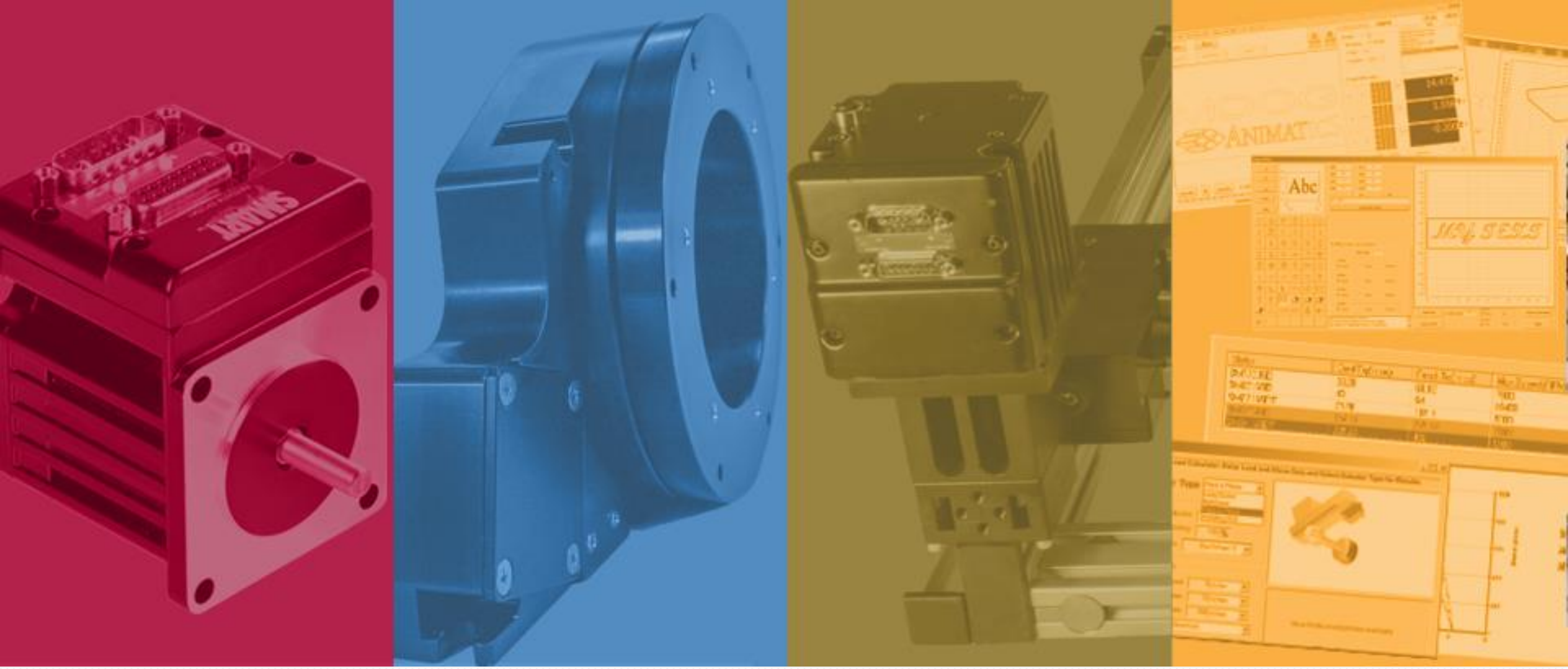

UNDERSTANDING COMBITRONIC™ TECHNOLOGY

Presented by: Moog Animatics

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Agenda

- History
- What is Combitronic™?
- How Does Combitronic™ Work?
- Programming Examples from Simple to Complex
- Other Design and Implementation Advantages
- Applications
- Conclusion

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History

History

- Developed in 2011, Moog Animatics introduced a new servo motor communication technology called "Combitronic™".
- This technology:
  - Greatly simplifies conventional servo motor communications
  - Provides a powerful set of features

COMBITRONIC™

The ease of use and features provided by Combitronic technology are not available from any other motor manufacturer in the industry!

What is Combitronic™?

What is Combitronic™?

- Combitronic technology provides the foundation for easy, yet powerful, multi-axis system design:

Enables	Simple to use, simple to deploy, multi-axis system		
Complex paths & Error handling	Like multi-axis linear interpolation		
Functions & Interrupts	Camming Function	PTS Function	Globally-triggered Interrupts
Combitronic Technology	Motor-to-motor communications		

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Primary Features

- The optional Combitronic technology provides the following primary 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 setup is required
  - All SmartMotor nodes have full read/write access to all other SmartMotor nodes

How Does Combitronic™ Work?

How Does Combitronic™ Work?

- Each SmartMotor™ is fully programmable and capable of being a master to multiple SmartMotors on the network
  - Not just through a few outgoing commands, I/O handshaking or value assignments
  - It is fully functional, bi-directional communications
  - Through a CAN bus, it resides on top of either the CANopen or DeviceNet protocol

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How Does Combitronic™ Work? (cont'd)

- Other than matching baud rates and ensuring unique node addresses, there are no other requirements
  - In a traditional network, all commands local to a SmartMotor controller are for the motor only
  - With 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

Combitronic protocol is not register or data-packet based – it simply uses the typical local commands amended with a colon and target node address.

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How Does Combitronic™ Work? (Example)

- SmartMotor servos use a single letter G command to start a motion profile:

```
G   'Issue Go in local motor
```

- Add Combitronic syntax to start one or all motors on the same network

```
G:2       'Combitronic Go to motor 2
G:0       'Combitronic global Go to all motors
```

Video: Combitronic Animation

Programming Examples from Simple to Complex

Ex. 1: Point A to B Move

- Trajectory commands for a simple point A to point B move:

```
'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 Mode 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 Mode to Position Mode
     G:3            'Start moving
```

Ex. 1: Point A to B Move (cont'd)

- Trajectory commands for a simple point A to point B move (cont'd):

```
'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 Mode to Position Mode
     G:q           'Set Mode to Position Mode
```

- 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.

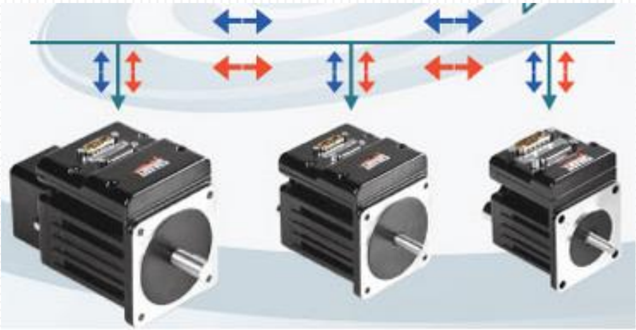
Single Axis Mechanism

Ex. 2: Data From Other Nodes

- 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):

```
'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 of position in another axis
IF PA:2<2000
            PRINT("Position of axis 2 is below 2000",#13)
ENDIF
```



Ex. 2: Data From Other Nodes (cont'd)

- 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):

```
'Dynamic checks of position in another axis:
WHILE PA:2<10000 LOOP
'Stay in loop until position of motor 2 is above 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
```

- In the last case, the snippet collected data from both the local motor and a remote motor, and then applied a math function and result to a third motor.

Ex. 3: I/O Commands Across Network

- The same communication and control principles apply to I/O commands as shown in the 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
```

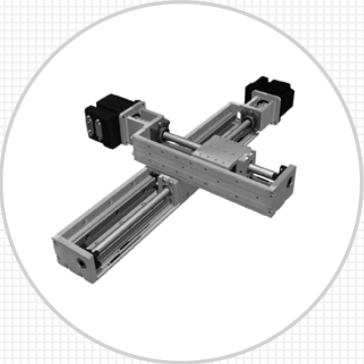
- <u>No</u> network configuration or host network manager is required
- Simple commands with remote addresses are used to freely access and control data across the network
- Firmware and software allow data to pass freely with full deterministic arbitration of all data packets

Ex. 4: 2-Axis Interpolated /Sync'd Motion

- All further extension of Combitronic-specified commands allow for multi-axis linear interpolated and synchronized motion from any given axis serving as master.
- All calculations and motion profiles are set up by the local axis in a simple format similar to single-axis 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" and "y" to motors "1"
             '   and "2"
GS           'Go synchronized
TSWAIT       'Wait at this line of code until the
             'Synchronized trajectory is complete
```

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



Two Axis Mechanism

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Ex. 5: 3-Axis Interpolated / Sync'd Motion

- In the previous example, X and Y motors move linearly and are synchronized to their destination. The following shows a 3-axis example:

```
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, and z to
motors                        '   1, 2, and 3
GS          'Go synchronized
TSWAIT      'Wait at this line of code until the
            'Synchronized trajectory is complete
```

- Again, the PTS command combined with Combitronic technology automatically deals with communications to the associated motor addresses.

Three Axis Mechanism

Video: Linear Interpolation with Table Top Robot and SmartMotor™

Combitronic™ Technology

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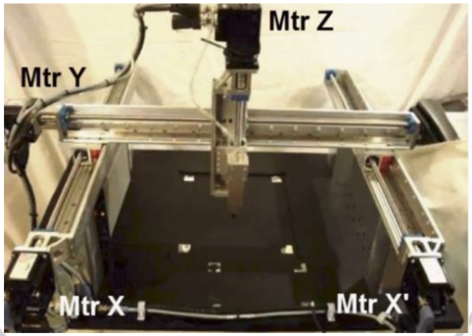
Ex. 6: Four Axis Gantry – X, X’ (Paired), Y, Z

- In the following example, the PTS command controls two synchronized motors (motor pair) operating the same axis of motion:
  - Allows up to three pairs of motors (X, X’; Y, Y’; Z, Z’)
  - Identify the address of the paired motor – no other code is needed



Palletizing Gantry with Paired X-Axis Motors

```
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
```

Video: Class 5 SmartMotor™ Palletizing Gantry

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Ex. 7: Clock Synch Multiple Networked Motors

- When multiple SmartMotor servos are on the same network, and there is a need for multi axis timed events, electronic gearing, or synchronized camming, all motor processor clocks must be synchronized together.
- This ensures long running cam tables, gearing profiles or traversing systems using gears, operate in perfect time.
- One line of code simply accomplishes this when added to the master motor as shown in the following IF command:

```
IF ADDR==1 CANCTL(14,2) ENDIF
```

Ex. 8: Sync'd Motion with Math Calculations

- This example shows a complex master pattern that was created through Combitronic-coordinated camming between multiple axes to provide multi-axis path capability by math function:

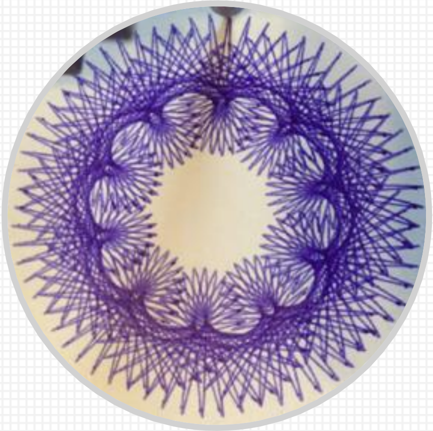
(This is only the math function part of the program)

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

NOTES:

- gg = X axis
- ggg = Y axis
- mm = radius_const

Video: [SmartMotor™ Three-Axis Demo System Performs Multi-Axis Path Capabilities by Math Function]



Complex Pattern

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Other Design and Implementation Advantages

Other Design and Implementation Advantages

In addition to previously discussed features, 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:**
  - Few components to specify, purchase, learn and mount, plus
  - Ease of programming provided by Combitronic technology, equals
  - Reduced development cycles, getting to market faster, and increased competitive advantage

Integrated Controls

Reduce/Eliminate Control Cabinet

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Other Advantages (cont'd)

- **Reduced Down-Time and Field Service:**
  - A traditional control can only be debugged in the cabinet
  - A SmartMotor integrated servo can be swapped out immediately
- **Increased Reliability:** By reducing the number of components, the machine's reliability is increased
- **Increased Versatility:**
  - In a cabinet-based controller approach, adding additional axes of motion can be difficult
  - Adding more SmartMotors requires no cabinet space and minimal cabling, and
  - Combitronic technology simplifies the programming
  - The additional axes automatically provide more I/O points and processing power

3D Cutaway of SmartMotor Controls

Applications

Case Study: High Axis Count Coordinated Motion

- *Industry*: Entertainment
- *Application*: Coordinated Movement of 65 Axes of Motion
- *Challenge*: Provide a cost-effective, aesthetically pleasing technology solution for 65 coordinated axes of motion to control an art exhibit in the San Jose airport

Video: Robotic Art Featuring SmartMotor™ in San Jose International Airport

65 Coordinated
Axes of Motion

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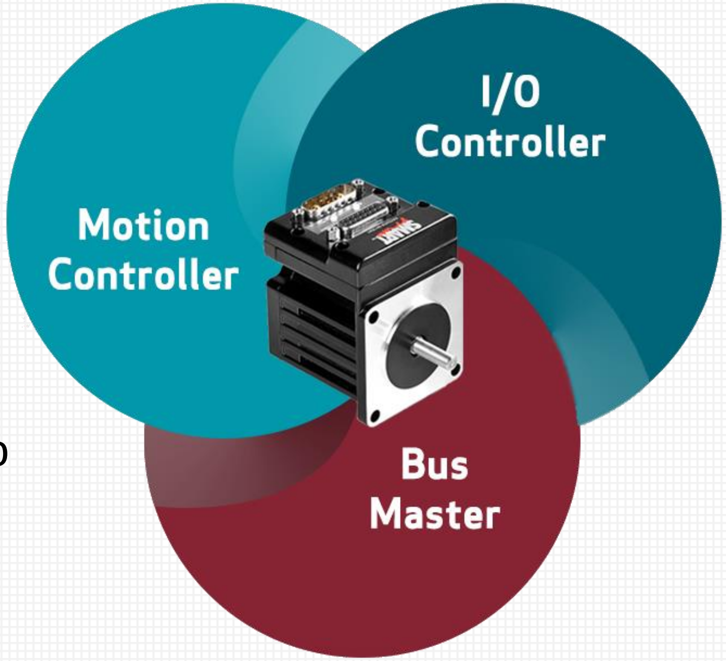
SmartMotor Works Harder For You

- Many times, simple 3D position coordinates are input from a PLC or HMI to the SmartMotors, then PTS commands do the “heavy lifting” multi-axis math work
- Beyond winding, electronic cam table or MFSDC cyclical motion parameters create raster scanning for vision inspection, material coating, and radar skyline scanning
- SmartMotor dual trajectory capabilities enable motion offset compensation, vibration damping, and dynamic tracking positioning
- SmartMotor interrupts and timers enable heater control, valve control, dispense pump control and more, without additional controllers
- Our DMX protocol allows multiple 8-bit channels to create 16, 24, or 32-bit resolvable parameter adjustments for finer and smoother control versus typical DMX motion devices



SmartMotor is a machine controller

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Conclusion

Conclusion

- Combitronic technology on the SmartMotor represents a major step forward in simplifying multi-axis motion control and motor-to-motor communications
- It will increasingly play an important role in machine design as machine builders are pressured by customers, economic factors and competition to:
  - Reduce time to market
  - Minimize the machine footprint
  - Improve machine reliability

Combitronic technology ties together the processing power of the networked SmartMotors to give a full multi-axis system solution!

Conclusion (cont'd)

- Combitronic technology provides the foundation for easy, yet powerful, multi-axis system design:

Enables	Simple to use, simple to deploy, multi-axis system		
Complex paths & Error handling	Like multi-axis linear interpolation		
Functions & Interrupts	Camming Function	PTS Function	Globally-triggered Interrupts
Combitronic Technology	Motor-to-motor communications		

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THANK YOU

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