Scan Times: PLC vs. PLuS

Programmable Logic Controllers (PLC's) and programmable limit switches such as the Electro Cam Corp. PLuS were developed to solve two different problems in the control of automated machinery. PLC's provide a programmable method of relating sensors, limit switches, selector switches, and other input devices to output components such as solenoid valves, motors, and pneumatic cylinders. Using a PLC, a programmer can easily change the way a machine operates by modifying the PLC's ladder logic program. There is no need to physically rewire the machine's components.

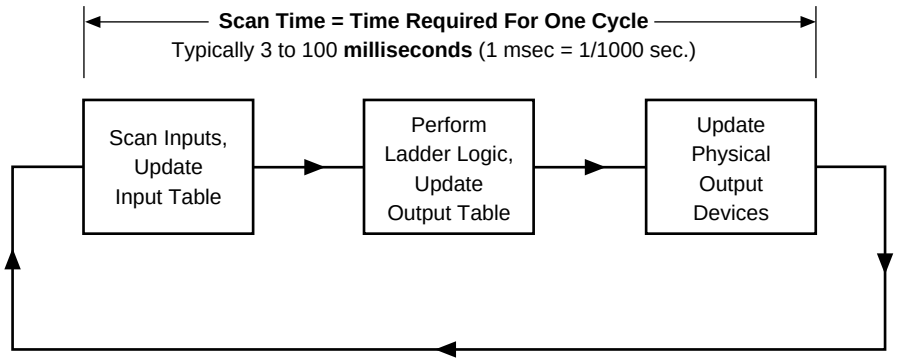
In contrast, PLuS controllers are designed to perform accurate control of repetitive high-speed machine functions. Because these functions are often correlated with a rotating shaft, PLuS's are designed to turn devices ON and OFF based on a rotary position signal generated by a transducer such as an encoder or resolver.

Many industrial control systems can benefit from including both a PLC and a PLuS. The PLC coordinates low-speed processes while the PLuS directly controls high-speed machine functions. In analyzing which machine processes are best handled by PLC's or PLuS's, an understanding of scan times is beneficial.

What is "Scan Time?"

As shown in Figure 1, a PLC performs a repetitive cycle of operations. First, the PLC sequentially scans the input devices and updates a memory table indicating their status. Next, the PLC executes its control programming, or ladder logic. As it processes the ladder logic, the PLC updates a memory table which indicates whether output devices should be ON or OFF. Finally, the PLC uses the output table to actually change the condition of the output devices.

Figure 1—PLC Processing Cycle

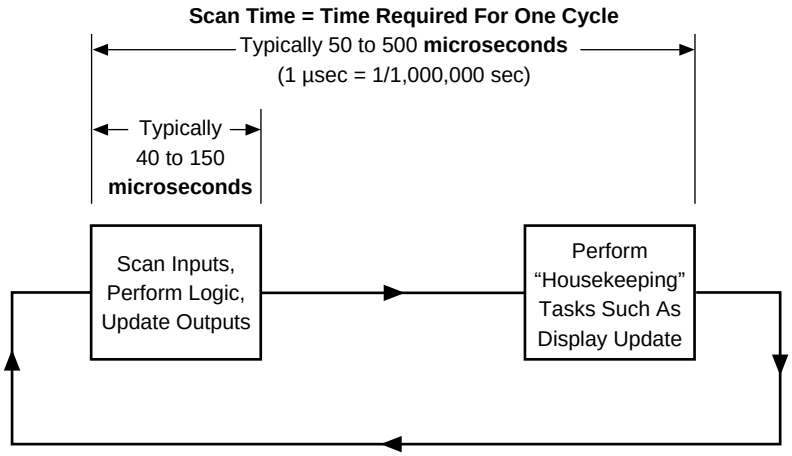


Electro Cam Corp.
13647 Metric Rd • Roscoe, IL 61073 U.S.A. • 815-389-2620 • FAX 815-389-3304 • 800-228-5487 (USA & Canada)

The PLC processes illustrated in Figure 1 are distinct operations carried out by the PLC's operating system software. To facilitate programming, each rung of the ladder logic consists of individual instructions which are stored in memory and interpreted by the operating system during each scan cycle. The more complex the ladder logic is, the longer the scan time will be. Other factors which can increase PLC scan times include serial communications with remote devices, as well as display interfaces which must be integrated into the processing cycle.

Unlike a PLC, the input scanning, logic functions, and output updates of a PLuS are executed in a single software procedure that is optimized for fast response times. As shown in Figure 2, the outputs are updated early in the processing cycle, rather than at the end. In addition, a PLuS usually controls fewer components than a PLC. As a result, PLuS scan times are much faster.

Figure 2—PLuS Processing Cycle



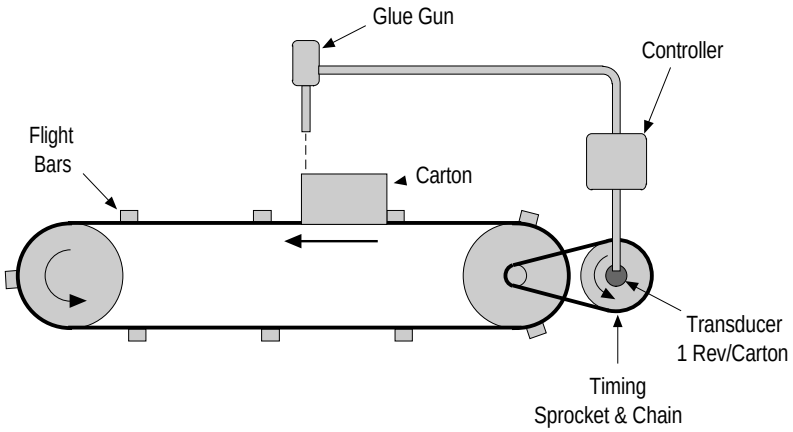
The Effects of Scan Times

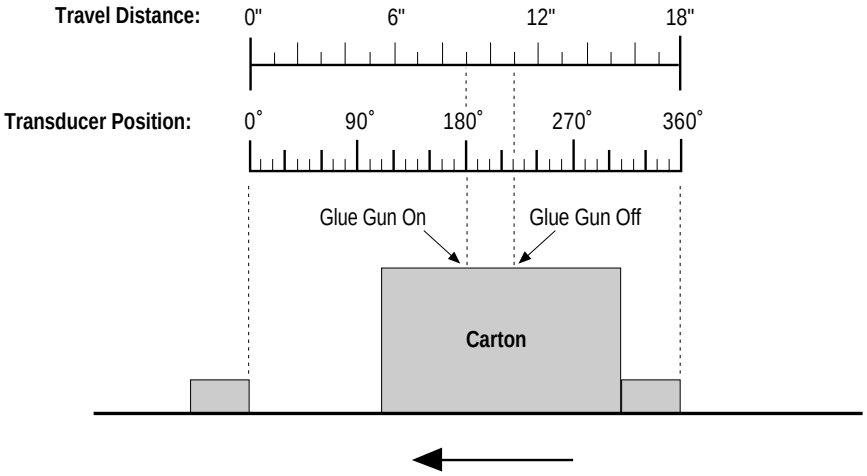
Scan times directly affect the accuracy with which a PLC or PLuS can control a machine. For example, Figure 3 illustrates a simple carton gluing application in which a conveyor moves cartons under a glue gun that sprays glue onto the carton flaps. The conveyor is connected through a timing chain and sprocket to a transducer which rotates once for each box that passes beneath the gun.

Figure 3 includes a linear representation of the transducer position showing how it relates to inches of carton travel. When the transducer reaches 180º, the carton is in position and the controller turns the glue gun on. At 220º, the controller turns the glue gun off.

At slow speeds, the scan time of the controller has a negligible effect on the accuracy of the glue bead. However, as the line speeds up, scan times introduce variation in bead length and position from carton to carton.

Figure 3—Simple Gluing Application





Timing Variations

In Figure 3, the controller reads the transducer position during the input scanning process. If a PLC scans this input just after the transducer reaches 180°, the output for the glue gun would turn on at the completion of the controller processing cycle shown in Figure 1. For a PLC with a scan time of 10 msec., the output would turn on 10 msec. after the transducer reached 180°.

However, if the transducer reached 180° just after its signal was scanned, the PLC would have missed the signal for that cycle and would not update the input table until the following cycle. Essentially, two processor cycles would pass before the output would turn on. For a PLC with a scan time of 10 msec., the output would turn on 20 msec. after the transducer reached 180°.

Because scan rate is independent of carton position, the 180° position could be reached at any time during a controller cycle, and the glue gun could be energized any time from one to two scans afterward. The same phenomenon occurs when turning the glue gun off.

At slow speeds, this variation is insignificant. At higher speeds, the carton can travel far enough during the processing period that the glue bead begins to vary in position and length. Figure 4 summarizes the effects of scan times on the hypothetical gluing machine shown in Figure 3. The actual size of the glue beads generated by this example are illustrated in Figure 5.

Due to variations introduced by scan time, the glue bead controlled by the PLC at 200 RPM can vary in total length by as much as 1.2" from carton to carton. The leading and trailing edges of the bead can each drift up to 0.6" independently of each other, and in no case will they be closer than 0.6" to the desired position.

In contrast, the beads produced by the PLuS vary only slightly from the desired bead. Clearly, the PLuS provides much more accurate control of bead length and position.

Figure 4—The Effects of Scan Time on Glue Bead Length & Position

Fundamental Relationships

Machine Speed	Transducer Rotation			Carton Travel		
	°/min	°/sec	°/msec	"/min	"/sec	"/msec
1 RPM	360°	6°	0.006°	18"	0.3"	0.0003"
10 RPM	3,600°	60°	0.060°	180"	3.0"	0.0030"
50 RPM	18,000°	300°	0.300°	900"	15.0"	0.0150"
100 RPM	36,000°	600°	0.600°	1,800"	30.0"	0.0300"
200 RPM	72,000°	1,200°	1.200°	3,600"	60.0"	0.0600"

Glue Bead Starting & Stopping Positions

PLC with 10 msec Scan Time vs. PLuS with 300 µsec Scan Time

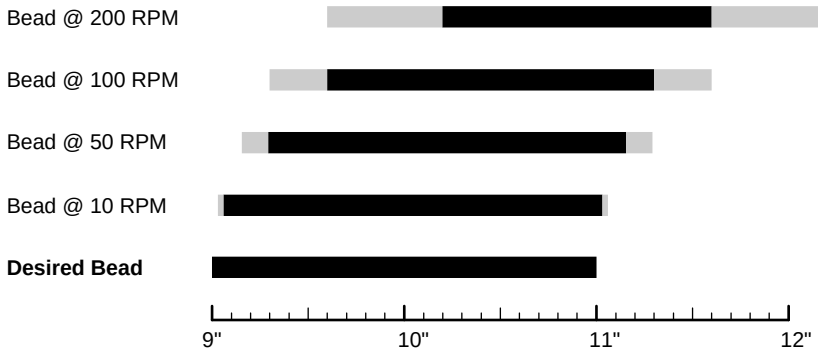
Controller	Machine Speed	Travel During		Glue Bead "On" Position		Glue Bead "Off" Position	
		One Scan	Two Scans	Earliest[1]	Latest[1]	Earliest[1]	Latest[1]
PLC 10 msec Scan Time	10 RPM	.03"	.06"	9.03"	9.06"	11.03"	11.06"
	50 RPM	.15"	.30"	9.15"	9.30"	11.15"	11.30"
	100 RPM	.30"	.60"	9.30"	9.60"	11.30"	11.60"
	200 RPM	.60"	1.20"	9.60"	10.20"	11.60"	12.20"
PLuS 300 µsec Scan Time	10 RPM	.0009"	.0018"	9.0009"	9.0018"	11.0009"	11.0018"
	50 RPM	.0045"	.0090"	9.0045"	9.0090"	11.0045"	11.0090"
	100 RPM	.0090"	.0180"	9.0090"	9.0180"	11.0090"	11.0180"
	200 RPM	.0180"	.0360"	9.0180"	9.0360"	11.0180"	11.0360"

Note: [1] For simplicity, the "earliest" and "latest" points for the PLuS are shown as one or two full processing cycles after the input scan. However, as Fig. 2 shows, a PLuS updates outputs earlier in the processing cycle. In reality, the variations caused by scan times would be smaller for the PLuS than shown in this chart.

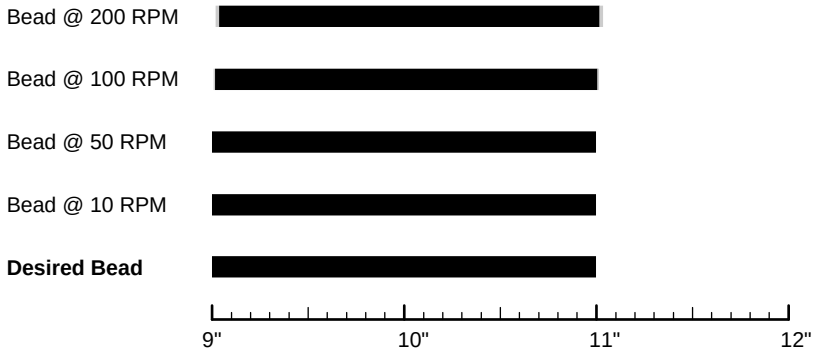
Figure 5—Graphical Presentation of Table from Figure 4

In the following illustrations, the gray portions of a bead indicate the range in which the glue gun may turn on or off for a given carton, depending on when the transducer signal is scanned.

Beads Generated by PLC with 10 Millisecond Scan Time



Beads Generated by PLuS with 300 Microsecond Scan Time



Factors that Influence PLuS Scan Times

As mentioned earlier, PLuS software is optimized for extremely fast scan times. The processing time required to turn devices ON and OFF is unaffected by the number of ON/OFF setpoints programmed into the controller. However, if special programming functions are applied to these setpoints, the PLuS scan times may increase.

Figure 6 lists some of the sophisticated functions available in Electro Cam Corp. PLuS's that may lengthen scan times. For any given function, the effect on scan time will vary depending on application factors such as the number of output devices, the number of input sensors, and the resolution of the transducer. Regardless of the complexity of the programming, the slowest PLuS scan times are still much faster than the scan times of reasonably priced PLC's.

Figure 6—Programming Functions that Affect PLuS Scan Times

Function	Description	Scan Time Considerations
Speed Compensation	• Automatically advances or retards setpoints in proportion to RPM. • Used to compensate during speed changes for the fixed response times of devices such as solenoids or glue guns. • Improves accuracy over a range of speeds, reducing scrap and waste.	• Scan times for Series 5144 & 6000 are unaffected by speed compensation. • Speed compensation lengthens scan times in Series 5000 units. The more output devices compensated, the greater will be the increase in scan times.
Timed Outputs	• A timed output will remain ON for a specified time regardless of RPM. • Used for devices such as pneumatic cylinders which require a fixed time to perform a task regardless of machine speed.	• The more timed outputs used, the greater the increase in scan time.
Groups & Modes	• Outputs can be grouped, and each group can be associated with an input terminal in any of six “modes” of operation. • Modes perform logic, such as enabling a group of outputs to operate only when a sensor signal is present. • Used to actuate devices such as glue guns only when a product is present; saves glue, reduces scrap and mess.	• The more groups defined, the greater the increase in scan time.

Interrupt-Driven PLuS’s

For applications where typical PLuS scan times are too slow, Electro Cam Corp. offers PLuS’s with “interrupt-driven” programming. Unlike conventional controllers which repeat the scanning cycle continuously, an interrupt-driven PLuS does not begin its processing until the rotary input signal changes. When the controller receives a change in position signal, it performs one complete processing cycle, then pauses and waits for the next change in position.

For interrupt-driven PLuS’s, the term “scan time” is essentially meaningless, since the controller does not perform uninterrupted scanning cycles. The maximum response time from the moment a position change occurs to the moment the outputs update is 40 microseconds. Another ten microseconds is required for “housekeeping” tasks such as updating the display. Figure 7 lists scan times or processing cycle times for various Electro Cam Corp. PLuS models.

Figure 7—Summary of Electro Cam Corp. Models

Conventional Models

Controller	Transducer	Resolution[1]	Typical Scan Times[2]
Series 5000	Resolver or Encoder	1024	150 to 250 microseconds
Series 5144	Resolver	1024	250 to 500 microseconds
Series 6144	Resolver	1024	300 to 500 microseconds

Interrupt-Driven Models

Controller	Transducer	Resolution[1]	Typical Cycle Times
Series 5000 MAN[3]	Resolver	1024	50 microseconds
Series 6244	Quadrature Encoder	1000	50 microseconds

Notes: [1] Maximum transducer resolution supported by the standard controller model. Some models offer a high resolution option (“-H”) of 4096 increments per transducer resolution.

[2] Times will vary depending on model and programming.

[3] Special unit optimized for laser coding of labels.

Resolution, RPM, and Scan Time

The position signal in a PLuS system is divided into a fixed number of increments per shaft rotation. This resolution determines the limits of accuracy possible in a machine process.

For example, in the “Simple Gluing Application” shown in Figure 3, the transducer shaft will rotate once for every 18" of conveyor travel. If the control system resolution were 1024 increments per revolution, the position signal from the transducer would change every 1/1024th of 18", or every 0.018" of conveyor travel. This means that glue bead position and length could be adjusted in increments of 0.018". Lower transducer resolutions would provide coarser adjustment increments, while higher resolutions would provide finer adjustments.

The time between a change from one position increment to the next depends on the system resolution and transducer speed, as shown in Figure 8. To respond to any possible change in position, a controller must be fast enough to scan the position input signal at least once per increment. Referring to Figure 8, if a control system had a resolution of 1024 increments per revolution, and the transducer speed were 500 RPM, the position signal to the controller would change every 117 µsec. In order to “see” every change in position signal, the controller would need to scan the signal at least once every 117 µsec. If the controller’s scan time were longer than 117 µsec, the controller would occasionally respond one increment late to a change in position, resulting in a lower effective resolution for the system.

Figure 8—Microseconds per Position Increment @ Various Speeds

	Resolution, Increments per 360°			
RPM	**256**	**512**	**1024**	**4096**
100	2344 µsec	1172 µsec	586 µsec	146 µsec
400	586 µsec	293 µsec	146 µsec	37 µsec
800	293 µsec	146 µsec	73 µsec	18 µsec
1200	195 µsec	98 µsec	49 µsec	12 µsec

Figure 8 is helpful in determining which PLuS model to use for various machine speeds. For example, the Series 5000 MAN unit listed in Figure 7 is interrupt-driven and has a processing cycle time of 50 microseconds. With a resolution of 1024 increments, this controller can complete one processing cycle per position increment at speeds up to 1200 RPM, as shown in Figure 8.

In contrast, the Series 6144 controller in Figure 7 has the same resolution, but scan times range from 300 to 500 microseconds, depending on the application. Using the 300 microsecond value and interpolating from the “1024” column in Figure 8, the controller can complete one processing cycle per increment at speeds up to (586 ÷ 300) x 100, or 195 RPM. At some higher speed, the time between position increments will be shorter than the controller’s scan time and the controller might intermittently respond one increment late to a change in transducer position.

In a gluing application similar to Figure 3, this could slightly increase the variation in glue bead positions and lengths shown in Figure 5. However, depending on the process and the machine speed, the benefits provided by the advanced programming and control features of the Series 6144 PLuS might outweigh this small additional inaccuracy at higher speeds.

Application Assistance

Electro Cam Corp. is highly experienced in analyzing machine control problems and finding economical solutions that provide excellent productivity and product quality. For application assistance, or to request more detailed information on our products, please call our application engineers:

Toll Free: 800-228-5487 (USA & Canada)

Regular: 815-389-2620