ACS Motion Control
Your Partner for High Performance Motion Control
SPS 2014
Agenda

> **New Features** (Maksim A., Oleg R.)
> **Automatic setup of System & Network** (Oleg R.)
> **Case studies**- (Boaz K.)
  
  *Touch screen testing*
  
  *Alternative to moving magnet*

> **Short Brake**

> **New Products** (Zeev K.)

> **NanoPWM™ products roadmap** (Zeev K.)

> **Q&A** (open discussion)
Motion control enhancement for laser processing applications

XSEG, Geometrical processing
Laser Cutting
A Growing Market

> Industrial laser applications revenue

According to http://www.laserstoday.com/
Laser Cutting
The Need

> Laser cutting applications require an input of pulses to control laser power
  > Pulses at high precise frequency ~1[MHz]
  > Pulses with precise width
  > Pulses with varying: frequency, width or frequency and width

> Fast and precise motion along complex trajectories
  > Pulses parameters depend on velocity (in 1, 2 or 3 dimensions) of the laser head
  > Pulses should be fired along certain locations of the motion trajectory

> Treating faults reported by the laser
Laser control is provided (by ACS) as a programmable mode of P/D

- implemented in 2 ACS products: PDMNT and CMHP/BA with PD option

**LC1 features**
- Programmable pulse polarity
- Enable/disable
- Laser reported faults. LC1 enters disable mode upon receiving a fault
- Programmable (Real time) pulses:
  - At wide range of frequencies ~10[Hz]-1.2[MHz]
  - With different pulse width ~6.7[nsec]-111[ms]

**Simultaneous initialization and activation of several Laser Control units**
LC1 modes
varying duty cycle (PWM)

> Real-time varying duty cycle, with a fixed (programmable) frequency
> **Real-time varying frequency with fixed (programmable) positive pulse width (P/D like)**
LC1 modes
Varying frequency, fixed duty cycle

> Real-time varying frequency with fixed (programmable) duty cycle
Laser parameters may be changed by ACSPL+ parameters according to:

- Laser velocity
- Laser position along the trajectory (XSEG)
- Different inputs supplied by the laser
> **XSEG (Extended Segmented Motion):**
> 1. XSEG is an extension of MSEG which is a Multi-Segment Motion
> 2. Multi-axis motion (more than 3)
> 3. Continuous 2D or 3D path
> 4. Common in CAD applications
> 5. Extensively used in Laser Cutting applications
> 6. Typically composed of ARC and LINE segments
ENABLE (0,1)
PTP (0,1), 0, 0

XSEG (0,1), 0, 0
   LINE (0,1), 100, 0
   LINE (0,1), 100, 70
   ARC1 (0,1), 70, 70, 70, 100, +
   LINE (0,1), 0, 100
   LINE (0,1), 0, 0
ENDS (0,1)

STOP
XSEG
Capabilities: throughput increase

> **XSEG implements a special look ahead algorithm**
  > motion parameters according to the upcoming segments

> **Corner detection**
  > User determines velocity at distant corners
XSEG Enhancements
The Need

> **Increase throughput**
  > Geometrical processing
  > Jerk limitation at junctions

> **Improve user experience**
  > Automatic mode
  > Full control
XSEG Enhancements
The Solution

> Geometrical processing of motion profile

> Predefined deviation

> Predefined curvature

*Motion along smoothed trajectory (lines and arcs) performed faster than motion along lines only!*
XSEG Enhancements
The Solution

> Automatic arc application
> Square 100x100

> Original profile without geometrical processing lasts 270[msec]

Square with permitted deviation of 1

Profile time 265[msec] ~2% improve

Square with permitted deviation of 10

Profile time 224[msec] ~17% improve

*Motion parameters (VEL, ACC, DEC, JERK) are same for all experiments
> Mickey Mouse shape ~500x500[mm]  
> ~750 linear segments with average length of 6[mm]

> Trajectory duration
  > Original - 7785[msec]
  > Deviation of 0.1 - 5446[msec] ~30% improvement
  > Deviation of 1 - 4204[msec] ~46% improvement
  > Automatic processing of each segment < 6[mm] - 6400[msec]  
    ~18% improvement
  > Automatic processing of each segment < 10[mm] - 6400[msec]  
    ~42% improvement
> Powerful programming with ACSPL+ and flexibility of ACS SPiiPlus controllers allows to command the laser with required modulating signal as a function of velocity, position etc.

> Enhanced XSEG algorithm provides
  > Better throughput
  > Simple user interface
NetworkBoost™ - Network Failure Detection & Recovery
> Motion control systems that utilize EtherCAT networks are sensitive to failures of the network cables.

> Even an intermittent failure can have a detrimental effect on motion which could significantly impact the uptime of machines, especially those that include many moving nodes and cables.
EtherCAT Node / Cable Failure
NetworkBoost™ - Requirements

> **NetworkBoost™** is based on Ring Topology
> The PC used must have two Ethernet ports
> Other than one EtherCAT cable, there is no need for any additional components
NetworkBoost™ - based on Ring Topology

> Enables the network to resume and continue its normal operation without replacing the failed cable

> As long as there is no additional cable failure
Network Failure Detection and Recovery

> **Cable Disconnection**
  > Failing cables / intermittent connection
  > An intermittent disconnection of one wire (signal) within a cable

> **RX-error / CRC-error**
  > Electrical noise that results in a corrupted frame
  > A single frame is lost

> **NetworkBoost™** provides the possibility to switch to two separate line topologies that avoid the use of the suspected link
> Detection of the location of the failure

> The system reactivation in the simple and quick way, with no need for the machine re-initialization

> Ability to save the configuration after the failure, so at the subsequent power-up, the system will be initialized correctly (even if the cable is still broken)

> Quick and simple way to reinitialize the network after the failure repair
Benefits of NetworkBoost™

> **NetworkBoost™** Maximize machine uptime

> *Simple and easy troubleshooting and recovery*

> *Minimal intervention by the machine operator*

> **Currently NetworkBoost™ is supported by:**

  > SPiiPlusSC

  > SPiiPlusEC

  > **MC4U with 2nd EtherCAT port will be available soon**

  > Support by additional Master Controllers will be available in the future
NetworkBoost™ Video

Ring Topology

PC
SPiiPlusSC

UDMNT
UDMLC
IOMNT

Node 0
Node 1
Node 2
SPiiPlusSC Enhancements
SPiiPlusSC Enhancements

- Windows 8.1 x86 support
- Windows 8.1 x64 support
- x86 UEFI systems support
- Hyper-threading support is optimized for x64 systems
- More Network Cards to be used for EtherCAT communication are supported
- NetworkBoost™ feature support
Position Events Generation (PEG) Enhancements
Position Events Generation (PEG) Enhancements

- Time-Based PEG support
- Incremental PEG Improvement
- Loading Random PEG Arrays - Time Improvements
**Minimum HW Revision**

> **Minimum HW Revision that supports Position Events Generation (PEG) Improvements:**

<table>
<thead>
<tr>
<th>Product</th>
<th>Minimum HW Revision</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPiiPlusNT-LT / DC-LT</td>
<td>N/A</td>
</tr>
<tr>
<td>SPiiPlusNT-HP / DC-HP</td>
<td>N/A</td>
</tr>
<tr>
<td>SPiiPlusNT-LD / DC-LD</td>
<td>N/A</td>
</tr>
<tr>
<td>UDMNT</td>
<td>A6</td>
</tr>
<tr>
<td>SPiiPlusCMNT / UDMPM</td>
<td>B9/B8</td>
</tr>
<tr>
<td>UDMPC</td>
<td>C9</td>
</tr>
<tr>
<td>SPiiPlusSAnt / SPiiPlusSAdc</td>
<td>N/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product</th>
<th>Minimum HW Revision</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPiiPlusCMBA / UDMBA</td>
<td>B8</td>
</tr>
<tr>
<td>SPiiPlusCMHP / UDMHP</td>
<td>B8</td>
</tr>
<tr>
<td>UDMLC</td>
<td>A8</td>
</tr>
<tr>
<td>UDMMC</td>
<td>A1</td>
</tr>
<tr>
<td>UDIlt</td>
<td>B2</td>
</tr>
<tr>
<td>UDImhp</td>
<td>B2</td>
</tr>
<tr>
<td>PDiCl</td>
<td>A2</td>
</tr>
</tbody>
</table>
> The following optional parameters of PEG_I and PEG_R commands are now supported:

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>time-based-pulses</td>
<td>Optional parameter - number of time-based pulses generated after each encoder-based pulse, the range is from 0 to 65,535</td>
</tr>
<tr>
<td>time-based-period</td>
<td>Optional parameter - period of time-based pulses (milliseconds), the range is from 0.00005334 to 1.7476. Time-based period must be at least pulse width + 26.6667 nsec (minimum distance between two pulses)</td>
</tr>
</tbody>
</table>

> Supported by C and COM libraries as well
Incremental PEG Improvement

> **PEG_I** has a new switch for preventing error accumulation by taking into account the distance rounding between incremental PEG events.

> This switch must be used if the distance between PEG events, specified in user units, does not match the whole number of encoder counts.

> Using this switch is recommended for any application that uses **PEG_I** command.
The new \textit{/f} switch should be specified for the \texttt{ASSIGNPEG} command.

Typical times to Load 3 PEG Engines in Parallel 
\[\text{[msec} \times \text{CTIME]}\] :

<table>
<thead>
<tr>
<th>Number of Points to Load</th>
<th>BEFORE Without specifying PEG states</th>
<th>BEFORE With specifying PEG states</th>
<th>AFTER Without specifying PEG states</th>
<th>AFTER With specifying PEG states</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>29</td>
<td>30</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>16</td>
<td>73</td>
<td>100</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>64</td>
<td>218</td>
<td>315</td>
<td>24</td>
<td>27</td>
</tr>
<tr>
<td>256</td>
<td>800</td>
<td>1185</td>
<td>52</td>
<td>71</td>
</tr>
<tr>
<td>1024</td>
<td>3127</td>
<td>4667</td>
<td>168</td>
<td>244</td>
</tr>
</tbody>
</table>
System and Network Automatic Setup
Disadvantages of Current Process

> **Two separate components:**
  > EtherCAT Configurator for EtherCAT network configuration
  > System Configuration Wizard for system modules configuration.

> **If EtherCAT network is not configured correctly, the System Configuration Wizard will not work properly**

> **Configurations of SPiiPlusNTM/SC with only non ACS IO modules (e.g. Beckhoff) are not supported by the System Configuration Wizard**
> **Automatic Setup**
  > Fully automatic setup of the actual system

> **Manual Setup**
  > Modifying System Configuration
  > Modifying Configuration From Database
  > Loading Configuration From Database
  > Modifying Axes and I/O Allocation
  > Modifying PDO Configuration of Non-ACS Drives
Automatic Setup

- System initialization.
- Scanning EtherCAT network.
- Identifying network units.
- Saving configuration to controller.
- System initialization.

Verification:
- Reading configuration from controller.
- Scanning EtherCAT network.
- Identifying network units.

Completed.
Manual Setup
Load Configuration From Database
Manual Setup
Modify Axes and I/O Allocation
Manual Setup
Modify PDO Configuration
Manual Setup

Conflicts

Verification: Scanning EtherCAT network.
Verification: Identifying network units.
Selected Configuration is incompatible with connected system. The process cannot continue.
System Viewer and Diagnostics
Examples of applications

- Printed circuit board assembly
- Wire and die bonding
- Touch screen testing
- Thin flexible glass thickness measurement

Typically, an XYZ stage where Z axis is a linear actuator (i.e. voice coil) designed to apply force
An actuator should gently land on a delicate component
  > Without impact
  > Avoiding damage to the component, the underlying surface and the actuator itself

The components may be placed at different heights

After landing a controlled force should be applied for a certain duration
  > The amount of force and duration are programmable

The system should move to a next point and repeat the process as fast as possible to increase throughput
Soft Landing Routine

- Z axis approaches a surface at an unknown height and lands on it with a programmed force that can be as low as 10 grams

A typical soft landing routine:

- High speed approach in position mode to a "safe" height above the surface or part
- Switching to velocity mode and slowly approaching the part while monitoring a touch-down criterion:
  - Position error
  - Drive command / motor current
  - Load Cell feedback
- If one of the above measures is higher than a set threshold it indicates that Z axis landed on the surface
> If touch-down has not been identified within a certain distance the Z axis retracts

> After landing the axis is switched to force mode with the same amount of current as in the switch-over point

> The current is then ramped to get the desired force value while monitoring deflection or force feedback
The controller may apply force in open or closed-loop.

Open loop force control
- Controlling motor current only, assuming a linear relation between current and force
- May require an algorithm to dampen vibrations (based on the encoder)
- May require non-linear spring compensation

Closed loop control
- Applications like Touch screen testing or thin glass thickness measurement typically include a load cell mounted on the tip of the actuator
- A servo loop is closed on the force feedback
> **Closed loop control**
> - It does not directly control the actuator
> - An external loop that creates position or velocity corrections to the inner position or velocity loops
> - The position/velocity loops are used for smoothing and damping

> **Example for closed loop topology:**
Typical Requirements

- Very aggressive XYZ moves (high acceleration > 10g)
- Fast settling
- Few msec from touchdown till the required force has stabilized
- Very small overshoot in force (<10%)
- Wide range of forces 10gF – 2000gF with high accuracy (+/- 2%)
- Fast removal of force and back to retract position
- Seamless transitions from position/velocity modes <-> force mode
Force Control Examples

Apply 1000gF

Apply 200gF
> Force control applications require very fast responses of the motion axes and force applying axis

> Require landing on delicate components with no impact or damage

> May operate in either open or closed-loop force modes

> The process should be done as fast as possible for maximal throughput
> ACS Motion Control solution addresses all the requirements

> Special soft-landing algorithm that allows to land and apply the required force with no overshoot
> 20kHz implementation for the maximum possible responsiveness
> Seamless transitions between the various servo modes
> ServoBoost™ algorithm for maximal bandwidth with zero settling time to sub-micron resolution
> Special profiles to prevent excitation of vibrations
Alternative to Moving Magnet
Advantages of Moving Magnet Solution

- Typically used for transport systems
- Fixed coil tracks and magnetic movers
- Can move along curved tracks
- In a closed track the magnets can move in an endless loop
- No moving cables
- Each magnet can be controlled individually and independently
Disadvantages of Moving Magnet Solution

> **Non-standard components**
  > Few companies offer moving magnet solution
  > Non-standard drives and controls

> **Complexity**
  > Complex commutation control
  > Multiplexing between sensors

> **Cost**
  > Many drives are required, one for each coil
    Number of drives increases with track length
  > Non standard components
Disadvantages of Moving Magnet Solution

> **Limited performance**
  > Typically 6-step “trapezoidal” commutation is used
  > Strong cogging - most severe during passage from coil to coil
  > Sensors are typically hall-based with limited resolution and accuracy
  > Not suitable for many applications like high performance printing machines

> **Limited force constant (up to 230N continuous)**
> Standard Linear motors that move on a closed track

> Coils
  > Standard iron-core coils, offered by many companies

> Magnets
  > Standard linear motor magnets
  > Special curved magnets may be used on the curved tracks for smoother motion

> Feedback
  > Hall-based sensors: analog sin-cos interpolated for high resolution
  > May be combined with high resolution encoders for higher resolution and accuracy
Advantages of the Alternative Solution

- Assembled from off-the-shelf standard components
  - Standard iron-core linear motors
  - Standard drives and motion controller
- Only one drive is required for each moving coil
- Number of drives is not dependent on the track length
- High resolution encoder may cover only the important regions of the track (i.e. printing zone)
Advantages of the Alternative Solution

> **Higher performance**
  > Sinusoidal commutation for considerably smoother motion
  > High resolution optical encoders may be used at the required regions
  > Lower cogging that can be completely compensated by algorithms
  > Few microns of position error is possible

> **Lower cost**

> **Higher force constant of the linear motors (up to 1900N continuous)**

> **Simple control scheme, easy to use**
  > Controlled like a regular brushless motor
Challenges of the Alternative Solution

> If standard linear motors are used for the curved tracks, there are “pizza slice” shape gaps between the magnets
  > How to pass smoothly?

> Commutation cycle may not be uniform during the curved portions
  > Commutation scheme may still be not standard

> Requires on-the-fly switching between feedbacks
  > From hall-based coarse feedback to high resolution feedback and back
  > Can it be done smoothly without stopping?

> Controller and drive will have to move together with the coils
  > Requires a method to provide voltages and communication e.g.- slip rings/bars
> **Special commutation algorithm**
>  > Adaptively compensates changes in the commutation period
>  > Compensates force reduction due to “pizza slice” shape gaps

> **Feedback switching algorithm**
>  *allows seamless transitions during motion*

> **Advanced control algorithms may be used for higher performance (ServoBoost™, cogging compensation)**
Summary

- Alternative solution for closed track transport systems
- Capable of achieving significantly better performance
- Significantly cheaper than the moving magnet solution
Expanding ACS EtherCAT Line of Higher Performance Motion Control

NetworkBoost™  EtherCAT
SPiiPlusEC
The Most Powerful EtherCAT Motion Controller

- Up to 64 axes and thousands of I/O
- 1 to 5KHz profile generation & EtherCAT cycle
- NetworkBoost™ failure detection & recovery
- 1GbE Ethernet host communication
- Powerful Processor: Intel Atom™ N2600 1.6 GHz
- Memory:
  - RAM- 1Gb
  - Flash NV memory- 1Gb
- Replacing the SPiiPlusNTM
SPiiPlusCMHV Control Module
EtherCAT Master + 2 built-in Drives

- Up to 32 axes and thousands of I/O
- 2 built-in high power universal drives
  - 230-480Vac
  - 5/10A, 10/20A, 15/30A
  - 20/20A+5/10A
  - Up to 400Vac, the current is 25% higher
- 230Vac (3/2015)
  - 5/15A, 10/30A, 15/45A, 20/60A
- STO
- Internal shunt regulator
- Dimensions: 260 x 246 x 119 mm³
SPiiPlusCMHV Control Module
EtherCAT Master + 2 built-in Drives

> **Feedback**
  > 4 incremental digital encoders
  > 2 Analog SIN-COS encoder
  > 2 absolute encoders
  > 2 resolvers

> **I/O**
  > Digital: 8/8
  > Analog: 4/2
  > Registration Mark: 4
  > PEG: 4
  > Motor Brake: 2, 24V/1A
UDM mc Universal Drive Module
2/4 Drives

> Motor supply: 12Vdc to 80Vdc

> Current
  > 5/10A, 10/20A, 20/40A

> Four axis with mix current levels:
  > 2 x 5A & 2 x 10A
  > 2 x 5A & 2 x 20A
  > 2 x 10A & 2 x 20A

> STO

EtherCAT
UDMmc Universal Drive Module 2/4 Drives

> Feedback
  > 4 digital incremental encoders
  > 4 absolute encoders

> I/O
  > Registration Mark: 4
  > PEG: 1
  > Motor Brake: 4, 24V/0.5A.

> Dimensions: 152 x 138 x 48 mm³
UDM Universal Drive Module
2 Drives

> 2 built-in high power universal drives
  > 230-480Vac
    > 5/10A, 10/20A, 15/30A
    > 20/20A+5/10A
  > 230Vac (3/2015)
    > 5/15A, 10/30A, 15/45A, 20/60A

> STO

> Internal shunt regulator

> Dimensions: 260 x 246 x 119 mm³
UDMHV Universal Drive Module
2 Drives

> **Feedback**
> 4 incremental digital encoders
> 2 Analog SIN-COS encoders
> 2 absolute encoders
> 2 resolvers

> **I/O**
> Digital: 8/8
> Analog: 4/2
> Registration Mark: 4
> PEG: 4
> Motor Brake: 2, 24V/1A
PDI_{CL} Pulse Direction Interface
4-Axis, with Feedback

> **Step motor control with position feedback verification**

> **Drive interface:**
  > Speed up to 4M pulses per second
  > Programmable pulse 80nS to 80μS

> **Position feedback**
  > 4 digital incremental digital encoders
  > 4 absolute encoders
PDICL Pulse Direction Interface
4-Axis, with Feedback

> **Digital I/O:**
  > 4 general purpose inputs
  > 4 Registration Mark

> **Four motor brake outputs, 24V, 0.2A**

> **One PEG (Position Event Generator)**

> **Dimensions: 121x100x48 mm³**
EM64
SIN-COS Encoder Multiplier & Splitter

- Sub-count PEG & position registration
- Interfacing analog Sin-Cos encoders to drives such as $\text{UDM}_{MC}$ & $\text{UDM}_{LC}$
- Digital encoder signals to external devices (camera triggering boards)
- Splitting encoder signals
EM64
SIN-COS Encoder Multiplier & Splitter

> **Programmable multiplication up to 64 counts per encoder cycle**

> **High speed**

<table>
<thead>
<tr>
<th>Sin-Cos Maximum frequency [KHz]</th>
<th>Multiplication Factor</th>
<th>Quadrature resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>800</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>640</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>400</td>
<td>8</td>
<td>32</td>
</tr>
<tr>
<td>320</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>200</td>
<td>16</td>
<td>64</td>
</tr>
</tbody>
</table>

> **2 output connectors, each comprises of both**
  > **The original analog encoder signals buffered**
  > **Post multiplication digital signals**
NanoPWM Roadmap

A Comprehensive product line Offering For Nanometer Positioning Stages 2015

Confidential
NanoPWM™ Revolutionary PWM Drive Technology (Patent Pending)

- Better performance when compared to commercially available linear drives - Guaranteed
- Sub-Nanometer position jitter
- Excellent constant velocity smoothness & error tracking
Expanding The Line of NanoPWM Drives Line of 2-Axis Drives

> Two lines
  > EtherCAT slaves– Similar to other ACS’ drive modules
  > Expending the line of ACS’ EtherCAT drives

> Drive with ±10V current commutation commands
  > Direct replacement for linear drives
  > Works also with non-ACS motion controllers
## Main Specifications (per axis/motor)

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>3.3</td>
<td>10</td>
<td>340</td>
<td>950</td>
</tr>
<tr>
<td>100</td>
<td>6.6</td>
<td>20</td>
<td>680</td>
<td>1900</td>
</tr>
<tr>
<td>100</td>
<td>10</td>
<td>30</td>
<td>1,020</td>
<td>2850</td>
</tr>
<tr>
<td>100</td>
<td>13.3</td>
<td>40</td>
<td>1,380</td>
<td>3,800</td>
</tr>
</tbody>
</table>

- **Common to both lines**
  - Two-axis design (for Gantry)
  - Motor over temp inputs
  - Mechanical brake outputs
  - STO (Safe Torque Off)

- **EtherCAT slaves**
  - 4x SIN-COS encoder 10MHz
  - 2 x absolute encoder
  - 4 x 12bit GP analog inputs
  - 4 x 16bits analog outputs (for IDE)
  - 4 Registration Mark inputs
  - 4 PEG outputs
Three Form Factors

> Chip like

> Bookshelf, panel mounted

> Rack mounted
<table>
<thead>
<tr>
<th></th>
<th>Chip-like</th>
<th>Bookshelf</th>
<th>MC4U enclosure</th>
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</thead>
<tbody>
<tr>
<td>EtherCAT</td>
<td>NPMpc</td>
<td>NPMpm</td>
<td>NPMrm</td>
</tr>
<tr>
<td>+/-10V</td>
<td>NPDpc</td>
<td>NPDpm</td>
<td>NPDrm</td>
</tr>
</tbody>
</table>

**NPM** - *NanoPWM Module* - EtherCAT slave

**NPD** - *NanoPWM Drive* - +/-10V commutation commands

**pc** - *printed circuit version*

**pm** - *panel mounted version*

**rm** - *rack mounted version*
NPMpc, NPDpc
Chip-Like

- Designed to be incorporated into custom designed carrier board

- Small: 155x85x30mm

- Light: 150gr per axis (300gr total)

- Fed by:
  - 24Vdc control supply
  - 24Vdc – 100Vdc drive supply
NPMpm, NPDpm Panel mounted

> **Based on the chip-like unit**

> **Dimensions: 240x155x50mm**

> **Built-in motor phases shortening relays**

(`“Dynamic brake”`)

> **Can be used for prototyping of the NPMpc, NPDpc chip-like versions**

> **Fed by**

> > 24Vdc control supply

> > 24Vdc – 100Vdc drive supply
NPMrm, NPDrm
Rack mounted

> **Complete solution**
  > Based on the chip-like unit
  > 11”, 19” racks
  > 2, 4 axis solution
  > 1, 2 units of NPMrm or NPDrm
  > 48, 72, 100Vdc power supplies
  > AC input (the lowest required the better)
  > Fed by
  > 24Vdc control supply
  > 100Vac – 230Vac drive supply
NPMpc
Revolutionary approach to High precision positioning stages
Stage With External Drives

- All cables are moving cables
- All cables are long
Moving cables oscillate
  - At low frequencies (<100Hz)
  - The frequency changes as a function of position

Input Shaping is not effective
  - It eliminates the oscillations but increases the period of the profile

Increasing accelerations is not effective
  - Induces more vibrations and increases settling time
Stage Moving Cables
Main Limitations to Performance

- **Move and settle time**
  - Adds significantly to the settle time
  - Large variance in results over different table position

- **Standstill jitter and following error during Constant Velocity**
  - Increased significantly
  - Large variance in results over different table position

- **Limits reliability – Moving cables are prone to failures**

- **The longer the cable the more EM noise**

- **Expensive**

- **Complex mechanical design**
Mounting the NanoPWM drives on the positioning stage

> The NPMpc NanoPWM provides the performance

> Light weight - 150gr per axis

> Adds less than 5% heat to the motor heat dissipation
  > Example:
  > Linear motor phase resistance: 1.0 Ohm

<table>
<thead>
<tr>
<th>Current (cont/peak sine amp.)</th>
<th>10/30</th>
<th>13.3/40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Heat dissipation</td>
<td>153W</td>
<td>265W</td>
</tr>
<tr>
<td>NPMpc Heat Dissipation</td>
<td>7W</td>
<td>9W</td>
</tr>
<tr>
<td>Added heat %</td>
<td>5%</td>
<td>3.3%</td>
</tr>
</tbody>
</table>
Stage With Integrated UDM PC Drives

- Supply
- Electrical cabinet
- Supply cable
- Network communication cable
- Communication cable
- Encoder to drive cable
- Motor to drive cable

The only moving cables can be replaced by slip bars.
NPMpc
Mounted On The Positioning Stage

> Most moving cable are eliminated
> All cables are significantly shorter
> Lighter weight
> Moving cables resonate at frequencies > 200Hz
> Input Shaping is effective
> Possible to increase acceleration
NPMpc
The Best Performance Possible

- The shortest Move & Settle times possible
- The lowest Standstill jitter possible
- The lowest following error during constant velocity
- Consistent over different stage locations
- Significantly less EM noise
- Lower cost of cables
- Enhanced reliability
- Simplified mechanical design
Enhance Performance Example

> A real 450mm wafer stage

> 25mm move

<table>
<thead>
<tr>
<th>Product</th>
<th>Settle to 50nm [msec]</th>
<th>Settle to 10nm [msec]</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC4U with NanoPWM (actual, external mounted)</td>
<td>110</td>
<td>120</td>
</tr>
<tr>
<td>NPMpc (expected)</td>
<td>&lt; 80</td>
<td>&lt; 95</td>
</tr>
</tbody>
</table>

Field Proven!
The NPMpc(s) will be mounted on a custom carrier board

The carrier board should be specified together with the stage vendor and the customer of the stage optimizing
  > Form factor and fitting into the stage
  > Connectivity
  > Added functionality that may not even be related to motion control

ACS will offer
  > Carrier board design services
  > Carrier production
  > Design guidelines for carrier board design by others
## NanoPWM Drives Roadmap

<table>
<thead>
<tr>
<th></th>
<th>Chip like</th>
<th>Panel mounted</th>
<th>Rack-mount full solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>EtherCAT version</td>
<td>NPMpc</td>
<td>NPMpm</td>
<td>NPMrm</td>
</tr>
<tr>
<td>+/-10V version</td>
<td>NPDpc</td>
<td>NPDpm</td>
<td>NPDrm</td>
</tr>
<tr>
<td>Functional Prototype for testing</td>
<td>2/2015</td>
<td>2/2015</td>
<td>5/2015</td>
</tr>
<tr>
<td>Fully tested units</td>
<td>4/2015</td>
<td>4/2015</td>
<td>6/2015</td>
</tr>
<tr>
<td>Production units</td>
<td>5/2015</td>
<td>5/2015</td>
<td>7/2015</td>
</tr>
</tbody>
</table>
Manufacturers of positioning stages can achieve:

- Higher performance that is unachievable today
- Simplified stage design
- Lower cost of material
Smarter Motion

Thank You