White Paper

Understanding Combitronic™ Technology

How Combitronic Technology Simplifies Servo Motor Communications and Deployment

Key Messages

- Combitronic technology, its features and how it operates
- Program examples are included to show the simple yet powerful control provided by this technology
- Photos and links to web videos are included, which provide actual working examples of this technology

What is Combitronic Technology?

Combitronic technology is an optional communications protocol that is available for the Moog Animatics SmartMotor™ servo. It operates over a standard "CAN" (Controller Area Network) interface. This is the same basic hardware used in most automobiles as well as in familiar industrial networks such as CANopen™ and DeviceNet™.

Combitronic technology may coexist with either CANopen or DeviceNet protocols. However, unlike these common control networks, Combitronic has no master or slave. Each Combitronic-equipped SmartMotor connected to the same network communicates on an equal footing, sharing all information, and therefore, sharing all processing resources.

What are the Primary Features?

The optional Combitronic technology provides the following features:

- Up to 120 SmartMotors can be addressed on a single network
- 1 MHz network bandwidth
- No bus master is required, but one may be used if desired
- No scan list or node list set up is required
- All SmartMotor nodes have full read/write access to all other SmartMotor nodes

How Does It Work?

Each Combitronic-equipped SmartMotor is fully programmable and capable of being a master to multiple other Combitronic-equipped SmartMotors on the same network. This is not just through a few outgoing commands, I/O handshaking or value assignments, but fully functional, bidirectional communications, which are seamlessly achieved through a given program in any motor.

This optional capability uses a proprietary command structure that resides on top of either the CANopen or DeviceNet protocol. Other than matching baud rates and ensuring unique addresses in each node, there are no other requirements to make it work.

In a traditional network, all commands local to a SmartMotor controller are for that motor only. With the optional Combitronic technology, those same commands can be applied to and reference other motors on the same network as if all the motors were being controlled by a central, multi-axis controller. However, from a user's perspective, the difference in this protocol is that it is not register based or data packet based—it simply uses the typical local commands that are amended with a colon and target node address (see the yellow highlights in the following example code).

For example, SmartMotor servos use a single letter G command to start a motion profile. This example shows the differences between starting just the local motor, and then adding Combitronic syntax to start one or all motors on the same network:

```
G         'Issue Go in local motor
G:2       'Issue Combitronic Go to motor 2
          'on the same network
G:0       'Issue Combitronic global Go to
          'all motors on the same network
```

NOTE: With Combitronic technology, no code is required in other nodes on the network. However, for certain Combitronic applications, downloading the same program to all SmartMotors on the network can simplify implementation while providing the full advantages of a multi-axis system.

Examples

The following examples expand on the previously shown Combitronic command capability to illustrate some of the primary features provided by this technology.

Example 1: Trajectory Commands for a Simple Point A to Point B Move

The following code snippets show several examples of trajectory commands for a simple move from point A to point B. The following block of snippets:

- Begins with control of the local axis only
- Controls axis 3 through the addition of Combitronic syntax
- Substitutes a variable for the address in the Combitronic syntax

```
'Simple local axis control:
   VT=100000            'Set velocity target
   ADT=100              'Set accel/decel target
   PRT=10000            'Set relative position
                        'distance to move
   MP                   'Set to Position Mode
   G                    'Start moving


'Simple locally commanded remote axis
'(for axis 3) control:
   VT:3=100000 'Set velocity target
   ADT:3=100   'Set accel/decel target
   PRT:3=10000 'Set relative position
               'distance to move
   MP:3        'Set to Position Mode
   G:3         'Start moving
```

```
'Simple locally commanded universal remote
'axis (for axis "q") control:
   VT:q=100000 'Set velocity target
   ADT:q=100   'Set accel/decel target
   PRT:q=10000 'Set relative position
               'distance to move
   MP:q        'Set to Position Mode
   G:q         'Start moving
```

In the last code snippet, if the variable "q" was set to zero, all nodes on the network would respond at exactly the same time with no propagation delay between them.

Example 2: Collecting Data or Conditional Code Based on Information from Other Nodes

In all of the previous examples, outgoing commands were used to control one or more motors.

The following snippets show several methods of receiving information (i.e., collecting data from other motors or running conditional code based on information from other motors). Again, note that the standard SmartMotor command only needs to be modified with a colon and motor address in order to communicate through Combitronic technology.

```
'Position capture in local other nodes:
x=PA            'Assign local motor position
                'to local variable "x"
y=PA:2          'Assign axis 2 position to
                'local variable "y"

'Conditional check another axis position
IF PA:2<2000
   PRINT("Axis 2 position is < 2000",#13)
ENDIF

'Dynamic checks of another axis position:
WHILE PA:2<10000 LOOP
'Loop until motor 2 position is > 10000

'Assigning vector sum velocity of two
'motors to a third motor
v=VA:1^2+VT:2^2
VT:3=SQRT(v)    'Axis 3 assigned velocity
                'proportional to path of 1 and 2
```

Each snippet collects data from another SmartMotor for use in the local motor. However, the last snippet collects data from both the local motor and a remote motor, and then applies a math function and result to a third motor.

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Example 3: Using I/O Commands across the Network

The same communication and control principles apply to I/O commands as shown in this example:

```
'I/O examples across the network
OS(2):3 'Set output 2 on in motor 3
OR(4):2 'Reset output 4 off in motor 2

IF IN(5):11==1   'If input 5 in motor 11 is on
   G:2           'Tell motor 2 to go.
ENDIF

WHILE IN(6):4==0 LOOP   'Wait for input 6 in
                        'axis 4 to go high
```

Again, note that no network configuration or host network manager is required. Simple commands with remote addresses provide the capability to freely access and control data across the network. Any motor on the network may do this at any time. Firmware and software allow data to pass freely with full deterministic arbitration of all data packets.

Example 4: Two-Axis Linear Interpolated and Synchronized Motion

A further extension of Combitronic-specific commands is available for multi-axis linear interpolated and synchronized motion from any given axis serving as the master. All calculations and motion profiles are set up by the local axis and use a format similar to single-axis motion profiles:

```
VTS=100000       'Set 2-axis synchronized path
                 'velocity target
ADTS=100         'Set 2-axis synchronized path
                 'accel/decel target
PTS(x;1,y;2)     'Set target positions "x" & "y"
                 'to motors "1" & "2"
GS               'Go synchronized
TSWAIT           'Wait at this line of code until
                 'synchronized trajectory completes
```

The PTS[1] command combined with Combitronic technology automatically deals with communications to the associated motor addresses.

Example 5: Three-Axis Linear Interpolated and Synchronized Motion

In the previous two-axis example, the X and Y motors move linearly and are synchronized to their destination.

The following code snippet shows a similar example expanded to three axes:

```
VTS=100000       'Set 3-axis synchronized path
                 'velocity target
ADTS=100         'Set 3-axis synchronized path
                 'accel/decel target
PTS(x;1,y;2,z;3)   'Set target positions x, y &
                   'z to motors 1, 2 & 3
GS               'Go synchronized
TSWAIT           'Wait at this line of code until
                 'synchronized trajectory completes
```

The following figure shows an expanded version of the multi-axis synchronized motion concept described in the previous examples. Note that it could be expanded up to 120 axes.

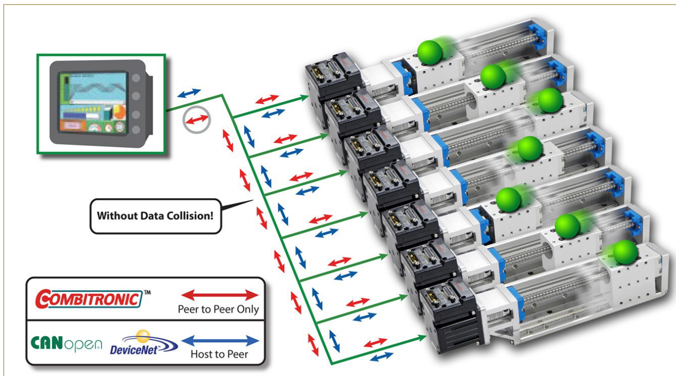

Figure 1: Multi-Axis Synchronized Motion (Click Image to View Video)

Example 6: Four Axis Gantry – X, X' (Paired X), Y, Z

Some gantry-type, multiple-axis machines have two synchronized motors, or motor pair, operating the same axis of motion (see the next figure). The following is the full syntax for the PTS command (discussed in previous examples), which shows additional/optional parameters (enclosed in braces "{ }") for support of two motors operating the same axis. The optional parameter contains the motor address for the second motor of the axis. (For the PRTS command, replace PTS with PRTS.)

```
PTS(ps1;ad1{;ad1'},ps2;ad2{;ad2'}[,ps3;ad3{;axis3'}])
```

NOTE: ps1= position 1; ad1 = address 1; etc.

As shown in the previous syntax, the PTS and PRTS commands allow up to three pairs of motors (X, X'; Y, Y'; Z, Z'). Beyond simply identifying the address of the paired motor, no additional coding is needed. Combitronic technology automatically handles all the synchronization.

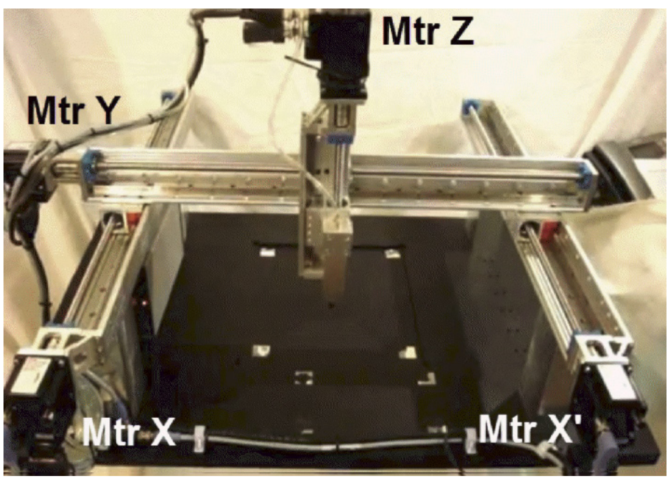

Figure 2: Four Axis Gantry with X-Axis Motor Pair (X, X') (Click Image to View Video)

This is illustrated in the following examples. (If you are using the PRTS command, substitute PRTS in place of PTS below.)

```
PTS(2000;5;6,1000;7)         'Two-motor X axis (X, X'),
                             'plus Y axis
PTS(2000;5;6,1000;7,500;8)   'Two-motor X axis (X, X'),
                             'plus Y & Z axes
```

In these cases, the same position, velocity and acceleration data sent to motor address 5 is also sent to motor address 6, with both motors driving the gantry's X axis.

Example 7: Synchronized Motion Using Math Calculations

The following figure shows an ellipse created through PTS and trig math capability.

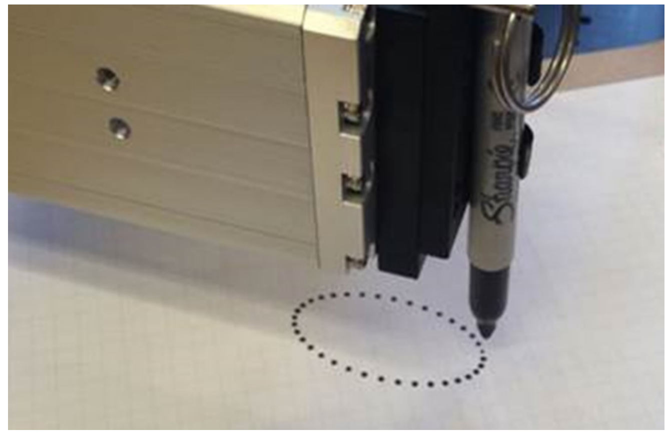

Figure 3: Ellipse Created through PTS and Trig Math Capability

The next figure shows a complex master pattern that was created through Combitronic-coordinated camming between multiple axes to provide multi-axis path capability by math function. The initial pattern was created by a subroutine block of code. Then, by simply retargeting the starting point for the subroutine through math calculations, the entire master pattern was created.

(This is only the math function part of the program.)

```
IF ADDR==gg
   'X AXIS
   pp=(mm*((af[2]-af[3])*COS(t)+af[4]*COS(af[0])))-xx
ELSEIF ADDR==ggg
   'Y AXIS
   pp=(mm*((af[2]-af[3])*SIN(t)-af[4]*SIN(af[0])))-yy
ENDIF
```

NOTES:
gg = X axis
ggg = Y axis
mm = radius_const

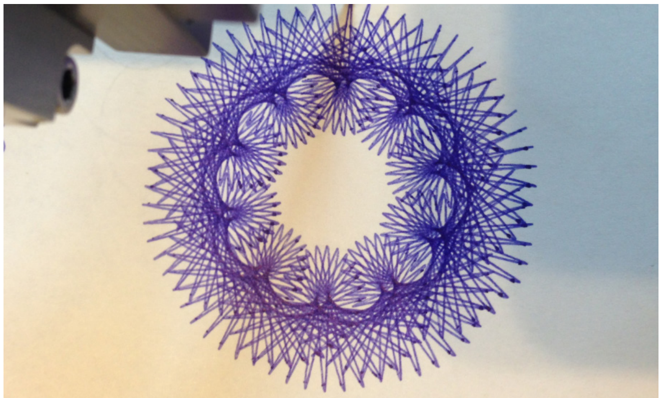

Figure 4: "Spirograph" Master Pattern (Click Image to View Video)

The following figure shows another complex figure that was created through Combitronic coordinated camming between multiple axes.

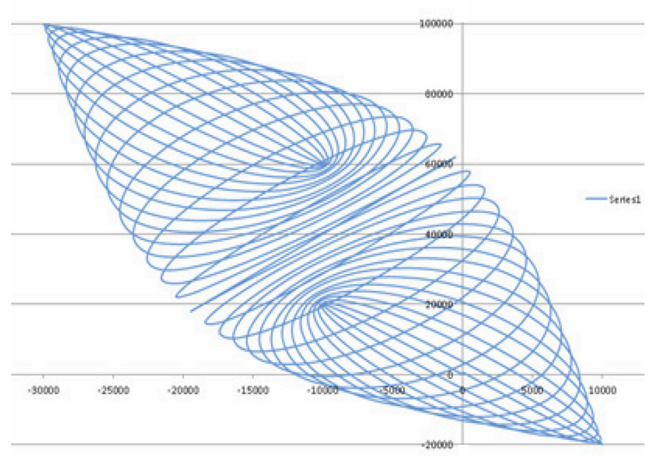

Figure 5: Mathematically-Calculated Synchronized Motion

Combitronic technology ties together the processing power of multiple SmartMotors for a full multi-axis system solution.

Other Design and Implementation Advantages

In addition to the features and benefits previously discussed, the SmartMotor integrated servo with optional Combitronic technology provides the following design and implementation advantages:

- Reduced Size: By integrating the controls onto the motor, the control cabinet is reduced in size or eliminated, which makes the machine much smaller.
- Reduced Cost: Fewer components and no cabinet cut costs dramatically.
- Reduced Development Time: Fewer components to specify, purchase, learn and mount, along with ease of programming provided by Combitronic technology, means reduced development cycles, getting to market faster, and increased competitive advantage.
- Reduced Downtime and Field Service: A traditional control can only be debugged in the cabinet while the machine is down and the factory processes are stopped. However, a SmartMotor integrated servo can be swapped out immediately. Then, while the machine continues to produce, the faulty component can be debugged or simply sent back to the manufacturer for analysis and repair.
- Increased Reliability: By reducing the number of components, the machine's reliability is increased. Additionally, the SmartMotor integrated servo requires less wiring, which is a typical failure point in most machines.
- Increased Versatility: In a cabinet-based controller approach, adding additional axes of motion can be difficult due to cabinet space limitations, much additional wiring, and the added burden of programming. However, adding more SmartMotor integrated servos requires no cabinet space and minimal cabling, and the optional Combitronic technology simplifies programming. Further, the additional axes automatically provide more I/O points and processing power.

Case Study: High Axis Count Coordinated Motion

Industry: Entertainment

Application: Coordinated Movement of 65 Axes of Motion

Challenge: Provide a cost-effective and aesthetically pleasing technology solution to control 65 coordinated axes of motion required for an art exhibit in the San Jose airport.

Situation

Coordinated motion of multiple axes is not a straightforward task. When the technology artists

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behind this motorized sculpture needed an integrated and effective way to choreograph the movement of 65 precisely engineered mechanisms, they recruited the help of Moog Animatics' SmartMotor integrated servos equipped with Combitronic technology.

Problem

The robotic artwork[2], a collaboration between artists Banny Banerjee, Matt Gorbet, Susan LK Gorbet and Maggie Orth, executes complex and precise choreographed patterns of movement such as pulsing to simulate breathing, wave effects, and sequential movements. The 65 motors are networked together and triggered with high-level commands sent over RS-232. When a motion command is sent, it is echoed from one motor to the next in each serial chain with less than one millisecond delay. Further, no signal integrity is lost as the commands move down the chain, so reliability is greatly improved. SmartMotor servos can simultaneously communicate through RS-232, RS-485, PROFIBUS, Ethernet and CAN buses. This communication flexibility offers a significant cost-effective advantage over traditional component-based motion systems.

Figure 6: 65 Coordinated Axes of Motion (Click Image to View Video)

Solution

SmartMotor capabilities truly shine when high-axis-count coordinated motion is needed. Class 5 SmartMotor servos have the ability to have one or several masters within a network. With the optional Combitronic communications over the CAN bus, a user may write one program in a motor that can monitor and alter other parameters and data in any other motor in the network in real time.

Field servicing a complex artwork on the ceiling of a functioning airport terminal would be an arduous task if the controllers weren't integrated with the motors, as identification of the exact root cause of a problem could be quite time consuming in a cabinet-based controller system. However, diagnostics are greatly simplified with SmartMotor technology because each node becomes its own machine that can simply be swapped out in case of a failure. All of this translates to reduced MTBF (mean time between failure), and more time allowing your machine(s) to do what is needed.

Conclusion

Combitronic communications combined with the SmartMotor integrated servo represents a major step forward in simplifying multi-axis motion control and motor-to-motor communications. This technology provides the foundation for simple, powerful and robust multi-axis system design:

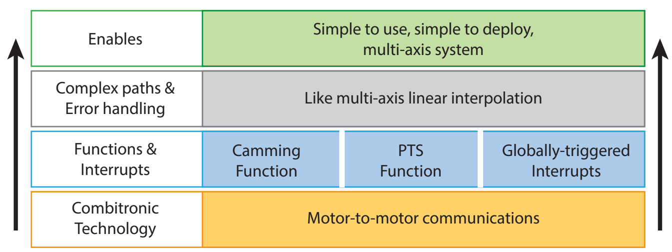

Figure 7: Combitronic Technology as a Foundation for Multi-Axis System Design

As machine builders are pressured by customers, economic factors and competition to reduce time to market and minimize the machine footprint, this technology will increasingly play an important role in machine design and implementation.

References

[1]For more information on the PTS command, see the *SmartMotor Developer's Guide*.

[2]Chronos and Kairos was commissioned by the City of San José Public Art Program, and engineered and fabricated by Monkey Wrench Design of San Francisco.

Figure 1	Multi-Axis Synchronized Motion provided by Moog
Figure 2	Four Axis Gantry with X-Axis Motor Pair (X, X') provided by Moog
Figure 3	Ellipse Created through PTS and Trig Math Capability provided by Moog
Figure 4	Spirograph" Master Pattern provided by Moog
Figure 5	Mathematically-Calculated Synchronized Motion provided by Moog
Figure 6	65 Coordinated Axes of Motion provided by Moog
Figure 7	Combitronic Technology as a Foundation for Multi-Axis System Design provided by Moog

About Moog Animatics

Since 1987, Moog Animatics has been designing, manufacturing and marketing motion control products. We bring total automation solutions to numerous industries, including semiconductor, defense, automotive, aerospace, biomedical, textile, security, marine sciences, packaging and many more.

When you need an innovative solution, you need Moog Animatics. We pride ourselves on offering the most creative and complete answers to your motion control questions.

The Moog Animatics headquarters is located in the heart of Silicon Valley, with international offices in Germany and Japan, and a vast network of Moog Animatics-trained Automation Solution Providers around the world.

For more information on how the SmartMotor integrated servo with Combitronic technology can benefit your application, please call 650.960.4215 or email us at animatics_sales@moog.com.

For product information, visit **www.animatics.com**

For more information or the office nearest you, contact us online, **animatics_sales@moog.com**

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