# Fundamentals of Speed Compensation

Speed compensation refers to the ability of an electronic controller to automatically adjust the timing of machine components in proportion to machine speed. Speed compensation allows devices with fixed response times, such as glue guns, to perform with high accuracy over a wide range of machine speeds. Without speed compensation, a glue bead may tend to "drift" out of position as shown in Figure 1. By using a controller capable of speed compensation, such as an Electro Cam Corp. PLuS Programmable Limit Switch, the glue bead position can be maintained precisely throughout the complete range of machine speeds.

### Benefits

Speed compensation provides substantial benefits:

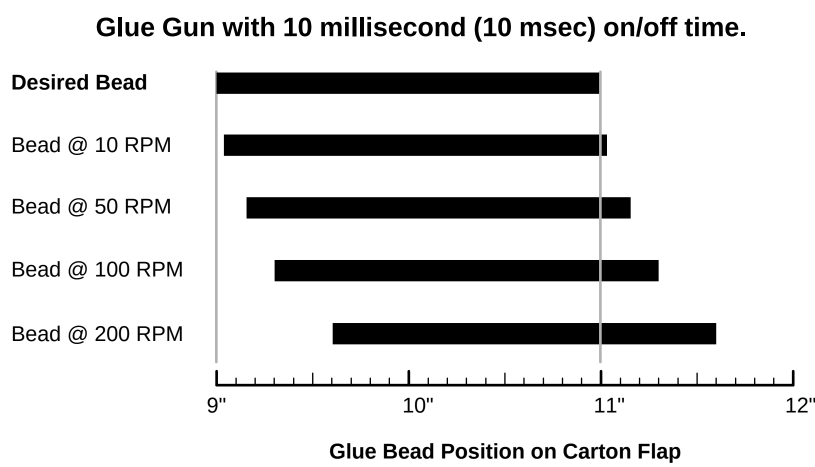
**Improved Accuracy—**Speed compensation maintains the accuracy of critical operations such as gluing, thereby reducing rejects, rework, and scrap.

**Increased Productivity—**By maintaining accuracy, speed compensation can increase line speeds by as much as 50 percent.

### Controllers

Most types of electronic machine control offer some form of speed compensation. However, programming speed compensation into PLC, stepper motor, or servo motor systems can be difficult. In addition, high-speed hardware for these systems can be expensive.

**Figure 1—Glue Bead "Drift" Without Speed Compensation**




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

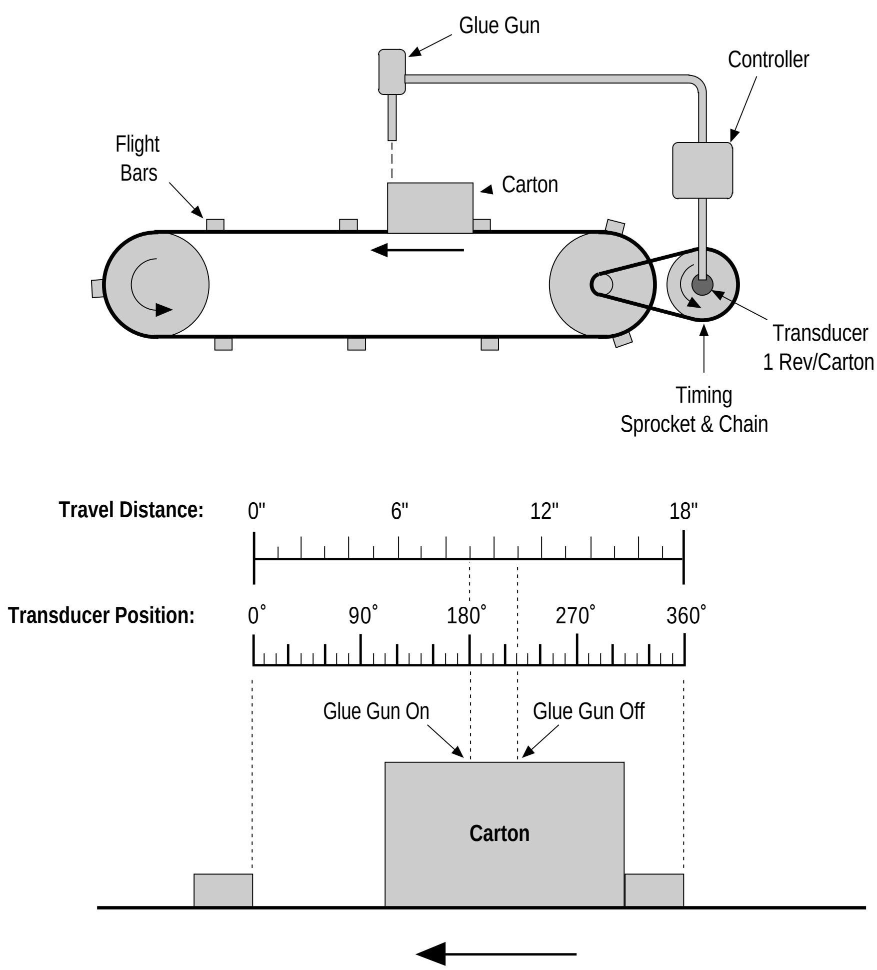
In comparison, speed compensation is an integral part of a PLuS controller's software and is optimized for high-speed machine control. A simple user interface makes it easy to adjust speed compensation values with the machine in motion. PLuS controllers eliminate the need to write custom speed compensation programming, providing excellent high-speed control at a fraction of the hardware cost of comparable systems.

## Application Example

Figure 2 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 carton that passes beneath the gun.

Figure 2 also includes a linear representation of the transducer position showing how it relates to inches of carton travel. When the transducer reaches 180°, the carton is in position and the controller turns the glue gun on. At 220°, the controller turns the glue gun off. The resulting glue bead is two inches long, as shown in Figure 1.

**Figure 2—Simple Gluing Application**



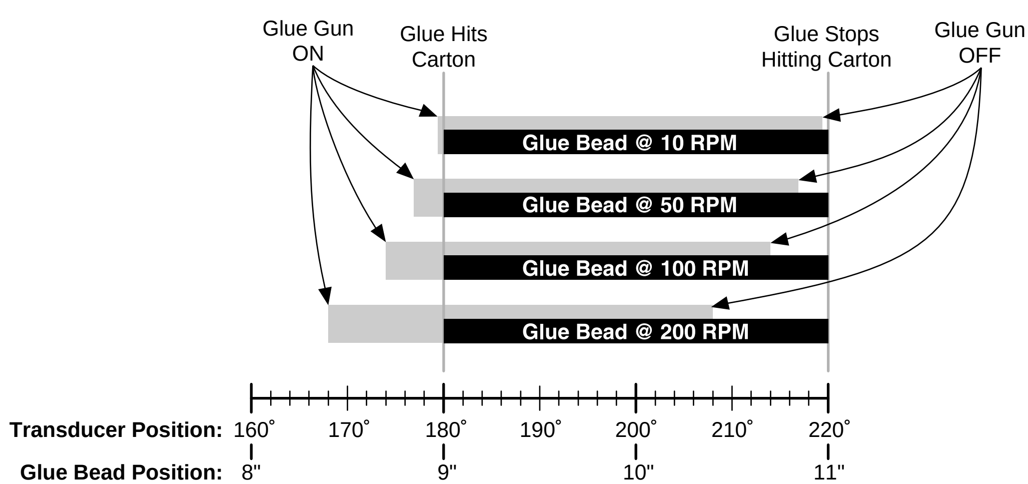
Suppose that the glue gun in Figure 2 has a response time of five msec. This means that when the controller energizes the gun, glue does not actually begin spraying until five msec later. Likewise, when the controller de-energizes the gun, glue does not stop spraying until five msec later.

Once the glue leaves the nozzle, it requires another five msec to travel across the gap and hit the carton. Combining the glue gun response time with the time for the glue to reach the carton results in a system response time of ten msec. This response time is constant regardless of how fast the cartons are traveling.

At very slow, or essentially zero speed, the system response time does not affect the glue bead position. However, as line speed increases, the cartons begin to travel a significant distance during the ten msec between the time the gun is energized at 180° and the glue hits each carton. In order to prevent the glue bead from "drifting" as shown in Figure 1, the gun must be energized before the transducer reaches 180°. The faster the cartons travel, the greater the advance required. Figure 3 shows how speed compensation can correct the glue pattern drift shown in Figure 1.

Electro Cam Corp. PLuS controllers can automatically calculate the compensation required as transducer speed varies. The remainder of this paper discusses various methods of programming and applying speed compensation using PLuS controllers.

**Figure 3—Speed Compensation Eliminates "Drift" of Figure 1**




## Calculating Speed Compensation

When calculating speed compensation, use these relationships between transducer speed and degrees of rotation:

1 RPM = 360º/min = 6º/sec = 0.006º/msec,

RPM x 0.006 = deg/msec,

thus: @ 100 RPM, the transducer will rotate 0.6º/msec
@ 1000 RPM, the transducer will rotate 6.0º/msec

In the previous example, the gluing system requires ten msec from the time the gun is energized to the time the glue hits the carton. At 100 RPM, the transducer will rotate 0.6º/msec. Therefore, in the ten msec response time, the transducer will rotate (10 msec x 0.6º), or 6º. This means the glue gun must be energized at 174º, which is 6º before the glue should start hitting the carton. To end the bead, the gun must be de-energized at 214º, or 6° before the glue should stop hitting the carton.

### Setting Speed Compensation

In many applications, speed compensation can be set by jogging the line to determine ON and OFF setpoints at zero speed, then entering the speed compensation value into the PLuS controller. In the previous example, the line would be jogged until the leading edge of the bead reaches the glue gun, which occurs at 180° of transducer rotation. The glue gun output would be set to turn on at this point. Then, the line would be jogged until the trailing edge of the bead is under the gun at 220°, and the glue gun output would be set to turn off.

Once these ON and OFF setpoints are established, the speed compensation value required is entered into the PLuS controller. Depending on the controller model, speed compensation values are entered as follows:

| PLuS Model | Speed Comp Value Entered | Example: Value Entered for 10 msec Response Time |
|---|---|---|
| PLuS 4000 | Deg./100 RPM | 6° |
| PLuS 5000 | Deg./1000 RPM | 60° |
| PLuS 5144 | Milliseconds | 10 msec |
| PLuS 6000 | Milliseconds | 10 msec |

### Response Time Unknown

For some machines, the response time of a component may not be known. To set up this type of equipment, jog a product through the machine and set the component ON and OFF setpoints as required. Then, estimate a speed compensation value and enter it.

Start the line, run it at a fixed line speed, and adjust the speed compensation value as required for proper operation. Once programmed, vary the line speed to confirm proper operation at all speeds. Fine tune the speed compensation value if necessary.

### Machine Can't Be Jogged

If a machine can't be jogged to determine ON and OFF setpoints, start the line, run product through it at a fixed line speed, and set the ON and OFF setpoints as required for proper operation. Write them down for reference in the next step. Speed compensation should be set to zero.

Next, increase the line speed and adjust the setpoints to restore proper operation. Once a second pair of setpoints is programmed, compare them to the first pair. Establish a ratio of degrees of advance versus speed as shown in a gluing example in Figure 4. Convert this ratio to a speed compensation value and enter it into the controller.

Since the new speed compensation value will affect the ON and OFF setpoints, start the line one more time and, at a constant speed, adjust the ON and OFF setpoints for proper operation. Once set, vary the line speed to confirm that the speed compensation value is accurately adjusting the setpoints over the operating speed range.

### Figure 4—Sample Calculations Based on Two Speeds

| | RPM | Glue On | Glue Off | Difference |
|---|---|---|---|---|
| **1st Line Speed:** | 200 | 73° | 156° | 83° |
| **2nd Line Speed:** | 680 | 49° | 132° | 83° |

**Difference in Position:** 73° - 49° = 24°
**Difference in Speed:** 680 RPM – 200 RPM = 480 RPM

**To Calculate Speed Compensation Values:**

Divide the difference in position by the difference in speed:

- 4000 Series: 24°/480 RPM = 5° per 100 RPM
- 5000 Series: 24°/480 RPM = 50° per 1000 RPM
- 5144/6144: 24°/480 RPM = 0.05° per 1 RPM. Since a shaft at 1 RPM rotates 0.006°/msec, this shaft would require (0.05/0.006), or 8.3 msec to rotate 0.05°. The response time is thus 8.3 msec, which should be entered as the speed compensation value.

### Leading/Trailing Edge Speed Compensation

In the previous examples, the response time of the glue gun was the same whether turning on or turning off. While this applies to many systems, some devices have different on/off response times. For these devices, PLuS controllers with the “-L” option provide the ability to program different speed compensation values for the ON and OFF setpoints. The amount of speed compensation is calculated using the same method as standard speed compensation, but two values can be entered for each device being controlled.

### Setting Leading/Trailing Speed Compensation

If the ON and OFF response times are known, jog the line to determine ON and OFF setpoints at zero speed and enter them into the controller. Then enter the leading and trailing speed compensation values as explained in the manual for the PLuS controller.

## Figure 5—Leading/Trailing Calculations Based on Two Speeds

| | RPM | Glue On | Glue Off | Difference |
|---|---|---|---|---|
| **1st Line Speed:** | 200 | 73° | 156° | 83° |
| **2nd Line Speed:** | 680 | 49° | 144° | 95° |

Note that the length of the pulse is 83° at 200 RPM, and 95° at 680 RPM. This means that the leading and trailing edges required different speed compensation values.

**Leading Edge:** **Difference in Position:** 73° – 49° = 24°
**Difference in Speed:** 680 RPM – 200 RPM = 480 RPM

Divide the difference in position by the difference in speed:

- 4000 Series: 24°/480 RPM = 5° per 100 RPM
- 5000 Series: 24°/480 RPM = 50° per 1000 RPM
- 5144/6144: 24°/480 RPM = 0.05° per 1 RPM. Since a shaft at 1 RPM rotates 0.006°/msec, this shaft would require (0.05/0.006), or 8.3 msec to rotate 0.05°. The response time is thus 8.3 msec, which should be entered as the **leading edge** speed compensation value.

**Trailing Edge:** **Difference in Position:** 156° – 144° = 12°
**Difference in Speed:** 680 RPM – 200 RPM = 480 RPM

Divide the difference in position by the difference in speed:

- 4000 Series: 12°/480 RPM = 2.5° per 100 RPM
- 5000 Series: 12°/480 RPM = 25° per 1000 RPM
- 5144/6144: 12°/480 RPM = 0.025° per 1 RPM. Since a shaft at 1 RPM rotates 0.006°/msec, this shaft would require (0.025/0.006), or 4.2 msec to rotate 0.025°. The response time is thus 4.2 msec, which should be entered as the **trailing edge** speed compensation value.

### Leading/Trailing Response Times Unknown

If the device response times are not known, jog the line to program ON and OFF setpoints at zero speed. Estimate both ON and OFF speed compensation values and enter them into the controller. Start the line, run the product through it at a fixed speed, and adjust each speed compensation value as required for proper operation. This can be done while the line is in motion. Once programmed, vary the line speed to confirm proper operation at all speeds. Fine tune the speed compensation values if necessary.

If it is impossible to jog the line, run the line at a fixed speed and set the ON and OFF setpoints as required. Speed compensation should be set to zero for both the leading and trailing edges. Write down the ON and OFF setpoints.

Next, increase the line speed and adjust the setpoints (not the speed compensation values) to restore proper operation. Once the second pair of setpoints is established, calculate separate leading and trailing edge speed compensation values as shown in Figure 5.

Since the new speed compensation value will affect the ON and OFF setpoints already programmed, start the line one more time and, at a constant speed, adjust the ON and OFF setpoints for proper operation.

## Negative Speed Compensation

Standard speed compensation advances the setpoints as machine speed increases. In some applications, however, negative speed compensation is required to retard the setpoints as speed increases. Negative speed compensation is usually found in two situations: Wrap-up, and sensor lag.

### "Wrap-Up"

As some machines increase in speed, the drive train transporting the products begins to "wrap-up", causing the product position to lag the resolver position. If the wrap-up is proportional to machine speed, negative speed compensation can be used to retard an output's setpoints from the true resolver position, thus maintaining output accuracy.

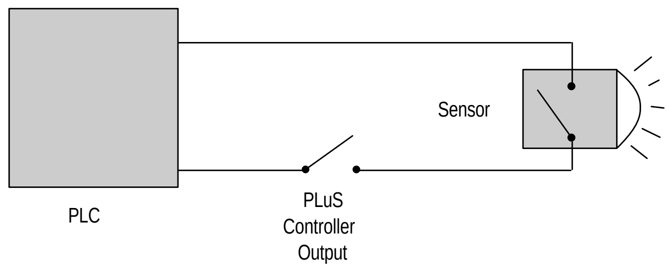
### Sensor Lag

While controller outputs are usually used to switch devices on and off, another use is to "gate" a sensor into a Programmable Logic Controller (PLC) or other computer. Figure 6 illustrates a basic sensor gating scheme. In the illustration, the signal from the sensor reaches the PLC only when the output from the PLS is turned on.

Most sensing devices have very fast response times. However, if a sensor's response time is slow, its signal will appear later and later in the machine cycle as the machine speeds up. Eventually, the sensor may lag the resolver so much that its signal fails to appear during the pulse programmed into the controller's output.

Negative speed compensation will correct this problem by causing the output to lag its programmed machine position by a specified value. Negative speed compensation is calculated using the same method as standard speed compensation.

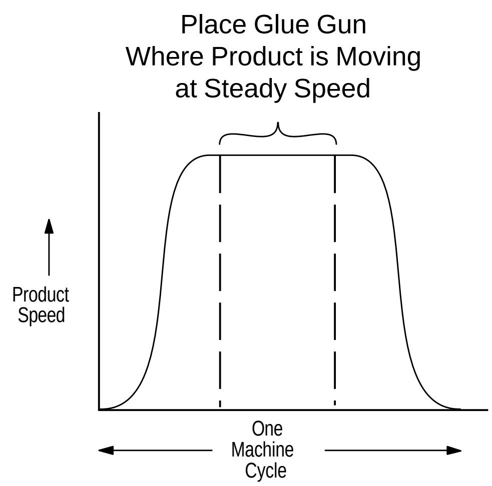
**Figure 6—Simple Sensor Gating Scheme**



## Placement On Indexing Applications

For speed compensation to work most effectively, the device being controlled should be located where the product is moving at a constant speed. On machines using index drives, products accelerate and decelerate with each machine cycle as shown in Fig. 7. Speed comensated devices should be located at the flat portion of the curve in such applications.

## Figure 7—Device Placement in Indexing Applications




## Rapid Acceleration or Deceleration

Most controllers capable of speed compensation have difficulty with machines that accelerate or decelerate rapidly. By the time the controller calculates the compensation and fires the outputs, the machine may have stopped or radically accelerated, causing inaccurate operation.

Recently, Electro Cam Corp. developed a new algorithm for speed compensation that substantially improves performance in these applications. Currently available in the Series 5144 and 6144 PLuS controllers, this enhancement prevents false firing of outputs under rapid acceleration or deceleration. For more information on this feature, or assistance with any application questions, please call Electro Cam Corp. toll free at 1-800-228-5487 (U.S. & Canada).



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