HartTools

Software Documentation

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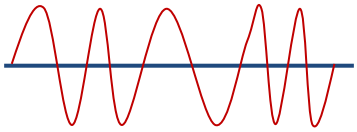
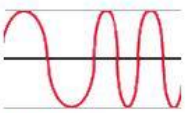
Date: 15.8.2023



Real Time
WINAPI

Software Solutions for
Hart Instruments Developers



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Contents

Overview

HartTools is a set of components used to provide applications based on Hart communication on a Windows computer.

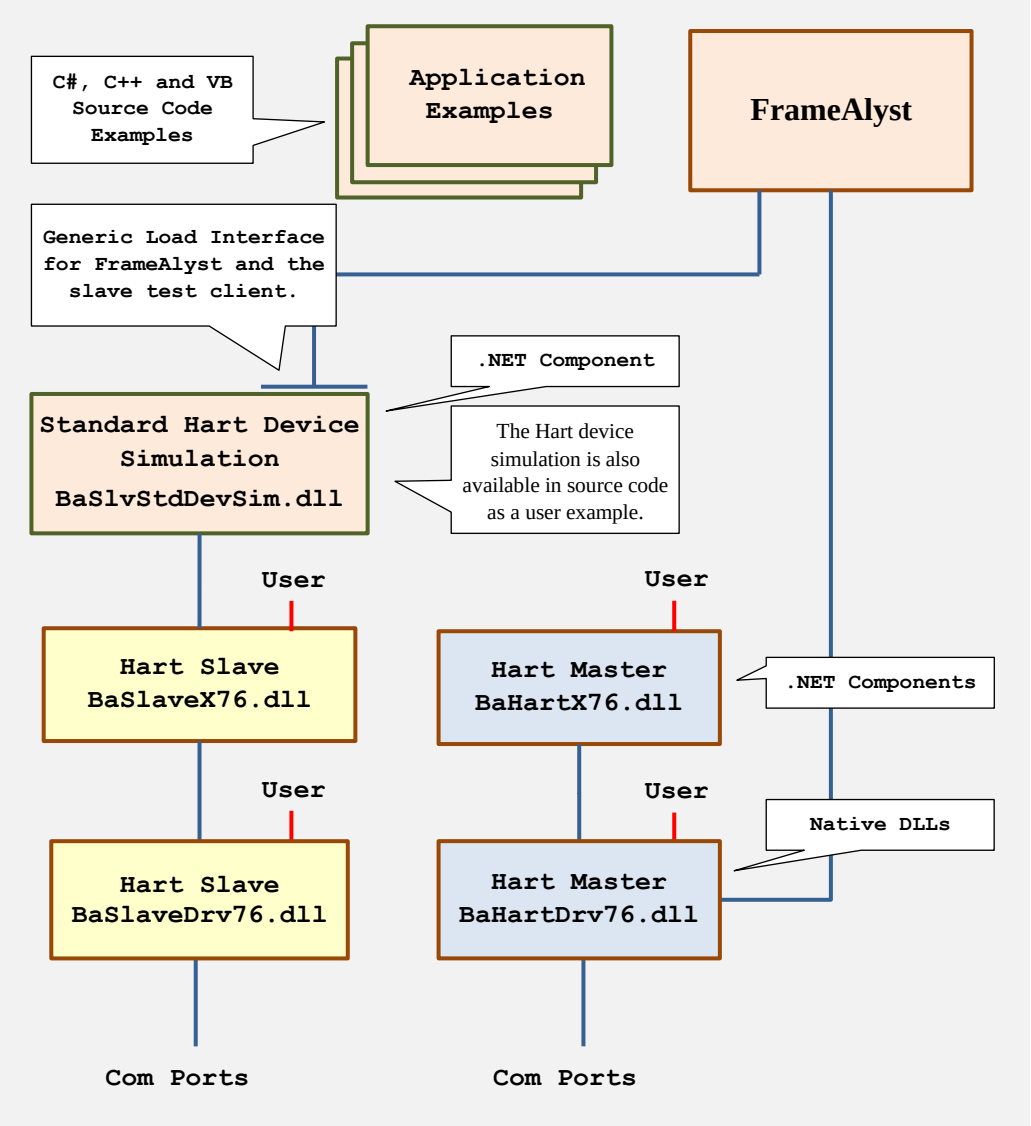


Figure 1: Components Architecture of Hart Tools 7.6

The Hart Tools are based on two native Windows DLLs. One for the master functionality and the other one for the slave services. For both a .NET component is provided.

The user may integrate the native DLLs or the .NET components into his application.

FrameAlyst is a standard application for monitoring and analyzing the communication streams. FrameAlyst is docking at the Hart Master DLL (BaHartDrv76.dll).

Because native DLLs can only be provided as 32 or 64 bit assemblies, both versions are available in the packet.

.NET DLLs are avaible for three architectures.

Component	Path	CPU	Description
BaHartDrv76.dll	.\UserDLLs\System\x86\ WindowsSystem(32 bit)	x86	The Hart master DLL is also providing a monitor interfaces for FrameAlyst and for the user.
	.\UserDLLs\System\x64\ WindowsSystem(64 bit)	x64	
BaHartSlv76.dll	.\UserDLLs\System\x86\ WindowsSystem(32 bit)	x86	The Hart slave DLL is providing function s which are needed by a Hart command interpreter.
	.\UserDLLs\System\x64\ WindowsSystem(64 bit)	x64	
BaHartX76.dll	.\UserDLLs\App\ .\Debug\ .\Debug(x64)\ .\Debug(86)\	Any x64 x86	The .NET Hart master component is an additional shell to the master DLL.
BaSlaveX76.dll	.\UserDLLs\App\ .\Debug\ .\Debug(x64)\ .\Debug(86)		The .NET Hart slave component is an additional shell to the slave DLL.
BaSlvStdDevSim.dll	.\ .\UserDLLs\App\ .\Debug\ .\Debug(x64)\ .\Debug(86)		The standard Hart device simulation serves to purposes. One is to provide a slave simulation to FrameAlyst and to provide an example of a slave device simulation for the user.
BaHartFrameAlyst76.exe	.\ .\UserDLLs\App\ .\Debug\		The FrameAlyst is the main application of the Hart Tools package.
	.\Debug(86)	x86	A 32 bit compilation of the application is provided to allow 32 bit debugging on a 64 bit machine.

Table 1: Components and Paths

Installation

The installation may be done into any directory. The solutions for the example applications are available at the path .\Examples\.

Note: The projects of the examples were generated with Visual Studio 2019. Trying the examples with an earlier Version of Visual Studio will not work.

On 64 bit platforms the installation provides the subdirectory .\Debug(x86) for debugging 32 bit applications on a 64 bit platform.

On 32 bit platforms the path .\Debug(x86) is not available because all applications and components which are compiled for Any CPU are automatically loaded as 32 bit modules.

Application Examples

Example	Subject	Description
HartDLL		
C#		
AppDeviceData.sln	Device Data Manager	This is a more complex example implementing the handling of data of various kinds.
ConnectAndRead.sln	Connection, Device Info	The Example demonstrates the usage of the connection information and the BHDrv_IsServiceCompleted method.
CsGetCyclicData.sln	Cyclic Data Callback	The example is showing how cyclic data is collected from the HartDLL (burst mode handling). The polling and the callback mechanisms are demonstrated.
GetUnIDbyTag.sln	Data Link Service	The example demonstrates the usage of the function BHDrv_ConnectByTagName of the HartDLL.
MultiThreadingDLL.sln	More than one Thread	The example demonstrates how to use several threads for Hart communication with the HartDLL. Two worker threads are used.
CsRdWrRangeAndTag.sln	Read and Write Data	In Hart commands usually more than one parameter is communicated. Here the handling is demonstrated.
SendExtCommand.sln	Hart 7, Service Callback	Sends a 16 bit command and demonstrates the use of the service callback for service completion.
C/C++		
UsingBaHartDrv.sln	BaHartDrv76.h	A little console application interfacing to the DLL.
Microsoft Office		
UsingHartDLL.xlsm	VBA Macros	Excel can be used to communicate through a Hart Network.
Visual Basic		
VbRdWrRangeAndTag.sln	VB Language	The example is showing the use of HartDLL is used in Visual Basic.
Python		
HartDLL-Example.py	Python	The example is showing the use of HartDLL with the Python interpreter
Visual Studio Code		
Workspace file	BaHartDrv76.h	A little console application interfacing to the DLL.
HartX		
C#		
CsUsingHartX.sln	.NET Objects	Demonstrates how to use Hart as a .NET object.
MultiThreadingX.sln	More than one Thread	Demonstrates how several instances of HartX are handled.
Microsoft Office		
ReadPVs.xlsm	Collecting Data	The example reads the dynamic values from a Hart slave.
Visual Basic		
VbUsingHartX.sln	Using .NET in VB	The example how the HartX is integrated into a VB application. Com port must be set in the source code of frmMain.vb.
SlaveX		
UserDevSimSlave.sln	Salve Device Simulation	It is much easier to develop the logic of a device in a PC simulation using Visual Studio. The solution is containing two projects. One for a user slave simulation and another one for a simple test client.

Table 2: Examples for the HartDLL, SlaveDLL, HartX and SlaveX

Directory Structure

After installation the following directory structure is created.

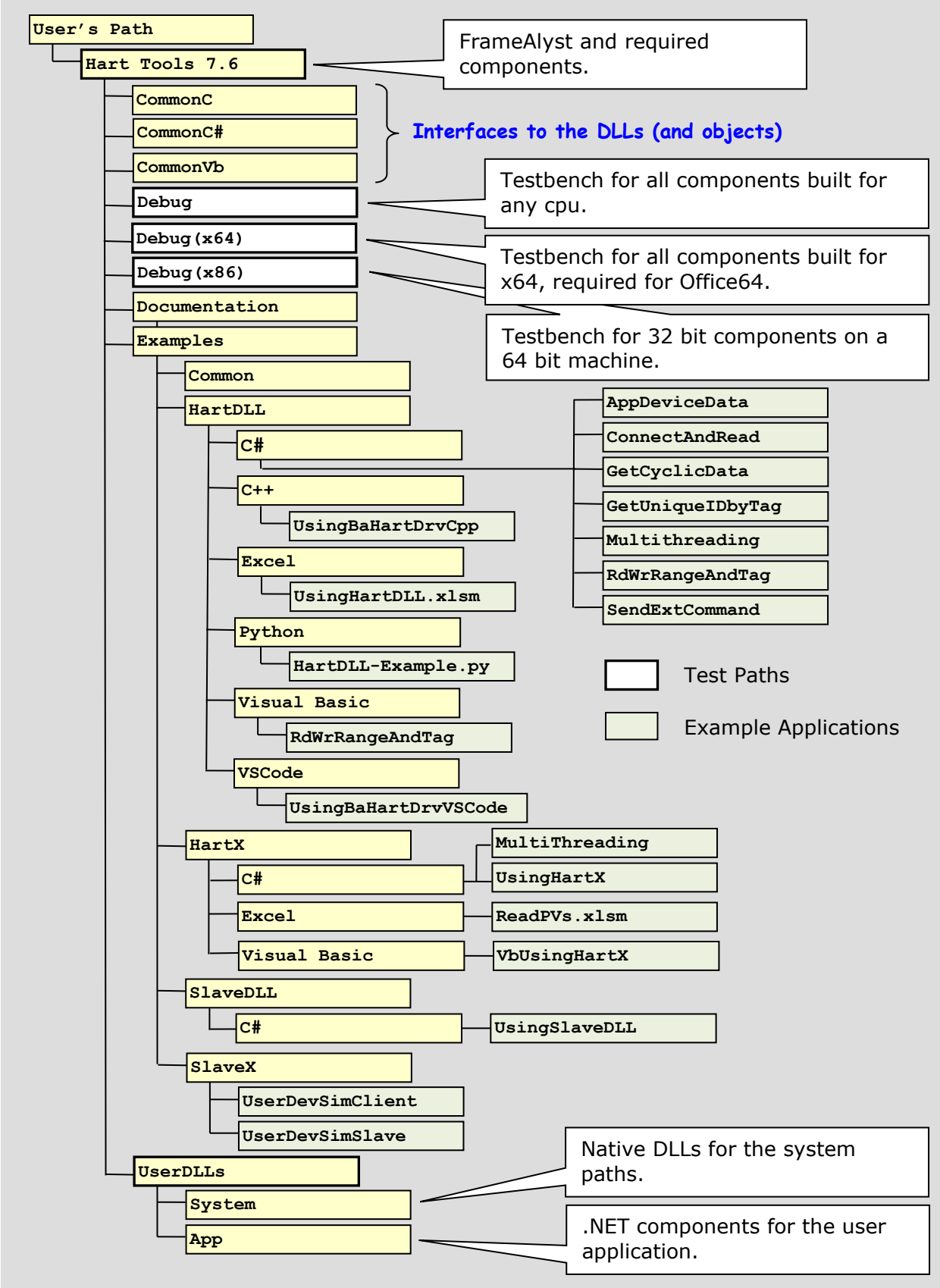
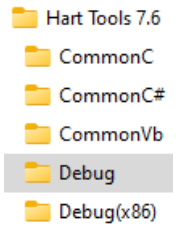


Figure 2: Directory Structure after Setup

Getting Started

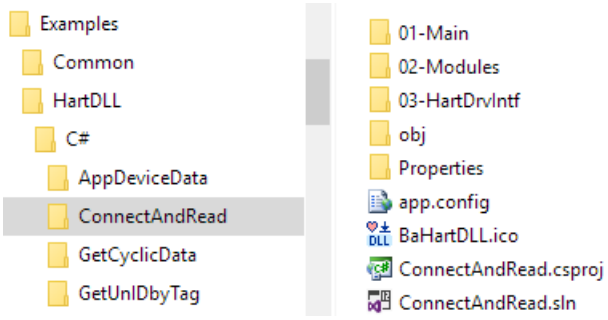
Debugging Example Projects



The main directory, were the Hart Tools 7.6 had been installed to, contains only the FrameAlyst and three examples which had been built for any CPU.

There are two directories for trying the examples using Visual Studio. Debug is used for modules which are built for any CPU and Debug(x86) is used for 32 Bit outputs.

CommonC, CommonC# and CommonVb are containing modules of common use such as header files, C# sources and Vb sources for interfaces and objects.



There are various examples available for different languages and platforms. They are mostly developed with Visual Studio 2019.

The solution and the project for an example are located in the directory which is named as the example solutions.

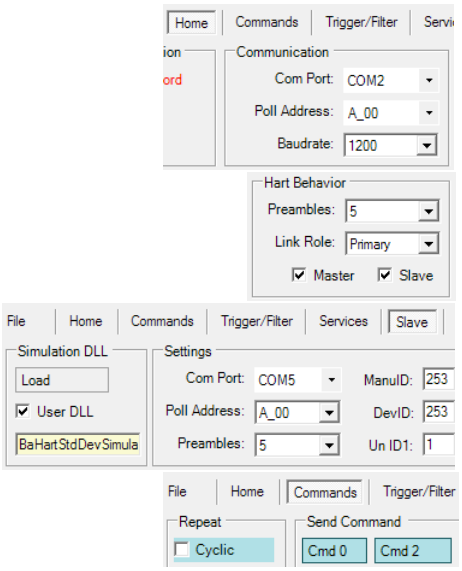
Note that most of the examples are delivering an 64 Bit output (any cpu) and a 32 bit output as well. The results are exported to the paths Debug and Debug(x86).

Slave Simulation with FrameAlyst

In Hart Tools 7.6 the slave simulation is working completely separated from the Hart Master DLL, which is also used by FrameAlyst. The slave simulation is written in C# and using the component SlaveX.

However the slave simulation is realized as a .NET component and requires a host system to load and run the component. At present the FrameAlyst is the only host who is loading the slave .NET assembly.

Instead of using physical com ports you may also use a pair of virtual com ports such as provided by Serial Port Kit or similar software solutions.



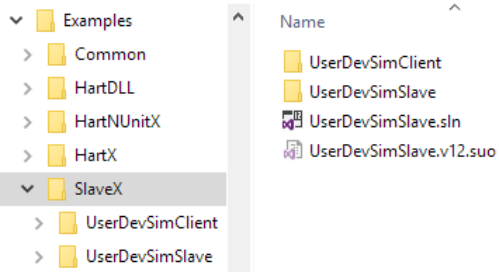
Select the com port used by the master in the Home-Tab of FrameAlyst.

Be sure that master and slave are activated.

The slave assembly of the slave simulation has to be loaded (BaHartStdDevSimulation.dll) and the com port of the slave has to be set in the Slave-Tab

After these settings the Commands-Tab of FrameAlyst can be used to test the functionality of the slave simulation.

Slave Simulation with Test Client



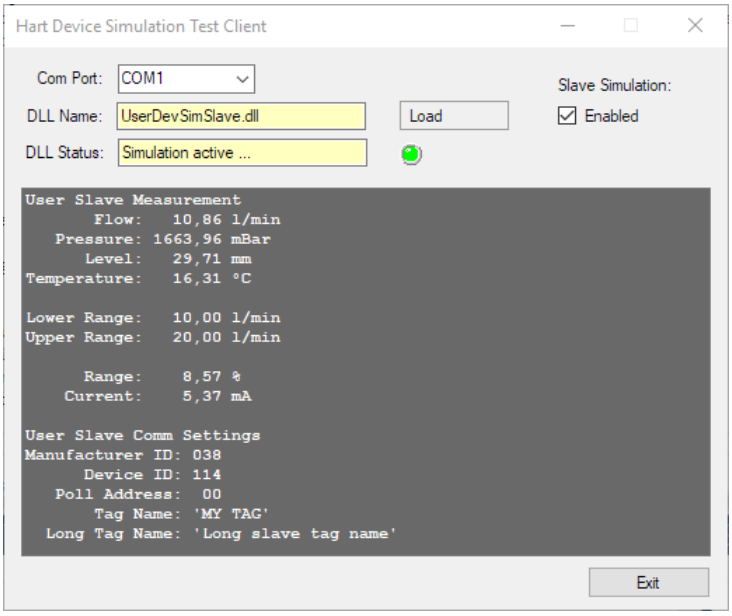
The directory Examples is containing a solution with two projects. One project is a custom build Hart slave written in C#.

The other project is a test client to load and run the slave simulation DLL.

The implementation is supporting all universal commands and the common practice commands 34, 35, 38, 48 and 512.

The slave is simulating the 4 PVs and is calculating the current and the percentage values from the range.

The debug session is started by executing the test client.



HartDLL (Client + OSAL)

Service Processing Flow Diagram

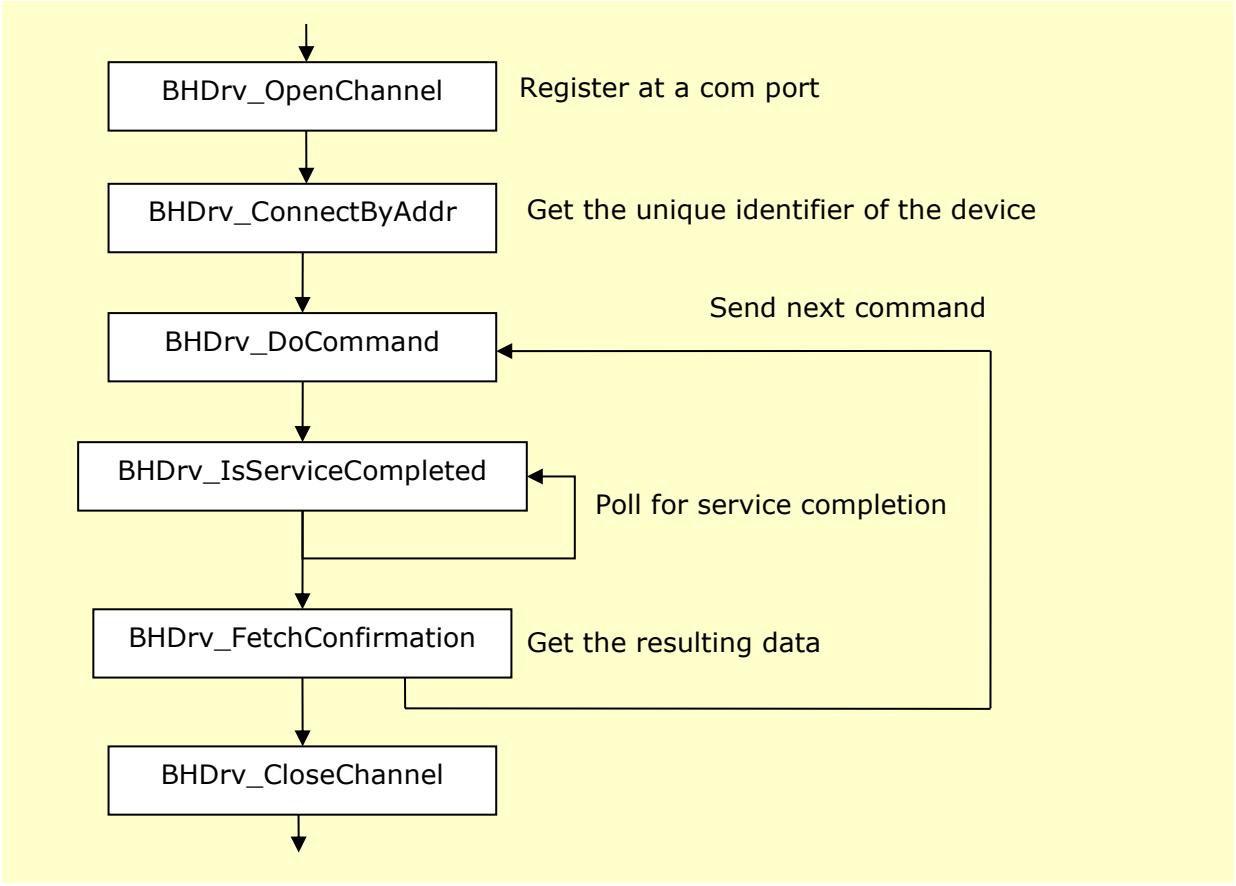


Figure 3: Polling for Service Completion

Because command 0 is the only command in Hart which is working with the short address (0..15/0..63) the unique identifier has to be fetched from the device to use it for the other commands. The unique identifier can be read by the commands 0, 11 and 21.

There are three ways to wait for the completion of a service. Picture 1 is showing the no wait mode. In the no wait mode the client program has to poll the DLL by calling BHDrv_IsServiceCompleted.

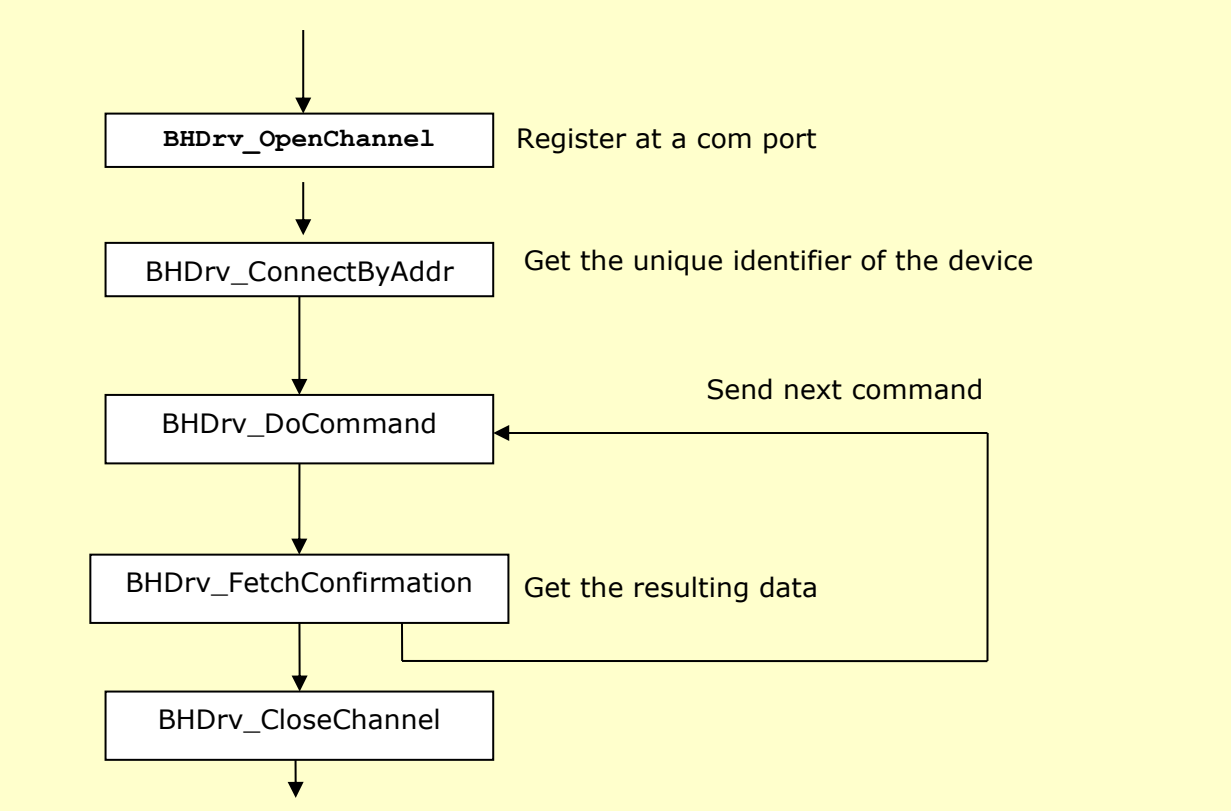


Figure 4: Using the Wait Mode of the DLL

When a service is processed using the function BHDrv_DoCommand with the option flag DRV_WAIT the program is returning when the service is totally completed even if there are errors or if the device is not responding.
Waiting for a service results in a small delay of approximately 250 ms.

Note: If a device is not responding, the function delay for a multiple of the number of retries which had been configured by the function BHDrv_SetConfiguration.

The third method is to register a callback function from the application software. In this case the DLL will call back as soon as any service of that application is completed.

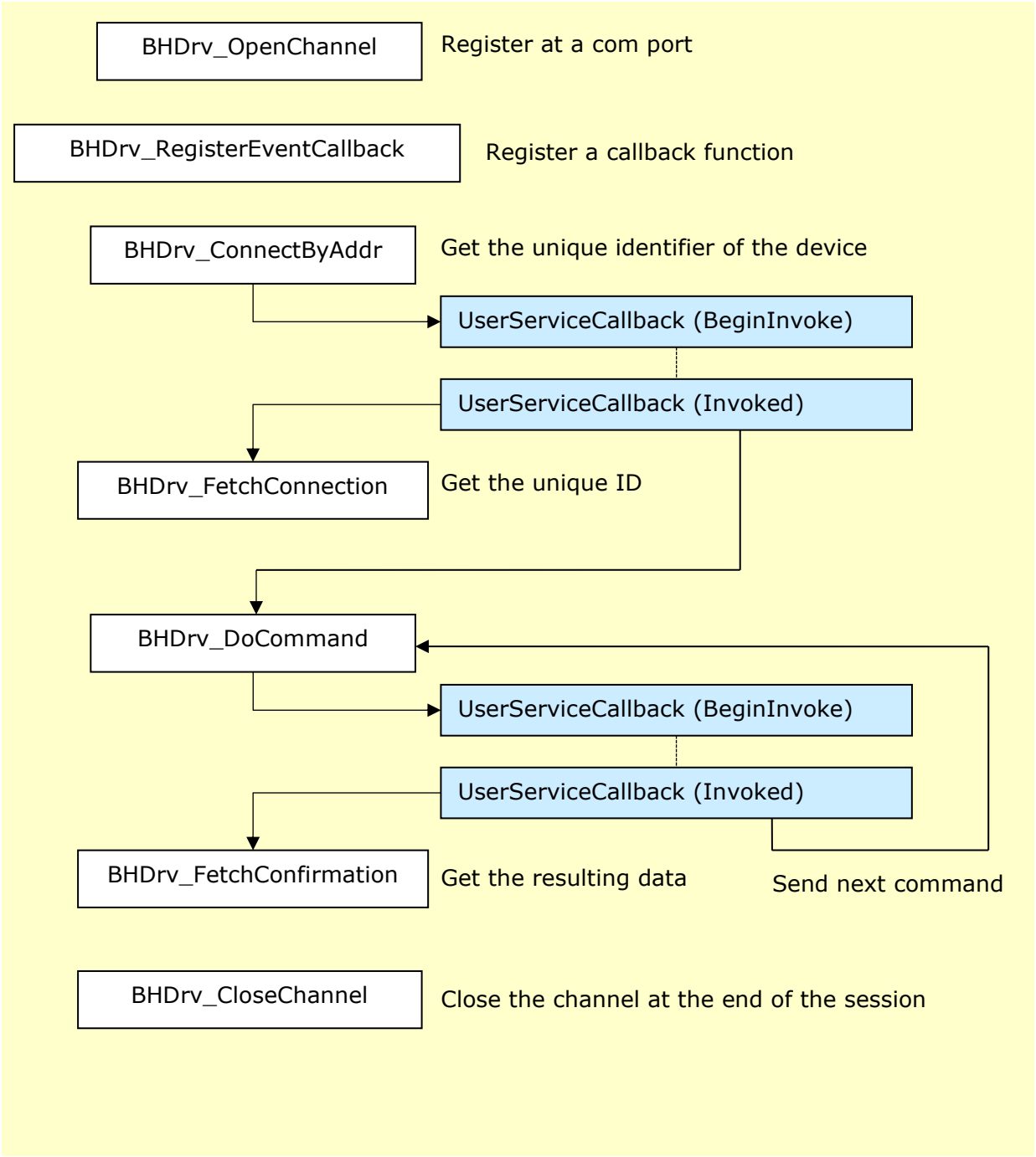


Figure 5: Using the a Callback Function for the DLL

The time between the call of the callback function and the execution of the invoked function is not determined because it is given by the Windows messaging system. But usually this time is short if the application is not busy in another event procedure.

Principle of Operation

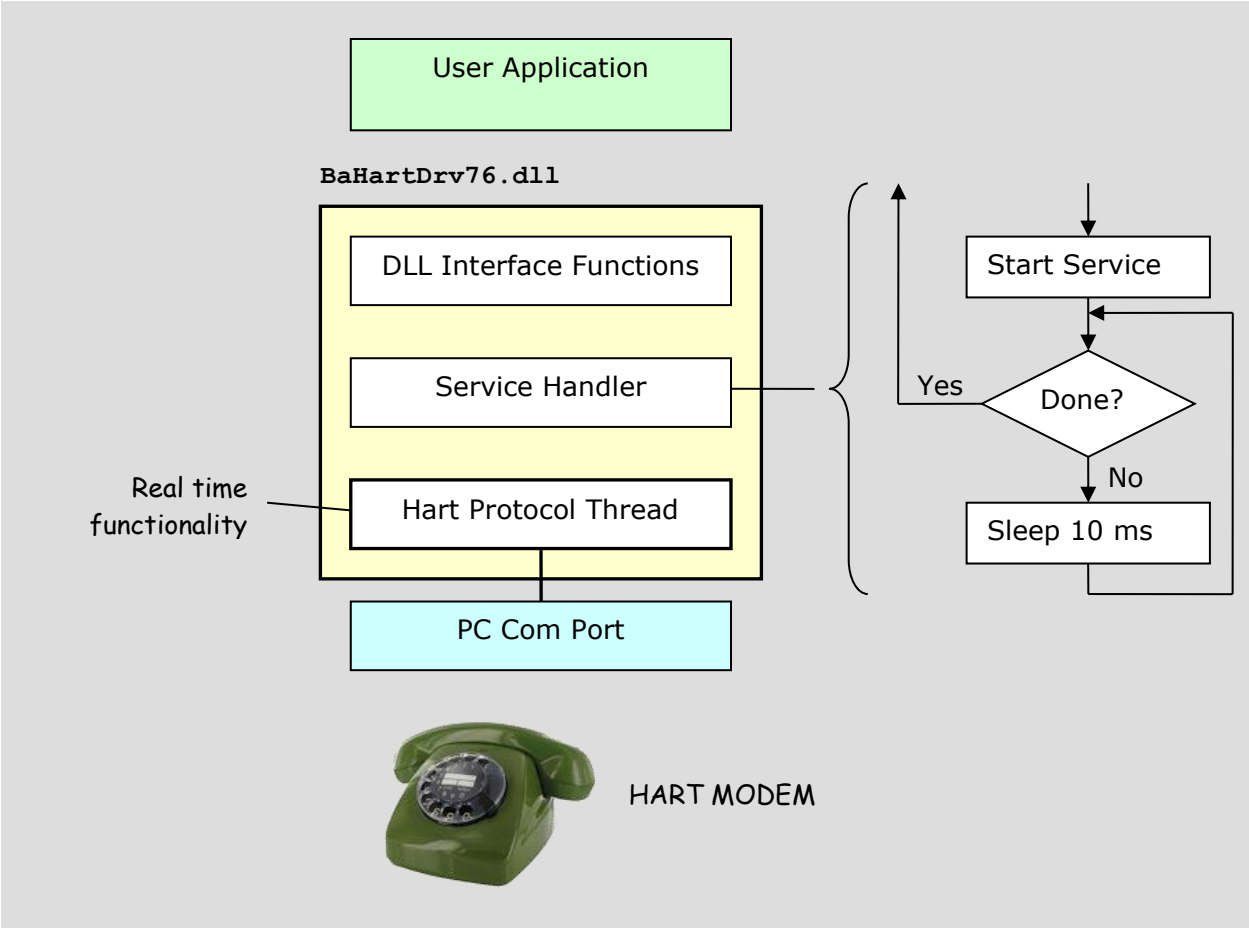


Figure 6: The Internal Structure of the DLL

The figure above shows that the DLL is using is using its own thread for the real time application. Thus the calling thread may be of any kind. Even if the DLL is waiting for the completion of the service it is taking the calling thread into sleep mode.

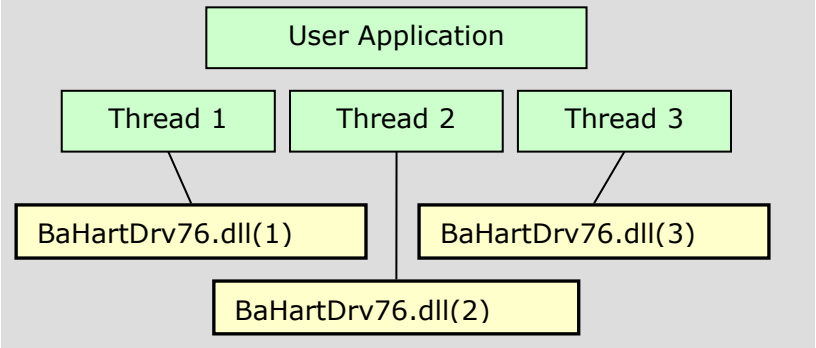
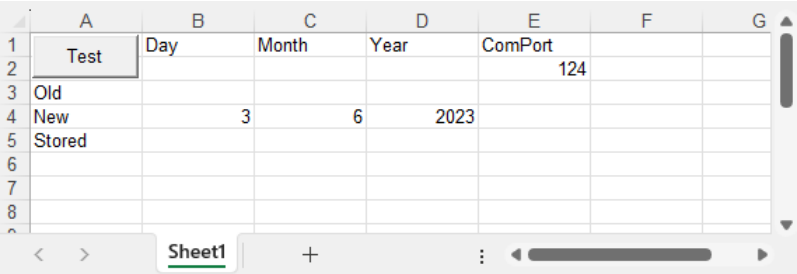


Figure 7: The DLL can be used by different Threads

The DLL may be called from several threads. The functions and communication services are thread safe. Each thread should register explicitly to get its own handle.

Excel



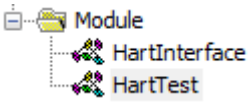
Double click the file UsingHartDLL.xlsm (Examples->HartDLL->Excel). Excel opens and appears with a button on one of the sheets. Press the button and the Visual Basic Editor will appear because the program was stopped at a breakpoint.

In most cases the program will stop because no device is connected. If you connect a real or a simulated device to the com port which was opened by

```
'Open Com from Cell E2
'Configuration will be default
iComPort = Range("E2")
hDrv = BHDrv_OpenChannel(iComPort)
```

the software will reach another Stop statement providing the Tag Name of the connected device.

Modules



While the module HartTest is containing the little test program the module HartInterface contains the necessary structures and functions declarations.

The following is an example of the declaration of one of the functions in the DLL.

```
Public Declare PtrSafe Sub BHDrv_FetchConnection Lib "BaHartDrv76.dll" _
  (ByVal hSrv As Long, _
   pstrConnection As Any _
  )
```

The declaration of structures has to be done like the following.

```
Type T_strConfirmation
    byCmd          As Byte
    byRsp1         As Byte
    byRsp2         As Byte
    byError        As Byte
    '---------------------
    byUsedRetries  As Byte
    byDevInBurst   As Byte
    iDuration      As Integer
    '---------------------
    lAppKey        As Long
    '---------------------
    usExtCmd       As Integer
    byReserved1    As Byte
    byDataLen      As Byte
    '---------------------
    sData          As String * 255
End Type
```

HartX (Client)

Service Processing Flow Diagram

If the wait flag is set in the call of DoCommand the following program flow is executed.

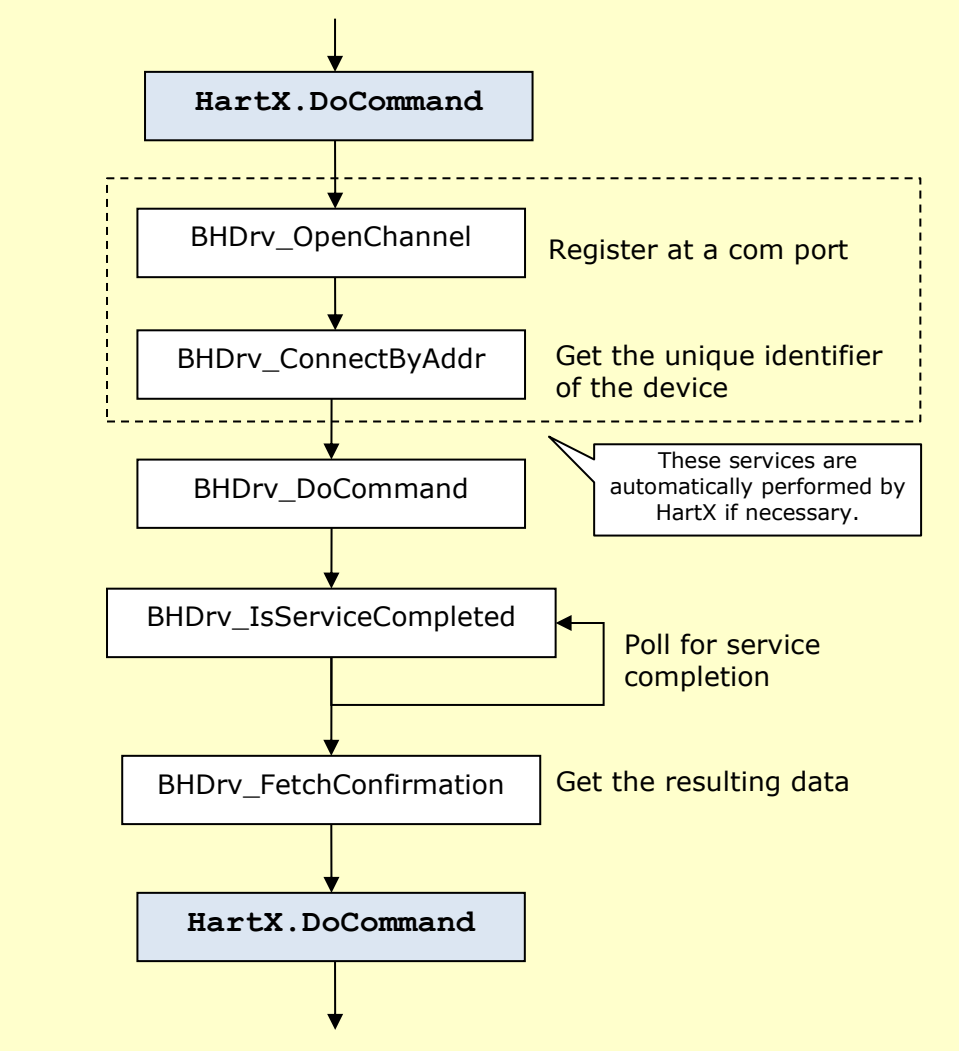


Figure 8: HartX Service Flow (waiting for service)

If the wait flag is cleared in the call of DoCommand will return immediately. After the service completion an event procedure will be called.

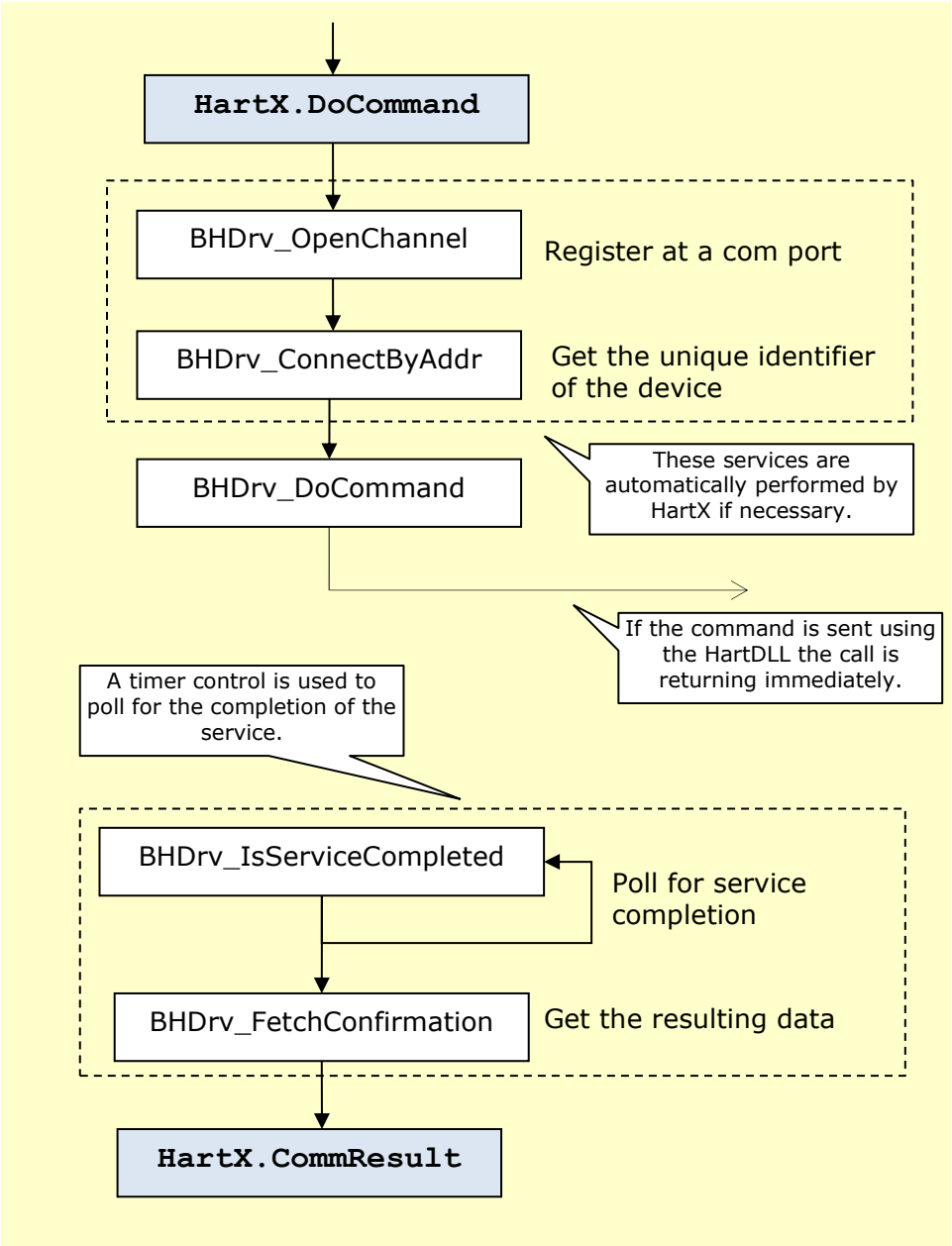


Figure 9: HartX Service Flow (not waiting for service)

Principle of Operation

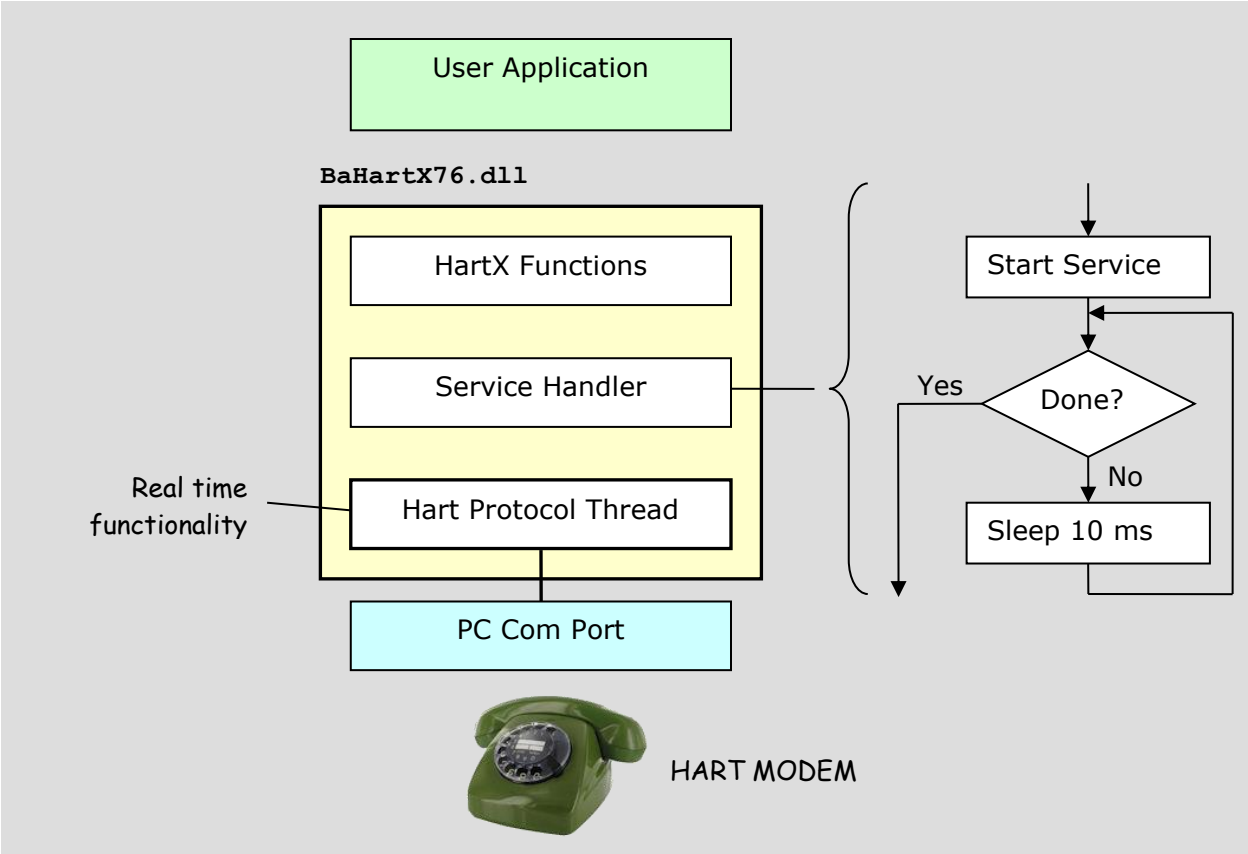


Figure 10: The Internal Structure of the DLL

The figure above shows that the HartX is using is using its own thread for the real time application. Thus the calling thread may be of any kind. Even if HartX is waiting for the completion of the service it is taking the calling thread into sleep mode.

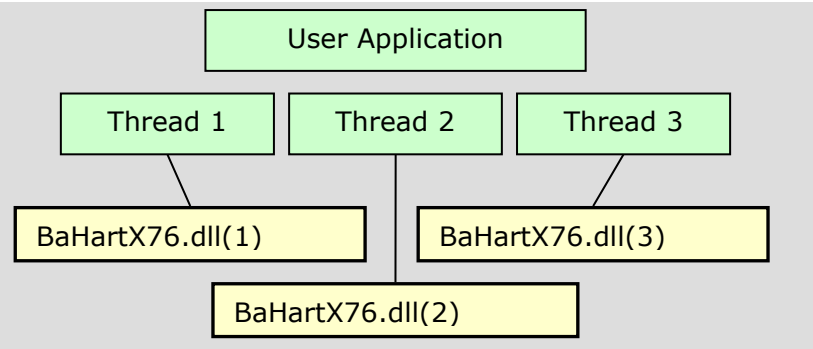


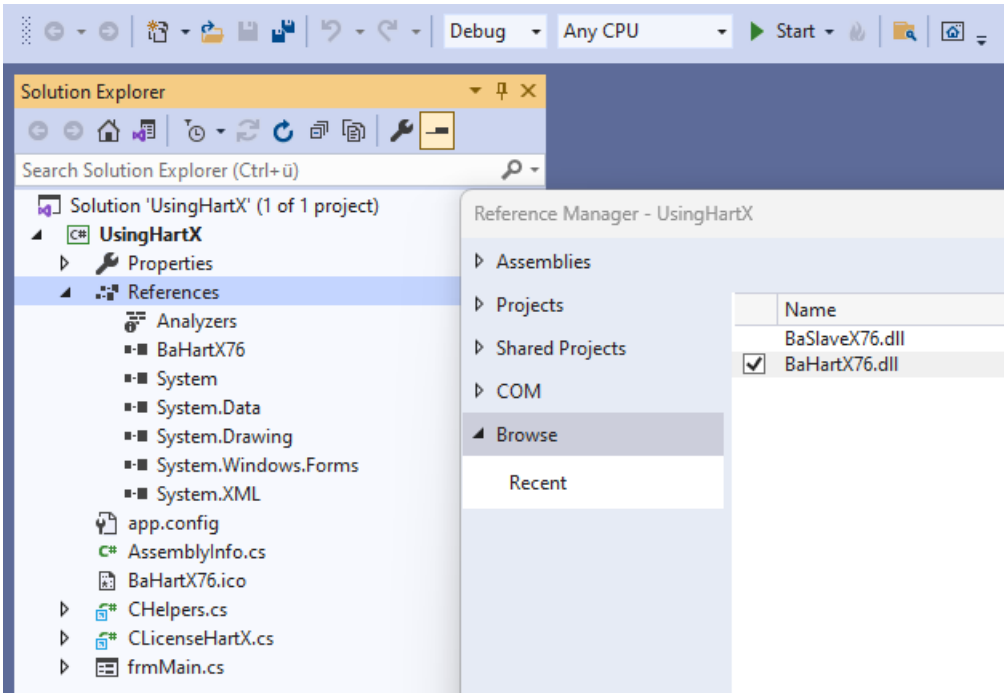
Figure 11: The DLL can be used by different Threads

HartX may be called from several threads. The functions and communication services are thread safe.

Visual Studio

Open Visual Studio and create a new project for a Windows Forms Application.

It is not necessary to install HartX76 on the toolbar. A simple reference to the library is enough.



The best way is to select the component from the path xAnyCPU because this library can be used in a 32 bit as well as in a 64 bit environment.

The next step is to set a reference in the namespace section.

```
namespace TestHartX
{
  using BaHartTools76.HartX;

  public partial class frmMain : Form
  {
    public frmMain()
    {
      InitializeComponent();
    }
  }
}
```

You should not forget to handle the licensing issue. Therefore a reference to the license module is set.

I recommend to include the module as a link to make sure that the module is shared and remains on its original place.

A variable is required to store a reference to the HartX.

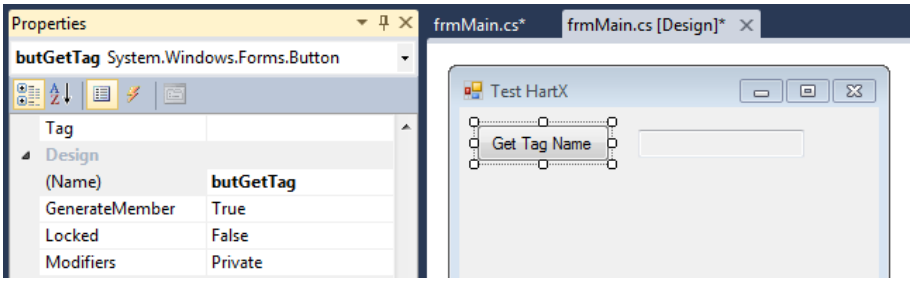
```
  public partial class frmMain : Form
  {
    private CHartX hartX = null;

    public frmMain()
    {
```

The instance of HartX is inserted in the form load event handler. With setting the com port the HartDLL is loaded by the HartX and a channel for the communications is opened.

But before setting the com port the license has to be set in the HartX.

```
private void frmMain_Load(object sender, EventArgs e)
{
  this.hartX = new CHartX();
  this.hartX.ValidateLicense
    ("30-Days-Trial-User-License",
     "Ea58v60F-x3jk-wi9n-RrI3-7c072aA6ae0B");
  this.hartX.ComPort = 2;
}
```

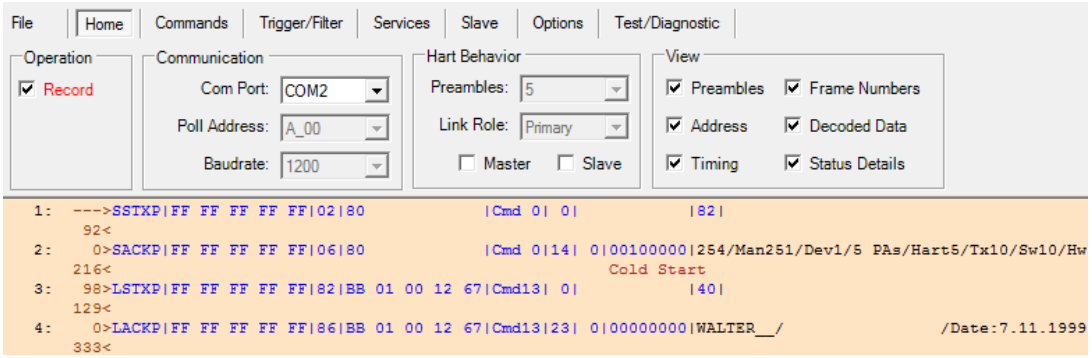
A button and a text box are used to perform some action.



The code required for reading the tag name is very short.

```
private void butGetTag_Click(object sender, EventArgs e)
{
  if (this.hartX.IsValidComPort)
  {
    // Read the tag name
    this.txtTagName.Text = "reading ...";
    this.hartX.XReqLen = 0;
    this.hartX.DoCommand(13, true);
    if (this.hartX.LastError == CHartX.EN_LastError.ERR_Success)
    {
      this.txtTagName.Text = this.hartX.P13TagName;
    }
    else
    {
      this.txtTagName.Text = "Error!";
    }
  }
}
```

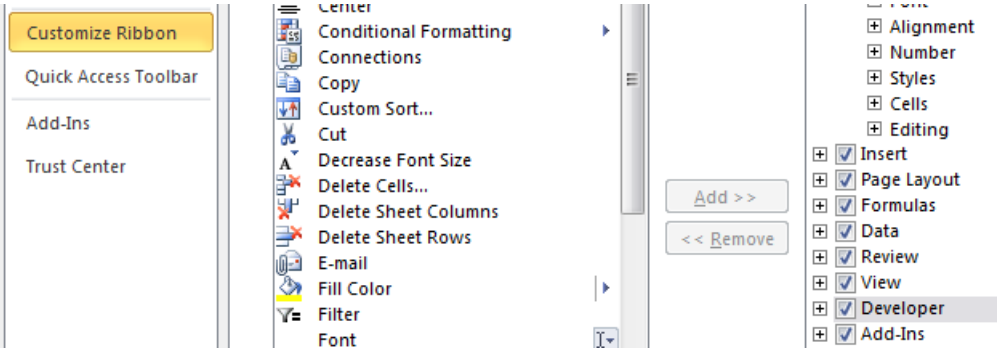
When clicking the button 'Get Tag Name' the following communication sequence is shown by FrameAlyst.



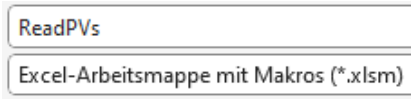
The HartX is firstly sending command 0 to get the unique identifier. Then the command 13 is used to get the Tag Name.

Excel

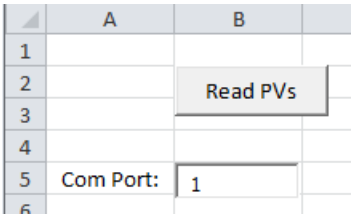
Before you can start to use VBA in Excel you have to activate the developer tabs in Options->Customize Ribbon.



To be sure that your macros (VBA program) are saved too you have to store the file as macro-enabled workbook.

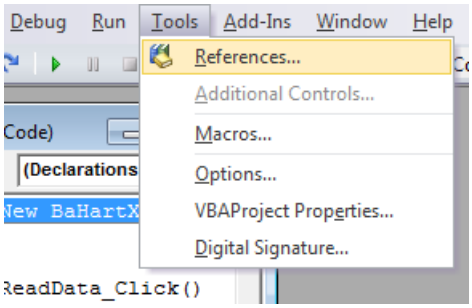


The example is using a button for starting and a textbox for the com port number.

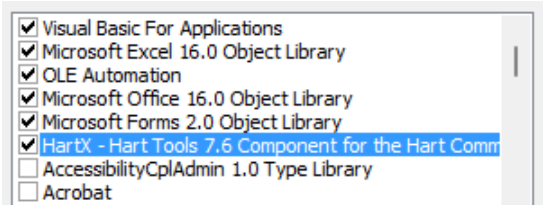


HartX is not a .net control but only a component. Therefore it has to be addressed by a reference. VBA does not accept a reference to the dll but to the type library (tlb) file.

The reference has to be set in the code Window which is opened by the selection of 'View Code' in the Developer tab.

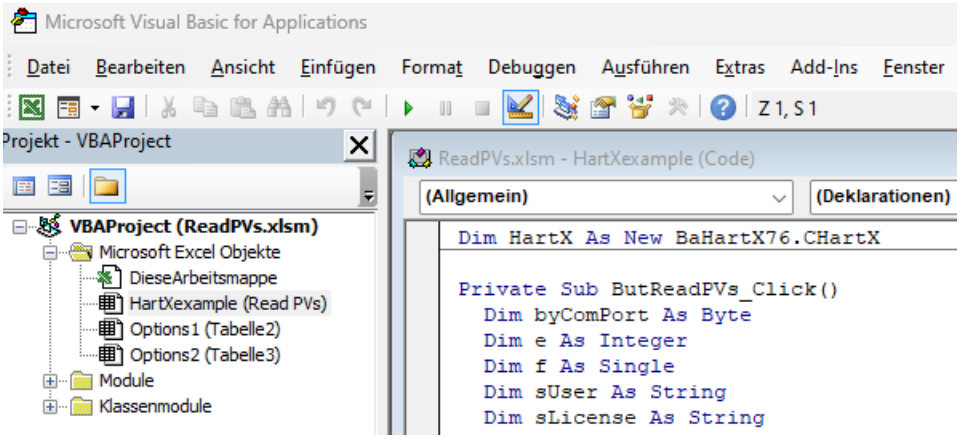


In the code window the menu Tools has the menu item References. After a click on this option the reference select Window opens.



Click on browse and navigate to the tlb of the HartX.

Next is to declare an object using the HartX reference.



The example is coded in the event procedure of the button.

```
Private Sub ButReadPVs_Click()
  Dim byComPort As Byte
  Dim e As Integer
  Dim f As Single
  Dim sUser As String
  Dim sLicense As String

  'Set the user license code
  sUser = "30-Days-Trial-User-License"
  sLicense = "Ea58v60F-x3jk-wi9n-RrI3-7c072aA6ae0B"

  HartX.ValidateLicense sUser, sLicense

  byComPort = Val(TxtComPort.Text)
  If (byComPort > 0) And _
     (byComPort < 255) _
  Then
```

The first call of the HartX should be the call of the ValidateLicense method in order to set the HartDLL into a functional mode.

However the simulation of PVs also works without any License code.

```
  ' Set the com port
  HartX.cComPort = byComPort
  ' Switch on simulation of the PVs
  HartX.SimPvEnabled = True
  ' Set the amplitude to 10.0
  HartX.SimAmplitude = 10#
  ' Initialize the cells
  Cells(1, 4) = "Number"
  Cells(1, 5) = "PV 1"
  Cells(1, 6) = "PV 2"
  For e = 0 To 19
    Cells(e + 2, 4) = ""
    Cells(e + 2, 5) = ""
    Cells(e + 2, 6) = ""
    'DoEvents
  Next e

'Read 20 times PV 1 and PV 2
For e = 0 To 19
  HartX.DoAction 3
  f = e
  Cells(e + 2, 4) = Format(f, "0.0")
  f = HartX.p03Pv1
  Cells(e + 2, 5) = Format(f, "0.0")
  f = HartX.p03Pv2
  Cells(e + 2, 6) = Format(f, "0.0")
  'DoEvents
Next e
```

The only thing to do for the communications is to set the com port to which the Hart device is connected to.

The property SimPvEnabled is setting the simulation mode of the HartX. If this mode is set the PVs are simulate between values set by the SimulateAmplitude property.

The 'main program' of the example is a for loop reading two PVs from the device for 20 times and writing the results to the worksheet.

The call of DoAction is driving the simulation of the PVs and simulates a delay of 200 ms like the communication would do. In the case the simulation is switched of DoAction would run the Hart protocol activities. After running the example the worksheet will look as below.

Read PVs

Com Port: 124

Number	PV 1	PV 2
0,0	0,0	-9,0
1,0	3,1	-8,0
2,0	5,9	-7,0
3,0	8,1	-6,0
4,0	9,5	-5,0
5,0	10,0	-4,0
6,0	9,5	-3,0
7,0	8,1	-2,0
8,0	5,9	-1,0
9,0	3,1	0,0
10,0	0,0	1,0
11,0	-3,1	2,0
12,0	-5,9	3,0
13,0	-8,1	4,0
14,0	-9,5	5,0
15,0	-10,0	6,0
16,0	-9,5	7,0
17,0	-8,1	8,0
18,0	-5,9	9,0
19,0	0,0	-10,0

Running it with the simulation switched off, the example will communicate with the real device.

```
' Switch off simulation of the PVs
HartX.SimPvEnabled = False
```

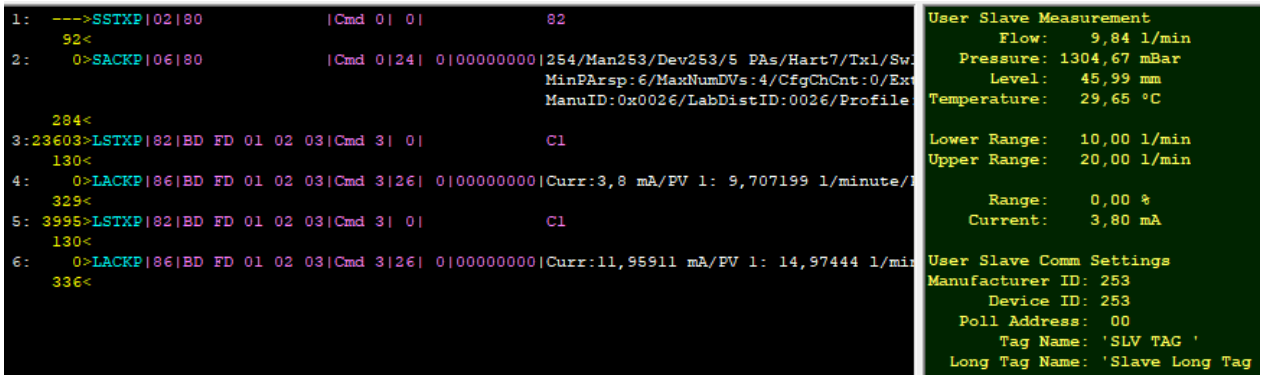
The worksheet may look like it is shown below.

Read PVs

Com Port: 6

Number	PV 1	PV 2
0,0	17,7	1816,9
1,0	17,2	1816,9
2,0	15,7	1823,2
3,0	15,9	1823,2
4,0	15,4	1838,6
5,0	14,1	1844,8
6,0	13,1	1861,9
7,0	13,3	1861,9
8,0	12,5	1872,4
9,0	12,3	1872,4
10,0	11,6	1888,5
11,0	10,3	1893,1
12,0	10,1	1893,1
13,0	10,5	1906,1
14,0	10,8	1912,7
15,0	11,5	1912,7
16,0	12,1	1912,0
17,0	12,1	1936,0
18,0	12,7	1936,0
19,0	13,0	1935,1

If you run FrameAlyst during the session you can see the communication activities.

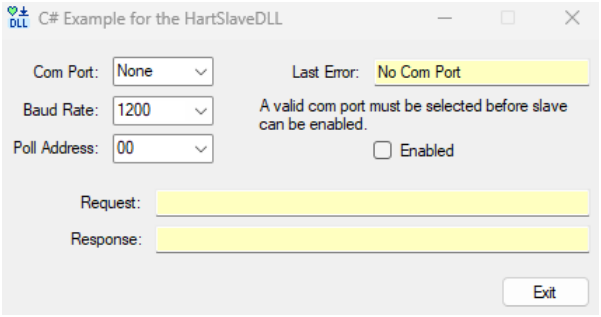


Before starting to accept the command 3 requests HartX is automatically sending command 0 to retrieve the unique identifier from the device.

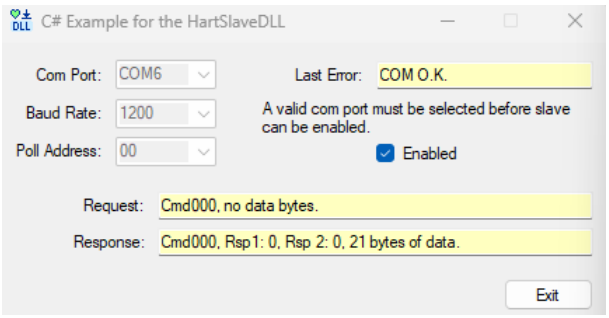
SlaveDLL (Server + OSAL)

Of course, a hard slave simulation can also only be built on the basis of the slave DLL. This example shows how to do this.

To make the example clear, the structure is as simple as possible. The appearance of the client is as follows.



As soon as the correct com port, baud rate and polling address have been selected, the slave can be enabled and responds to the commands of a connected master.



With the other slave simulations, the simulation was integrated in a dll. In this example, however, everything takes place in one application.

The management of the slave, if you can call it that, is housed in a simple timer.

```
private void Tim50_Tick(object sender, EventArgs e)
{
    switch (this.status)
    {
        case EN_Status.IDLE:
            status = EN_Status.READY;
            break;
        case EN_Status.READY:
            this.handleOfService = HartSlaveDLL.BHSlv_GetRequest(this.handleOfChannel,
                ref command, ref indInfo, ref datalen, ref data[0]);
            if ( this.handleOfService != HartSlaveDLL.INVALIDserviceHandle)
            {
                status = EN_Status.WAIT_RESPONSE;
            }
            break;
        case EN_Status.WAIT_RESPONSE:
            CommandInterpreter();
            break;
    }
```

When working with baud rates higher than 1200 bit/s, such a simple timer is no longer sufficient and the developer should consider using a worker thread that works in ms cycles and

implements an asynchronous connection to the application. Such a worker thread could represent a cycle of 1 ms.

The command interpreter is extremely simple. But the example is only intended to show how such an application works in principle.

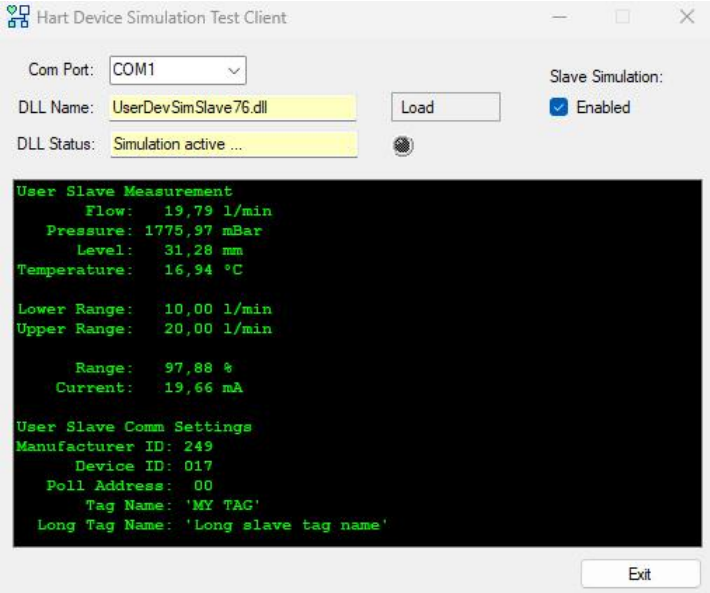
```
private void CommandInterpreter()
{
    byte response1 = 0;
    byte response2 = 0;

    switch (this.activeCommand)
    {
        case 0:
            bytesOfData[0] = 254;
            bytesOfData[1] = dllconfiguration.ManufacturerID;
            bytesOfData[2] = dllconfiguration.DeviceID;
            ...
            bytesOfData[21] = 0;
            countOfBytes = 21;
            response1 = 0;
            response2 = 0;
            HartSlaveDLL.BHSlv_PutResponse(..., response1, response2);
            this.status = EN_Status.IDLE;
            break;
        case 1:
            bytesOfData[0] = 32; // Temperature unit
            HartSlaveDLL.BHSlv_PutFloat(23.00f, 1, ref bytesOfData[0],
                HartSlaveDLL.MSBfirst);
            this.countOfBytes = 5;
            response1 = 0;
            response2 = 0;
            HartSlaveDLL.BHSlv_PutResponse(..., response1, response2);
            this.status = EN_Status.IDLE;
            break;
        default:
            countOfBytes = 0;
            response1 = 64;
            response2 = 0;
            HartSlaveDLL.BHSlv_PutResponse(..., 64, 0);
            this.status = EN_Status.IDLE;
            break;
    }
}
```

The connection to the SkaveDLL takes place exactly like the connection to the HartDLL via a corresponding C# file (BaHartSlv76_Iface.cs).

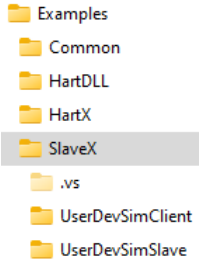
```
[DllImport("BaHartSlv76.dll", CharSet = CharSet.Ansi)]
// The function allocates the selected com port if possible and starts its own working
// thread for accessing Hart services. The value which is returned is a handle which
// has to be passed to all functions which are requesting any access.
//      comPort: Number of the PC com port (1..255)
//     baudRate: Bits per second
//       return: Com port could not be registered, Any other value: Registration successful
public static extern int BHSlv_OpenChannel(int comPort, int baudRate);

[DllImport("BaHartSlv76.dll", CharSet = CharSet.Ansi)]
// It is required to call this function at least when the application is terminating.
//     channel: The handle which was returned by OpenChannel
public static extern void BHSlv_CloseChannel(int channel);
```

SlaveX (Server)

Test Client



Since the slave simulation is only one component that is implemented in the form of a dll, you need a Windows process that loads this library. A simple executable program, the appearance of which is shown above, is sufficient for this.

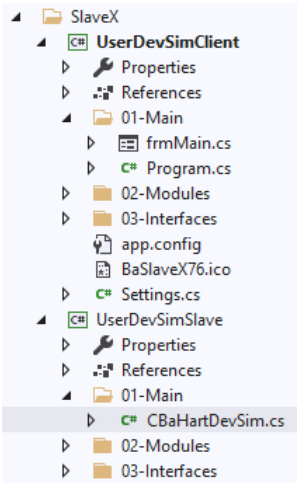


The client loads data from the simulations dll via a more or less standardized interface and displays them.

The solution (UserDevSimSlave.sln) is located in the examples area in the SlaveX directory.

The projects for the test client and the slave simulation are located in the associated subdirectories.

Slave Simulation



On the left you can see how the projects are displayed in the solution explorer in Visual Studio 2019.

The hard slave simulation is located in the UserDevSimSlave project and starts in the CBaHartDevSim.cs module.

To simplify debugging, I recommend first marking the UserDevSimClient project as the start project.

There are two options for configuring the environment. In general you should choose 'Debug' with AnyCpu, because then it doesn't matter whether the computer works with 32 or 54 bit. Debug - x86 is only recommended if you want to debug a 32-bit environment on a 64-bit computer.

Using FrameAlyst as Debugging Master

Of course you can also use FrameAlyst for testing the Hart communications. The diagram below shows how such a configuration works.

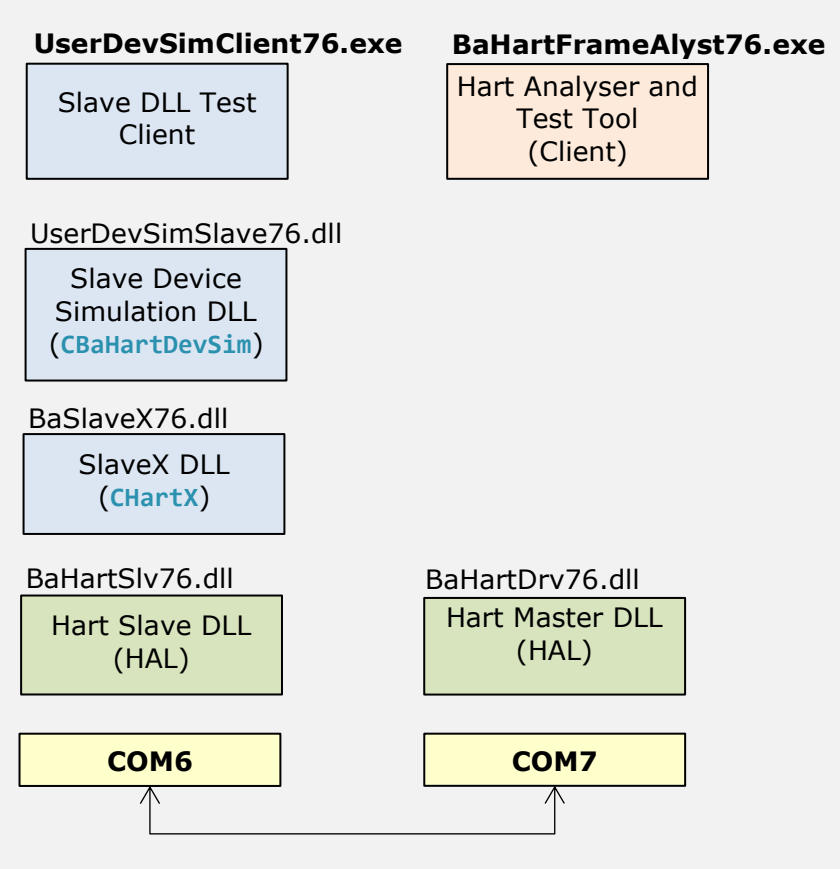
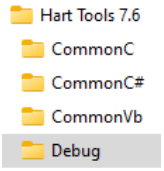
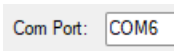


Figure 12: Using FrameAlyst as Master

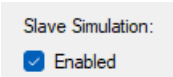


The Debug subdirectory should be used.

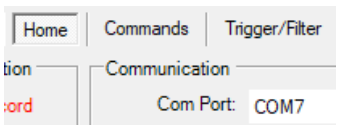
Please note that the native DLLs (BaHartSlv76.dll and BaHartDrv76.dll) are not found in the debug directories but in the Windows system directories for 32 or 64 bit libraries.



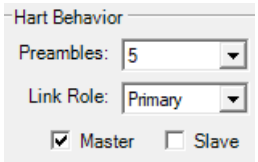
The correct com port must be selected in the slave test client.



In addition, the slave must be activated.

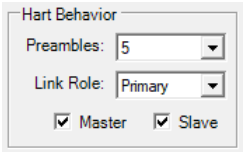


The correct com port must be selected in FrameAlyst.



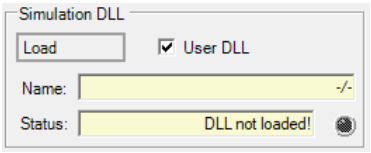
Furthermore, the master must be activated in FrameAlyst.

User Slave DLL in FrameAlyst

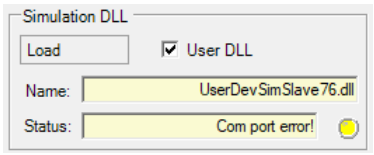


Of course, the slave user simulation can also be loaded in FrameAlyst. The following steps are necessary for this.

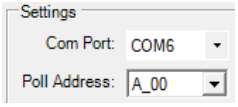
First, the slave emulation must be activated in FrameAlyst. This is done on the 'Home' tab.



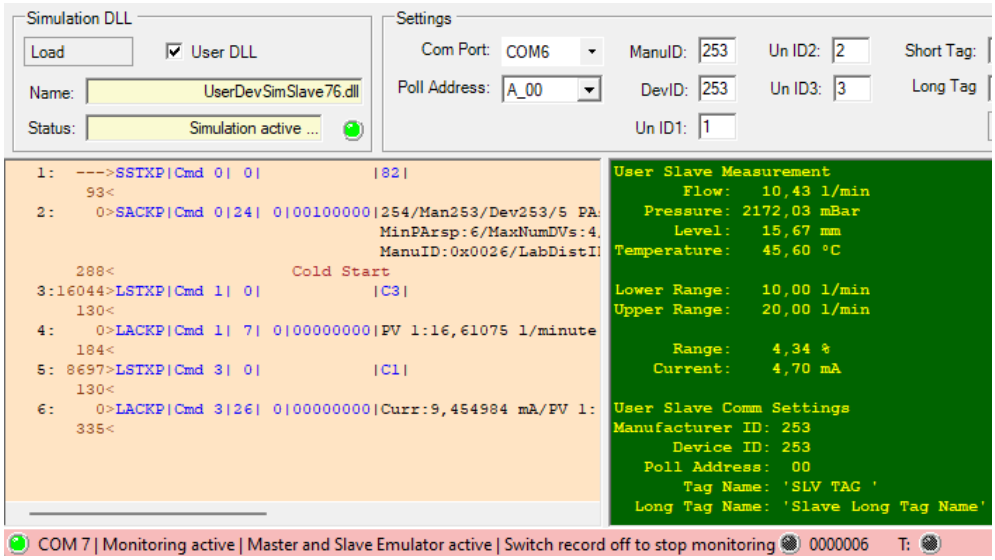
Next, the check mark for UserDLL must be set and the device simulation DLL must be loaded using the Load button.



The display then looks like it is shown on the left.

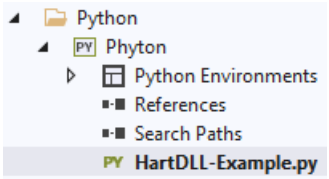


However, a valid com port must now be selected.



Python Example

The module demonstrates the use of the HartDll from HartTools 7.6. It is kept very simple and shows the basic procedure for loading and using the Windows DLL HartDrv76 in Python 3.7.9. The example is loading the DLL, registering the license and establishing a connection with a hart slave.

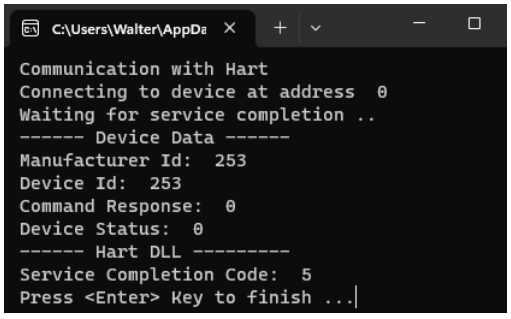


In fact, the whole implementation consists of a single module. The references and search paths filter are empty.

The main part of this program is shown below.

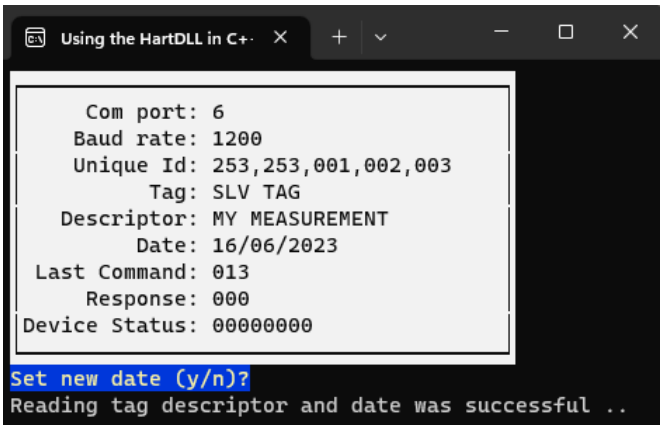
```
# Load the dll
Hartdll = windll.LoadLibrary("BaHartDrv76.dll")
# Register license
Hartdll.BHDrv_ValidateLicense("30-Days-Trial-User-License".encode(),
                              "Ea58v60F-x3jk-wi9n-RrI3-7c072aA6ae0B".encode())
# Open a channel on com port
myhandle = Hartdll.BHDrv_OpenChannel(comport)
# Connect to a device if it is a valid com port
# Address = 0, WaitForService = 1, NumRetries = 2
if myhandle != -0x1:
    print(" Connecting to device at address ", address)
    print(" Waiting for service completion ..")
    myservice = Hartdll.BHDrv_ConnectByAddr(myhandle, address, 1, 2)
    if myservice != -0x1:
        Hartdll.BHDrv_FetchConnection(myservice, byref(connectionData))
        if connectionData.ServiceCode == 5:
            print(" ------ Device Data ------")
            print(" Manufacturer Id: ", connectionData.ManIdByte)
            print(" Device Id: ", connectionData.DevId)
            print(" Command Response: ", connectionData.RespCode1)
            print(" Device Status: ", connectionData.RespCode2)
            print(" ------ Hart DLL ---------")
            print(" Service Completion Code: ", connectionData.ServiceCode)
        else:
            print(" ------ Hart DLL ---------")
            print(" Service Completion Code: ", connectionData.ServiceCode)
    else:
        print(" HartDLL out of service handles!")
else:
    print(" Could not open com port: ", comport)
# Close channel if valid
if myhandle != -0x1:
    Hartdll.BHDrv_CloseChannel(myhandle)
```

This shows a certain superiority of an interpreter like Python. Python has fully implemented handling of DLLs. Therefore, special declarations are not necessary when dealing with the Hart DLL. Only the structures that are given to the DLL as records need to be declared, since the Python interpreter cannot guess that.



Running the program delivers the output as it is shown on the left.

Visual Studio Code Example

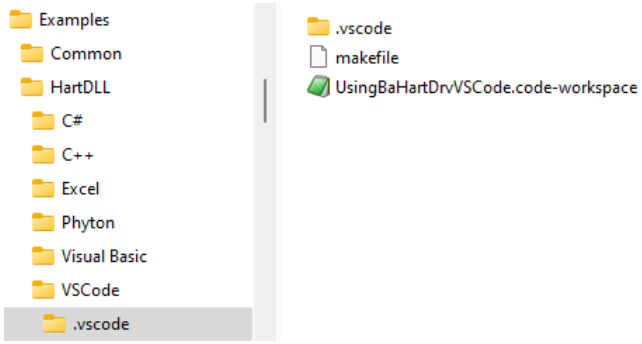


Although Visual Studio Code is only an editor, it can be configured extensively. Since VSCode is becoming more and more popular, I've set up an example Hart DLL on top of this software.

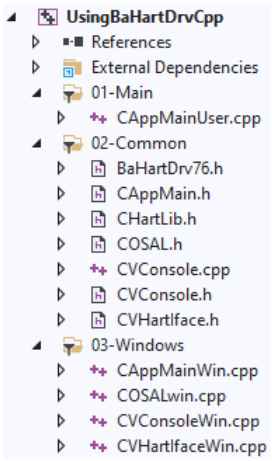
It is the same software as in the UsingBaHartDrvCpp example.

A GNU compiler was used for demonstration purposes. It is the MinGw version. To learn how to integrate MinGw into VSCode, please follow this link: https://code.visualstudio.com/docs/cpp/config-mingw.

In the examples you will find the VSCode variant in a separate path, as shown on the left.



The application name is UsingBaHartDrvVSCode. To open ot VSCode I created a workspace. This file is named: UsingBaHartDrvVSCode.code-workspace.



The screenshot on the left shows the division into the individual modules. Here, as an exception, I took the representation in Visual Studio 2019, since VSCode is not necessarily a prime example of clarity. The dependencies are implemented in the VSCode project in the associated makefile, which you can find in the workspace path (see above).

The output directory is the general debug directory for 'Any CPU' and 64 bit modules.

I don't want to leave one special feature unmentioned. While the '02-Common' subdirectory contains modules that are valid for all platforms, the 03-Windows directory is intended for the components that are used specifically for Windows.

The following shows how the code from the example application is further realized.

```
// The 'main' program
void CAppMain::Execute()
{
  CVConsole::Init(STEADY_DISPLAY_WIDTH,
                  STEADY_DISPLAY_HEIGHT);
  CVConsole::SetTitle("Using the HartDLL in C++");
```

The outputs and inputs are made via a console. Behind this is access to the Windows terminal. The applied methods are defined in the CVConsole class.

```
class CVConsole
{
public:
  static void Init(uint8_t t_steady_area_width,
                   uint8_t t_steady_area_height);
  static void WaitForExit();
  static void Terminate();

  // General functions
  static void SetTitle(char_t* tp_text);
  static void DisplayStatus(char_t* tp_text);

  // Output functions
  static void Print(char_t* tp_text);
  static void Print(uint8_t t_line, char_t* tp_text);
  static void Printf(uint8_t t_line, char_t* tp_format, ...);

  // Input functions
  static uint8_t  QueryUint8(char_t* tp_prompt);
  static uint16_t QueryUint16(char_t* tp_prompt);
  static bool8_t  QueryYes(char_t* tp_prompt);
  static void     ClearInputLine();
```

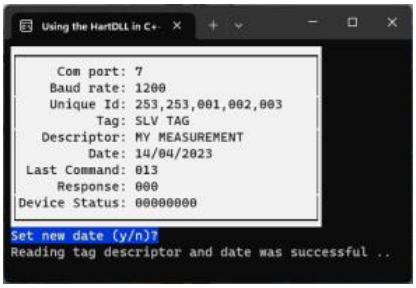
For example, the function Init looks like this.

```
void CVConsole::Init(uint8_t t_steady_area_width,
                     uint8_t t_steady_area_height)
{
   // Change language
   system("chcp 437");

   // Init steady display area
   s_steady_display_width = t_steady_area_width;
   s_steady_display_height = t_steady_area_height;

   // Get the cosoles handle
   s_std_handle = GetStdHandle(STD_OUTPUT_HANDLE);

   // Get original mode
   GetConsoleMode(s_std_handle, &s_saved_mode);

   // Get the screen buffer information
   GetConsoleScreenBufferInfo(s_std_handle,
                              &s_screen_buffer_info);

   // Set virtual terminal mode
   s_new_mode = s_saved_mode |
                ENABLE_VIRTUAL_TERMINAL_PROCESSING;
   SetConsoleMode(s_std_handle, s_new_mode);

   // Clear display
   ClearSteadyDisplay();

   // Register the local handler
   SetConsoleCtrlHandler(MyHandler, TRUE);

   // Hide the xursor
   DisableCursor();
}
```

The realization here still looks relatively abstract for the most part, but it already accesses certain functions of the console API. A look at the ClearSteadyDisplay() function shows how further refinements are being made.

```
void CVConsole::ClearSteadyDisplay()
{
    WORD attribs = GetTextAttributes();
    char_t tmp[200];

    // Enable linr drawing characters
    std::cout << ESC ENABLE_DRAWING;

    for (SHORT e = 0; e < s_steady_display_height; e++)
    {
        // Set cursor
        SetConsoleCursorPosition(s_std_handle, { 1, (SHORT)e });
        // Clear line
        std::cout << CSI CLEAR_LINE << "\r";
        if (e == 0)
        {
            tmp[0] = 0x6c;
            tmp[s_steady_display_width - 1] = 0x6b;
            memset(&tmp[1], 0x71, s_steady_display_width - 2);
        }
        else if (e == (s_steady_display_height - 1))
        {
            tmp[0] = 0x6d;
            tmp[s_steady_display_width - 1] = 0x6a;
            memset(&tmp[1], 0x71, s_steady_display_width - 2);
        }
        else
        {
            tmp[0] = 0x78;
            tmp[s_steady_display_width - 1] = 0x78;
            memset(&tmp[1], ' ', s_steady_display_width - 2);
        }

        tmp[s_steady_display_width] = 0;
        SetConsoleTextAttribute(s_std_handle, STEADY_DISPLAY_COLOR);
        std::cout << tmp;
        SetConsoleTextAttribute(s_std_handle, attribs);
    }

    std::cout << ESC DISABLE_DRAWING;
    // Restore attributes
    SetConsoleTextAttribute(s_std_handle, attribs);
}
```

This function 'paints' the background and the border of the white display area and is not quite as trivial as the two higher levels. But the function is self-contained and therefore easier to understand.



The integration of the HART protocol communication software is designed similarly to the integration of the console. The basis here is the HartTools DLL together with the header file BaHartDrv76.h. The class with the access functions is declared as follows.

```
class CVHartIface
{
public:
    static void Init();
    static void Terminate();

    static bool8_t  OpenChannel(uint16_t t_port);
    static void     CloseChannel();
    static void     SetPrimaryMaster(bool8_t t_primary);
    static bool8_t  IsDeviceConnected();
    static bool8_t  ReadTagDescriptorAndDate();
    static bool8_t  IsDateValid();
    static bool8_t  SetNewDate(uint8_t t_day, uint8_t t_month, uint16_t t_year);

    static uint16_t GetBaudRate();
    static uint8_t  GetDay();
    static uint8_t  GetMonth();
    static uint16_t GetYear();
    static char_t*  GetTag();
    static char_t*  GetDescriptor();
    static void     GetUniqueId(uint8_t* tp_long_addr);
    static uint8_t  GetLastCommand();
    static uint8_t  GetResponse();
    static void     GetDeviceStatus(char_t* tp_status);
    static bool8_t  GetConnected();
};
```

The functions of this class then access the interface of the DLL.

```
static bool8_t IsCmdSuccessful(T_DRV_HANDLE th_drv,
                               uint8_t      t_cmd,
                               uint8_t*     tp_req_data,
                               uint8_t      t_req_data_len)
{
    bool8_t    result = FALSE8;
    T_HSERVICE h_srv;

    if (th_drv == INVALID_DRV_HANDLE)
    {
        return FALSE8;
    }

    h_srv = BHDrv_DoCommand(th_drv,
                            t_cmd,
                            DRV_WAIT,
                            tp_req_data,
                            t_req_data_len,
                            0,
                            s_connection.aucUniqueId);
    if (h_srv != INVALID_SRV_HANDLE)
    {
        BHDrv_FetchConfirmation(h_srv, &s_confirmation);
        if (s_confirmation.ucError == SRV_SUCCESSFUL)
        {
            result = TRUE8;
            s_last_command = t_cmd;
            s_response = s_confirmation.ucRespCode1;
            s_device_status = s_confirmation.ucRespCode2;
        }
        else if (s_confirmation.ucError == SRV_NO_DEV_RESP)
        {
            s_connected = FALSE8;
        }
    }

    return result;
}
```

Detailed Descriptions

FrameAlyst

When the development of FrameAlyst was started it was mainly targeted to simply monitoring Hart frames to detect errors in the device implementation.

Later the tool was expanded to use the HartDLL for the emulation of a master function.

In the recent years also a slave emulations were introduced. While in the latest implementation either a slave or a master emulation was available today the new FrameAlyst is supporting both functionalities at a time.

Features

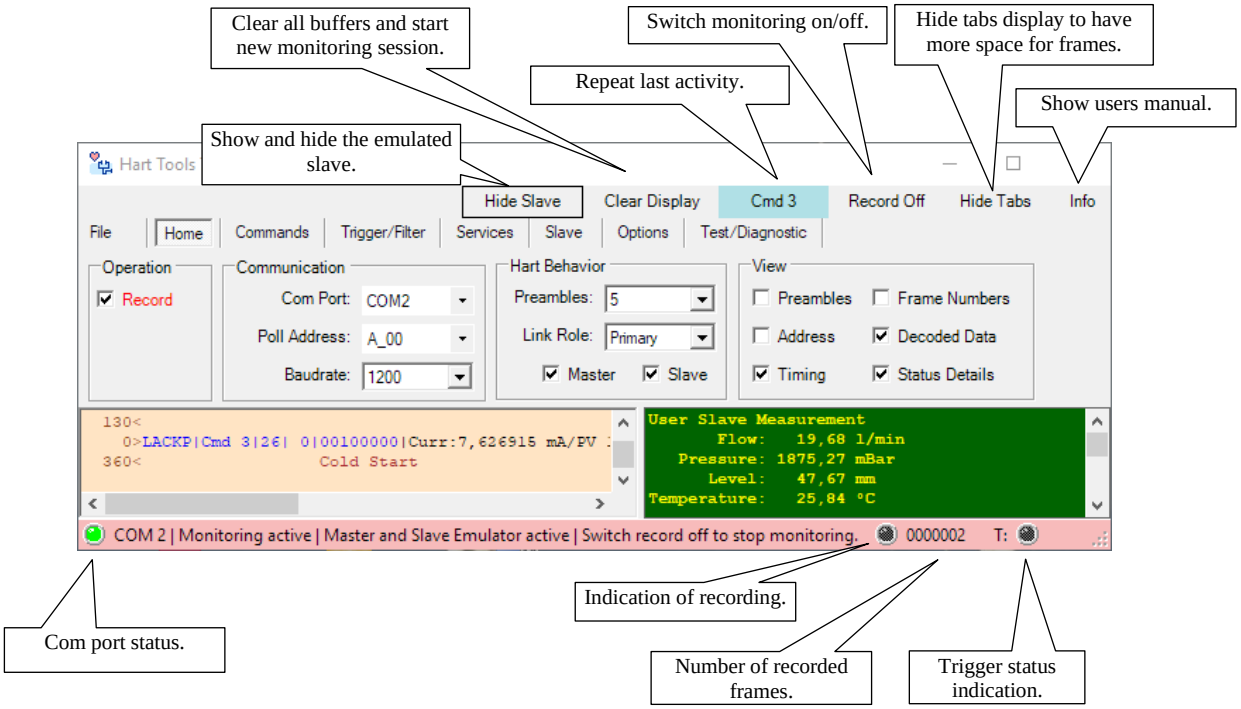
The main features which are supported by FrameAlyst are the following.

- Master emulation
- Slave emulation
- Slave DLL interface
- Trigger functions
- Filter functions
- Scripting
- Command data decoding
- Storing recorded data
- Test and diagnostic functions
- Integrated services
- Coding and Decoding
- Data syntax editor
- Data logging in xml-format

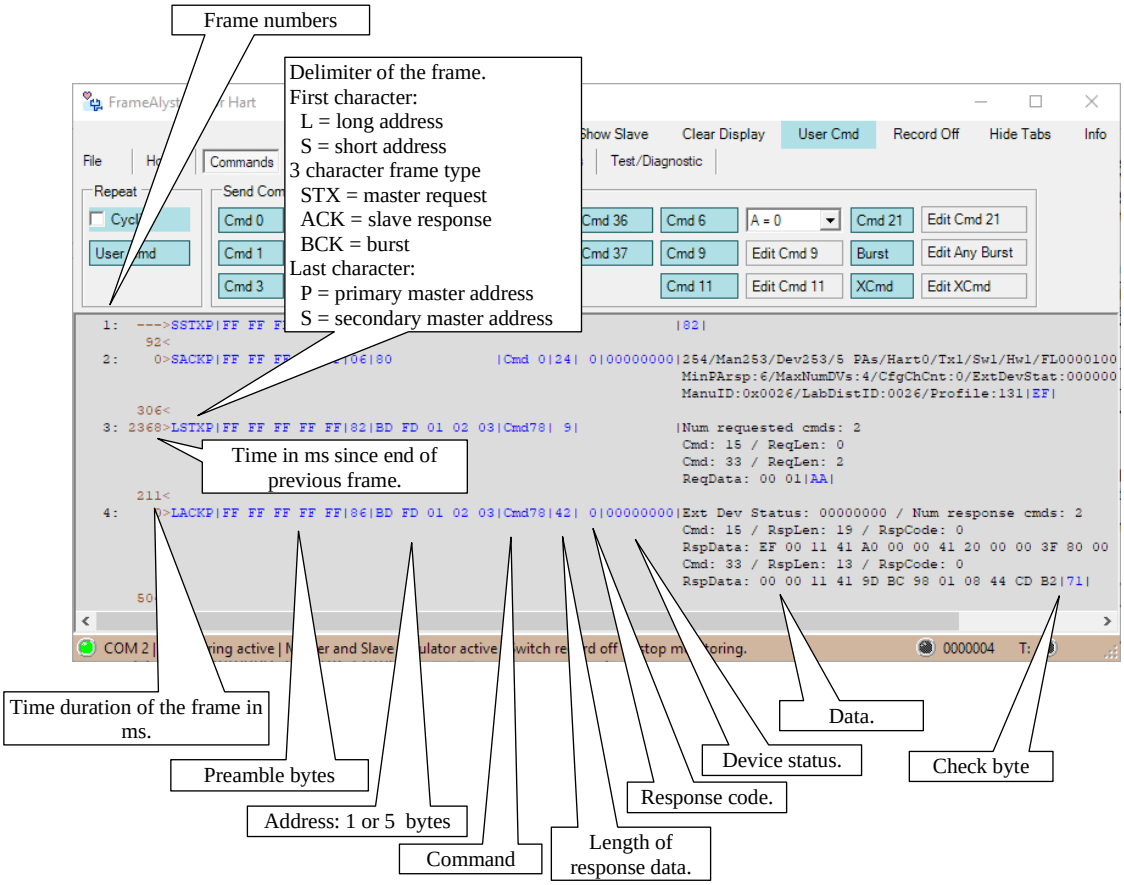
Functions and Menus

Common Elements

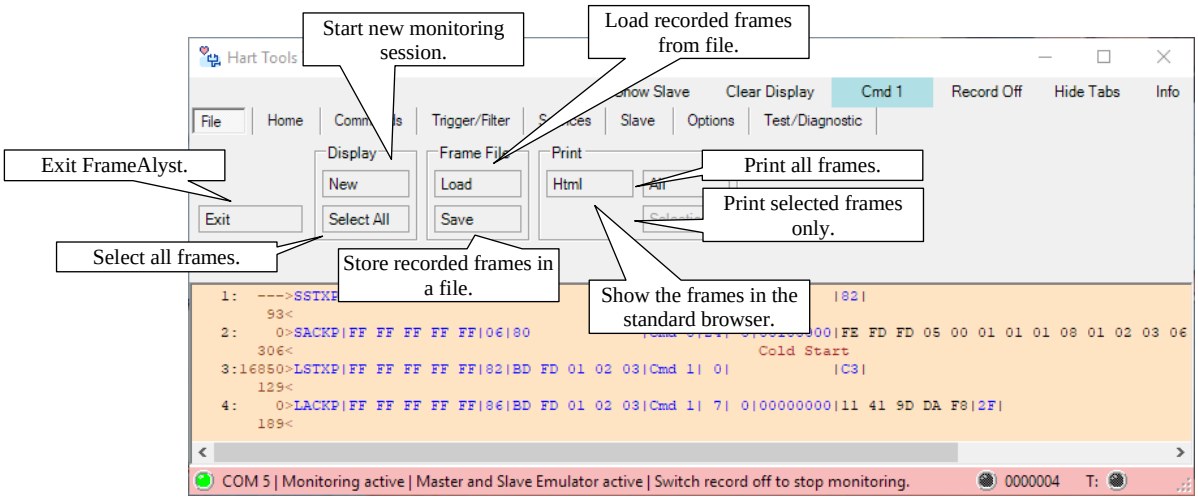
The handling of FrameAlyst is based on tabs rather than menus.



Display Items (Frames)

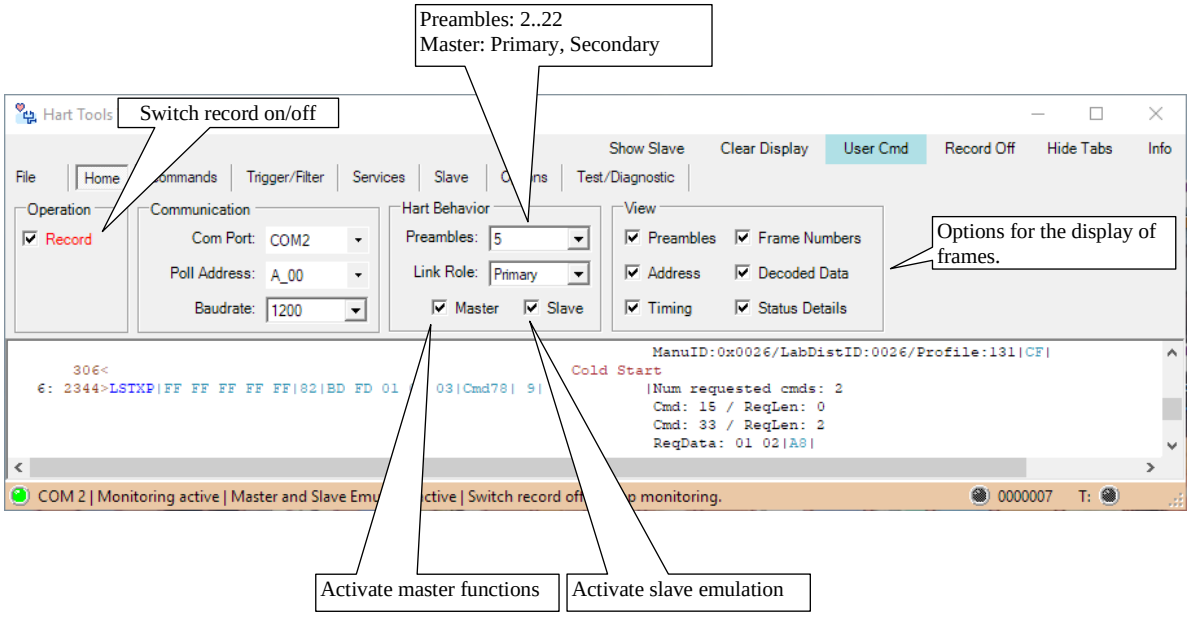


File Menu

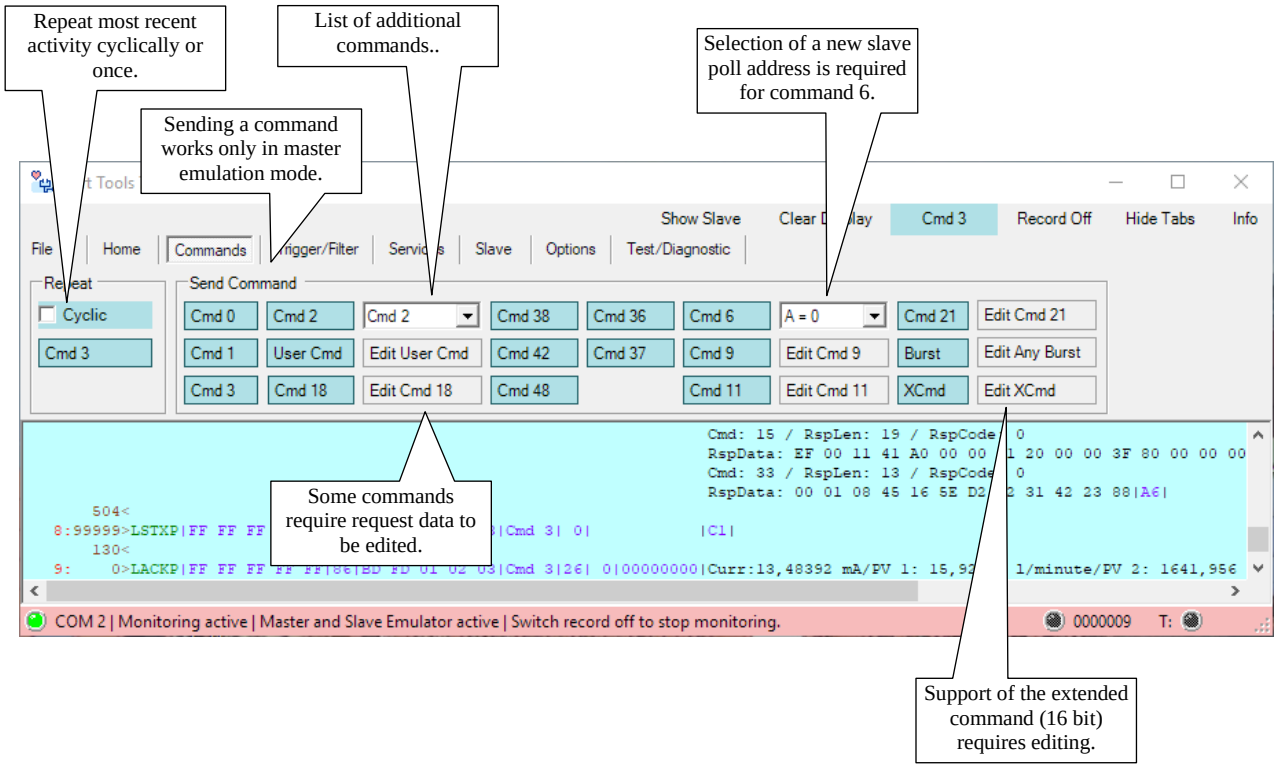


The frames are still stored in the format which was used in the past. However when saving the frame data you may also select an xml format or html format.

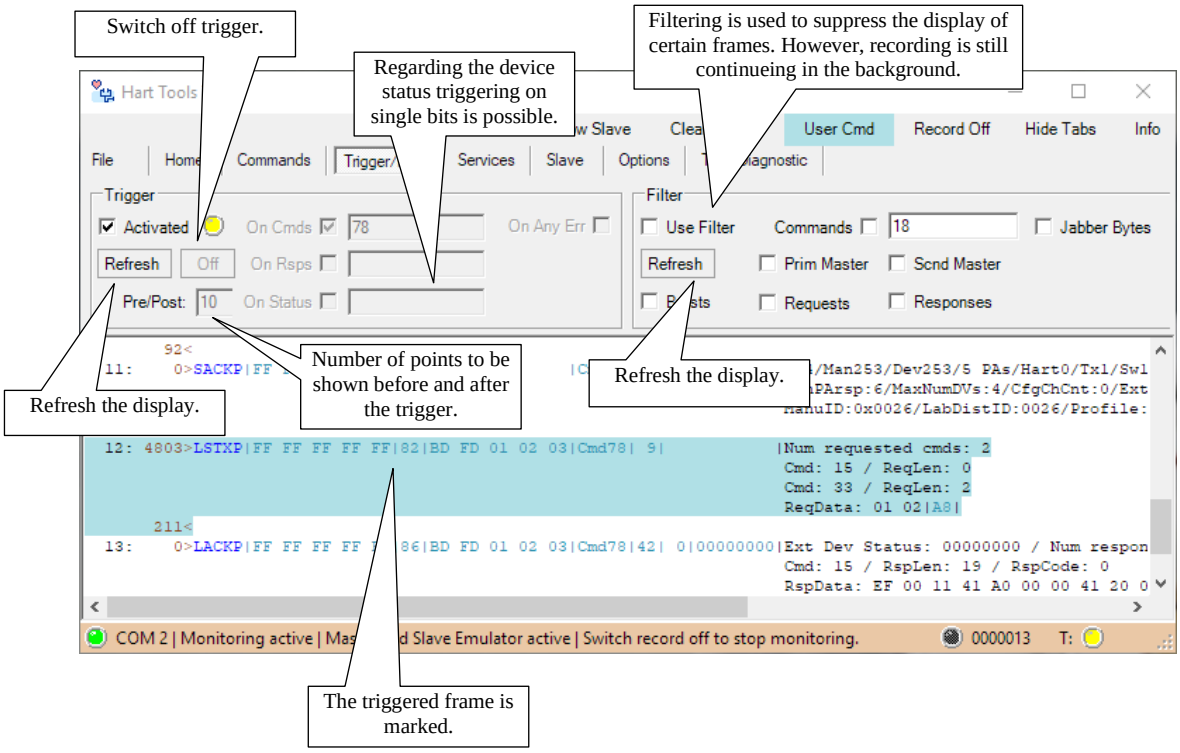
Home Menu



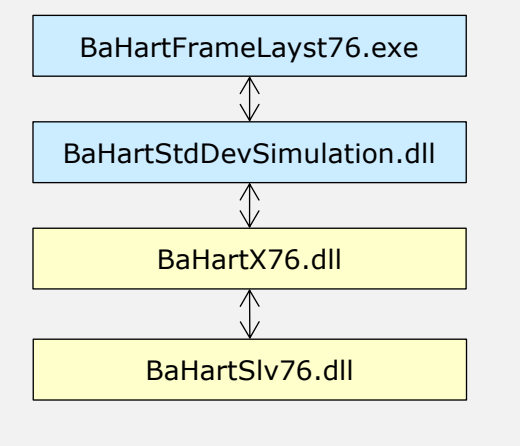
Hart Commands Menu



Trigger/Filter Menu



Slave Menu

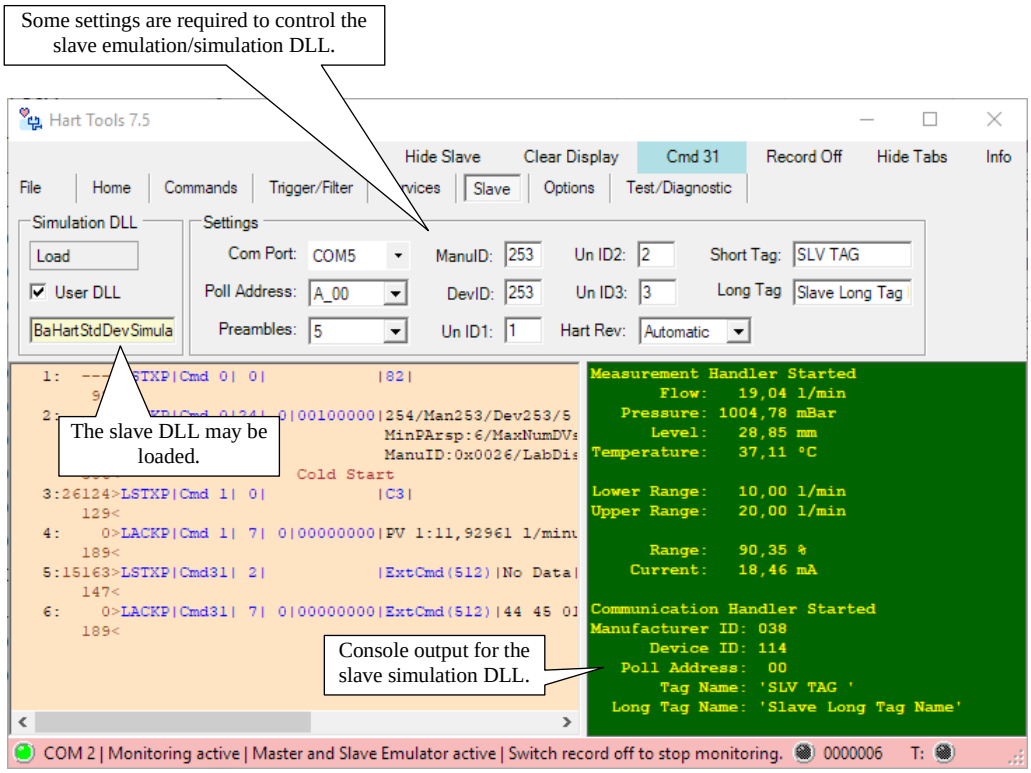


FrameAlyst able to load a DLL for the simulation of a slave device. This DLL is a class library written in C#. Thus it is also possible for the user to provide another slave device DLL written in C#.

The device simulation uses BaHartX76.dll which is a shell for the native library BaHartSlv76.dll.

Figure 13: Slave Emulation Architecture

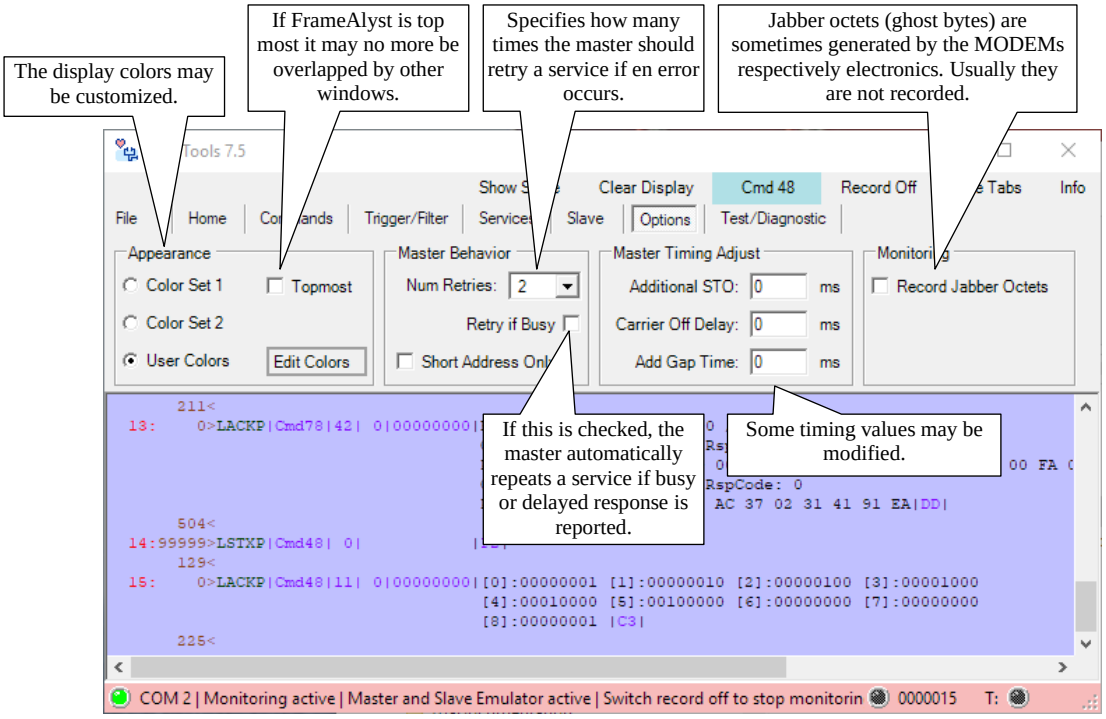
The slave may be configured through FrameAlyst.



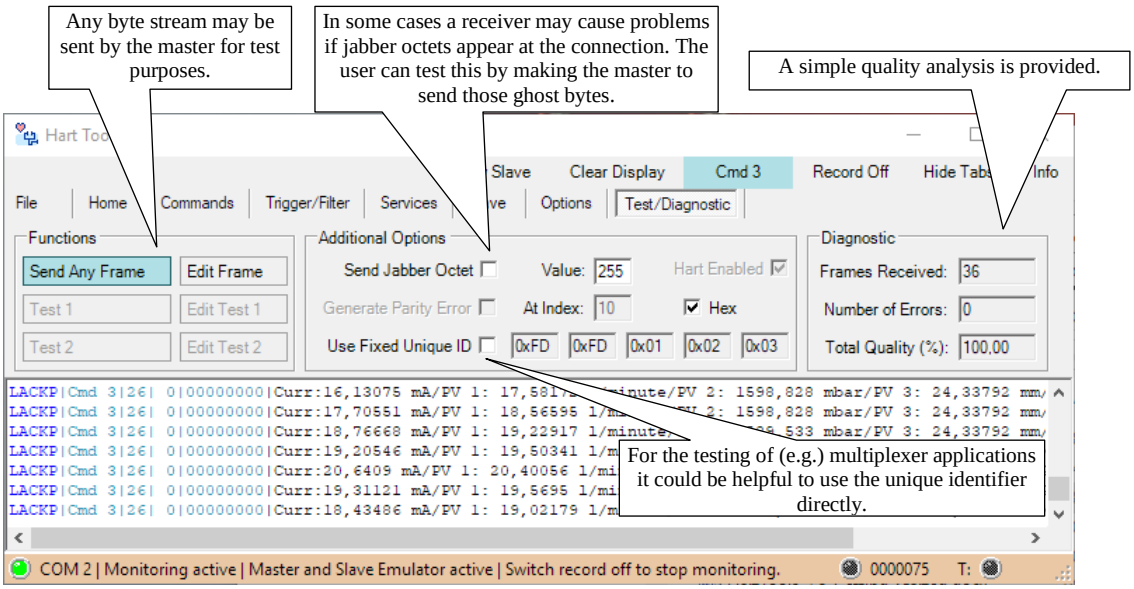
The slave interface of the HartDLL allows the developer of a Hart master device to simulate any slave functionality and any erroneous behavior of a Hart slave device.

Because the slave is running through a com port it can be be part of a multidrop environment.

Options Menu



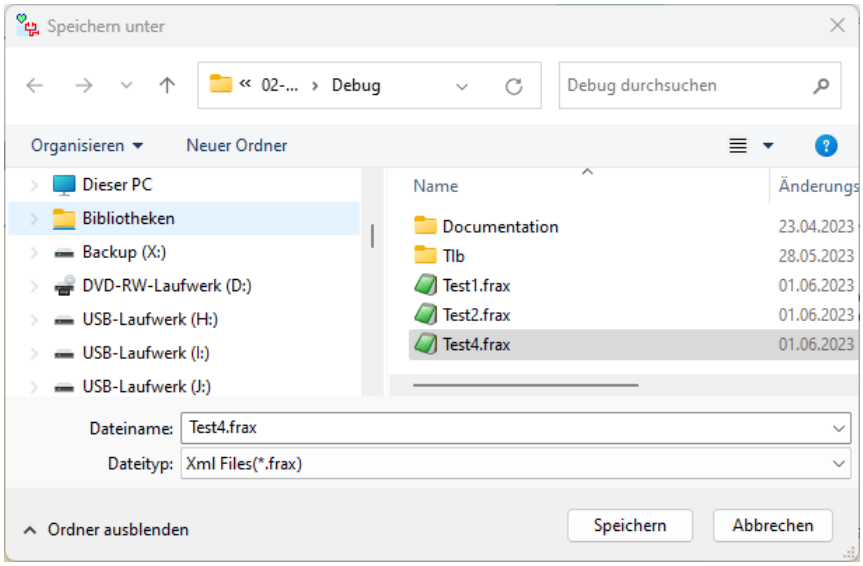
Test/Diagnostic Menu



The above display was generated by using the filter for the suppression of requests.

Additional Features

Store in Xml and Html Format



If you select the file extension .frax, the frames will be strored in xml format.

Alternatively you may also choose an html format as a documentation of the debug session.

An example of an xml output is shown on the following page.

Xml Format Example

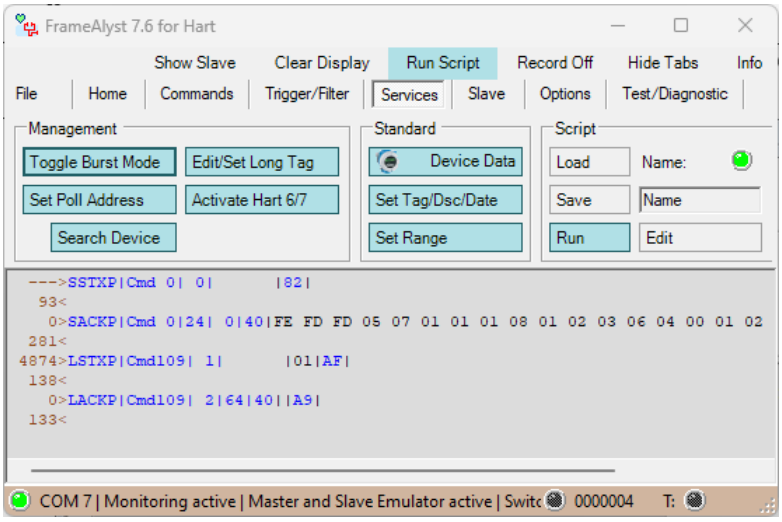
```
<?xml version="1.0"?>
<FrameAlystRecords>
  <Header>
    <FrameAlystVersion>7.6.0</FrameAlystVersion>
    <SessionInfo>FrameAlyst 7.6 for Hart</SessionInfo>
    <NumberOfFrames>8</NumberOfFrames>
    <TimeAndDate>01.06.2023 16:51:41</TimeAndDate>
  </Header>
  <Frames>
    <Frame Number="00000">
      <RawData>
        <Properties StartTime="442846195" EndTime="442846324" NumberOfBytes="14" WasGapTimeOut="False" ClientTxFlag="True" IsValidFrame
        <FrameBytes>255,255,255,255,255,130,189,253,1,2,3,0,0,194</FrameBytes>
      </RawData>
      <AddInfo>
        <HeadingComment>Script: CMD(0) / NO DATA</HeadingComment>
      </AddInfo>
    </Frame>
    <Frame Number="00001">
      <RawData>
        <Properties StartTime="442846298" EndTime="442846626" NumberOfBytes="38" WasGapTimeOut="False" ClientTxFlag="False" IsValidFram
        <FrameBytes>255,255,255,255,255,134,189,253,1,2,3,0,24,0,0,254,253,253,5,7,1,1,1,8,1,2,3,6,4,0,0,2,0,38,0,38,131,168</FrameByte
      </RawData>
      <AddInfo />
    </Frame>
    <Frame Number="00002">
      <RawData>
        <Properties StartTime="442846718" EndTime="442847040" NumberOfBytes="35" WasGapTimeOut="False" ClientTxFlag="True" IsValidFrame
        <FrameBytes>255,255,255,255,255,130,189,253,1,2,3,18,21,48,149,49,211,8,32,24,195,215,130,8,32,130,8,32,130,8,32,1,6,123,112</F
      </RawData>
      <AddInfo>
        <HeadingComment>Script: CMD(18) / DATA(Pasc6;LIT140  ;Pasc12;FLOW           ;1;6;123)</HeadingComment>
      </AddInfo>
    </Frame>
  </Frames>
</FrameAlystRecords>
```

Regarding Html format you may either store the records in an Html file or click ‘html’ in the print functions. The print function for ‘html’ is opening your standard browser directly to display the frames.

Html Output Example

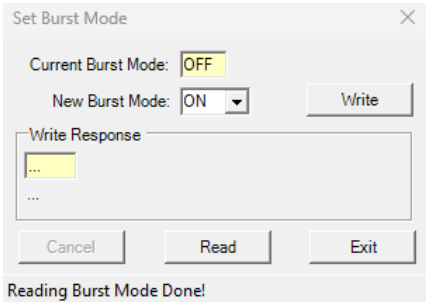
Services Menu

Services are some more complex functions as only sending a command.



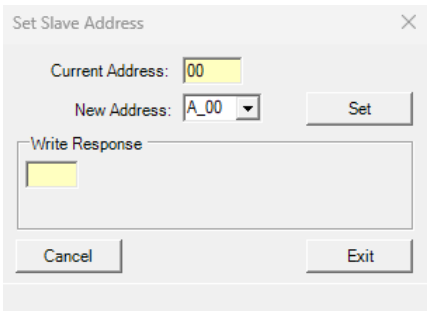
The services are only working if the FrameAlyst is using the master emulation.

Toggle Burst Mode



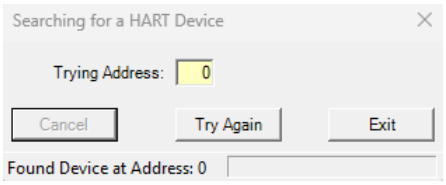
This service is handling command 109.

Set Poll Address

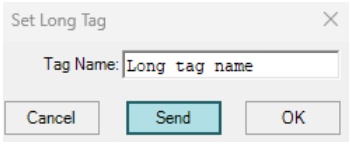


Set slave poll address is handling command 6. Note: Hart5 is only supporting addresses 0..15 while Hart 7 has a range of 0..63.

Search Device



Edit/Set Long Tag



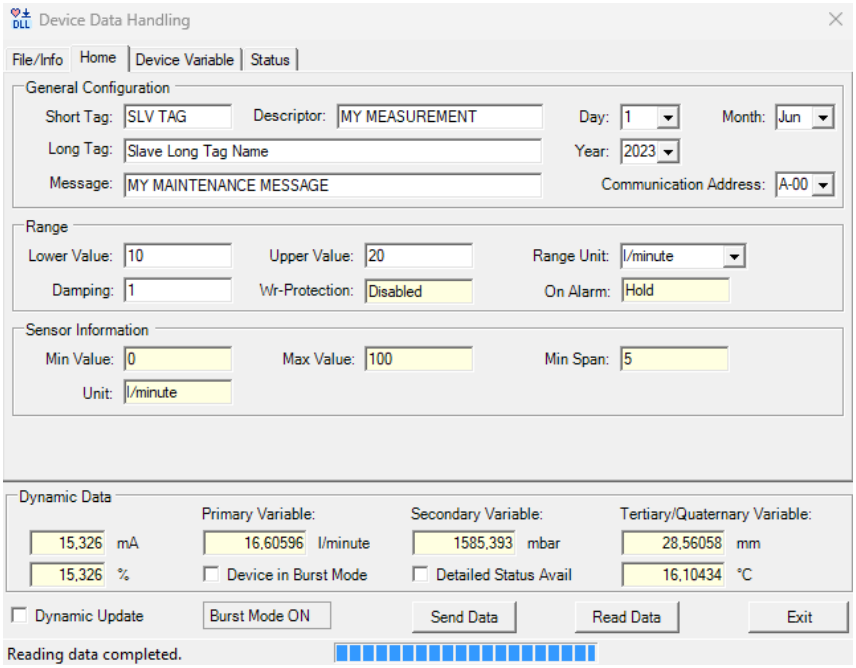
The long tag is an iso latin-1 string of a length of a maximum of 32 characters. If it contains less than 32 characters it is terminated by 0x00.

Activate Hart 6/7

There is no form provided which is used to realize this mean.

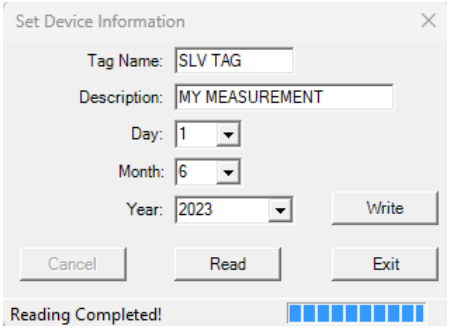
The service is using commands 7 and 6 to signal the slave device that a Hart 6/7 host is connected.

Handle Device Data



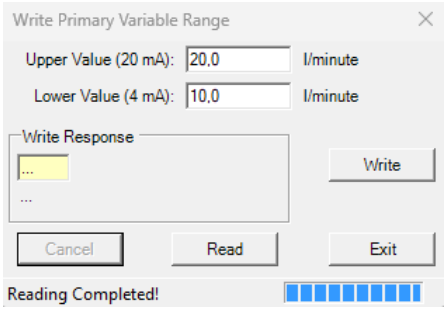
This service is reading the main information from a device.

Set Tag, Descriptor and Date



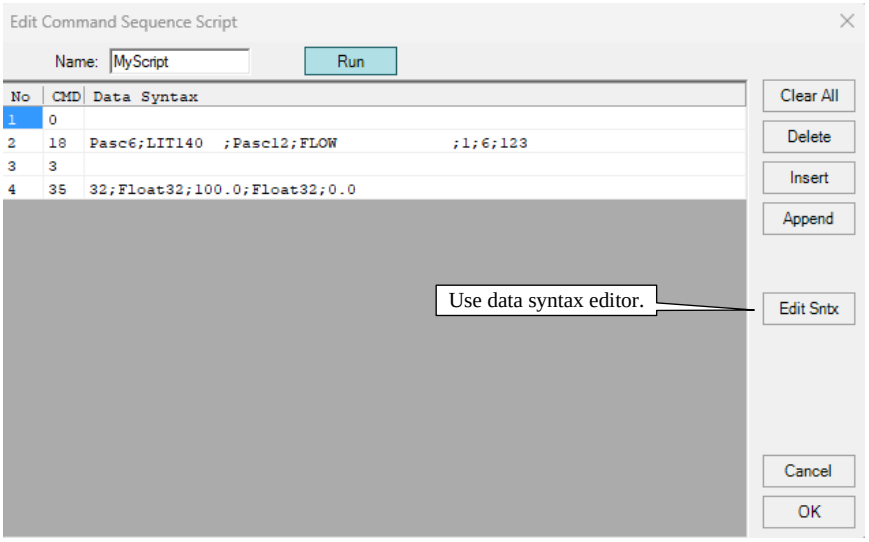
This application is setting the short tag, the descriptor and the date.

Set Range

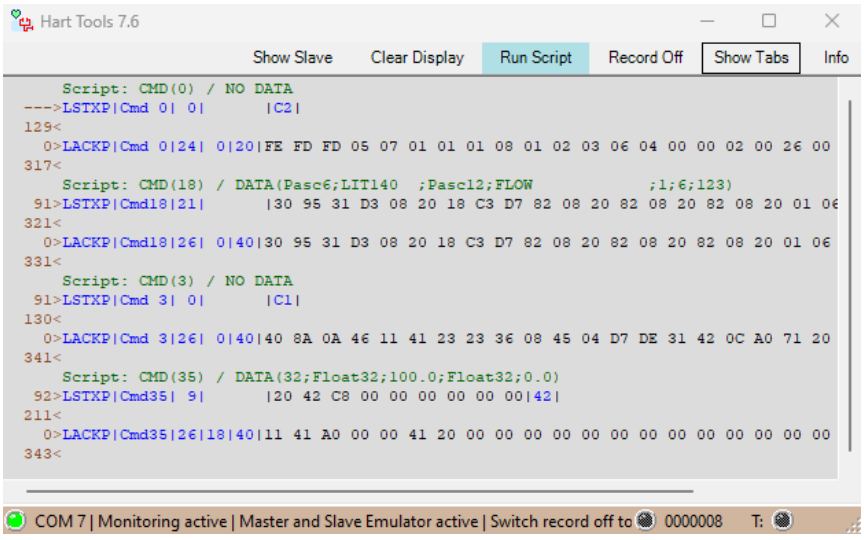


The service is trying to write the upper and the lower range value of the primary variable of a device.

Edit and Run Scripts



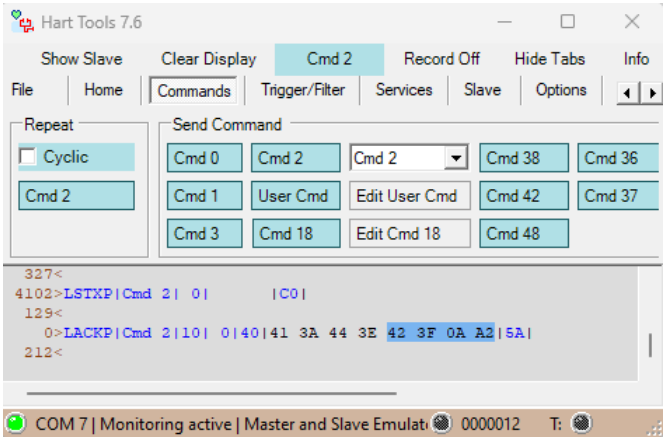
The example above is sending the commands 0, 18, 3 and 35.



The script may be stored in a file and be loaded from a file. The active script is always stored in the settings of the software and automatically reloaded after the start of FrameAlyst.

If command 255 is specified in the script, the data will be sent as is not formatted as a Hart frame.

Decoding Data in a Frame



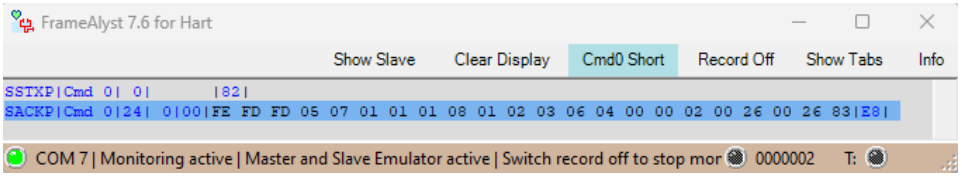
By using the right mouse button a context menu will be displayed.

Integer
Float
HartUnit
PackedASCII
Text
Binary

Copy to AnyFrame

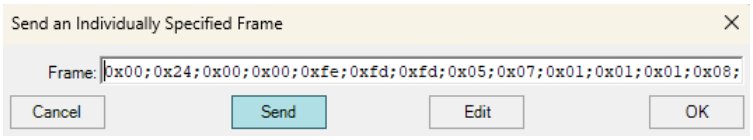
Select the decoding of your choice and the value will be displayed in a tool tip.

Copy to SendAnyFrame

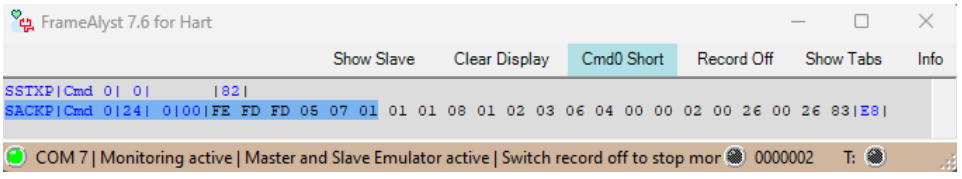


Select the whole frame, click the right mouse button and click 'Copy to AnyFrame' in the context menu.

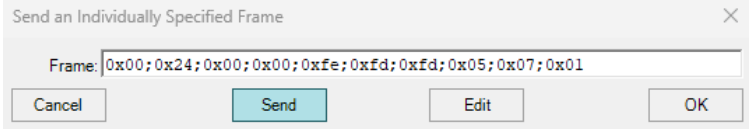
The data will be copied to this function and the edit any frame window will open.



It is also possible to copy only a part of the data.



It will appear as is in the any frame editing function.



Copy Bytes to the Clipboard

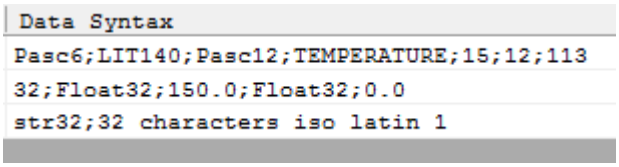
The same functionality as shown allows also to copy data bytes to the Windows clipboard by selecting 'Bytes to ClipBoard' in the context menu.

Editing Data Syntax

Data syntax allows to easily specify a stream of bytes to be send.

Prefix	Type	Example	Comment
None	Decimal or Hexadecimal	24; 0x18	The software will determine the required length
dec8, dec16, dec24, dec32	Decimal number	dec16; 1011	
bin8, bin16, bin24, bin32	Binary number	bin8; 10001101	
hex8, hex 16, hex24, hex32	Hexadecimal number	hex16; fa13	
float32	Single precision	float32; 1.34	
float64	Double precision	float64; 1.11e+48	
pca6, pca12, pca24	Packed ascii	pca6;LITT1400	pca6 = 8 characters pca12 = 16 characters pca24 = 32 characters
str8, str16, str32	Fixed length string	str32;my-device	Resulting byte array will be filled by 0s

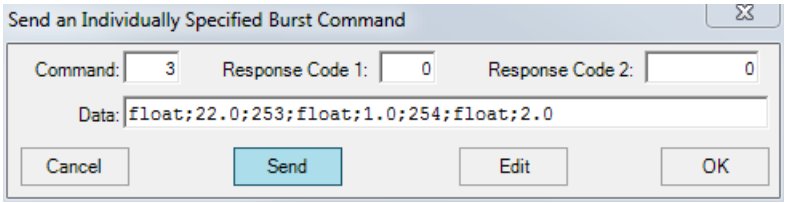
All items the prefix and the data lement are separated by a colon ';'.



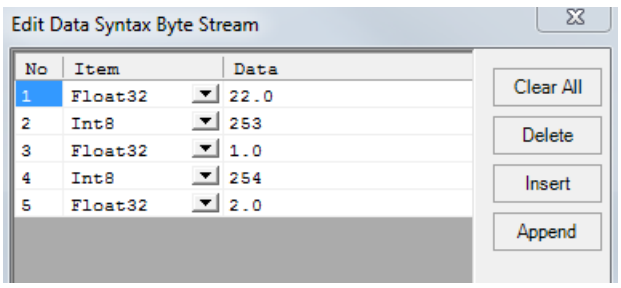
A few examples are shown above

However, it could be much easier to do this by the data syntax editor.

When editing a command that requires data to be specified

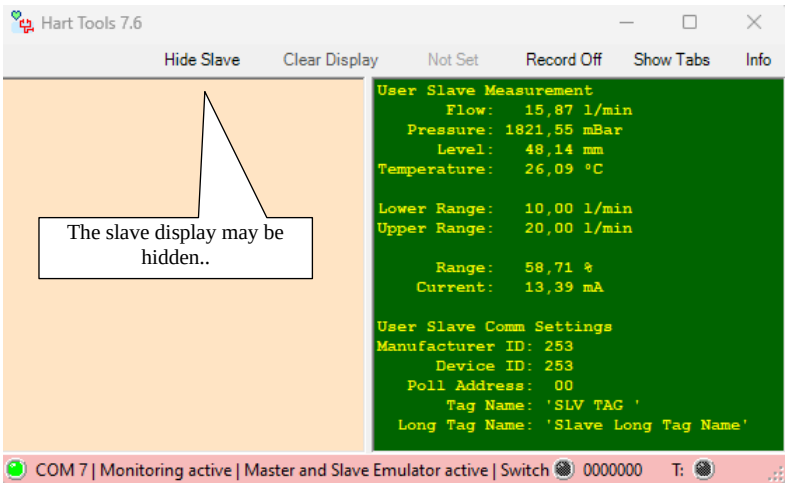


the data syntax editor will open on a click of the edit button.

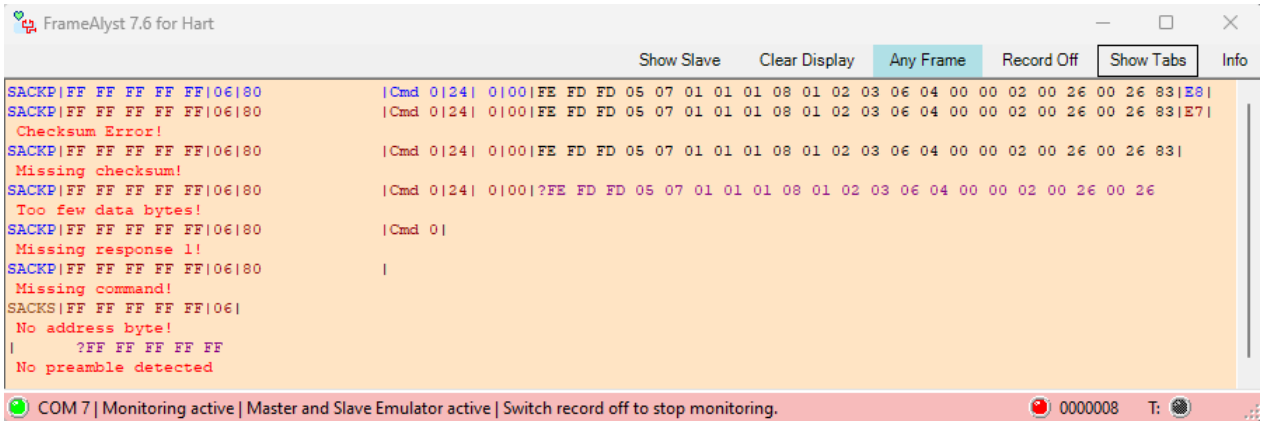


Displaying the Slave Emulation

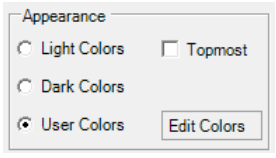
If the slave emulation is active, FrameAlyst provides a callback to the slave simulation which is used by this software for printing text with the printf function in the C libraries.



Handling of Erroneous Frames



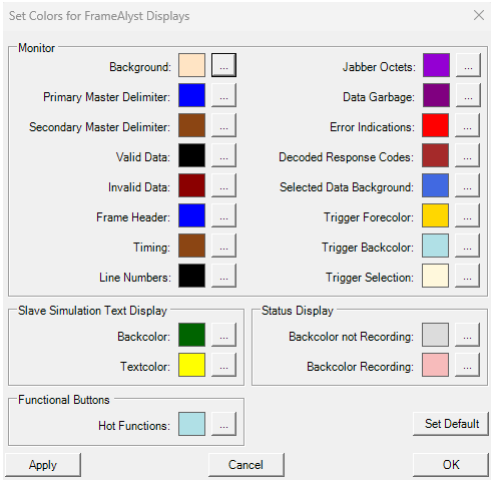
Setting Custom Colors



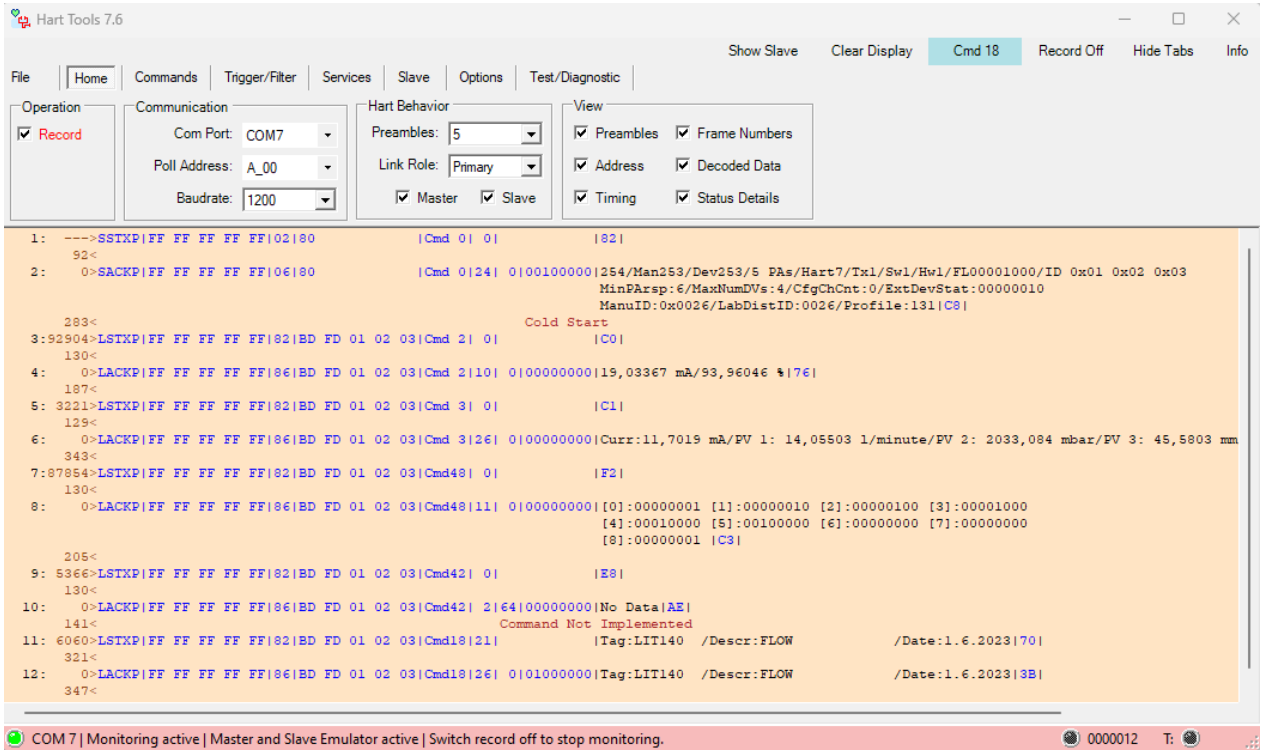
The tab Options is providing User Colors.

The user colors can be edited by clicking the button 'Edit Colors'.

The color editing form is shown in the following.



Frame Display Examples



HartDLL (Client + OSAL)

The Hart Driver DLL is implementing the Hart communication protocol by resolving the real time requirements.

The DLL is not (!) using any framework like MFC. It does not use the Windows Registry and is not depending on any other DLL except the standard Windows system DLLs. The DLL itself is using standard Windows API calls and is therefore compatible to all Versions of Windows with the 32 bit and 64 bit API.

The implementation of the Hart Protocol does not contain any restriction to frame lengths like in Hart 5.x (e.g.). Therefore the all communication functions can be used for devices supporting Hart 5, Hart 6 or Hart 7.

Before using the communication the application software has to register for a com port of the PC. This can be any com port from 1 to 255 including virtual com ports as they are used for USB hart modems.

Distribution of Applications

The only thing you have to provide with your application is a copy of the DLL (BaHartDrv74.dll). The best way is to provide a copy of the 32 bit DLL (x86) as well as a copy of the 64 bit DLL (x64). The files should be copied to the Windows system paths for 32 and 64 bit DLLs.

Note: Be sure that the first call of your application is a call of the validation function of the DLL (BHDrv_ValidateLicense) passing a valid license code and the correct user name to the DLL.

Functions

All functions of the DLL are thread safe. The interface for the functions calls is the same as the WINAPI functions. Thus the DLL may be used by all applications which support calls to the WINAPI functions.

Declaration	Description
Operation	
`void BHDrv_ValidateLicense (const char* userName, const char* license)`	The first call into the DLL should be a call to this function passing the correct license key and the user name to the software. The user name and the licensee code is provided by the User License Certificate.
`signed int BHDrv_OpenChannel (unsigned short comPort)`	The function allocates the selected com port if possible and starts its own working thread for accessing Hart services. The value which is returned is a handle (channel) which has to be passed to all functions which are requesting a service. If it was not possible to open the com port the function is returning INVALD_DRV_HANDLE to indicate the error. The com port number is limited to the range of 1 .. 255.
`void BHDrv_CloseChannel (signed int channel)`	It is required to call this function at least when the application is terminating.
`void BHDrv_GetConfiguration (signed int channel, T_strConfiguration* pstrConfig)`	The function copies the configuration data to a data structure provided by the caller.
`void BHDrv_SetConfiguration (signed int channel, T_strConfiguration* pstrConfig)`	The function is setting all details required for the configuration. The data is passed in a structure provided by the caller.
`void BHDrv_GetRunTimeInfo (signed int channel, T_strRunTimeInfo* pstrRunTimeInfo)`	Return some information about the communication channel (e.g. if the use of a FIFO at the UART was detected.
`void BHDrv_RegisterEventCallback (signed int channel, void (__stdcall* HandleServiceEvent) (signed int channel, unsigned short usEvent, signed int service, unsigned int data))`	Register a function which is called when any requested service is completed. The service handle of the service is passed to the called CB function. HandleServiceEvent is the pointer to the handling function which is provided by the user. The parameter usEvent may have the values NONE, CONFIRMATION or BURST_INDICATION. The parameter channel is passed to the application to allow the support of more than one communication channel in one callback.
`void BHDrv_ClearEventCallback (signed int channel)`	Deletes a previously registered callback. After a call of this function no more callbacks to HandleServiceEvent will occur.
Connection Services	
`unsigned int BHDrv_ConnectByAddr (signed int channel, unsigned char address, unsigned char qos, unsigned char numRetries)`	Use command 0 with short address to get the connection information. channel: The handle which was returned by the OpenChannel function address: 0 .. 63 qos: DRV_WAIT or DRV_NO_WAIT numRetries: 0 .. 10 The function returns a service handle if successful or INVALID_SRV_HANDLE if there was an error.
`unsigned int BHDrv_ConnectByUniqueID (signed int channel, unsigned char * dataRef, unsigned char qos, unsigned char numRetries)`	Use command 0 with short address to get the connection information. channel: The handle which was returned by the OpenChannel function dataRef: Pointer to a five byte array with the unique identifier qos: DRV_WAIT or DRV_NO_WAIT numRetries: 0 .. 10 The function returns a service handle if successful or INVALID_SRV_HANDLE if there was an error.
`unsigned int BHDrv_ConnectByShortTag (unsigned int channel, unsigned char * dataRef, unsigned char qos, unsigned char numRetries)`	Use command 0 with short address to get the connection information. channel: The handle which was returned by the OpenChannel function dataRef: Pointer to the byte array of a length of 6 packed ASCII bytes qos: DRV_WAIT or DRV_NO_WAIT numRetries: 0 .. 10 The function returns a service handle if successful or INVALID_SRV_HANDLE if there was an error.

Declaration	Description	
`unsigned int BHDrv_ConnectByLongTag (unsigned int channel, unsigned char* dataRef, unsigned char ucQOS, unsigned char numRetries)`	Use command 0 with short address to get the connection information.	
	channel	The handle which was returned by the OpenChannel function
	dataRef	Pointer to the 32 byte ISO Latin 1 string with the long tag name
	qos	DRV_WAIT or DRV_NO_WAIT
	numRetries	0 .. 10
	The function returns a service handle if successful or INVALID_SRV_HANDLE if there was an error.	
`void BHDrv_FetchConnection (signed int service, T_strConnection* pstrConnData)`	Fills a structure provided by the caller with the connection information. hSrv is the service handle which was returned by one of the connection functions. Note: After a call of this function the driver is deleting the service. hSrv is no longer valid after calling FetchConnection once.	
Communication Services		
`unsigned char BHDrv_IsSendClear (signed int channel)`	The function returns B_TRUE, if no more service is pending.	
`signed int BHDrv_SendAnyData (signed int channel, unsigned char* dataRef, unsigned char dataLen)`	Send any octet stream via the connected com port.	
	channel	The handle which was returned by the OpenChannel function
	dataRef	Pointer to a native array of bytes
	dataLen	Number of bytes to be sent
	The function returns a service handle if successful or INVALID_SRV_HANDLE if there was an error. The function is provided for debugging purposes allowing to send any stream of data through the serial interface. Note: It is very important to acknowledge this service by calling the function FetchConfirmation after completion. Only with this call the service handle is deleted.	
`signed int BHDrv_DoCommand (signed int channel, unsigned char command, unsigned char qos, unsigned char* dataRef, unsigned char dataLen, unsigned long appKey, unsigned char* bytesUniqueID)`	Send a command in the range 0..255.	
	channel	The handle which was returned by the OpenChannel function
	command	Hart command (0..255) to be sent with the request
	qos	DRV_WAIT or DRV_NO_WAIT
	dataRef	Pointer to a native byte array which is sent as payload data
	dataLen	Length of the byte array
	appKey	Any value. The value which the user is setting here is returned by the confirmation as is.
	bytesUniqueID	Five byte unique identifier of the addressed device
	The function returns a service handle if successful or INVALID_SRV_HANDLE if there was an error. Do command can be used for the support of most of the Hart services including all user specific commands. Note: It is not(!) recommended to pass a function pointer through dwAppKey. This will cause problems with 64 bit applications!	
`signed int BHDrv_DoExtCmd (signed int channel, unsigned short command, unsigned char qos, unsigned char* dataRef, unsigned char dataLen, unsigned long appKey, unsigned char* bytesUniqueID)`	Send a command in the range 0..65535.	
	channel	The handle which was returned by the OpenChannel function
	command	Extended Hart command **(0..65535**) to be sent with the request
	qos	DRV_WAIT or DRV_NO_WAIT
	dataRaf	Pointer to a native byte array which is sent as payload data
	dataLen	Length of the byte array
	appKey	Any value. The value which the user is setting here is returned by the confirmation as is.
	bytesUniqueID	Five byte unique identifier of the addressed device
	The function returns a service handle if successful or INVALID_SRV_HANDLE if there was an error. The extended command in Hart 6/7 is an extension which is using the byte command 31 to carry a larger command within the data area. Therefore this function was introduced more or less for the convenience of the HartDLL user. The function is automatically taking care of the correct usage of command 31. Note: It is not(!) recommended to pass a function pointer through dwAppKey. This will cause problems with 64 bit applications!	

Declaration	Description	
`signed int BHDrv_DoBurstCommand (signed int channel, unsigned char command, unsigned char qos, unsigned char* dataRef, unsigned char dataLen, unsigned long appKey, unsigned char* bytesUniqueID, unsigned char invertMaster)`	Send a burst command (cyclic service) in the range of 0..255.	
	channel	The handle which was returned by the OpenChannel function
	ucCommand	Hart command (0..255) to be sent with the request
	ucQOS	DRV_WAIT or DRV_NO_WAIT
	pucReqData	Pointer to a native byte array which is sent as payload data
	ucReqDataLen	Length of the byte array
	dwAppKey	Any value. The value which the user is setting here is returned by the confirmation as is.
	pucUniqueID	Five byte unique identifier of the addressed device
	invertMaster	0: do nothing, !=0: primary to secondary and visa versa
	The function returns a service handle if successful or INVALID_SRV_HANDLE if there was an error. To send a burst command may be helpful for device developers or for debugging a network. Note: Even if the burst command is only sent and no response is received, it is very important to acknowledge this service by calling the function FetchConfirmation after completion. Only with this call the service handle is deleted.	
`unsigned char BHDrv_IsServiceCompleted (signed int service)`	Returns T_TRUE if the service (service) was completed.	
`void BHDrv_FetchConfirmation (unsigned int service, T_strConfirmation* pstrConfData)`	Fills a structure provided by the caller with the service results information such as the response codes and the response data (if any).	
Cyclic Data Services		
`void BHDrv_CycSrvStart (signed int channel)`	The function is enabling the reception of incoming burst messages. Note: If this function is called eventual existing messages in the drivers queue are deleted, thus the reception of Hart burst messages starts with an empty queue. However, before BHDrv_CycSrcStart is called incoming burst messages are discarded.	
`void BHDrv_CycSrvStop (signed int channel)`	After the call of this function the reception of burst messages is halted. Messages already in the queue may be read by BHDrv_CycSrvGetData.	
`unsigned char BHDrv_CycSrvGetData (signed int channel, T_strCyclicData* pstrCycData)`	Read cyclic data from the queue in the HartDLL. The returned value indicates if cyclic data was fetched from the queue or not: CYCDAT_OK or CYCDAT_NO_DATA.	
`void BHDrv_CycSrvRegisterCB (unsigned int channel, void (__stdcall* pfSubscribeCycData) (T_strCyclicData* pstrCycData))`	For asynchronous reading of cyclic data a callback function may be registered at the DLL. A pointer to a user function is passed, which is called when cyclic data was received. The user function accepts the channel handle and a pointer to a structure containing the received cyclic data.	
`void BHDrv_CycSrvUnregister (signed int channel)`	After this function was called no more callbacks will be done.	

Declaration	Description
Decoding	
`unsigned char BHDrv_PickInt8 (unsigned char offset, unsigned char* dataRef)`	Return the value of the byte in the byte array buffer pointed to by dataRef at the position offset.
`unsigned short BHDrv_PickInt16 (unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Return the value of the integer 16 from the byte array buffer pointed to by dataRef at the position offset. Assume that the most significant byte is the first if endian is MSB_FIRST(0), which is the Hart standard.
`unsigned long BHDrv_PickInt24 (unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Return the value of the integer 24 from the byte array buffer pointed to by dtaRef at the position offset. Assume that the most significant byte is the first if endian is MSB_FIRST(0), which is the Hart standard.
`unsigned long BHDrv_PickInt32 (unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Return the value of the integer 32 from the byte array buffer pointed to by dataRef at the position offset. Assume that the most significant byte is the first if endian is MSB_FIRST(0), which is the Hart standard.
`float BHDrv_PickFloat (unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Return the value of the single precision IEEE754 number from the byte array buffer pointed to by dataRef at the position offset. Assume that the most significant byte is the first if endian is MSB_FIRST(0), which is the Hart standard.
`double BHDrv_PickDouble (unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Return the value of the double precision IEEE754 number from the byte array buffer pointed to by dataRef at the position offset. Assume that the most significant byte is the first if endian is MSB_FIRST(0), which is the Hart standard.
`void BHDrv_PickPackedASCII (unsigned char* sb, unsigned char stringLen, unsigned char offset, unsigned char* dataRef)`	Generate a string and copy it to the buffer pointed to by sb. The final string should have the length stringLen. The packedASCII source is a set of bytes in the byte array buffer pointed to by dataRef. Note: The string length has to by a multiple of 4 while the number of packedASCII bytes is a multiple of 3.
`void BHDrv_PickOctets (unsigned char* dataDestination, unsigned char numOctets, unsigned char offset, unsigned char* dataSource)`	Copy a number (numOctets) of bytes from the byte array buffer pointed to by dataSource to the user buffer pointed to by dataDestination.
`void BHDrv_PickString (unsigned char* sb, unsigned char stringLen, unsigned char offset, unsigned char* dataRef)`	This function does the same as BHDrv_PickOctets.

Declaration	Description
Encoding	
`void BHDrv_PutInt8 (unsigned char data, unsigned char offset, unsigned char* dataRef)`	Insert an integer 8 into the byte array buffer pointed to by dataRef starting at the position offset.
`void BHDrv_PutInt16 (unsigned short data, unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Insert an integer 16 into the byte array buffer pointed to by dataRef starting at the position offset. Start with the most significant byte if endian is MSB_FIRST(0), which is the Hart standard.
`void BHDrv_PutInt24 (unsigned long data, unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Insert an integer 24 into the byte array buffer pointed to by dataRef starting at the position offset. Start with the most significant byte if endian is MSB_FIRST(0), which is the Hart standard.
`void BHDrv_PutInt32 (unsigned long data, unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Insert an integer 32 into the byte array buffer pointed to by dataRef starting at the position offset. Start with the most significant byte if endian is MSB_FIRST(0), which is the Hart standard.
`void BHDrv_PutFloat (float data, unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Insert a single precision IEEE 754 float value into the byte array buffer pointed to by dataRef starting at the position offset. Start with the most significant byte if endian is MSB_FIRST(0), which is the Hart standard.
`void BHDrv_PutDouble (double data, unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Insert a double precision IEEE 754 float value into the byte array buffer pointed to by dataRef starting at the position offset. Start with the most significant byte if endian is MSB_FIRST(0), which is the Hart standard.
`void BHDrv_PutPackedASCII (unsigned char* sb, unsigned char sLen, unsigned char offset, unsigned char* dataRef)`	Insert a string of the length of sLen in packed ASCII format into the byte array buffer pointed to by dataRef starting at the position offset.
`void BHDrv_PutOctets (unsigned char* dataSource, unsigned char dataLen, unsigned char offset, unsigned char* dataDestination)`	Copy a number of dataLen bytes into the byte array buffer pointed to by dataDestination starting at the position offset.
`void BHDrv_PutString (unsigned char* sb, unsigned char sLen, unsigned char offset, unsigned char* dataDestination)`	This function does the same as BHDrv_PutOctets.

Table 3: HartDLL, List of Functions

HartX (Client)

The .NET Component HartX is implementing the Hart communication protocol by resolving all the real time requirements and coding as well as decoding issues.

The implementation of the Hart Protocol does not contain any restriction to frame lengths like in Hart 5.x (e.g.). Therefore the all communication functions can be used for devices supporting Hart 5, Hart 6 or Hart 7.

Before using the communication the component has to select a com port of the PC. This can be any com port from 1 to 254 including virtual com ports as they are used for USB modems.

Distribution of Applications

The user has to provide a copy of the component DLL and the driver DLL (BaHartX.dll and BaHartDrv76.dll). The best way is to provide a copy of the 32 bit native DLLs (x86) as well as a copy of the 64 bit native DLLs (x64). The files should be copied to the Windows system paths for 32 and 64 bit DLLs.

Note: Be sure that the first call of your application is a call of the validation function of the DLL (HartX.ValidateLicense) passing a valid license code and the correct user name to the component DLL (the assembly).

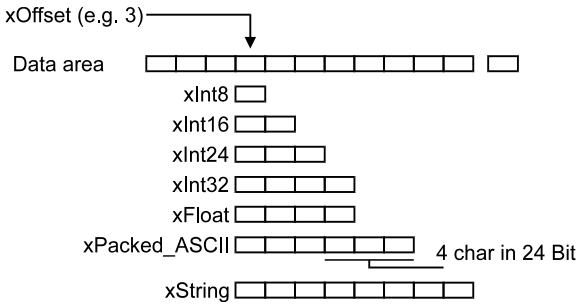
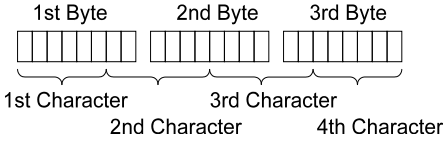
CHartX

Properties

Name	Type	Acc	Description
Operation/Control			
AddrMode	enum	R/W	AM_ShortAddress(0), AM_LongAddress(1) AM_ShortTag(2) -> packed ASCII(6), 8 characters AM_LongTag(3) -> string, 32 characters)
ComPort	byte		0: None 1-254: Com port number (com port in use when set) 255: Reserved, do not(!) use
AddrTagShort	string		Short tag name used for addressing. The string should have a length of 8 and should contain only capital letters.
AddrTagLong	string		Long tag name used for addressing. The string should have a length of 32.
ComState	enum		CS_OFF(0): No connection, CS_ON(1): Connection to device Note: If ComState is toggled from CS_OFF to CS_ON a command for retrieving the unique identifier is executed. This activity is not(!) generating an event.
BaudRate			BR_1200(0), BR_9600(1), BR_19200(2), BR_38400(3), BR_57600(4), BR_115200(5)
NoPreambles	byte		Number of preambles to be sent with a request (typically 5, range 5 .. 20)
PollAddress			Poll address used to get the unique ID (0..63)
NewPollAddress			Poll address to be set in the slave using action ACT_WrPollAddr.
NumRetries			Number of retries in case of error (0..255)
MasterRole	enum		The initial master role when starting communications MR_PrimaryMaster(0), MR_SecondaryMaster(1)
RetryIfBusy			Indicates if the control should retry as long as the device is responding with busy[1]: OPT_No(0), OPT_Yes(1).
LastError		RO	Most recent error: ERR_Success(0), ERR_NoComPortSelected(1), ERR_InvalidComPort(2), ERR_ComError(3), ERR_NoDeviceResponse(4), ERR_SlaveAddressError(5), ERR_UndefinedError(6), ERR_ServiceInvokationError(7), ERR_LicenseError(8)
LastErrorText	string		Text for the LastError value
UseUniqueID	bool	R/W	Indicates if the unique identifier shall be used directly as it was entered by the user.
UniqueID	byte[]		Array of 5 bytes for the unique identifier.
UniqueId0	byte		Long address byte 1
UniqueId1			Long address byte 2
UniqueId2			Long address byte 3
UniqueId3			Long address byte 4
UniqueId4			Long address byte 5
HandleOfChannel	int	RO	Handle of channel which was returned by the HartDLL. This is meant for debugging purposes.
DataLength	byte		Number of data bytes in the confirmation of a service. This can be used for debugging.
Response1			Response code for the command
CommandResponseText	string		Text for the response code 1.
Response2	byte		Device status
DeviceStatusText	string		Text for the response code 2
Information			
IsDeviceConnected	bool	RO	Indicates whether the unique identifier could be read from the device.
IsValidComPort	bool		Indicates whether the selected com port could be opened successfully.
BusyCount	int		Returns the number of currently active aynchronous services. These are services which had been started by DoCommand with the wait flag set to false.

[1] This could cause a very large delay, has to be handled with care.

Name	Type	Acc	Description
Simulation			
SimPvEnabled	bool	R/W	Sets or gets a flag indicating whether the simulation for the four PVs is active.
SimAmplitude	float		The simulation is running Pv values between 0.0 and 1.0. SimAmplitude is the factor to multiply the internal values with.
Parameter Properties			
These properties are used to get portions of data from the recently conducted command.			
Command 0 (Read Unique ID)			
Usually this command is automatically executed if the control is not yet 'connected' to the device (unique identifier unknown).			
p00Device	byte	RO	Device ID (8 bit)
p00DeviceNumber	uint		3 byte unique device ID
p00HardwRev	byte		Hardware revision
p00SoftwRev			Software revision
p00VendorID			Manufacturer/Vendor identifier
Command 1 (Read Primary Variable)			
p01Pv	float	RO	Value of process variable 1
p01PvUnit	byte		Unit code of process variable 1
p01PvUnitString	string		String for the unit of process variable 1
Command 2 (Read Current and Percentage)			
p02Current	float	RO	Value of the current output [mA]
p02Percent			Value of the percentage 0..100 %
Command 3 (Read dynamic Variables)			
p01Pv	float	RO	Value of process variable 1
p01PvUnit	byte		Unit code of process variable 1
p01PvUnitString	string		String for the unit of process variable 1
p02Pv	float		Value of process variable 2
p02PvUnit	byte		Unit code of process variable 2
p02PvUnitString	string		String for the unit of process variable 2
p03Pv	float		Value of process variable 3
p03PvUnit	byte		Unit code of process variable 3
p03PvUnitString	string		String for the unit of process variable 3
p04Pv	float		Value of process variable 4
p04PvUnit	byte		Unit code of process variable 4
p04PvUnitString	string		String for the unit of process variable 4
Command 12 (Read Message)			
p12Message	string	R/W	Hart message, the string should have a length of 32.
Command 13 (Read Tag, Descriptor, Date)			
p13DateDay	byte	R/W	Day of month 1..31
p13DataMonth			Month of the year 1..12
p13DateYear			Year as offset to 1900
p13Descriptor	string		String of 16 characters for the description
p13TagName	string		String of 8 characters for the short tag
Command 14 (Read Transducer Information)			
p14LoSensLimit	float	RO	Lower sensor limit
p14MinSpan			Minimum span
p14SensLimUnit	byte		Unit code for the sensor information (values)
p14SensSerNum	uint		24 bit sensor serial number
p14UpSensLimit	float		Upper sensor limit

Name	Type	Acc	Description
Command 15 (Read Device Information)			
p15AlmSelCode	byte	RO	Alarm selection code
p15LabDistCode			Label distributor code
p15LoRange	float		Lower range value
p15RangeUnit	byte		Unit code for the range values
p15UpRange	float		Upper range value
p15WrProtCode	byte		Write protection 0: None >0: Write protected
p15XferFuncCode			Transfer function code
Command 20 (Read Long Tag Name)			
p20TagNameLong	string	R/W	The long tag name, the string should have a length of 32
X-Properties (Any Command)			
xReqLen	byte	R/W	Defines the length of the request data buffer
xOffset			Defines the offset into the buffer for coding and decoding 
xStringLen			Defines the length of a string for coding and decoding
xPackedASCLen			Defines the length of a packed ascii string
xHexDataDump	string	RO	Returns a string with the hex dump of the buffer with a length of xReqLen
xInt8	byte	R/W	Sets or gets an 8 bit integer value in/from the buffer
xInt16	ushort		Sets or gets an 16 bit integer value in/from the buffer
xInt24	uint		Sets or gets an 24 bit integer value in/from the buffer
xInt32	uint		Sets or gets an 32 bit integer value in/from the buffer
xFloat	float		Sets or gets a float value in/from the buffer
xDouble	double		Sets or gets a double value in/from the buffer
xString	string		Sets or gets a string of xStringLen in/from the buffer
xPacked_ASCII	string		Sets or gets a packed ascii string of xPackedASCLen in/from the buffer. It very important to set the property xPackedASCIILen before accessing the property xPackedASCII. The format PackedASCII stores 4 characters in three octets (24 bits), using only 6 bits for each character. The xPackedASCIILen has to be set to the number of octets used to store the string. Possible values are 3,6,9.. etc.. For instance a xPackedASCIILen of 3 allows to access a string of a length of four characters. 

Methods

Declaration	Description	
`bool Lock()`	The method is trying to lock against the access by other threads. However the method is waiting for approximately 5 seconds. If the lock could not be placed in this time if will return false. Note: Each lock has to be followed by a call of the Unlock method. Otherwise the system may be blocked.	
`void Unlock()`	The method is removing a lock against concurrent access.	
`EN_LastError DoAction (EN_Action Action, bool wait)`	The DoAction method is mainly used to handle the parameter properties.	
	`EN_Action Action`	
	`ACT_None(0)`	Perform no action
	`ACT_RdPv(1)`	Read the primary process variable and the unit (Command 1). Update p01 properties.
	`ACT_RdCurrPerc(2)`	Read the value for the current (4..20 mA) and the pv in % (Command 2). Update p02 properties.
	`ACT_RdAllPv(3)`	Read all available process variables (Command 3). Update p03 properties.
	`ACT_RdMessage(4)`	Read the message (Command 12). Update p12 property.
	`ACT_RdTagDescrDate(5)`	Read Tag, Descriptor and Date (Command 13). Update p13 properties.
	`ACT_RdSensLimits(6)`	Read sensor limit data (Command 14). Update p14 properties.
	`ACT_RdRange(7)`	Read range data (Command 15). Update p15 properties.
	`ACT_WrMessage(8)`	Write message (Command 17). Use the p12 property.
	`ACT_WrTagDescrData(9)`	Write Tag, Descriptor and Date (Command 18). Use p13 properties.
	`ACT_WrPollAddr(10)`	Write a new poll address into the device. Use NewPollAddress for this action.
	`ACT_ResetStatus(11)`	Forces the control to forget the unique identifier of the most recently connected HART device.
`EN_LastError Connect()`	The method is retrieving the unique identifier (long address) from the Hart slave. Note: This method waits for a response and does not generate an event.	
`void Disconnect()`	The method deletes the internally stored unique identifier and discards all outstanding services.	
`EN_LastError DoCommand (byte command, bool wait)`	The method is performing a Hart command in the range 0 .. 255. For the data send with the request it is using xReqLen and the internal data buffer with the data bytes.	
`EN_LastError DoCommand (ushort command, bool wait)`	The method is performing a 16 bit Hart command. For the data send with the request it is using xReqLen and the internal data buffer with the data bytes.	
`void Close()`	Has to be called when the application terminates. Note: This method is simply setting the com port to 0 thus releasing the HartDLL.	
`string GetHartUnit (byte UnitCode)`	Returns the string associated with the 8 bit Hart unit code.	
`void FillBuffer (byte FillValue)`	Initialize all bytes in the internal buffer by the given FillValue.	
`void ValidateLicense (string UserName, string License)`	Call this function firstly after construction to activate all internal functions.	

If the parameter wait is set, the service will be completed if the function returns. Otherwise the event function CommResult will be called after completion.

Functions declared to return EN_LastError will return ERR_Success if the operation was successfully completed.

Events

Declaration	Description	
`void CommResult ( CommResultEventArgs CompletedService)`	The DoAction method is mainly used to handle the parameter properties.	
	`CommResultEventArgs CompletedService`	
	`Command`	Command used for the service
	`IsExtCommand`	True if extended command
	`LastError`	Code of last error
	`LastErrorText`	Text of last error
	`UsedAction`	Action triggered, if 0 no action was triggered.

SlaveDLL (Server + OSAL)

Like the HARTDLL for the master the SlaveDLL is providing rudimentary services for the handling of the Hart protocol by a slave implementation.

However, there are also some differences in the implementation. In the following the term channel is missing. It was replaced by the term channel.

Another issue is the connection. No connection services are provided because the slave does not have to handle any connection oriented details.

Functions

Declaration	Description
Control	
`void BHSlv_ValidateLicense (const char* userName, const char* license)`	The first call into the DLL should be a call to this function passing the correct license key and the user name to the software. The user name and the licensee code is provided by the User License Certificate.
`signed int BHSlv_OpenChannel (unsigned int comPort, unsigned int baudRate)`	The function allocates the selected com port if possible and starts its own working thread for accessing Hart services. The value which is returned is a handle (channel) which has to be passed to all functions which are requesting a service. If it was not possible to open the com port the function is returning INVALID_SLV_HANDLE to indicate the error. The com port number is limited to the range of 1 .. 255.
`void BHSlv_CloseChannel (signed int channel)`	It is required to call this function at least when the application is terminating.
`void BHSlv_GetCommConfig (signed int channel, T_strSlvCommSettings* config)`	The function copies the configuration data to a data structure provided by the caller.
`void BHSlv_SetCommConfig (signed int channel, T_strSlvCommSettings* config)`	The function is setting all details required for the configuration. The data is passed in a structure provided by the caller.
`void BHSlv_RegisterEventCallback (signed int channel, void (__stdcall* HandleServiceEvent) (signed int channel, unsigned short event, unsigned int service, unsigned int data))`	Register a function which is called when any requested service is completed. The service handle of the service is passed to the called CB function. HandleServiceEvent is the pointer to the handling function which is provided by the user. The parameter usEvent may have the values NONE, REQUEST_RECEIVED or BURST_REQUIRED. The parameter channel is passed to the application to allow the support of more than one communication channel in one callback.
`BHSlv_SetEventFlags (signed int channel, unsigned short eventFlags);`	Set the event flags mask.
`void BHSlv_ClearEventCallback (signed int channel)`	Deletes a previously registered callback. After a call of this function no more callbacks to HandleServiceEvent will occur.

Declaration	Description	
Operation		
`signed int BHSlv_GetRequest (signed int channel, unsigned short* command, unsigned short* indInfo, unsigned char* dataLen, unsigned char* bytesOfData);`	The function is used for polling to get an indication if a master request was received.	
	channel	The handle which was returned by the OpenChannel function
	command	Return the command via this pointer.
	indInfo	Get additional info about the request.
	dataLen	Returns the number of payload bytes.
	bytesOfData	Returns the payload data.
	The function returns a service handle if successful or INVALID_SLV_HANDLE if there was an error.	
`void BHSlv_PutResponse (signed int channel, signed int service, unsigned char dataLen, unsigned char* bytesOfData, unsigned char response1, unsigned char response2);`	Provides all information to build the response for the recently received request.	
	channel	The handle which was returned by the OpenChannel function
	service	The handle returned by the GetRequest function.
	dataLen	Number of bytes for payload data
	bytesOfData	Byte array for payload data
	response1	Response code 1
	response2	Response code 2
Decoding		
`unsigned char BHSlv_PickInt8 (unsigned char offset, unsigned char* dataRef)`	Return the value of the byte in the byte array buffer pointed to by dataRef at the position offset.	
`unsigned short BHSlv_PickInt16 (unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Return the value of the integer 16 from the byte array buffer pointed to by dataRef at the position offset. Assume that the most significant byte is the first if endian is MSB_FIRST(0), which is the Hart standard.	
`unsigned long BHSlv_PickInt24 (unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Return the value of the integer 24 from the byte array buffer pointed to by dtaRef at the position offset. Assume that the most significant byte is the first if endian is MSB_FIRST(0), which is the Hart standard.	
`unsigned long BHSlv_PickInt32 (unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Return the value of the integer 32 from the byte array buffer pointed to by dataRef at the position offset. Assume that the most significant byte is the first if endian is MSB_FIRST(0), which is the Hart standard.	
`float BHSlv_PickFloat (unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Return the value of the single precision IEEE754 number from the byte array buffer pointed to by dataRef at the position offset. Assume that the most significant byte is the first if endian is MSB_FIRST(0), which is the Hart standard.	
`double BHSlv_PickDouble (unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Return the value of the double precision IEEE754 number from the byte array buffer pointed to by dataRef at the position offset. Assume that the most significant byte is the first if endian is MSB_FIRST(0), which is the Hart standard.	
`void BHSlv_PickPackedASCII (unsigned char* sb, unsigned char stringLen, unsigned char offset, unsigned char* dataRef)`	Generate a string and copy it to the buffer pointed to by sb. The final string should have the length stringLen. The packedASCII source is a set of bytes in the byte array buffer pointed to by dataRef. Note: The string length has to by a multiple of 4 while the number of packedASCII bytes is a multiple of 3.	
`void BHSlv_PickOctets (unsigned char* dataDestination, unsigned char numOctets, unsigned char offset, unsigned char* dataSource)`	Copy a number (numOctets) of bytes from the byte array buffer pointed to by dataSource to the user buffer pointed to by dataDestination.	
`void BHSlv_PickString (unsigned char* sb, unsigned char stringLen, unsigned char offset, unsigned char* dataRef)`	This function does the same as BHDrv_PickOctets.	

Declaration	Description
Encoding	
`void BHSlv_PutInt8 (unsigned char data, unsigned char offset, unsigned char* dataRef)`	Insert an integer 8 into the byte array buffer pointed to by dataRef starting at the position offset.
`void BHSlv_PutInt16 (unsigned short data, unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Insert an integer 16 into the byte array buffer pointed to by dataRef starting at the position offset. Start with the most significant byte if endian is MSB_FIRST(0), which is the Hart standard.
`void BHSlv_PutInt24 (unsigned long data, unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Insert an integer 24 into the byte array buffer pointed to by dataRef starting at the position offset. Start with the most significant byte if endian is MSB_FIRST(0), which is the Hart standard.
`void BHSlv_PutInt32 (unsigned long data, unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Insert an integer 32 into the byte array buffer pointed to by dataRef starting at the position offset. Start with the most significant byte if endian is MSB_FIRST(0), which is the Hart standard.
`void BHSlv_PutFloat (float data, unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Insert a single precision IEEE 754 float value into the byte array buffer pointed to by dataRef starting at the position offset. Start with the most significant byte if endian is MSB_FIRST(0), which is the Hart standard.
`void BHSlv_PutDouble (double data, unsigned char offset, unsigned char* dataRef, unsigned char endian)`	Insert a double precision IEEE 754 float value into the byte array buffer pointed to by dataRef starting at the position offset. Start with the most significant byte if endian is MSB_FIRST(0), which is the Hart standard.
`void BHSlv_PutPackedASCII (unsigned char* sb, unsigned char sLen, unsigned char offset, unsigned char* dataRef)`	Insert a string of the length of sLen in packed ASCII format into the byte array buffer pointed to by dataRef starting at the position offset.
`void BHSlv_PutOctets (unsigned char* dataSource, unsigned char dataLen, unsigned char offset, unsigned char* dataDestination)`	Copy a number of dataLen bytes into the byte array buffer pointed to by dataDestination starting at the position offset.
`void BHSlv_PutString (unsigned char* sb, unsigned char sLen, unsigned char offset, unsigned char* dataDestination)`	This function does the same as BHSlv_PutOctets.

Table 4: SlaveDLL, List of Functions

SlaveX (Server)

SlaveX is providing a small set of objects used to build a command interpreter easily and quickly.

A Hart slave is basically implementing a command interpreter for the Hart protocol. This is based on the use of the Hart communication services provided in the object HartSlave.

CSlaveX

Properties

Name	Type	Acc	Description
IsValidChannel	bool	RO	Returns true if there is a valid com port adressed by the channel.
ComPort	byte		Returns the comport number.
Status	EN_Status		Returns the status.

			EN_Status : int
			{
			IDLE = 0,
			READY = 1,
			WAIT_RESPONSE = 2,
			DISABLED = 3,
			UNKNOWN = -1
			}

PrintCallback	IntPtr	WO	Sets the pointer to a print callback function.
DataBase	CDataBase	RO	Returns a reference to the database of the component.

Methods

Declaration	Description
void Start(int comPort, int baudRate)	Starts the simulation at a defined com port and a baudrate between 1200 to 115200 Bits/s
void Configure()	Sets up internal data of the component using the static class CDataBase.
void Enable()	Enables the component.
void Disable()	Disables the component.
CRequest GetRequest()	Returns an instance of the CRequest class if a request was detected by the communication layers.
void PutResponse(CResponse reponse, byte devstatus)	Accepts the response to be sent and the HART device status.
void Print(byte row, string text)	Print a text on the debug output of the client if any is provided.

CRequest

The object is passed to the command interpreter when a Hart command was received by the communication DLL.

Properties

Name	Type	Acc	Description
Command	ushort	RO	The command that was passed with the request.
Len	byte		Number of bytes of productive data.
Data	byte[]		Returns an array of bytes with the payload data of the request.
Flags	ushort		Returns a bit stream which is not yet defined.

Methods

Declaration	Description
`byte GetByte(byte offset)`	Returns the value of a 8 bit unsigned integer at the position (offset) in the data of the request.
`ushort GetInt16(byte offset)`	Returns the value of a 16 bit unsigned integer at the position (offset) in the data of the request.
`ulong GetInt24(byte offset)`	Returns the value of a 24 bit unsigned integer at the position (offset) in the data of the request.
`float GetFloat(byte offset)`	Returns the value of a 32 bit float as IEEE754 at the position (offset) in the data of the request.
`string GetPackedASCII(byte offset, byte len)`	Returns the decoded string from a PackedASCII string at the position (offset) in the data of the request. len is the number of bytes of the PackedASCII coded string. Note: len has to be an integer multiple of 3, while the length of the resulting string is a multiple of 4.
`string GetString(byte offset, byte len)`	Returns the string with length (len) at the position (offset) in the data of the request.

CResponse

Properties

Name	Type	Acc	Description
`CmdResultCode`	`byte`	`R/W`	Gets or sets the cmd reponse code.
`DeviceStatus`	`byte`		Gets or sets the Hart device status.
`DataLength`	`byte`	`RO`	Gets the number of bytes of payload data in the response.
`Data`	`byte[]`		Gets an array of bytes with the payload data for the response.

Methods

Declaration	Description
`void SetByte(byte offset, byte value)`	Sets the value of an 8 bit unsigned integer at the position (offset) in the data of the response.
`void SetInt16(byte offset, ushort value)`	Sets the value of a 16 bit unsigned integer at the position (offset) in the data of the response.
`void SetInt24(byte offset, uint value)`	Sets the value of a 24 bit unsigned integer at the position (offset) in the data of the response.
`void SetInt32(byte offset, uint value)`	Sets the value of a 32 bit unsigned integer at the position (offset) in the data of the response.
`void SetFloat(byte offset, float value)`	Sets the value of a 32 bit float at the position (offset) in the data of the response.
`void SetPackedASCII(byte offset, string value, byte len)`	Convert the string (value) into PackedASCII-format and insert the resulting bytes at the position (offset) in the data of the response. len is the number of PackedASCII bytes to be inserted. It should be an integer multiple of 3. If this is not the case it is reduced to the next lower integer multiple of 3. The length of the string (val) should be an integer multiple of 4 following the formula: value.length = len / 3 * 4 if value.length is shorter than the required length the string is filled by ' '. If it is longer the string is truncated. Example: The Hart short tag name has to have 8 characters. Therefore len has to be 6.
`void SetString(byte offset, string value, byte len)`	Insert the bytes of a ISO Latin-1 string (val) with the length len at the position (offset) in the data of the response. If the string is shorter than len it is filled by char(0). If the string is longer than len it is truncated.

Additional Information

Structures

Type	Name	Description	
T_strConfiguration			
unsigned int	uiBaudRate	Baudrate as defined in winbase.h CBR_1200 CBR_2400 CBR_4800 CBR_9600 CBR_19200 CBR_38400 CBR_57600 CBR_115200 Default: CBR_1200	
unsigned char	ucNumPreambles	Number of preambles used for a request (0..22) Default: 5	
unsigned char	ucNumRetries	Number of retries if device response is erroneous (0..3) Default: 2	
unsigned char	ucRetryIfBusy	0:	Do not retry if device is responding with busy code
		1..255:	Retry the command if device is responding with busy code. The number of retries is reflected in the confirmation as ucUsedRetries.
		Default: 1	
unsigned char	ucInitialMasterRole	0: Primary master 1: Secondary master Default: 0	
unsigned char	ucReserved	Not used (former addressing mode)	
unsigned char	ucDoNotUseRtsDtr	0: Use handshake signals 1: Do not use handshake signals Default: 0	
unsigned short	usAddTimeOut	Additional time out to wait for a slave response in ms. Typical 100, 200 etc. Default: 0	
unsigned short	usAddGapTime	Additional time for gap between characters in ms. Typical 5, 10 etc. Default: 0	
unsigned short	usAddRtsOffDelay	Additional delay before Rts is switched off (carrier off) in ms. Typical 1, 2, 5, 10 etc. Default: 0	
unsigned char	bSendJabberOctet	0: Normal sending 1: Append ucJabberOctet to each frame Default: 0	
unsigned char	ucJabberOctet	Value of the jabber octet	
unsigned char	bGenParityError	Generate a parity error on a particular position	
unsigned char	ucParityErrorPos	Number of the byte at which the error should be injected	
unsigned char	bHartEnabled	0: Hart not running 1: Hart protocol active	
unsigned char	bRecJabberOctet	0: Ignore jabber octets 1: Report jabber octets to the monitor	
T_strRunTimeInfo			
unsigned char	bActualMaster	0: Primary Master 1: Secondary Master	
unsigned char	bFifoDetected	>0: More than 3 characters are received at once	
unsigned char	ucBlockSize	Number of characters received at once	
unsigned char	ucReserved		

Type	Name	Description	
T_strConnection			
unsigned char	ucManId	Manufacturer id as defined by the Hart Communication Foundation	
unsigned char	ucDevId	Vendor's device id	
unsigned char	ucNumPreambs	Number of preambles defined by the device	
unsigned char	ucCmdRevNum	Command set revision number as defined by Hart	
unsigned char	ucSpecRevCode	Device specific revision code	
unsigned char	ucSwRev	Software revision code (0..255)	
unsigned char	ucHwRev	Hardware revision code	
unsigned char	ucHartFlags	The flags as defined by Hart	
unsigned char	ucError	Service completion code	
		SRV_EMPTY(0)	Not active
		SRV_NO_DEV_RESP(1)	No device response
		SRV_COMM_ERR(2)	There was some error (too few data e.g.)
		SRV_INVALID_HANDLE(3)	Service handle is invalid
		SRV_IN_PROGRESS(4)	Service working
		SRV_SUCCESSFUL(5)	Service successfully completed
		SRV_RESOURCE_ERROR(6)	Out of memory
		SRV_TOO_FEW_DATA_BYTES(7)	Used for cmd 31
unsigned char	ucRespCode1	Response code 1 as defined by the Hart specification	
unsigned char	ucRespCode2	Response code 2 as defined by the Hart specification	
unsigned char	ucUsedRetries	Number of retries which were used for completion	
unsigned char	bDeviceInBurstMode	0: Normal mode 1: Device is in burst mode	
unsigned char	ucExtDevStatus	Extended device status	
unsigned short	usCfgChCount	Configuration changed counter	
unsigned char	ucMinNumPreambs	Minimum number of preambles	
unsigned char	ucMaxNumDVs	Maximum number of device variables	
unsigned short	usManuID	Extended manufacturer ID	
unsigned short	usLabDistID	Extended label distributor ID	
unsigned char	ucDevProfile	Device profile	
unsigned char	ucReserved	-/-	
unsigned char	aucUniqueID[5]	Unique identifier	
T_strCyclicData			
unsigned long	ulTimeStamp	Time in ms since recording of burst messages was started	
unsigned char	ucCmd	Command of the received frame	
unsigned char	ucRsp1	Device response code 1	
unsigned char	ucRsp2	Device response code 2	
unsigned char	ucDataLen	Number of bytes in productive data	
unsigned char	aucData[255]	Productive data of the burst message	

Type	Name	Description	
T_strConfirmation			
unsigned char	ucCmd	Command which was executed	
unsigned char	ucRespCode1	Response code 1 as defined by the Hart specification	
unsigned char	ucRespCode2	Response code 2 as defined by the Hart specification	
unsigned char	ucError	Service completion code	
		SRV_EMPTY(0)	Not active
		SRV_NO_DEV_RESP(1)	No device response
		SRV_COMM_ERR(2)	There was some error (too few data e.g.)
		SRV_INVALID_HANDLE(3)	Service handle is invalid
		SRV_IN_PROGRESS(4)	Service working
		SRV_SUCCESSFUL(5)	Service successfully completed
		SRV_RESOURCE_ERROR(6)	Out of memory
		SRV_TOO_FEW_DATA_BYTES(7)	Used for cmd 31
unsigned char	ucUsedRetries	Number of retries which were used for completion	
unsigned char	bDeviceInBurstMode	0: Normal mode 1: Device is in burst mode	
unsigned short	usDuration	Time for service execution in ms	
unsigned long	dwAppKey	Is returned by the FetchConfirmation function as it was passed to the DoCommand function.	
unsigned short	usExtCmd	Extended cmd number	
unsigned char	ucReserved	Reserved for future use	
unsigned char	ucLen	Number of response data bytes (octets)	
unsigned char	aucData [DATA_BUF_LEN]	Response data bytes (DATA_BUF_LEN = 255)	
T_strSlaveDynamicValues			
float	fPercent	Actual percent of range	
float	fCurrent	Actual current value as ma	
unsigned char	ucUnitCodePV1	Hart unit code for PV1	
unsigned char	ucUnitCodePV2	Hart unit code for PV2	
unsigned char	ucUnitCodePV3	Hart unit code for PV3	
unsigned char	ucUnitCodePV4	Hart unit code for PV4	
float	fPV1	Value of PV1	
float	fPV2	Value of PV2	
float	fPV3	Value of PV3	
float	fPV4	Value of PV4	
unsigned char	bDeviceMalfunction	Signals device mal function	
unsigned char	bCfgChangedPrimMaster	Configuration change flag for primary master	
unsigned char	bCfgChangedScndMaster	Configuration change flag for primary master	
unsigned char	bColdStartPrimMaster	Cold start flag for primary master	
unsigned char	bColdStartScndMaster	Cold start flag for secondary master	
unsigned char	bMoreStatusAvail	Flags more status available (see command 48)	
unsigned char	bLoopCurrentFixed	Signals fixed current mode active	
unsigned char	bLoopCurrentSaturated	Signals current output saturated	
unsigned char	bNonPrimVarOutLimits	Signals none primary variable out of limits	
unsigned char	bPrimVarOutLimits	Signals primary variable out of limits	
unsigned char	bUseExtValues	Indication to the slave simulation to use the values of this structure instead of its own.	
unsigned char	ucReserved1	Reserved for future use	

Type	Name	Description
T_strSlaveConfiguration		
unsigned char	ucManufacturerID	Manufacturer's identifier
unsigned char	ucDeviceID	Device identifier
unsigned char	ucNumPreambles	Number of preambles needed in a request (2..20, recommended: 2)
unsigned char	ucCmdSetRevision	Hart compatibility version (5..7, recommended: 5)
unsigned char	ucTransmSpecRev	Transmitter specific revision
unsigned char	ucSoftwareRevision	Software revision number
unsigned char	ucHardwareRevision	Hardware revision number
unsigned char	ucReserved1	Reserved for future use
unsigned char	ucDevNum1	Device number [LSB]
unsigned char	ucDevNum2	Device number [LSB+1]
unsigned char	ucDevNum3	Device number [LSB+2]
unsigned char	ucReserved2	Reserved for future use
unsigned char	aucShortTag[12]	Tag name, 8 characters (see 3.3.2.1 Packed ASCII Coding for possible characters)
unsigned char	aucLongTag[36]	Long tag name, 32 characters iso latin 1
unsigned char	ucPollAddress	Slave polling address
unsigned char	ucNumberOfPVs	Defines the number of variables to be sent with command 3
unsigned char	ucReserved3	Reserved for future use
unsigned char	ucReserved4	Reserved for future use
unsigned char	aucMessage[36]	Message, 32 characters coded in packed ASCII
unsigned char	aucDescription[20]	Description, 16 characters coded in packed ASCII
unsigned char	ucDay	Day of Hart date (1..31)
unsigned char	ucMonth	Month of Hart date (1..12)
unsigned short	usYear	Year of Hart date (1900..2155)

Constants

Name	Value	Description
Service Completion Codes		
SRV_EMPTY	0x00	Service not active
SRV_NO_DEV_RESP	0x01	Device did not respond
SRV_COMM_ERR	0x02	There was a communication error (too few data e.g.)
SRV_INVALID_HANDLE	0x03	Service handle not valid
SRV_IN_PROGRESS	0x04	Service not yet completed
SRV_SUCCESSFUL	0x05	Service successfully completed
SRV_RESOURCE_ERROR	0x06	Out of memory
SRV_TOO_FEW_DATA_BYTES	0x07	Used with cmd 31
Values of Handles		
INVALID_DRV_HANDLE	-1	Driver handle not valid
INVALID_SRV_HANDLE	-1	Service handle not valid
Endian		
MSB_FIRST	0x00	Big Endian (Hart standard): Most Significant Byte first
LSB_FIRST	0x01	Little Endian: Least Significant Byte first
Wait Options		
DRV_NO_WAIT	0x00	User will poll for the completion of service
DRV_WAIT	0x01	The function returns if service is completed
Slave Modes		
SLAVE_DISABLED	0x00	Slave emulation is not active
SLAVE_ENABLED	0x01	Slave emulation is active
Cyclic Data Handling		
CYCDAT_OK	0x00	Cyclic data available
CYCDAT_NO_DATA	0x01	Cyclic data not (yet) available
Boolean Values		
T_FALSE	0x00	True
T_TRUE	0x01	False
Events		
NONE	0x00	
CONFIRMATION	0x01	
BURST_INDICATION	0x02	
REQUEST	0x03	

Hart at a Glance

Frame Coding

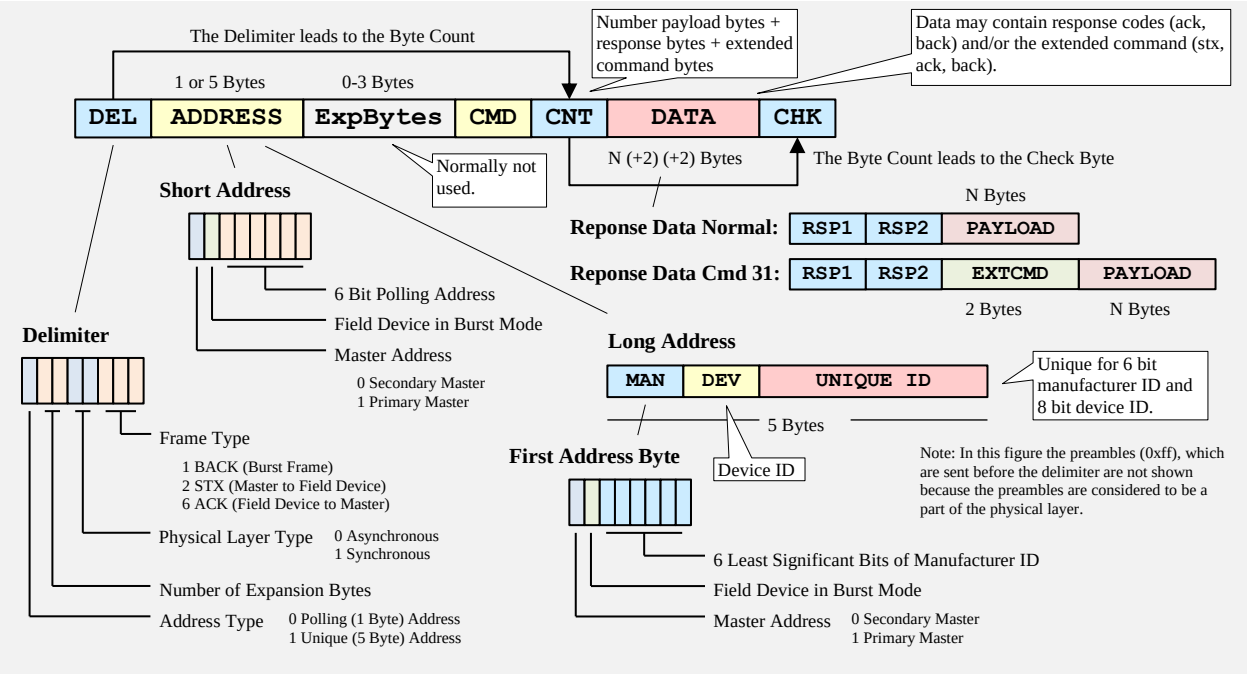


Figure 14: The Basic Coding of a Hart Frame

The figure above is giving an overview of the coding of a Hart frame. Usually Hart services are composed of a request (stx) by the master followed the response (ack) of a slave. Bursts (back) are frames looking like a response (including response codes) but sent by the slave without any request. The slave is sending these frames in burst mode within defined time slots following the rules of the protocol specification. In fact Hart is a token passing protocol which allows also the slave to be a token holder and send burst frames.

The following chapter is showing a list of Hart commands which are used very often. The list is showing the major differences between Hart 5.3, Hart 6 and Hart 7.4.

New items in Hart 6 are marked with yellow color while new items of Hart 7.4 are marked by blue color.

However, the following is not replacing any specification and is not showing the details which are needed for an implementation. The details has to be taken from the Hart specifications which are provided by the FieldComm Group: Hart Specifications.
That the listed commands are most commonly used is not the opinion of the HCF but the opinion of the author of this document.

Commonly Used Commands

No	Title	Request Data			Response Data		
Universal							
00	**Read Unique Identifier**	None			0	int8	254
					1		Manufacturer ID
					2		Short device ID
					3		Number preambles request
					4		Hart revision
					5		Device revision
					6		Software revision
					7		Hw rev and signaling code
					8		Flags
					9	int24	DevUniqueID
					12	int8	Number preambles response
					13		Maximum number device variables
					14	int16	Configuration change counter
					16	int8	Extended device status
					17	int16	Extended manufacturer code
					19		Extended label distributor code
					21	int8	Device profile
01	**Read Primary Variable**	None			0	int8	PV Units
					1	float	Primary variable
02	**Read Current and Percent of Range**	None			0	float	Current
					1	float	Percent of range
03	**Read Current and Dyn. Variables**	None			0	float	Current
					4	int8	PV1 units code
					5	float	PV1 value
					9	int8	PV2 units code
					10	float	PV2 value
					14	int8	PV3 units code
					15	float	PV3 value
					19	int8	PV4 units code
					20	float	PV4 value
06	**Write Polling Address**	0	int8	Polling Address	0	int8	PV Units
		1	int8	Loop current mode	1	int8	Loop current mode
07	**Read Loop Configuration**	None			0	int8	Polling address
					1		Loop current mode
08	**Read Dyn. Vars Classification**	None			0	int8	PV1 classification
					1		PV2 classification
					2		PV3 classification
					3		PV4 classification

No	Title	Request Data			Response Data		
Universal							
09	**Read Device Variables with Status**	0	int8	Slot0: Device variable code	0	int8	Extended device status
		1		Slot1: Device variable code	1	Slot0: Device variable properties	
		2		Slot2: Device variable code	1	int8	Device variable code
		3		Slot3: Device variable code	2		Device variable classification
		4	int8	Slot4: Device variable code	3		Device variable units code
		5		Slot5: Device variable code	4	float	Device variable value
		6		Slot6: Device variable code	8	int8	Device variable status
		7		Slot7: Device variable code	9	struct	Slot1: Device variable properties
					17		Slot2: Device variable properties
					25		Slot3: Device variable properties
					33	struct	Slot4: Device variable properties
					41		Slot5: Device variable properties
					49		Slot6: Device variable properties
					57		Slot7: Device variable properties
					65	time	Time stamp slot0
11	**Read Unique ID by Short Tag**	0	pac6	Tag name (packed ascii) 6 bytes = 8 characters	Same as command 0 read unique identifier		
12	**Read Message**	None			0	pac24	Message (packed ascii) 24 bytes = 32 characters
13	**Read Tag, Descriptor, Date**	None			0	pac6	Short tag (packed ascii) 6 bytes = 8 characters
					6	pac12	Descriptor (packed ascii) 12 bytes = 16 characters
					18	int8	Day
					19		Month
					20		Year (offset to 1900)
14	**Read Primary Variable Transducer Information**	None			0	int24	Transducer serial number
					3	int8	Units code
					4	float	Upper transducer limit
					8		Lower transducer limit
					12		Minimum span
15	**Read Device Information**	None			0	int8	Alarm selection code
					1		Transfer function code
					2		Units code
					3	float	PV upper range value (for 20 mA)
					7		PV lower range value (for 4 mA)
					11		PV damping value
					15	int8	Write protect code
					16		Reserved, must be set to 250
					17		PV analog channel flags
16	**Read Ass. Num**	None			0	int24	Final assembly number
17	**Write Message**	Same as response command 12			Same as response command 12		
18	**Write Tag, Descriptor, Date**	Same as response command 13			Same as response command 13		
19	**Write Ass. Num**	Same as response command 16			Same as response command 16		
20	**Read Long Tag**	None			0	str32	Long tag: 32 ISO Latin-1 characters
21	**Read Unique ID by Long Tag**	0	str32	Long tag: 32 ISO Latin-1 characters	Same as command 0 read unique identifier		
22	**Write Long Tag**	Same as response command 20			Same as response command 20		

No	Title	Request Data			Response Data		
Universal / Common Practice							
38	**Reset Config Changed Flag**	None			None		
		0	int16	Configuration change counter	0	int16	Configuration change counter
48	**Read Additional Device Status**	None					
		0	int8[5]	Transmitter specific status	0	int8[5]	Transmitter specific status
					6	int8[2]	Operating mode
		6	int8	Extended device status	6	int8	Extended device status
		7		Device operating mode	7		Device operating mode
					8	int8[3]	Analog output status
		8	int8	Standard status 0	8	int8	Standard status 0
		9		Standard status 1	9		Standard status 1
		10		Analog channel saturated	10		Analog channel saturated
					11	int8[3]	Analog output fixed
		11	int8	Standard status 2	11	int8	Standard status 2
		12		Standard status 3	12		Standard status 3
		13		Analog channel fixed	13		Analog channel fixed
					14	int8[3]	Transmitter specific status
		14	int8[10]	Transmitter specific status	14	int8[10]	Transmitter specific status
Common Practice							
33	**Read Device Variables**	0	int8	Slot0: Device variable code	0	Slot0: Device variable properties	
		1		Slot1: Device variable code	0	int8	Device variable code
		2		Slot2: Device variable code	1		Device variable units code
		3		Slot3: Device variable code	2	float	Device variable value
					6	struct	Slot1: Device variable properties
					12		Slot2: Device variable properties
					18		Slot3: Device variable properties
34	**Write Prim. Var. Damping**	0	float	PV 1 damping value	0	float	PV 1 damping value
35	**Write Prim. Var. Range Values**	0	int8	Units code	0	int8	Units code
		1	float	Upper range value	1	float	Upper range value
		5		Lower range value	5		Lower range value
36	**Set Prim. Var. Upper Range**	None			None		
37	**Set Prim. Var. Lower Range**	None			None		
40	**Enter/Exit Fixed Current**	0	float	Current value	0	float	Actual current value
42	**Device Reset**	None			None		
43	**Set Primary Variable Zero**	None			None		
44	**Write Prim. Var. Units**	0	int8	PV 1 units code	0	int8	PV 1 units code
45	**Trim Prim. Var. Current Zero**	0	float	Measured current value	0	float	Actual current value
46	**Trim Prim. Var. Current Gain**	0	float	Measured current value	0	float	Actual current value
50	**Read Dynamic Variable Assignments**	None			0	int8	PV 1 variable code
					1		PV 2 variable code
					2		PV 3 variable code
					3		PV 4 variable code

No	Title	Request Data			Response Data		
Common Practice							
51	**Write Dynamic Variable Assignments**	0	int8	PV 1 variable code	0	int8	PV 1 variable code
		1		PV 2 variable code	1		PV 2 variable code
		2		PV 3 variable code	2		PV 3 variable code
		3		PV 4 variable code	3		PV 4 variable code
54	**Read Device Variable Information**	0	int8	Device variable code	0	int8	Device variable code
					1	int24	Sensor serial number
					4	int8	Units code
					5	float	Variable upper limit
					9		Variable lower limit
					13		Variable damping
					17		Variable minimum span
					21	int8	Variable classification
					22		Variable family
					23	time	Acquisition period
					27	bin8	Variable properties
71	**Lock Device**	0	int8	Lock code	0	int8	Lock code
76	**Read Lock State**	None			0	int8	Lock status
78	**Read Aggregated Commands**	0	int8	Number of commands requested	0	int8	Extended device status
		1	str[]	Array of command requests struct { int16 command int8 byteCount int8[] requestData }	1	int8	Number of commands requested
					2	str[]	Array of command responses struct { int16 command int8 byteCount int8 responseCode int8[] responseData }
79[2]	**Write Device Variable**	0	int8	Device Variable Code	0	int8	Device Variable Code
		1		DV command code	1		DV command code
		2		DV units code	2		DV units code
		3	float	DV value	3	float	DV value
		7	int8	DV status	7	int8	DV status
103	**Write Burst Period**	0	int8	Burst message	0	int8	Burst message
		1	time	Update period	1	time	Update period
		5		Maximum update period	5		Maximum update period
104	**Write Burst Trigger**	0	int8	Burst message	0	int8	Burst message
		1		Trigger mode selection code	1		Trigger mode selection code
		2		Device variable classification for trigger level	2		Device variable classification for trigger level
		3		Units code	3		Units code
		4	float	Trigger level	4	float	Trigger level

[2] Used to simulate the value of a device variable

No	Title	Request Data			Response Data		
Common Practice							
105	**Read Burst Mode Configuration**	None			0	int8	Burst mode control code
					1	int8	Burst command number
					2	int8	Burst command slot 0
					3	int8	Burst command slot 1
					4	int8	Burst command slot 2
					5	int8	Burst command slot 3
		0	int8	Burst message	0	int8	Burst mode control code
					1		0x1f (31) command expansion
					2		DV code slot0
					3		DV code slot1
					4		DV code slot2
					5		DV code slot3
					6		DV code slot4
					7		DV code slot5
					8		DV code slot6
					9		DV code slot7
					10		Burst message
					11		Maximum number of burst messages
					12	int16	Extended command number
					14	time	Update time
					18		Maximum update time
					22	int8	Burst trigger mode code
					23		DV classification for trigger value
					24		Units code
					25	float	trigger value
106	**Flush Delayed Responses**	None			None		
107	**Write Burst Device Variables**	0	int8	DV code slot 0	0	int8	DV code slot 0
		1		DV code slot 1	1		DV code slot 1
		2		DV code slot 2	2		DV code slot 2
		3		DV code slot 3	3		DV code slot 3
		4	int8	DV code slot 4	4	int8	DV code slot 4
		5		DV code slot 5	5		DV code slot 5
		6		DV code slot 6	6		DV code slot 6
		7		DV code slot 7	7		DV code slot 7
		8		Burst message	8		Burst message
108	**Write Burst Mode Command**	0	int8	Command number for the burst response	0	int8	Command number of the burst response
109	**Burst Mode Control**	0	int8	Burst mode control code	0	int8	Burst mode control code
113	**Catch Device Variable**	0	int8	Destination DV code	0	int8	Destination DV code
		1		Capture mode code	1		Capture mode code
		2		Source slave manufacturer ID	2	int8[5]	Source slave address
		3		Source slave device type			
		2	int16	Source slave expanded device type			
		4	int8[3]	Source slave device ID			
		7	int8	Source command number	7	int8	Source command number
		8		Source slot number	8		Source slot number
		9	float	Shed time for this mapping	9	float	Shed time for this mapping
		7	int8	0x1f (31) command expansion	7	int8	0x1f (31) command expansion
		8		Source slot number	8		Source slot number
		9	float	Shed time for this mapping	9	float	Shed time for this mapping
		13	int16	Ext source command number	13	int16	Ext source command number

No	Title	Request Data			Response Data		
Common Practice							
114	**Read Caught Device Variable**	0	int8	Destination DV code	0	int8	Destination DV code
					1		Capture mode code
					2	int8[5]	Source slave address
					7	int8	Source command number
					8		Source slot number
					9	float	Shed time for this mapping
					7	int8	0x1f (31) command expansion
					8		Source slot number
					9	float	Shed time for this mapping
					13	int16	Ext source command number
523	**Read Condensed Status Mapping Array**	0	int8	Starting index status map	0	int8	Actual starting index
		1		Number of entries to read	1		Number of entries returned
					2	int4[]	Status map codes array
524	**Write Condensed Status Mapping Array**	0	int8	Starting index status map	0	int8	Actual starting index
		1		Number of entries to write	1		Number of entries returned
		2	int4[]	Status map codes array	2	int4[]	Status map codes array
525	**Reset Condensed Status Map**	None			None		
526	**Write Status Simulation Mode**	0	int8	Status simulation mode	0	int8	Status simulation mode
527	**Simulate Status Bit**	0	int8	Status bit index	0	int8	Status bit index
		1		Status bit value	1		Status bit value

Response Codes

As response code 1 is command specific it is documented together with the command specifications. However response code 2 is of general nature and contains 8 bit flags with the following meaning.

Flag Number / Meaning	Description
Bit #7 Field Device Malfunction	The device has detected a hardware error or failure. Further information may be available through the Read Additional Transmitter Status Command, #48.
Bit #6 Configuration Changed	A write or set command has been executed.
Bit #5 Cold Start	Power has been removed and reapplied resulting in the reinstallations of the setup information. The first command to recognize this condition will automatically reset this flag. This flag may also be set following a Master Reset or a Self Test.
Bit #4 More Status Available	More status information is available than can be returned in the Field Device Status. Command #48, Read Additional Status Information, will provide this additional status information.
Bit #3 Primary Variable Analog Output Fixed	The analog and digital analog outputs for the Primary Variable are held at the requested value. They will not respond to the applied process.
Bit #2 Primary Variable Analog Output Saturated	The analog and digital analog outputs for the Primary Variable are beyond their limits and no longer represent the true applied process.
Bit #1 Non Primary Variable Out of Limits	The process applied to a sensor, other than that of the Primary Variable, is beyond the operating limits of the device. The Read Additional Transmitter Status Command, #48, may be required to identify the variable.
Bit #0 Primary Variable Out of Limits	The process applied to the sensor for the Primary Variable is beyond the operating limits of the device.

Data Types

Float IEEE 754

The following summarizes the IEEE 754 and recommends that standards are referred to for implementation.

The floating point values passed by the protocol are based on the IEEE 754 single precision floating point standard.

Data Byte	#0	#1	#2	#3
	SEEEEEEE	EMMMMMMM	MMMMMMMM	MMMMMMMM

```
S - Sign of the mantissa; 1 = negative
E - Exponent; Biased by 127 decimal in two's complement format
M - Mantissa; 23 least significant bits, fractional portion
```

The value of the floating point number described above is obtained by multiplying 2, raised to the power of the unbiased exponent, by the 24-bit mantissa. The 24-bit mantissa is composed of an assumed most significant bit of 1, a decimal point following the 1, and the 23 bits of the mantissa.

$$S1.M \cdot 2^{(E-127)}$$

The floating point parameters not used by a device will be filled with 7F A0 00 00: Not-a-Number.

Double IEEE 754

The following summarizes the IEEE 754 and recommends that standards are referred to for implementation.

The floating point values passed by the protocol are based on the IEEE 754 single precision floating point standard.

Data Byte	#0	#1	#2	#3
	SEEEEEEE	EEEEMMMM	MMMMMMMM	MMMMMMMM
Data Byte	#4	#5	#6	#7
	MMMMMMMM	MMMMMMMM	MMMMMMMM	MMMMMMMM

```
S - Sign of the mantissa; 1 = negative
E - Exponent; Biased by 1023 decimal in two's complement
format
M - Mantissa; 52 least significant bits, fractional portion
```

The value of the floating point number described above is obtained by multiplying 2, raised to the power of the unbiased exponent, by the 53-bit mantissa. The 53-bit mantissa is composed of an assumed most significant bit of 1, a decimal point following the 1, and the 52 bits of the mantissa.

$$S1.M \cdot 2^{(E-1023)}$$

Packed ASCII

The packed ASCII Format uses 6 Bit to encode a character. Therefore 4 characters in the original string require 3 octets in the resulting data. It is recommended to provide strings always as a multiple ordinal of 4 characters

Construction of Packed-ASCII characters:

a) Truncate Bit #6 and #7 of each ASCII character.
b) Pack four, 6 bit-ASCII characters into three bytes.

Reconstruction of ASCII characters:

a) Unpack the four, 6-bit ASCII characters.
b) Place the complement of Bit #5 of each unpacked, 6-bit ASCII character into Bit #6.
c) Set Bit #7 of each of the unpacked ASCII characters to zero.
d) The Packed ASCII code (hexadecimal) allows the representation of the following characters.

CHAR	CODE	CHAR	CODE	CHAR	CODE	CHAR	CODE
@	00	P	10	Space	20	0	30
A	01	Q	11	!	21	1	31
B	02	R	12	"	22	2	32
C	03	S	13	#	23	3	33
D	04	T	14	$	24	4	34
E	05	U	15	%	25	5	35
F	06	V	16	&	26	6	36
G	07	W	17	'	27	7	37
H	08	X	18	(	28	8	38
I	09	Y	19	)	29	9	39
J	0A	Z	1A	*	2A	:	3A
K	0B	[	1B	+	2B	;	3B
L	0C	\	1C	,	2C	<	3C
M	0D	]	1D	-	2D	=	3D
N	0E	^	1E	.	2E	>	3E
O	0F	_	1F	/	2F	?	3F

e) Note: The implementation of the function is assuming that the packed ascii string should be an ordinal multiple of 3. If the length of the passed string is not an ordinal multiple of 4 the missing packed ascii characters are replaced by spaces.

Appendix

Abbreviations

Abbreviation	Description
HCF	Hart Communication Foundation
DLL	Windows: Dynamic Link Library OSI-ISO: Data Link Layer
HAL	Hardware Abstraction Layer
HART	Highway Addressable Remote Transducer See also: http://en.wikipedia.org/wiki/Highway_Addressable_Remote_Transducer_Protocol
HMI	Human Machine Interface
ISO	International Standards Organisation
MODEM	MOdulator DEModulator
NV-memory	Non-Volatile memory
OSAL	Operating System Abstraction Layer
OSI	Open Systems Interconnection
UART	Universal Asynchronous Receiver Transmitter