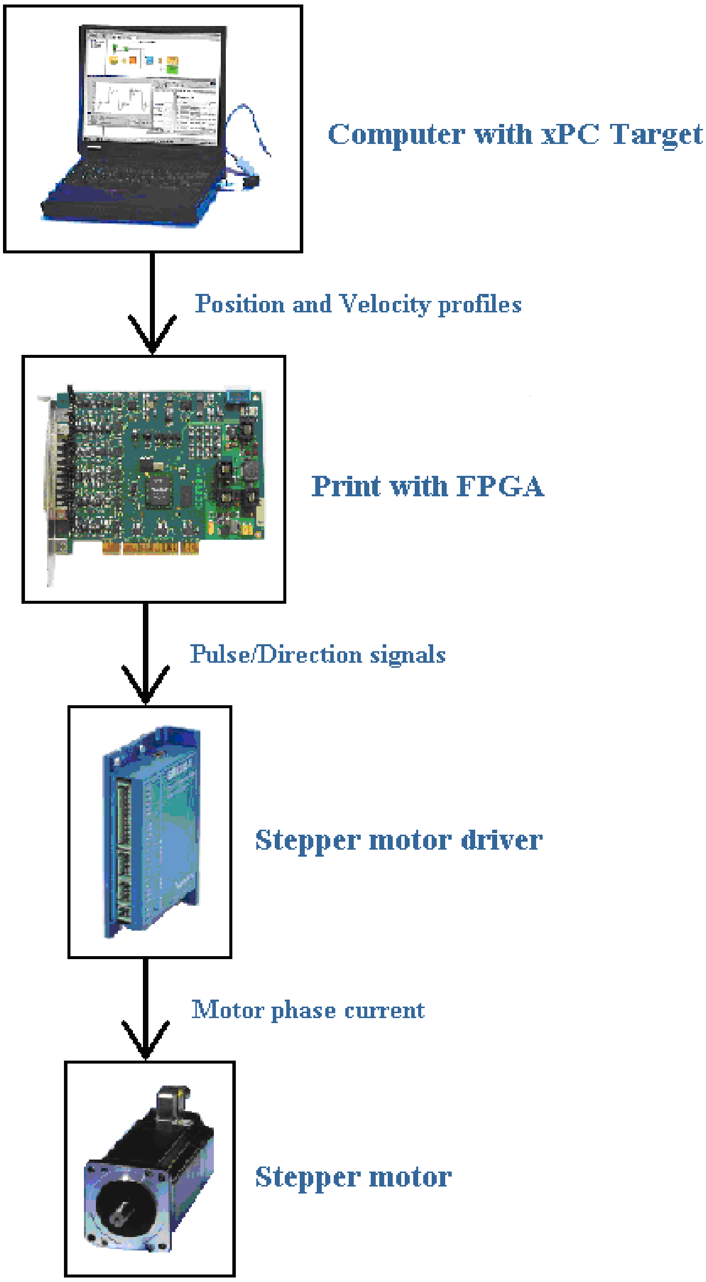
Precise positioning using DC^3

By Ir. Rob Pulles, CCM Centre for Concepts in Mechatronics BV.



Abstract
Drive Chain Compliancy Compensation (DC^3) is a revolutionary algorithm for precise positioning for a wide range of applications. Standard drive principals become far more efficient using a DC^3-setpointgenerator. Using this algorithm improvements are found in both tracking error and the maximum acceleration. These improvements lead to a higher throughput without the costs of more expensive hardware.

Introduction

For most producers there is a continuous desire to have faster and more accurate machines. When existing hardware is at its limits towards cost/quality, improvements can be found by using advanced steering.

Most drive principles use a rotational actuator, which defines the position of the load. This can be done with a measurement system in combination with a controller; the servo. A cheaper category uses stepper motors. Often people (unjustly) think a servo improves the drive system significantly. Because the prices of servo's are dropping many designers tend to choose a servo.

Positioning a stepper motor

At CCM we use a setpointgenerator implemented in xPC Target of the Mathworks to generate a real time position and velocity profile, see cover.
These profiles are sent to our Clib4Motion. This CLIB is a data-acquisition PCI-board which is developed by CCM. It is equipped with an Altera Cyclone2C20 FPGA. This FPGA provides the possibility to process data on board. Fast control loop algorithms, accurate process synchronization and digital signal processing are examples of implementations that can be achieved with this FPGA.
At CCM we programmed this FPGA to use the position and velocity profiles and generate a pulse/direction signal form them for the stepper motor driver. Figure 1 shows the implementation schematically.

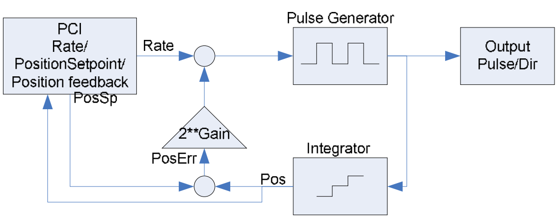


Figure 1 FPGA implementation to create pulse/dir signals

The stepper motor driver turns these signals into a current for each stepper motor phase.

Closer look to a Stepper motor

A stepper motor is steered by a constant current and a changing rotary field. This leads to a new reference position for the inertia. In figure 2, 4 positions are shown. The yellow angle shows the position change in relation to the starting position.
The more pole pairs (combination of teeth on the inertia of the motor and the teeth of the phases) the larger the amount of possible reference positions.

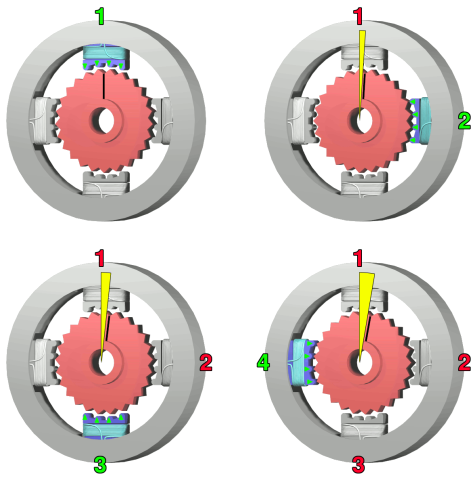


Figure 2 Movement of a stepper motor

Strengths and weaknesses

Stepper motors are cheap, intrinsic stable and there is no need of a measurement system. The use of a servo always requires some calculations to test the dynamics on bandwidth and robustness.
Both a servo and a stepper motor are characterized by an oscillating movement around the reference position. This is caused by a compliant element in the drive chain. The disadvantage of the stepper motor is that it has almost no damping (only damping caused by friction). Because of this the stepper motor has a relatively long settle time.

Oscillation

The oscillation in a stepper motor is caused by the combination of the electromechanical stiffness and it's inertia. To clarify the essence of the system, we use a lumped mass representation of a stepper motor with an extra load inertia caused by a disk, see figure 3.

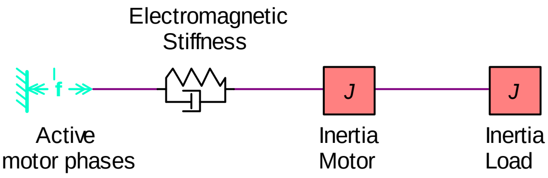


Figure 3 Lumped mass model

After moving to a new setpoint using this standard stepper motor and a driver (no intelligence on board) the load will start to vibrate around the reference position, see figure 4. This vibration result in possibly exceeding the maximum holding torque and with this the loss of steps.
In figure 4 we see a tracking error that oscillates with the systems natural frequency. As earlier explained the oscillation is only damped by the (small) contribution of friction, so there is a long settle time.

Using DC^3

By using DC^3 we change the setpoint profile for the stepper motor. This change is done in such a way that the load can follow the reference profile a lot better. The result of this change can be seen in figure 4.

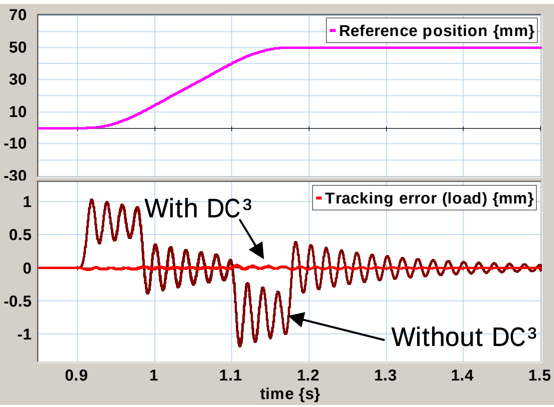


Figure 4 Tracking error [mm] and Reference position [mm], with and without DC^3

The tracking error still oscillates with its natural frequency, since the system isn't changed. But its amplitude is a lot smaller. This results in a shorter settle time and less chance of exceeding the maximum holding torque.
The DC^3-algorithm is intentionally meant for stepper motors, but it is also applicable for servo systems of which the response is dominated by a compliant element.

Advantages using DC^3

- 8x Settling time reduction
- 4x Better tracking error
- Easy upgrade in existing systems
- Accurate and low cost motion control
- Decrease maximum torque level
- Reduced motor load and/or wear

Who are we?

CCM is an independent research and development company, founded in 1969 by Professor Alexandre Horowitz. CCM has a long experience in inventing original concepts but is also capable of realizing the entire development process up to a finished product or installed production equipment. CCM integrates know-how in the fields of mechanical engineering, (opto-)physics, electrical and electronic engineering and information technology.

Development is done by CCM in a professional way, which enables us to control the costs for realizing functionality, performance and time to market.

CCM aims at a win-win situation, by building a strategic business relationship through intensive knowledge exchange.

CCM stands out thanks to a special know-how in the following areas;

- Machine dynamics with related control technology, specifically for fast and precise positioning and handling.
- 'Mechanical-photonics'; the design and realization of critical optical measurements
- Energy storage systems on the basis of fast moving flywheels
- Power electronics

CCM focuses on the following market areas:

- Semiconductor industry
- (bio-)medical/pharmaceutical industry
- Printing/imaging
- Aerospace
- Energy storage/electric drives

Mainly our customers are OEM companies such as: ASML, BESI, PamGene, Organon, AKZO, Océ, AGFA.

How to contact CCM

CCM Centre for Concepts in Mechatronics BV
P.O. Box 12, NL – 5670 AA Nuenen
De Pinckart 24, NL – 5674 CC Nuenen
Phone: +31 (0)40-263 50 00
Fax: +31 (0)40-263 55 55
Website: www.ccm.nl