DMX GUIDE

Class 5 SmartMotor™ Technology

with COMBITRONIC™

MOOG ANIMATICS

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Moog Animatics Class 5 SmartMotor™ DMX Guide, Rev. A, PN: SC80100004-001.

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Introduction

This chapter provides an overview of the DMX features provided by the Moog Animatics SmartMotor. It also provides information on safety, and where to find related documents and additional resources.

Purpose

This manual explains the Moog Animatics Class 5 SmartMotor™ support for the Digital MultipleX (DMX) communications protocol. It describes the major concepts that must be understood to integrate a SmartMotor as a DMX slave device. However, it only minimally covers the low-level details of the DMX protocol.

> **NOTE:** The Remote Device Management (RDM) bidirectional communication extension of the DMX protocol is not supported.

The feature set described in this version of the manual refers to firmware in the 5.x.4.y series, where x = 0, 16, 32, 97 or 98, and y=3 or greater. Versions 5.0.4, 5.16.4, and 5.32.4 are specific to D-style motors, and versions 5.97.4 and 5.98.4 are specific to M-style motors. Refer to the following lists.

> **NOTE:** The SmartMotor firmware must be one of the listed versions.

For D-style motors:

- 5.0.4.y (where y is 3 or greater)
- 5.16.4.y (where y is 3 or greater)
- 5.32.4.y (where y is 3 or greater)

For M-style motors:

- 5.97.4.y (where y is 3 or greater)
- 5.98.4.y (where y is 3 or greater)

This manual is intended for programmers or system developers who have read and understand the Engineering Commission of United States Institute for Theatre Technology (USITT) DMX512-A standard. Therefore, this manual is not a tutorial on that standard or the DMX protocol. Instead, it should be used to understand the specific implementation details for the Moog Animatics Class 5 SmartMotor. Additionally, code examples are provided to assist the programmer with the SmartMotor integration.

The Command Reference section of this manual includes details about the specific DMX commands available in the SmartMotor through the DMX firmware. For details, see DMX Commands on page 28.

Combitronic Technology

The most unique feature of the SmartMotor is its ability to communicate with other SmartMotors and share resources using Moog Animatics' Combitronic™ technology. Combitronic is a protocol that operates over a standard CAN interface. It may coexist with CANopen and other protocols. It requires no single dedicated master to operate. Each SmartMotor connected to the same network communicates on an equal footing, sharing all information, and therefore, sharing all processing resources.

While the Combitronic protocol can be used in parallel with a DMX network, there are certain restrictions:

- The DMX wiring does not carry the Combitronic signal. Therefore, additional cabling (available from Moog Animatics) must be used to build the Combitronic network.

- There is bidirectional, end-to-end connectivity only within the same Combitronic network of motors. Therefore, one Combitronic network cannot communicate with another.

When a Combitronic network is used in parallel with a DMX network, you can:

- Avoid the cost of repeaters.
- Gain bidirectional, end-to-end connectivity within the Combitronic network of motors. There are no other motors on the market that can talk to each other on a side bus while being a slave to the DMX host controller.
- Compute or synchronize motion between motors within the same Combitronic network. For example, DMX values (from the host controller) could be used to adjust amplitude and frequency of SmartMotor Cam tables for an electronic camming or gearing application that controls the motion pattern of a bank of stage lights.

In short, DMX-equipped SmartMotors retain all the features and benefits of the standard Class 5 SmartMotor, including features like electronic camming, gearing, and Combitronic support.

For additional details, see the *Moog Animatics Class 5 SmartMotor™ User's Guide*.

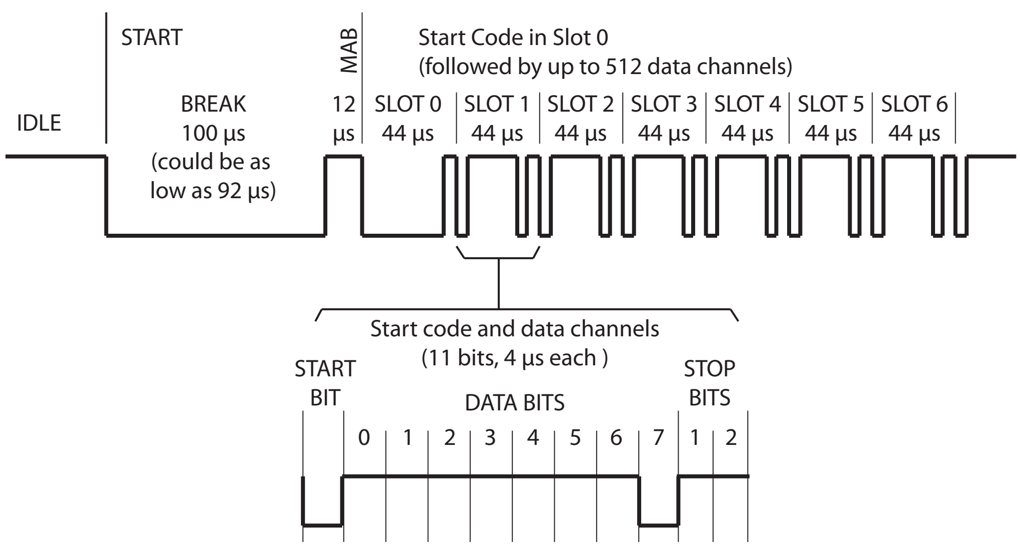
DMX Overview

DMX is a standard for digital communications networks that are used to control lighting, stage effects, dimmers, fog machines and related applications. This control may include positioning and/or focusing of lights or other objects to aid in visual effects of stage productions or other live events. As a result, its use is often expanded to the movement or control of curtains, stage props or other objects that require motion.

DMX, or further expanded as DMX512, is an EIA-485 (RS-485) hardware-based protocol that is unidirectional in nature — the controller only sends data; it does not receive data. Further, it has no error checking or checksums that are required for use in hazardous applications. Therefore, its use must be limited to safe operating environments where failure due to transmission errors would not cause harm to personnel or equipment.

WARNING: DMX networks must not be used in applications where failure due to transmission errors would cause harm to personnel or equipment.

DMX512 controllers transmit asynchronous serial data at 250 kilobaud (kBd). The data format is fixed and begins with a single start bit, eight data bits, and two stop bits with no parity. Up to 512 8-bit data bytes or "channels" of data may be transmitted to all nodes at once. The data is ordered serially and typically runs continuously from a DMX master controller. The full data packet begins with a break, followed by a Mark after Break (MAB), then Slot 0 beginning with a one-byte Start Code, and that is followed by up to 512 data slots. Refer to the following figure.



DMX Data Transmission

Safety Information

This section describes the safety symbols and other safety information.

Safety Symbols

The manual may use one or more of the following safety symbols:

WARNING: This symbol indicates a potentially non-lethal mechanical hazard, where failure to follow the instructions could result in serious injury to the operator or major damage to the equipment.

CAUTION: This symbol indicates a potential minor hazard, where failure to follow the instructions could result in slight injury to the operator or minor damage to the equipment.

NOTE: Notes are used to emphasize non-safety concepts or related information.

Other Safety Considerations

The Moog Animatics SmartMotors are supplied as components that are intended for use in an automated machine or system. As such, it is beyond the scope of this manual to attempt to cover all the safety standards and considerations that are part of the overall machine/system design and manufacturing safety. Therefore, the following information is intended to be used only as a general guideline for the machine/system designer.

It is the responsibility of the machine/system designer to perform a thorough "Risk Assessment" and to ensure that the machine/system and its safeguards comply with the safety standards specified by the governing authority (for example, ISO, OSHA, UL, etc.) for the locale where the machine is being installed and operated. For more details, see Machine Safety on page 10.

Motor Sizing

It is the responsibility of the machine/system designer to select SmartMotors that are properly sized for the specific application. Undersized motors may: perform poorly, cause excessive downtime or cause unsafe operating conditions by not being able to handle the loads placed on them. The *Moog Animatics Product Catalog*, contains information and equations that can be used for selecting the appropriate motor for the application.

Replacement motors must have the same specifications and firmware version used in the approved and validated system. Specification changes or firmware upgrades require the approval of the system designer and may require another Risk Assessment.

Environmental Considerations

It is the responsibility of the machine/system designer to evaluate the intended operating environment for dust, high-humidity or presence of water (for example, a food-processing environment that requires water or steam wash down of equipment), corrosives or chemicals that may come in contact with the machine, etc. Moog Animatics manufactures specialized IP-rated motors for operating in extreme conditions. For details, see the *Moog Animatics Product Catalog*.

Machine Safety

In order to protect personnel from any safety hazards in the machine or system, the machine/system builder must perform a "Risk Assessment", which is often based on the ISO 13849 standard. The design/implementation of barriers, emergency stop (E-stop) mechanisms and other safeguards will be driven by the Risk Assessment and the safety standards specified by the governing authority (for example, ISO, OSHA, UL, etc.) for the locale where the machine is being installed and operated. The methodology and details of such an assessment are beyond the scope of this manual. However, there are various sources of Risk Assessment information available in print and on the internet.

> **NOTE:** The following list is an example of items that would be evaluated when performing the Risk Assessment. Additional items may be required. The safeguards must ensure the safety of all personnel who may come in contact with or be in the vicinity of the machine.

In general, the machine/system safeguards must:

- Provide a barrier to prevent unauthorized entry or access to the machine or system. The barrier must be designed so that personnel cannot reach into any identified danger zones.
- Position the control panel so that it is outside the barrier area but located for an unrestricted view of the moving mechanism. The control panel must include an E-stop mechanism. Buttons that start the machine must be protected from accidental activation.
- Provide E-stop mechanisms located at the control panel and at other points around the perimeter of the barrier that will stop all machine movement when tripped.
- Provide appropriate sensors and interlocks on gates or other points of entry into the protected zone that will stop all machine movement when tripped.
- Ensure that if a portable control/programming device is supplied (for example, a hand-held operator/programmer pendant), the device is equipped with an E-stop mechanism.

  > **NOTE:** A portable operation/programming device requires *many* additional system design considerations and safeguards beyond those listed in this section. For details, see the safety standards specified by the governing authority (for example, ISO, OSHA, UL, etc.) for the locale where the machine is being installed and operated.

- Prevent contact with moving mechanisms (for example, arms, gears, belts, pulleys, tooling, etc.).
- Prevent contact with a part that is thrown from the machine tooling or other part-handling equipment.

- Prevent contact with any electrical, hydraulic, pneumatic, thermal, chemical or other hazards that may be present at the machine.
- Prevent unauthorized access to wiring and power-supply cabinets, electrical boxes, etc.
- Provide a proper control system, program logic and error checking to ensure the safety of all personnel and equipment (for example, to prevent a run-away condition). The control system must be designed so that it does not automatically restart the machine/system after a power failure.
- Prevent unauthorized access or changes to the control system or software.

Documentation and Training

It is the responsibility of the machine/system designer to provide documentation on safety, operation, maintenance and programming, along with training for all machine operators, maintenance technicians, programmers, and other personnel who may have access to the machine. This documentation must include proper lockout/tagout procedures for maintenance and programming operations.

It is the responsibility of the operating company to ensure that:

- All operators, maintenance technicians, programmers and other personnel are tested and qualified before acquiring access to the machine or system.
- The above personnel perform their assigned functions in a responsible and safe manner to comply with the procedures in the supplied documentation and the company safety practices.
- The equipment is maintained as described in the documentation and training supplied by the machine/system designer.

Additional Equipment and Considerations

The Risk Assessment and the operating company's standard safety policies will dictate the need for additional equipment. In general, it is the responsibility of the operating company to ensure that:

- Unauthorized access to the machine is prevented at all times.
- The personnel are supplied with the proper equipment for the environment and their job functions, which may include: safety glasses, hearing protection, safety footwear, smocks or aprons, gloves, hard hats and other protective gear.
- The work area is equipped with proper safety equipment such as first aid equipment, fire suppression equipment, emergency eye wash and full-body wash stations, etc.
- There are no modifications made to the machine or system without proper engineering evaluation for design, safety, reliability, etc., and a Risk Assessment.

Safety Information Resources

Additional SmartMotor safety information can be found on the Moog Animatics website; open the file "109_Controls, Warnings and Cautions.pdf" located at:

http://www.animatics.com/support/moog-animatics-catalog.html

OSHA standards information can be found at:

https://www.osha.gov/law-regs.html

ANSI-RIA robotic safety information can be found at:

http://www.robotics.org/robotic-content.cfm/Robotics/Safety-Compliance/id/23

UL standards information can be found at:

http://www.ul.com/global/eng/pages/solutions/standards/accessstandards/catalogofstandards/

ISO standards information can be found at:

http://www.iso.org/iso/home/standards.htm

EU standards information can be found at:

http://ec.europa.eu/enterprise/policies/european-standards/harmonised-standards/index_en.htm

Additional Documents

The Moog Animatics website contains additional documents that are related to the information in this manual. Please refer to the following list:

- *Moog Animatics Class 5 SmartMotor™ User's Guide*

  http://www.animatics.com/support/download-center.html

- *SmartMotor™ Product Certificate of Conformance*

  http://www.animatics.com/download/Animatics_SmartMotor_Servida_Class_5_Declaration_of_Conformity_CE_Rev_1.pdf

- *SmartMotor™ UL Certification*

  http://www.animatics.com/download/MA_UL_online_listing.pdf

- *Moog Animatics Product Catalog*

  http://www.animatics.com/support/moog-animatics-catalog.html

Additional Resources

The Moog Animatics website contains additional resources such as product information, documentation, product support and more. Please refer to the following list:

- General company information:

  http://www.animatics.com

- Product information:

  http://www.animatics.com/products.html

- Product support (Downloads, How To videos, Forums, Knowledge Base, and FAQs):

  http://www.animatics.com/support.html

- Sales and distributor information:

  http://www.animatics.com/sales-offices.html

- Application ideas (including videos and sample programs):

  http://www.animatics.com/applications.html

DMX Resources

The following equipment and software can be used to test your DMX system:

- DMX512 Standard:

  http://www.usitt.org/content.asp?contentid=370

- Lights Up software (open source, GNU license):

  http://lightsup.sourceforge.net/

- Enttec Open DMX USB interface:

  http://www.enttec.com/index.php?main_menu=Products&pn=70303

Connections, Wiring and Status LEDs

This chapter provides information on the SmartMotor connectors, a multidrop cable diagram, and a description of the SmartMotor status LEDs.

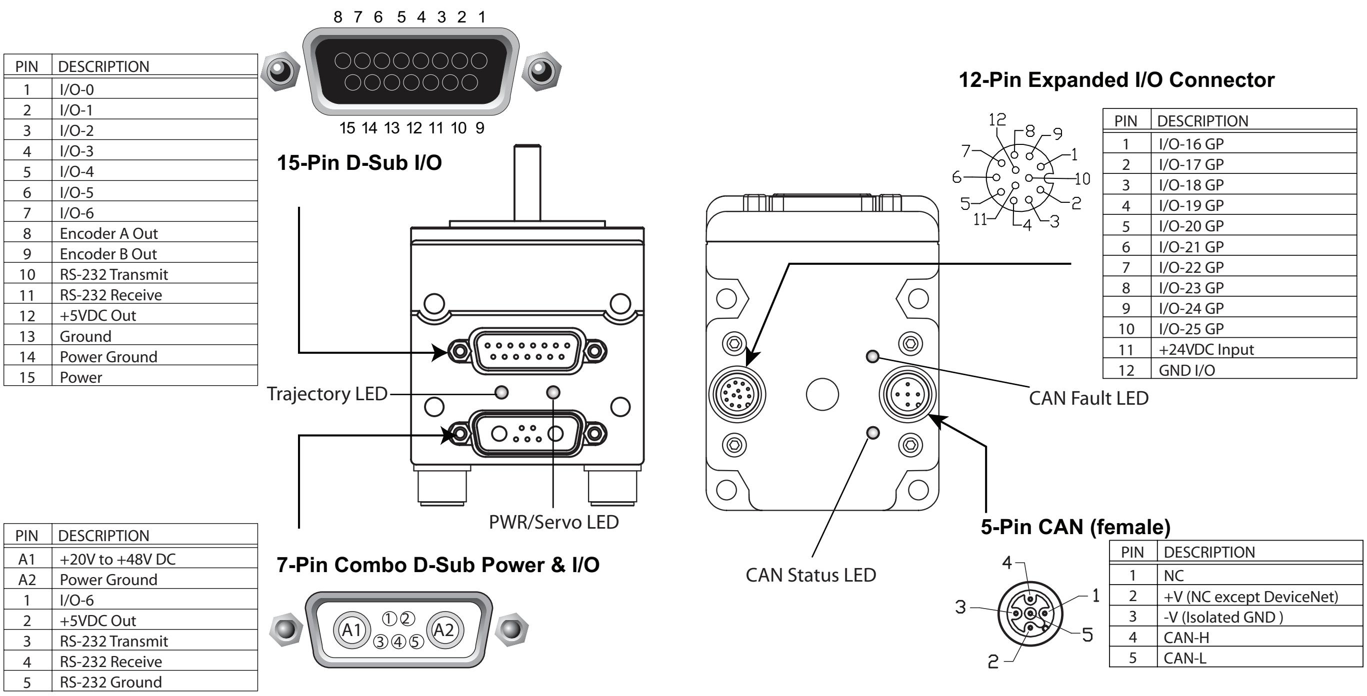
Connectors and Pinouts

D-Style Motors: Connectors and Pinouts

NOTE: DMX support is on RS-485 "COM1"; it uses pins 5 and 6 of the 15-pin D-Sub I/O connector (see the following figure). Also, see D-Style Multidrop Signal Cable Diagram on page 19.

The following figure provides a brief overview of the connectors and pinouts available on the D-style SmartMotors. For details, see the *Moog Animatics Class 5 SmartMotor™ User's Guide*.

NOTE: On the SmartMotor, the RS-485 line labeled "A" is the non-inverting line (D+). This may be different than other systems where "B" is the non-inverting line.



15-Pin D-Sub I/O

PIN	DESCRIPTION
1	I/O-0
2	I/O-1
3	I/O-2
4	I/O-3
5	I/O-4
6	I/O-5
7	I/O-6
8	Encoder A Out
9	Encoder B Out
10	RS-232 Transmit
11	RS-232 Receive
12	+5VDC Out
13	Ground
14	Power Ground
15	Power

7-Pin Combo D-Sub Power & I/O

PIN	DESCRIPTION
A1	+20V to +48V DC
A2	Power Ground
1	I/O-6
2	+5VDC Out
3	RS-232 Transmit
4	RS-232 Receive
5	RS-232 Ground

12-Pin Expanded I/O Connector

PIN	DESCRIPTION
1	I/O-16 GP
2	I/O-17 GP
3	I/O-18 GP
4	I/O-19 GP
5	I/O-20 GP
6	I/O-21 GP
7	I/O-22 GP
8	I/O-23 GP
9	I/O-24 GP
10	I/O-25 GP
11	+24VDC Input
12	GND I/O

5-Pin CAN (female)

PIN	DESCRIPTION
1	NC
2	+V (NC except DeviceNet)
3	-V (Isolated GND)
4	CAN-H
5	CAN-L

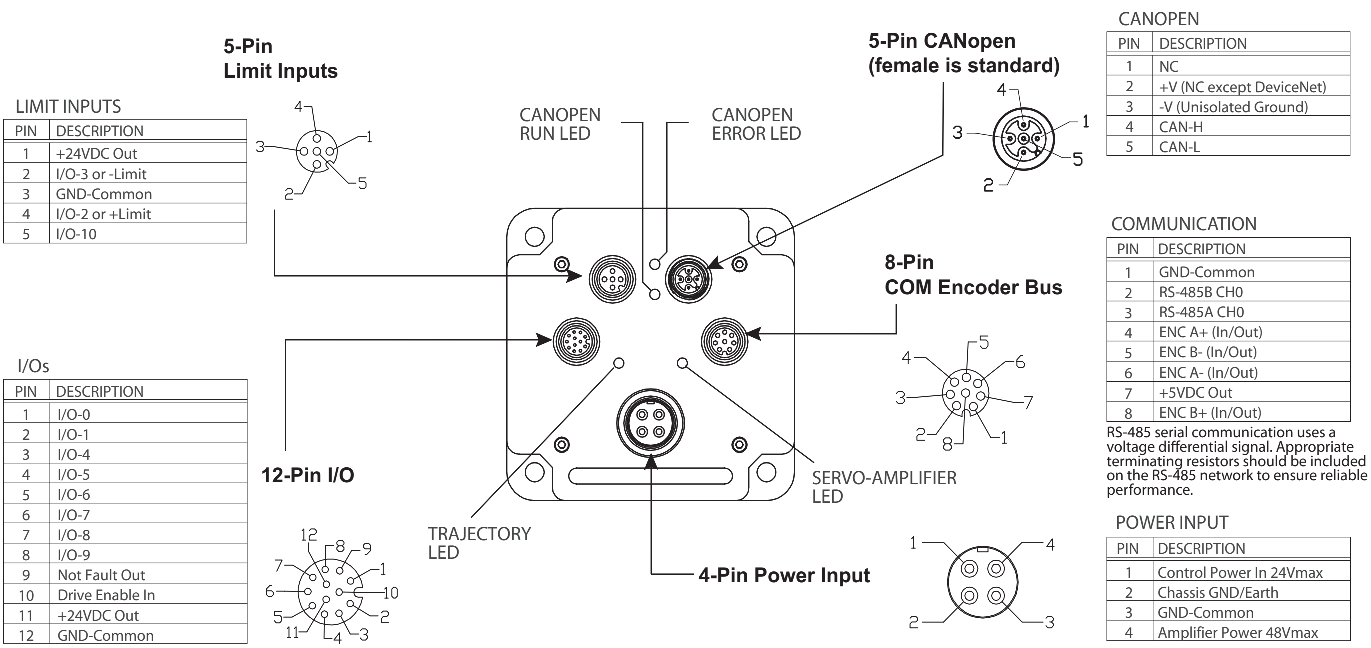
NOTE: The DE power option is recommended. For details, see the *Moog Animatics Class 5 SmartMotor™ User's Guide*.

M-Style Motors: Connectors and Pinouts

> **NOTE:** DMX support is on RS-485 "COM0"; it uses pins 2 and 3 of the 8-Pin COM Encoder Bus connector (see the following figure). Also, see M-Style Multidrop Signal Cable Diagram on page 20.

The following figure provides a brief overview of the connectors and pinouts available on the M-style SmartMotors. For details, see the *Moog Animatics Class 5 SmartMotor™ User's Guide*.

> **NOTE:** On the SmartMotor, the RS-485 line labeled "A" is the non-inverting line (D+). This may be different than other systems where "B" is the non-inverting line.



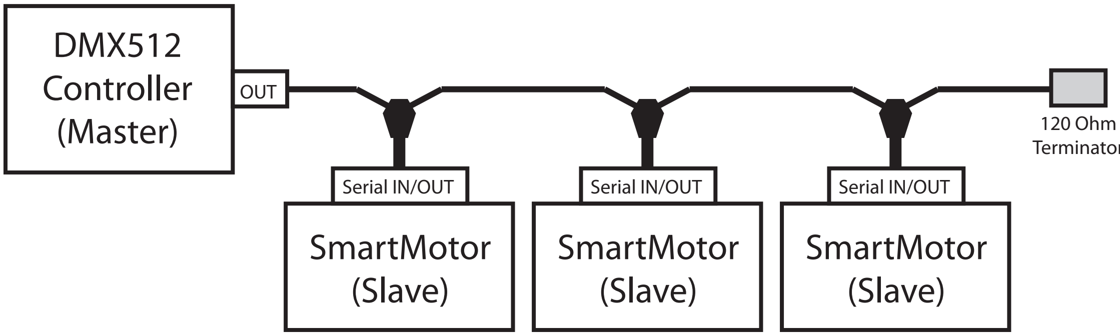
DMX Network Topology

As mentioned previously, DMX512 is based on the EIA-485 standard. It comes with all the limits and requirements of a system based on an RS-485 multi-drop bus. Further, there must be proper bus termination, as required by the EIA-485 standard. Refer to the following figure.

The EIA-485-A standard for the physical connection allows a length of 1000 feet at 250 kBd. However, Moog Animatics does not guarantee this distance under all conditions. The user is responsible for testing and verifying operation in the application environment, including: wire length, DMX host device, and number of DMX nodes.

At the opposite end from the DMX controller, a 120 Ohm bus terminator must be used (see the following figure) — this prevents reflected impedance and noise issues that would otherwise occur.

CAUTION: The 120 Ohm terminator is required at the end of the bus opposite the DMX controller.



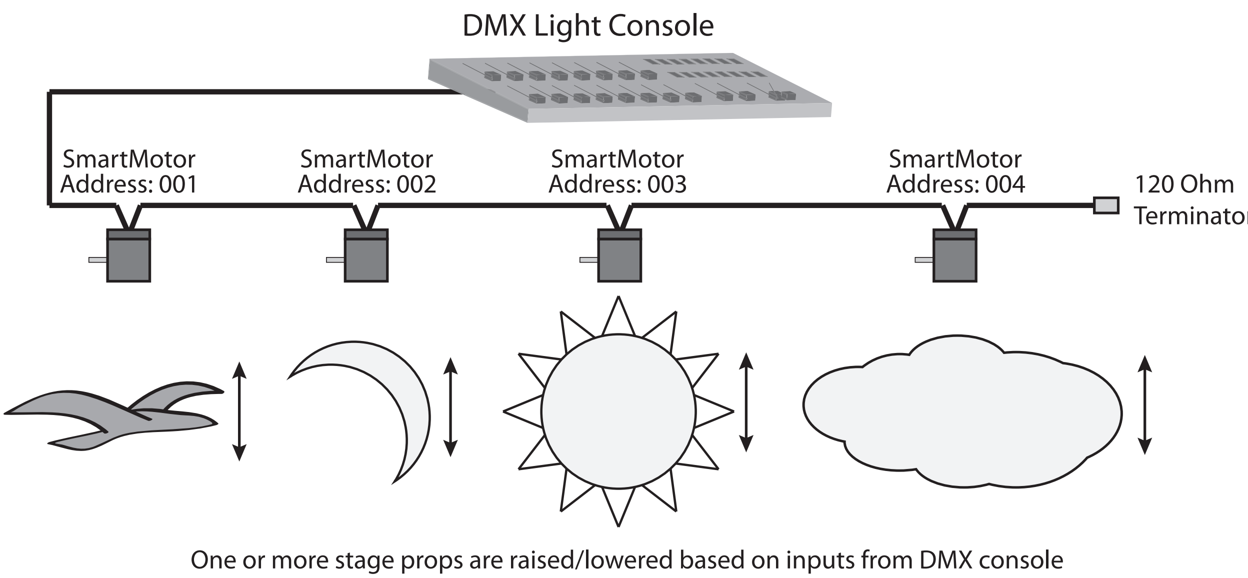
DMX Network Topology

> **NOTE:** Any drops from the main bus should be kept as short as possible, so the system looks like an "in line" network, as shown in the previous figure.

Each DMX network is called a "universe" and can consist of up to 512 data bytes. If more than 512 data bytes are required, then another universe will be required.

> **NOTE:** Some large DMX controllers (such as an operator console) have multiple outputs, which allow them to control multiple universes.

For example, the following figure shows a DMX network of SmartMotors being used to raise/lower one or more stage props based on inputs from the DMX controller. Each motor is assigned a unique DMX address, so it can be operated from the DMX control console. Also, note the 120 Ohm terminator, which is required at the end of the bus.



DMX and SmartMotors Controlling Stage Props

System Cable Diagram

As shown in the previous section, DMX networks are most reliable when a straight bus is used. Common problems with DMX bus wiring are often traced to branches or other configurations. These often create multipath signal reflections that cause communication errors. Adhere to the following cabling requirements:

- The maximum cable length should not exceed 1000 feet at 250 kBd.

CAUTION: The EIA-485-A standard for the physical connection allows a length of 1000 feet at 250 kBd. However, Moog Animatics does not guarantee this distance under all conditions. The user is responsible for testing and verifying operation in the application environment, including: wire length, DMX host device, and number of DMX nodes.

- Each slave must be inline or a short drop from the main bus; do not use branches.
- Use a 120 Ohm terminator at the downstream end of the bus, which is the end opposite the DMX512 controller.

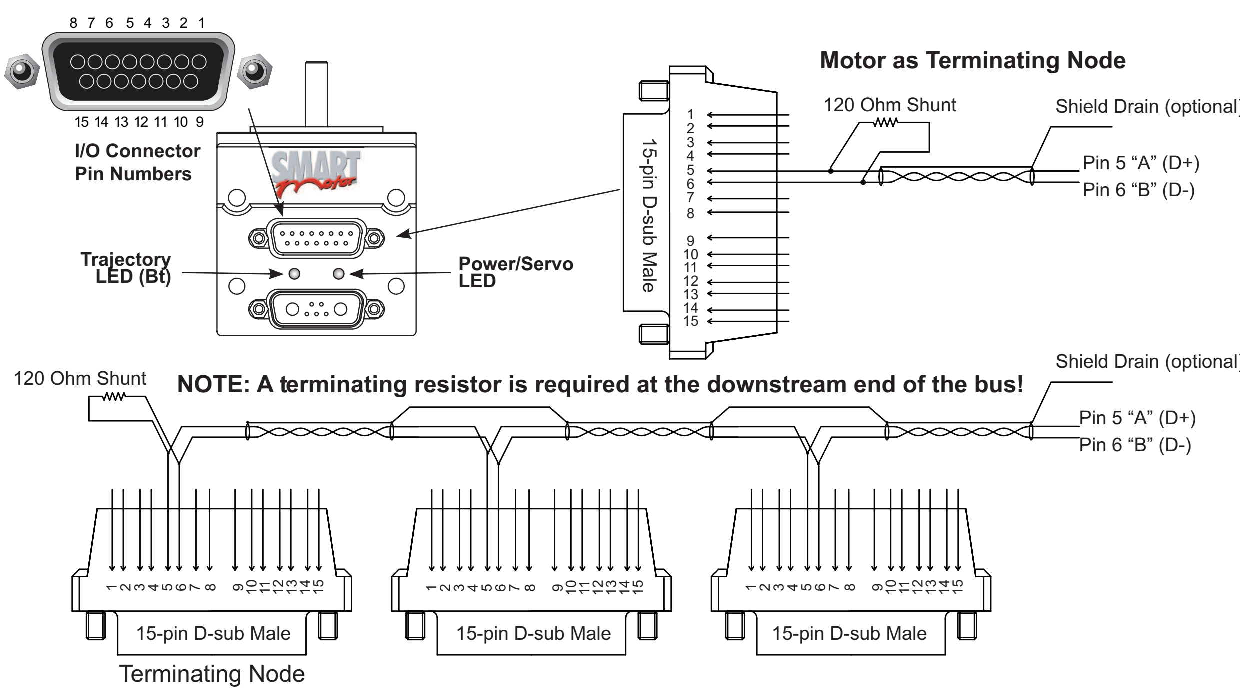
CAUTION: The 120 Ohm terminator is required at the downstream end of the bus.

D-Style Multidrop Signal Cable Diagram

The following figure shows a multidrop signal cable configuration for D-style motors. To supply power, it is recommended that you use the DE power option. For details, see the *Moog Animatics Class 5 SmartMotor™ User's Guide*.

> **NOTE:** DMX support is on RS-485 "COM1"; it uses pins 5 and 6 of the 15-pin D-Sub I/O connector.

> **NOTE:** On the SmartMotor, the RS-485 line labeled "A" is the non-inverting line (D+). This may be different than other systems where "B" is the non-inverting line.



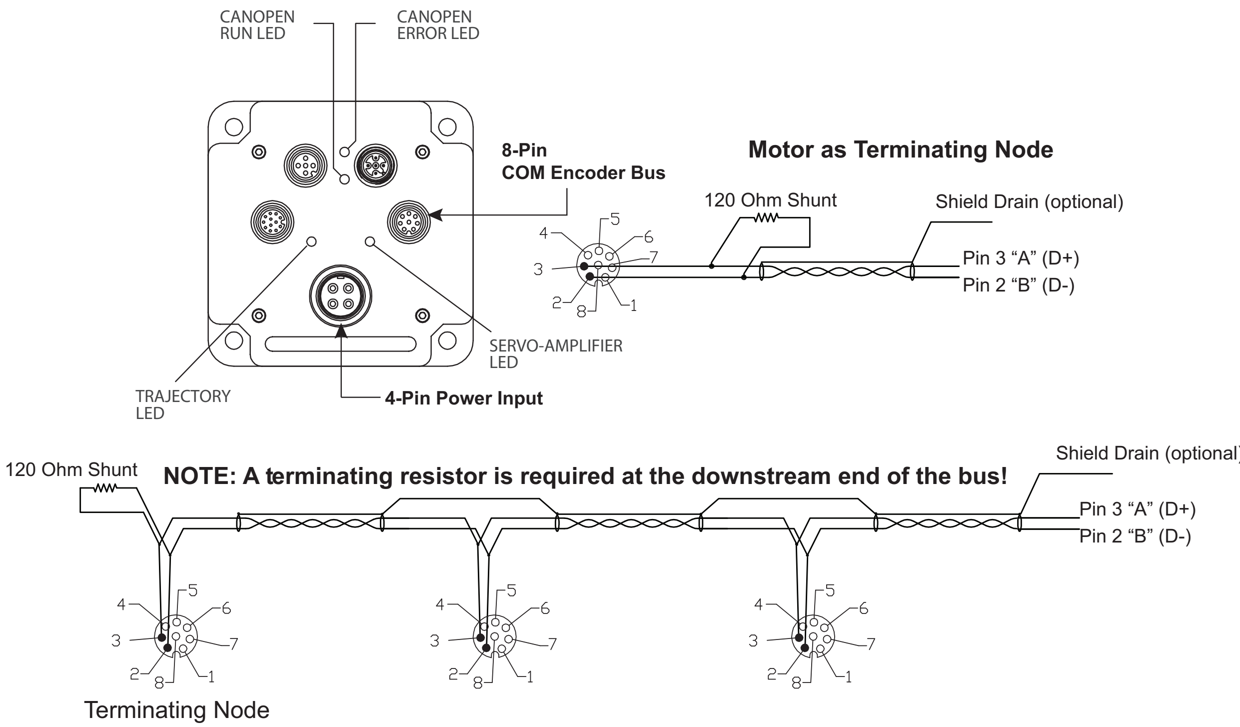
D-Style Multidrop Cable Diagram

M-Style Multidrop Signal Cable Diagram

The following figure shows a multidrop signal cable configuration for M-style motors. Power is supplied through the separate 4-Pin Power Input connector. For details, see the *Moog Animatics Class 5 SmartMotor™ User's Guide*.

NOTE: DMX support is on RS-485 "COM0"; it uses pins 2 and 3 of the 8-Pin COM Encoder Bus connector.

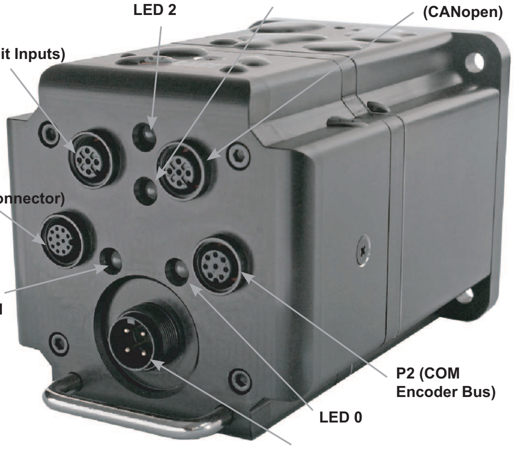
NOTE: On the SmartMotor, the RS-485 line labeled "A" is the non-inverting line (D+). This may be different than other systems where "B" is the non-inverting line.

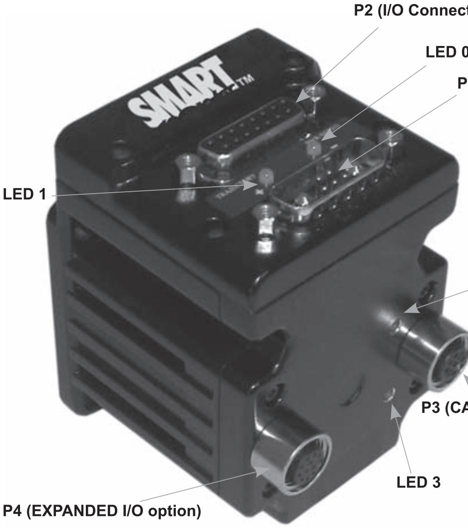


M-Style Multidrop Signal Cable Diagram

Understanding the Status LEDs

The Status LEDs provide the same functionality for the D-style and M-style (including IP-sealed) SmartMotors.





LED 0:	Drive Status Indicator	
	Off	No Power
	Solid green	Drive On
	Flashing green	Drive Off
	Flashing red	Watchdog Fault
	Solid red	Major Fault
	Alt. red/green	In Boot Load, Needs Firmware
LED 1:	Trajectory Status Indicator	
	Off	Not Busy
	Solid green	Drive On, Trajectory In Progress

LED 2:	CAN Bus Network Fault (Red LED)	
	Off	No Error
	Single flash	At Least One Error Exceeded Limit
	Double flash	Heartbeat or Guard Error
	Solid	Busy Off State
LED 3:	CAN Bus Network Status (Green LED)	
	Blinking	Pre-Operational State (during boot-up)
	Solid	Normal Operation
	Single	Device is in Stopped State

LED Status on Power-Up:

- With no program and the travel limits are low:
  - LED 0 will be solid red indicating the motor is in a fault state due to travel limit fault.
  - LED 1 will be off.
- With no program and the travel limits are high:
  - LED 0 will be solid red for 500 milliseconds and then begin flashing green.
  - LED 1 will be off.
- With a program that only disables travel limits and nothing else:
  - LED 0 will be solid red for 500 milliseconds and then begin flashing green.
  - LED 1 will be off.

DMX on the SmartMotor

This chapter provides information about DMX operation on the SmartMotor.

DMX Implementation

The SmartMotor has the ability to accept DMX512 protocol through the RS-485 port. Flexibility is maintained by allowing the user to assign and accept multiple slots of incoming DMX protocol — the starting slot and number of slots may be defined by the user.

DMX data packets are unsigned 8-bit integer data. As a result, and to conform to only positive integer values, incoming slots of 8-bit data are stored into 16-bit signed array variables in SmartMotor memory.

SmartMotors have predefined 16-bit array data variables consisting of aw[0] through aw [101]. Therefore, the SmartMotor is limited to 102 DMX channels. The "aw" stands for "array word" and is an indexed 16-bit signed integer value. If a slot is assigned to an aw[ ] array variable, the value returned will be between 0 and 255. This assures proper sign convention for all values. It also allows for easier addition and bit shifting to optimize incoming data.

> **NOTE:** The SmartMotor is limited to 102 DMX channels.

The user program must read incoming DMX data in the aw[ ] registers and perform all actions from that data, including motion and/or digital outputs.

For example, if you want to control the position of a theater light, you would:

1. Select an unused DMX controller channel,
2. Program the base address in the SmartMotor aligned with that particular channel,
3. Write a program that reads the corresponding array variable in the SmartMotor,
4. Assign corresponding parameters in the motor, including position, velocity, acceleration and torque, call out a specific subroutine, and more.

By using the SmartMotor, the entire motion control system requires less cabling and becomes more compact because no control cabinet is needed. Further, additional axes can be added as needed.

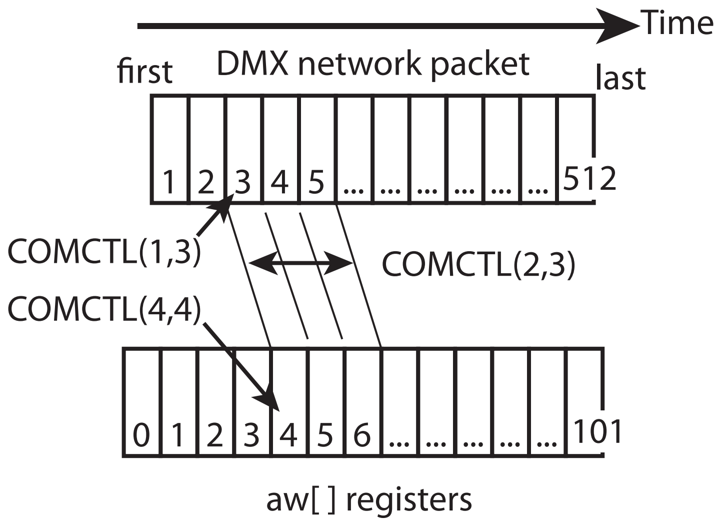
Data Storage and Usage

Address information for the DMX protocol can be stored in one of the following ways:

- It can be "hard coded" into the program, or
- The VST/VLD commands can be used to store/retrieve this information to/from the desired SmartMotor memory location.

It is up to the system programmer to select the method that works best for the application.

> **NOTE:** Technically, there is no "address" for a DMX slave device. The slave device sees all (possibly 512 bytes) of the data and decides which part it wants to use.



Data Transfer from DMX to SmartMotor Array

Data from the DMX packet is stored into the SmartMotor user-variable word array. Even though the channels are 8-bit data, the 16-bit word locations are used for storage in order to represent the data as unsigned numbers. When stored as words, the values 0 through 255 appear unsigned. (If the values were presented as bytes, they would appear negative to user programs when larger than half of the scale.)

Typically, most DMX devices (including the SmartMotor) use a "base channel". The SmartMotor does that using COMCTL(1,x), where x is the base channel: 1-512.

Example

Settings:

- Base DMX channel = 5
- Number of DMX channels = 2

DMX Channel	SmartMotor Variable
1	
2	
3	
4	
5	aw[0]
6	aw[1]
7	
...	

Status Bits

To allow a user program to respond to the conditions of the DMX data stream, several user bits were implemented in the first user status word. This is accessible for reading as Status Word 12. See the next table for a description of the bits in Status Word 12.

Note the following:

- These bits cannot be cleared using ZS or Z(word,bit) commands. See notes in table for specific usage.
- All bits in Status Word 12 are cleared when opening the DMX channel. Do not use any of user status bits 0-15 as a general-purpose user status bits. Use user status bits 16-31 (Status Word 13) if general-purpose user status bits are required.

End of Packet

User bit 2 reports when the end of a packet is received. This allows for better synchronization among slave devices. Previously, a device reading channel 1 versus a device reading channel 512 could have up to 22 milliseconds of skew if they were depending on user bit 1. User bit 2 would minimize or eliminate this skew.

To use this feature, see the COMCTL(3,value) command. Note that:

- Bit 2 must be cleared to acknowledge receipt.
- The system programmer may choose a lower channel for value if the upper channels are not used or if the DMX master does not send all 512 channels.

The following table provides bit descriptions for Status Word 12:

Status Word	Bit	Description	Set By	Cleared By
12	0	DMX packets seen within the last second. Packets may have any start code. They may or may not be relevant data.	Arrival of any start code.	Timeout after 1 second of no valid packets.
12	1	DMX data received. Set when the last expected motor channel arrives, not when the whole packet arrives. For example, if the channel quantity is set to expect 2 channels, then the flag is set when the second byte is saved to aw[1].	Arrival of last expected channel.	User: use command UR (1).
12	2	COMCTL(3,value) sync on channel "value", where value is the channel number 1-512; value=512 by default. User bit 2 is set when that channel is received. Therefore, a full 512 channel packet will set this bit at the end of the packet.	Set on arrival of last expected host-capable channel.	User: use command UR (2).
12	3 - 15	Reserved.		

The following diagram shows when each bit is set.

DMX Network Packet

	Start code	First data											Last data
Byte:	0	1	2	3	4	5	6	7	...	256	...	511	512
Data configuration: COMCTL(1,3), COMCTL(2,4)				Selected data									
Status bit B(12,0)	Bit set												
Status bit B(12,1)							Bit set[a]						
Status bit B(12,2), e.g., when COMCTL(3,256)										Bit set[a]			
a) Bit set when this byte is complete													

The following diagram shows how COMCTL(3,value) is useful in applications with multiple motors.

DMX Network Packet

	Start code	First data					Last data
Byte:	0	1	2	3	4	...	512
Data configuration motor 1: COMCTL(1,1), COMCTL(2,1)		Selected data					
Data configuration motor 1: COMCTL(1,2), COMCTL(2,1)			Selected data				
Data configuration motor 1: COMCTL(1,3), COMCTL(2,1)				Selected data			
Data configuration motor 1: COMCTL(1,4), COMCTL(2,1)					Selected data		
Status bit B(12,2), e.g., when COMCTL(3,4) in all motors					Bit set[a,b,c]		

a) Bit set when this byte is complete.
b) All motors see the bit at the same time.
c) All motors have received their data at this point.

DMX Commands

The following sections describe the DMX-specific commands that are available on the SmartMotor. The commands are organized by function.

Select DMX Channels

The following commands are used to select the DMX channels:

NOTE: If the input is out of range, these commands will be ignored and issue a command error. They do not retain any settings between power cycles.

- **COMCTL(1,value)** Set base channel [value] (1 through 512); default is 1 at power-up.
- **COMCTL(2,value)** Set number of channels [value] to read starting with base channel (1 through 102); default is 1 at power-up.
- **COMCTL(3,value)** Sync on channel, where value is the channel number 1-512; default is 512 at power-up. User bit 2 is set when that channel is received. Therefore, a full 512 channel packet will set this bit at the end of the packet.
- **COMCTL(4,value)** Allows for the selection of the aw[ ] register where the DMX data begins loading; default is 0 at power-up. For example, COMCTL(4,10) will start loading DMX data at aw[10].

Special Range Checking

The following range checks would apply due to a combination of the previously listed commands:

- If the value of the base channel + number of channels exceeds 512, then the additional channels will be ignored.
- If the value of the aw[ ] starting channel + number of channels exceeds 102, then the additional channels will be ignored.

These checks are performed after commands COMCTL(1,value), COMCTL(2,value) and COMCTL(4,value).

Open DMX Channel

The following commands are used to open a DMX channel:

- **OCHN(DMX,1,N,250000,2,8,D)** uses COM1 for D-style motors; by default, DMX on COM1 is disabled (port closed).
- **OCHN(DMX,0,N,250000,2,8,D)** uses COM0 for M-style motors.

Data begins writing into the aw[x] registers as soon as the port is open and valid DMX packets arrive.

Any other parameters will result in command error, and the state of the port remains unchanged. DMX specifies these settings: 250 kBd, 8 data bits, 2 stop bits, no parity check.

Close DMX Channel

The following commands are used to close a DMX channel:

- **CCHN(DMX,1)** for D-style motors
- **CCHN(DMX,0)** for M-style motors

These commands:

- Stop listening for DMX data
- Clear flags in Status Word 12
- Values in the aw[ ] array are left as is

  NOTE: Data in the aw[ ] array may be only partially updated if the channel closes at the moment the DMX data is being loaded.

Example Programs

This chapter contains example programs that you can use as a guide for developing your SmartMotor applications. For more details on SmartMotor programming, see the *Moog Animatics Class 5 SmartMotor™ User's Guide*.

> **NOTE:** The programs and code samples in this manual are provided for example purposes only. It is the user's responsibility to decide if a particular code sample or program applies to the application being developed and to adjust the values to fit that application.

Home Against a Hard Stop

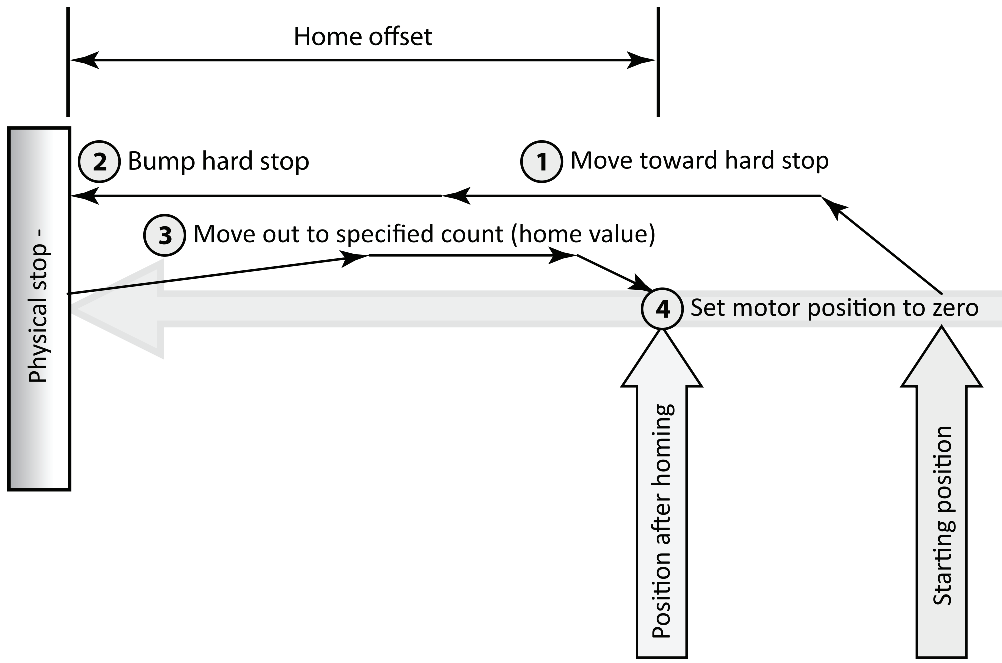
Because the SmartMotor has the capability of lowering its own power level and reading its position error, it can be programmed to gently feel for the end of travel. This provides a means to develop a consistent home position subsequent to each power-up.

Machine reliability requires the elimination of potential failure sources. Eliminating a home switch and its associated cable leverages SmartMotor benefits and improves machine reliability.

The following program lowers the current limit, moves against a limit, looks for resistance and then declares and moves to a home position located 100 counts from the hard stop. The figure following the program illustrates these steps.

```
MDS                 'Using Sine mode commutation
KP=3200             'Increase stiffness from default
KD=10200            'Increase damping from default
F                   'Activate new tuning parameters
AMPS=100            'Lower current limit to 10%
VT=-10000           'Set maximum velocity
ADT=100             'Set maximum acceleration
MV                  'Set Velocity mode
G                   'Start motion
WHILE EA>-100       'Loop while position error is small
LOOP                'Loop back to WHILE
O=-100              'While pressed, declare home offset
S                   'Abruptly stop trajectory
MP                  'Switch to Position mode
VT=20000            'Set higher maximum velocity
PT=0                'Set target position to be home
G                   'Start motion
TWAIT               'Wait for motion to complete
AMPS=1000           'Restore current limit to maximum
END                 'End Program
```

Find home using hard stop



Homing Against a Hard Stop

Position Mode Control Example

The following example is provided to help you understand position mode control through DMX code. It is recommended to use three DMX channels for maximum position resolution. However, just one channel may be used.

Also, note that there is a home to hard stop subroutine embedded in this program. It is important to always home the motor before executing the main DMX code. For more homing details, see Home Against a Hard Stop on page 32.

```
'=================================================================
'Position Mode Example Code
'=================================================================

ADDR=1          'Set motor serial address as needed.
                'This does not affect DMX address.
ECHO            'Set ECHO on,  not required for DMX.
EIGN(W,0)       'Disable hardware limit switch checking
                '(for demo purposes).
ZS              'Clear any startup errors.

'Variables for DMX control:
b=1     'Set DMX base address (valid address: 1 through 512).
n=3     'Set number of DMX channels to use.
'NOTE: Max that may be summed is 3 or 24-bit position unsigned int.
s=0     'First motor array variable index to use starting with aw[s].
        'NOTE: aw[0 thru 101] are available
'NOTE: Data ranges for the value of "n" for number of channels are:
'n=1     0 to 255
'n=2     0 to 65535
'n=3     0 to 16777215
m=1     'Scale factor multiplied by data to give target position.
'NOTE: For 2 or 3 channels (16 or 24-bit position), this should be 1.
'For a single channel with 8 bit positioning, you may need to
'increase "m". Jerky motion may result by using just a single channel
'with only 8-bit resolution

'Configure DMX data usage and motor variable storage:
IF n>3       PRINT("n too large.",#13) END ENDIF
                'Limit "n" based on a max of 3 bytes.
IF b>(513-n) PRINT("b too large.",#13) END ENDIF
                'Limit "b" based on max data slot.
IF s>(102-n) PRINT("s too large.",#13) END ENDIF
                'Limit "s" to max array value.
q=b+n-1 'Last data channel used (will be trigger when data received).
COMCTL(1,b)     'Set base DMX channel to value from CADDR.
COMCTL(2,n)     'Accept one DMX channel of data.
COMCTL(3,q)     'Status word 12 bit 2 will be set to the value 1
                'when channel "q" arrives.
COMCTL(4,s)     'Set start of array index storage (good for
                'bypassing cam mode dynamic array).
```

```
OCHN(DMX,1,N,250000,2,8,D)      'Open DMX channel: COM1, no parity,
                                '250 kBd, 2 stop, 8 data, datamode

GOSUB(100)       'Always run a homing routine before DMX.
'==================================================================
'     Set Initial Values
UR(2)            'Clear flag so we know when the end of the next
                 'data packet arrives.
MP               'Set to Position mode.
ADT=800          'Accel/decel value (adjust as needed).
VT=1500000       'Velocity (adjust as needed).
'===================================================================
'     Set up interrupts to linger at higher values:
ITR(0,0,0,0,0)   'Interrupt to catch all motor drive faults.
EITR(0)          'Enable fault interrupt.
ITRE             'Enable global interrupts.

'===================================================================
'     Main Program Loop

WHILE 1    'NOTE: This loop constantly polls DMX data and scales.
           'it directly to target position.
  IF B(12,2)==1 'Check for next data packet.
    UR(2)        'Clear flag so we will know when next packet arrives.
    nn=n-1
    p=0          'Zero data value.
    WHILE nn>=0
      p=p*256+aw[nn+s]   'Set p variable for next data value.
      nn=nn-1
    LOOP         'Loop takes 4 milliseconds when using three
                 'channels (24 bit).
    PT=p*m       'Calculate target position.
    G            'Start moving to latest trajectory.
  ENDIF
LOOP
END        'End of the main program.

'===================================================================
'     Fault Routine Code (place here)
C0
  END
RETURNI

'===================================================================
'     Home Motor
C100             'Set up parameters (edit as required)
  rr=-1          'Home direction
  vv=10000       'Home speed
  aa=1000        'Home accel
  ee=100         'Home error limit
  tt=3000        'Home torque limit
  hh=4000        'Home offset
```

```
  '   Home Routine (home to hard stop)
  AMPS=512       'Reduce power.
  VT=vv*rr       'Set home velocity.
  ADT=aa         'Set home accel.
  MV             'Set to velocity mode.
  ZS             'Clear previous errors.
  T=tt*rr        'Preset torque values.
  G              'Begin move toward hard stop.
  WHILE ABS(EA)<ee LOOP   'Loop while position error is within limit.
  MTB            'Mode Torque Break to stop.
  MT             'Switch to Torque mode in case bounce off hard stop.
  G              'Start motion.
  WAIT=50        'Wait 50 milliseconds.
  O=hh*rr        'Set origin to home offset.
  AMPS=1023      'Set power back to max.
  MP PT=0 G TWAIT   'Set motor to zero.
RETURN
```

DMX Five Channel Example

The following example allows you to use up to five channels. The function of each is shown in the following table.

Channel	Purpose
1st	Velocity
2nd	Accel/Decel
3rd	8-bit position control
4th	+ 8 for 16-bit optional position control
5th	+ 8 more for 24-bit optional position control
In the example code (see below): "b" sets base DMX channel "n" sets number of position channels to use (0 through 3)	

Also, note that there is a home to hard stop subroutine embedded in this program. It is important to always home the motor before executing the main DMX code. For more homing details, see Home Against a Hard Stop on page 32.

```
'==================================================================
'DMX Five Channel Example
'==================================================================

ADDR=1      'Set Motor serial address as needed.
            'This does not affect DMX address.
ECHO        'Set ECHO on,  not required for DMX

EIGN(W,0)   'Disable hardware limit switch check (for demo purposes).
ZS          'Clear any startup errors.
'Variables for DMX control
b=1      'Set DMX base address  Valid Address: 1 thru 512
n=3      'Set number of DMX channels to use for Position control
'NOTE: Max that may be summed is 3 or 24 bit position unsigned int.
s=0      'First motor array variable index to use starting with aw[s].
         'NOTE: aw[0 thru 101] are available
'The main WHILE loop will calculate the binary total value of incoming data.
'NOTE: Data ranges for the value of "n" for number of channels are:
'n=1        0 to 255
'n=2        0 to 65535
'n=3        0 to 16777215

m=1        'Scale Factor multiplied by data to give target position.
'NOTE: For 2 or 3 channels (16 or 24-bit position), this should be 1.
'For a single channel with 8-bit positioning, you may need to
'increase "m". Jerky motion may result by using just a single
'channel with only 8-bit resolution.
vvv=2000    'Scale factor for velocity target times max of 255
aaa=10      'Scale factor for Accel/Decel  times max of 255
```

```
'Configure DMX data usage and motor variable storage:
IF n>3       PRINT("n too large.",#13) END ENDIF
                'Limit "n" based on a max of 3 bytes.
IF b>(513-n) PRINT("b too large.",#13) END ENDIF
                'Limit "b" based on max data slot.
IF s>(102-n) PRINT("s too large.",#13) END ENDIF
                'Limit "s" to max array value.
q=b+n-1 'Last data channel used (will be trigger when data received).
nnn=n+2
COMCTL(1,b)    'Set base DMX channel to value from CADDR.
COMCTL(2,nnn)  'Accept "n" DMX channels of data.
COMCTL(3,q)    'Status word 12 bit 2 is set to 1 when channel "q"
               'arrives.
COMCTL(4,s)    'Set start of array index storage (r bypass cam mode
               'dynamic array).

OCHN(DMX,1,N,250000,2,8,D)  'Open DMX channel: COM1, no parity,
                            '250 kBd, 2 stop, 8 data, datamode

GOSUB(100)     'Always run a homing routine before DMX.
'================================================================
'     Set Initial Values
UR(2)          'Clear flag so that we know when the end of the next
               'data packet arrives.
MP             'Set to Position mode.
ADT=800        'Accel/Decel Value (adjust as needed).
VT=1500000     'Velocity (adjust as needed).

'================================================================
'     Set up interrupts to linger at higher values.
ITR(0,0,0,0,0) 'Interrupt to catch all motor drive faults
EITR(0)        'Enable Fault Interrupt
ITRE           'Enable Global interrupts

ss=s+2

'=================================================================
'     Main Program Loop
WHILE 1     'NOTE: This loop constantly polls DMX data and scales it
            'directly to target position.
  IF B(12,2)==1  'Check for next data packet.
    UR(2)        'Clear flag so we know when next packet arrives.
    nn=n-1
    p=0          'Zero data value.
    WHILE nn>=0  'Byte shifting and summing data.
      p=p*256+aw[nn+ss]
      nn=nn-1
    LOOP             'Loop takes 4 msec when using three
                     'channels (24 bit).
    VT=aw[s]*vvv     'Set velocity target off of first channel
                     'x multiplier.
```

```
    ADT=aw[s+1]*aaa  'Set Accel/Decel target off of second channel
                     'x multiplier.
    PT=p*m           'Position target is total for data collected.
    G                'Start moving.
  ENDIF
LOOP
END     ' End of the main program.
'====================================================================
'     Fault Routine Code (place here)
C0
     END
RETURNI
'=====================================================================
'     Home Motor
C100            'Set up parameters (edit as required)
  rr=-1         'Home direction
  vv=10000      'Home speed
  aa=1000       'Home accel
  ee=100        'Home error limit
  tt=3000       'Home torque limit
  hh=4000       'Home offset

  '   Home Routine (home to hard stop)
  AMPS=512      'Reduce power.
  VT=vv*rr      'Set home velocity.
  ADT=aa        'Set home accel.
  MV            'Set to velocity mode.
  ZS            'Clear previous errors.
  T=tt*rr       'Preset torque values.
  G             'Begin move toward hard stop.
  WHILE ABS(EA)<ee LOOP   'Loop while position error is within limit.
  MTB           'Mode Torque Break to stop.
  MT            'Switch to Torque mode in case bounce off hard stop.
  G             'Start motion.
  WAIT=50       'Wait 50 milliseconds.
  O=hh*rr       'Set origin to home offset.
  AMPS=1023     'Set power back to max.
  MP PT=0 G TWAIT   'Set motor to zero.
RETURN
```

DMX Packet Test Example

The following example will test up to two channels summed together as a single 24-bit data block. It will provide the time between data packets and the data itself. It is recommended to use three DMX channels for maximum position resolution.

Also, note that there is a home to hard stop subroutine embedded in this program. It is important to always home the motor before executing the main DMX code. For more homing details, see Home Against a Hard Stop on page 32.

```
'=====================================================================
'DMX Packet Test Code
'=====================================================================
ADDR=1       'Set Motor serial address as needed.
             'This does not affect DMX address.
ECHO         'Set ECHO on, not required for DMX.
EIGN(W,0)    'Disable hardware limit switch checking
             '(for demo purposes).
ZS           'Clear any startup errors.

'Variables for DMX control
b=1     'Set DMX base address  Valid Address: 1 thru 512
n=3     'Set number of DMX channels to use
'NOTE: max that may be summed is 3 or 24 bit position unsigned int.
s=0     'First motor array variable index to use starting with aw[s].
        'NOTE: aw[0 thru 101] are available.
'The main WHILE loop calculates binary total value of incoming data.
'NOTE: Data ranges for value of "n" for number of channels are:
'n=1          0 to 255
'n=2          0 to 65535
'n=3          0 to 16777215

'Configure DMX data usage and motor variable storage:
IF n>3       PRINT("n too large.",#13) END ENDIF
                'Limit "n" based on a max of 3 bytes.
IF b>(513-n) PRINT("b too large.",#13) END ENDIF
                'Limit "b" based on max data slot.
IF s>(102-n) PRINT("s too large.",#13) END ENDIF
                'Limit "s" to max array value.
q=b+n-1 'Last data channel used (will be trigger when data received).
COMCTL(1,b)     'Set base DMX channel to value from CADDR.
COMCTL(2,n)     'Accept 1 DMX channel of data.
COMCTL(3,q)     'Status word 12 bit 2 will be set to 1 when
                'channel "q" arrives.
COMCTL(4,s)     'Set start of array index storage (good for
                'bypassing cam mode dynamic array).

OCHN(DMX,1,N,250000,2,8,D)  'Open DMX channel: COM1, no parity,
                '250 kBd, 2 stop, 8 data, datamode.

'GOSUB(100)     'Always run a homing routine before DMX
                '(see other examples)
```

```
'===================================================================
'     Set Initial Values
UR(2)           'Clear flag so that we know when the end of the next
                'data packet arrives.
'===================================================================
'===================================================================
'     Main Program Loop
WHILE 1     'NOTE: This loop constantly polls DMX data and scales
            'it directly to target position.
     IF B(12,2)==1 'Check for next data packet.
          t=CLK-tt 't=time in msec since last data packet received.
          tt=CLK
          UR(2)    'Clear flag so we know when next packet arrives.
          nn=n-1
          p=0             'Zero data value
          WHILE nn>=0     'Byte-shifting and summing data
               p=p*256+aw[nn+s]
               nn=nn-1
          LOOP     'Loop takes 4 milliseconds when using three
                   'channels (24 bit).
          pp=p     'Total for data collected.
     ENDIF
LOOP
END     'End of the main program.
'===================================================================
'     Fault Routine Code (place here)
C0
     END
RETURNI
'===================================================================
```

Troubleshooting

The following table provides troubleshooting information for solving common problems. For additional support resources, see the Moog Animatics Support page at:

http://www.animatics.com/support.html

Issue	Cause	Solution
Communication and Control Issues		
Motor control power light does not illuminate.	Motor is equipped with the DE option.	To energize control power, apply 24-48 VDC to pin 15 and ground to pin 14.
	Motor has drive power routed through drive-enable pins.	Ensure cabling is correct and drive power is not being delivered through the 15-pin connector.
Motor does not communicate with SMI.	Transmit, receive or ground pins are not connected correctly.	Ensure that transmit, receive and ground are all connected properly to the host PC.
	Motor program is stuck in a continuous loop or is disabling communications.	To prevent the program from running on power up, use the Communications Lockup Wizard located on the SMI software Communications menu.
Motor disconnects from SMI sporadically.	COM port buffer settings are too high.	Adjust the COM port buffer settings to their lowest values.
	Poor connection on serial cable.	Check the serial cable connections and/or replace it.
	Power supply unit (PSU) brownout.	PSU may be too high-precision and/or undersized for the application, which causes it to brown-out during motion. Make moves less aggressive, increase PSU size or change to a linear unregulated power supply.
Motor stops communicating after power reset, requires re-detection.	Motor does not have its address set in the user program. NOTE: Serial addresses are lost when motor power is off or reset.	Use the SADDR or ADDR= command within the program to set the motor address.
Red PWR SERVO light illuminated.	Critical fault.	To discover the source of the fault, use the Motor View tool located on the SMI software Tools menu.

Issue	Cause	Solution
Erratic/no communication over RS-485.	RS-485 biasing is incorrect.	See EIA-485-A standards. Verify that shunt is used (see System Cable Diagram on page 18).
	Incorrect signal cable wiring.	See System Cable Diagram on page 18.
	Cable lengths are too long or incorrect topology.	See EIA-485-A standards. See DMX Network Topology on page 17.
Common Faults		
Bus voltage fault.	Bus voltage is either too high or too low for operation.	Check servo bus voltage. If motor uses the DE power option, ensure that both drive and control power are connected.
Overcurrent occurred.	Motor intermittently drew more than its rated level of current. Does not cease motion.	Consider making motion less abrupt with softer tuning parameters or acceleration profiles.
Excessive temperature fault.	Motor has exceeded temperature limit of 85°C. Motor will remain unresponsive until it cools down below 80°C.	Motor may be undersized or ambient temperature is too high. Consider adding heat sinks or forced air cooling to the system.
Excessive position error.	The motor's commanded position and actual position differ by more than the user-supplied error limit.	Increase error limit, decrease load or make movement less aggressive.
Historical positive/negative hardware limit faults.	A limit switch was tripped in the past.	Clear errors with the ZS command.
	Motor does not have limit switches attached.	Configure the motor to be used without limit switches by setting their inputs as general use.
Programming and SMI Issues		
Several commands not recognized during compiling.	Compiler default firmware version set incorrectly.	Use the Compiler default firmware version option in the SMI software Compile menu to select a default firmware version closest to the motor's firmware version. In the SMI software, view the motor's firmware version by right-clicking the motor and selecting Properties.
SmartMotor not positioning object at expected location.	Motor not homed before executing DMX code.	See Home Against a Hard Stop on page 32.
SmartMotor not responding to DMX commands.	Varies.	Check status bits (see Status Bits on page 26). Use Packet Test program (see DMX Packet Test Example on page 40).

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