SATEC

expertmeter™

High Performance Analyzer
PM180

IEEE C37.118.2 Synchrophasor Data Transfer Protocol

Reference Guide

BG0627 Rev. A5

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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.
A4	Oct 2024	Added configurable channel names and second commanded TCP/UDP and spontaneous UDP data streams.
A5	Nov 2024	Updated IEEE C37.118.2 configuration data.

Table of Contents

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 unicast client-server UDP and TCP data transmission and spontaneous multicast or unicast UDP data transmission using two data streams with programmable data rates. The data stream ID number assigned to PMU streams uniquely identifies each data stream. Only requests with matching data stream ID numbers are responded by the PMU.

The synchrophasor measurement data reporting rate can be configured in submultiples of the nominal power line frequency from 1 to 60 frames per second.

Each data stream can be individually configured to any data rate that is submultiple of the PMU reporting rate.

NOTE

Devices with firmware earlier than V31.XX.60 provide only one commanded unicast TCP/UDP data stream and one spontaneous multicast/unicast UDP data stream with the same ID number and a data rate fixed at the PMU reporting rate.

2.1.1 Commanded Unicast TCP and UDP Data Transmission

Commanded unicast data transfer is controlled by commands sent by the client over a unicast TCP or UDP connection to the PMU's local TCP or UDP port, respectively.

Configuration and header frames are always sent to the IP address and port from which the corresponding command was received, while data frames are sent to the IP address and port from which the start command was sent. This does not necessarily have to be the same port.

Streaming Data Slots

The PMU provides up to 5 simultaneous unicast TCP and/or UDP connections for streaming synchrophasor data at a user-programmable data rate using one of two commanded data streams. The transmission start command should indicate the selected stream identifier.

The stream data rate must be a submultiple of the PMU reporting rate. If it is not, the device will set it to the PMU reporting rate.

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

TCP Connection Timeout

The PM180 uses TCP_KEEPALIVE 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).

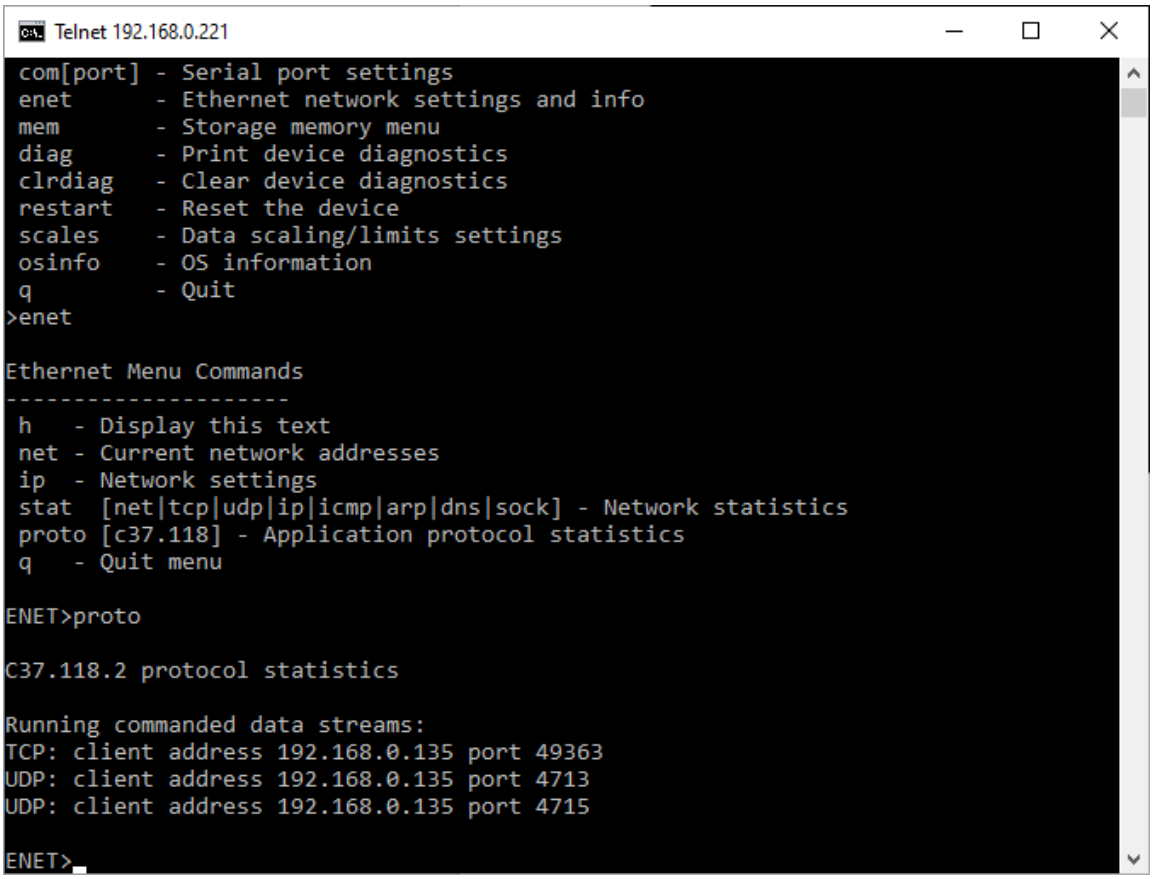
Uncontrollable Commanded UDP Data Flow

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.



2.1.2 Spontaneous UDP Data Transmission

Unlike commanded data transfer, spontaneous data frames are sent to a user-configured IP address and destination port. The PMU provides two data streams for simultaneous transmission of synchrophasor data frames to two different destinations at user-programmable data rates.

Spontaneous data transfer must be enabled or disabled explicitly by the user through the IEEE C37.118.2 settings (see Section 3 for details) or over an alternate client-server TCP or UDP connection to a local PMU TCP or UDP port, respectively, by referring to the appropriate spontaneous data stream identifier. Regardless of how the data stream is enabled, its state is stored in non-volatile memory, so that if it is enabled, data transfer is automatically started after the device reboots.

Configuration and header frames can be requested and received over an alternate TCP or UDP connection by referencing the appropriate data stream identifier, just as in a regular

client-server connection. Configuration frames can also be sent spontaneously to a user-configured destination port without an explicit command, like spontaneous data frames are sent (see Spontaneous Configuration Frames below).

Spontaneous UDP data transmission can operate in unicast, multicast or broadcast mode depending on the destination IP address the user 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. 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, power factor, voltage and current THD) and digital input status information (up to 32 inputs can be included).

The phasor data can represent single phase phasors (tree phase voltage and tree 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 CFG-3 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.

Channel Names

The names of the phasor, analog data and digital status channels are user configurable. The channel name can be up to 16 characters long. The default channel names are listed in the following table.

Channel name	Description
VA	V1 phase phasor
VB	V2 phase phasor
VC	V3 phase phasor
IA	I1 phase phasor
IB	I2 phase phasor
IC	I3 phase phasor
V1	Positive sequence voltage phasor
I1	Positive sequence current phasor
P	Total active power (analog channel)
Q	Total reactive power (analog channel)
S	Total apparent power (analog channel)

Channel name	Description
PF	Total power factor (analog channel)
VTHDA	V1 phase THD (analog channel)
VTHDB	V2 phase THD (analog channel)
VTHDC	V3 phase THD (analog channel)
ITHDA	I1 phase THD (analog channel)
ITHDB	I2 phase THD (analog channel)
ITHDC	I3 phase THD (analog channel)
DI1	Digital status channel 1
…	
DI32	Digital status channel 32

Conversion Factors

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

In spontaneous UDP data transmission mode, CFG-2 or CFG-3 configuration frames can be sent spontaneously without an explicit user command. When enabled, a configuration frame is sent periodically every 30 seconds.

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 extentions specified for the IRIG-B profle 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 an ordinary PTPv2 clock complying with IEEE Std 1588-2008 and uses the IEEE C37.238 power profile per IEEE C37.238-2011 and IEC/IEEE 61850-9-3 as follows:

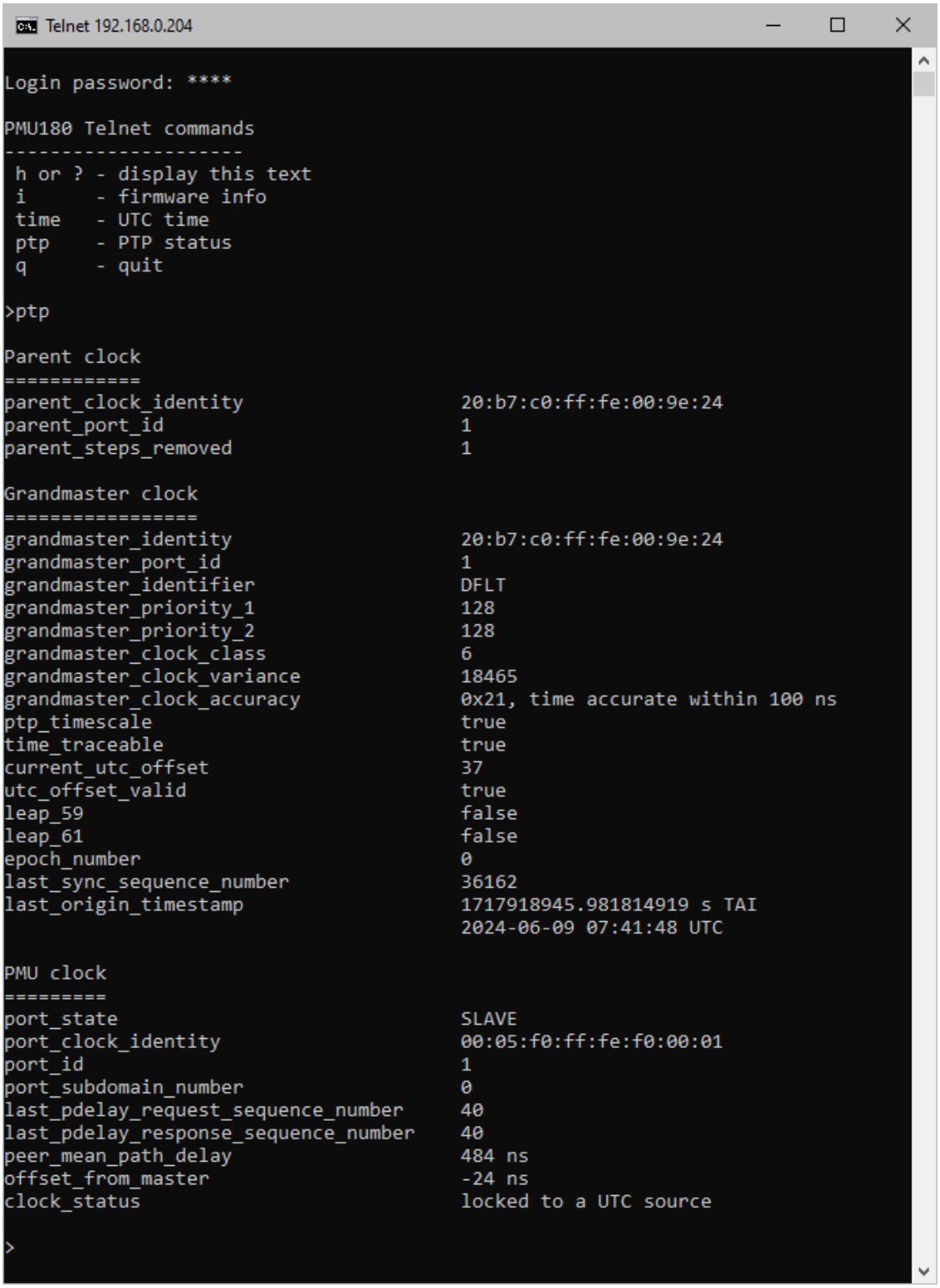
1. PTP version 2.
2. PTP transport over Layer 2 Ethernet (IEEE 802.3), IEEE 1588-2008, Annex F.
3. Multicast addressing.
4. Peer-to-peer (P2P) path delay measurement mechanism.
5. Announce interval = 1 s
6. Sync interval = 1 s
7. Capable of working with one-step and two-step master clocks.
8. Responds 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 picture. 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_identity 20:b7:c0:ff:fe:00:9e:24
parent_port_id 1
parent_steps_removed 1
Grandmaster clock
grandmaster_identity 20:b7:c0:ff:fe:00:9e:24
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
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 36162
last_origin_timestamp 1717918945.981814919 s TAI
2024-06-09 07:41:48 UTC
PMU clock
port_state SLAVE
port_clock_identity 00:05:f0:ff:fe:f0:00:01
port_id 1
port_subdomain_number 0
last_pdelay_request_sequence_number 40
last_pdelay_response_sequence_number 40
peer_mean_path_delay 484 ns
offset_from_master -24 ns
clock_status locked to a UTC source
>

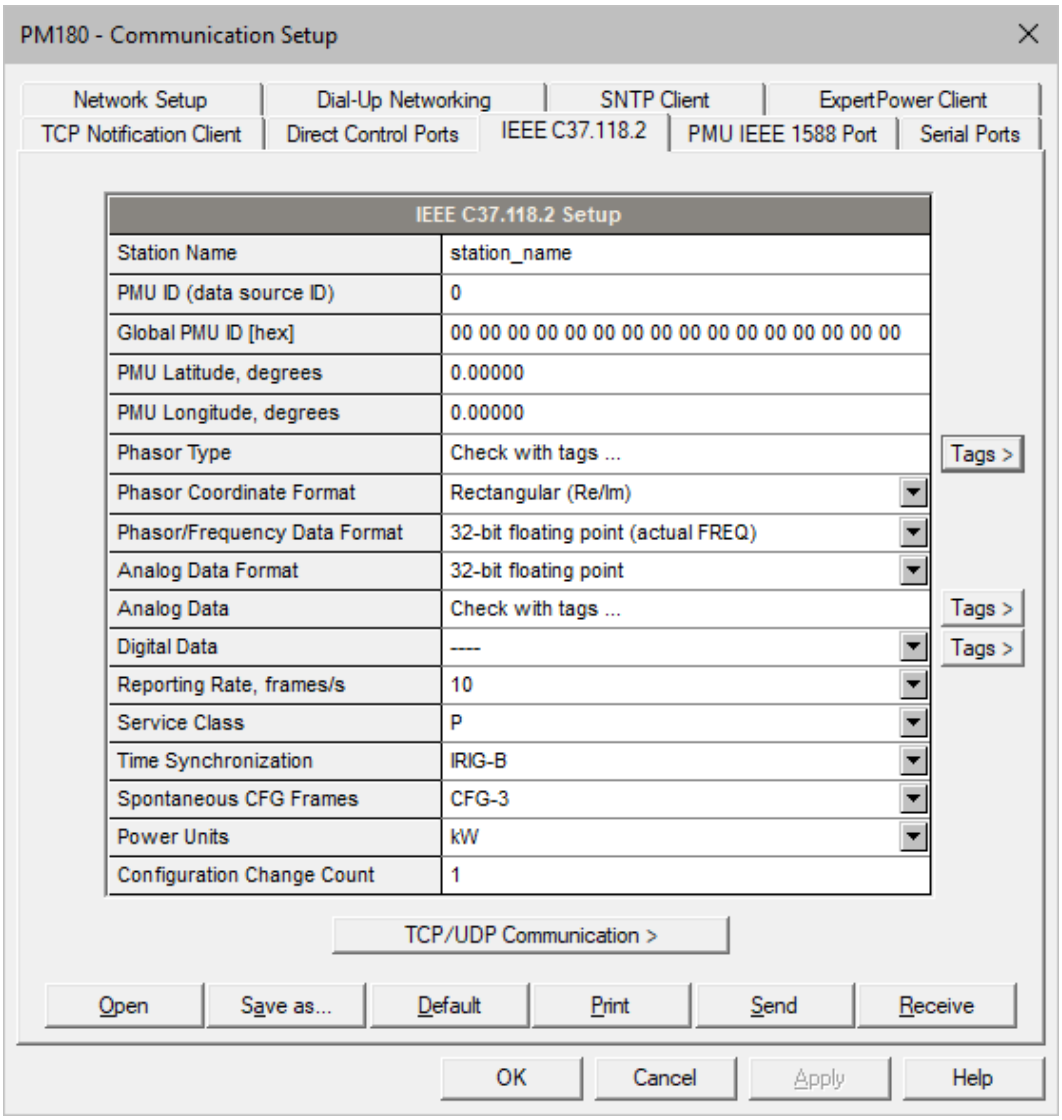
3 Configuring IEEE C37.118.2

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.

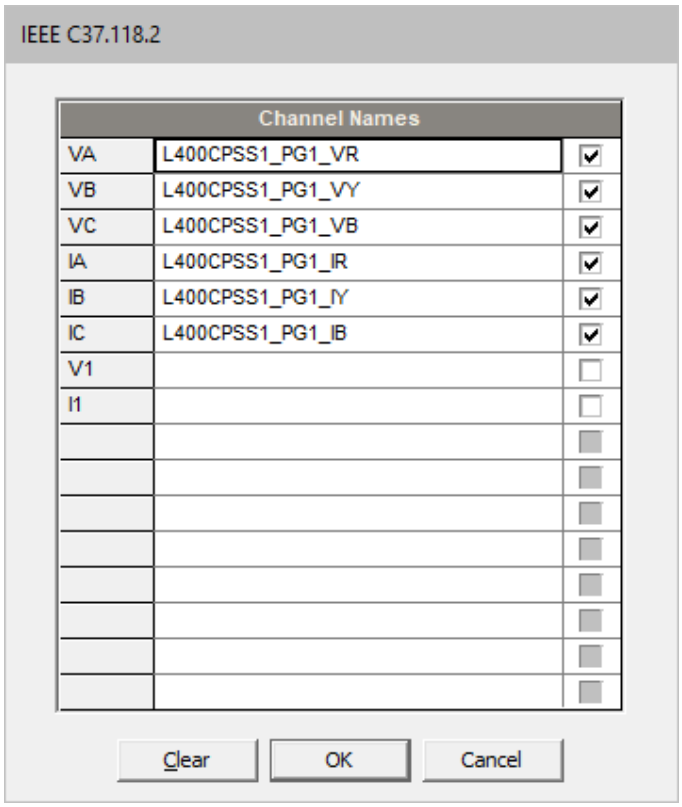
3.1.1 Configuring IEEE C37.118.2 Options

To configure the IEEE C37.118.2 options:

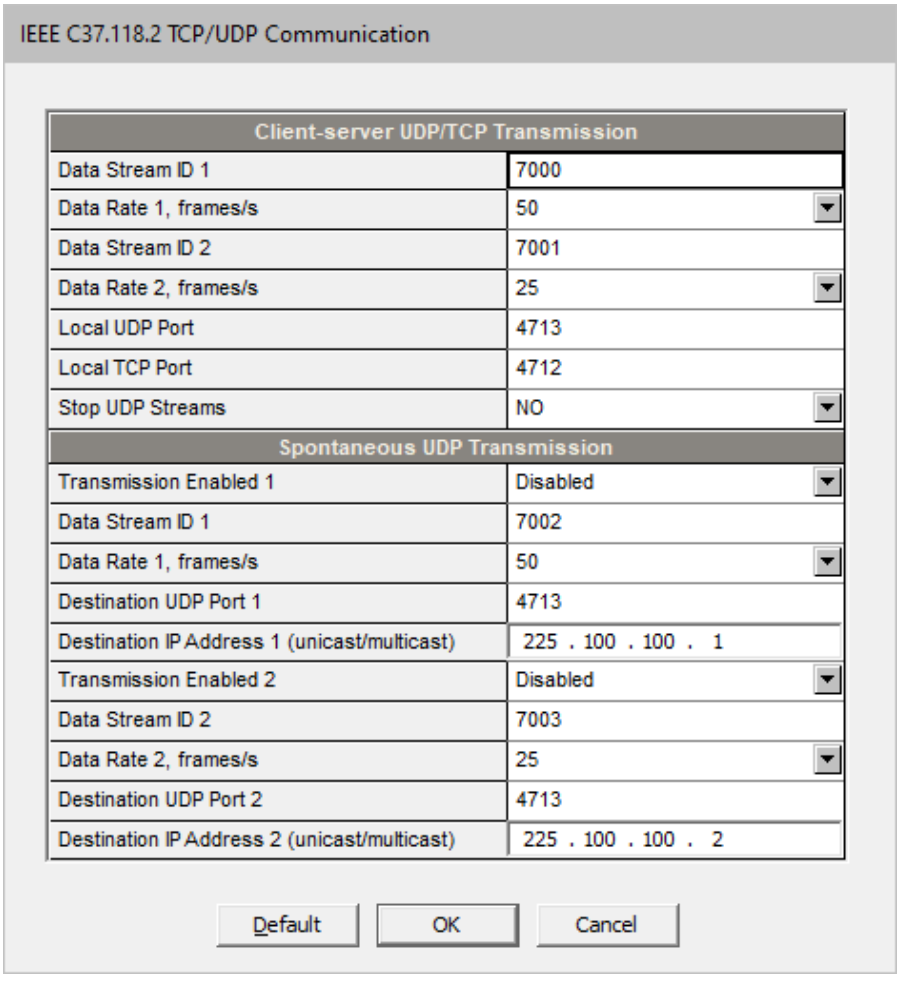
1. Ensure that the selected connection protocol to communicate with your device is set to Modbus RTU or Modbus ASCII.
2. Select Communications Setup from the Meter Setup menu and then click on the IEEE C37.118.2 tab.



3. Select the desired PMU and data frame parameters. See the table below for the available options and their explanations.
4. To select phasor and analog data components and/or change the default phasor, analog, and digital channel names, click the appropriate Tags button on the right, check the channels you want to include in the data frames and enter custom channel names, then click OK. Channel names can be up to 16 characters long.



5. Click the TCP/UDP Communication button to configure IEEE C37.118.2 data streams.



6. Configure device's local TCP and UDP port numbers for client connections, and the destination addresses and ports for spontaneous transmission as desired. The default port numbers are set to the values recommended by IEEE C37.118.2.
7. Configure the data stream parameters as required for your application. **Avoid assigning the same identifier to multiple streams, as this will make streams following the first one unavailable to client commands.**
8. Click Save as… to store your setup in the device site database, and click Send to send the setup to the device.

The following table provides information on the available options.

Parameter	Options	Default	Description
IEEE C37.118.2 Setup			
Station Name	Up to 19 ASCII characters	station_name	Identifies the station
PMU ID (data source ID)	0, 1-65534	0 (Note 4)	Data source ID number
Global PMU ID [hex]	128-bit string (16 raw bytes in hexadecimal notation)		Identifies the PMU in a system that has more than 65535 PMUs.
PMU Latitude, degrees	-90.00000 to 90.00000	0.00000	PMU latitude (WGS84)
PMU Longitude, degrees	-180.00000 to 180.00000	0.00000	PMU longitude (WGS84)
Phasor Type	Phasor components	VA,VB,VC,IA,IB, IC	See Channel Names in Section 2.2.2.
Phasor Coordinate Format	Rectangular (Re/Im) Polar (Mag/Ang)	Rectangular	Vector data format: Rectangular – real and imaginary, Polar – magnitude and angle
Phasor/Frequency Data Format	16-bit integer, 32-bit floating point, 32-bit floating point (actual FREQ)	32-bit floating point with actual frequency	Data type for phasor and frequency data (Note 1)
Analog Data Format	16-bit integer, 32-bit floating point	32-bit floating point	Data format for analog data
Analog Data	Analog components	None	See Channel Names in Section 2.2.2.
Digital Data	None, 16 DI, 32 DI	None	Digital status words to be included in data frames (Note 5)
Reporting Rate, frames/s	1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 25, 30, 50, 60	10	Synchrophasor measurement rate (Note 2)
Service Class	P, M	P	PMU performance class
Time Synchronization	IRIG-B, IEEE 1588 (PTPv2)	IRIG-B	UTC time source
Spontaneous CFG Frames	NO, CFG-2, CFG-3	NO	Enables spontaneous configuration frames
Power Units	kW, W, MW	kW	Analog power channels units
Configuration Change Count	0-65535	0	Configuration change count
Client-server UDP/TCP Transmission			
Data Stream ID 1	1-65534	7000	Commanded data stream 1 ID number
Data Rate 1, frames/s	Submultiple of the PMU reporting rate	10	Commanded data stream 1 transmission rate
Data Stream ID 2	1-65534	7001	Commanded data stream 2 ID number
Data Rate 2, frames/s	Submultiple of the PMU reporting rate	10	Commanded data stream 2 transmission rate

Parameter	Options	Default	Description
Local UDP Port	1024-49151	4713	Device UDP port number for client-server connections
Local TCP Port	1024-49151	4712	Device TCP port number for client-server connections
Stop UDP Streams	NO, YES	NO	Stops all active controlled UDP streams
Spontaneous UDP Transmission			
Transmission Enabled 1	Disabled, Enabled	Disabled	Enables spontaneous data stream 1 transmission
Data Stream ID 1	1-65534	7002	Spontaneous data stream 1 ID number
Data Rate 1, frames/s	Submultiple of the PMU reporting rate	10	Spontaneous data stream 1 transmission rate
Destination UDP Port 1	1024-49151	4713	Destination port number for spontaneous data stream 1 transmission
Destination IP Address 1 (unicast/multicast)		225.100.100.1	Destination IP address for spontaneous data stream 1 transmission
Transmission Enabled 2	Disabled, Enabled	Disabled	Enables spontaneous data stream 2 transmission
Data Stream ID 2	1-65534	7003	Spontaneous data stream 2 ID number
Data Rate 2, frames/s	Submultiple of the PMU reporting rate	10	Spontaneous data stream 2 transmission rate
Destination UDP Port 2	1024-49151	4713	Destination port number for spontaneous data stream 2 transmission
Destination IP Address 2 (unicast/multicast)		225.100.100.2	Destination IP address for spontaneous data stream 2 transmission

NOTES:

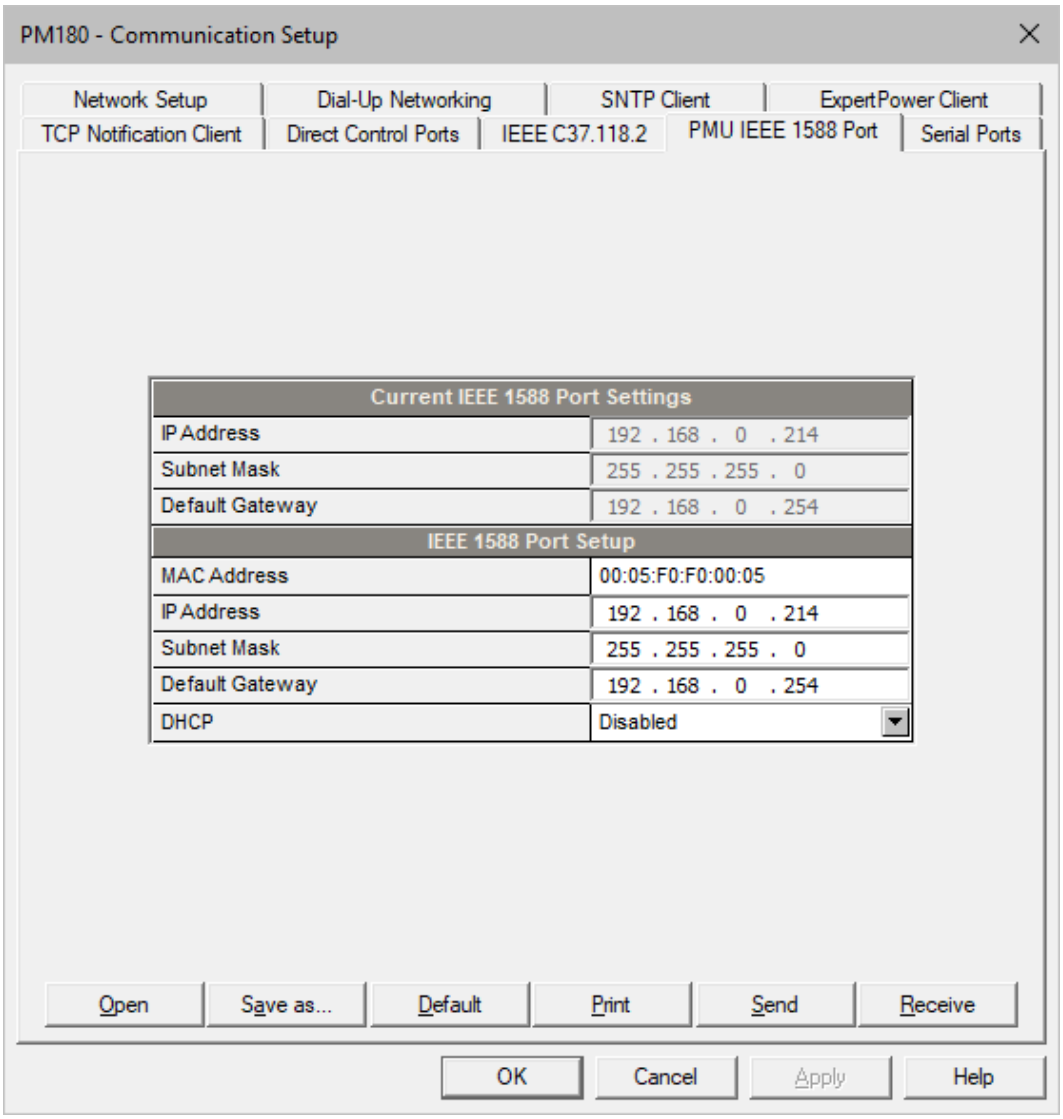
1. When 32-bit floating point (actual FREQ) is selected, the measured frequency is transmitted as the actual frequency, otherwise it is transmitted as the deviation from the nominal frequency.
2. The selected PMU reporting rate is automatically rounded up to the nearest sub-multiple of the nominal frequency. In case of using both IEEE C37.118.2 and IEC 61850 synchrophasor data communications, the new data rate is applied to both protocols.
3. A stream data rate must be a submultiple of the PMU reporting rate, otherwise it will be automatically set to the PMU reporting rate.
4. If the PMU data source ID number is set to 0 (default), the PMU ID repeats the data stream ID number in configuration messages.
5. When custom digital channel names are used, only channels with assigned custom names are indicated as valid inputs in configuration frames.
6. 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.
7. 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.
8. 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.

9. If you are using a TCP connection as an alternate channel for spontaneous stream control rather than for streaming synchrophasor data and want to keep the connection open, disable the TCP connection idle timeout via the device's network setup.
10. **Devices with firmware earlier than V31.XX.60 provide only one commanded TCP/UDP data stream and one spontaneous UDP data stream with the same ID number and a data rate fixed at the PMU reporting rate. Although the second data stream settings are accepted by the device, they will not take effect.**

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.



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.