PMC Precision MicroControl Corp. TechNOTE

Title: Motion Trajectory Generation with MultiFlex Motion Controllers
Products(s): All MultiFlex motion controllers
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Summary

PMC's MultFlex family of motion controllers feature versatile trajectory generation in conjunction with the servo PID loop to provide flexibility and precision in customizing motion paths.

More Information

Closed-loop servo position-mode moves in PMC motion controllers are based upon the operation of two entities in the control system. The PID loop performs high-rate position-feedback filter calculations to control the command voltage to the motor. The trajectory generator is responsible for generating one of two supported types of velocity profiles to provide optimal target positions to the filter.

The trapezoidal profile generates a step-function in acceleration, resulting in a faster time to maximum velocity, but has somewhat longer settling times, depending upon the mechanical constants of the system. The s-curve profile is based upon a piecewise-continuous sine acceleration curve that is somewhat slower to the position target but settles more quickly. The following pages contain a description of the calculations required to generate the two supported velocity profiles.

A position move can be fundamentally described to the controller based upon three parameters in terms of encoder position counts,

A	maximum acceleration $(\frac{counts}{\sec^2})$
D	maximum deceleration $(\frac{counts}{\sec^2})$
V	maximum velocity $(\frac{counts}{\sec})$

An additional scaling factor must be considered to understand the normalization that takes place in the controller,

N	trajectory updates per sec. ($\sec^{-1}$)

Precision MicroControl Corp.
Intelligent Motion Control Since 1987
2075-N Corte del Nogal
Carlsbad, CA 92011 • USA
Tel: (760) 930-0101
Fax: (760) 930-0222
E-Mail: support@pmccorp.com
Web: http://www.pmccorp.com

In the current revision of the controller firmware, the value of N is fixed at 1000[1]. In the following development, the values of A and D are assumed to be the same, although this is not a requirement and the examples presented can be easily extended to cases where they are different.

Two pre-calculated values are required to define the trajectory based upon the parameters described above,

T_A	acceleration time (s)
S_A	acceleration distance (counts)

When the total move distance, S_{TOT} , is defined, all other characteristics of the trajectory can be derived from these according to,

$S_V = S_{TOT} - 2S_A$	constant velocity distance (counts)
$T_V = \frac{S_V}{V}$	constant velocity time (s)

Before calculating the expected trajectory values, the user parameters must be scaled to controller units to allow correct interpretation of the updated acceleration, velocity and position values produced by each cycle through the trajectory generator. The scaling can be performed according to the following,

$ACC = A / N^2$	controller acceleration$\left(\frac{counts}{cycle^2}\right)$
$VEL = V / N$	controller velocity $\left(\frac{counts}{cycle}\right)$

This example illustrates these scaling operations using the following set of user parameters,

$A = 100{,}000 \ \frac{counts}{\sec^2}$ $\quad$ $V = 40{,}000 \ \frac{counts}{\sec}$ $\quad$ $S_{TOT} = 40{,}000$ counts

resulting in the scaled values,

$ACC = 0.1 \ \frac{counts}{cycle^2}$ $\quad$ $VEL = 40 \ \frac{counts}{cycle}$

to produce the following trajectory profiles:

[1] The production version of controller firmware for the Multiflex ETH controller will have selectable trajectory generator rates of 1 kHz/4 kHz/8kHz.

parameter	trapezoidal	s-curve
T_A (cycles)	400	628
S_A (counts)	8000	12,560
S_V (counts)	24000	14,880
T_V (cycles)	600	372

The following pages describe the method of determining T_A and S_A for the trapezoidal and s-curve profiles in detail. In both cases, the trajectory is defined by an acceleration profile and the velocity and position curves are obtained by successive integration with respect to time.

Trapezoidal Velocity Profile

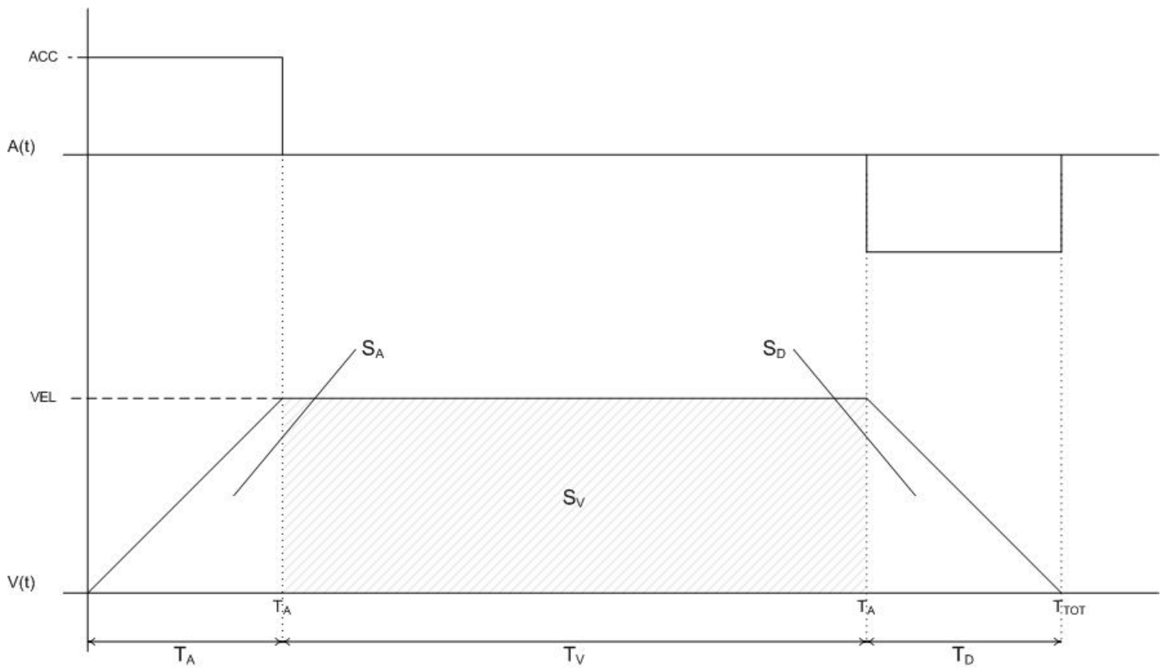

Figure 1. Trapezoidal Velocity Profile

$$A(t) = ACC$$

$$\begin{aligned} V(t) &= \int A(t)dt \\ &= \int ACCdt \\ &= ACC * (t) \end{aligned}$$

$$S(t) = \int V(t)dt$$

$$= \int ACC(t)dt$$

$$= \frac{1}{2}(ACC) * t^2$$

The resulting pre-calculated values for the trapezoidal velocity profile are:

$$\boxed{\begin{aligned} T_A &= \frac{VEL}{ACC} \\ S_A &= \frac{1}{2}(T_A * VEL) \end{aligned}}$$

S-Curve Velocity Profile

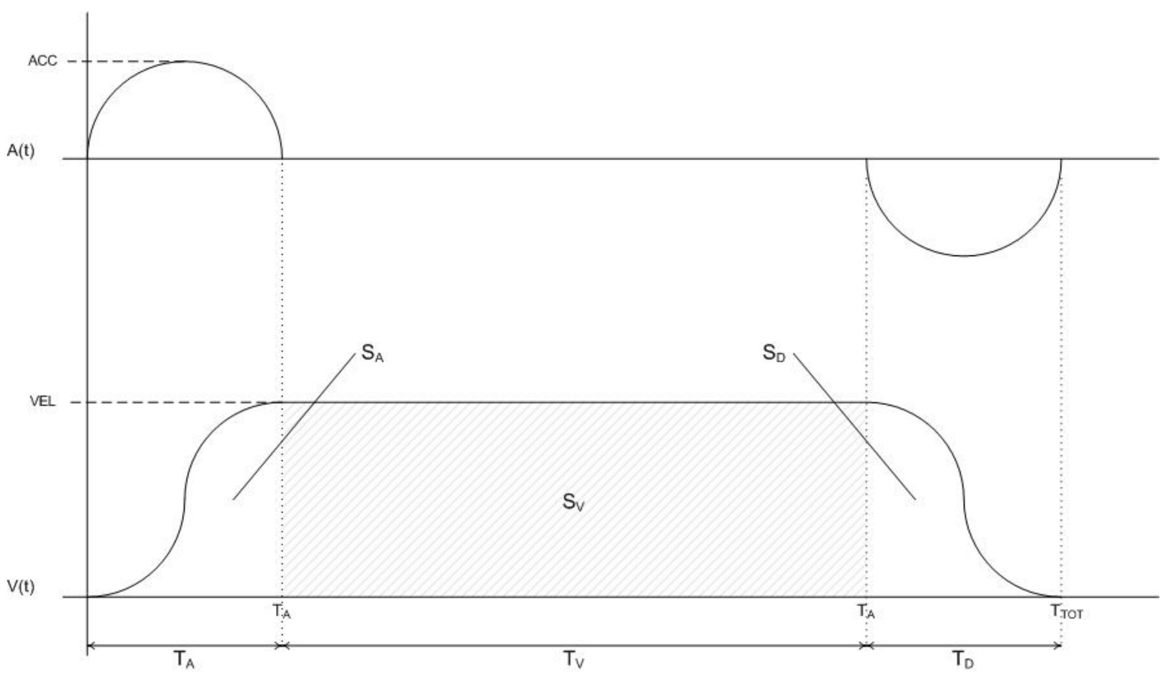

Figure 2. S-Curve Velocity Profile

$$A(t) = ACC \sin 2\Pi t$$

$$\begin{aligned} V(t) &= \int A(t)dt \\ &= \int ACC \sin 2\Pi t dt \\ &= ACC(1 - \cos 2\Pi t) \end{aligned}$$

$$S(t) = \int V(t)dt$$

$$= \int ACC(1 - \cos 2\Pi t)dt$$

$$= ACC(\sin 2\Pi t)$$

The resulting pre-calculated values for the S-Curve velocity profile are:

$$\boxed{\begin{aligned} T_A &= \frac{\Pi}{2}\left(\frac{VEL}{ACC}\right) \\ S_A &= \frac{1}{2}(T_A * VEL) \end{aligned}}$$

The final two figures show recorded data from a PMC Multiflex controller based on two position moves in each profile mode, using the example parameters discussed earlier in thedocument. The position data has been arbitrarily scaled for illustrative purposes and the time axis is in seconds.

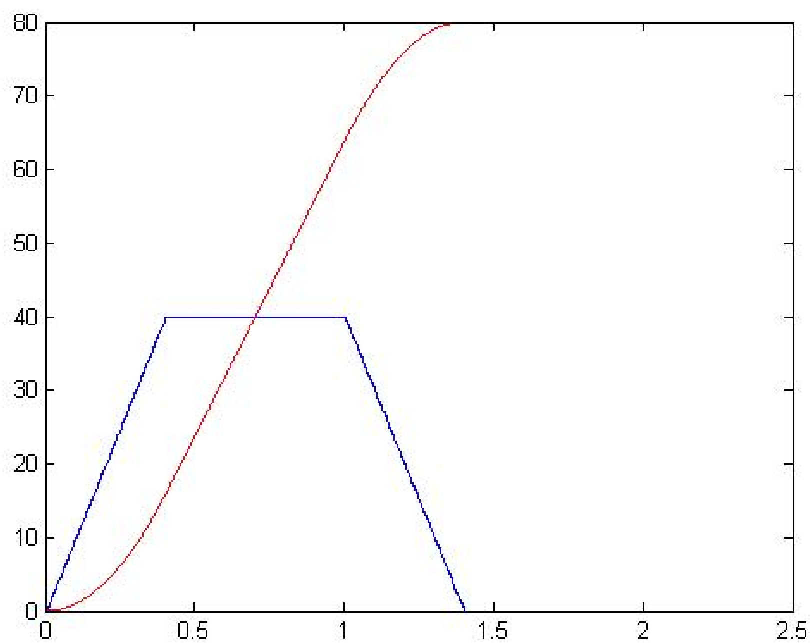

Figure 3. Trapezoidal Velocity and Position Profile

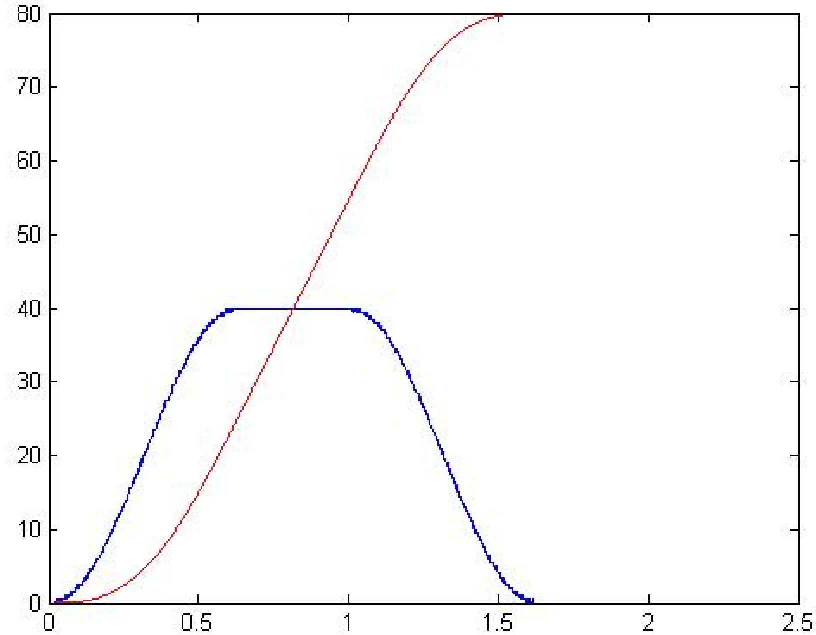

Figure 4. S-curve Velocity and Position Profile