Series MI Communication User Guide

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Amendments

Date	Comment(s)
08/08/2018	Removed CAN version. Roll Call command. Version 1.7
08/11/2011	Added text for MI-3001-485 variant. Version 1.6
10/27/2010	Fixed incorrect checksum values in a couple examples. Version 1.5
10/01/2009	Removed Set Multi-Drop Delay command. Version 1.4
08/17/2009	Added section 1.4 All Respond Address use and limitations. Version 1.3
07/14/2009	Added Set Multi-Drop Delay command for RS232 support. Version 1.2
04/08/2009	Command response now includes address, length, and command. Version 1.1
3/27/2008	MI Communication User Guide. Version 1.0

MI Communication User Guide

1   General

This document describes how to communicate with a **MI-3001-232** or **MI-3001-485** MEMS Digital inclinometer using the Megatron protocol.

- A MI-3001-232 connects to a RS232 serial port.
- A MI-3001-485 connects to a RS485 port. A USB-to-RS485 adapter is typically used to connect to a PC. Up to 32 MI-3001-485 devices can be connected to the same RS485 bus.

The following section provides some basic information about the serial communication between the host computer and a MI-3001-232 or MI-3001-485.

- The default RS232/RS485 parameters are 115200 baud, 8 data bits and no parity. The baud rate can be changed to any of the following: 115200, 57600, 38400, 19200 or 9600.
- The MI only responds to commands from the host. It does not initiate communication and cannot be configured to respond periodically.
- The MI responds within 2 milliseconds for all "Get" commands and within 25 milliseconds for all "Set" commands.
- A command from the host must be less than 500 milliseconds in duration (first byte to last byte) or the MI will discard the command.
- The byte order for multi-byte values is Big Endian (most significant byte first).
- The data is transmitted in binary format rather than ASCII, so it cannot be viewed on a text terminal.
- Unless otherwise specified, all data values are signed (2's complement).
- All commands have a response. "Get" commands return data while "Set" commands return a status indicating the outcome of the command.
- All set messages and all set and get responses include a checksum to verify data integrity.
   - The checksum is calculated by adding all the bytes in the message except the checksum, negating (take the 2's complement) the value and taking the low byte of the result. The checksum is placed in the last byte of the message.
   - To verify data integrity, add all the response bytes including the checksum and verify that the lowest byte of the sum is equal to zero.

All angles are reported in degrees multiplied by 1000.
For example, an angle of 123.456 degrees is reported as 123456.
The range of the reported angle depends on the output mode.

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Angle output mode	Angle range
0 (bidirectional)	-180.000 to 179.999
1 (unidirectional)	0 to 359.999

The actual data is transmitted as 2's complement binary data.

MI axes are numbered 0, 1 and 2. A single axis MI (MI-3001-1) uses Axis 2.

Accelerometer values are reported in units of gravity (G) multiplied by 102300.
For example, an acceleration of 0.5 g is reported as 51150.

1.1 *Command Format*

A command refers to a message sent from the host to a MI.
The basic format for a command is:
Address, Length, Command, Data, [Checksum]
Address – one byte destination address i.e. the intended recipient of the command
Length – one byte command length (excluding the address or length bytes)
Command – one byte command (described in this document)
Data - zero or more bytes of data required for this command
Checksum – one byte checksum (LSB of negative of the sum of all bytes in message) used only for "Set" commands. "Get" commands do not have a command checksum

The factory default address the MI is 127.
The address of each MI can be set to any value from 1 to 100 or 127.
All MIs respond to a command sent to address 126.

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1.2 *Response Format*

A response refers to a message sent from a MI to the host.
The basic format for a response is:
Address, Length, Command, Data, Checksum
Address – one byte source address i.e. who sent the response.
Length – one byte response length (doesn't include the address or length bytes)
Command – one byte command (same as the original command)
Data – one or more byte response (described in this document)
Checksum – one byte checksum (LSB of negative sum of all bytes in message)

1.3 *Status Values*

"Set" commands change parameters in the MI. These changes are saved in non-volatile memory. The MI responds to "Set" commands with a status byte. The following table contains the possible status byte values:

Status Value (hex)	Description
00	Success
01	Invalid command
02	Reserved
03	Invalid parameter
04	Checksum error
05	Command failed
06	Reserved
07	Flash erase error
08	Flash program error
09	Address out of range

1.4 *All Respond Address*

When a command is sent to address 126 (0x7E), all connected MIs will respond. The "all respond" address can only be used with commands that have a response length value less than or equal to eight. The following commands can be used with the all respond address:

Roll Call
Get Angle for axis 0, 1, or 2
Set Angle
Set Angle Offset
Get and Set directions
Get and Set damping
Get and Set angle output range

Get All Angles for example, cannot be used with the all respond address.

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2 MI Commands

2.1 Get and Set Angles
This command group provides the ability to get or set the angles for each axis.

2.1.1 Get All Angles (command 80)

	Parameter	# bytes	Units	Notes
Command	address	1		Destination address.
	01 (hex)	1		Message length (not including the address or length bytes).
	80 (hex)	1		Get all angles command.
Response	address	1		Source address.
	10 (hex)	1		Response length (not including the address or length bytes)
	80 (hex)	1		Get all angles command.
	angle0	4	deg. * 1000	Range depends on output mode.
	angle1	4		
	angle2	4		
	Temperature	2	deg. C * 100	-500 to 19000
	checksum	1		

Example (get all angles from address 5):

```
           address
           |  length
           |  |  command
           || |
  Command:   05 01 80

  address
  |  length
  |  |  command
  |  |  |  angle0-----  angle1-----  angle2-----  temperature
  |  |  |  |            |            |            |       checksum
  Response:  05 0A 80 00 02 7D B2 FF FF 4E F8 00 00 4E DE 08 FC CC
```

Values:
    angle0 = 00027DB2 (hex) = 163.250 degrees
    angle1 = FFFF4EF8 (hex) = -45.320 degrees
    angle2 = 00004EDE (hex) = 20.190 degrees

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2.1.2 Get Angle for Axis 0 (command 81)

	Parameter	# bytes	Units	Notes
Command	address	1		Destination address.
	01 (hex)	1		Message length (not including the address or length bytes).
	81 (hex)	1		Get angle for axis 0 command.
Response	address	1		Source address.
	06 (hex)	1		Response length (not including the address or length bytes).
	81 (hex)	1		Get angle for axis 0 command.
	angle	4	deg. * 1000	Range depends on output mode
	checksum	1		

For a single axis MI, the angle reported will always be zero.

Example (get angle of axis 0 from address 5):

```
          address
          |  length
          || command
 Command:  05 01 81

 address
 |  length
 |  |  command
 |  |  |  angle------ checksum
 Response:  05 06 81 FF FF 4E FF 29
```

Values:
        Axis 0 angle = FFFF4EFF (hex) = -45.313 degrees

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2.1.3 Get Angle for Axis 1   (command 82)

	Parameter	# bytes	Units	Notes
Command	address	1		Destination address.
	01 (hex)	1		Message length (not including the address or length bytes).
	82 (hex)	1		Get angle for axis 1 command.
Response	address	1		Source address.
	06 (hex)	1		Response length (not including the address or length bytes).
	82 (hex)	1		Get angle for axis 1 command.
	angle	4	deg. * 1000	Range depends on output mode
	checksum	1		

For a single axis MI, the angle reported will always be zero.

Example (get angle of axis 1 from address 5):

```
          address
          |  length
          || command
 Command:   05 01 82

 address
 |  length
 |  |  command
 |  |  |  angle------ checksum
 Response:   05 06 81 FF FF 4E FF 29
```

Values:
      Axis 1 angle = FFFF4EFF (hex) = -45.313 degrees

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2.1.4 Get Angle for Axis 2 (command 83)

	Parameter	# bytes	Units	Notes
Command	address	1		Destination address.
	01 (hex)	1		Message length (not including the address or length bytes).
	83 (hex)	1		Get angle for axis 2 command.
Response	address	1		Source address.
	06 (hex)	1		Response length (not including the address or length bytes).
	83 (hex)	1		Get angle for axis 2 command.
	angle	4	deg. * 1000	Range depends on output mode
	checksum	1		

For a single axis MI, the angle reported will always be zero.

Example (get angle of axis 2 from address 5):

```
            address
            |  length
            || command
   Command:  05 01 83

   address
   |  length
   |  |  command
   |  |  |  angle------ checksum
   Response:  05 06 83 FF FF 4E FF 27
```

Values:
Axis 2 angle = FFFF4EFF (hex) = -45.313 degrees

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2.1.5 Set Angle   (command 84)

Set angle will calculate and save an angle offset such that the current angle equals the specified angle. If the MI has moved, be sure to wait the number milliseconds specified in the Set Damping command for the angle to stabilize before writing the angle. This command is commonly used to set current angle to zero.

	Parameter	# bytes	Units	Notes
Command	address	1		Destination address
	07 (hex)	1		Message length (not including the address or length bytes).
	84 (hex)	1		Set angle command
	axis	1		0, 1 or 2
	angle	4	deg. * 1000	Range depends on output mode
	checksum	1		
Response	address	1		Source address
	03 (hex)	1		Response length (not including the address or length bytes).
	84 (hex)	1		Set angle command
	status	1		0 = pass, see Status table above.
	checksum	1		

Example (setting angle of axis 2 to 10.500 degrees on address 5):

```
          address
          |  length
          |  |  command
          |  |  |  axis
          || |  |  angle-----      checksum
Command:   05 07 84 02 00 00 29 04 41

address
          |  length
          |  |  command
          |  |  |  status
          |  |  |  |  checksum
Response:  05 03 84 00 74
```

Values:
        Axis 2 angle = 00002904 (hex) = 10.500 degrees

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2.2 Angle Offsets

The user can specify an angle offset that the MI will internally add to the angle before it gets reported it to the host. The angle offset is applied internally as follows:

> reported angle = absolute angle + angle offset

The MI will keep the reported angle within the valid range set by the Set Angle Output Range command.

2.2.1 Get All Angle Offsets (command 85)

	Parameter	# bytes	Units	Notes
Command	address	1		Destination address
	01 (hex)	1		Message length (not including the address or length bytes).
	85 (hex)	1		Get all angle offsets command
Response	address	1		Source address
	0E (hex)	1		Response length (not including the address or length bytes).
	85 (hex)	1		Get all angle offsets command
	angle0 offset	4	deg. * 1000	Range depends on output mode. The factory default values are 0.
	angle1 offset	4		
	angle2 offset	4		
	checksum	1		

Example (get all angle offsets from address 5):

```
          address
          |  length
          || command
Command:  05 01 85

address
|  length
|  | command
|  |  | offset0---- offset1---- offset2---- checksum
Response:  05 0E 85 00 00 28 0A FF FF 4E 76 00 00 AF C8 FD
```

Values:
    offset 0 = 0000280A (hex) = 10.250 degrees
    offset 1 = FFFF4E76 (hex) = -45.45 degrees
    offset 2 = 0000AFC8 (hex) = -20.536 degrees

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2.2.2 Set Angle Offset   (command 86)

	Parameter	# bytes	Units	Notes
Command	address	1		Destination address
	07 (hex)	1		Message length (not including the address or length bytes).
	86 (hex)	1		Set angle offset command
	axis	1		0, 1 or 2
	angle offset	4	deg. * 1000	Range depends on output mode.
	checksum	1		
Response	address	1		Source address
	03 (hex)	1		Response length (not including the address or length bytes).
	86 (hex)	1		Set angle offset command
	status	1		0 = pass, see table above
	checksum	1		

Example (setting angle offset of axis 2 to 30.000 degrees on address 5):

```
          address
          |  length
          |  |  command
          |  |  |  axis
          || |  |  angle-----      checksum
Command:   05 07 86 02 00 00 75 30 C7

          address
          |  length
          |  |  command
          |  |  |  status
          |  |  |  |  checksum
Response:  05 03 86 00 72
```

Values:
       angle = 00007530 (hex) = 30.000 degrees

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2.3 *Get All Data*   (command 87)

	Parameter	# bytes	Units	Notes
Command	address	1		Destination address
	01 (hex)	1		Message length (not including the address or length bytes).
	87 (hex)	1		Get all data command
Response	address	1		Source address
	20(hex)	1		Response length (not including the address or length bytes).
	87 (hex)	1		Get all data command.
	angle0	4	deg. *1000	Range depends on output mode.
	angle1	4		
	angle2	4		
	Temperature	2	deg. C * 100	-500 to 19000
	accel0	4	G * 102,300	
	accel1	4		
	accel2	4		
	serial number	4		32-bit unsigned value
	checksum	1		

Example (get all data from address 5):

```
          address
          |  length
          || command
Command:  05 01 87

address
          |  length
          |  |  command
          |  |  |  angle0----- angle1----- angle2----- temperature
Response: 05 20 87 FF FF F9 89 FF FF 4E F8 FF FD 73 66 08 FC

          accel0----- accel1----- accel2----- serial num- checksum
          00 00 02 5C 00 00 04 28 FF FE 82 25 00 00 61 C9 5F
```

Values:

     angle0 = FFFFF989 (hex) = -1.655 degrees
     angle1 = FFFF4EF8 (hex) = -45.320 degrees
     angle2 = FFFD7366 (hex) = -167.066 degrees
     accel0 = 0000025C (hex) = 0.00590g.
     accel1 = 00000428 (hex) = 0.01040g.
     accel2 = FFFE8225 (hex) = -0.95557g.
     serial number = 000061C9 (hex) = 25033.

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2.4 *Directions*

Each MI axis can be configured as normal or reversed direction. The following two commands can be used to get or set direction parameters of the desired axis (axes).

2.4.1 Get All Directions   (command 88)

	Parameter	# bytes	Units	Notes
Command	address	1		Destination address
	01 (hex)	1		Message length (not including the address or length bytes).
	88(hex)	1		Get all directions command
Response	address	1		Source address
	05 (hex)	1		Response length (not including the address or length bytes).
	88 (hex)	1		Get all directions command
	direction 0	1		0 = normal, 1 = reversed
	direction 1	1		0 is the factory default
	direction 2	1		
	checksum	1		

Example (get all directions from address 5):

```
          address
          | length
          | | command
          || |
Command:   05 01 88

address
| length
| | command
| | | D0 D1 D2 checksum
Response:  05 05 88 00 00 01 6D
```

Values:

      Axis 0 and 1 are normal direction and axis 2 is reversed.

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2.4.2 Set Direction (command 89)

	Parameter	# bytes	Units	Notes
Command	address	1		Destination address
	04 (hex)	1		Message length (not including the address or length bytes).
	89 (hex)	1		Set angle direction command
	axis	1		0, 1, or 2
	direction	1		0 = normal, 1 = reversed
	checksum	1		
Response	address	1		Source address
	03 (hex)	1		Response length (not including the address or length bytes).
	89 (hex)	1		Set angle direction command
	status	1		0 = pass, see Status table above.
	checksum	1		

Example (set axis 2 direction to reversed on address 5):

```
          address
          |  length
          |  |  command
          |  |  |  axis
          |  |  |  |  direction
          || |  |  |  checksum
Command:   05 04 89 02 01 6B

          address
          |  length
          |  |  command
          |  |  |  status
          |  |  |  |  checksum
Response:  05 03 89 00 6F
```

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2.5 *Damping*

Electronic damping is achieved by averaging multiple readings to reduce noise. As the damping time is increased, the angle readings have less noise but the response time is slower.

2.5.1 Get Damping (command 8A)

	Parameter	# bytes	Units	Notes
Command	address	1		Destination address
	01 (hex)	1		Message length (not including the address or length bytes).
	8A (hex)	1		Get damping command
Response	address	1		Source address
	04 (hex)	1		Response length (not including the address or length bytes).
	8A (hex)	1		Get damping command
	damping time	2	Milliseconds	2 to 5,000 milliseconds
	checksum	1		

Example (get damping time from address 5):

```
          address
          | length
          || command
  Command:   05 01 8A

  address
  | length
  | | command
  | | | damp  checksum
  Response:   05 04 8A 03 E8 82
```

Values:
    Damping time = 03E8 (hex) = 1000 milliseconds.

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2.5.2 Set Damping   (command 8B)

	Parameter	# bytes	Units	Notes
Command	address	1		Destination address
	04 (hex)	1		Message length (not including the address or length bytes).
	8B (hex)	1		Set damping time command
	damping time	2	Milliseconds	2 to 5,000 milliseconds
	checksum	1		
Response	address	1		Source address
	03 (hex)	1		Response length (not including the address or length bytes).
	8B (hex)	1		Set damping time command
	status	1		0 = pass, see Status table above.
	checksum	1		

Example (set damping time to 500 milliseconds on address 5):

```
          address
          |   length
          |   |   command
          |   |   |   damping time
          || |   |   checksum
Command:   05 04 8B 01 F4 77

          address
          |   length
          |   |   command
          |   |   |   status
          |   |   |   |   checksum
Response:  05 03 8B 00 6D
```

Values:
      Damping time = 01F4 (hex) = 500 milliseconds.

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2.6 *Angle Output Range Setup*

There are two commands in this group.

2.6.1 Get Angle Output Range   (command 8C)

	Parameter	# bytes	Units	Notes
Command	address	1		Destination address.
	01 (hex)	1		Message length (not including the address or length bytes).
	8C (hex)	1		Get angle output range command.
Response	address	1		Source address.
	03 (hex)	1		Response length (not including the address or length bytes).
	8C (hex)	1		Get angle output range command.
	angle range	1		0 = range is -180.000 to 179.999 (bidirectional) 1 = range is 0.000 to 359.999 (unidirectional)
	checksum	1		

Example (get output angle range from address 5):

```
          address
          | length
          || command
Command:  05 02 8C

address
          | length
          | | command
          | | | output range
          | | | | checksum
Response:  05 03 8C 00 6C
```

Values:
    Angle output range = 00 (hex) is bidirectional.

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2.6.2 Set Angle Output Range   (command 8D)

	Parameter	# bytes	Units	Notes
Command	address	1		Destination address.
	03 (hex)	1		Message length (not including the address or length bytes).
	8D (hex)	1		Set angle output range command.
	angle range	1		0 = range is -180.000 to 179.999 (bidirectional) 1 = range is 0.000 to 359.999 (unidirectional)
	checksum	1		
Response	address	1		Source address.
	03 (hex)	1		Response length (not including the address or length bytes).
	8D (hex)	1		Set angle output range command.
	status	1		0 = pass, see Status table above.
	checksum	1		

Example (set output angle range on address 5):

```
          address
          |  length
          |  |  command
          |  |  |  angle range
          || |  |  checksum
 Command:  05 03 8D 01 6A

 address
          |  length
          |  |  command
          |  |  |  status
          |  |  |  |  checksum
 Response:  05 03 8D 00 6B
```

Values:
      Output angle range = 01(hex), (0.000 to 359.999)

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2.7 *Device information*

This function provides factory defined settings.

2.7.1 Get Device Information   (command 8E)

	Parameter	# bytes	Units	Notes
Command	address	1		Destination address.
	01 (hex)	1		Message length (not including the address or length bytes).
	8E (hex)	1		Get device information command.
Response	address	1		Source address.
	14 (hex)	1		Response length (not including the address or length bytes).
	8E (hex)	1		
	serial number	4		Unsigned number set at factory.
	firmware version	6		ASCII characters padded with spaces (not null terminated).
	product type	6		ASCII characters padded with spaces (not null terminated).
	calibration state	2		Reserved.
	checksum	1		

Example (get device information from address 5):

```
          address
          |  length
          || command
Command:  05 01 8E

address
          |  length
          |  | command
          |  | | serial num- firmware ver.---- product type----- cal. state
          |  | | |             |                 |                 |    checksum
Response: 05 14 8E 00 00 61 C9 30 2E 33 32 20 20 58 34 2D 31 20 20 00 2C D6
```

Values:

serial number = 000061C9 (hex) = 25033 firmware
version = 302E33322020 (hex) = "0.32 " product
type = 58342D312020 (hex) = "MI-3001 "

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2.7.2 Set Baud Rate   (command 8F)

	Parameter	# bytes	Units	Range
Command	address	1		Destination address.
	03 (hex)	1		Message length (not including the address or length bytes).
	8F (hex)	1		Change baud rate command.
	baud rate index	1		0 = 115.2 kbps 1 = 57.6 kbps 2 = 38.4 kbps 3 = 19.2 kbps 4 = 9.6 kbps The factory default is 0.
	checksum	1		
Response	address	1		Source address.
	03 (hex)	1		Response length (not including the address or length bytes).
	8F (hex)	1		Change baud rate command.
	status	1		0 = pass, see Status table above.
	checksum	1		

This command can be used to change the baud rate of the MI.

The response is sent using the previous baud rate. The baud rate is changed about 10 milliseconds after a successful response is sent.

Example (set baud rate to 9600 bytes per second on address 5):

```
          address
          |  length
          |  |  command
          |  |  |  baud rate code
          || |  |  checksum
  Command:   05 03 8F 04 65

  address
          |  length
          |  |  command
          |  |  |  status
          |  |  |  |  checksum
  Response:  05 03 8F 00 69
```

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2.8 *Set Address*   (command 91)

	Parameter	# bytes	Units	Range
Command	address	1		Destination address.
	08 (hex)	1		Message length (not including the address or length bytes).
	91 (hex)	1		Set address command.
	device type	1		1 = MI-3 (3 axis MI) 4 = MI-3001 (single axis MI)
	serial number	4		
	new address	1		Valid address 1 to 100.
	checksum	1		
Response	address	1		Source address.
	03 (hex)	1		Response length (not including the address or length bytes).
	91 (hex)	1		Set address command.
	status	1		0 = pass, see Status table above.
	checksum	1		

This command changes the address of a device and returns the original address in the response. All subsequent commands will use and respond with the new address.

Example (change device address from 5 to 1):

```
          address
          |  length
          |  |  command
          |  |  |  device type
          |  |  |  |  serial num
          |  |  |  |  |            new address
          || |  |  |  |            checksum
Command:   05 08 91 04 00 00 61 C9 01 33

          address
          |  length
          |  |  command
          |  |  |  status
          |  |  |  |  checksum
Response:  05 03 91 00 67
```

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