AN877

DeviceNet™ Group 2 Slave Firmware for PIC18 with CAN

Author: Ross Fosler
Microchip Technology Inc.

INTRODUCTION

The DeviceNet™ system is an open network standard, built on the Controller Area Network (CAN), designed to reduce the cost and time to install industrial devices while providing compatibility with multiple vendors. The DeviceNet specification is available from the Open DeviceNet Vendor Association, Inc. (ODVA). Example DeviceNet devices might include motor starters, valves, sensors, displays and more.

The DeviceNet specification covers multiple layers, from the wiring and protection circuits, up to the software protocol and application definition (see Figure 1); however, this application note only focuses on a specific development of the software known in the specification as the Predefined Master/Slave Connection Set. To be even more accurate, this application note only presents a slave node within the Predefined Connection Set, also referred to as a Group 2 Slave.

The Group 2 Slave developed here is designed with the following features:

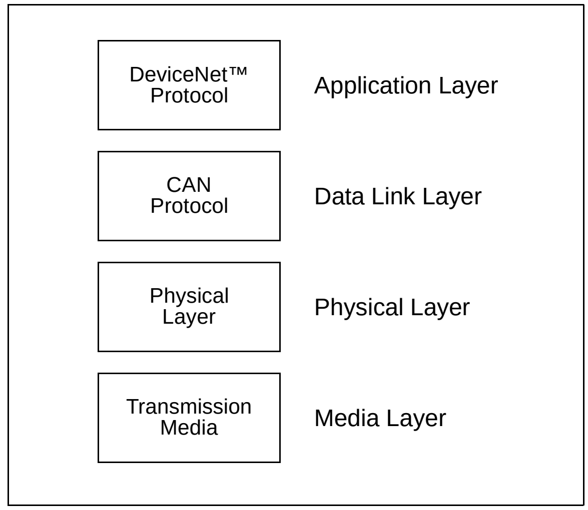
- Supports Polling Messaging
- Supports Multicast Polling Messaging
- Supports Change of State/Cyclic Messaging
- Supports Bit Strobe Messaging
- Supports Acknowledged Fragmentation
- Supports Unacknowledged Fragmentation

This application note, with attached firmware, is provided to accelerate the process to design a Group 2 Slave node but not do all of the work. There are many details to a slave node that require an understanding of the target application; therefore, this implementation is provided in a very general form with numerous configurable parameters, event handling functions and variables that must be set or developed for the application. Essentially, you cannot develop a DeviceNet application without some knowledge of the DeviceNet system and its specification. It is a good idea to have the complete specification available for reference while designing a node.

The firmware associated with this document may change as new features are added.

Throughout this application note, there are references to the specification. All references are to Volume I of the specification unless otherwise noted.

FIGURE 1: LAYER PROTOCOL



OVERVIEW OF THE FIRMWARE

The DeviceNet system is described in the specification as a collection of objects. Figure 2 shows a simplified view of the object model. There are a number of possible objects within the object model but the required objects include:

- Connection Object
- Message Router Object
- Identity Object
- DeviceNet Object

These are the objects that are developed in this application note. Other objects not listed may become available in future revisions of the firmware.

The Connection Object

The Connection Object manages all communications between the CAN bus and higher level objects and contains a number of source files. It can contain multiple instances as defined by the Predefined Master/Slave Connection Set (see Chapter 7 of the specification). Table 1 lists the files associated with the Connection Object.

The DeviceNet Object

In this design, there is one instance of the DeviceNet Object. It contains network related information about the node, such as baud rate, MAC ID and more. It is split into two source files as shown in Table 2; one file contains lower level information, while the other is application dependent and requires development based on the requirements of the application.

The Identity Object

The Identity Object contains information that identifies the device, such as serial number and description. Like the DeviceNet Object and the Connection Object, there are some application specific dependencies that must be developed for the Identity Object. Table 3 identifies the files associated with the Identity Object.

The Router Object

The Router Object routes Explicit Messages to the appropriate object. In this design, routes are static, plus the object has no external visibility over the DeviceNet system.

FIGURE 2: SIMPLE OVERVIEW OF OBJECT CONNECTION

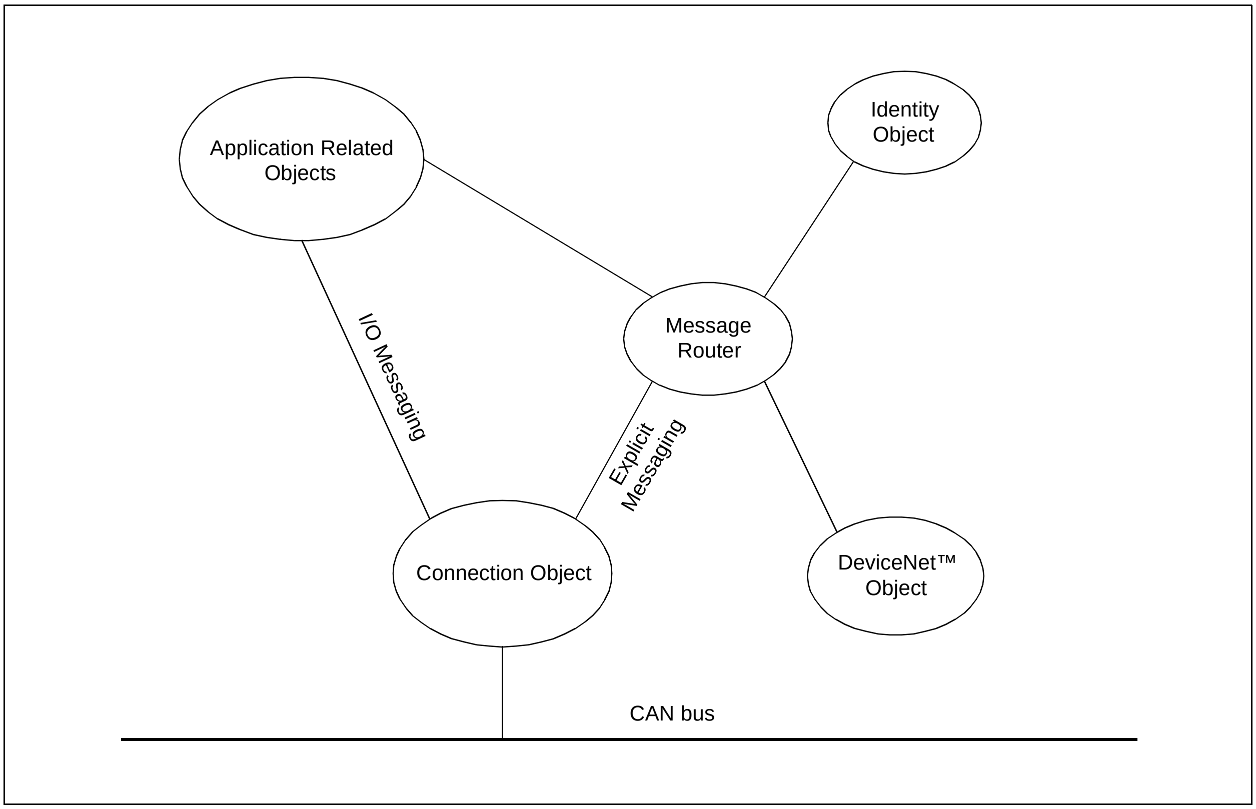


TABLE 1: CONNECTION OBJECT RELATED FILES

File Name	Description
`conn.c`	This file contains several connection managing functions to capture communications events and dispatch them to appropriate instances or other managing functions.
`conn1.c`	This file provides the Predefined Explicit Messaging connection functionality.
`conn2.c`	This file provides the Predefined Polled/Change of State/Cyclic I/O Messaging connection functionality.
`conn3.c`	This file provides the Predefined Bit Strobed I/O Messaging connection functionality.
`conn4.c`	This file provides the Predefined Change of State/Cyclic I/O Messaging connection functionality.
`conn5.c`	This file provides the Predefined Multicast Polled I/O Messaging connection functionality.
`conn6.c`	This file provides the Unconnected Explicit Messaging functionality which looks similar to other regular I/O connections, but does not support all the events and fragmentation.
`conn7.c`	This file provides the Duplicate MAC ID Messaging functionality which looks similar to other regular I/O connections, but does not support all the events and fragmentation.
`frag.c`	This file contains the I/O Fragmentation managing functions.
`CAN.C`	This file contains the abstracted CAN driver routines. The functions are abstract to support the possibility of having a variety of CAN options.
`EMM.c`	This file is referred to as the Explicit Messaging Manager. It contains functions to interface Explicit Messaging to the router. Routing specific information is parsed and placed in the Router Object.
`UEMM.c`	This file is referred to as the Unconnected Explicit Messaging Manager. It contains functions to interface Unconnected Explicit Messaging to the router. However, only the “Allocate” and “Release” commands directed to the DeviceNet Object are allowed; all other messages are ignored.
`NASM.c`	This file contains the Network Access State Machine functions. These functions are bound together with the Identity Object and the Duplicate MAC ID Message.
`UsrConn.c`	Application specific logic for the Connection Object is contained within this file; therefore, this file must be developed for the application.

TABLE 2: DeviceNet OBJECT RELATED FILES

File Name	Description
`dnet.c`	This file contains most of the required logic for the DeviceNet Object. It contains DeviceNet global variables and Explicit Message handling for the commands identified in Section 5-5 of the specification.
`UsrDNet.c`	Logic that depends on the application is contained within this file; therefore, this file must be developed for the application.

TABLE 3: IDENTITY OBJECT RELATED FILES

File Name	Description
`ident.c`	This file contains most of the required logic for the Identity Object. It contains global variables and Explicit Message handling for the commands identified in Volume II, Section 6-2 of the specification.
`UsrIdent.c`	Logic that depends on the application is contained within this file; therefore, this file must be developed for the application.

TABLE 4: ADDITIONAL HELPER FILES

File Name	Description
`class.h`	Defined classes of objects.
`errors.h`	Defined Explicit Messaging errors.
`typedefs.h`	Internal data types.

THE CONNECTION OBJECT

The Connection Object, as shown in Figure 3, is the largest and most complex object in the design. Within the object, all data and error events must be managed which explains the complexity.

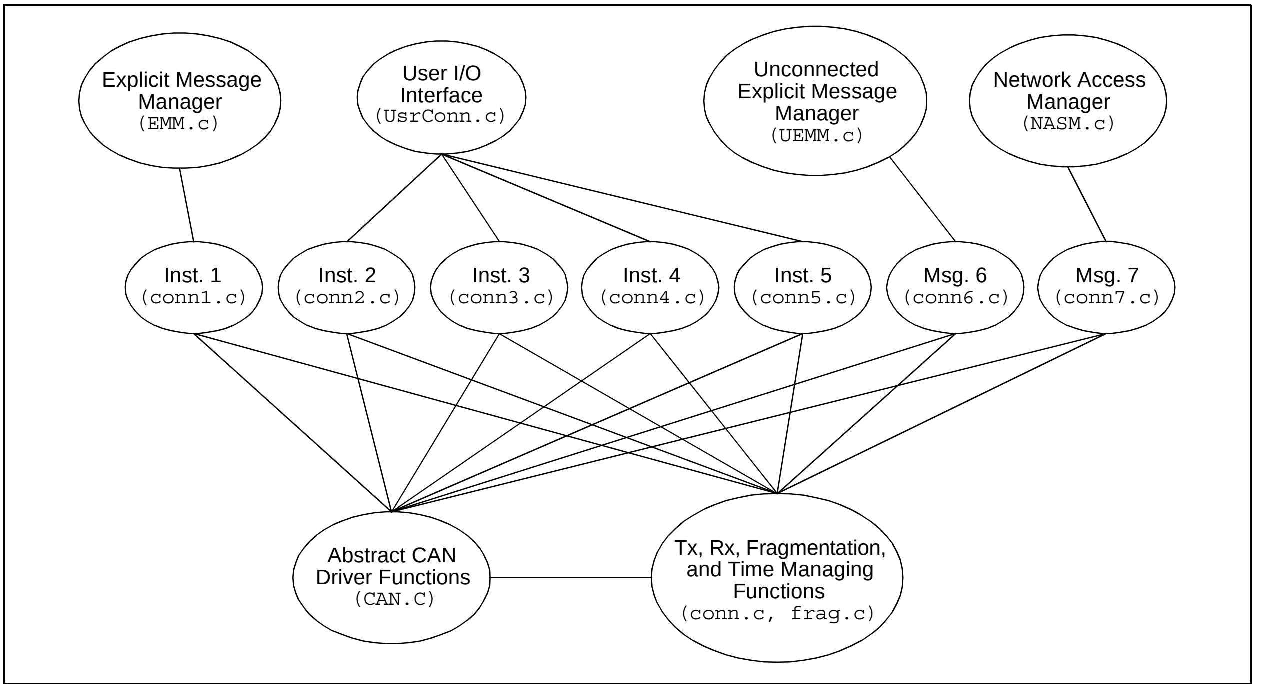
All events are received by the managing functions within the `conn.c` file through calls to the CAN driver. The events are decoded and dispatched to the appropriate instance based on the availability of the connection. Note that an instance of a connection does not exist until it is explicitly created (see Section 5-5 of the specification). The only two messages that are received without explicitly instantiating a connection are the Unconnected Explicit Request Message and the Duplicate MAC ID Check Message (see Section 7-2 of the specification).

Once instantiated, each instance manages the events that it receives. In general, the events include:

- `ConnxCreate` – Creates the object
- `ConnxClose` – Closes the object
- `ConnxTimerEvent` – Handles connection related timers
- `ConnxRxEvent` – Handles received data
- `ConnxTxOpenEvent` – Handles transmit availability
- `ConnxTxEvent` – Notification when data has been put on the bus
- `ConnxExplicitEvent` – Handles Explicit Messaging requests

At the upper level of the Connection Object are additional managers which process the received data for the instances. This includes Unconnected and Connected Explicit Message handling, Network Access Control (see Chapter 6 of the specification) and the application specific I/O.

FIGURE 3: THE CONNECTION OBJECT AND HIGHER MANAGEMENT OBJECTS



Internal Connection Object Services

The Connection Object manages I/O connection data movement to and from the user supplied buffer. It is up to the application to decide how to handle the data above the Connection Object.

There are up to four possible predefined instances that are defined (see Chapter 7 of the specification):

- Polled Messaging
- Bit Strobed Messaging
- Cyclic/Change of State Messaging
- Multicast Polled Messaging

Some basic internal services are provided through the Connection Object for the purpose of managing I/O data.

`mConnReadRdy`

Query the Connection Object to determine the status of the read buffer of the specified connection number. Returns true if a message has been received and is waiting in the receive buffer. Valid numbers are 1 through 7; however, only numbers 2 through 5 should be used since these are where the I/O connections reside.

Syntax

```
unsigned char mConnReadRdy (unsigned char hInstance)
```

Example

```
if (mConnReadRdy(2))
{
       // Process application stuff
       ApplicationProcess();
       // Free the connection to accept more data
       mConnRead(2);
}
```

`mConnWriteRdy`

Query the Connection Object to determine the status of the write buffer of the specified connection number. Returns true if the buffer is open to accept new data from transmission. Valid numbers are 1 through 7; however, only numbers 2 through 5 should be used since these are where the I/O connections reside.

Syntax

```
unsigned char mConnWriteRdy (unsigned char hInstance)
```

Example

```
if (mConnWriteRdy(2))
{
       // Process application stuff
       ApplicationProcess();
       // Release the connection to write the data
       mConnWrite(2);
}
```

mConnRead

Calling this function with the appropriate instance number will indicate to the Connection Object that all data has been processed and the connection should be ready to receive more data.

Syntax

```
void mConnRead (unsigned char hInstance)
```

mConnWrite

Calling this function with the appropriate instance number will indicate to the Connection Object that all data has been loaded into the connection's buffer for transmitting on the bus.

Syntax

```
void mConnWrite (unsigned char hInstance)
```

Connection Object Events

There are events and global registers that cannot be defined without the application. For this reason, they are passed up to the `UsrConn.c` object for application specific processing. Code must be developed in this file to manage appropriate events.

Upon instantiation, a "Create Event" is generated with the appropriate instance number passed. This event must be handled to set up some application dependent attributes. The attributes that must be set up are:

- Produced path
- Consumed path
- Produced path length
- Consumed path length
- Pointer to the consumed data
- Pointer to the produced data
- Length of the consumed data
- Length of the produced data

Like the "Create Event", there is also a "Close Event" when the connection is closed. This is provided to notify the application when the connection is no longer available.

Two other events that may or may not necessarily be set up are the "Rx Event" and the "Tx Event". These events are generated when data has been transmitted or received. These are provided for any application specific event handling; however, they do not necessarily need to be handled as an event. Receive and transmit can be polled through normal Connection Object functions.

One other event is the "Set Attribute Event". This event must be handled for any attribute that is not entirely dependent on the Connection Object alone. The attributes are:

- `_ATTRIB_CLASS_TRIGGER`
- `_ATTRIB_PRODUCED_CONN_PATH`
- `_ATTRIB_CONSUMED_CONN_PATH`
- `_ATTRIB_PRODUCED_CONN_SIZE`

Not all attributes are required to be settable; however, the event must be handled to generate an error if the event occurs.

`UsrConnCreateEvent`

This event function is called when a connection is created by an allocate request. The instance number is passed indicating the source of the event. This event is an indication to the application to provide resources necessary for the connection to function. Other than application specific resources, buffer space and path information must be provided. If resources are not available, then the application should return '`0`' to this event; otherwise, the application should return any other value to allow the creation of the connection.

Syntax

```
unsigned char UsrConnCreateEvent (unsigned char hInstance)
```

Example

```
unsigned char UsrConnCreateEvent(unsigned char hInstance)
{
        switch (hInstance)
        {
            case 2:
                // Set path information according to Appendix I
                // of the DeviceNet specification
                // Set the connection sizes
                uConn2.attrib.consumed_con_size.word = 13;
                uConn2.attrib.produced_con_size.word = 20;

                // Set the pointers to the buffers
                uConn2.rx.pMsg = uConn2RxBuffer;
                uConn2.tx.pMsg = uConn2TxBuffer;
                            return(1);
            case 3:
                // Set path and connection information
                return(1);
            case 4:
                // Set path and connection information
                return(1);
            case 5:
                // Set path and connection information
                return(1);
        }
    }
```

UsrConnCloseEvent

This event function is called when a connection is closed by a time-out or release request. The instance number is passed indicating the source of the event. This event is an indication to the application to release any allocated resources.

Syntax

```
void UsrConnCloseEvent (unsigned char hInstance)
```

UsrConnRxDataEvent

This event function is called when a connection has received data. The instance number is passed indicating the source of the event.

Syntax

```
void UsrConnRxDataEvent (unsigned char hInstance)
```

UsrConnTxDataEvent

This event function is called when a connection has transmitted its data. The instance number is passed indicating the source of the event.

Syntax

```
void UsrConnTxDataEvent (unsigned char hInstance)
```

UsrConnSetAttribEvent

This event is generated when an attribute that is defined by the application has been requested to be changed by an Explicit Message. The application must decode the attribute and generate an appropriate response to the request. Refer to the Router Object for details on internal services to handle Explicit Message responses.

Syntax

```
void UserConnSet AttribEvent (unsigned char hInstance)
```

Example

```
switch (mRouteGetAttributeID())
{
        case _ATTRIB_CLASS_TRIGGER:
            // Process request to set this attribute
            break;
        case _ATTRIB_PRODUCED_CONN_PATH:
            // Process request to set this attribute
            break;
        case _ATTRIB_CONSUMED_CONN_PATH:
            // Process request to set this attribute
            break;
        case _ATTRIB_PRODUCED_CONN_SIZE:
            // Process request to set this attribute
            break;
}
```

Connection Attributes

Connection attributes are common to all I/O connections. Depending on the connection, some of the attributes may not be settable. Table 5 lists and identifies the attributes.

TABLE 5: COMMON VISIBLE CONNECTION ATTRIBUTES

Attribute	Definition
state	Indicates the state of the connection instance.
transportClass	Indicates the type of connection.
produced_cid	This attribute contains the produced connection ID.
consumed_cid	This attribute contains the consumed connection ID.
initial_comm_char	
produced_con_size	This specifies the maximum size of the produced message for this connection.
consumed_con_size	This specifies the maximum size of the consumed message for this connection.
expected_packet_rate	This specifies the minimum rate at which data is expected to be received for this connection.
produced_path_len	Specifies the length of the produced path information.
produced_path	Specifies the produced path.
consumed_path_len	Specifies the length of the consumed path information.
consumed_path	Specifies the consumed path.

THE DeviceNet OBJECT

The DeviceNet Object contains primarily device specific information; some of this information is application specific and some does not depend on the application. Thus, like other objects in this design, it is split. Most of the decoding, general logic and global variables are provided in `dnet.c`, while application dependent functions and globals are available in `UsrDNet.c`.

Internal DeviceNet Object Services

In this section, several internal services are identified and described which are available to manage the DeviceNet Object and the device. These services should be used by the application's managing functions to indicate any hardware changes. For example, the application should use the functions `mDNetSetMACSwChange` and `mDNetSetBaudSwChange` to indicate any changes in the switches, if switches are installed in the device.

Note:	Many of the functions are purely macro based, so extra code space is not used if the function is not used in the application.

`mDNetSetMACID`

This function sets the MAC ID. Use this at initialization time.

Syntax

```
void mDNetSetMACID (USINT MACID)
```

`mDNetSetSetBaudRate`

This function sets the baud rate. Valid values are 0, 1 and 2. Use this at initialization time.

Syntax

```
void mDNetSetBaudRate (USINT BaudRate)
```

`mDNetSetBOI`

Set the bus off interrupt action. This should be asserted at initialization and can be asserted during normal operation when handling a "Set Attribute Event".

Syntax

```
void mDNetSetBOI (BOOL BOI)
```

`mDNetSetMACSwChange`

Set the MAC ID switch change indication if supported. The application should use this to notify the DeviceNet Object of the change. Typically, if the application has switches, it should notify the DeviceNet firmware that the switch has changed since last reset.

Syntax

```
void mDNetSetMACSwChange (BOOL SwitchChange)
```

`mDNetSetBaudSwChange`

Set the baud rate switch change indication if supported. The application should use this to notify the DeviceNet Object of the change. Typically, if the application has switches, it should notify the DeviceNet firmware that the switch has changed since last reset.

Syntax

```
void mDNetSetBaudSwChange (BOOL SwitchChange)
```

mDNetSetMACSwValue

Set the MAC ID switch value if supported. The application should use this to notify the DeviceNet Object of the switch value.

Syntax

```
void mDNetSetMACSwValue (USINT SwitchValue)
```

mDNetSetBaudSwValue

Set the baud rate switch value if supported. The application should use this to notify the DeviceNet Object of the switch value.

Syntax

```
void mDNetSetBaudSwValue (USINT SwitchValue)
```

mDNetGetMACID

Get the current MAC ID value stored in the DeviceNet Object.

Syntax

```
USINT mDNetGetMACID ()
```

mDNetGetBaudRate

Get the current baud rate value stored in the DeviceNet Object.

Syntax

```
USINT mDNetGetBaudRate()
```

mDNetGetBOI

Get the current bus off interrupt value stored in the DeviceNet Object.

Syntax

```
BOOL mDNetGetBOI ()
```

mDNetGetBusOffCount

Get the current bus off count value stored in the DeviceNet Object. This value is updated by the Connection Object Error Management function.

Syntax

```
USINT mDNetGetBusOffCount ()
```

mDNetGetAllocChoice

Get the current allocation choice byte. This value is changed based on the requests from the server and the internal watchdog timers. This could be used internally to get an indication of what connection has been allocated.

Syntax

```
USINT mDNetGetAllocChoice ()
```

mDNetGetMasterMACID

Get the current allocated Master MAC ID. Valid values are 0 to 63 and 255. A value of 255 indicates that no client has allocated this node.

Syntax

```
USINT mDNetGetMasterMACID ()
```

mDNetMACSwChange

Get the stored MAC ID switch change value.

Syntax

```
void mDNetSetBOI (unsigned char MACID)
```

mDNetBaudSwChange

Get the stored baud rate switch change value.

Syntax

```
void mDNetSetBOI (unsigned char MACID)
```

mDNetGetMACSwValue

Get the stored MAC ID switch value.

Syntax

```
USINT mDNetGetMACSwValue ()
```

mDNetGetBaudSwValue

Get the stored baud rate switch value.

Syntax

```
USINT mDNetGetBaudSwValue ()
```

DeviceNet Object Events

There are two events that must be handled by the application that occur in the DeviceNet Object, which are listed below.

Within the `UsrDNetInitEvent` function, several attributes specific to the DeviceNet Object must be set. For example, the MAC ID and the baud rate can be switch values, or internal values stored in memory, depending on the application design. Thus, these initializations are left to the application designer. The same situation applies to the `UsrDNetSetAttribEvent` function. Refer to Section 5-5 of the specification for information on the DeviceNet Object. The specification identifies the settable attributes and the conditions that enable the settable attributes.

UsrDNetInitEvent

This event occurs when the DeviceNet Object is initialized. A number of attributes must be set up.

Syntax

```
void UsrDNetInitEvent (void)
```

Example

```
void UsrDNetInitEvent(void)
{
       mDNetSetMACID(12);
       mDNetSetBaudRate(0);
       mDNetSetBOI(0);
       mDNetSetMACSwChange(0);
       mDNetSetBaudSwChange(0);
       mDNetSetMACSwValue(0);
       mDNetSetBaudSwValue(0);
}
```

UsrDNetSetAttribEvent

The “Set Attribute Event” occurs when the setting of an attribute cannot be handled internally because of some application dependency.

Syntax

```
void UsrDNetSetAttribEvent (void)
```

Example

```
void UsrDNetSetAttribEvent(void)
{
       switch (mRouteGetAttributeID())
       {
          case _ATTRIB_MAC_ID:
             // Application code to handle setting MAC ID
             break;

          case _ATTRIB_BAUD_RATE:
             // Application code to handle setting baud rate
             break;

          case _ATTRIB_BOI:
             // Application code to handle setting BOI
             break;
       }
}
```

THE IDENTITY OBJECT

The Identity Object contains device identification information; some of this information is application specific and some does not depend on the application. Thus, like other objects in this design, it is split. Most of the decoding, general logic and global variables are provided in `ident.c`, while application dependent functions and globals are available in `UsrIdent.c`.

Identity Object Events

UsrIdentityCommunicationFaultEvent

This event is generated when communications has faulted (i.e., the bus off count has exceeded 255). Refer to Chapter 6 of the DeviceNet specification.

Syntax

```
void UsrIdentityCommunicationFaultEvent(void)
```

UsrIdentityFaultEvent

This event occurs when the Network Access State Machine has been corrupted. If this ever occurs, a Reset is probably necessary.

Syntax

```
void UsrIdentityFaultEvent(void)
```

UsrIdentityReset

This function is called when a Reset has been requested. This occurs through an Explicit Messaging request.

Syntax

```
void UsrIdentityReset(void)
```

Example

```
void UsrIdentityReset(void)
{
        USINT resetData;

        // Ignore the first byte (it is actually the attribute ID)
        mRouteGetByte();

        // Verify that one byte has been received
        if (mRouteTestValidInputDataLen(1))
        {
            // Get the data (6-2.3.1)
            resetData = mRouteGetByte();

            if (resetData == 0)
            {
                // Perform a soft reset
            }
            else if (resetData == 1)
            {
                // Perform an ‘out of the box’ reset
            }
        }
}
```


UsrIdentityInitEvent

This is the initialization event. The identity globals must be set up in this event.

Syntax

```
void UsrIdentityInitEvent(void)
```

Example

```
    ROM unsigned char cProductName[] = {"Microchip Device"};

void UsrIdentityInitEvent(void)
{
        mIdentitySetVendorID(12345);
        mIdentitySetDeviceType(2);
        mIdentitySetProductCode(3);
        mIdentitySetMajorRevision(1);
        mIdentitySetMinorRevision(0);
        mIdentitySetStatus(0);
        mIdentitySetSerial(28933892);
        mIdentitySetNameP(cProductName);
        mIdentitySetNameLen(sizeof(cProductName));
}
```

Internal Identity Object Services

The following identifies and describes several internal services that are available to manage the Identity Object and the device. These services should be used by the application's managing functions to indicate any changes related to the Identity Object, most notably the status of the device. For example, the application should use the function, `mIdentitySetStatus`, to indicate any application level Fault conditions. See the functions below.

mIdentitySetVendorID

Use this to set the vendor ID of the node. This number is assigned by ODVA.

Syntax

```
void mIdentitySetVendorID (UINT VendorID)
void mIdentitySetVendorIDL (USINT VendorID)
void mIdentitySetVendorIDH (USINT VendorID)
```

mIdentityGetVendorID

Use this to get the stored vendor ID.

Syntax

```
UINT mIdentityGetVendorID (void)
USINT mIdentityGetVendorIDL (void)
USINT mIdentityGetVendorIDH (void)
```

mIdentitySetDeviceType

Use this to set the device type.

Syntax

```
void mIdentitySetDeviceType (UINT DeviceType)
void mIdentitySetDeviceTypeL (USINT DeviceType)
void mIdentitySetDeviceTypeH (USINT DeviceType)
```

mIdentityGetDeviceType

Use this to get the device type.

Syntax

```
UINT mIdentityGetDeviceType (void)
USINT mIdentityGetDeviceTypeL (void)
USINT mIdentityGetDeviceTypeH (void)
```

mIdentitySetProductCode

Set the product code.

Syntax

```
void mIdentitySetProductCode (UINT ProductCode)
void mIdentitySetProductCodeL (USINT ProductCode)
void mIdentitySetProductCodeH (USINT ProductCode)
```

mIdentityGetProductCode

Get the product code.

Syntax

```
UINT mIdentityGetProductCode (void)
USINT mIdentityGetProductCodeL (void)
USINT mIdentityGetProductCodeH (void)
```

mIdentitySetMajorRevision

Set the major revision.

Syntax

```
void mIdentitySetMajorRevision (USINT MajorRev)
```

mIdentityGetMajorRevision

Get the major revision.

Syntax

```
USINT mIdentityGetMajorRevision (void)
```

mIdentitySetMinorRevision

Set the minor revision.

Syntax

```
void mIdentitySetMinorRevision (USINT MinorRev)
```

mIdentityGetMinorRevision

Get the minor revision.

Syntax

```
USINT mIdentityGetMinorRevision (void)
```

mIdentitySetSerial

Set the serial number.

Syntax

```
void mIdentitySetSerial (UDINT SerialNo)
void mIdentitySetSerialL (USINT SerialNo)
void mIdentitySetSerialH (USINT SerialNo)
void mIdentitySetSerialUL (USINT SerialNo)
void mIdentitySetSerialUH (USINT SerialNo)
```

mIdentityGetSerial

Get the serial number.

Syntax

```
UDINT mIdentityGetSerial (void)
USINT mIdentityGetSerialL (void)
USINT mIdentityGetSerialH (void)
USINT mIdentityGetSerialUL (void)
USINT mIdentityGetSerialUH (void)
```

mIdentitySetStatus

Set the status of the device. This must be set by the application to indicate the current status of the device (see Section 6-2.2 of the specification).

Syntax

```
void mIdentitySetStatus (WORD DevStat)
void mIdentitySetStatusL (unsigned char DevStat)
void mIdentitySetStatusH (unsigned char DevStat)
```

mIdentityGetStatus

Get the status of the device.

Syntax

```
WORD mIdentityGetStatus (void)
unsigned char mIdentityGetStatusL (void)
unsigned char mIdentityGetStatusH (void)
```

mIdentitySetNameP

Set a ROM pointer to the name of the device.

Syntax

```
void mIdentitySetNameP (ROM unsigned char pName)
```

mIdentitySetNameLen

Set the length of the name.

Syntax

```
void mIdentitySetNameLen (unsigned char NameLen)
```

THE ROUTER OBJECT

Although the Router Object has no external visibility through Explicit Messaging, it has many internal functions for routing Explicit Message data. These functions are listed and described in the **"Internal Routing Services"** section.

Handling Explicit Messaging

Every application object that has attributes and services has an Explicit Message handling function that decodes the path information. The router automatically parses the appropriate information and makes it available to the application. Plus, there are a number of functions that are also available. All of the possible functions are listed in the **"Internal Routing Services"** section. Following are some of the more important internal functions:

- `mRoutePutByte` – Put a byte into the response buffer and automatically adjust some internal pointers to the next byte in the buffer.
- `mRouteGetByte` – Read a byte from the receive buffer and automatically adjust to the next byte in the buffer.
- `mRouteTestValidInputDataLen` – Test the length of the attribute data against the expected data length.
- `mRoutePutError` – Set the appropriate error response.
- `mRouteGetServiceID` – Get the service ID.
- `mRouteGetInstanceID` – Get the instance ID.
- `mRouteGetAttributeID` – Get the attribute ID.
- `mRouteGetInBufferPtr` – Get the pointer to the buffer.
- `mRouteGetInBufferDataLength` – Get the amount of data in the input buffer.
- `mRouteGetOutBufferPtr` – Get a pointer to the output buffer.
- `mRouteGetOutBufferLength` – Get the maximum length of the output buffer.

Refer to the source code for examples on handling Explicit Messaging events.

Internal Routing Services

mRoutePutByte

Put a byte into the buffer to be transmitted by the Explicit Messaging connection. Internal pointers are maintained automatically. Thus, multiple writes will write bytes sequentially in the buffer.

Syntax

```
void mRoutePutByte (USINT dataByte)
```

mRouteGetByte

Get a byte from the received Explicit Messaging connection buffer. Internal pointers are maintained automatically. Thus, multiple reads will read bytes sequentially from the buffer.

Syntax

```
USINT mRouteGetByte (void)
```

mRouteTestValidInputDataLen

Verify the length of the input data. An error response is automatically generated if the boundary conditions are not met.

Syntax

```
unsigned char mRouteTestValidInputDataLen (unsigned char len)
```


mRouteTestNonValidInputDataLen

Verify the length of the input data. An error response is automatically generated if the boundary conditions are not met.

Syntax

```
unsigned char mRouteTestNonValidInputDataLen (unsigned char len)
```

mRoutePutError

Put an error response in the buffer. Refer to `errors.h` and the specification for a list of known errors.

Syntax

```
void mRoutePutError (USINT errorCode)
```

mRouteRxLen

Get the receive data length.

Syntax

```
USINT mRouteRxLen (void)
```

mRouteTxLen

Get the transmit data length.

Syntax

```
USINT mRouteTxLen (void)
```

mRouteGetHeader

Get the header of the received Explicit Message.

Syntax

```
USINT mRouteGetHeader (void)
```

mRouteGetServiceID

Get the service ID of the received Explicit Message.

Syntax

```
USINT mRouteGetServiceID (void)
```

mRouteGetClassID

Get the class ID of the received Explicit Message.

Syntax

```
USINT mRouteGetClassID (void)
UINT mRouteGetClassID (void)
```

mRouteGetInstanceID

Get the instance ID of the received Explicit Message.

Syntax

```
USINT mRouteGetInstanceID (void)
UINT mRouteGetInstanceID (void)
```

mRouteGetAttributeID

Get the attribute ID of the received Explicit Message.

Syntax

```
USINT mRouteGetAttributeID (void)
```

mRouteGetInBufferPtr

Get the pointer to the input buffer.

Syntax

```
USINT * mRouteGetInBufferPtr (void)
```

mRouteGetOutBufferPtr

Get the pointer to the output buffer.

Syntax

```
USINT * mRouteGetOutBufferPtr (void)
```

mRouteGetInBufferLength

Get the length of the input buffer.

Syntax

```
USINT mRouteGetInBufferLength (void)
```

mRouteGetInBufferDataLength

Get the length of data in the input buffer.

Syntax

```
USINT mRouteGetInBufferDataLength (void)
```

mRouteGetOutBufferLength

Get the length of the output buffer.

Syntax

```
USINT mRouteGetOutBufferLength (void)
```

mRouteGetOutBufferDataLength

Get the length of the data in the output buffer.

Syntax

```
USINT mRouteGetOutBufferDataLength (void)
```

mRoutePutServiceID

Set the service ID. Typically this is used only when changing the Explicit Message response to an error response.

Syntax

```
void mRoutePutServiceID (USINT ServiceID)
```

mRoutePutInBufferPtr

Set the input buffer pointer.

Syntax

```
void mRoutePutInBufferPtr (USINT * pInBuf)
```

mRoutePutOutBufferPtr

Set the output buffer pointer.

Syntax

```
void mRoutePutOutBufferPtr (USINT * pOutBuf)
```

mRoutePutInBufferLength

Set the input buffer length.

Syntax

```
void mRoutePutInBufferLength (USINT length)
```

mRoutePutInBufferDataLength

Set the length of the data in the input buffer.

Syntax

```
void mRoutePutInBufferDataLength (USINT length)
```

mRoutePutOutBufferLength

Set the output buffer length.

Syntax

```
void mRoutePutOutBufferLength (USINT length)
```

mRoutePutOutBufferDataLength

Set the length of data in the output buffer.

Syntax

```
void mRoutePutOutBufferDataLength (USINT length)
```

SUPPORTING FUNCTIONS

All of the managing and initialization functionality is combined into a single source object. The primary function is to manage communication, errors, time and initialization while providing a simple interface. In this case, there are three functions listed and described below. These functions should be called by the application's main program.

Setting Up a Timer

The `GoDNetProcessAllTickEvents` function must be called at the rate specified by the `TICK_RESOLUTION` compile time option. The source of the timing event can be determined by the application. Refer to the source code for an example.

GoDNetProcessAllMsgEvents

This function processes all message and error management functions, essentially generating communications related events. It should be called as often as possible to avoid missing events from the CAN driver.

Syntax

```
void GoDNetProcessAllMsgEvents (void)
```

Example

See example for the `GoDNetInitializeAll` function below.

GoDNetProcessAllTickEvents

This function combines all time related management into a single function. This function should be called based on an application generated timing event. A timer or some external trigger could be used to do this.

Syntax

```
void GoDNetProcessAllTickEvents (void)
```

Example

See example for the `GoDNetInitializeAll` function below.

GoDNetInitializeAll

This function should be called at least one time. It generates all the initialization events, external and internal, to set up the node for the DeviceNet system.

Syntax

```
void GoDNetInitializeAll (void)
```

Example

```
void main(void)
{
        // Init the timer
        TimerInit();

        // Init all appropriate DeviceNet parameters
        GoDNetInitializeAll();

        while (1)
        {
            // Process all DeviceNet Messaging events
            GoDNetProcessAllMsgEvents();

            // Process all DeviceNet timer events
            if (TimerIsOverflowEvent())
               GoDNetProcessAllTickEvents();

            // Process any application firmware
        }
}
```

COMPILE TIME SETUP

There are several compile time options that must be set to configure the DeviceNet firmware. They are listed and described in Table 6.

TABLE 6: COMPILE TIME OPTIONS

Option	Definition
B125k_BRG1_SJW	Set the BRG values to achieve 125k for the desired clock frequency. Refer to the PIC18FXX8 device data sheet (DS41159) for information on the CAN module.
B125k_BRG1_PRESCALE	
B125k_BRG2_SEG2PHTS	
B125k_BRG3_WAKFIL	
B125k_BRG2_SEG1PH	
B125k_BRG3_SEG2PH	
B125k_BRG2_PRSEG	
B125k_BRG2_SAM	
B250k_BRG1_SJW	Set the BRG values to achieve 250k for the desired clock frequency. Refer to the PIC18FXX8 device data sheet (DS41159) for information on the CAN module.
B250k_BRG1_PRESCALE	
B250k_BRG2_SEG2PHTS	
B250k_BRG3_WAKFIL	
B250k_BRG2_SEG1PH	
B250k_BRG3_SEG2PH	
B250k_BRG2_PRSEG	
B250k_BRG2_SAM	
B500k_BRG1_SJW	Set the BRG values to achieve 500k for the desired clock frequency. Refer to the PIC18FXX8 device data sheet (DS41159) for information on the CAN module.
B500k_BRG1_PRESCALE	
B500k_BRG2_SEG2PHTS	
B500k_BRG3_WAKFIL	
B500k_BRG2_SEG1PH	
B500k_BRG3_SEG2PH	
B500k_BRG2_PRSEG	
B500k_BRG2_SAM	
CLASS_WIDTH_16BIT	If this parameter is true, then the Router Object will assume 16-bit class ID for all connected Explicit Messages; otherwise, 8-bit is default.
INSTANCE_WIDTH_16BIT	If this parameter is true, then the Router Object will assume 16-bit instance ID for all connected Explicit Messages; otherwise, 8-bit is default.
TICK_RESOLUTION	Set the tick resolution that will be supplied to the firmware. The resolution must be 1, 2, 4, 8, 16 or 32 ms.
SUPPORT_POLLED	Enable support for Polled I/O Messaging.
SUPPORT_BIT_STROBED	Enable support for Bit Strobed I/O Messaging.
SUPPORT_MULTICAST_POLL	Enable support for Multicast Polled I/O Messaging.
SUPPORT_COS	Enable support for COS I/O Messaging.
SUPPORT_CYCLIC	Enable support for Cyclic I/O Messaging.
SUPPORT_COS_BOTH_DIR	Enable support for COS/Cyclic I/O Messaging for both directions.
FRAGMENTATION_UNACK	Enable fragmentation support for I/O Messages.
FRAGMENTATION_ACK	Enable fragmentation support for Explicit Messages.
EXPLICIT_ACK_TIMER	Acknowledge time-out for fragmented transmission.
CONN_EXPLICIT_RX_SIZE	Set the receive buffer size for Explicit Messages.

TABLE 6: COMPILE TIME OPTIONS (CONTINUED)

Option	Definition
CONN_EXPLICIT_TX_SIZE	Set the transmit buffer size for Explicit Messages.
CONN_POLLED_RX_FRAG	Allow fragmentation for Receive Polled Messages.
CONN_POLLED_TX_FRAG	Allow fragmentation for Transmit Polled Messages.
CONN_MULTICAST_RX_FRAG	Allow fragmentation for Receive Multicast Polled Messages.
CONN_MULTICAST_TX_FRAG	Allow fragmentation for Transmit Multicast Polled Messages.
CONN_COS_CYCLIC_RX_FRAG	Allow fragmentation for Receive COS/Cyclic Messages.
CONN_COS_CYCLIC_TX_FRAG	Allow fragmentation for Transmit COS/Cyclic Messages.
ALLOW_MAC_ID ALLOW_BAUD_RATE ALLOW_BOI ALLOW_BUS_OFF_COUNT ALLOW_ATTRIB_ALLOC_INFO ALLOW_MAC_ID_SW_CH ALLOW_BAUD_RATE_SW_CH ALLOW_MAC_ID_SW_VAL ALLOW_BAUD_RATE_SW_VAL	Enable visibility of these parameters within the DeviceNet Object.
SETTABLE_BUS_OFF_COUNT SETTABLE_BOI SETTABLE_BAUD_RATE SETTABLE_MAC_ID	Enable settability of these parameters within the DeviceNet Object.
CLASS_USER_DEFINED_1 CLASS_USER_DEFINED_1_NAME CLASS_USER_DEFINED_2 CLASS_USER_DEFINED_2_NAME CLASS_USER_DEFINED_3 CLASS_USER_DEFINED_3_NAME CLASS_USER_DEFINED_4 CLASS_USER_DEFINED_4_NAME CLASS_USER_DEFINED_5 CLASS_USER_DEFINED_5_NAME CLASS_USER_DEFINED_6 CLASS_USER_DEFINED_6_NAME CLASS_USER_DEFINED_7 CLASS_USER_DEFINED_7_NAME CLASS_USER_DEFINED_8 CLASS_USER_DEFINED_8_NAME	These options set the application specific Explicit Messaging information for the Router Object. The first parameter is the class ID and the second is the name of the Explicit Message handling function. A class ID of '0' is considered non-existent.

ABOUT THE CAN DRIVER

The Connection Object makes calls to the CAN driver to set up communications and to capture the necessary events, such as receive, transmit, and bus off. The driver provided is only a very simple form of driver. The functionality is heavily hardware dependent. A much more complex driver is possible if the latency and processing requirements become more stringent in the application. The following is a list of driver functions called by the Connection Object:

`CANOpen`

Open communications over CAN.

Syntax

```
NEAR unsigned char CANOpen(void)
```

`CANClose`

Close communications over CAN.

Syntax

```
NEAR unsigned char CANClose(void)
```

`CANIsOpen`

Query to determine if communications are open.

Syntax

```
NEAR unsigned char CANNIsOpen(void)
```

`CANSetFilter`

Set a filter. This is a request, thus the driver may not always be able to completely filter an entire CAN ID.

Syntax

```
NEAR unsigned char CANSetFilter(NEAR unsigned int filterID)
```

`CANClrFilter`

Clear a filter. This is a request, thus the driver may not always be able to completely remove filtering of an entire CAN ID.

Syntax

```
NEAR unsigned char CANClrFilter(NEAR unsigned int filterID)
```

`CANSetBitRate`

Set the bit rate for communications. The format for this follows:

DeviceNet: 0 = 125 kbps, 1 = 250 kbps, 2 = 500 kbps

This function will only work if communication is off-line.

Syntax

```
NEAR unsigned char CANSetBitRate(NEAR unsigned char bitrate)
```

CANIsBusError

Check for a bus off error.

Syntax

```
NEAR unsigned char CANIsBusError(void)
```

CANIsRxRdy

Check to see if data is available.

Syntax

```
NEAR unsigned char CANIsRxRdy(void)
```

CANRead

Indicate to the driver that all data has been read. This should allow the driver to use the released resources to receive more data.

Syntax

```
void CANRead(void)
```

CANIsTxRdy

Check to see if a buffer is available.

Syntax

```
NEAR unsigned char CANIsTxRdy(void)
```

CANIsMsgSent

Return the tag of the message that was placed on the bus.

Syntax

```
NEAR unsigned char CANIsMsgSent(void)
```

CANSend

Indicate to the driver that data has been loaded and is ready to send.

Syntax

```
void CANSend(NEAR unsigned char txTag)
```

CANGetRxCID

Get the received CAN ID.

Syntax

```
NEAR unsigned int CANGetRxCID(void)
```

CANGetRxCnt

Get the received count.

Syntax

```
NEAR unsigned char CANGetRxCnt(void)
```

CANGetRxDataPtr

Get a pointer to the data.

Syntax

```
unsigned char * NEAR CANGetRxDataPtr(void)
```

CANGetRxDataTypX

Copy a block of bytes from the driver buffer to the specified location. Type 0 is 8 bytes, Type 1 is 7 bytes, Type 2 is 6 bytes.

Syntax

```
void CANGetRxDataTyp0(unsigned char * NEAR usrBuf)
void CANGetRxDataTyp1(unsigned char * NEAR usrBuf)
void CANGetRxDataTyp2(unsigned char * NEAR usrBuf)
```

CANPutTxCID

Load the CAN ID into the transmit.

Syntax

```
void CANPutTxCID(NEAR unsigned int txCID)
```

CANPutTxCnt

Set the amount of data loaded.

Syntax

```
void CANPutTxCnt(NEAR unsigned char txCount)
```

CANGetTxDataPtr

Get a pointer to the transmit buffer.

Syntax

```
unsigned char * NEAR CANGetTxDataPtr(void)
```

CANPutTxDataTypX

Copy a block of bytes from the specified location to the driver buffer. Type 0 is 8 bytes, Type 1 is 7 bytes, Type 2 is 6 bytes.

Syntax

```
void CANPutTxDataTyp0(unsigned char * NEAR usrBuf)
void CANPutTxDataTyp1(unsigned char * NEAR usrBuf)
void CANPutTxDataTyp2(unsigned char * NEAR usrBuf)
```

CANInit

Initialize the driver.

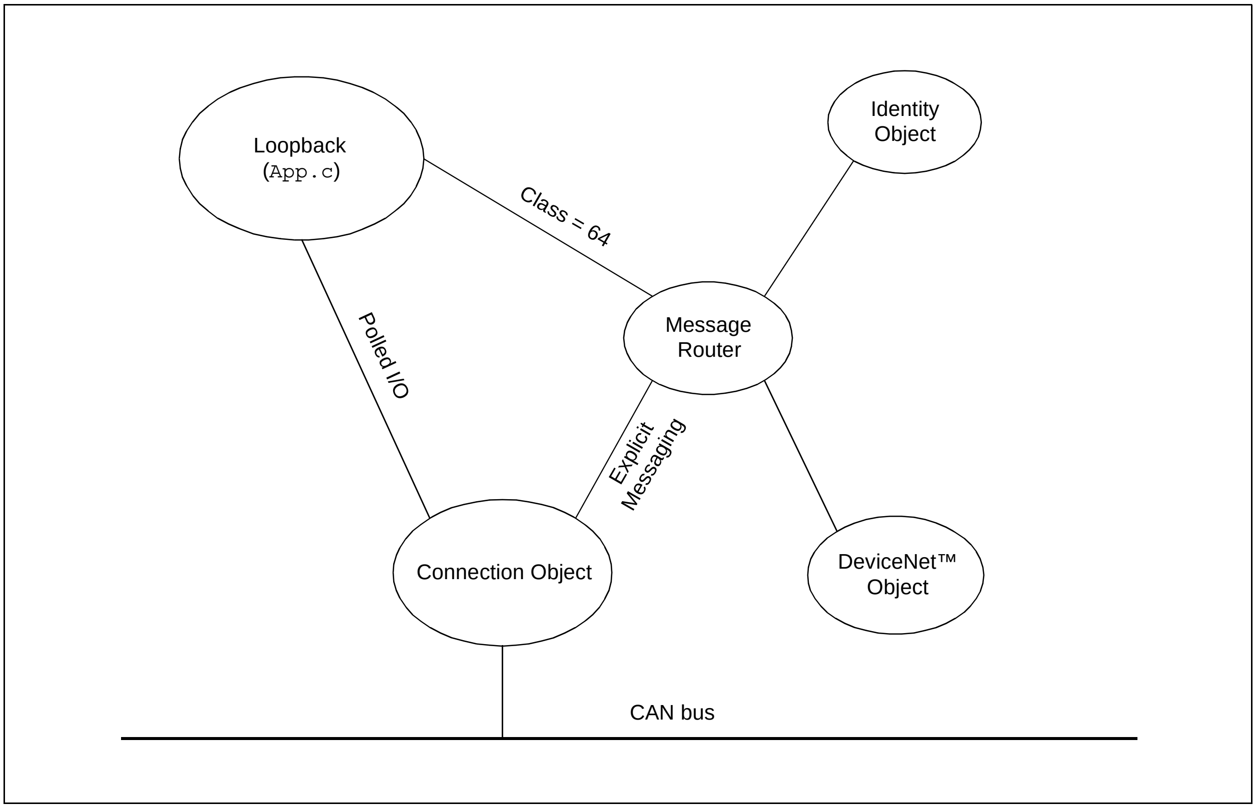
Syntax

```
void CANInit(void)
```

ABOUT THE SAMPLE FIRMWARE

The firmware provided with this application note demonstrates a simple loopback function in both the Explicit and I/O data paths. In the I/O data path, Polled Messaging is used to echo any data it receives. In the Explicit path, sending a "Get Attribute" request to CLASS 64, INSTANCE 1, ATTRIBUTE 64, will send an Explicit response with all the data received in the "Get Attribute" request. Figure 4 shows the basic object model. Refer to the `App.c` file for information about the Application Object.

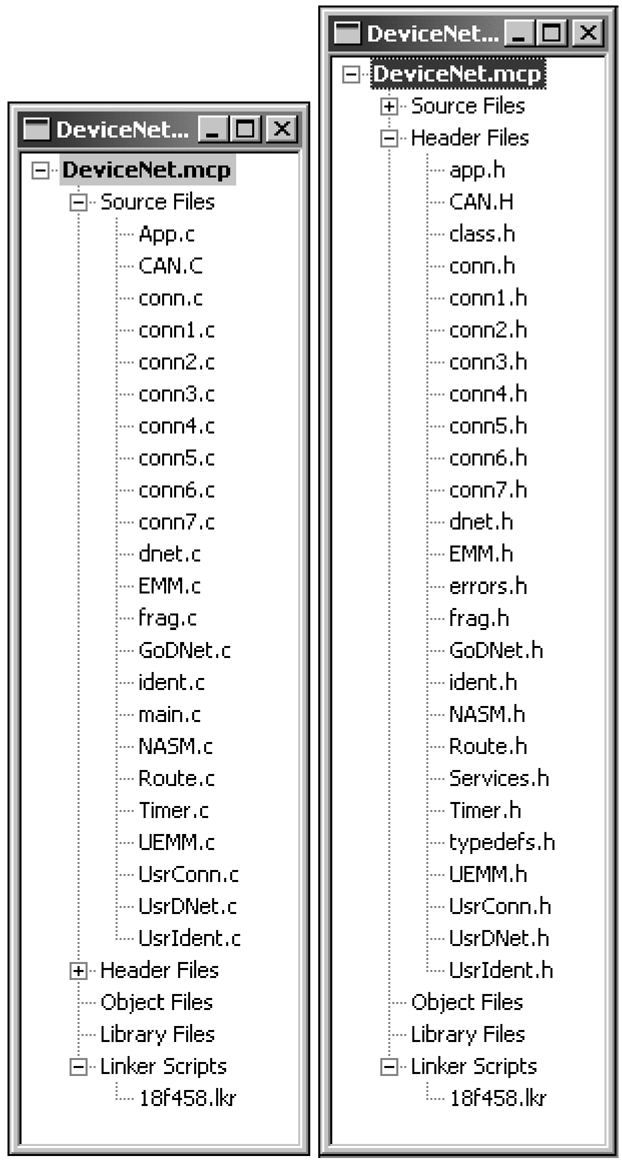
FIGURE 4: BASIC OBJECT MODEL



Along with the DeviceNet specific files and a simple Loopback Application Object are demonstration timer functions in `Timer.c`. The DeviceNet system does specify some timing requirements. The Demonstration Timer Object is designed to use Timer0; however, the network stack does not limit timing operations to any particular time input.

The project has many files. To reduce confusion, images of the project files are presented in Figure 5. The recommended storage class for the entire project is 'Overlay' with the exception of the CAN driver, `CAN.C`, which should use the 'Static' storage class.

FIGURE 5: PROJECT FILES



FUTURE OBJECTS

There are two objects that may become available in future revisions of the associated source code that are not currently available. They are the Assembly Object and the Parameter Object. These objects are not required by the specification; however, many applications may require them.

MEMORY USAGE

Memory usage varies considerably based on the optimizations and compile time options. Typical minimum build is about 8k, while the maximum is about 12.5k.

SUMMARY

There are many parts of the firmware to work with to design a DeviceNet node. Again, here are the key items to remember:

- **Compile Time** –There are several compile time options listed in Table 6 that should be set.
- **Initialization Code** – The Connection, Identity, and DeviceNet Objects all have initialization parameters that must be set prior to normal operation.
- **Explicit Messaging Events** – All the objects, except for the Router, have some Explicit Messaging events that are not handled internally because they rely on some specific application level information. Thus, they must be handled by the application.
- **Network and Other Events** – There are several other events, such as initialization, that must be handled appropriately. These must be developed by the application designer.
- **Application Objects** – The Application Object or Objects must, of course, be defined and developed. Each object must handle Explicit Messaging as well as some I/O Messaging.
- **Set Up Timing** – A time source is required to maintain connection based timers. This must be provided by the application designer.
- **The Main Managing Functions** – The main managing functions must be called appropriately to capture all events.

APPENDIX A: SOURCE CODE

The complete source code, including any demo applications and necessary support files, is available for download as a single archive file from the Microchip corporate web site, at:

www.microchip.com

NOTES:

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as “unbreakable.”

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break microchip’s code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Microchip received QS-9000 quality system certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona in July 1999 and Mountain View, California in March 2002. The Company’s quality system processes and procedures are QS-9000 compliant for its PICmicro® 8-bit MCUs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, non-volatile memory and analog products. In addition, Microchip’s quality system for the design and manufacture of development systems is ISO 9001 certified.

WORLDWIDE SALES AND SERVICE

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support: 480-792-7627
Web Address: http://www.microchip.com

Atlanta
3780 Mansell Road, Suite 130
Alpharetta, GA 30022
Tel: 770-640-0034
Fax: 770-640-0307

Boston
2 Lan Drive, Suite 120
Westford, MA 01886
Tel: 978-692-3848
Fax: 978-692-3821

Chicago
333 Pierce Road, Suite 180
Itasca, IL 60143
Tel: 630-285-0071
Fax: 630-285-0075

Dallas
4570 Westgrove Drive, Suite 160
Addison, TX 75001
Tel: 972-818-7423
Fax: 972-818-2924

Detroit
Tri-Atria Office Building
32255 Northwestern Highway, Suite 190
Farmington Hills, MI 48334
Tel: 248-538-2250
Fax: 248-538-2260

Kokomo
2767 S. Albright Road
Kokomo, IN 46902
Tel: 765-864-8360
Fax: 765-864-8387

Los Angeles
18201 Von Karman, Suite 1090
Irvine, CA 92612
Tel: 949-263-1888
Fax: 949-263-1338

Phoenix
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7966
Fax: 480-792-4338

San Jose
2107 North First Street, Suite 590
San Jose, CA 95131
Tel: 408-436-7950
Fax: 408-436-7955

Toronto
6285 Northam Drive, Suite 108
Mississauga, Ontario L4V 1X5, Canada
Tel: 905-673-0699
Fax: 905-673-6509

ASIA/PACIFIC

Australia
Suite 22, 41 Rawson Street
Epping 2121, NSW
Australia
Tel: 61-2-9868-6733
Fax: 61-2-9868-6755

China - Beijing
Unit 915
Bei Hai Wan Tai Bldg.
No. 6 Chaoyangmen Beidajie
Beijing, 100027, No. China
Tel: 86-10-85282100
Fax: 86-10-85282104

China - Chengdu
Rm. 2401-2402, 24th Floor,
Ming Xing Financial Tower
No. 88 TIDU Street
Chengdu 610016, China
Tel: 86-28-86766200
Fax: 86-28-86766599

China - Fuzhou
Unit 28F, World Trade Plaza
No. 71 Wusi Road
Fuzhou 350001, China
Tel: 86-591-7503506
Fax: 86-591-7503521

China - Hong Kong SAR
Unit 901-6, Tower 2, Metroplaza
223 Hing Fong Road
Kwai Fong, N.T., Hong Kong
Tel: 852-2401-1200
Fax: 852-2401-3431

China - Shanghai
Room 701, Bldg. B
Far East International Plaza
No. 317 Xian Xia Road
Shanghai, 200051
Tel: 86-21-6275-5700
Fax: 86-21-6275-5060

China - Shenzhen
Rm. 1812, 18/F, Building A, United Plaza
No. 5022 Binhe Road, Futian District
Shenzhen 518033, China
Tel: 86-755-82901380
Fax: 86-755-8295-1393

China - Shunde
Room 401, Hongjian Building
No. 2 Fengxiangnan Road, Ronggui Town
Shunde City, Guangdong 528303, China
Tel: 86-765-8395507 Fax: 86-765-8395571

China - Qingdao
Rm. B505A, Fullhope Plaza,
No. 12 Hong Kong Central Rd.
Qingdao 266071, China
Tel: 86-532-5027355 Fax: 86-532-5027205

India
Divyasree Chambers
1 Floor, Wing A (A3/A4)
No. 11, O'Shaugnessey Road
Bangalore, 560 025, India
Tel: 91-80-2290061 Fax: 91-80-2290062

Japan
Benex S-1 6F
3-18-20, Shinyokohama
Kohoku-Ku, Yokohama-shi
Kanagawa, 222-0033, Japan
Tel: 81-45-471- 6166 Fax: 81-45-471-6122

Korea
168-1, Youngbo Bldg. 3 Floor
Samsung-Dong, Kangnam-Ku
Seoul, Korea 135-882
Tel: 82-2-554-7200 Fax: 82-2-558-5932 or
82-2-558-5934

Singapore
200 Middle Road
#07-02 Prime Centre
Singapore, 188980
Tel: 65-6334-8870 Fax: 65-6334-8850

Taiwan
Kaohsiung Branch
30F - 1 No. 8
Min Chuan 2nd Road
Kaohsiung 806, Taiwan
Tel: 886-7-536-4818
Fax: 886-7-536-4803

Taiwan
Taiwan Branch
11F-3, No. 207
Tung Hua North Road
Taipei, 105, Taiwan
Tel: 886-2-2717-7175 Fax: 886-2-2545-0139

EUROPE

Austria
Durisolstrasse 2
A-4600 Wels
Austria
Tel: 43-7242-2244-399
Fax: 43-7242-2244-393

Denmark
Regus Business Centre
Lautrup hoj 1-3
Ballerup DK-2750 Denmark
Tel: 45-4420-9895 Fax: 45-4420-9910

France
Parc d'Activite du Moulin de Massy
43 Rue du Saule Trapu
Batiment A - ler Etage
91300 Massy, France
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany
Steinheilstrasse 10
D-85737 Ismaning, Germany
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Italy
Via Quasimodo, 12
20025 Legnano (MI)
Milan, Italy
Tel: 39-0331-742611
Fax: 39-0331-466781

Netherlands
P. A. De Biesbosch 14
NL-5152 SC Drunen, Netherlands
Tel: 31-416-690399
Fax: 31-416-690340

United Kingdom
505 Eskdale Road
Winnersh Triangle
Wokingham
Berkshire, England RG41 5TU
Tel: 44-118-921-5869
Fax: 44-118-921-5820

07/28/03