# Where uniformity testing meets the road

## New PC-based automation system improves control and monitoring while meeting customer requirements.

**Troy L. Anenson, the vice president of engineering at CTI in Akron, Ohio.**

Akron, Ohio has, at one time or another, been the home of at least four major American tire manufacturers. Numerous other tire companies can trace their roots to Akron and the surrounding northern Ohio areas. It's no wonder Akron has historically been called the "Rubber Capital of the World."

It's also no wonder our company, CTI (www.comtime.com), is located in Akron, as we service the tire industry. Along with its sister company, Akron Special Machinery (ASM) (www.akronspecialmachinery.com), CTI is part of the Poling Group of Companies (www.polinggroup.com). The Poling Group consists of six companies with one common goal: helping customers increase machine throughput and optimize product quality.

The Poling Group recently released the CX111, its latest tire uniformity testing machine. Tire companies use uniformity measurements to ensure the tires they sell conform to test conditions mutually agreed upon and accepted by tire and automobile manufacturers worldwide. These test procedures are quite complex and require a high degree of sophisticated control, data manipulation and reporting. See the sidebar for more details on tire testing.

ASM designs and builds the machines (Figure 1). CTI designs the electrical and control systems—and provides programming, data acquisition system design, system integration, and field service for the ASM machines.

The CX111 includes the latest version of our Tire Testing & Optimization Controller (TTOC6). The new TTOC6 controller, which includes our new Tire Data Acquisition (TDAQ) system, provides the most cost effective, versatile, and accurate tire testing automation system available.

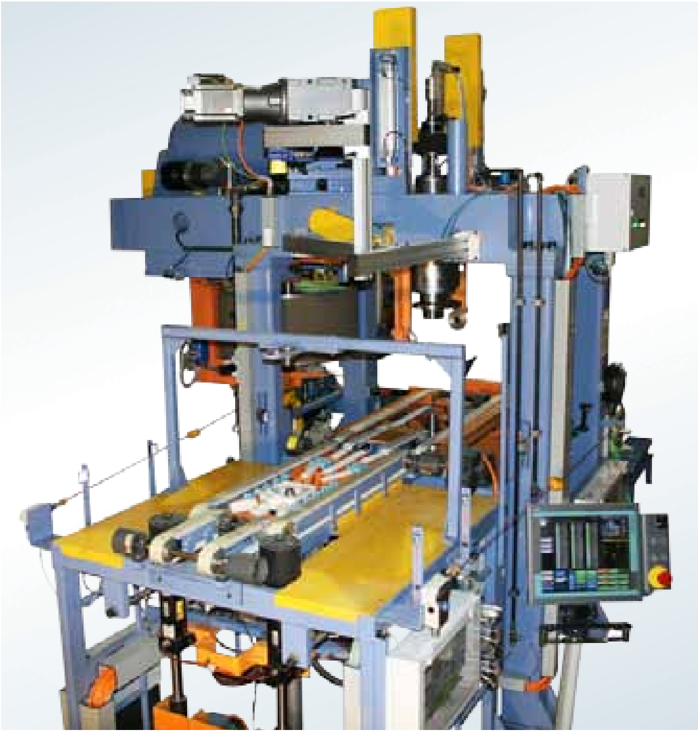

Figure 1, tire machine: The recently released CX111 is the latest tire uniformity testing machine from the Poling Group. It includes the latest version of CTI's TTOC6 controller.

### Implementing Real-Time Control and Safety with a PC

When we created our new control system, we had several goals in mind as outlined in Table 1. We wanted to improve the capabilities of the tire testing machine, increase flexibility, simplify maintenance, and provide an easy-to-use graphical user interface. Additionally, based on the requirements specified by one of our largest customers, a major tire company, we added PC-based control.

Typically, the CX111 control system uses a data handling industrial PC for test measurements, data acquisition, and web-enabled visualization—and a PLC for real-time control. But for this project, the customer specified PC-based real-time control using Totally Integrated Automation (TIA) solutions from Siemens Industry (www.usa.siemens.com/industry).

To reach our goals and satisfy customer requirements, we worked with Siemens to develop and prove the real-time control system. Siemens provided TIA-based solutions including SIMATIC IPC627C industrial PCs, WinAC RTX F fail-safe PC-based control software, and ET 200S distributed standard and safety I/O. Siemens also supplied direct motor starters and reverse motor starters installed at the ET 200S distributed I/O nodes, reducing the hardwiring typically required in standalone motor starters.

Other Siemens components include managed and unmanaged Ethernet switches, a 19-inch Flat Panel Monitor PRO touch screen HMI, a wireless HMI Mobile Panel running WinCC Flexible HMI software, and Sinamics S120 drives. See Figure 2 for a system architecture diagram depicting the entire information and automation system.

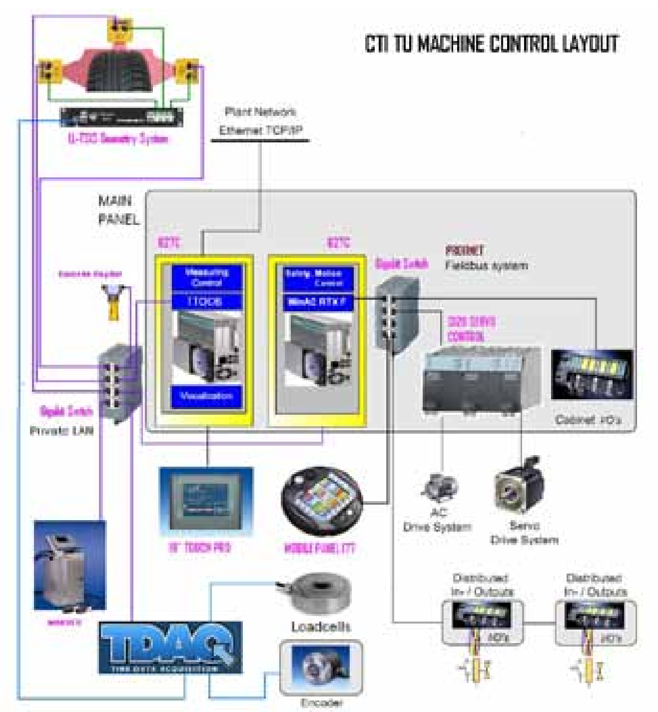


Figure 2, system architecture: This diagram shows a typical control system architecture for machines using two industrial PCs.

### New Control System Drives Tire Testing Performance

For this project, we used two industrial PCs to implement the information and control system. The data handling PC (TTOC6) is used for tire test control, data acquisition, and visualization. The real-time control PC is used for machine sequencing and field device control which includes material handling, motion control, and safety machine functions.

We chose to implement the Siemens WinAC RTX F fail-safe software controller for PC-based real-time control. We selected this software-based solution because it permits both standard and safety-related control tasks to be performed on one PC. This greatly simplified the control system architecture, while providing flexibility and power not possible within a typical hard-wired safety system.

Regardless of whether customers choose PLC- or PC-based control, we use the data handling PC to perform tasks not related to real-time control and safety. These tasks include high-level mathematical calculations such as Fourier analysis and high-speed data acquisition, tasks better suited to a PC than a PLC.

Although there are only two dual axis load cells that provide sensing for primary tire uniformity measurements, our customers can choose up to 300 measurement values, all derived from the primary uniformity measurements. We wrote the test software that processes the primary tire uniformity measurements and generates the hundreds of values derived from these measurements.

We use the Linux operating system on the data handling PC. A 19-inch touchscreen panel serves as the machine's main HMI (Figure 3). The HMI runs our custom software application to provide visualization.


Figure 3, screen shot: This totally-enclosed 19-inch touch screen panel has been customized with CTI's software application written to run on a Linux-based industrial PC.

The data handling PC communicates with its connected components via Ethernet through the unmanaged switch, with the exception of the 19-inch touch screen which is directly connected. If so specified, this PC can also communicate with upper level enterprise systems through a managed switch.

## Controlling Machine Sequencing

The real-time control PC communicates with the data handling PC through that computer's unmanaged switch. It communicates with the machine's field devices using the PROFINET industrial Ethernet protocol through its own unmanaged switch.

Most of the machine's motors are servos, but we typically use standard AC motors to run the conveyors. A nice feature about the Siemens motor drives is their ability to control servo motors, or AC motors in V/Hz mode. We don't have to buy different drives for our machines, and our customers can stock the same drive for both purposes.

The machine's distributed I/O architecture allows isolation between data and power wiring. Distributed I/O includes photo sensors, pressure sensors, machine access safety gate interlocks, solenoid valves that control the inflation and hydraulic systems, and other devices (Figure 4).

Figure 4, distributed I-O: Distributed I/O simplifies machine wiring, reduces debug and commissioning time, and reduces susceptibility to electrical noise.

An interlocked safety gate, which is part of the safety I/O, prevents access to the machine during normal operation. The hydraulic servo system maintains control of the separation forces of the tire during testing. When operators require access to the machine for changing to a different size rim, a key switch is used to put the machine and the hydraulic system into safe mode.

When an operator presses the button to request entrance to the rim changing area, the machine is placed into a safe state, and then the gate unlocks to allow entrance. This zone-based safety control reduces changeover time while providing safe working conditions.

The distributed I/O also includes temperature sensing and PID control for the heaters within the marking systems, if included with the machine. RTDs in the marker's sensor heads provide temperature measurement to distributed I/O analog modules.

When performing changeovers, machine setup, calibration, or maintenance—operators can use the small mobile panel HMI. The handheld HMI device communicates with the sequencing PC via PROFINET through the computer's unmanaged switch.

## Automation Solutions Steer Tire Testing Results

When we upgraded our controller to expand the capabilities of the tire uniformity testing machine, we were able to satisfy the requirements of one of our biggest customers. Although the initial impetus to use the Siemens PC-based control and safety system came from our customer, we quickly saw multiple benefits.

Using the distributed I/O over the PROFINET protocol enabled us to greatly reduce machine wiring, which simplified the design and minimized wiring-induced noise. Integrated safety let us program safety functionality in software, just as we do for real-time control functions. This gives us much more flexibility as we no longer have to hardwire components and safety relays to create the safety system logic.

We ship each section of the machine separately, and we no longer have to disconnect the I/O because it's local to each machine section. The PROFINET protocol auto-detects all sections of the machine when reassembled. All we have to do when the machine sections arrive at the customer's location is plug the PROFINET Ethernet connections back in, hook up the power and verify everything works as designed.

The Siemens TIA solutions are flexible and cost effective, and they satisfied our design needs and our customers' requirements. Integrated PC-based real-time control and safety greatly simplified the overall automation architecture, and significantly lowered commissioning time and effort.

Just as Akron will probably always be known for tire manufacturing, CTI will be known for its state-of-the-art tire uniformity machine controls. Along with our partner Siemens, we can now deliver a PC-based control and safety system that not only meets all of our customer requirements, but also adds features and benefits.

## Sidebar: Tire Testing Nuts and Bolts

During the tire manufacturing process, tire uniformity is measured after the tire has been cured. Machine subsystems typically include tire handling, automatic adjustable-width chuck, measurement rims, bead lubrication, inflation, loadwheel, spindle drive, and force measurement.

The tire enters the uniformity testing machine via material handling, typically a conveyor. Its beads are lubricated to ensure proper fit, a secure seal, and to prevent them from sticking to the measurement rims.

The tire is positioned between the rims according to a barcode applied on the tire's sidewall. This barcode references the specific test recipe unique to the tire under test, and also serves as a reference point while the tire is rotating during the test. The tire is chucked by raising the lower rim until its separation distance from the upper rim matches the value from the recipe. The tire is quickly inflated to the proper test pressure then rotated against a simulated road surface called a loadwheel, and measured for force variations (Figure 5).

Figure 5, tire testing: During tire uniformity testing, the tire is rotated against a loadwheel and measured for force variations.

The loadwheel is the nuts and bolts of the machine. It's a 33.6-inch diameter cylinder that's pushed into the rotating tire to apply a radial load. The radial load—also known as the tire's test load—is typically 80% of the tire's maximum load rating. Load cells are strategically attached to the loadwheel carriage.

After the tire is inflated, the loadwheel is pushed against the tire to apply the proper radial load according to the tire's test recipe. The spindle drive rotates the tire at 60 RPM, which typically equates to around 5 MPH, depending on the O.D. of the tire. When the tire's speed, force, and pressure are stable—the load cells measure the forces that the tire imposes on the loadwheel.

The four channels from the two load cells are the machine's primary sensors. They are mounted in the X and Y directions and measure radial and lateral top, and radial and lateral bottom forces. Load cell signals are processed, digitized, and analyzed to extract multiple measurement parameters.

After testing, the tires are graded according to various standards such as those required by the U.S. Dept. of Transportation. Some tire uniformity testing machines include tire marking systems as options. However, some tire manufacturers prefer to have marking means that are external to the testing machines.

Tire manufacturers require testing machines to measure certain uniformity parameters. The number of possible uniformity tests is extensive, and only a few of the primary parameters are listed here.

**Radial force variation -** Radial force variation quantifies the change in force in the radial direction as the tire rotates under load. Variation in the thickness or elastomeric properties of the tire can cause radial force variation.

**Harmonic waveform analysis -** Harmonics can occur in the radial and lateral directions. Most tires are made in segmented molds. If the tire mold isn't perfectly centered, the tire will likely fail because of excessive harmonics. The order of harmonics corresponds to the number of mold segments. Fourier Transform algorithms within the test program perform hydraulic waveform analysis.

**Lateral force variation -** Lateral force variation quantifies the change in force in the lateral direction as the tire rotates under load. This type of variation can cause steering pull in one direction.

**Conicity -** Conicity describes a tire's tendency to roll like a cone and is based on lateral force behavior. Conicity affects vehicle steering. It's quantified by measuring lateral force in both rotation directions, and is calculated as half the difference of the directional values. Conicity values are either positive or negative. Automotive manufacturers actually prefer tires with some conicity.

Siemens Industry, Inc.
5300 Triangle Parkway
Norcross, GA 30092

1-800-241-4453
info.us@siemens.com

**www.usa.siemens.com**

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