Technical Article

What Is “Real-time Control” and Why Do You Need It?

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Every day, consumers interact with systems that assess their surroundings and act accordingly. In a vehicle, when pressing the accelerator, the vehicle speeds up almost instantaneously – there is no noticeable delay between pressing the pedal to acceleration.

To apply this example to the topic of this article, if the vehicle were a system, the surroundings pressing the accelerator and the output the vehicle speed, the system is implementing what's known as "real-time control." Real-time control is the ability of a closed-loop system to gather data, process that data and update the system within a defined time window. If the system misses that defined window, its stability, precision and efficiency will degrade. Diminished control can be detrimental to system performance; for example, not achieving the necessary speeds or even overheating. In this article, I'll explain the functional blocks of a real-time control system and provide an example of a robotics application.

While not necessarily involved in the control of the system, communications to other system components should also co-exist with the main control loop. The primary functional blocks involved in real-time control are sensing (gathering data), control (interpreting and using the data), and actuation (updating the system) (Figure 1).

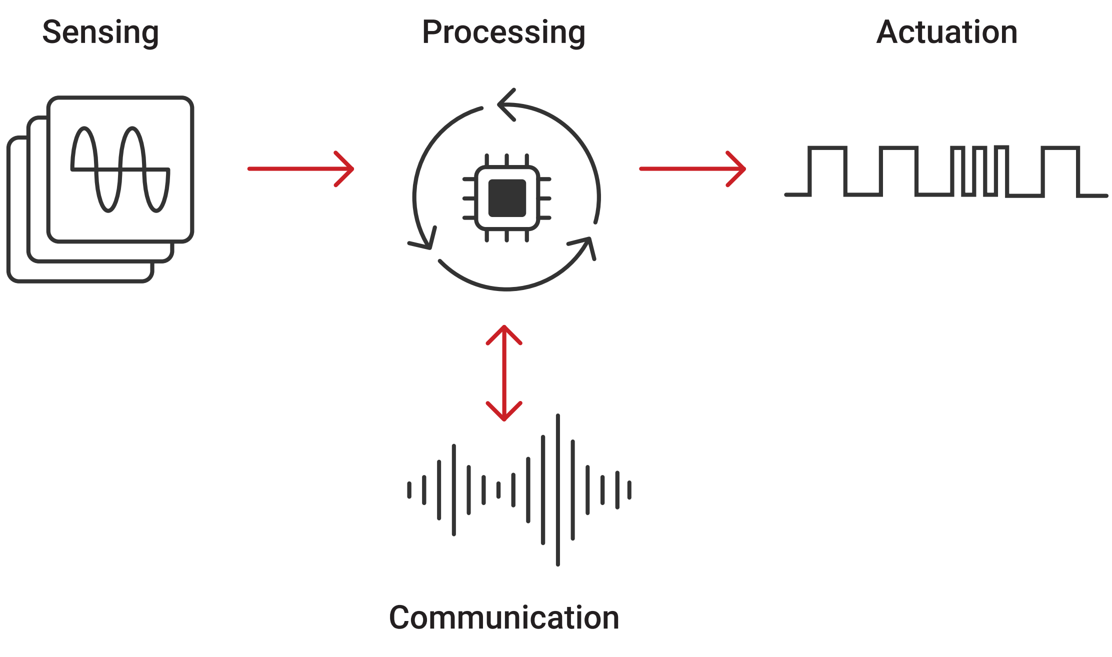

Figure 1. The Primary Functional Blocks of a Real-time Control Loop

Let's look at these components in more detail.

- Sensing refers to the measurement of external factors such as voltage, current, motor speed or temperature. These key parameters need accurate and precise measurements in order to give the system reliable data occurring at a specific point in time.

- The central processing unit applies control techniques to the incoming data in order to calculate the next output command. Microcontrollers (MCUs) or controllers such as C2000™ real-time MCUs, Sitara™ Arm®-based MCUs, integrated brushless-DC motor drives and DC/DC controllers that contain high **processing** capabilities can help ensure that the system meets the minimum window of time – usually within microseconds to a few milliseconds.
- **Actuation** is the application of the calculated output command to the system in order to control the output. Changing the duty cycle of a pulse width modulator (PWM) unit driving a power electronics system is an example of actuation. TI products that help enhance actuation include analog drivers, isolated gate drivers and gallium nitride (GaN) field-effect transistors with integrated gate drivers.
- Finally, deterministic high-speed communication interfaces such as Fast Serial Interface or Ethernet achieve timely **communication** between the system and external devices or internal components.

In robotics, for example, real-time control precisely controls the position and speed of the motor, positioning a robot arm with <100-µm accuracy. Such accuracy is possible through the constant measurement of motor currents and voltages, as well as the motor position. The processing unit compares the measured values with calculated values, as shown in Figure 2. Based on the results, the processing unit adjusts the PWM signal to the motor. And the whole process needs to occur in just a few microseconds in order to meet the system's accuracy and timing needs.

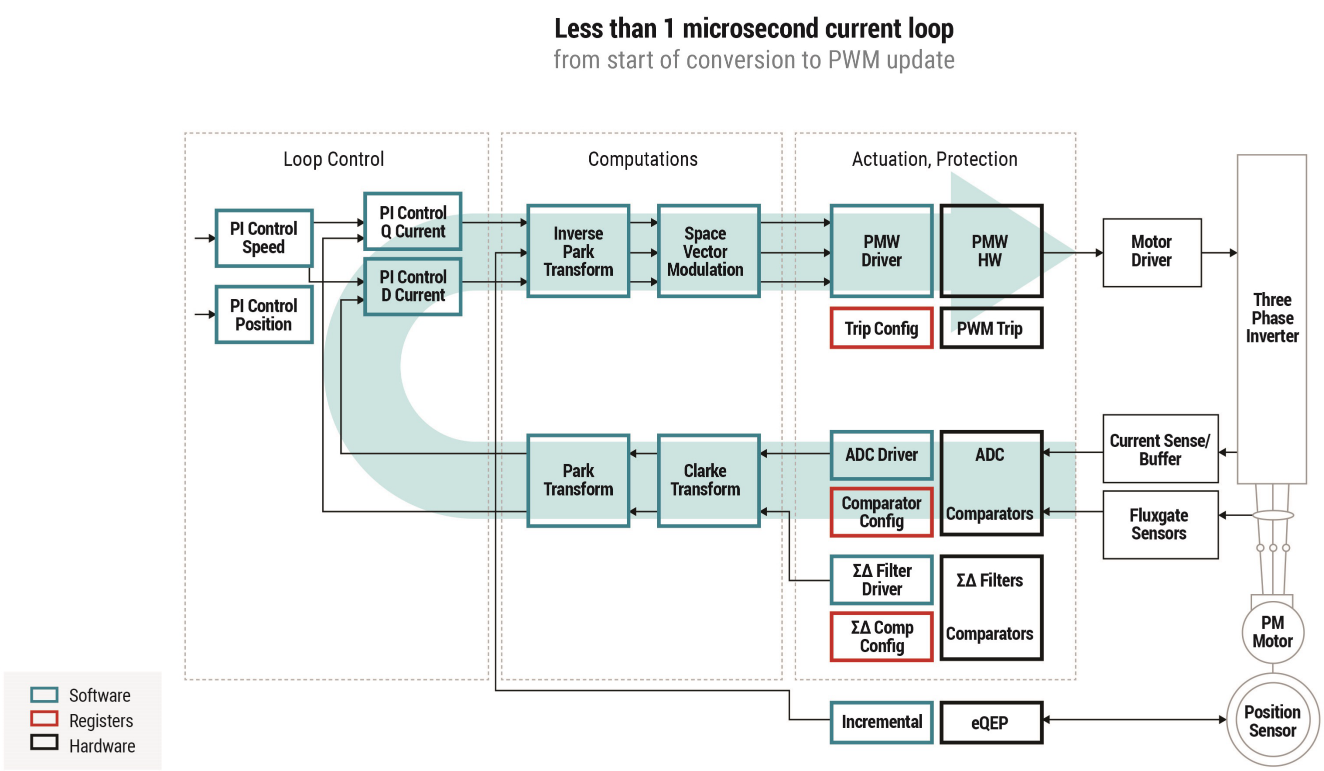

Figure 2. Fast Current Loop Diagram

Real-time control is also the basis for efficient and reliable power-supply systems. For example, real-time control helps keep the output power of a charging station stable and regulates current going into a car battery to maintain its life and avoid overheating. Combining real-time control with an MCU and new technologies such as GaN can increase power density and efficiency, helping minimize power losses in an application.

Consistent increases in the performance of modern motor-drive systems have correspondingly increased the requirements for real-time control. For example, highly fast and precise computer numerical control machines (machines that control a wide range of complex machinery such as grinders and turning mills) can achieve accuracies <5 µm while rotating more than 20,000 times per minute. Such functionality is only achievable with extremely fast control loops, which means that the time delay between the measurement of the signal and the adjustment of the systems is typically achieved in <1 µs.

Because of the highly time-sensitive computational burden, many designers use a combination of field-programmable gate arrays, fast external analog-to-digital converters and multiple MCUs. But TI's C2000 MCUs and Sitara processors offer a higher level of analog integration that enable them to perform a current loop within <1 µs, which is known as a fast current loop. Making use of the fast-current loop in modern control topologies enables designers to develop smaller and higher-performing systems at a lower cost.

It is also possible to reduce cost further by using a fully integrated solution such as TI's MCF8316 motor driver. Such devices have pre-programmed brushless DC motor control algorithms that just need fine-tuning, achievable through a simple I^2C interface from the MCU to configure integrated electrically erasable programmable read-only memory during the system design phase. They also come with a hardware configuration, enabling system designers to tune the motor without an MCU. The MCF8316 integrates six metal-oxide semiconductor field-effect transistors to deliver the current to the motor, which results in a full real-time motor control solution in a 7-mm-by-5-mm package.

Real-time control is an important part of application areas such as grid infrastructure, appliances, electric and hybrid electric vehicles, power delivery, motor drives, and robotics. There is an increasing need to meet smaller execution windows for all of these applications in order to enable even faster response times. TI's complete portfolio of sensing, processing, control and communication technologies offer power efficiency, performance and low-latency response times to enable smaller, more reliable real-time control systems.

To learn more about the sensing functional block of real-time control, read the next article in this series, "3 tips to optimize data reliability with sensors in real-time control systems."

Additional Resources

- See the application note, "The Essentials Guide for Developing with C2000 Real-Time Microcontrollers."
- Read the white paper, "Time-Sensitive Networking for Industrial Automation."
- Review the "Real-Time Control Reference Guide."
- Read the article, "How MCUs can Unlock the Full Potential of Electrification Designs."
- Check out the Dual-Axis Motor Drive Using Fast Current Loop (FCL) and SFRA on a Single MCU Reference Design.

Learn more about our products by going to the TI robotics landing page and TI motor drives landing page.

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