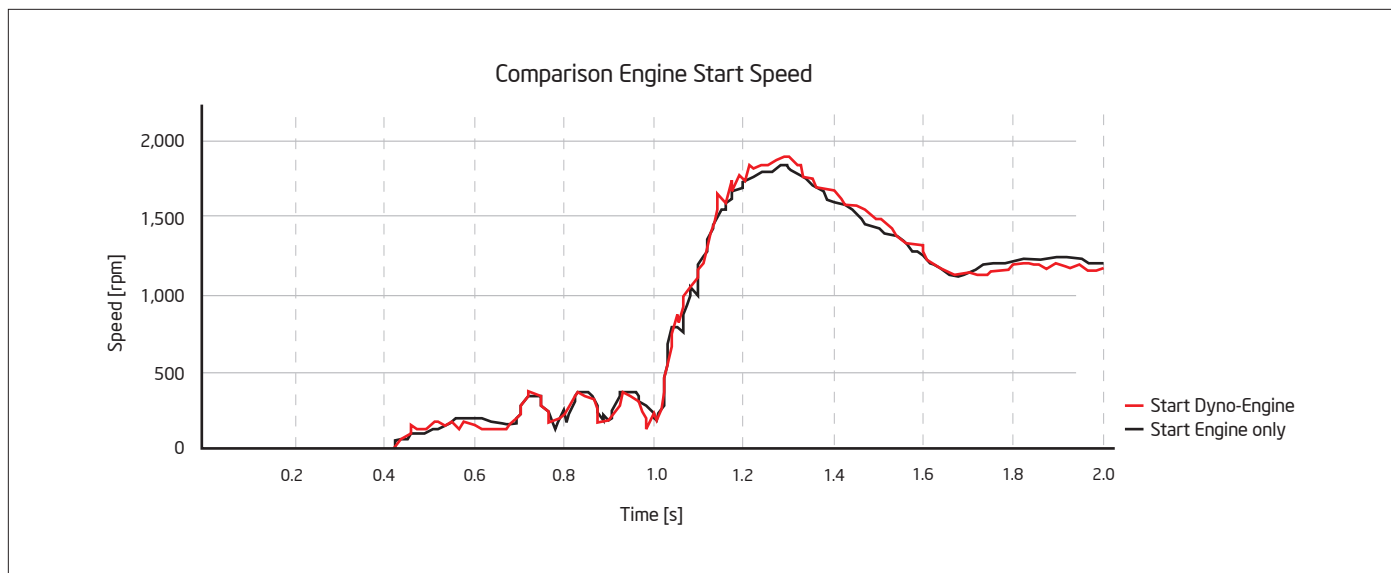


Figure 5. Engine start comparisons with real and simulated starter motor.

Pushing the Performance Envelope

Formula 1 racing embodies the bleeding edge of automotive technology, resulting in unprecedented performance demands on test beds’ ability to perform real-time control and simulation. Racing drivetrains are characterized by the need to withstand high torque and high rotational speed with low inertia. Because racing engine prototypes can cost €250,000 each, the reliability of the test system is crucial.

To meet this requirement, AVL constructed a special test bed consisting of two dynamometers joined by a gearbox. Each dynamometer needs to be controlled precisely, as the loads vary rapidly due to the engine’s high rate of change of speed. Because a high-performance interface between the central computer and the dynamometers is required, AVL used high-performance EtherCAT (Ethernet for Control Automation) to interface its PUMA Open system to the dynamometers, with a data rate of up to 10 kHz – a much higher rate than is required for normal engine testing. This was possible because the PUMA Open’s INtime real-time technology supports high-performance Ethernet interfaces and can sample control loops at rates faster than the 1 kHz rates that are typically associated with high-performance control systems.

Real-Time at the Core

As discussed earlier in this paper, the seamless integration of real-time applications on the same platform with human interface processing enables shared, centralized access to parameters and management of data, and ensures that there are no delays due to external communication interfaces, which commonly occur in systems that have separate hardware for Windows tasks and real-time tasks.

Using multi-core processors – in AVL’s case, an Intel® quad-core processor – adds performance to systems that combine Windows and RTOS processing by allowing non-real-time software tasks to run on a separate core from the real-time tasks. Moreover, the real-time tasks can be distributed over a number of cores possibly running multiple instances of the RTOS applications independently at the same time. This makes a whole new set of capabilities possible, including the potential of running multiple instances of highly accurate simulation models simultaneously and/or enabling higher calculation frequencies to yield faster response times for systems that are getting increasingly faster. For instance, a simulation model can be run on one core while the acquisition of test data is performed by software running on another, while a Windows-based interface runs on yet another core of a multi-core processor.

Conclusion

By combining real-time processing using INtime with Windows processing – and using a multi-core Intel® processor to partition resources – AVL has developed an advanced testing platform designed to serve the needs of automotive system designers for years to come.

The Intel® Embedded Design Center provides qualified developers with Web-based access to technical resources. Access Intel Confidential design materials, step-by step guidance, application reference solutions, training, and Intel's tool loaner program, and connect with an e-help desk and the embedded community. Design Fast. Design Smart. Get started today. edc.intel.com.

† Intel® Virtualization Technology requires a computer system with an enabled Intel® processor, BIOS, virtual machine monitor (VMM) and, for some uses, certain platform software enabled for it. Functionality, performance or other benefits will vary depending on hardware and software configurations and may require a BIOS update. Software applications may not be compatible with all operating systems. Please check with your application vendor.

The Intel® Embedded Design Center provides qualified developers with web-based access to technical resources. Access Intel Confidential design materials, step-by-step guidance, application reference solutions, training, Intel's tool loaner program, and connect with an e-help desk and the embedded community. Design Fast. Design Smart. Get started today. <http://intel.com/embedded/edc>.

INFORMATION IN THIS DOCUMENT IS PROVIDED IN CONNECTION WITH INTEL® PRODUCTS. NO LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS IS GRANTED BY THIS DOCUMENT. EXCEPT AS PROVIDED IN INTEL'S TERMS AND CONDITIONS OF SALE FOR SUCH PRODUCTS, INTEL ASSUMES NO LIABILITY WHATSOEVER, AND INTEL DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY, RELATING TO SALE AND/OR USE OF INTEL PRODUCTS INCLUDING LIABILITY OR WARRANTIES RELATING TO FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT. UNLESS OTHERWISE AGREED IN WRITING BY INTEL, THE INTEL PRODUCTS ARE NOT DESIGNED NOR INTENDED FOR ANY APPLICATION IN WHICH THE FAILURE OF THE INTEL PRODUCT COULD CREATE A SITUATION WHERE PERSONAL INJURY OR DEATH MAY OCCUR.

Intel may make changes to specifications and product descriptions at any time, without notice. Designers must not rely on the absence or characteristics of any features or instructions marked "reserved" or "undefined." Intel reserves these for future definition and shall have no responsibility whatsoever for conflicts or incompatibilities arising from future changes to them. The information here is subject to change without notice. Do not finalize a design with this information.

The products described in this document may contain design defects or errors known as errata which may cause the product to deviate from published specifications. Current characterized errata are available on request. Contact your local Intel sales office or your distributor to obtain the latest specifications and before placing your product order. Copies of documents which have an order number and are referenced in this document, or other Intel literature, may be obtained by calling 1-800-548-4725, or by visiting Intel's Web site at www.intel.com.

Copyright © 2010 Intel Corporation. All rights reserved. Intel, the Intel logo, and Core are trademarks of Intel Corporation in the U.S. and other countries.

*Other names and brands may be claimed as the property of others.

