



**PowerTools Pro Application Note**  
**PTAN #7, rev. 1, 3/30/2009**  
**Applicable Products: Epsilon EP-P, FM4E,**  
**SM EZMotion, Digitax ST-Z**

**Cams with  
Non-Zero  
Starting Velocities**



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## **Introduction**

The Camming ability within PowerTools can create very sophisticated, virtually unlimited, motion control profiles. One special case of camming is cams that have a non-zero starting velocity. This is a difficult concept to understand; intuitively any motion starting from a stand still should have a non-zero starting velocity, right? But this is not the case with cams.

This app note shows the user how to identify cams with non-zero starting velocities and what measures can be used to mitigate the issues they create

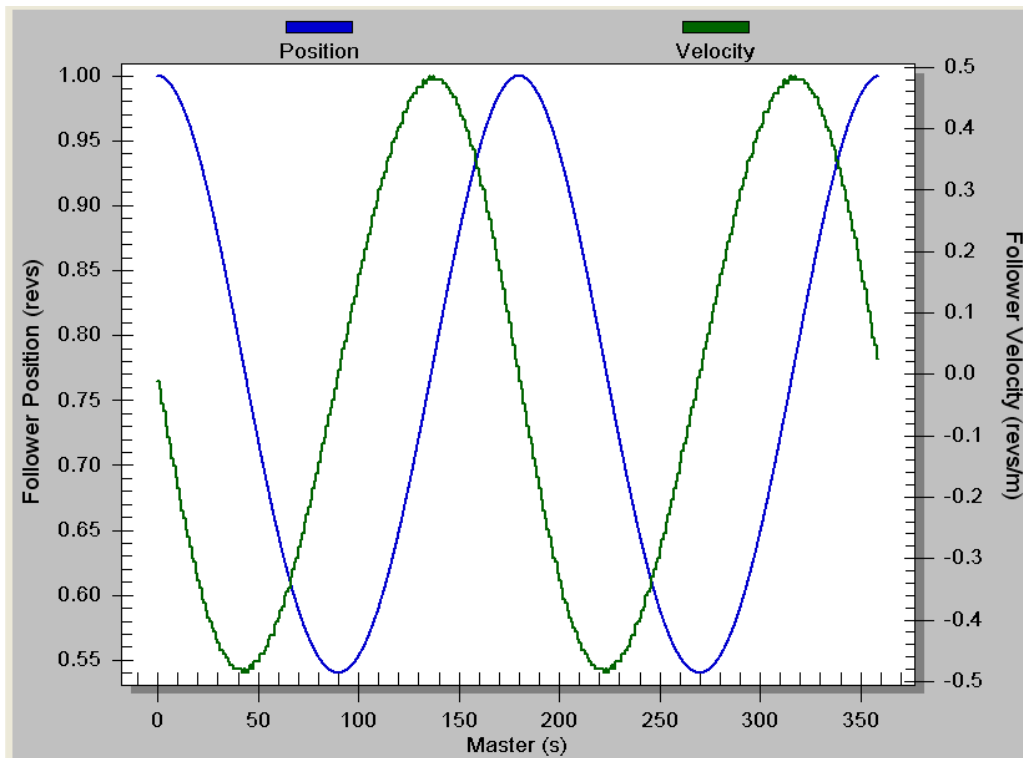
We can construct a cam in PowerTools to replicate trigonometric functions as shown below. An xls file was used to quickly construct a data table of master (angle) vs. follower (position) values. Don't let the coarseness of the graph bother you, this is due to the limited resolution of the data that the xls file produced. The xls file was saved as a csv file and imported into PowerTools.

Let's first take a look at the Cosine curve. The Cosine function has a zero starting velocity and will be used to illustrate the differences between zero and non-zero starting velocities.

Below is a graphical view of the position and velocity of a Cosine curve plotted against the master position (or angle). The master position could also be time in real time cam.

Notice that the Position (blue line) of the cosine curve at master =0, is at its maximum and that the initial velocity (green line) is at zero. The Velocity scale is shown on the right side of the plot.

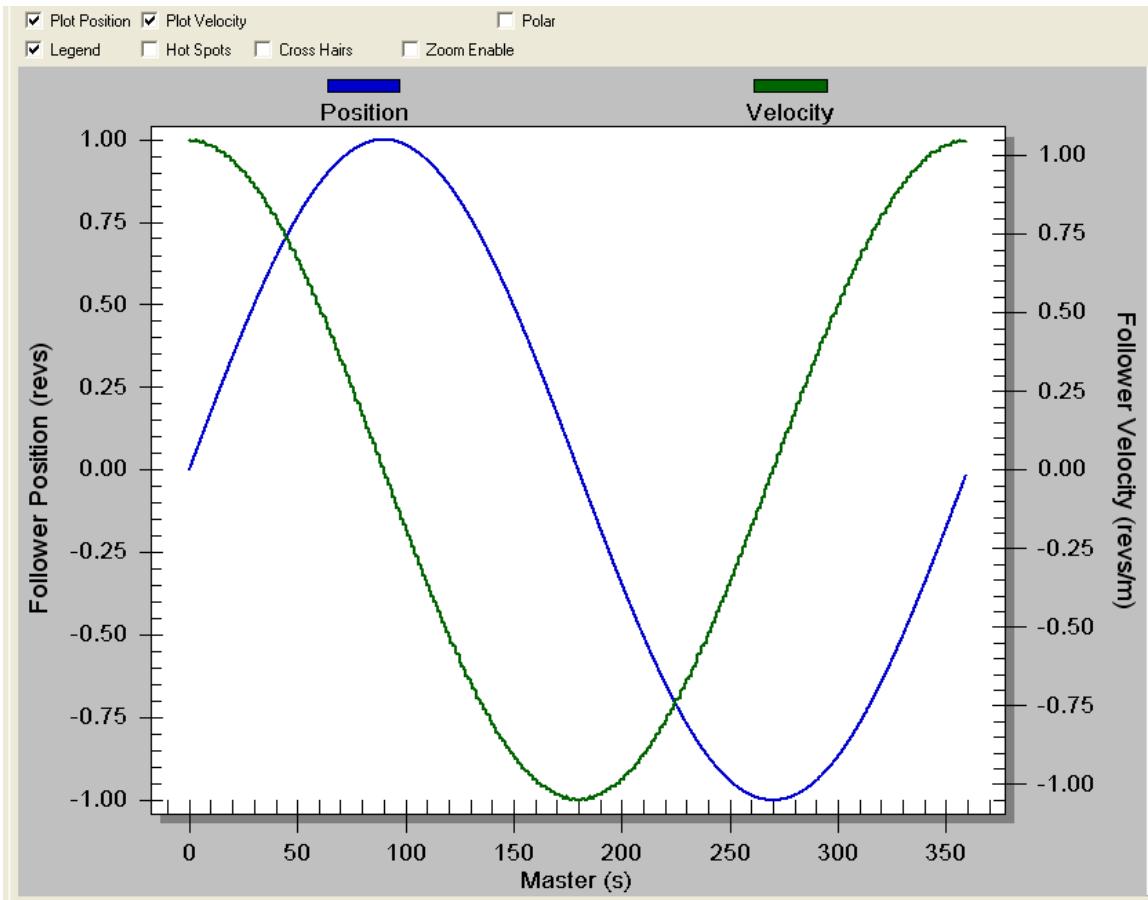
Mathematically speaking: velocity is the 1<sup>st</sup> derivative (the slope) of the position curve. The slope of the position curve at the master=0 point is a flat line or zero slope.



To illustrate a non-zero starting velocity let's take a look at the Sin curve. Here is a graphical view of the position and velocity of a Sin curve plotted against the master angle. The master position could also be time, if used in a real-time cam.

Notice that the Position (blue line) of the sin curve at master =0, is 0 (or  $\text{Sin}(0) = 0$ ) and that the initial velocity (green line) is at it's maximum.

Mathematically speaking: the velocity is the 1st derivative (the slope) of the position curve. As you can see the slope of the position curve at master =0 is at its maximum value. This is an example of a non-zero starting velocity cam.





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The dilemma comes when the cam is started. The cam profile will command the velocity to reach its maximum instantaneously, causing a harsh jerk in the motion profile. Once the cam has started, the cam motion will follow the sine profile.

The drive could artificially limit the acceleration ramp, but then it would not be following a true sine curve.

To mitigate the instantaneous acceleration at start, the following techniques can be used:

1. Start the cam, then start the master's motion
  - a. The master's finite acceleration will allow the cam to come up to speed smoothly and follow the sin curve.
2. Chain an acceleration cam into the cam
  - a. This will not follow the sin curve perfectly during the acceleration, but it will prevent the harsh instantaneous acceleration
2. For systems without a physical master - use a VM index to start the cam
  - a. Initiate the cam
  - b. Initiate the Virtual Master
    - i. The VM Acceleration value or Feedrate Override ramp will force the follower to accelerate slowly, but also allow the follower to keep in perfect match to the sine curve