Modbus is a serial communications protocol for connection industrial electronic devices. There are protocol versions for various communication mediums, including serial ports and TCP/IP.

Out of the function codes defined in the Modbus application protocol the PX2 firmware will support the following:

- Bit access
  - ? Read Coils (0x01)
  - ? Write Single Coil (0x05)
  - ? Write Multiple Coils (0x0F)
- 16 bits access
  - ? Read Holding Registers (0x03)
  - ? Write Single Register (0x06)
  - ? Write Multiple Registers (0x10)

## Functionality

The following features of the PX2 will be available using Modbus:

- Inlet, OCP, transfer switch and outlet sensors
- Outlet switching
- Transfer switch state and settings
- External sensors (type and reading)

The following functionality will not be available:

- Device configuration
- Model object settings
- Sensor thresholds and state
- External sensor identification (serial numbers)
- Event rules

## Testing Client

The implementation can be tested using the pymodbus Python client implementation:

```
import struct
from pymodbus.client.sync import ModbusTcpClient as ModbusClient
client = ModbusClient("192.168.2.123")

# read the outlet count (holding register 3):
rr = client.read_holding_registers(3, 1)
print "Number of outlets: %d" % rr.registers[0]

# read OCP 2 status:
rr = client.read_coils(2, 1)
print "OCP status: ", (rr.bits[0] and "closed" or "open")

# switch outlets 5..7 off:
client.write_coils(0x105, [False] * 3)

# read outlet 0 RMS voltage (convert 2 16-bit registers to 32-bit
floating point):
rr = client.read_holding_registers(0x8008, 2)
```

```
buffer = struct.pack("!HH", rr.registers[0], rr.registers[1])
voltage = struct.unpack("!f", buffer)
print "Outlet 0 voltage: %f V" % voltage

# read inlet 0 active energy counter (64-bit integer):
rr = client.read_holding_registers(0x3018, 4)
energy = (rr.registers[0] << 48) + (rr.registers[1] << 32) +
(rr.registers[2] << 16) + rr.registers[3]
print "Inlet 0 active energy: %d Wh" % energy
```

## Register Layout

The register sets accessed by single-bit and 16-bit function codes are distinct. Single-bit commands are used to access discrete hardware states (OCP state, outlet switching) while 16-bit commands will be used to query PDU capabilities and numeric sensor readings.

| Base Address | Size | Function |
|---|---|---|
| 0x0000 | 768 registers | Basic parameters, PDU layout |
| 0x0800 | 256 registers | External sensors |
| 0x2000 | 4096 registers | Transfer switches |
| 0x3000 | 4096 registers | Inlets |
| 0x4000 | 16384 registers | Overcurrent protectors |
| 0x8000 | 32768 registers | Outlets |

### Data Types

The following data types are used:

- Word: 16-bit unsigned integer
- DWord: 32-bit unsigned integer value (two registers, big-endian)
- QWord: 64-bit unsigned integer value (four registers, big-endian)
- Float: IEEE 32-bit floating point value (two registers, big-endian)
- Bit Mask: 16 separate bits

### Basic PDU Parameters

| Address | Type | Access | Parameter |
|---|---|---|---|
| 0x00 | Word | R | Register set version (8 bit major, 8 bit minor) |
| 0x01 | Word | R | Inlet count |
| 0x02 | Word | R | OCP count |
| 0x03 | Word | R | Outlet count |
| 0x04 | Word | R | Transfer switch count |

## External Sensors

- Up to 16 external sensors, 16 registers each
- Base address (i = 0..15): 0x800 + (i * 16)

<table>
<tr><th>Offset</th><th>Type</th><th>Access</th><th>Parameter</th></tr>
<tr><td>0x00</td><td>Word</td><td>R</td><td>Sensor type:<table><tr><th>Value</th><th>Type</th></tr><tr><td>0</td><td>unassigned</td></tr><tr><td>1</td><td>Temperature</td></tr><tr><td>2</td><td>Humidity</td></tr><tr><td>3</td><td>Air flow</td></tr><tr><td>4</td><td>Differential air pressure</td></tr><tr><td>5</td><td>Contact closure</td></tr><tr><td>6</td><td>Vibration</td></tr><tr><td>7</td><td>Water leak</td></tr><tr><td>8</td><td>Smoke detector</td></tr><tr><td>9</td><td>Ambient light</td></tr><tr><td>10</td><td>Dry contact actuator</td></tr><tr><td>11</td><td>Magnetic contact</td></tr><tr><td>12</td><td>Passive infrared motion detector</td></tr><tr><td>13</td><td>Tamper detector</td></tr></table></td></tr>
<tr><td>0x01</td><td>Word</td><td>R</td><td>State (for state sensors)</td></tr>
<tr><td>0x02~0x03</td><td>Float</td><td>R</td><td>Sensor reading (for numeric sensors)</td></tr>
<tr><td>0x04</td><td>Word</td><td>R/W</td><td>Control (for external actors, e.g. a door lock)</td></tr>
<tr><td>0x05~0x0f</td><td></td><td></td><td>Reserved</td></tr>
</table>

## Transfer Switches

- Up to 16 transfer switches, 256 registers each
- Base address (i = 0..15): 0x2000 + (i * 256)

<table>
<tr><th>Offset</th><th>Type</th><th>Access</th><th>Parameter</th></tr>
<tr><td>0x00</td><td>Bit Mask</td><td>R</td><td>Capabilities:<table><tr><th>Bit</th><th>Capability</th></tr><tr><td>0</td><td>Inlet voltage phase difference sensor</td></tr><tr><td>1~15</td><td>Reserved</td></tr></table></td></tr>
<tr><td>0x01</td><td>Word</td><td>R</td><td>Selected inlet (0 = none, 1 = Inlet 1, 2 = Inlet 2)</td></tr>
<tr><td>0x02</td><td>Word</td><td>R</td><td>Preferred inlet (1 = Inlet 1, 2 = Inlet 2)</td></tr>
<tr><td>0x03</td><td>Word</td><td>W</td><td>Transfer to inlet. If the new inlet is available it will become both active and preferred.<table><tr><th>Bit</th><th>Description</th></tr><tr><td>0~30</td><td>New active inlet (1 = Inlet 1, 2 = Inlet 2)</td></tr><tr><td>31</td><td>Force switch even if the phase difference between the inlets is too large</td></tr></table></td></tr>
<tr><td>0x04</td><td>Bit Mask</td><td>R</td><td>Fault flags:<table><tr><th>Bit</th><th>Description</th></tr><tr><td>0</td><td>Inlet phases out of sync</td></tr><tr><td>1</td><td>Overload</td></tr><tr><td>2~15</td><td>Reserved</td></tr></table></td></tr>
<tr><td>0x05</td><td>Bit Mask</td><td>R</td><td>Inlet 1 fault flags:<table><tr><th>Bit</th><th>Description</th></tr><tr><td>0</td><td>+12V Power Supply Fault</td></tr><tr><td>1</td><td>Fuse blown</td></tr><tr><td>2</td><td>MOV fault</td></tr><tr><td>3</td><td>Switch open</td></tr><tr><td>4</td><td>Switch short</td></tr></table></td></tr>
</table>

<table>
<tr><td></td><td></td><td></td><td><table><tr><th>Bit</th><th>Description</th></tr><tr><td>5~15</td><td>Reserved</td></tr></table></td></tr>
<tr><td>0x06</td><td>Bit Mask</td><td>R</td><td>Inlet 2 fault flags (see above)</td></tr>
<tr><td>0x07</td><td></td><td></td><td>Reserved</td></tr>
<tr><td>0x08~0x09</td><td>Float</td><td>R</td><td>Inlet voltage phase difference (degrees)</td></tr>
<tr><td>0x0a~0x1f</td><td></td><td></td><td>Reserved</td></tr>
<tr><td>0x20</td><td>Bit Mask</td><td>R/W</td><td>Transfer settings:<table><tr><th>Bit</th><th>Description</th></tr><tr><td>0</td><td>Enable automatic retransfer</td></tr><tr><td>1</td><td>Don't automatically retransfer if inlet phases are out of sync</td></tr><tr><td>2</td><td>Enable 'manual transfer' front panel button</td></tr><tr><td>3~15</td><td>Reserved</td></tr></table></td></tr>
<tr><td>0x21</td><td>Word</td><td>R/W</td><td>Auto retransfer wait time (s)</td></tr>
<tr><td>0x22</td><td>Bit Mask</td><td>R/W</td><td>Inlet 1 enabled voltage thresholds:<table><tr><th>Bit</th><th>Description</th></tr><tr><td>0</td><td>Lower critical threshold enabled</td></tr><tr><td>1</td><td>Lower warning threshold enabled</td></tr><tr><td>2</td><td>Upper warning threshold enabled</td></tr><tr><td>3</td><td>Upper critical threshold enabled</td></tr><tr><td>4~15</td><td>Reserved</td></tr></table></td></tr>
<tr><td>0x23</td><td>Word</td><td>R/W</td><td>Inlet 1 lower critical voltage threshold (0.01V)</td></tr>
<tr><td>0x24</td><td>Word</td><td>R/W</td><td>Inlet 1 lower warning voltage threshold (0.01V)</td></tr>
<tr><td>0x25</td><td>Word</td><td>R/W</td><td>Inlet 1 upper warning voltage threshold (0.01V)</td></tr>
<tr><td>0x26</td><td>Word</td><td>R/W</td><td>Inlet 1 upper critical voltage threshold (0.01V)</td></tr>
</table>

| | | | |
|---|---|---|---|
| 0x27 | Word | R/W | Inlet 1 voltage assertion timeout (s) |
| 0x28 | Word | R/W | Inlet 1 voltage deassertion hysteresis (0.01V) |
| 0x29 | Bit Mask | R/W | Inlet 1 enabled frequency thresholds (see above) |
| 0x2a | Word | R/W | Inlet 1 lower critical frequency threshold (0.01Hz) |
| 0x2b | Word | R/W | Inlet 1 lower warning frequency threshold (0.01 Hz) |
| 0x2c | Word | R/W | Inlet 1 upper warning frequency threshold (0.01 Hz) |
| 0x2d | Word | R/W | Inlet 1 upper critical frequency threshold (0.01Hz) |
| 0x2e | Word | R/W | Inlet 1 frequency assertion timeout (s) |
| 0x2f | Word | R/W | Inlet 1 frequency deassertion hysteresis (0.01Hz) |
| 0x30 | Bit Mask | R/W | Inlet 2 enabled voltage thresholds (see above) |
| 0x31 | Word | R/W | Inlet 2 lower critical voltage threshold (0.01V) |
| 0x32 | Word | R/W | Inlet 2 lower warning voltage threshold (0.01V) |
| 0x33 | Word | R/W | Inlet 2 upper warning voltage threshold (0.01V) |
| 0x34 | Word | R/W | Inlet 2 upper critical voltage threshold (0.01V) |
| 0x35 | Word | R/W | Inlet 2 voltage assertion timeout (s) |
| 0x36 | Word | R/W | Inlet 2 voltage deassertion hysteresis (0.01V) |
| 0x37 | Bit Mask | R/W | Inlet 2 enabled frequency thresholds (see above) |
| 0x38 | Word | R/W | Inlet 2 lower critical frequency threshold (0.01Hz) |
| 0x39 | Word | R/W | Inlet 2 lower warning frequency threshold (0.01 Hz) |
| 0x3a | Word | R/W | Inlet 2 upper warning frequency threshold (0.01 Hz) |
| 0x3b | Word | R/W | Inlet 2 upper critical frequency threshold (0.01Hz) |
| 0x3c | Word | R/W | Inlet 2 frequency assertion timeout (s) |
| 0x3d | Word | R/W | Inlet 2 frequency deassertion hysteresis (0.01Hz) |
| 0x3e~0xff | | | Reserved |

## Inlets

- Up to 16 inlets, 256 registers each
- Base address (i = 0..15): 0x3000 + (i * 256)

<table>
<tr><th>Offset</th><th>Type</th><th>Access</th><th>Parameter</th></tr>
<tr><td>0x00</td><td>Bit Mask</td><td>R</td><td>Capabilities:<table><tr><th>Bit</th><th>Capability</th></tr><tr><td>0</td><td>Voltage sensor</td></tr><tr><td>1</td><td>Current sensor</td></tr><tr><td>2</td><td>Peak current sensor</td></tr><tr><td>3</td><td>Reserved</td></tr><tr><td>4</td><td>Unbalanced current sensor</td></tr><tr><td>5</td><td>Active power sensor</td></tr><tr><td>6</td><td>Apparent power sensor</td></tr><tr><td>7</td><td>Power factor sensor</td></tr><tr><td>8</td><td>Active energy counter</td></tr><tr><td>9</td><td>Apparent energy counter</td></tr><tr><td>10</td><td>Phase angle sensor</td></tr><tr><td>11</td><td>Line frequency sensor</td></tr><tr><td>12</td><td>Reactive power sensor</td></tr><tr><td>13</td><td>Reactive energy counter</td></tr><tr><td>14</td><td>Power quality</td></tr><tr><td>15</td><td>Surge protector status</td></tr></table></td></tr>
<tr><td>0x01</td><td>Word</td><td>R</td><td>Reserved</td></tr>
<tr><td>0x02</td><td>Word</td><td>R</td><td>Pole count</td></tr>
<tr><td>0x03</td><td>Word</td><td>R</td><td>Voltage rating (V, min)</td></tr>
<tr><td>0x04</td><td>Word</td><td>R</td><td>Voltage rating (V, max)</td></tr>
<tr><td>0x05</td><td>Word</td><td>R</td><td>Current rating (A)</td></tr>
</table>

| Offset | Type | Access | Parameter |
|---|---|---|---|
| 0x06~0x07 | | | Reserved |
| 0x08~0x09 | Float | R | RMS voltage (V) |
| 0x0a~0x0b | Float | R | RMS current (A) |
| 0x0c~0x0d | Float | R | Peak current (V) |
| 0x0e~0x0f | Float | R | Reserved |
| 0x10~0x11 | Float | R | Unbalanced current (%) |
| 0x12~0x13 | Float | R | Active power (W) |
| 0x14~0x15 | Float | R | Apparent power (VA) |
| 0x16~0x17 | Float | R | Power factor (no unit) |
| 0x18~0x1b | QWord | R | Active energy (Wh) |
| 0x1c~0x1f | QWord | R | Apparent energy (VAh) |
| 0x20~0x21 | Float | R | Phase angle (U-I, degrees) |
| 0x22~0x23 | Float | R | Line frequency (Hz) |
| 0x24~0x25 | Float | R | Reactive power (var) |
| 0x26~0x29 | QWord | R | Reactive energy (varh) |
| 0x2a | Word | R | Power quality:<br>**Value** / **Description**<br>0 – Unknown<br>1 – Normal<br>2 – Warning<br>3 – Critical |
| 0x2b~0x2f | | | Reserved |
| 0x30 | Word | R | Surge protector status: 0 = OK, 1 = alarm |
| 0x31~0x3f | | | Reserved |

| Offset | Type | Access | Parameter |
|---|---|---|---|
| 0x40~0x6f | | | Pole 1 |
| 0x70~0x9f | | | Pole 2 |
| 0xa0~0xcf | | | Pole 3 |
| 0xd0~0xff | | | Pole 4 |

### Overcurrent Protectors

- Up to 64 OCPs, 256 registers each
- Base address (i = 0..63): 0x4000 + (i * 256)
- Coil address (i = 0..63): 0x0000 + i

| Offset | Type | Access | Parameter |
|---|---|---|---|
| 0x00 | Bit Mask | R | Capabilities:<br>Bit / Capability<br>0 – Reserved<br>1 – Current sensor<br>2 – Peak current sensor<br>3~14 – Reserved<br>15 – Trip detection (coil) |
| 0x01 | Word | R | Reserved |
| 0x02 | Word | R | Pole count |
| 0x03~0x04 | | | Reserved |
| 0x05 | Word | R | Current rating (A) |
| 0x06~0x07 | | | Reserved |
| 0x08~0x09 | Float | R | Reserved |
| 0x0a~0x0b | Float | R | RMS current (A) |
| 0x0c~0x0d | Float | R | Peak current (A) |
| 0x0e~0x3f | | | Reserved |
| 0x40~0x6f | | | Pole 1 |

| Offset | Type | Access | Parameter |
|---|---|---|---|
| 0x70~0x9f | | | Pole 2 |
| 0xa0~0xcf | | | Pole 3 |
| 0xd0~0xff | | | Pole 4 |

The OCP status is reported as a single bit (coil) that can be queried using the Read Coils function:

- 0: OCP open
- 1: OCP closed

### Outlets

- Up to 128 outlets, 256 registers each
- Base address (i = 0..127): 0x8000 + (i * 256)
- Coil address (i = 0..127): 0x0100 + i

| Offset | Type | Access | Parameter |
|---|---|---|---|
| 0x00 | Bit Mask | R | Capabilities:<br>Bit 0: Voltage sensor<br>Bit 1: Current sensor<br>Bit 2: Peak current sensor<br>Bit 3: Maximum current sensor<br>Bit 4: Unbalanced current sensor<br>Bit 5: Active power sensor<br>Bit 6: Apparent power sensor<br>Bit 7: Power factor sensor<br>Bit 8: Active energy counter<br>Bit 9: Apparent energy counter<br>Bit 10: Phase angle sensor<br>Bit 11: Line frequency sensor<br>Bit 12: Reactive power sensor<br>Bit 13: Reactive energy counter |

| Offset | Type | Access | Parameter |
|---|---|---|---|
| | | | <table><tr><th>Bit</th><th>Capability</th></tr><tr><td>14</td><td>Reserved</td></tr><tr><td>15</td><td>Switched</td></tr></table> |
| 0x01 | Word | R | Reserved |
| 0x02 | Word | R | Pole count |
| 0x03 | Word | R | Voltage rating (V, min) |
| 0x04 | Word | R | Voltage rating (V, max) |
| 0x05 | Word | R | Current rating (A) |
| 0x06~0x07 | | | Reserved |
| 0x08~0x09 | Float | R | RMS voltage (V) |
| 0x0a~0x0b | Float | R | RMS current (A) |
| 0x0c~0x0d | Float | R | Peak current (A) |
| 0x0e~0x0f | Float | R | Maximum current (A) |
| 0x10~0x11 | Float | R | Unbalanced current (%) |
| 0x12~0x13 | Float | R | Active power (W) |
| 0x14~0x15 | Float | R | Apparent power (VA) |
| 0x16~0x17 | Float | R | Power factor (no unit) |
| 0x18~0x1b | QWord | R | Active energy (Wh) |
| 0x1c~0x1f | QWord | R | Apparent energy (VAh) |
| 0x20~0x21 | Float | R | Phase angle (U-I, degrees) |
| 0x22~0x23 | Float | R | Line frequency (Hz) |
| 0x24~0x25 | Float | R | Reactive power (var) |
| 0x26~0x29 | QWord | R | Reactive energy (varh) |
| 0x2a~0x3f | | | Reserved |

| Offset | Type | Access | Parameter |
|---|---|---|---|
| 0x40~0x6f | | | Pole 1 |
| 0x70~0x9f | | | Pole 2 |
| 0xa0~0xcf | | | Pole 3 |
| 0xd0~0xff | | | Pole 4 |

Switched outlets (i.e. if bit 15 in capabilites bit mask is set) are controlled using a single bit (coil) accessed using the Read/Write Coils functions:

- 0: Switch off outlet / Outlet is switched off
- 1: Switch on outlet / Outlet is switched on

### Poles

- 32 registers each
- Embedded into the register space of inlets, OCPs or outlets

| Offset | Type | Access | Parameter |
|---|---|---|---|
| 0x00 | Bit Mask | R | Capabilities:<br>Bit / Capability<br>0 Voltage sensor<br>1 Current sensor<br>2 Peak current sensor<br>3~4 Reserved<br>5 Active power sensor<br>6 Apparent power sensor<br>7 Power factor sensor<br>8 Active energy counter<br>9 Apparent energy counter<br>10 Phase angle sensor<br>11 Line frequency sensor<br>12 Reactive power sensor<br>13 Reactive energy counter |

| Offset | Type | Access | Parameter |
|---|---|---|---|
| | | | Bit: 14~15 — Capability: Reserved |
| 0x01~0x07 | | | Reserved |
| 0x08~0x09 | Float | R | RMS voltage (V) |
| 0x0a~0x0b | Float | R | RMS current (A) |
| 0x0c~0x0d | Float | R | Peak current (A) |
| 0x0e~0x0f | | | Reserved |
| 0x10~0x11 | Float | R | Unbalanced current (%) |
| 0x12~0x13 | Float | R | Active power (W) |
| 0x14~0x15 | Float | R | Apparent power (VA) |
| 0x16~0x17 | Float | R | Power factor (no unit) |
| 0x18~0x1b | QWord | R | Active energy (Wh) |
| 0x1c~0x1f | QWord | R | Apparent energy (VAh) |
| 0x20~0x21 | Float | R | Phase angle (U-I, degrees) |
| 0x22~0x23 | Float | R | Line frequency (Hz) |
| 0x24~0x25 | Float | R | Reactive power (var) |
| 0x26~0x29 | QWord | R | Reactive energy (varh) |
| 0x2a~0x2f | | | Reserved |