ANALOG INPUT SCALING

12 bit: \(0 - 4095\) \(\approx\) \(-2048\) to \(2047\)
16 bit: \(0 - 65535\) \(\approx\) \(-32768\) to \(32767\)

\[\pm 10,000 \, \text{V} \]
\[\% 0.31 \, \text{V} / \text{bit}\]

12 bit \(\approx\) 4.9 V / bit

16 bit \(\approx\) 12 bit

32767 \(\Rightarrow\) 12 bit

ENGINEERING UNITS

\(10,000 = 10,100 \, \text{ft} / \text{sec}\)

\[\frac{10,000}{10} = 2047\]

\[60 \times 100\]

\[6000 \times 59.99 \, \text{Hz}\]

1000 x 10 = 10,000
DNP Details – Levels

• Three Levels of Implementation
• Level Implementation Determines Protocol Capabilities.
• Standard Features Per Level
• Optional Features Per Level
• Level 1 – Least Complex → Level 3 Most Complex
  – Level 1 Features are included in the Level 3 Implementations
  – All Level Implementations Are Interoperable Utilizing The Same Physical Network

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DNP Details – Levels

DNP IMPLEMENTATION HIERARCHY

DNP 3.0

Level 1

Optional Features

Level 2

Optional Features

Level 3

Optional Features

Same Definition for Serial and Ethernet Infrastructures

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DNP Details – Levels

– DNP Level 1

  • DNP Level 1 is intended for use between a master station or data concentrator and a small end device (e.g. Meter, relay or capacitor bank controller)
    – Level 1 slave functions
      » Reads of class data objects
      » Reads of binary output and analog output data objects
      » Control operations to binary output and analog output data objects
      » Write to restart internal indication bit
      » Cold restart
      » Write time
      » If capable of sending unsolicited messages must be able to turn off
DNP Details – Levels

– DNP Level 1
  – Level 1 master functions
    » Accept the following data object types
    » Binary inputs and events
    » Counters and counter events
    » Analog inputs and events
    » Binary and analog output status
DNP Details – Levels

– DNP Level 2
  – Perform all Level 1 slave functions AND
    » Accepts freeze requests on binary counter objects
    » Parses read requests for variation 0 (all variations) for some objects
    » Parses read requests for variations 1,2 & 3 of binary change objects
    » Parses and may respond to requests for frozen counter objects
    » May send unsolicited responses containing static data
  
  – Perform all Level 1 master functions
DNP Details – Levels

– DNP Level 3
   – Perform all Level 1 & 2 slave functions AND
     » Slave will process read requests for many specific objects and variations
     » Supports a larger range of requests and function codes
     » Enabling and disabling of unsolicited responses on a class-by-class basis
     » Eg, will process the following
       • Class 1 – (object 60, var 2, qualifier 6)
       • Class 2 – (object 60, var 3, qualifier 6)
       • Class 3 – (object 60, var 4, qualifier 6)
DNP Details - Deadbands

- So what’s with all of this “Analog Change” stuff?
- Assignment Supported Via Protocol in Some Level 3 Devices
- Assigns A Band, That When Exceeded, Reports The Data
  - Change Event (IIN Bit Update For Report By Exception)
  - Unsolicited (Report Data When Unsolicited Event Buffer Is Saturated)
DNP Details - Classes

- A Class Scan Inputs A Collection of Objects Returned In One Request
- Class 0 Is Referred To As A Static Scan
  - Only Static Data Is Returned
  - All Device Data Is Returned In Response To A Class 0 Scan
  - Is Comprised of Static Object Returned Data
    - Object 1 – Digital Input
    - Object 10 – Digital Output
    - Object 20 – Counter
    - Object 30 – Analog Inputs
    - Object 40 – Analog Output
- Class 1, or Class 2, or Class 3
  - Is A Collection of Arbitrary Data Elements Grouped Together by the System Architect To Be Returned On An Event Change
  - Is referenced By The IIN (Internal indication and Notification Bits)
  - Is Comprised of Objects Change Events
    - Object 2 – Change Event Digital
    - Object 32 – Change Event Analog
    - Object 21 – Change Event Counter

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Class 1 - Binary

Prioritize Class 1 - Critical Areas
2 sec Class 2 - "Important" Areas
3 min Class 3 - Non-Critical Data
DNP Details – Polling

- Four DNP Operation Modes.
  - Polled static operation
    - Ask for Information Status (Static Data)... What is the status NOW!
    - DNP Terminology “Class 0 Poll” or “Static Data Poll”
  - Polled Report-by-Exception (RBE)
    - The Master Host may request static data, but the outstation remote slave device will respond with a flag indicating changed data is available for retrieval
    - When Host senses Change Flag, then host will Request Class 1,2,3 data or Change Event Data
  - Unsolicited RBE with background integrity poll
    - When Data Changes, in the IED Database the IED reports any data change without the host asking if any data changed
    - On a timed basis will ask for Changed Data and Static Data
  - Unsolicited RBE or quiescent
    - The host node only waits for the IED to send Change Event Data upon a data element change

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DNP Details – Device Health/Internal Indications

- Internal Indications (IIN)
  - IIN1.0
    - All_STATIONS
      - An all-stations message was received
  - IIN1.1
    - The RTU has unreported class 1 events
  - IIN1.2
    - The RTU has unreported class 2 events
  - IIN1.3
    - The RTU has unreported class 3 events
  - IIN1.4
    - Time synchronization is required
  - IIN1.5
    - LOCAL_CONTROL
  - IIN1.6
    - DEVICE_TROUBLE
    - An abnormal, device-specific condition exists

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DNP Details – Device Health/Internal Indications

- Internal Indications (IIN)

  - IIN2.0      NO_FUNC_CODE_SUPPORT
    – The RTU does not support this function code
  - IIN2.1      OBJECT_UNKNOWN
    – RTU does not support requested operation for objects in the request
  - IIN2.2      PARAMETER_ERROR
    – A parameter error was detected
  - IIN2.3      EVENT_BUFFER_OVERFLOW
    – An event buffer overflow condition exists in the RTU and at least one unconfirmed event was lost
  - IIN2.4      ALREADY_EXECUTING
    – The operation requested is already executing. Support is optional
  - IIN2.5      CONFIG_CORRUPT
    – The outstation detected corrupt configuration. Support is optional
  - IIN2.6, 7   RESERVED_2 , _1
    – Reserved for future use. Always set to 0

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DNP Details – Message Structure

Master Station (Client)
- Station A

Host

START

Not A Master Station (Server)
- Station B

Outstation

<table>
<thead>
<tr>
<th>05 64</th>
<th>LENGTH</th>
<th>DLCF</th>
<th>DLSB</th>
<th>DMSB</th>
<th>SLSB</th>
<th>SMSB</th>
<th>CRC HI</th>
<th>CRC LO</th>
</tr>
</thead>
</table>

Data Link Control Field
- DESTINATION Node Address
- SOURCE Node Address

FROM PRIMARY (Initiation Station) to SECONDARY
FROM SECONDARY (Responding Station) to PRIMARY

- This is the minimum DNP message Length (Block 0) and is a Length of 5 Octets (10 octets including START and CRC).
# DNP Details – Message Structure

## DATA LINK Control Field

<table>
<thead>
<tr>
<th>DIR</th>
<th>PRM</th>
<th>FCB</th>
<th>FCV</th>
<th>RES</th>
<th>OFC</th>
<th>FUNCTION CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

FROM PRIMARY (Initiation Station) to SECONDARY
FROM SECONDARY (Responding Station) to PRIMARY

- **DIR** = DIRECTION -
  - 1 = From A to B
  - 0 = From B to A
  - Frame direction with respect to the master.

- **PRM** = Data Flow Control
  - 1 = Frame from Initiating Station
  - 0 = Frame from Responding Station
  - Initiation Frame or Responding Frame Designation.

- **FCB** = Frame Count Bit
  - Toggles with each SEND/CONFIRM COMBINATION
  - (With Each Completed Host / Outstation transaction).
  - Indicates duplication or frame loss.

- **FCV** = Frame Count Valid
  - 1 = Frame Count Bit Valid
  - 0 = Ignore Frame Count Bit.
  - Enables Function of Frame Count Bit. (Sent From Host)

- **RES** = Reserved Bit - No Function Defined

- **DFC** = Data Flow Control
  - 1 = D L Buffer Overflow Condition in Receiving Station
  - 0 = Primary Can Send Data.
  - Prevents Overflow of Data buffers in IED (Buffer Health Indication of Responding Station)
FIN = Final Indication  
1 = FINAL Frame in sequence  
0 = More Frames Follow

FIR = FIRst Frame  
1 = FIRst Frame In a Sequence  
0 = Not The First Frame

0 <= Sequence Number <= 63  (Number rolls over if more frames than 63)

- Allows Primary and Secondary Devices to Assemble Multi-Fragment Messages.

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APPLICATION LAYER

- Application Header is 2 Octets As Illustrated
- Application Fragment contains Individual Object Headers and Object Data
APPLICATION LAYER

- Application Header is 2 Octets As Illustrated
- Application Fragment contains Individual Object Headers and Object Data
Application Header (Request)

FIN = Final Indication  
FIR = FIRst Frame  
AP CONF. = Application Confirm  
UNSOL = Unsolicited  
SEQUENCE NUMBER

1 = FINal Fragment in sequence  
1 = First Fragment In a Sequence  
1 = Ap Layer Confirm Expected  
1 = Unsolicited Message  
0 <= X <= 15 – Sequence Fragment Number  
0 = More Fragments Follow  
0 = Not The First Fragment  
0 = No Ap Layer Confirm Expected.  
0 = Pollled Message  
(Rollover at 15)
DNP Details – Message Example

– Query

   » 05 64 14 C4 01 00 65 00 29 7D
   » DE CE 01 3C 04 06 3C 03 06 3C 02 06 3C 01 06 EE 5D

• 05 64 // start
• 14 // length (not including CRC)
• C4 // data link control field
• 01 00 // destination device address
• 65 00 // source device address
• 29 7D crc
DNP Details – Message Example

– Query

» 05 64 14 C4 01 00 05 00 2B 25
» DE CE 01 3C 04 06 3C 03.06 3C 02 06 3C 01 06 EE 5D

• DE CE // Transport Header / Application Control
• 01 // Application Function (Read)
• 3C 04 06 // Obj60 (class), Var4 (class 3), Qual6 (all points)
• 3C 03 06 // Obj60 (class), Var4 (class 2), Qual6 (all points)
• 3C 02 06 // Obj60 (class), Var4 (class 1), Qual6 (all points)
• 3C 01 06 // Obj60 (class), Var4 (class 0), Qual6 (all points)
• EE 5D crc
DNP Details – Message Example

– Response

05 64 FF 44 65 00 01 00 17 ED

64 EE 81 00 00 20 02 17 14 10 01 3A 0E 11 01 2C EA BF
06 17 01 A7 00 1C 01 A3 00 2F 01 F6 F1 30 01 E7 4D 90
F8 31 01 7C 03 06 01 D2 0D 25 01 EB F1 26 01 F6 31 C5
F8 10 01 48 0E 11 01 3F 06 1C 01 A7 00 2F 01 ED 09 1B
F1 30 01 EE F8 06 01 B6 0D 07 01 72 06 22 01 A3 66 0D
00 25 01 FA F1 26 01 04 F9 01 02 00 00 EF 01 81 21 12
01 01 01 81 01 01 01 01 01 01 01 01 01 01 01 74 13
01 01 01 01 01 01 01 01 01 01 01 01 01 01 01 67 CF
01 01 01 01 01 01 01 01 01 01 01 01 01 01 01 38 02
81 01 01 01 01 01 01 01 01 01 01 01 01 01 01 87 F4
81 81 81 81 01 01 01 01 01 01 01 01 01 01 01 86 E7
01 01 01 01 01 01 01 01 01 01 01 01 01 01 01 88 C3
01 01 01 81 01 01 01 01 01 01 01 01 01 01 01 74 13
01 01 01 01 01 01 01 01 81 01 01 01 01 01 01 4F 3F
01 01 01 01 01 81 01 01 01 01 01 81 01 01 01 5D 9D
01 01 01 01 01 01 01 01 8D 7B

- 05 64 // start
- FF // length (not including CRC)
- 44 // data link control field
- 65 00 // destination device address
- 01 00 // source device address

17 ED crc

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DNP Details – Message Example

05 64 FF 64 65 00 01 00 17 ED

64 EE 81 00 00 20 02 17 14 10 01 3A 0E 11 01 2C EA BF

- 64 EE // Transport Header / Application Control
- 81 // Application Function (Read)
- 00 00 // Internal Indications
- 20 02 17 // Object/Variation/Qualifier
- 14 // Number of objects returned
- 10 (index) 01 (quality) 3A 0E (value) // Index Flag, Value
- 15 02 crc
DNP Details – Message Example

- 05 64 FF 44 65 00 01 00 17 ED
- 64 EE 81 00 00 20 02 17 14 10 01 3A 0E 11 01 2C EA BF
- 06 17 01 A7 00 1C 01 A3 00 2F 01 F6 F1 30 01 E7 4D 90

- 11 (index) 01 (flag) 2C 06 (value) // Index Flag, Value
- 17 (index) 01 (flag) A7 00 (value) // Index Flag, Value
- 1C (index) 01 (flag) A3 00 (value) // Index Flag, Value
- 2F (index) 01 (flag) F6 F1 (value) // Index Flag, Value
DNP Details – Device Profile

– All DNP Server/Slave devices must have a device profile  CLIENT/MASTER
Questions?

• Thank you for your attention.