

# RTAC System Performance

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## INTRODUCTION

The SEL-3530, SEL-3530-4, and SEL-2241 Real-Time Automation Controllers (RTACs) are ultrarugged remote terminal unit (RTU) and programmable logic controller (PLC) systems. An RTAC can operate as the controller for the SEL-2240 Axion™, which is a modular I/O system where up to 60 modules can connect to a high-speed, deterministic EtherCAT® network. These modules can be digital inputs, digital outputs, or power couplers. AC analog, dc analog, and resistance temperature detector (RTD) modules are presently under development. Regardless of the processing cycle time configured on the RTAC, the EtherCAT network updates all the points of the Axion system every 1 millisecond. The user can program logic on the RTAC with the IEC 61131-3 languages Ladder Logic, Structured Text, and Continuous Function Chart.

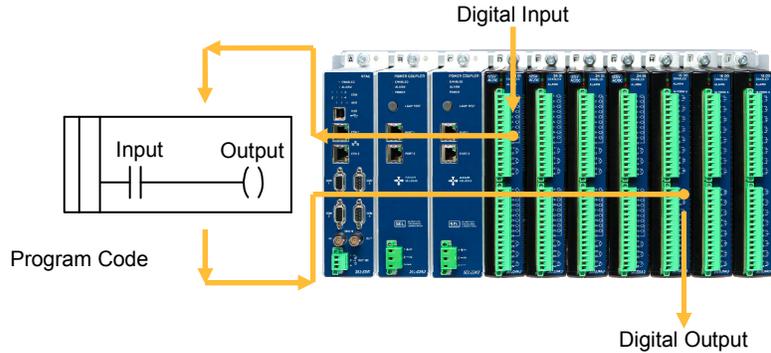
We performed processing analysis and testing to determine the performance of the RTAC with the Axion I/O system. The tests are divided into the following three groups:

- Processing time—the time it takes the RTAC to read and process a digital input, perform logic, and send the command to assert a digital output. We measured this time internally in the RTAC, and the results do not include the contact switching time of the digital output.
- Roundtrip time—the time it takes the RTAC to read and process a digital input, perform logic, and assert a digital output. We measured this time using an external device, and the results include the contact switching time of the digital output as well as other diagnostic tasks performed by the RTAC. The roundtrip time is useful to determine how fast the RTAC can respond to an external input event.
- Scan cycle time—the time it takes the RTAC to process the logic. We recorded measurements from systems of several sizes to indicate how the number of modules affects the scan time.

This paper summarizes these tests results and, in the last section, provides recommendations to determine an optimal processing cycle time for any particular application.

## INTERNAL PROCESSING TIME

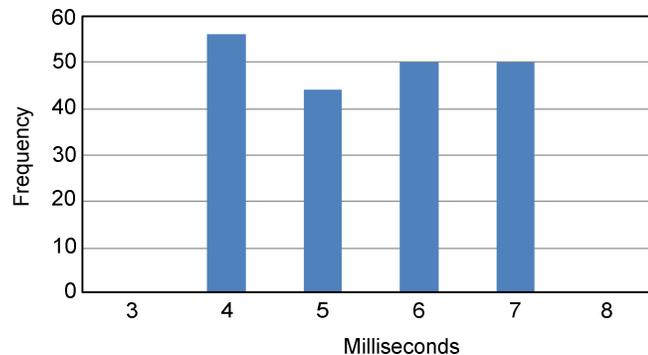
The processing time is the time required by the RTAC to read a digital input signal, execute the logic, and assert a digital output that is programmed in the logic to follow the state of the input, as illustrated in Figure 1. We measured the time internally, from the assertion of the input to the assertion of the output.



**Figure 1 Internal Processing Time Measurement Diagram**

We used the internal Sequence of Events (SOE) of the RTAC to time-stamp the assertion of the digital input and the digital output. The processing time was calculated by subtracting the time stamp of the output from the time stamp of the input. We measured the time between the assertion of the tag `SEL_24DI_1_ECAT.INPUT_001` and the assertion of the tag `SEL_16DO_1_ECAT.OUTPUT_001.status.stval`.

We asserted the digital input 200 times and measured the processing time for each independent event. The histogram chart in Figure 2 shows the distribution of the processing time. With the task cycle time (rate at which the RTAC executes all tasks, including the user programs) configured at 4 milliseconds, all the values recorded were between 4 and 7 milliseconds, with an average of 5.47 milliseconds. In all of the samples, the RTAC took less than two processing cycles to complete the internal processing.



**Figure 2 Internal Processing Time Histogram**

## ROUNDRIP TIME

We measured the roundtrip time using an SEL-2440 DPAC Discrete Programmable Automation Controller. An output on the DPAC asserts a digital input on the Axion, which causes a digital output on the Axion to assert an input on the DPAC, as illustrated in Figure 3.

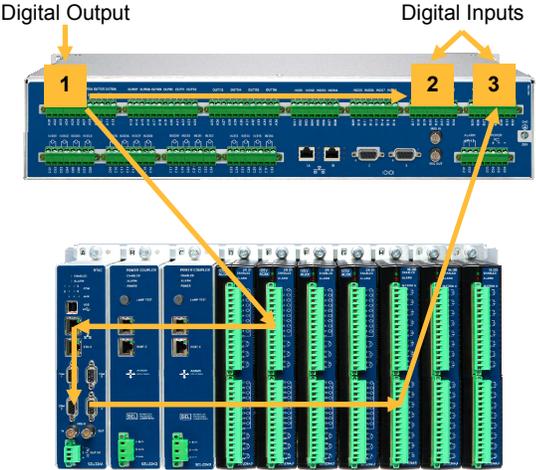


Figure 3 Roundtrip Time Diagram

We calculated the roundtrip time using the following procedure. We wired a DPAC output to both the Axion input card and to a DPAC input. The DPAC output contact (Point 1 in Figure 3) was asserted and received by a digital input on both the Axion and the DPAC. The DPAC recorded the assertion of the input (Point 2 in Figure 3). The RTAC module in the Axion received the DPAC output event and, after performing the appropriate logic, asserted the output. The DPAC recorded this event as well (Point 3 in Figure 3). The time elapsed between the assertion of Points 2 and 3 is the roundtrip time of the Axion (the time between Points 1 and 2 is the DPAC contact switching time and is not part of the roundtrip). All timing measurements used the 1-microsecond accurate Sequential Event Recorder built into the DPAC.

The DPAC asserted the output multiple times to generate multiple events, and we calculated the roundtrip time on each sample. The final results are shown in Table 1.

Table 1 Roundtrip Time Results

Minimum Time	Average Time	Maximum Time
8.708 ms	9.98 ms	12.533 ms

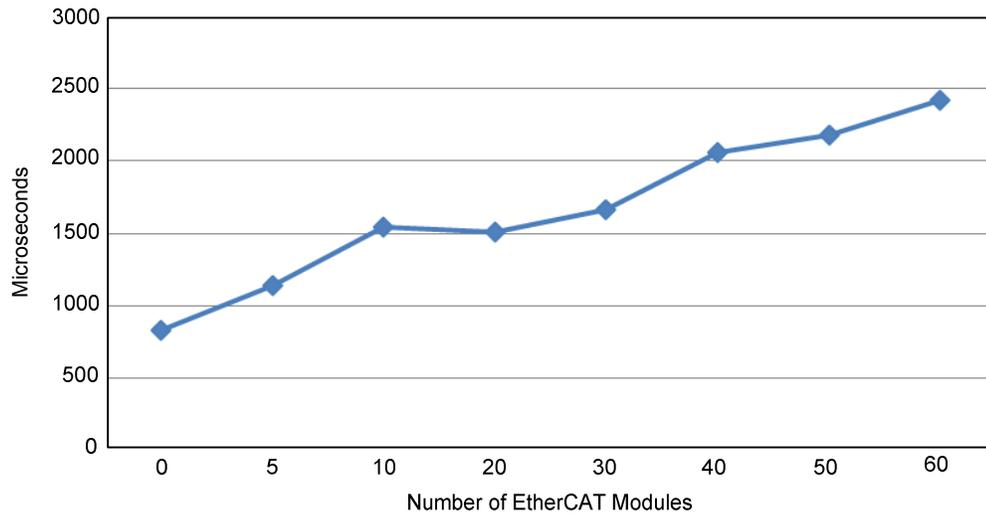
## SCAN CYCLE TIME

The RTAC and other PLC systems perform a repetitive cycle of operations every processing cycle. In the RTAC, these operations include the following:

- EtherCAT I/O processing (scans all the inputs and updates the outputs according to the program logic).
- Program logic execution (Ladder Logic, Structured Text, Continuous Function Chart, Tag Processor, and so on).
- Serial and Ethernet communications (Modbus<sup>®</sup>, DNP3, Generic Object-Oriented Substation Event [GOOSE], and so on) with remote devices.

The scan cycle time is the time it takes the controller to perform all the tasks listed above. It directly affects the speed at which the PLC can control a machine or process. Many factors affect the scan cycle time: the length and complexity of the program, the number of I/O modules in the EtherCAT network, the number of client and server connections (Modbus, DNP3, IEC 61850 GOOSE, MIRRORRED BITS<sup>®</sup> communications, and SEL protocols), the amount of data exchanged on each communications transaction, and so on. In this section, we show how the number of EtherCAT modules affects the scan cycle time.

We added a Structured Text program in the project, including: 20 timer instructions, 20 counter instructions, 50 bit operation instructions, and 20 math instructions with floating-point operations. We recorded the scan cycle time while the RTAC executed this program with several quantities of EtherCAT modules in the system. Figure 4 shows the scan cycle time for each individual configuration.



**Figure 4 Scan Cycle Time Versus Number of EtherCAT Modules**

When the RTAC executed with no EtherCAT modules in the network, the average scan cycle time was 832 microseconds. When the RTAC executed with 60 modules in the network (the maximum number of modules allowed in the network), the average scan cycle time was 2,420 microseconds. For a typical two-node or three-node system, the scan cycle time is approximately 1,500 microseconds.

## CONSIDERATIONS FOR SELECTING THE PROCESSING CYCLE TIME

The duration of the scan cycle can significantly increase if several serial or Ethernet client and/or server devices are present in the project. The RTAC sends the communications request and waits for the communications to complete. This waiting time depends on the response latency of the external device. The scan time may last a few milliseconds when there is no client or server configured in the project or tens of milliseconds (or more) when the RTAC communicates with several DNP3, Modbus, MIRRORRED BITS communications, GOOSE, or SEL protocol devices.

A general guide for selecting an optimum processing cycle time is to set the task cycle time to double the value of the average scan cycle time. The following steps must be taken:

1. Download the project to the RTAC, and wait until the EtherCAT network is online (**Client\_State** tag in EtherCAT program organizational unit [POU] equals 5).
2. Ensure that all the communications servers and clients are running properly.

3. Force the **reset\_all\_task\_timers** tag to true and then back to false.
4. Wait a few minutes to accumulate new samples for the calculation of the average scan cycle.
5. Read the **SystemTotal\_task\_timer.average\_us** tag value, and multiply that value by two. Round the result to the nearest whole number, and set the task cycle time to that number.

In the example shown in Figure 5, the average scan cycle time is approximately 4.3 milliseconds. In this case, we can confidently set the task cycle time to 9 milliseconds. This allows the processing time to have a 50 percent margin.

SystemTotal_task_timer		TaskTimer	
start	BOOL	FALSE	
stop	BOOL	TRUE	
reset	BOOL	FALSE	
last_us	ULINT	4114	
average_us	ULINT	4345	
max_us	ULINT	7012	
min_us	ULINT	4035	
num_cycles	ULINT	53437	

Task cycle time:	9	4-1000 ms
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Figure 5 Selecting Task Cycle Time

## CONCLUSION

The tests described in this paper show that, with proper configuration, the RTAC can meet or exceed the requirements of most RTU and PLC applications. This paper quantifies the basic performance indicators of the RTAC. For more in-depth RTAC performance information, please refer to the SEL-2240 Axion Instruction Manual, available at <http://www.selinc.com>.

## BIOGRAPHY

**Francisco Chumbiauca** is originally from Lima, Peru. He attended Universidad Peruana de Ciencias Aplicadas (Peruvian University of Applied Sciences) and received his bachelor's degree in Electrical Engineering in 2005. Francisco worked for Schneider Electric as an intern from 2004 to 2005. From 2006 to 2009, he worked for Rockwell Automation as a field support and training engineer for the Andean Region, traveling throughout Peru, Ecuador, Colombia, and Venezuela and assisting customers with startup, maintenance, and troubleshooting of Allen Bradley controllers and industrial networks. Francisco joined Schweitzer Engineering Laboratories, Inc. in July 2010 as an automation engineer.

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