Simplified Digital Connectivity using MODBUS TCP/IP for iSeries Instruments

August 20, 2009

The Thermo Scientific line of iSeries instruments has advanced communication features that can be utilized with minimal effort. The purpose of this bulletin is to outline the advantages of using digital connectivity for iSeries instruments, and to explain in simplified terms how to connect your iSeries analyzers using digital technology. The use of digital technology via Ethernet connectivity provides a substantial cost savings for users. Using standard, open source protocols removes custom programming from the scope of system integration. This bulletin is specific to using MODBUS TCP, and will not cover Geysitech (Bayern-Hessen) or CLINK protocols. (See any Thermo Scientific iSeries manual for further discussion on those protocols, as well as legacy serial connection systems).

For the purpose of this paper, the term ‘System” means any of the following:

- A set of analyzers used to monitor the emissions from a stationary or mobile source, i.e. CEM or CEMS, CMMS, Opacity, Flow, etc.
- A set of analyzers or single analyzer used in an ambient monitoring station.
- A single analyzer connected to a network, simple point-to-point PC, or PLC/Data logger.
- Any other situation where analyzers are employed and the data is stored by another device.

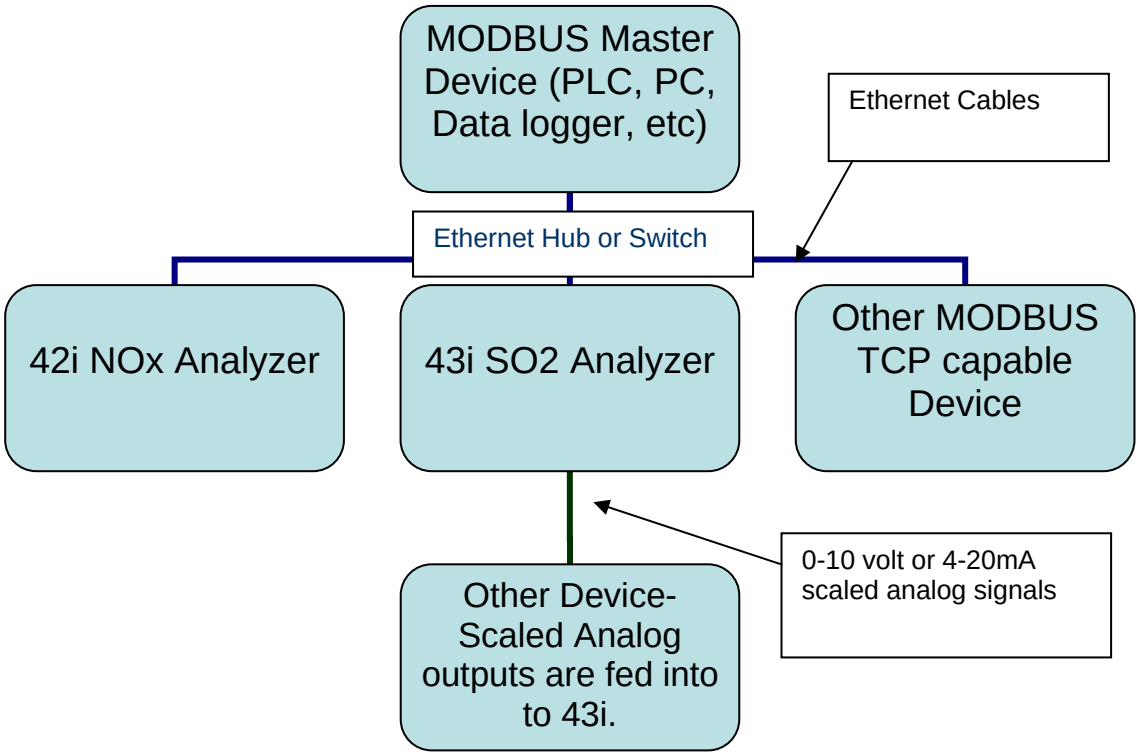

Figure 1: Example Digital System

First, we offer many points to consider when designing a System:

- The amount of information that can be carried over an Ethernet cable is thousands of times more than a single analog paired cable.(i.e. 0-10 volt or 4-20mA scaled signal)
- For a large system, the amount of wiring required for all signals is dramatically reduced when Ethernet is used instead of scaled analog signals.
- Analog signals create artificial ranges that would not exist if digital connectivity is employed. Modern CEM and Ambient systems can be considered 'rangeless' in regards to connectivity.
- Hubs, routers, switches, and fiber optic connection options are now common in locations where gas analyzers are used.
- Remote diagnostic capabilities are greatly enhanced when using Ethernet vs. scaled analog signals.
- The standard iSeries analyzer contains 6 scaled analog outputs. Ethernet allows virtually unlimited outputs with 1-second update times.
- Other scaled analog signals can be fed into the iSeries line of analyzers, such as a wind speed sensor, Opacity Monitor, Flow Monitor, or Oxygen analyzer. This data is then available over the Ethernet. Any device with a standard output can be logged using this feature.
- Every single I/O point has the potential to require troubleshooting, and can be costly and time consuming to install. With analog communications, many paired cables are required per each analyzer used. Using Ethernet, only a single connection is used. This will result in significant reduction in labor and material costs. There is only one single point on troubleshooting.
- Additionally, with analog systems, each analog channel requires calibration. With digital Ethernet, this is never required.

Using MODBUS TCP, a license free protocol, you can connect numerous devices on a standard network.

MODBUS Master: This is the device that manages the system. Popular devices include:

- ESC Model 8832 Data logger
- Allen Bradley PLC with ProSoft Module
- Modicon, GE FANUC, Siemens, or other PLC
- A standard PC running ModScan32 or other software program

These are just examples, and many more devices can be found on www.MODBUS.org

Typical communications functions performed by the MODBUS Master include:

- *Checking data values and logging data (use the Read Registers)*
- *Reading system and alarm status, and reacting (use the Read Coils)*
- *Triggering actions/events such as calibration checks or calibrations (Use the Write Coils)*

Coils: Coils are binary 'registers' that are either "On" or "Off". Some coils are controlled by the iSeries Analyzer, and others are controlled by the MODBUS Master. Coils allow the MODBUS Master to 'see' the statuses of many items, and control others. There are 2 types of coils, "Read Coils", and "Write Coils".

Read Coils: These are statuses that the MODBUS Master device reads. Typical coils include alarms that the instrument annunciates, modes that the instrument is in, and status in regards to ancillary items inside the analyzer that may or may not be active.

Example Read Coil table is shown with an excerpt from the list for the 42i NOx analyzer:

Coil Number	Status
1	AUTORANGE (NOx)
2	LOCAL/REMOTE
3	SERVICE
4	UNITS
5	ZERO MODE
6	SPAN MODE
7	NO MODE
8	NOx MODE
11	GEN ALARM
12	NO CONC MAX ALARM
22	INT TEMP ALARM
23	CHAMB TEMP ALARM
24	COOLER TEMP ALARM
25	NO2 CONVERTER TEMP ALARM
26	NOT USED
27	PERM OVEN GAS TEMP ALARM
28	PRESSURE ALARM
29	FLOW ALARM
30	OZONE FLOW ALARM
31	MOTHERBOARD STATUS ALARM
32	INTERFACE BD STATUS ALARM
33	I/O EXP BD STATUS ALARM

Write Coils: These are the actions that the MODBUS Master causes to happen. Typical actions are to adjust calibrations, to trigger span and zero valves to open/close, change instrument modes, etc.

Example Write Coil table is shown for 42i NOx analyzer:

Coil	Action Triggered
101	ZERO MODE
102	SPAN MODE
103	NO MODE
104	NOX MODE
105	NOT USED
106	PRE MODE
107	SET BACKGROUND
108	CAL TO LO SPAN
109	AOUTS TO ZERO
110	AOUTS TO FS
111	CAL TO HI SPAN

Registers: Registers are floating point values that can be read by the MODBUS Master. These are simply values (numbers) that are exchanged between the MODBUS Master and the iSeries Analyzer. The MODBUS Master reads the "Read Coils" on the iSeries Analyzer to obtain values for concentrations, pressures, flowrates, etc.
The iSeries Analyzer does not command and control the MODBUS Master, thus "Write Registers" are not supported or needed.

Read Registers: These are values that the MODBUS Master reads from the iSeries Analyzer.

Example Read Register Table from 42i NOx analyzer

Register Number	Variable
1 & 2	NO
3 & 4	NO2
5 & 6	NOx
11 & 12	LOW NO
13 & 14	LOW NO2
15 & 16	LOW NOx
21 & 22	HIGH NO
23 & 24	HIGH NO2
25 & 26	HIGH NOx
31 & 32	RANGE (NOx)
35 & 36	INTERNAL TEMPERATURE
37 & 38	CHAMBER TEMPERATURE
39 & 40	COOLER TEMPERATURE
41 & 42	NO2 CONVERTER TEMP
45 & 46	PERM OVEN GAS
47 & 48	PERM OVEN HEATER
49 & 50	CHAMBER PRESSURE
51 & 52	SAMPLE FLOW
53 & 54	PMT VOLTS
55 & 56	ANALOG IN 1
57 & 58	ANALOG IN 2
59 & 60	ANALOG IN 3

In summary, there are 3 things that need to be programmed in order to command, control, and log data from any iSeries Analyzer. These are the Read Coils for obtaining alarms and statuses, Write Coils for command and control, and Read Registers for gathering the concentration and diagnostic information. It is common for the MODBUS Master to "poll" each device on the network once per second.

Points to consider when designing your system using Digital Connectivity:

- Consider that analog signals will be brought in via Ethernet, thus no expensive analog input cards will be required for the system. If a PLC is used as a MODBUS Master, only a single communication module is required, instead of the multiple cards required for legacy analog operation.
- Consider bringing in diagnostic data from each instrument into the MODBUS Master and logging it, along with the concentration data. This will allow you to trend diagnostics, and can enhance maintenance and diagnostics.

- After your network is constructed, consider converting from Ethernet to Fiber Optic cable from the shelter to other plant networks.
- Note that each device on a MODBUS TCP network needs a unique ID. On the iSeries Analyzer, the default MODBUS ID is the instrument model number. i.e. The default ID on the 42i NOx analyzer is 42. This can be easily changed in the communication menu on the analyzer. Valid numbers are from 0 to 127.

The appendix of each iSeries Analyzer manual provides a description of the MODBUS Protocol Interface and is supported both over RS-232/485 (RTU protocol) as well as TCP/IP over Ethernet. The MODBUS protocol support for the *i*Series enables the user to perform the functions of reading the various concentrations and other analog values or variables, read the status of the digital outputs of the instrument, and to trigger or simulate the activation of a digital input to the instrument. This is achieved by using the supported MODBUS commands that are listed in the appendix.

MODBUS TCP/IP has become an industry standard because of its openness, simplicity, low development cost, and minimum hardware required to support it. Since TCP/IP is the transport protocol of the Internet, this automatically means that MODBUS TCP/IP can be used over the internet. In practical terms, this means that any MODBUS TCP/IP device can be controlled and managed over the internet from anywhere in the world. It is also ideal for use over networks including wireless broadband GPRS/EDGE/CDMA, satellite, and local area network systems.

We at Thermo Fisher Scientific are dedicated to helping you and your team keep-up with the latest technology and communication protocols. For more information and consultation on connectivity, feel free to contact us at www.thermo.com/aqi or call our technical support line at 866-282-0430.