Meriam Serial Protocol Implementation Guide

for

M330 Embedded Pressure Instrument
M1500 Digital Pressure Transmitter

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Table of Contents:

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Using the M330 Development Interface

M330 Embedded Pressure Instrument

The Meriam M330 EPI is an accurate, self-contained, fully compensated, digital pressure measurement instrument designed to be tightly integrated into a larger system. Digital communication with the M330 EPI is accommodated via I^2C or UART (both standard) or SPI (available order option). Meriam Serial Protocol (MSP) is used to communicate with the M330.

The M330 Development Kit (pn Z9A450) allows the M330 to connect directly to a host PC (using the included USB cable) for evaluation or software development activities. Customers will need the M330 Development Kit, a PC and expertise with suitable development software (C/C^{++}, Visual Basic) to design M330 communications software for their system. The MSP Implementation Guide provides the protocol command strings for the M330. The guide is included with each M330 EPI and M330 Development Kit (see the Product CD) or can be downloaded at www.meriam.com.

M330 Development Kit & Instructions

The M330 Development Kit includes the following components:

Part Number	Description
Z9A449	M330 Development Interface (hardware)
Z9P342	USB type A (male) by USB type B (male)
Z9A000003PN06	Product CD including Meriam Serial Protocol Implementation Guide, Source Code Samples, USB Drivers

To develop communication software for the M330:

1. Install USB Drivers on the host PC (drivers and instructions are found on the supplied Product CD)
2. Connect a M330 EPI unit to the M330 Development Interface module as shown below.
3. Use the Kit's USB cable to connect the assembly to the host PC.
4. Use the Meriam Serial Protocol Implementation Guide, as desired, to develop the communication software for the application.

M330 Embedded Pressure Instrument **M330 Development Interface** **USB Cable**

Contact Meriam Technical Support (sales@meriam.com) with questions that arise.

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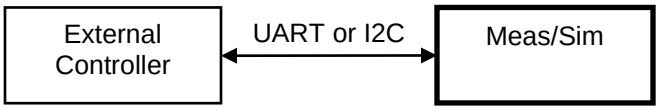
Preface:
Meriam's new modular-based products are comprised of the following "Classes" and "Types" of "Modules" which can be used alone or in combination to make a finished good.

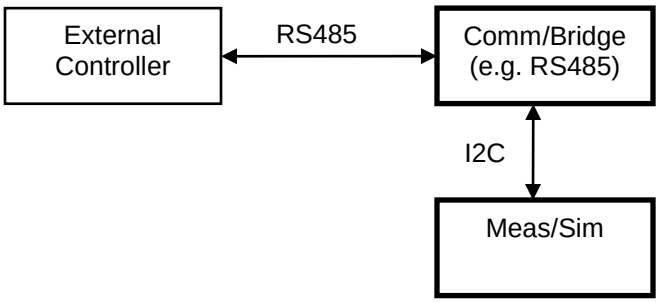
Class	Type
Measurement/Simulation	EPI (pressure), EVI (volt, mA)
Communications/Bridge	RS-232/RS-485, USB20
Repository/Data logging	Repository

The following diagrams show how modules can be combined, from the most basic Embedded Instrument to a Meriam Instrument (also called a Short-Stack or Full-Stack).

Embedded Instrument: example - EPI



Short-Stack: example – M1500



Overview:
This document describes the message structure and communication protocol between a Controller and an Embedded Instrument or Short-Stack.

For consistency and ease of interface, the same message structure and protocol is supported across ALL hardware interfaces. This commonality greatly simplifies communication code.

Of course, not all commands are supported on all modules.

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Message Structure:
A message consists of two basic parts:

- Header including CRC (fixed at 12 bytes)
- Data (variable length)

The fixed-length Header contains basic information about the message, including its length and CRC. The Data portion of the packet (or payload) contains the message-specific, variable-length data, and extended addressing if applicable.

All data (larger than one byte) is little-endian.

Communication Protocol:
There are two messages types:

- Command
- Response

The Command message is sent from the Controller (the Master) to the Embedded Instrument or Short-Stack (the Slave). This Command message evokes (or solicits) a Response message.

The commands and responses are intentionally very compact to minimize protocol overhead.

Terminology:

Transaction = an exchange of information between a Master and Slave

- The Master transmits a Command Message and receives a Response Message.

Master = the side that initiates communication

- The Master is not typically able to receive an unsolicited response message.

Slave = the side the responds to communication

- The Slave is almost always ready to receive an unsolicited command message.
- The Slave is not typically able to receive an unsolicited response message.

Message = a complete “packet” of information (control information and user data (also known as payload) – per Wikipedia)

- A Message is composed of a fixed-length header and a variable length data area
- The Master transmits a Command Message. The Slave composes a Response Message

Normal Message Addressing = addressing for use within a Short/Full-Stack

- Source = 1 byte: typically Module address specified in the Header
- Destination = 1 byte: typically Module address specified in the Header

Extended Message Addressing = addressing required to externally access (e.g. PC app, etc.) a Short/Full-Stack, 6 bytes concatenated to the end of the actual data in the Data (or Payload) area

- Source = 3 bytes: Network, Bridge, and Module address
- Destination = 3 bytes: Network, Bridge, and Module address

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Command Format - from "Controller" to Embedded Instrument or Short-Stack:

Header

1	PRE1	Preamble1	= 0x80	version 1 = 0x80
2	PRE2	Preamble2	= 0x0?	version 1: 0x00 = normal addressing 0x01 = extended addressing note: 0x01 may map to 0x03 internally, however, the user will only specify a 0x00 or 0x01
3	LEN	Length	= 0x??	length of DATA area note: does NOT include extended addressing
4	SADD	Srce Address	= 0x??	source (transmitter) address
5	DADD	Dest Address	= 0x??	destination (receiver) address note: these addresses describe the current link/hop
6	CMD1	Command1	= 0x??	main command
7	CMD2	Command2	= 0x??	command argument
8	CMD3	Command3	= 0x??	command argument
9	STAT	Status	= 0x00-0xFF	version 1 = repurposed to command attribute suppress response (SR) bit: 1xxx xxxx = SRc = for this command
10	CNTR	Counter	= 0x00	version 1 = spare
11	CRCL	CRC16 (LSB)	= 0x00-0xFF	CRC16 of above 10 bytes and Data area
12	CRCH	CRC16 (MSB)	= 0x00-0xFF	(i.e. PRE1 thru CNTR and DATA area, inclusive)

Data (Payload)

13-n	DATA	Data	=	command-specific, variable-length data

plus optional extended addressing, which describes the complete address of the command originator and the complete address of the intended command recipient

n+1	SNET	SrceNetwork	= 0x00-0xFF	source network address
n+2	SBRI	SrceBridge	= 0x10-0x70	source bridge address
n+3	SMOD	SrceModule	= 0x10-0x70	source module address
n+4	DNET	DestNetwork	= 0x00-0xFF	destination network address
n+5	DBRI	DestBridge	= 0x10-0x70	destination bridge address
n+6	DMOD	DestModule	= 0x10-0x70	destination module address

Data types used to describe the DATA (or Payload) part of the message:

```
U8  (1 Byte)  = unsigned 8-bit
S8  (1 Byte)  = signed   8-bit

U16 (2 Bytes) = unsigned 16-bit, little-endian
S16 (2 Bytes) = signed   16-bit, little-endian

U32 (4 Bytes) = unsigned 32-bit, little-endian
S32 (4 Bytes) = signed   32-bit, little-endian

F32 (4 Bytes) = 32-bit IEEE float, little-endian
```


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Response Format – from Embedded Instrument or Short-Stack to "Controller":

Header

1	PRE1	Preamble1	= 0x40	version 1 = 0x40
2	PRE2	Preamble2	= 0x0?	version 1: 0x00 = normal addressing 0x01 = extended addressing
3	LEN	Length	= 0x??	length of DATA area note: does NOT include extended addressing
4	SADD	Srce Address	= 0x??	source (transmitter) address
5	DADD	Dest Address	= 0x??	destination (receiver) address note: these addresses describe the current link/hop
6	CMD1	Command1	= 0x??	echoed
7	CMD2	Command2	= 0x??	echoed
8	CMD3	Command3	= 0x??	echoed (or result)
9	STAT	Status	= 0x00	general status, see status page
10	CNTR	Counter	= 0x00	version 1 = spare
11	CRCL	CRC16 (LSB)	= 0x00-0xFF	CRC16 of above 10 bytes and Data area
12	CRCH	CRC16 (MSB)	= 0x00-0xFF	(i.e. PRE1 thru CNTR and DATA area, inclusive)

Data (Payload)

13-n	DATA	Data	=	command-specific, variable-length data

plus optional extended addressing, which describes the complete address of the response originator (i.e. intended command recipient) and the complete address of the response recipient (i.e. command originator)

n+1	SNET	SrceNetwork	= 0x00-0xFF	source network address
n+2	SBRI	SrceBridge	= 0x10-0x70	source bridge address
n+3	SMOD	SrceModule	= 0x10-0x70	source module address
n+4	DNET	DestNetwork	= 0x00-0xFF	destination network address
n+5	DBRI	DestBridge	= 0x10-0x70	destination bridge address
n+6	DMOD	DestModule	= 0x10-0x70	destination module address

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Module Classes, Types and Default Addresses

```
#define C_MEASUREMENT_SIMULATION  0x00                    //Measurement/Simulation Class
#define T_EPI                     0                       //Embedded Pressure Instrument Type
#define T_EVI                     1                       //Embedded Volt Cur Instrument Type
                                                          //
#define C_COMMUNICATIONS_BRIDGE   0x01                    //Communications/Bridge Class
#define T_RS232_RS485             0                       //RS232/RS485 Type
#define T_USB20                   1                       //USB2.0 Type
                                                          //
#define C_REPOSITORY_DATALOGGING  0x02                    //Repository/Data logging Class
#define T_REPOSITORY              0                       //Repository Type



#define D_BROADCAST_ADDR          0x00
#define D_WILDCARD_ADDR           0xF0
                                                          //Communications/Bridge Class
#define D_MODULE_ADDR_COMM        0x28                    //|   same address for all
#define D_BRIDGE_ADDR_COMM        D_WILDCARD_ADDR         //|   Types (RS232, USB, etc.)
#define D_NETWORK_ADDR_COMM       D_MODULE_ADDR_COMM      //|   within this Class
                                                          //
                                                          //Repository/Data logging Class
#define D_MODULE_ADDR_REPOSITORY  0x20                    //Repository
#define D_BRIDGE_ADDR_REPOSITORY  D_WILDCARD_ADDR         //|
#define D_NETWORK_ADDR_REPOSITORY D_WILDCARD_ADDR         //|
                                                          //
                                                          //Measurement/Simulation Class
#define D_MODULE_ADDR_EPI         0x40                    //Embedded Pressure Instrument
#define D_BRIDGE_ADDR_EPI         D_WILDCARD_ADDR         //|
#define D_NETWORK_ADDR_EPI        D_WILDCARD_ADDR         //|
                                                          //
#define D_MODULE_ADDR_EVI         0x41                    //Embedded Volt Cur Instrument
#define D_BRIDGE_ADDR_EVI         D_WILDCARD_ADDR         //|
#define D_NETWORK_ADDR_EVI        D_WILDCARD_ADDR         //|
```

What Follows:
The next several pages describe the currently supported user commands and their responses.

Only the command-specific header and data bytes are shown. The rest of the header must be populated properly (preamble, addressing, CRC, etc.) as shown on the preceding pages.

A support file, EIProtocol.h, contains defines (like the ones directly above) and data structures/unions that support the following commands.

Note: for information on where it find the latest EIProtocol.h file, see Appendix B

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CMD_RESET (0x00)

Command Format - from "Controller" to Embedded Instrument:

```
    LEN   Length         = 0x00         length of DATA area
    CMD1  Command1       = 0x00
    CMD2  Command2       = 0x00-0xFF    Types of reset:
                                        0x00 = complete reset, soft reboot
    ----
```

Response Format – from Embedded Instrument to "Controller":

```
    LEN   Length         = 0x00         length of DATA area
    CMD1  Command1       = 0x00         echoed
    CMD2  Command2       = 0x00-0xFF    echoed
    STAT  Status         = 0x00-0xFF    general status, see status page
    ----
```

Example:

```
    To ...
        Controller--->EI:

        EI--->Controller:
```


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CMD_GET_SET_INFO (0x02)

Command Format - from "Controller" to Embedded Instrument:

```
    LEN   Length         = 0x??         length of DATA area
    CMD1  Command1       = 0x02
    CMD2  Command2       = 0x00-0xFF    Upper nibble bit-encoded with attributes:
                                        xxx1 xxxx = spare
                                        xx1x xxxx = spare
                                        x1xx xxxx = error (memory = 0)            error is future
                                        1xxx xxxx = set (get = 0)                   set is future

                                        Lower nibble not bit-encoded:
                                        xxxx 0000 = normal (EI) list

    CMD3  Command3       = 0x00-0xFF    reference number
    ----
    U8  Data Bytes       =              data for a set (write)
```

Response Format – from Embedded Instrument to "Controller":

```
    LEN   Length         = 0x??         length of DATA area
    CMD1  Command1       = 0x02         echoed
    CMD2  Command2       = 0x00-0xFF    echoed
    STAT  Status         = 0x00-0xFF    general status, see status page
    ----
    U8  Status           = 0x00-0xFF    individual status, see status page

    U8  Data Bytes       =              data for a get (read)
```

Example:

```
    To ...
        Controller--->EI:

        EI--->Controller:
```


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Types of information:

Normal Reference:

Memory
0x00 = main summary: SNs, class, type, addresses, etc.

0x11 = sensor 1 measurement info: sensor type, limits, accuracy, etc.

0x21 = sensor 2 measurement info: same as 0x11

Example structures (always refer to EIProtocol.h):

```
struct
{
    Byte  stat;                     //individual status, see status page
    Byte  bRunningCode;             //currently running code (BOOT, RAM, FW)
    char  szStackSN[12];
    char  szModuleSN[12];
    Byte  bClass;
    Byte  bType;
    Byte  bHardwareRev;
    Byte  bMemMapRev;
    char  szFirmwareRev[8];
    Byte  bNetworkAddr;             //the current address
    Byte  bBridgeAddr;              //|
    Byte  bModuleAddr;              //|
    Byte  bSpare;

} r00;                              //response r00, 42 bytes

struct
{
    Byte  stat;                     //individual status, see status page
    Byte  pad;                      //spare to align on Word boundary
    Byte  bSensorType;
    Byte  bNativeUnits;             //native unit of sensor (PSI for pressure)
    Byte  bSplashUnits;             //"sold as" engineering unit (e.g. 200 inW20C)
    Byte  bSpare;
    float fLSL;                     //"sold as" lower sensor unit in splash units
    float fUSL;                     //"sold as" upper sensor limit in splash units
    Byte  bAccyType;
    Byte  bSpare2;
    Byte  bAccyData[16];

} r11;                              //response r11, 32 bytes
```


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CMD_GET_SET_UNITS (0x03)

Command Format - from "Controller" to Embedded Instrument:

```
    LEN   Length         = 0x??         length of DATA area
    CMD1  Command1       = 0x03
    CMD2  Command2       = 0x00-0xFF    Upper nibble bit-encoded with channel:
                                        xxx1 xxxx = channel 1
                                              EPI (Pressure):  measure P1 pressure
                                              EVI (Volt Amp):  meas/sim volts
                                        xx1x xxxx = channel 2
                                              EPI (Pressure):  measure P2 pressure
                                              EVI (Volt Amp):  meas/sim milliamps
                                        x1xx xxxx = channel 3
                                              ExI (i.e. all):  spare
                                        1xxx xxxx = channel 4:
                                              ExI (i.e. all):  measure internal temperature

                                        Lower nibble not bit-encoded:
                                        xxxx 0000 = get current engineering unit(s) for the
                                              specified channel(s)
                                        xxxx 0001 = set specified engineering unit(s) for the
                                              specified channel(s)
                                        xxxx 0010 = read specified engineering unit(s) data
                                              for the specified channel(s)

                                        notes:
                                              the last option (read) can be used to enumerate a
                                              complete list of all supported engineering units,
                                              one at a time, (via repeated calls) without changing
                                              any settings

                                              this command is mode-dependent; it will get/set/read
                                              the units for the active mode (i.e. meas or sim)
    ----
    U8  Unit*            = 0x00-0xFF    value depends upon Command2, for:
                                        xxxx 0000, U8 is a don't care
                                        xxxx 0001, U8 specifies engineering unit index to set
                                        xxxx 0010, U8 specifies engineering unit index to read

    * repeated in groups of 1 byte based upon the number of channels selected in CMD2
```


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CMD_GET_SET_UNITS (0x03) (continued)

Response Format – from Embedded Instrument to "Controller":

```
    LEN   Length         = 0x??         length of DATA area
    CMD1  Command1       = 0x03         echoed
    CMD2  Command2       = 0x00-0xFF    echoed
    STAT  Status         = 0x00-0xFF    general status, see status page
    ----
    U8  Status**         = 0x00-0xFF    individual status, see status page
    U8  Unit**           = 0x00-0xFF    for get:
                                              the current unit for the specified channel
                                        for set:
                                              if specified unit was valid, the specified unit
                                              if specified unit was invalid, the current unit
                                        for read:
                                              if specified unit was valid, the specified unit
                                              if specified unit was invalid, the Nth (last) unit
    S8  Max. LOD**       = 0x00-0xFF    worst-case digits to left of decimal
    S8  Max. AROD**      = 0x00-0xFF    worst-case digits to right of decimal to show accuracy
    S8  Max. RROD**      = 0x00-0xFF    worst-case digits to right of decimal to show precision
                                        notes:
                                              the above xODs are worst-case/greatest for the unit
                                              if either ROD is < 0, scientific notation is req'd
    U8  Spare**          = 0x00         spare to align to Word boundary
    U8  Unit Text**      = 0x00-0xFF    short units text string (e.g. "inW20C")
    U8  |        **      = 0x00-0xFF    | up to 6 characters + NULL, left-justified
    U8  |        **      = 0x00-0xFF    |
    U8  |        **      = 0x00-0xFF    |
    U8  |        **      = 0x00-0xFF    |
    U8  |        **      = 0x00-0xFF    |
    U8  |        **      = 0x00         | always a NULL
    U8  Spare**          = 0x00         spare to align to Word boundary
    F32 Conversion**     =              conversion coefficient (PSI to specified engineering unit)

    ** repeated in groups of 18 bytes based upon the number of channels selected in CMD2
```

Example:

To ...

Controller--->EI:

EI--->Controller:

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EPI Pressure Channel Units:

0	PSI	17	mHg0C
1	inW20C	18	cmHg0C
2	inW4C	19	mmHg0C
3	inW60F	20	torr
4	ftW20C	21	kg/cm2
5	ftW4C	22	kg/m2
6	ftW60F	23	Pa
7	mmW20C	24	hPa
8	mmW4C	25	kPa
9	mmW60F	26	MPa
10	cmW20C	27	Bar
11	cmW4C	28	mBar
12	cmW60F	29	ATM
13	mW20C	30	oz/in2
14	mW4C	31	lb/ft2
15	mW60F	32	User 1*
16	inHg0C	33	User 2*

* measurements are returned in PSI (unless sensor EE factory programmed otherwise), conversions must be done outside of EPI

EVI Volt Channel and Current Channel Units:

0	mA DC
1	V DC

MAP Internal Temperature Channel Units:

0	°F
1	°C
2	K
3	°R

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CMD_GET_MEAS (0x04)

Command Format - from "Controller" to Embedded Instrument:

```
    LEN   Length         = 0x00          length of DATA area
    CMD1  Command1       = 0x04
    CMD2  Command2       = 0x00-0xFF     Upper nibble bit-encoded with channel:
                                         xxx1 xxxx = channel 1
                                               EPI (Pressure):  measure P1 pressure
                                               EVI (Volt Amp):  meas/sim volts
                                         xx1x xxxx = channel 2
                                               EPI (Pressure):  measure P2 pressure
                                               EVI (Volt Amp):  meas/sim milliamps
                                         x1xx xxxx = channel 3
                                               ExI (i.e. all):  spare
                                         1xxx xxxx = channel 4:
                                               ExI (i.e. all):  measure internal temperature

                                         Lower nibble not bit-encoded:
                                         xxxx 0000 = gets measurement float* for specified
                                               channel(s)
                                         xxxx 0001 = same as 0000, but also resets min and max
                                               floats (to the current measurement) for specified
                                               channel(s)
                                         xxxx 0010 = same as 0000, but also gets min and max
                                               floats for specified channel(s)
                                         xxxx 0011 = same as 0010, but also gets scaled measurement
                                               integers (0-65535) for specified channel(s)

                                         note:
                                               this command is mode-dependent; it will get/set/read
                                               the units for the active mode (i.e. meas or sim)
    ----

    * measurement may be filtered/damped, depending on respective user settings
```


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CMD_GET_MEAS (0x04) (continued)

Response Format – from Embedded Instrument to "Controller":

```
    LEN   Length         = 0x??         length of DATA area
    CMD1  Command1       = 0x04         echoed
    CMD2  Command2       = 0x00-0xFF    echoed
    STAT  Status         = 0x00-0xFF    general status, see status page
    ----
    DATA                                depends upon lower nibble of CMD2 as shown next


    CMD2 = xxxx0000, xxxx0001
    U8  Status           = 0x00-0xFF    individual status, see status page
    S8  AROD             = 0x00-0xFF    meas-specific digits to right of decimal to show accuracy
    S8  RROD             = 0x00-0xFF    meas-specific digits to right of decimal to show precision
                                        notes:
                                             the above xODs are signed Bytes
                                             the above xODs are actual/meas-specific for the unit
                                             if either ROD is < 0, scientific notation is req'd
    U8  Spare            = 0x00         spare to align Float on Word boundary
    F32  Measurement     =              measurement data, 32-bit float in little-endian


    CMD2 = xxxx0010
    U8  Status           = 0x00-0xFF    individual status, see status page
    S8  AROD             = 0x00-0xFF    meas-specific digits to right of decimal to show accuracy
    S8  RROD             = 0x00-0xFF    meas-specific digits to right of decimal to show precision
    U8  Spare            = 0x00         spare to align Float on Word boundary
    F32  Measurement     =              measurement data, 32-bit float in little-endian
    F32  Minimum         =              minimum meas data, 32-bit float in little-endian
    F32  Maximum         =              maximum meas data, 32-bit float in little-endian


    CMD2 = xxxx0011
    U8  Status           = 0x00-0xFF    individual status, see status page
    S8  AROD             = 0x00-0xFF    meas-specific digits to right of decimal to show accuracy
    S8  RROD             = 0x00-0xFF    meas-specific digits to right of decimal to show precision
    U8  Spare            = 0x00         spare to align Float on Word boundary
    F32  Measurement     =              measurement data, 32-bit float in little-endian
    F32  Minimum         =              minimum meas data, 32-bit float in little-endian
    F32  Maximum         =              maximum meas data, 32-bit float in little-endian
    U16  Scaled          =              scaled meas data, 16-bit unsigned int in little-endian
```

Example:

```
    To ...
        Controller--->EI:

        EI--->Controller:
```


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CMD_FIELD_RECAL (0x06)

Command Format - from "Controller" to Embedded Instrument:

```
LEN   Length         = 0x??         length of DATA area
CMD1  Command1       = 0x06
CMD2  Command2       = 0x00-0xFF    Upper nibble bit-encoded with channel:
                                    xxx1 xxxx = channel 1
                                          EPI (Pressure):  measure P1 pressure
                                          EVI (Volt Amp):  measure volts
                                    xx1x xxxx = channel 2
                                          EPI (Pressure):  measure P2 pressure
                                          EVI (Volt Amp):  measure milliamps
                                    x1xx xxxx = channel 3
                                          ExI (i.e. all):  spare
                                    1xxx xxxx = channel 4:
                                          ExI (i.e. all):  measure internal temperature
                                    note: only one channel supported at a time,
                                          except for zero

                                    Lower nibble not bit-encoded:
                                    xxxx 0000 = zero the specified channel(s)
                                    xxxx 0001 = restore factory defaults
                                    xxxx 0010 = get supported field recals        - future
                                    xxxx 0011 = start field recal
                                    xxxx 0100 = save point
                                    xxxx 0101 = next point
                                    xxxx 0110 = finish field recal
                                    xxxx 0111 = state field recal

                                    xxxx 1111 = internal temperature              - future

----
DATA                                depends upon lower nibble of CMD2 as shown next


CMD2 = xxxx0000
NO DATA (just command header)


CMD2 = xxxx0001
CMD3  Command3       = 0x00-0xFF    Upper nibble spare:

                                    Lower nibble not bit-encoded:
                                    xxxx 0000 = restore all points and field-recal
                                    xxxx 0001 = restore all points
                                    xxxx 0010 = restore field-recal
NO DATA (just command header)
```


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CMD2 = xxxx0010
future...

CMD2 = xxxx0011 (start field recal)

U8	Recal Number	= 0x00-0xFF	field recal number (from "get supported FR")
U8	View/Perform	= 0x00-0xFF	0x00 = View recal, 0x01 = Perform recal

CMD2 = xxxx0100 (save point)

U8	Recal Number	= 0x00-0xFF	must be same value used in "start FR"
U8	View/Perform	= 0x00-0xFF	must be same value used in "start FR"
U8	Cur Point	= 0x00-0xFF	must be same value returned from "start FR"/"next point"
U8	Num Points	= 0x00-0xFF	must be same value returned from "start FR"/"next point"
F32	Apply Point*	=	for View: the new Apply Point for Recal: the actual "applied" point

* exactly the Apply Point or between the Min/Max Apply Points, returned from "start FR"/"next point"

for View and Recal: if attempting to save a point outside Min/Max Apply Points, the EI response will return an error

for Recal: if attempting to save a point outside the Max Error (|applied - actual|), the EI response will return an error

CMD2 = xxxx0101 (next point)

U8	Recal Number	= 0x00-0xFF	must be same value used in "start FR"
U8	View/Perform	= 0x00-0xFF	must be same value used in "start FR"
U8	Cur Point	= 0x00-0xFF	must be same value returned from "start FR"/"next point"
U8	Num Points	= 0x00-0xFF	must be same value returned from "start FR"/"next point"

CMD2 = xxxx0110 (finish field recal)

U8	Recal Number	= 0x00-0xFF	must be same value used in "start FR"
U8	View/Perform	= 0x00-0xFF	must be same value used in "start FR"
U8	Abort/Save	= 0x00-0xFF	0x00 = Abort recal, 0x01 = Save recal
U8	Disable/Enable	= 0x00-0xFF	0x00 = Disable recal, 0x01 = Enable recal

CMD2 = xxxx0111 (state field recal)

U8	Recal Number	= 0x00-0xFF	not used, references current field recal
U8	View/Perform	= 0x00-0xFF	not used, references current field recal
U8	Get/Set	= 0x00-0xFF	0x00 = Get recal state, 0x01 = Set recal state
U8	Disable/Enable	= 0x00-0xFF	for Get: not used for Set: 0x00 = Disable recal, 0x01 = Enable recal

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CMD_FIELD_RECAL (0x06) (continued)

Response Format – from Embedded Instrument to "Controller":

```
LEN   Length         = 0x??         length of DATA area
CMD1  Command1       = 0x06         echoed
CMD2  Command2       = 0x00-0xFF    echoed
STAT  Status         = 0x00-0xFF    general status, see status page
----
DATA                                depends upon lower nibble of CMD2 as shown next
```

CMD2 = xxxx0000, xxxx0001

```
U8  Status           = 0x00-0xFF    individual status, see status page
```

* repeated in groups of 1 byte based the number of channels selected in CMD2 (for xxxx0000 only)

CMD2 = xxxx0010

future...

CMD2 = xxxx0011 (start field recal)

```
U8  Status           = 0x00-0xFF    individual status, see status page
U8  Spare            = 0x00         spare to align on Word boundary
U8  Recal Number     = 0x00-0xFF    echoed
U8  View/Perform     = 0x00-0xFF    echoed
U8  Cur Point        = 0x00-0xFF    current point (x of n)
U8  Num Points       = 0x00-0xFF    # of points (n)
F32 Apply Point      =              recal value to apply
F32 Min Apply Point  =              min recal limit for this point
F32 Max Apply Point  =              max recal limit for this point
F32 Max Error        =              max error (|applied - actual|)
```

CMD2 = xxxx0100 (save point)

```
U8  Status           = 0x00-0xFF    individual status, see status page
U8  Spare            = 0x00         spare to align on Word boundary
U8  Recal Number     = 0x00-0xFF    echoed
U8  View/Perform     = 0x00-0xFF    echoed
U8  Cur Point        = 0x00-0xFF    echoed
U8  Num Points       = 0x00-0xFF    echoed
F32 Apply Point      =              echoed or previous value if "save point" failed
F32 Min Apply Point  =              min recal limit for this point
F32 Max Apply Point  =              max recal limit for this point
F32 Max Error        =              max error (|applied - actual|)
```


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CMD2 = xxxx0101 (next point)

U8	Status	= 0x00-0xFF	individual status, see status page
U8	Spare	= 0x00	spare to align on Word boundary
U8	Recal Number	= 0x00-0xFF	echoed
U8	View/Perform	= 0x00-0xFF	echoed
U8	Cur Point	= 0x00-0xFF	the next point, which is now the current point
U8	Num Points	= 0x00-0xFF	echoed
F32	Apply Point	=	recal value to apply
F32	Min Apply Point	=	min recal limit for this point
F32	Max Apply Point	=	max recal limit for this point
F32	Max Error	=	max error (|applied - actual|)

CMD2 = xxxx0110 (finish field recal)

U8	Status	= 0x00-0xFF	individual status, see status page
U8	Spare	= 0x00	spare to align on Word boundary
U8	Recal Number	= 0x00-0xFF	echoed
U8	View/Perform	= 0x00-0xFF	echoed
U8	Abort/Save	= 0x00-0xFF	echoed
U8	Disable/Enable	= 0x00-0xFF	the current field recal state

CMD2 = xxxx0111 (state field recal)

U8	Status	= 0x00-0xFF	individual status, see status page
U8	Spare	= 0x00	spare to align on Word boundary
U8	Recal Number	= 0x00-0xFF	echoed
U8	View/Perform	= 0x00-0xFF	echoed
U8	Get/Set	= 0x00-0xFF	echoed
U8	Disable/Enable	= 0x00-0xFF	the current field recal state

Example:

To ...

Controller--->EI:

EI--->Controller:

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Status

General Status (in Response Header):

0x00 good

Miscellaneous: 0x01-0x0F
0x01 instrument busy, message discarded
0x02 message CRC invalid, message discarded
0x03 message incomplete after timeout, message discarded

Bad Header argument: 0x10-0x1F
0x10 command1 not supported or invalid
0x11 command2 not supported or invalid
0x12 command3 not supported or invalid
0x13 command1 not supported in current mode
0x14 command2 not supported in current mode
0x15 command3 not supported in current mode

Production and/or Hardware failures: 0xF0-0xFF
0xF0 POST (power on self test) failed - general

Note: this page is continually being expanded, latest constants in EIProtocol.h

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Status (continued)

Individual Status (in Response Data):

0x00 good

Miscellaneous: 0x01-0x0F
0x01 engineering unit invalid
0x02 memory/data location invalid
0x03 sensor not present or invalid
0x04 memory/data get/set failed
0x05 cmd1/2/3 not supported for this channel
0x06 payload arguments/data invalid
0x0F a general catch-all status

Calibration: 0x10-0x1F
0x14 calibration expired

Measurement: 0x20-0x2F
0x20 measurement soft over range
0x21 measurement hard over range
0x22 temperature soft over range
0x23 temperature hard over range

Simulation: 0x30-0x3F
0x30 simulation value too low
0x31 simulation value too high

Field Recalibration: 0x40-0x4F
0x40 field recal not allowed
0x41 too far from zero to zero
0x42 recal point outside valid range
0x43 recal point error beyond limit
0x44 general recal script error
0x45 general recal point library error
0x46 recal command out of sequence

Note: this page is continually being expanded, latest constants in EIProtocol.h

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Appendix A

CRC16 Detail:
Normal (i.e. not reflected) CRC-16-CCITT.

A CRC16 of "123456789" returns 0x31C3.

For a 18-byte message (as shown below in Red):

1. CRC16 bytes 1-10 of the header,
2. CRC16 bytes 13-18 of the payload,
3. insert the CRC16 into bytes 11 and 12, little-endian.

An example of CMD_GET_MEAS (internal temperature channel) from a PC to an RS232 module.

The Command is Red, the Response is Blue, the CRC16s are boxed.

Notice extended addressing is used.

```
TX: 80 01 00 03 28 04 80 00 00 00 D5 21 03 80 80 28 F0 2A

RX: 40 01 08 28 03 04 80 00 00 00 8A 40 00 01 02 00
RX: 91 7F 00 42 28 F0 2A 03 80 80
```

Message/Protocol Transmit and Receive Detail:

RS232, USB20, I2C, and UART:
Steps in text:

1. Controller assembles the Command message,
2. Controller transmits the entire Command message to the EI,
3. EI processes command and assembles the Response message,
4. EI transmits the entire Response message to the Controller.

Steps in diagram:

	Controller	EI
1.	Processing	
2.	Command Header + Data>>>	
3.	Processing	
4.	<<<Response Header + Data	

Note: The Controller should wait >= 5mSec after receiving a Response before issuing another Command.

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Message/Protocol Transmit and Receive Detail (continued):

SPI: (for *advanced* users only)
Steps in text:

1. Controller assembles the Command message,
2. Controller clocks-out the Command message Header to the EI,
   EI clocks 0x00s back
3. Controller waits TS1* (while the EI parses length from message header and sets up DMA to receive balance of message),
4. Controller clocks-out the Command message Data to the EI,
   EI clocks 0x01s back
5. Controller waits TS1* (while the EI completes command receipt and loads 0x02 into transmit register), then Controller begins clocking 0x03s**
   EI clocks 0x02s back while BUSY (processing the command and assembling the Response message)
6. Controller clocks-out 12 (Response message Header size) 0x03s,
   EI clocks the Response message Header back
7. Controller waits TS1* (while it parses length from message header and sets up DMA to receive balance of message),
8. Controller clocks-out Length (from Response message Header) 0x04s.
   EI clocks the Response message Data back

Steps in diagram:

	Controller	EI
1.	Processing	
2.	Command Header>>>	
	<<<all 0x00s	
3.	Pause	
4.	Command Data>>>	
	<<<all 0x01s	
5.	Busy to Ready**	
	<<<all 0x02s	
6.	12 0x03s>>>	
	<<<Response Header	
7.	Pause	
8.	Length 0x04s>>>	
	<<<Response Data	

*TS1 – 5mSec

**BUSY indication (done in protocol, no hardware line). The Controller can poll the EI by clocking-out 0x03s. If the Controller receives 0x02s, the EI is BUSY – as soon as the Controller receives Response Preamble1 (0x40), the Controller must clock-out another 11 0x03s to complete receipt of the Response Header. While the EI is BUSY, the Controller can deselect it, go perform another task, and reselect the EI and check the status (i.e. send 0x03s). So, the Controller does NOT have to wait (i.e. keep the EI selected and keep clocking 0x03s) while the EI is BUSY.

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Appendix B

EIProtocol.h file:
The latest EIProtocol.h.file for use in programming is available at www.meriam.com

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