



expertmeter™

High Performance Analyzer  
PM180

IEEE C37.118.2 Synchrophasor Data  
Transfer Protocol

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Reference Guide

Every effort has been made to ensure that the material herein is complete and accurate. However, the manufacturer is not responsible for any mistakes in printing or faulty instructions contained in this book. Notification of any errors or misprints will be received with appreciation.

For further information regarding a particular installation, operation or maintenance of equipment, contact the manufacturer or your local representative or distributor.

#### REVISION HISTORY

A1	June 2019	Release
A2	Sep 2021	Added UTC synchronization options. Added M performance class selection.
A3	June 2022	Added positive sequence phasors, CFG-3 frame and spontaneous/unsolicited transmission of CFG frames.

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# 1 General

This document describes protocol implementation features and configuring of the IEEE C37.118.2 synchrophasor data transfer protocol in the PM180 phasor measurement unit (PMU).

The PM180 PMU supports commanded client-server UDP and TCP data transmission and spontaneous UDP data transmission over IP protocol. Serial communication is not supported as obsolete and rarely used for synchrophasor data transfer.

Streaming of synchrophasor data is also available over Ethernet via the IEC 61850 protocol by mapping the IEEE C37.118.2 synchrophasor data stream to IEC 61850-9-2 sampled values service (see the PM180 IEC 61850 communication protocol reference guide for more information).

## Reference documents:

IEEE Std C37.118.1-2011, IEEE Standard for Synchrophasor Measurements for Power Systems

IEEE Std C37.118.1a-2014, IEEE Standard for Synchrophasor Measurements for Power Systems, Amendment 1: Modification of Selected Performance Requirements

IEEE Std C37.118.2-2011, IEEE Standard for Synchrophasor Data Transfer for Power Systems

IEEE Std 1588-2008, IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems

IEEE C37.238-2017, IEEE Standard Profile for Use of IEEE 1588 Precision Time Protocol in Power System Applications

## 2 Protocol Implementation

The IEEE C37.118.2 protocol is implemented in the PM180 in a flexible manner. Most of IEEE C37.118.2 features are user-configurable allowing easy adaptation for use in different installations. To keep maximum interoperability with phasor data concentrators (PDC) and controlling stations, the PM180 supports all standard frame types for synchrophasor data interrogation and streaming.

The PAS configuration software supplied with the PM180 provides all necessary tools for remote configuration of the device.

See Chapter 3 for instructions on how to configure IEEE C37.118.2 options in the device for your particular installation.

See the PM180 Operation Manual for more information on configuring the meter via PAS.

The protocol implementation details are explained in the following sections.

### 2.1 IEEE C37.118.2 Data Communications

The PM180 PMU provides commanded client-server UDP and TCP data transmission and spontaneous UDP data transmission over IP protocol.

The synchrophasor data is transmitted at a programmable reporting rate of 1 to 60 frames per second at sub-multiples of the nominal power line frequency.

The data stream ID number you assigned to the PMU via the IEEE C37.118.2 setup uniquely identifies a synchrophasor data stream. Only requests with the matching data stream ID are responded by the PMU.

#### 2.1.1 Unicast Commanded UDP and TCP Data Transmission

Commanded data transmission must be explicitly turned on by a command sent by a client to receive synchrophasor data via a unicast UDP or TCP connection.

##### **Streaming Data Slots**

The PM180 PMU provides 5 data streaming slots for continuous streaming synchrophasor data via unicast UDP or/and TCP connections.

Although the UDP server responds to commands from unlimited number of UDP clients and the TCP server can support up to 8 client connections, the commands to turn on data transmission on new connections after all 5 data streams are running will be ignored.

##### **TCP Connection Timeout**

The PM180 uses TCP\_KEEPAALIVE probes by default to check that the link with the client is operating and closes the connection if the link is broken for more than 30 seconds.

An idling TCP connection is also closed if there is no activity on both sides, i.e. there are no master commands received or no streaming data transmission, within a programmable connection idle timeout. You can change or disable the TCP connection idling timeout via the device Network Setup (see the PM180 Operation Manual for details).

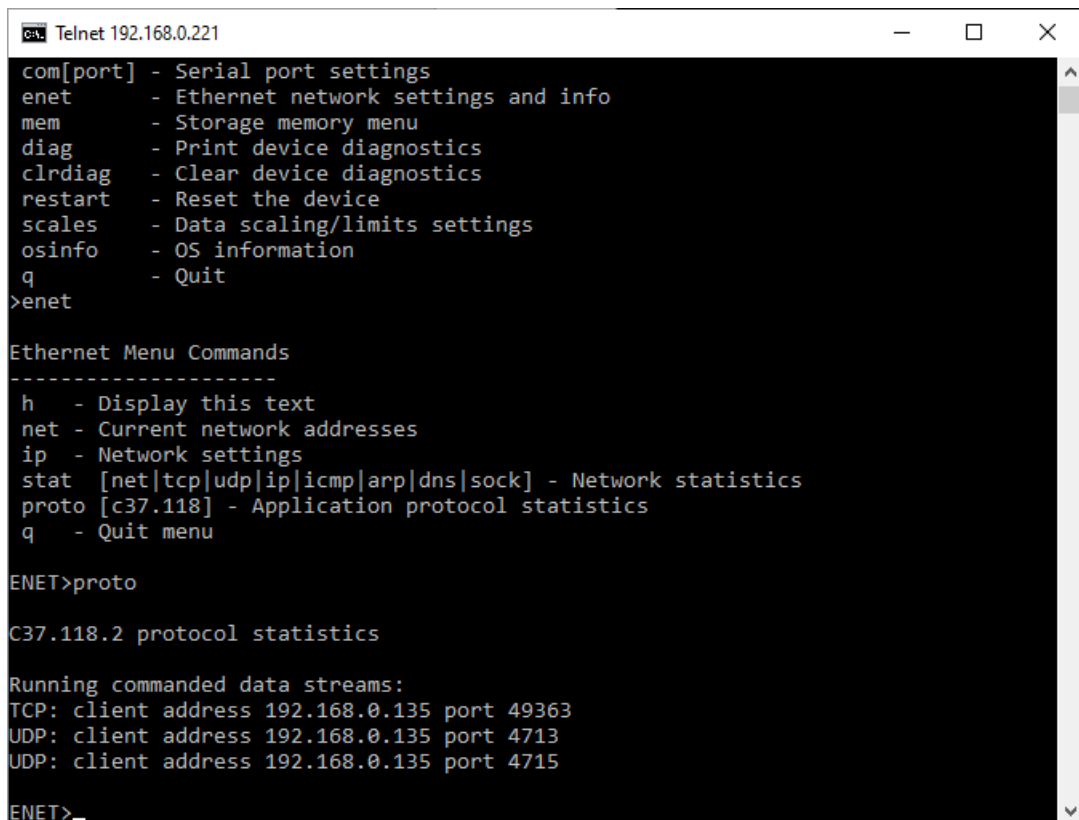
##### **Uncontrollable Commanded UDP Data Flow**

Unlike TCP connections, in case of the commanded UDP transmission, IEEE C37.118.2 does not provide tools for probing whether a client who initiated transmission is still alive and listening to the synchrophasor data stream.

Abnormal termination of client operations without explicit turning off the data transmission may leave the streaming slot active forever and thus limit the number of slots available for new data streams.

The PM180 provides a command you can send to the device via the IEEE C37.118.2 setup dialog (see Section 3) that stops all active commanded UDP streams and releases the corresponding data streaming slots.

You can check which data streams are currently active via the device Telnet server. Run a Telnet client on your PC, log on to the device, type "enet" on the main menu command prompt, and then type "proto". See the PM180 Operation Manual for more information on operating Telnet. The following picture shows what the active data stream list may look like.



```
Telnet 192.168.0.221
com[port] - Serial port settings
enet      - Ethernet network settings and info
mem       - Storage memory menu
diag      - Print device diagnostics
clrdiag   - Clear device diagnostics
restart   - Reset the device
scales    - Data scaling/limits settings
osinfo    - OS information
q         - Quit
>enet
Ethernet Menu Commands
-----
h - Display this text
net - Current network addresses
ip - Network settings
stat [net|tcp|udp|ip|icmp|arp|dns|sock] - Network statistics
proto [c37.118] - Application protocol statistics
q - Quit menu
ENET>proto
C37.118.2 protocol statistics
Running commanded data streams:
TCP: client address 192.168.0.135 port 49363
UDP: client address 192.168.0.135 port 4713
UDP: client address 192.168.0.135 port 4715
ENET>
```

## 2.1.2 Spontaneous UDP Data Transmission

Spontaneous synchrophasor data transmission is explicitly enabled and disabled by the user via the IEEE C37.118.2 setup (see Section 3 for details). The destination UDP port and IP address are configurable.

Spontaneous UDP data transmission operates in unicast, multicast or broadcast mode depending on the destination IP address you specified.

If the UDP clients have an ability to join a multicast group, you can select one from the multicast address range of 225.0.0.0 through 239.255.255.255.

For broadcast transmission within your local network, set the host part of the network address to 255 as shown in the default IP address example. Use a routable broadcast address to expand the broadcast transmission beyond your local network.

## 2.2 IEEE C37.118.2 Message Frames

### 2.2.1 Data Frames

Synchrophasor data frames transmit a time stamped set of measurements that include phasor estimates, frequency deviation from the nominal power line frequency and the rate of change of frequency. In addition, the data frame can be expanded to contain analog data (total active, reactive and apparent power, and power factor) and digital input status information (up to 32 inputs can be included).

The phasor data can represent single phase phasors (three phase voltage and three phase currents) or 3-phase positive sequence voltage and current, or both in a single frame.

The complex phasor values can be sent in a rectangular coordinates format (real and imaginary) or in polar coordinates (magnitude and angle). The phasor and frequency data can be represented in 32-bit IEEE floating-point format or as 16-bit scaled integer numbers. In case of using integer format, the data conversion factors are provided via the IEEE C37.118.2 configuration frames.

See Section 3 for information on configuring IEEE C37.118.2 data frames.

## 2.2.2 Configuration Frames

IEEE C37.118.2 configuration frames provide information about a synchrophasor data stream in binary format. The PM180 PMU supports CFG-1, CFG-2 and CFG3 configuration frames.

The configuration frame contents correspond to the specification given by IEEE C37.118.2. In CFG-3 frames, the PMU GUID is not supported and is transmitted as a null string.

### Conversion Factors for 16-bit Integer Format

In case of transmission data in 16-bit integer format, conversion factors for phasor channels in the CFG-2 frame are represented as an unsigned 24-bit word in  $10^{-5}$  volts or amperes per bit to scale.

Conversion factors for analog channels in CFG-2 frames are represented as an unsigned 24-bit word in  $10^{-3}$  per bit to scale. Power readings are transmitted in kW/kvar/kVA units.

If transmitted data is in floating-point format, this 24-bit value will represent a unity scale factor and shall be ignored.

### Spontaneous Configuration Frames

Configuration frames CFG-2 or CFG-3 can be sent spontaneously without the explicit user command. If enabled, the configuration frame is sent once before start of transmission in unicast UDP/TCP modes, and periodically every 30 s in multicast/spontaneous UDP mode.

## 2.2.3 Header Frame

A header frame gives information about a synchrophasor data stream in human-readable format. An example header frame for positive sequence phasor data is shown below.

Station Name: My Station
ID Code: 7000
UTC Time: 2019-06-03 05:31:51.786
Time Quality: Locked
Time Base: 1000000
Revision Count: 4
Data Rate: 50
Total Phasors: 6
Total Analogs: 0
Total Digitals: 0
Phasor Coordinate Format: Rectangular
Phasor Data Format: Integer
Frequency Data Format: Integer
V1 Conversion Factor: 5.05387
I1 Conversion Factor: 0.61037
Angle Conversion Factor: 0.0001
Frequency Conversion Factor: 0.001
df/dt Conversion Factor: 0.01
Nominal Frequency: 50 Hz

## 2.3 UTC Time Synchronization

The PMU clock can be synchronized to UTC using an IRIG-B timecode source or an IEEE 1588 PTPv2 master clock source.

### 2.3.1 IRIG-B Time Synchronization

Connect the IRIG-B signal wires to the 1pps/CM terminals on the PM180 CPU module.

The PM180 IRIG-B port uses an unmodulated (pulse-width coded) timecode signal (unbalanced 5V level) according to the IRIG 200-04 standard. It supports B000/B001 and B004/B005 timecode formats with time code extensions specified for the IRIG-B profile in Annex D of IEEE Std C37.118.1-2011.

The PMU IRIG-B port can synchronize to the IRIG-B timecode source with sub-microsecond accuracy.

To enable the IRIG-B port as a UTC source, select the IRIG-B time synchronization option in the IEEE C37.118.2 setup (see Section 3.1.1 for details).

NOTE: The "PMU OK" LED on the PMU module flashes yellow ones a second when the PMU clock is not in sync with the UTC/IRIG-B clock, and flashes green when synchronized.

### 2.3.2 IEEE 1588 PTP Time Synchronization

To use an IEEE 1588 master clock as a UTC source, your PMU must be provided with the IEEE 1588 Ethernet port.

**The IEEE 1588 PMU port must be connected to an IEEE 1588 grandmaster clock through a PTPv2 peer-to-peer transparent clock switch compliant with IEEE Std 1588-2008.**

The IEEE 1588 PMU port implements the ordinary PTPv2 clock, complying with the IEEE Std 1588-2008 standard, and uses the following PTP profile:

1. PTP version 2.
2. PTP transport over Layer 2 Ethernet (IEEE 802.3), IEEE 1588-2008, Annex F.
3. Multicast addressing.
4. Peer-to-peer (P2P) path delay measurement mechanism.
5. Capable of working with one-step and two-step master clocks.
6. Responds to peer path delay requests with two-step peer delay responses (Pdelay\_Resp, Pdelay\_Resp\_Follow\_Up messages).

The IEEE 1588 PMU port can synchronize to the PTP grandmaster clock with sub-microsecond accuracy, which can be degraded by network topology, PTP switch accuracy, or transmission media asymmetry.

To enable the IEEE 1588 port as a UTC source, select the IEEE 1588 time synchronization option in the IEEE C37.118.2 setup, and configure the port network addresses (for details, see Sections 3.1.1 and 3.1.2).

NOTE: The "PMU OK" LED on the PMU module flashes yellow ones a second when the PMU clock is not in sync with the IEEE 1588 grandmaster clock, and flashes green when synchronized.

The PMU comes with a Telnet server that can be used to check the PMU clock status and time accuracy, as shown in the following pictures. Connect with a Windows Telnet client to the PMU using the IP address of the IEEE 1588 PMU port, login with the password "1588" and enter "ptp".



```
Telnet 192.168.0.204
Login password: ****

PMU180 Telnet commands
-----
h or ? - display this text
i       - firmware info
time    - UTC time
ptp     - PTP status
q       - quit

>ptp

Parent clock
=====
parent_clock_uuid      08:00:17:00:00:02
parent_port_id         1
parent_steps_removed   1

Grandmaster clock
=====
grandmaster_identity   20:b7:c0:ff:fe:00:9e:24
grandmaster_clock_uuid 08:00:17:00:00:02
grandmaster_port_id    1
grandmaster_identifier DFLT
grandmaster_priority_1 128
grandmaster_priority_2 128
grandmaster_clock_class 6
grandmaster_clock_variance 18465
grandmaster_clock_accuracy 0x21, time accurate within 100 ns
```

```
Telnet 192.168.0.204

grandmaster_identifier DFLT
grandmaster_priority_1 128
grandmaster_priority_2 128
grandmaster_clock_class 6
grandmaster_clock_variance 18465
grandmaster_clock_accuracy 0x21, time accurate within 100 ns
ptp_timescale true
time_traceable true
current_utc_offset 37
utc_offset_valid true
leap_59 false
leap_61 false
epoch_number 0
last_sync_sequence_number 197
last_origin_timestamp 1614233543.259591937 s TAI
2021-02-25 06:11:46 UTC

PMU clock
=====
port_state SLAVE
port_clock_identity 00:05:f0:ff:fe:f0:00:05
port_id 1
port_subdomain_number 0
last_pdelay_request_sequence_number 65
last_pdelay_response_sequence_number 65
peer_mean_path_delay 25 ns
offset_from_master -17 ns
clock_status locked to a UTC source

>
```

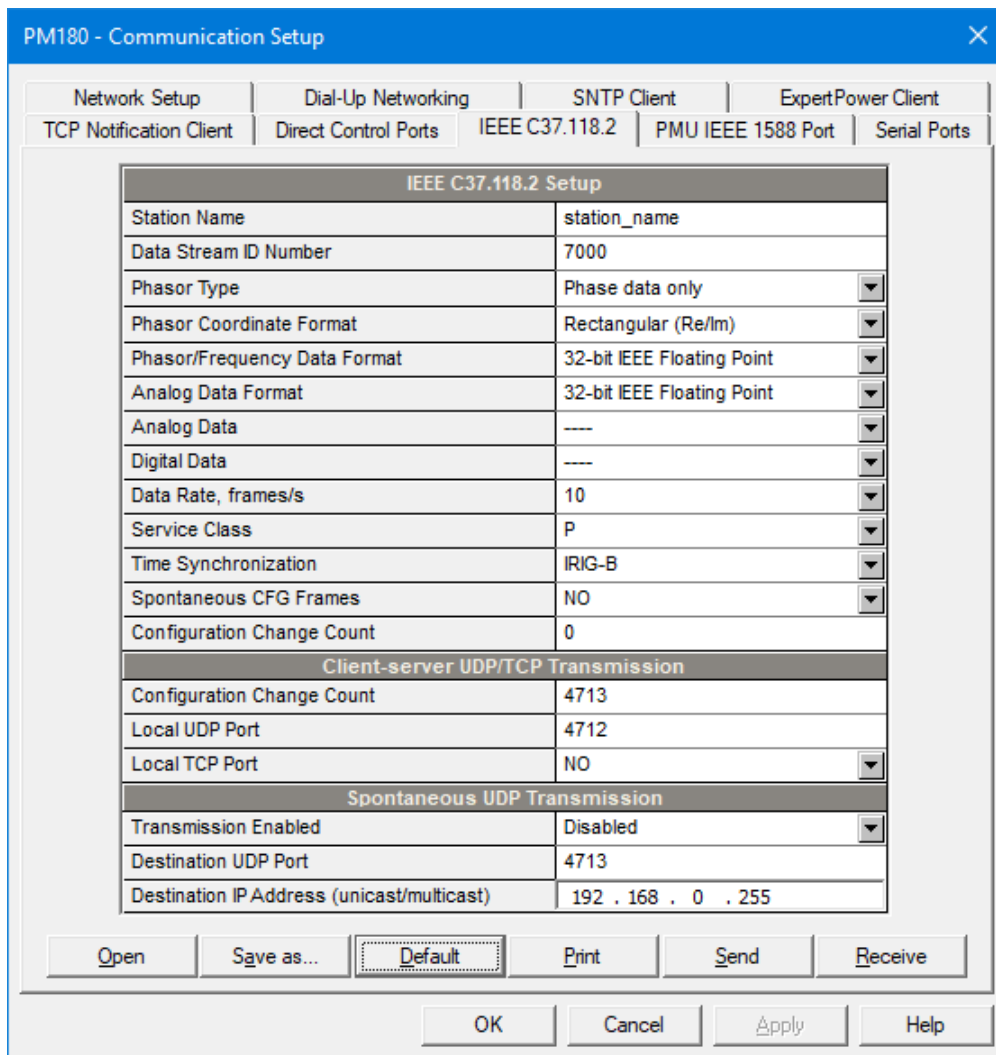
### 3 Configuring IEEE C37.118.2

Use the PAS configuration software provided with your device to configure IEEE C37.118.2 options. See the PM180 Operation Manual for more information on installation and operating PAS on your computer.

#### 3.1.1 Configuring IEEE C37.118.2 Options

To configure the IEEE C37.118.2 options:

1. Ensure that the selected connection protocol to communicate with your device is set to Modbus RTU or Modbus ASCII.
2. Select Communications Setup from the Meter Setup menu and then click on the IEEE C37.118.2 tab.



3. Select desired options.
4. Click Save as... to store your setup in the device site database, and click Send to send the setup to the device.

See the following table for the available options.

Parameter	Options	Default	Description
<b>IEEE C37.118.2 Setup</b>			
Station Name	Up to 16 ASCII characters	station_name	Identifies the station
Data Stream ID Number	1-65534	7000	Identifies the data stream
Phasor Type	Phase data only, Pos. Sequence only, Phase + Pos. Sequence	Phase data only	Type of phasor estimates in the data frame
Phasor Coordinate Format	Rectangular = phasor real and imaginary, Polar = magnitude and angle	Rectangular	Representation format for phasor vector
Phasor/Frequency Data Format	16-bit integer, 32-bit IEEE floating point	32-bit IEEE floating point	Data format for phasor and frequency data
Analog Data Format	16-bit integer, 32-bit IEEE floating point	32-bit IEEE floating point	Data format for analog data
Analog Data	None, 'P,Q,S,PF'	None	Enables analog power data transmission
Digital Data	None, 16 DI, 32 DI	None	Enables digital input status data transmission
Data Rate, frames/s	1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 25, 30, 50, 60	10	Rate of data transmission
Service Class	P, M	P	Selects the PMU performance class
Time Synchronization	IRIG-B, IEEE 1588 (PTPv2)	IRIG-B	Selects an external UTC time source
Spontaneous CFG Frames	NO, CFG-2, CFG-3	NO	Enables spontaneous configuration frames
Configuration Change Count	0-65535	0	
<b>Client-server UDP/TCP Transmission</b>			
Local UDP Port	1024-49151	4713	Local UDP port number for commanded client-server UDP operation
Local TCP Port	1024-49151	4712	Local TCP port number for client-server TCP operation
Stop UDP Streams	NO, YES	NO	Stops all active commanded UDP streams. Can be used to stop uncontrollable UDP streams in case of an abnormal client disconnection.
<b>Spontaneous UDP Transmission</b>			
Transmission Enabled	Disabled, Enabled	Disabled	Enables spontaneous data transmission
Destination UDP Port	1024-49151	4713	Destination port number for spontaneous data transmission
Destination IP Address (unicast/multicast)		192.168.0.255	Destination IP address for spontaneous data transmission. Can be unicast, multicast or broadcast address.

**NOTES:**

1. Configure the synchrophasor data frame properties and local port settings before turning on the data transmission. Changing either invalidates all active data streams and stops data transmission in progress.

2. Changing the local TCP port causes closing all active connections and restarting the network services. If you make changes via an Internet connection, wait a couple of seconds until the network is ready for operation before sending a new connection request.
3. The selected data rate is automatically rounded up to the nearest sub-multiple of the nominal frequency. In case of using both IEEE C37.118.2 and IEC 61850 synchrophasor data communications, the new data rate is applied to both protocols.
4. Changing the synchrophasor data frame properties advances the configuration change count. You can set it to any desired number by explicit writing the count value.

### 3.1.2 Configuring the IEEE 1588 Port

To configure the PMU IEEE 1588 Ethernet port:

1. Select Communications Setup from the Meter Setup menu and then click on the PMU IEEE 1588 Port tab.

Current IEEE 1588 Port Settings	
IP Address	192 . 168 . 0 . 204
Subnet Mask	255 . 255 . 255 . 0
Default Gateway	192 . 168 . 0 . 254

IEEE 1588 Port Setup	
MAC Address	00:05:F0:F0:00:01
IP Address	192 . 168 . 0 . 204
Subnet Mask	255 . 255 . 255 . 0
Default Gateway	192 . 168 . 0 . 1
DHCP	Disabled

2. Setup the required static IP address, subnet mask and default gateway for the IEEE 1588 Ethernet port, or enable the DHCP option to dynamically assign network addresses by a DHCP server.
3. Click Save as... to store your setup in the device site database, and click Send to send the setup to the device.

NOTES:

1. Use the DHCP option with caution, especially if the network is managed by the Microsoft Network server. Since the PMU is not a client for the Microsoft network, the address that the PMU can receive may already be assigned to one of the PCs on the network.
2. If you selected DHCP, the assigned network addresses will be displayed on this tab under the Current IEEE 1588 Port Settings section. It may take a couple of minutes for the PMU to acquire new network addresses.