A CANopen Stack for PIC18 ECAN™ Microcontrollers

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INTRODUCTION

CANopen is a field bus protocol based on the Controller Area Network (CAN). As the name implies, it is a open network standard accepted throughout the world. While created as a field bus protocol for industrial automation, CANopen finds use in a wide range of other non-industrial applications. There are so many possibilities, in fact, that it is possible to write volumes on specialized uses of the protocol.

Rather than being specific to one narrow application or even one field, we present here a more generalized approach: a generic communication stack based on CANopen that can be tailored to the user's needs. This article focuses only on what is covered in the CAN in Automation (CiA) standard DS-301. In fact, most of the discussion is limited to the predefined areas of the specification, with emphasis on understanding how the code provided with this application note functions and how users might develop an application on the CANopen Stack. To help illustrate this, a simple example application is developed based on the CiA DS-401 specification, *Generic I/O Modules*. The additional code provided is solely for demonstration; thus there is no detailed discussion of the demonstration code. However, code examples with comments from the demo application are frequently used throughout this document.

All code provided with this application note is developed for the PIC18F8680 and PIC18F4680 families of devices, which include ECAN technology as part of their peripheral set. It is designed to compile with Microchip's C18 v2.30 (or greater) compiler. Although developed for these specific device families, the code is adaptable to other PIC18 families with CAN.

It is expected that the reader already has some knowledge of CANopen, or has access to the latest CANopen standard (listed in the References section) to refer to for theory and/or critical terminology. The information covered in this application note leans towards understanding the implementation and developing on that foundation, rather than discussing the many details of CANopen.

OVERVIEW OF THE STACK

The CANopen Stack provides the lower layers of the protocol. Some of the features of this design include:

- Embedded state machine for handling all communications between all nodes and objects
- Default Service Data Object (SDO) Server
- Up to 4 transmit and 4 receive Process Data Objects (TPDOs and RPDOs)
- Explicit and Segmented Messaging Support
- Statically-mapped PDO support
- Structured dictionary for the PDOs and SDO
- Node Guard/Life Guard
- SYNC consumer
- Heartbeat Producer
- ECAN Driver support

As this list shows, the CANopen Stack discussed here is designed for applications that are typically more "slave". This design is more static in nature, which leads to more efficient code with better effective use of code space.

In addition, the actual CANopen code is broken into a series of smaller source and header files, all written in C. This allows users to select the appropriate services that they may need for their application and selectively build a project tailored to their specific requirements. A complete list of source files is presented in Table 1.

Of course, the actual application and some aspects of the communications must still be developed by the user. The provided CANopen Stack code affords a base on which the application may be built.

TABLE 1: CANopen SOURCE FILES

File Name	Description
CO_CANDRV.c CO_CANDRV.h	ECAN module driver. These files may be replaced by other device-specific drivers, if required.
CO_COMM.c CO_COMM.h	Communications management services. Required for all applications.
CO_DEV.c CO_DEV.h	Device specific files. Users must edit this file for their device.
CO_DICT.c CO_DICT.h CO_DICT.def	The object dictionary. Required for all applications.
CO_MAIN.c CO_MAIN.h	CANopen main services. Required for all applications.
CO_MEMIO.c CO_MEMIO.h	Memory copy functions used by the dictionary. Required for all applications.
CO_NMT.c CO_NMT.h	Network management communications endpoint.
CO_NMTE.c CO_NMTE.h	Node Guard, Heartbeat and Boot-up communications endpoint.
CO_PDO.c CO_PDO.h	General PDO services.
CO_PDO1.c CO_PDO1.h CO_PDO2.c CO_PDO2.h CO_PDO3.c CO_PDO3.h CO_PDO4.c CO_PDO4.h	PDO object handling endpoints. Provided in a template format that requires development by the user for the specific application. Must be used with the general PDO services files.
CO_SDO1.c CO_SDO1.h	Default server SDO communications endpoint.
CO_SYNC.c CO_SYNC.h	Consumer synchronization communications endpoint.
CO_TOOLS.c CO_TOOLS.h	Tools for converting Microchip and CANopen CAN identifier formats. For better process performance, all COB IDs are stored internally in the Microchip format. When COB ID is presented due to a request, then the ID is converted to CANopen.
CO_ABERR.h	Common error definitions. Required for all applications.

CANopen FIRMWARE MODEL

The firmware is designed in three levels, as shown in Figure 1. The lowest level is the ECAN driver providing hardware abstracted CAN support. The communications management level is the primary interface between the driver and the individual endpoint handling.

Besides the application, there is also the dictionary. In essence, it resides outside of the communication object, and is directly connected to the SDO endpoint.

The Driver

At the lowest level is the ECAN driver, which serves as an abstracted hardware interface. It is implemented by the source files `CO_CANDRV.c` and `CO_CANDRV.h`.

The driver handles all ECAN hardware related functionality, and conveniently abstracts much of the complex filtering that is part of the CAN protocol. This is discussed in greater detail later in this document.

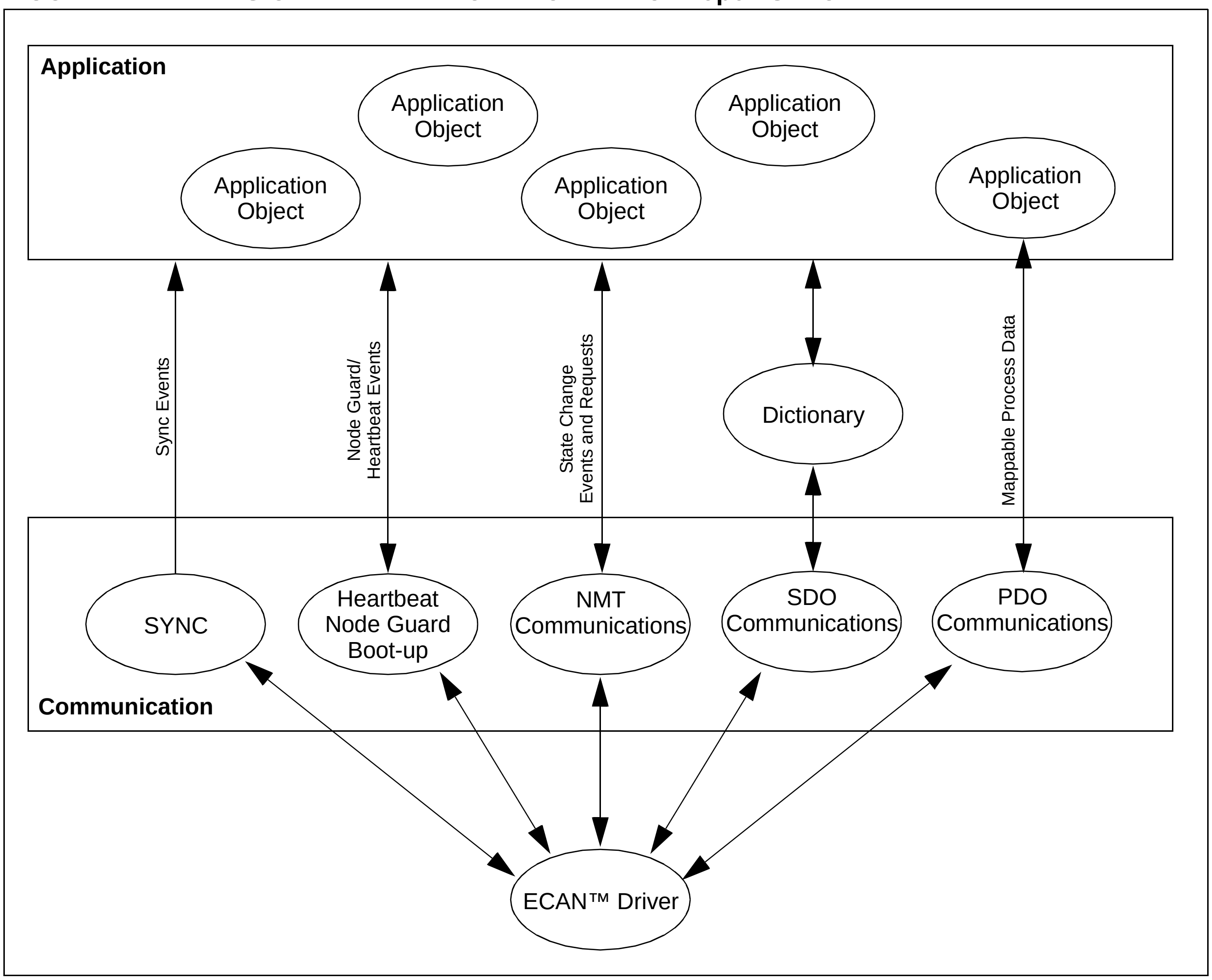
Communications Management

The communications manager is part of the total communications object. It is provided to capture any events from the ECAN driver and the higher application levels, and dispatch these to the appropriate handling communications sub-objects and functions. Essentially, opening, closing, transmitting to, and receiving from an endpoint is all directed by the communications manager. Communications management is provided in the files `CO_COMM.c and CO_COMM.h`.

The manager has knowledge of what state each endpoint is in as well as the state of the device globally. Thus it can block messages to endpoints as necessary based on local or global state.

Another feature of the manager is that it uses a single-byte "handle" method supported by the driver to decode message events. The handle is of a particular structure designed to accelerate performance; it is significantly faster that decoding the 11-bit or 29-bit CAN identifier in order to determine the handling function for a particular message.

FIGURE 1: BASIC FIRMWARE MODEL OF THE CANopen STACK



Endpoints

The CANopen specification defines several possible endpoints. The five endpoint objects listed below are implemented in this example; others may be made available in the future.

- The Default Server SDO
- Up to four Static PDOs
- Synchronization Consumer
- Network Management Slave
- Node Guard or Heartbeat

SERVER SDO COMMUNICATION

The default server SDO (Service Data Object) is provided. The SDO communications path is directly linked to the object dictionary; SDO messages contain information that relates the SDO to a particular object. Data in every message is decoded, validated, and (if valid) eventually executed.

There are essentially two basic operations: read and write. Thus each complete SDO transfer (which may be multiple messages) will either read or write a single object referenced in the dictionary. The default SDO is contained in the source files `CO_SDO1.c` and `CO_SDO1.h`.

PDO COMMUNICATION

The PDO (Process Data Object) communications path is linked directly to the applicable application object or objects. Thus the path is assumed by the device and no path information is contained within the communication. Essentially the data is mapped internally to one or more objects. Data is either statically mapped (compiled) or dynamically mapped (set at runtime). One message can contain data from more than one object.

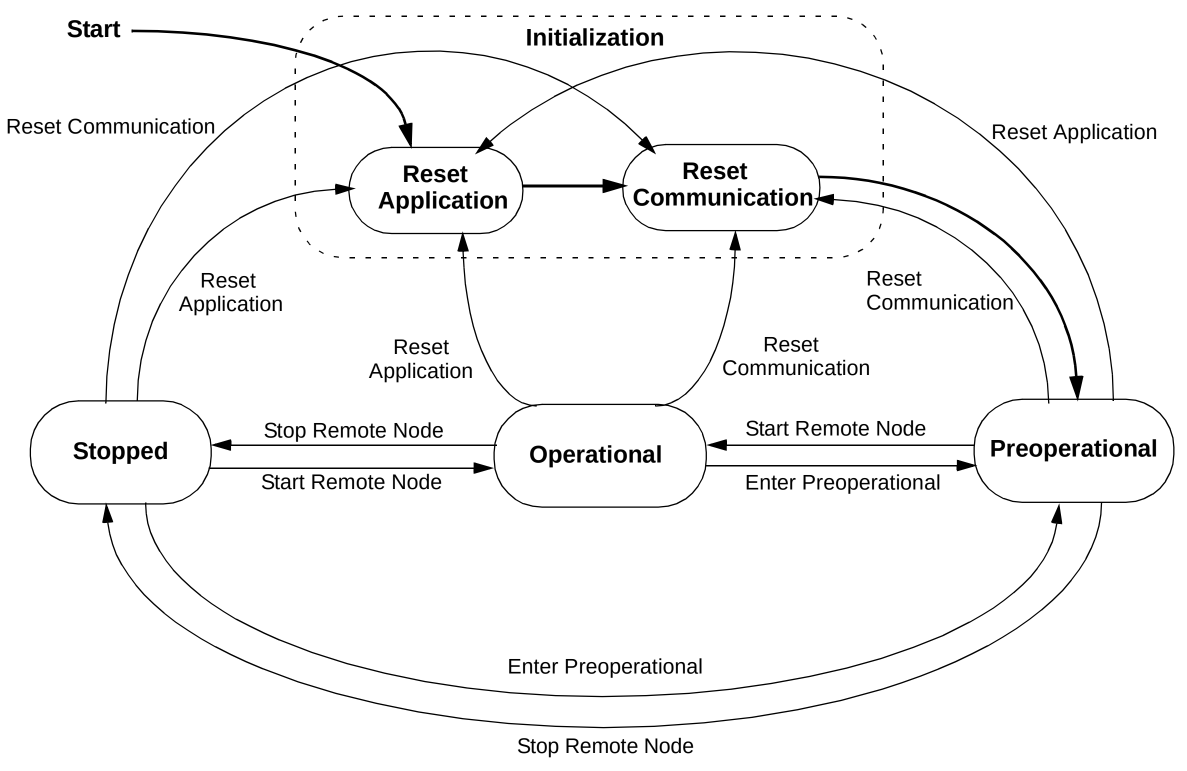
The firmware provided with this application note supports the four default PDOs. Overall PDO services are provided in the source files `CO_PDO.c` and `CO_PDO.h`. The additional files `CO_PDOn.c` and `CO_PDOn.h` (where n may have a value of 1 to 4) are used to implement the individual PDOs. These are provided in template form, and must be developed to meet the application requirements.

NETWORK MANAGEMENT CONSUMER

A Network Management (NMT) slave is provided as required by the specification. The NMT Object receives commands to change the state of the device or reset the device's application and/or communications. Figure 2 shows the CANopen state machine, as well as the commands that trigger state changes.

Network management is provided in the source files `CO_NMT.c` and `CO_NMT.h`.

FIGURE 2: STATE MACHINE FOR A CANopen DEVICE



Note: Unlabeled transitions (shown with darker lines) are automatic and do not require an external event.

NODE GUARD/HEARTBEAT

There is a single Node Guard or Heartbeat endpoint as required by the CANopen specifications. They both exist in code; however, only one of these Watchdog methods are enabled at any given time (also defined in the specifications).

Node Guard and Heartbeat endpoint functionality is provided in the source files `CO_NMTE.c` and `CO_NMTE.h`.

SYNCHRONIZATION CONSUMER

One synchronization consumer (SYNC) is provided. The SYNC message is simply an event to the application to generate any synchronized PDO messages.

The source files `CO_SYNC.c` and `CO_SYNC.h` contain the SYNC object.

The Dictionary

The object dictionary functions as a central information database for the device. Every object within the device is represented within the dictionary by an index, sub-index, and some access information. An object can be as simple as a single byte of data or a more complex data structure. Table 2 shows the basic areas of the dictionary that are defined by index in the CANopen specification.

The development and definition of dictionary objects is discussed in greater detail in **"Objects and the Object Dictionary"** (page 36).

TABLE 2: LOCATION RANGES WITHIN THE OBJECT DICTIONARY

Index	Object
0001-001F	Static Data Type
0020-003F	Complex Data Types
0040-005F	Manufacturer Specific Data Types
0060-007F	Device Profile Static Data Types
0080-009F	Device Profile Complex Data Types
00A0-0FFF	Reserved
1000-1FFF	Communication Profile Area
2000-5FFF	Manufacturer Specific Profile Area
6000-9FFF	Standardized Profile Area
A000-FFFF	Reserved

By using the index, any defined object can be accessed. From the network point of view, access to an object is provided through the SDO or PDO endpoint as shown in Figure 1. CANopen dictionary functionality is implemented with these files:

- `CO_DICT.c`
- `CO_DICT.h`
- `CO_DICT.def`
- `CO_STD.def`
- `CO_MFTR.def`
- `CO_PDO.def`

Standard Device Objects

The standard device objects, although not shown in Figure 1, are required by the specification. The standard objects include information such as status, the device name, serial number, and version information. They are provided in the source files `CO_DEV.c` and `CO_DEV.h`.

Application Objects

At the upper level of the stack is the application object, which must be defined for the specific application and included in the dictionary. The actual objects are defined and written by users for their specific application.

Other Firmware

There are other files provided to define standard data types, define errors, support memory copy functions, and supply COB ID conversion tools. They are:

- `CO_TOOLS.c`
- `CO_TOOLS.h`
- `CO_MEMIO.c`
- `CO_MEMIO.h`
- `CO_ABERR.h`
- `CO_TYPES.h`

COMPILE TIME SETUP

There are a total of 40 compile time options available to configure the source code for a particular application. Most of these are used to configure the factors that control the CAN bit rate (Phase Segment timing, Synchronization Jump Width, baud rate prescaler, etc.). All of the options are listed in Table 3.

Setting Device Information

The CANopen specification identifies a number of objects that identify a particular device. Device specific information is provided through a simple set of data that is referenced from the object dictionary. This information must be included in developing the application. Table 4 lists these objects.

TABLE 3: COMPILE TIME OPTIONS

Name	Description
CAN_BITRATE0_BRGCON1 CAN_BITRATE0_BRGCON2 CAN_BITRATE0_BRGCON3	The default bit rate setting for the application. The BRGCON values correspond to the configurations for that BRGCON registers, and determine all the required parameters for the CAN bit rate. Users should refer to the appropriate data sheet for detailed information on the configuration of these registers.
CAN_BITRATEn_BRGCON1 CAN_BITRATEn_BRGCON2 CAN_BITRATEn_BRGCON3	Bit rate setting n, where n has a valid range of 1 through 8. These are optional settings that may be used in place of the default bit rate. As with the default bit rate, the BRGCON values correspond to the settings for that BRGCON register.
CAN_BITRATEn	Enables the use of bit rate setting n.
CAN_MAX_RCV_ENDP	Sets the maximum allowed receive endpoints within the driver. The recommended value is 8 to support all the receive endpoints within CANopen. It is possible to set this as high as 16.
CO_NUM_OF_PDO	This sets the number of PDOs supported. The valid range is 1 through 4.
CO_SPEED_UP_CODE	Enables some in-line assembly of the user's application code. Execution performance can be improved by setting this option.
CO_SDO1_MAX_RX_BUF	Sets the maximum buffer space used by the default SDO. A good value for this is the largest writable object.
CO_SDO1_MAX_SEG_TIME	Sets the maximum time for the SDO watchdog to wait for a completed segment before resetting the SDO state machine.

TABLE 4: STANDARD DEVICE OBJECTS

Object Name	Description
rom unsigned long rCO_DevType	The device type
rom unsigned char rCO_DevName[]	The name of the device
rom unsigned char rCO_DevHardwareVer[]	The hardware version
rom unsigned char rCO_DevSoftwareVer[]	The software version
rom unsigned char rCO_DevIdentityIndx	The device identity index
rom unsigned long rCO_DevVendorID	The vendor ID
rom unsigned long rCO_DevProductCode	The product code
rom unsigned long rCO_DevRevNo	The revision number
rom unsigned long rCO_DevSerialNo	The device serial number
unsigned char uCO_DevErrReg	The device error register
unsigned long uCO_DevManufacturerStatReg	The manufacturer specific status register

WRITING THE APPLICATION

There is significant work that goes into developing an application and communications according to the CANopen specifications. The firmware provided eliminates some of the effort by providing some of the lower-level communications handling. Aside from the work necessary to develop the application itself, the following items must be developed for the application.

- Define the application objects in the dictionary
- Develop handling for complex objects
- Develop handling functions for the necessary CANopen communications events
- Develop PDOs

This section introduces the “toolbox” provided by the associated firmware. All the event functions and services are described for any application that may need them.

Main Services

The CANopen protocol is started by calling the `mCO_InitAll()` function. This issues a CAN driver Reset and causes the boot-up message to be sent. However, prior to starting the CANopen protocol, the default communications specific parameters must be set to their appropriate state. For example, the node_id and baud rate are critical for proper messaging. Other settings include the Node Guard settings, Heartbeat settings, the device error object, as well as the manufacturer specific status.

Once started, all processing occurs through the functions `mCO_ProcessAllEvents()` and `mCO_ProcessAllTimeEvents()`. The first handles all general communications related processing like sending and receiving CAN messages for each endpoint. The later function handles communication endpoints that have specific time requirements such as the NMTE (Heartbeat/Node Guard) and any PDO endpoint. The `mCO_ProcessAllEvents()` function should be called as often as possible to capture all messaging events from the driver. The `mCO_ProcessAllTimeEvents()` function should be called at 1 ms intervals.

mCO_ProcessAllEvents

This is the main routine from which all events are processed. From this, transmit and receive events are processed within the Communications Manager. This function must be called as often as possible to process any communications events. How often this needs to be called is highly dependent on the driver and the necessity to respond to driver events before overflow.

Syntax

```
void mCO_ProcessAllEvents(void)
```

Parameters

None

Return Values

None

Example

(See following page)

Example

```
void main(void)
{
   // Perform any application specific initialization
      TimerInit();               // Init my timer

   mSYNC_SetCOBID(0x12);      // Set the SYNC COB ID (MCHP format)
   mCO_SetNodeID(0x01);       // Set the node_id
   mCO_SetBaud(0x00);         // Set the baudrate
   mNMTE_SetHeartBeat(0x00);  // Set the initial heartbeat
   mNMTE_SetGuardTime(0x00);  // Set the initial guard time
   mNMTE_SetLifeFactor(0x00); // Set the initial life time
   mCO_InitAll();             // Initialize CANopen to run

   while(1)
   {
      // Process CANopen events
      mCO_ProcessAllEvents();
      // Process application specific functions
      // 1ms timer events
      if (TimerIsOverflowEvent())
      {
         // Process timer related events
         mCO_ProcessAllTimeEvents();

         // Perform other time functions
      }
   }
}
```

`mCO_ProcessAllTimeEvents`

This is the main routine from which all low-resolution time-related events are processed. This function must be called every 1 ms. High-resolution events (typically in the µs region) must be handled in the application. Internally this function ensures that all objects in the stack that require time control get a tick event.

Syntax

```
void mCO_ProcessAllTimeEvents(void)
```

Parameters

None

Return Values

None

Example

Refer to the example provided in `mCO_ProcessAllEvents`.

`mCO_InitAll`

This function must be called after setting up all initial object parameters. It will issue a Reset to the CAN driver and start opening the required communications. Once called, the node will be live on the network and the boot-up message will be sent.

Syntax

```
void mCO_InitAll(void)
```

Parameters

None

Return Values

None

Example

Refer to the example provided in `mCO_ProcessAllEvents`.

`mCO_SetNodeID`

Call this function to set the node_id. node_id must be an unsigned char with the Most Significant bit reserved. In addition, the CANopen specifications reserve the NodeID 00h; valid values for the NodeID range from 01h to 7Fh. This function must be called prior to `mCO_InitAll()` to effectively set the ID.

Syntax

```
void mCO_SetNodeID(unsigned char node_id)
```

Parameters

`unsigned char node_id:` The node_id for this node, valid range from 01h to 7Fh.

Return Values

None

Example

Refer to the example provided in `mCO_ProcessAllEvents`.

`mCO_GetNodeID`

Call this function to get the current ID used by the stack. The ID is returned as an unsigned char.

Syntax

`unsigned char node_id mCO_GetNodeID(void)`

Parameters

None

Return Values

`unsigned char node_id:` The node_id for this node, valid range from 01h to 7Fh.

Example

None

`mCO_SetBaud`

Call this function to set the baud rate of the node. The value must be between 0 and 8 inclusive. Any other value will default to the 0 setting. The exact baud rate is determined by the CAN driver definitions (page 46). This function must be called prior to `mCO_InitAll()` to change the baud rate.

Syntax

`void mCO_SetBaud(unsigned char bitrate)`

Parameters

`unsigned char bitrate`

Return Values

None

Example

Refer to the example provided in `mCO_ProcessAllEvents`.

`mCO_GetBaud`

Call this function to get the current baud rate used by this node. The baud rate is returned as an unsigned char. The exact baud rate is determined by the CAN driver definitions (see **"ECAN™ Driver"**, page 46).

Syntax

`unsigned char mCO_SetBaud(void)`

Parameters

None

Return Values

`unsigned char:` The current bit rate setting used by the node.

Example

Refer to the example provided in `mCO_ProcessAllEvents`.

PDO Events and Services

This section describes the functions used for PDO support. All of these are essentially low-level communications support such as opening, closing, and communicating with specific PDO endpoints. Before discussing these functions, however, a review of how to develop these data objects is in order.

PDO DEVELOPMENT

A critical part of the application design task is developing PDOs. Some decisions have to be made regarding what features to support: choosing between dynamic and static PDO mapping, selecting a Transmission Synchronization mode, and whether or not to support inhibit time. The CANopen Stack source code provided includes a base set of tools to support PDO communication for which such features can be built on.

The critical points for developing PDO support includes developing code to handle these items:

- PDO Communications events
- PDO Mapping
- PDO Synchronization
- PDO Event and Inhibit time

PDO Communications Events

Every enabled PDO will have some communications events to support setting the typical aspects of the PDO. Events are actually call back functions specified in the dictionary to handle specific PDO communications parameters. For example, a master sends a request via an SDO to a slave device to change the type of the PDO (refer to the specifications for information on communication types). The request is passed upwards through the stack to the dictionary and eventually to the function that handles access to the type.

Example 1 and Example 2 demonstrate the link between the dictionary and the actual function `CO_COMM_TPDO1_TypeAccessEvent()`. Example 1 shows the entry in the dictionary. Example 2 shows the actual callback. In this case the example demonstrates support only for types 0 to 240, 254, and 255. (The PDO transmission types are shown in Table 5.) Note that none of the events are discussed in detail since they are created by the application designer and thus, handled by the designer's firmware.

EXAMPLE 1: PDO DICTIONARY ENTRY

```
{0x1800,0x00,CONST,1,{(rom unsigned char *)&uDemoTPDO1Len}},\\
{0x1800,0x01,RW | FUNC,4,{(rom unsigned char *)&CO_COMM_TPDO1_COBIDAccessEvent}},\\
{0x1800,0x02,RW | FUNC,1,{(rom unsigned char *)&CO_COMM_TPDO1_TypeAccessEvent}}
```


EXAMPLE 2: EVENT HANDLER

```
void CO_COMM_TPDO1_TypeAccessEvent(void)
{
    unsigned char tempType;
    switch (mCO_DictGetCmd())
    {
        //case DICT_OBJ_INFO:// Get information about the object
            // The application should use this to load the
            // structure with length, access, and mapping.
        //  break;
        case DICT_OBJ_READ: // Read the object
            // Write the Type to the buffer
            *(uDict.obj->pReqBuf) = uDemoSyncSet;
            break;
        case DICT_OBJ_WRITE: // Write the object
            tempType = *(uDict.obj->pReqBuf);
            if ((tempType >= 0) && (tempType <= 240))
            {
                // Set the new type and resync
                uDemoSyncCount = uDemoSyncSet = tempType;
            }
            else
            if ((tempType == 254) || (tempType == 255))
            {
                uDemoSyncSet = tempType;
            }
            else {mCO_DictSetRet(E_PARAM_RANGE);} //error
            break;
    }
}
```

TABLE 5: PDO TRANSMISSION TYPES

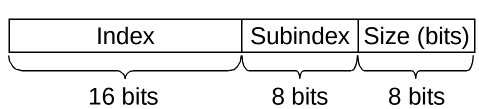
Transmission Type	PDO Transmission Sync Character				
	Cyclic	Acyclic	Synchronous	Asynchronous	Remote Request
0		X	X		
1 through 240	X		X		
241 through 251	Reserved				
252			X		X
253				X	X
254				X	
255				X	

PDO Mapping

PDO mapping can be either static or dynamic. No code is provided specifically for support for either. However, no code is really necessary to represent static mapping. Thus, static code is significantly easier and requires less processing to support. Dynamic PDO mapping is more challenging because it requires referencing the dictionary one or multiple times per PDO. Only static mapping is demonstrated for this version of the CANopen Stack.

Example 3 shows the entry within the dictionary. The actual mapping is just ROM data as shown in Example 4. Any requests through the default SDO to the mapping data in the dictionary will read static data directly from ROM. It is assumed that the static data stored in ROM is of the mapping format specified in the CANopen specifications and described in Figure 3.

FIGURE 3: MAPPING FORMAT FOR ROM DATA



EXAMPLE 3: PDO MAPPING DICTIONARY ENTRY

```
#define    DICTIONARY_PDO1_RX_MAP                                  \\
           {0x1600,0x00,CONST,1,{(rom unsigned char *)&rMaxIndex2}},\\
           {0x1600,0x01,CONST,4,{(rom unsigned char *)&uRPDO1Map}},\\
           {0x1600,0x02,CONST,4,{(rom unsigned char *)&uPDO1Dummy}},\\
           {0x1600,0x03,CONST,4,{(rom unsigned char *)&uPDO1Dummy}},\\
           {0x1600,0x04,CONST,4,{(rom unsigned char *)&uPDO1Dummy}},\\
           {0x1600,0x05,CONST,4,{(rom unsigned char *)&uPDO1Dummy}},\\
           {0x1600,0x06,CONST,4,{(rom unsigned char *)&uPDO1Dummy}},\\
           {0x1600,0x07,CONST,4,{(rom unsigned char *)&uPDO1Dummy}},\\
           {0x1600,0x08,CONST,4,{(rom unsigned char *)&uPDO1Dummy}}
```

EXAMPLE 4: DICTIONARY STRUCTURE

```
rom unsigned long uTPDO1Map = 0x60000108;
rom unsigned long uRPDO1Map = 0x62000108;
rom unsigned long uPDO1Dummy = 0x00000008;
```


Synchronization

PDOs can be synchronized by linking their function to the SYNC object. Synchronization depends on the transmission type. The types defined by the specification are listed in Table 5.

Synchronization is simply a matter of using the `CO_COMMSyncEvent()` function to handle the PDO endpoint. This is discussed in more detail in the section on sync events (page 27).

Timers

The event timer is supported while the inhibit timer is left up to the application designer to provide. This is primarily due to the fine time resolution required (100 µs). If the application requires the event timer, it is possible to handle the `CO_PDO1LSTimerEvent()` to get 1 ms tick events.

mRPDOOpen

Open the RPDO endpoint where n represents the PDO number. There are only 4 PDOs available. Typically this function would be called within a RPDO communications object write event. Essentially a PDO communications object write event is generated when a node on the network is requesting to start PDO communications.

Syntax

```
void mRPDOOpen(const unsigned char PDOnum)
```

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.

Return Values

None

Example

(See following page)

Example

```
// Process access events to the COB ID
void CO_COMM_RPDO1_COBIDAccessEvent(void)
{
    switch (mCO_DictGetCmd())
    {
        case DICT_OBJ_READ: // Read the object
            // Translate MCHP COB to CANopen COB
            mTOOLS_MCHP2CO(mRPDOGetCOB(1));

            // Return the COBID
            *(unsigned long *)(uDict.obj->pReqBuf) = mTOOLS_GetCOBID();
            break;

        case DICT_OBJ_WRITE: // Write the object
            // Translate the COB to MCHP format
            mTOOLS_CO2MCHP(*(unsigned long *)(uDict.obj->pReqBuf));

            // If the request is to stop the PDO
            if ((*(UNSIGNED32 *)(&mTOOLS_GetCOBID())).PDO_DIS)
            {
                // And if the COB received matches the stored COB and type then close
                if (!((mTOOLS_GetCOBID() ^ mRPDOGetCOB(1)) & 0xFFFFEFFF))
                {
                    // but only close if the PDO endpoint was open
                    if (mRPDOIsOpen(1)) {mRPDOClose(1);}

                    // Indicate to the local object that this PDO is disabled
                    (*(UNSIGNED32 *)(&mRPDOGetCOB(1))).PDO_DIS = 1;
                }
                else {mCO_DictSetRet(E_PARAM_RANGE);} //error
            }

            // Else if the RPDO is not open then start the RPDO
            else
            {
                // And if the COB received matches the stored COB and type then open
                if (!((mTOOLS_GetCOBID() ^ mRPDOGetCOB(1)) & 0xFFFFEFFF))
                {
                    // but only open if the PDO endpoint was closed
                    if (!mRPDOIsOpen(1)) {mRPDOOpen(1);}

                    // Indicate to the local object that this PDO is enabled
                    (*(UNSIGNED32 *)(&mRPDOGetCOB(1))).PDO_DIS = 0;
                }
                else {mCO_DictSetRet(E_PARAM_RANGE);} //error
            }
            break;
    }
}
```

mRPDOIsOpen

Query to determine if the RPDO is open. Typically this should be called within a PDO communications object event.

Syntax

`BOOL mRPDOIsOpen(const unsigned char PDOnum)`

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.

Return Values

`TRUE`: The RPDO is open and accepting messages.

`FALSE`: The RPDO is closed and will not accept messages.

Example

Refer to the example provided in `mRPDOOpen`.

mRPDOClose

Close the RPDO endpoint. Typically this should be called within a PDO communications object event.

Syntax

`void mRPDOClose(const unsigned char PDOnum)`

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.

Return Values

None

Example

Refer to the example provided in `mRPDOOpen`.

mRPDOIsGetRdy

This function queries the Communications Manager for any new received PDOs where n represents the PDO number.

Syntax

`BOOL mRPDOnIsGetRdy(const unsigned char PDOnum)`

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.

Return Values

`TRUE:` Data has been received and is ready to be processed.

`FALSE:` No data is available yet.

Example

(See following page)

Example

```
void DemoProcessEvents(void)
{
   unsigned char change;
   unsigned char rise;
   unsigned char fall;

   // Read the input port
   (*(UNSIGNED8 *)uLocalXmtBuffer).bits.b0 = PORTBbits.RB5;
   (*(UNSIGNED8 *)uLocalXmtBuffer).bits.b1 = PORTBbits.RB4;

   // Determine the change if any
   change = uIOinDigiInOld ^ uLocalXmtBuffer[0];
      // Determine if there were any rise events
   rise = (uIOinIntRise & change) & uLocalXmtBuffer[0];
      // Determine if there were any fall events
   fall = (uIOinIntFall & change) & ~uLocalXmtBuffer[0];
   // Determine if there were any change events
   change = (uIOinIntChange & change);
   // Cycle the current value to the old
   uIOinDigiInOld = uLocalXmtBuffer[0];
   // If any of these are true then indicate an interrupt condition
   if (uIOinIntEnable & (change | rise | fall)) uDemoState.bits.b1 = 1;

   if (uDemoState.bits.b1)
   {
      switch (uDemoSyncSet)
      {
         case 0:      // Acyclic synchronous transmit
            // Set a synchronous transmit flag
            uDemoState.bits.b2 = 1;
            break;
         case 254: // Asynchronous transmit
         case 255:
            // Reset the asynchronous transmit flag
            uDemoState.bits.b0 = 1;
            break;
      }
   }
   // If ready to send
   if (mTPDOIsPutRdy(1) && uDemoState.bits.b0)
   {
      // Tell the stack that data is loaded for transmit
      mTPDOWritten(1);

      // Reset any synchronous or asynchronous flags
      uDemoState.bits.b0 = 0;
      uDemoState.bits.b1 = 0;
   }
   // If any data has been received
   if (mRPDOIsGetRdy(1))
   {
      // Write out the first byte of the buffer
      LATD = uLocalRcvBuffer[0];

      // PDO read, free the driver to accept more data
      mRPDORead(1);
   }
}
```

mRPDORead

This function is called to indicate to the Communications Manager that the last message it received has been read and processed as necessary. This allows the Communications Manager to accept another PDO message from the driver. The application could simply copy the data or even process the data in-line.

Syntax

```
void mRPDORead(const unsigned char PDOnum)
```

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.

Return Values

None

Example

Refer to the example provided in `mRPDOIsGetRdy()`.

mRPDOSetCOB

This function sets the RPDO COB ID, where n represents the PDO number (valid range from 1 to 4). This could be set prior to opening the PDO. The COB ID must be in the Microchip standard format.

Syntax

```
void mRPDOSetCOB(const unsigned char PDOnum, unsigned long rpdoCOB)
```

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.
`unsigned long rpdoCOB:` The COB ID received by this PDO.

Return Values

None

Example

(See following page)

Example

```
void DemoInit(void)
{
   // Port D is all output
   LATD = 0;
   TRISD = 0;

   uDemoSyncSet = 255;

   uIOinFilter = 0;
   uIOinPolarity = 0;
   uIOinIntChange = 1;
   uIOinIntRise = 0;
   uIOinIntFall = 0;
   uIOinIntEnable = 1;

   uIOinDigiInOld = uLocalXmtBuffer[0] = 0;
   uLocalRcvBuffer[1] = uLocalXmtBuffer[1] = 0;
   uLocalRcvBuffer[2] = uLocalXmtBuffer[2] = 0;
   uLocalRcvBuffer[3] = uLocalXmtBuffer[3] = 0;
   uLocalRcvBuffer[4] = uLocalXmtBuffer[4] = 0;
   uLocalRcvBuffer[5] = uLocalXmtBuffer[5] = 0;
   uLocalRcvBuffer[6] = uLocalXmtBuffer[6] = 0;
   uLocalRcvBuffer[7] = uLocalXmtBuffer[7] = 0;


   // Convert to MCHP
   mTOOLS_CO2MCHP(mCOMM_GetNodeID().byte + 0xC0000180L);

   // Store the COB
   mTPDOSetCOB(1, mTOOLS_GetCOBID());

   // Convert to MCHP
   mTOOLS_CO2MCHP(mCOMM_GetNodeID().byte + 0xC0000200L);

   // Store the COB
   mRPDOSetCOB(1, mTOOLS_GetCOBID());

   // Set the pointer to the buffers
   mTPDOSetTxPtr(1, (unsigned char *)(&uLocalXmtBuffer[0]));

   // Set the pointer to the buffers
   mRPDOSetRxPtr(1, (unsigned char *)(&uLocalRcvBuffer[0]));

   // Set the length
   mTPDOSetLen(1, 8);
}
```

`mRPDOGetCOB`

This function gets the RPDO COB ID currently used.

Syntax

`unsigned long mRPDOGetCOB(const unsigned char PDOnum)`

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.

Return Values

`unsigned long:` The COB ID received by this PDO.

Example

Refer to the example provided in `mRPDOOpen`.

`mRPDOGetLen`

This function gets the length of the last received PDO.

Syntax

`unsigned char mRPDOGetLen(const unsigned char PDOnum)`

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.

Return Values

`unsigned char:` The length of the message, valid values from 0 to 8 bytes.

Example

None

`mRPDOGetRxPtr`

This function gets the stored pointer to the local receive buffer. The pointer must be set prior to opening communications to the endpoint. When communications is open all messages will be stored in the location referenced by this pointer.

Syntax

`unsigned char * mRPDOGetRxPtr(const unsigned char PDOnum)`

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.
`unsigned char *pRXBUF`

Return Values

`unsigned char *`: Pointer to the buffer space

Example

None

mRPDOSetRxPtr

This function sets the pointer to the local receive buffer. The pointer must be set prior to opening communications to the endpoint. When communications are open all messages will be stored in the location referenced by this pointer.

Syntax

```
void mRPDOSetRxPtr(const unsigned char PDOnum, unsigned char *pRXBUF)
```

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.
`unsigned char *pRXBUF`

Return Values

None

Example

Refer to the example provided in `mRPDOSetCOB()`.

mTPDOOpen

Open the TPDO endpoint. There are only four PDOs available. Typically this should be called within a TPDO communications object write event. Essentially a PDO communications object write event is generated when a node on the network is requesting to start PDO communications.

Syntax

```
void mTPDOnOpen(const unsigned char PDOnum)
```

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.

Return Values

None

Example

(See following page)

Example

```
// Process access events to the COB ID
void CO_COMM_TPDO1_COBIDAccessEvent(void)
{
    switch (mCO_DictGetCmd())
    {
        case DICT_OBJ_READ: // Read the object
            // Translate MCHP COB to CANopen COB
            mTOOLS_MCHP2CO(mTPDOGetCOB(1));

            // Return the COBID
            *(unsigned long *)(uDict.obj->pReqBuf) = mTOOLS_GetCOBID();
            break;

        case DICT_OBJ_WRITE: // Write the object
            // Translate the COB to MCHP format
            mTOOLS_CO2MCHP(*(unsigned long *)(uDict.obj->pReqBuf));

            // If the request is to stop the PDO
            if ((*(UNSIGNED32 *)(&mTOOLS_GetCOBID())).PDO_DIS)
            {
                // And if the COB received matches the stored COB and type then close
                if (!((mTOOLS_GetCOBID() ^ mTPDOGetCOB(1)) & 0xFFFFEFFF))
                {
                    // but only close if the PDO endpoint was open
                    if (mTPDOIsOpen(1)) {mTPDOClose(1);}

                    // Indicate to the local object that this PDO is disabled
                    (*(UNSIGNED32 *)(&mTPDOGetCOB(1))).PDO_DIS = 1;
                }
                else {mCO_DictSetRet(E_PARAM_RANGE);} //error
            }

            // Else if the TPDO is not open then start the TPDO
            else
            {
                // And if the COB received matches the stored COB and type then open
                if (!((mTOOLS_GetCOBID() ^ mTPDOGetCOB(1)) & 0xFFFFEFFF))
                {
                    // but only open if the PDO endpoint was closed
                    if (!mTPDOIsOpen(1)) {mTPDOOpen(1);}

                    // Indicate to the local object that this PDO is enabled
                    (*(UNSIGNED32 *)(&mTPDOGetCOB(1))).PDO_DIS = 0;
                }
                else {mCO_DictSetRet(E_PARAM_RANGE);} //error
            }
            break;
    }
}
```

mTPDOIsOpen

Query to determine if the TPDO is open. Typically this should be called within a PDO communications object event.

Syntax

`BOOL mTPDOIsOpen(const unsigned char PDOnum)`

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.

Return Values

`TRUE:` The Communications Manager is ready to accept new data.

`FALSE:` The Communications Manager is busy transmitting the previous message.

Example

Refer to the example provided in `mTPDOOpen()`.

mTPDOClose

Close the TPDO endpoint where n represents the PDO number (valid range from 1 to 4). Typically this should be called within a PDO communications object event.

Syntax

`void mTPDOClose(const unsigned char PDOnum)`

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.

Return Values

None

Example

Refer to the example provided in `mTPDOOpen()`.

mTPDOIsPutRdy

This function queries the Communications Manager for an available slot for transmitting a PDO. This function will return true if the manager is ready to accept a message to send on the bus.

Syntax

`BOOL mTPDOIsPutRdy(const unsigned char PDOnum)`

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.

Return Values

`TRUE`: The Communications Manager is ready to accept new data.

`FALSE:` The Communications Manager is busy transmitting the previous message.

Example

Refer to the example provided in `mRPDOIsGetRdy()`.

mTPDOWritten

Indicates to the Communications Manager that a message has been loaded for the manager to send. This allows the Communications Manager to queue the message for transmission. The `CO_PDOTXFinEvent()` event function is called when the message is placed on the bus.

Syntax

`void mTPDOWritten(const unsigned char PDOnum)`

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.

Return Values

None

Example

Refer to the example provided in `mRPDOIsGetRdy()`.

mTPDOSetCOB

This function sets the TPDO COB ID. This should be set prior to sending a TPDO. The COB ID must be in the Microchip standard format.

Syntax

`void mTPDOSetCOB(const unsigned char PDOnum, unsigned long tpdoCOB)`

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.

`unsigned long tpdoCOB:` The COB ID to be sent.

Return Values

None

Example

Refer to the example provided in `mRPDOSetCOB()`.

mTPDOGetCOB

This function gets the TPDO COB ID currently used.

Syntax

`unsigned long mTPDOnGetCOB(const unsigned char PDOnum)`

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.

Return Values

`unsigned long:` The COB ID currently used by this PDO.

Example

Refer to the example provided in `mRPDOSetCOB()`.

mTPDOSetLen

This function sets the TPDO data length. The length must be between 0 and 8.

Syntax

```
unsigned long mTPDOnSetLen(const unsigned char PDOnum, unsigned char length)
```

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.

`unsigned char length:` The length of the PDO, must be from 0 to 8 bytes.

Return Values

None

Example

Refer to the example provided in `mRPDOSetCOB()`.

mTPDOGetTxPtr

This function gets the pointer currently pointing to the local transmit buffer. When transmitting, all messages will be transmitted from the location referenced by this pointer.

Syntax

```
unsigned char * mTPDOGetTxPtr(const unsigned char PDOnum)
```

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.

Return Values

`unsigned char *`: Returns the currently used pointer to the buffer

Example

None

mTPDOnSetTxPtr

This function sets the pointer to the local transmit buffer. When transmitting, all messages will be transmitted from the location referenced by this pointer.

Syntax

```
void mTPDOnSetTxPtr(const unsigned char PDOnum)
```

Parameters

`const unsigned char PDOnum:` Valid range of 1 to 4. Must be an actual number, not a macro.

Return Values

None

Example

Refer to the example provided in `mRPDOIsGetRdy()`.

CO_PDOnLSTimerEvent

This is the timer event callback function. This function is called every 1 ms if the PDO is enabled. Typically the application could use this for the PDO event timer function specified in CANopen.

Syntax

`void CO_PDOnLSTimerEvent(void)`

Parameters

None

Return Values

None

Example

None

CO_PDOnTXFinEvent

This is the transmit finished event callback function. This event is generated when a message that was queued to transmit has been placed on the CAN.

Syntax

`void CO_PDOnTxFinEvent(void)`

Parameters

None

Return Values

None

Example

None

SYNC Events and Services

There is only one event that is received from the SYNC object; it is the `CO_COMMSyncEvent()`. This event is generated only when a SYNC message is received, and it is used for synchronized PDO processing. This event should be handled in the application's PDO message processing.

There are only two services useful for SYNC object support. The most important part is to set the COB ID for the SYNC object before initializing the CANopen communications since the endpoint is automatically opened upon initialization.

CO_COMMSyncEvent

This is the only event that is generated from the SYNC object. This event is generated only when a SYNC message is received, and it is used for synchronized PDO processing. This event should be handled in the application's PDO message processing.

Syntax

```
void CO_COMMSyncEvent(void)
```

Parameters

None

Return Values

None

Example

This is a simple example of a handling function for a variable synchronous PDO Type that is cyclic in nature. This is defined by a PDO Type (TPDO communications parameter at subindex 2) that is between 1 and 240 inclusive.

```
void CO_COMMSyncEvent(void)
{
    // Process only if in a synchronous mode
    if ((uDemoSyncSet == 0) && (uDemoState.bits.b2))
    {
        // Reset the synchronous transmit and transfer to async
        uDemoState.bits.b2 = 0;
        uDemoState.bits.b0 = 1;
    }
    else
    if ((uDemoSyncSet >= 1) && (uDemoSyncSet <= 240))
    {
        // Adjust the sync counter
        uDemoSyncCount--;

        // If time to generate sync
        if (uDemoSyncCount == 0)
        {
            // Reset the sync counter
            uDemoSyncCount = uDemoSyncSet;

            // Start the PDO transmission
            uDemoState.bits.b0 = 1;
        }
    }
}
```

mSYNC_SetCOBID

This function is used to set the COB ID for the SYNC object. This should be called at least once before initializing to properly set the COB ID within the firmware.

Syntax

```
void mSYNC_SetCOBID(unsigned long SYNC_COB)
```

Parameters

The COB ID in the Microchip format.

`unsigned long SYNC_COB`

Return Values

None

Example

Refer to the example provided in `mCO_ProcessAllEvents`.

mSYNC_GetCOBID

This function is used to get the COB ID currently used for the SYNC object.

Syntax

```
unsigned long mSYNC_GetCOBID(void)
```

Parameters

None

Return Values

`unsigned long SYNC_COB:` The COB ID in the Microchip format.

Example

None

Network Management Events and Services

Network management is provided through the NMT object, which essentially encompasses the node state machine (see Figure 2).

There are a handful of services provided to enter the node into a particular state. However, the state will change through normal network management requests from the NMT master. When a state is changed due to a request from the master, then an event is generated. All the events and services are listed below.

mNMT_Start

Call this function to start communications that have been stopped. Typically this is automatically called by the NMT managing routines as a result of a NMT request from the master to set the appropriate state.

Syntax

```
void mNMT_Start(void)
```

Parameters

None

Return Values

None

Example

None

mNMT_Stop

Call this function to stop a node that was in the operational or preoperational state. Typically this is automatically called by the NMT managing routines as a result of a NMT request from the master to set the appropriate state.

Syntax

```
void mNMT_Stop(void)
```

Parameters

None

Return Values

None

Example

None

`mNMT_GotoPreopState`

Call this function to place the node into the preoperational state. Typically this is automatically called by the NMT managing routines as a result of an NMT request from the master to set the appropriate state.

Syntax

`void mNMT_GotoPreopState(void)`

Parameters

None

Return Values

None

Example

None

`mNMT_GotoOperState`

Call this function to place the node into the operational state. Typically this is automatically called by the NMT managing routines as a result of an NMT request from the master to set the appropriate state.

Syntax

`void mNMT_GotoOperState(void)`

Parameters

None

Return Values

None

Example

None

`mNMT_StateIsStopped`

Query to determine if the node is currently in a stopped state.

Syntax

`BOOL mNMT_StateIsStopped(void)`

Parameters

None

Return Values

`TRUE`: If node is in STOPPED state.

`FALSE:` If node is in PREOPERATIONAL or OPERATIONAL state.

Example

None

`mNMT_StateIsOperational`

Query to determine if the node is currently in the operational state.

Syntax

```
BOOL mNMT_StateIsOperational(void)
```

Parameters

None

Return Values

`TRUE:` If node is in OPERATIONAL state.

`FALSE:` If node is STOPPED or PREOPERATIONAL state.

Example

None

`mNMT_StateIsPreOperational`

Query to determine if the node is currently in the operational state.

Syntax

```
BOOL mNMT_StateIsPreOperational(void)
```

Parameters

None

Return Values

`TRUE:` If node is in PREOPERATIONAL state.

`FALSE:` If node is in STOPPED or OPERATIONAL state.

Example

None

`CO_NMTStateChangeEvent`

This callback function is called when the state of the system has been changed through Network Management Request.

Syntax

```
void CO_NMTStateChangeEvent(void)
```

Parameters

None

Return Values

None

Example

None

CO_NMTResetEvent

This callback function is called when a communications Reset has been requested. The communications is automatically reset after this event is handled.

Syntax

`void CO_NMTStateChangeEvent(void)`

Parameters

None

Return Values

None

Example

None

CO_NMTAppResetRequest

This callback function is called when an application Reset has been requested. How this event is handled depends on the application design. After handling this event the `CO_COMMResetEvent()` event will be generated. The communications are automatically reset after the `CO_COMMResetEvent()` event is handled.

Syntax

`void CO_NMTAppResetRequest(void)`

Parameters

None

Return Values

None

Example

None

Node Guard/Heartbeat Events and Services

A combined Node Guard/Heartbeat object is provided as required by the specification. There are a small number of services provided to initialize and get information about the object.

There is only one possible event generated by the Node Guard/Heartbeat object, which relates specifically to the node guard half of the object. The `CO_NMTENodeGuardErrEvent()` function is called when the lifetime of the object has been exceeded. The lifetime is defined in the specification as the product of the lifetime factor and the guard time.

mNMTE_SetHeartBeat

Call this function to set the Heartbeat. The Heartbeat is an unsigned long in the format specified by the CANopen specifications. This should be set prior to initializing communications.

Syntax

```
void mNMTE_SetHeartBeat(unsigned long HeartBeat)
```

Parameters

`unsigned long HeartBeat`

Return Values

None

Example

None

mNMTE_GetHeartBeat

Use this function to return the current Heartbeat setting. An unsigned long is returned.

Syntax

```
unsigned long mNMTE_GetHeartBeat(void)
```

Parameters

None

Return Values

`unsigned long HeartBeat`

Example

None

mNMTE_SetGuardTime

Call this function to set the guard time. The guard time is an unsigned long in the format specified by the CANopen specifications. This should be set prior to initializing communications.

Syntax

```
void mNMTE_SetGuardTime(unsigned long GuardTime)
```

Parameters

None

Return Values

None

Example

None

mNMTE_GetGuardTime

Use this function to return the current guard time setting. An unsigned long is returned.

Syntax

```
unsigned long mNMTE_GetGuardTime(void)
```

Parameters

None

Return Values

`unsigned long GuardTime`

Example

None

mNMTE_SetLifeFactor

Use this function to return the current guard time setting. An unsigned long is returned.

Syntax

```
void mNMTE_SetLifeFactor(unsigned char LifeFactor)
```

Parameters

None

Return Values

None

Example

None

mNMTE_GetLifeFactor

Use this function to return the current guard time setting. An unsigned char long is returned.

Syntax

`unsigned char mNMTE_GetLifeFactor(void)`

Parameters

None

Return Values

`unsigned char LifeFactor`

Example

None

CO_NMTENodeGuardErrEvent

This callback function is called when there is a node guard event. A node guard event occurs when a node guard message is not received within the defined lifetime (the product of life time factor and guard time). How this event is handled is dependent on the application.

Syntax

`void CO_NMTENodeGuardErrEvent(void)`

Parameters

None

Return Values

None

Example

None

Objects and the Object Dictionary

In this design each dictionary entry is a structure within program memory. Within each structure is the necessary information to identify the object and its location. The identity is flexible enough that more than simple data types, arrays, and structures can be defined as objects. A function can be defined as an object as well, and this is where the true flexibility lies for complex objects.

THE OBJECT STRUCTURE

An object defined in the Object Dictionary is stored in program memory; its structure is shown in Example 5. This structure contains enough information to describe any object.

- index: the index of the object
- subindex: the subindex of the object
- ctl: the control byte. This defines the type of object.
- len: the length of the object in bytes.
- *pROM: a pointer to the object or object handling function. The pointer should always be cast to rom unsigned char *.

EXAMPLE 5: DICTIONARY STRUCTURE

```
typedef struct _DICTIONARY_OBJECT_TEMPLATE
{
    unsigned int index;
    unsigned char subindex;
    unsigned char ctl;
    unsigned int len;
    rom unsigned char * pROM;
}DICT_OBJECT_TEMPLATE;
```

OBJECT GROUPS

The Object Dictionary is broken into groups for faster dictionary searching. Thus every entry within the Object Dictionary must be stored within the appropriate group. Table 6 identifies all the groups. Any entries in the dictionary should be placed in numerical order within the appropriate group.

OBJECT CONTROL BITS

How an object is handled within the dictionary depends on its control bits. An object could be read/write, read only, or even functionally defined to accommodate very unique objects. Table 7 defines the bits of the object control byte.

To easily manipulate individual bits within the control byte, a series of symbolic bit modifiers have been provided. Table 8 provides the logical AND modifiers to control the object. These can be combined manually to form a specific control. For example, the following statement defines an object that is readable, writable, defined as a function, and mappable:

```
RD & WR & N_ROM & N_EE & FDEF & MAP &
N_FSUB
```

In a similar fashion, Table 9 provides the typical logical OR modifier definitions to control the object. These can also be combined with the bit names shown in Table 8. For example, the following statement defines an object that is readable, writable, defined as a function, and mappable (same as previous):

```
RW | FUNC | MAP_BIT
```

Several examples of the usage of bit modifiers are shown in Example 6, in entries 4, 8, 9 and 10.

EXAMPLE 6: DICTIONARY OBJECT ENTRY EXAMPLE

```
#define DICTIONARY_DEVICE_INFO                                                              \\
        {0x1000,0x00,CONST,4,{(rom unsigned char *)&rCO_DevType}},                          \\
        {0x1001,0x00,RO,1,{(rom unsigned char *)&uCO_DevErrReg}},                           \\
        {0x1002,0x00,RO,4,{(rom unsigned char *)&uCO_DevManufacturerStatReg}},              \\
        {0x1005,0x00,FUNC | RW,4,{(rom unsigned char *)&_CO_COMM_SYNC_COBIDAccessEvent}},   \\
        {0x1008,0x00,CONST,24,{(rom unsigned char *)&rCO_DevName}},                         \\
        {0x1009,0x00,CONST,4,{(rom unsigned char *)&rCO_DevHardwareVer}},                   \\
        {0x100A,0x00,CONST,4,{(rom unsigned char *)&rCO_DevSoftwareVer}},                   \\
        {0x100C,0x00,FUNC | RW,2,{(rom unsigned char *)&_CO_COMM_NMTE_GuardTimeAccessEvent}}, \\
        {0x100D,0x00,FUNC | RW,1,{(rom unsigned char *)&_CO_COMM_NMTE_LifeFactorAccessEvent}} \\
        {0x1017,0x00,FUNC | RW,2,{(rom unsigned char *)&_CO_COMM_NMTE_HeartBeatAccessEvent}}, \\
        {0x1018,0x00,CONST,1,{(rom unsigned char *)&rCO_DevIdentityIndx}},                  \\
        {0x1018,0x01,CONST,4,{(rom unsigned char *)&rCO_DevVendorID}},                      \\
        {0x1018,0x02,CONST,4,{(rom unsigned char *)&rCO_DevProductCode}},                   \\
        {0x1018,0x03,CONST,4,{(rom unsigned char *)&rCO_DevRevNo}},                         \\
        {0x1018,0x04,CONST,4,{(rom unsigned char *)&rCO_DevSerialNo}}
```

TABLE 6: OBJECT GROUPS

Object Group Name	Index	Description
DICTIONARY_DATA_TYPES	0000h	Data types defined in the object dictionary. Although data types are defined within the object dictionary, the specification indicates that support is not required.
DICTIONARY_DEVICE_INFO	1000h	This group is within the CANopen communications section and contains the device specific information including COBIDs, certain endpoints, and status.
DICTIONARY_SDO	1200h	One group for SDO parameters is provided.
DICTIONARY_PDO1_RX_COMM	1400h	Individual groups are provided for four RPDO communications parameters.
DICTIONARY_PDO2_RX_COMM	1401h	
DICTIONARY_PDO3_RX_COMM	1402h	
DICTIONARY_PDO4_RX_COMM	1403h	
DICTIONARY_PDO1_RX_MAP	1600h	Individual groups are provided for four RPDO mapping parameters.
DICTIONARY_PDO2_RX_MAP	1601h	
DICTIONARY_PDO3_RX_MAP	1602h	
DICTIONARY_PDO4_RX_MAP	1603h	
DICTIONARY_PDO1_TX_COMM	1800h	Individual groups are provided for four TPDO communications parameters.
DICTIONARY_PDO2_TX_COMM	1801h	
DICTIONARY_PDO3_TX_COMM	1802h	
DICTIONARY_PDO4_TX_COMM	1803h	
DICTIONARY_PDO1_TX_MAP	1A00h	Individual groups are provided for four TPDO mapping parameters.
DICTIONARY_PDO2_TX_MAP	1A01h	
DICTIONARY_PDO3_TX_MAP	1A02h	
DICTIONARY_PDO4_TX_MAP	1A03h	
DICTIONARY_MANUFACTURER_SPECIFIC_1	2000h	These groups are provided for manufacturer specific objects.
DICTIONARY_MANUFACTURER_SPECIFIC_2	3000h	
DICTIONARY_MANUFACTURER_SPECIFIC_3	4000h	
DICTIONARY_MANUFACTURER_SPECIFIC_4	5000h	
DICTIONARY_STANDARD_1	6000h	These groups are provided for CANopen standard objects.
DICTIONARY_STANDARD_2	7000h	
DICTIONARY_STANDARD_3	8000h	
DICTIONARY_STANDARD_4	9000h	

TABLE 7: CONTROL BIT DEFINITIONS

Bits	Name	Description
Bit 0	RD_BIT	This bit defines the read access of the object. If this bit is set then the object is readable from a node on the network.
Bit 1	WR_BIT	This bit defines the write access of the object. If this bit is set then the object is writable by a node on the network.
Bit 2	ROM_BIT	This bit defines an object that is located within ROM. Setting this bit does not imply the object cannot be written. This only defines the location where this bit is stored.
Bit 3	EE_BIT	This bit defines an object that is located in EEPROM. Note, no automatic handling is provided at this time for EEPROM. If the EE_BIT is set then the FDEF_BIT should also be set so the dictionary access tools know that the application designer is handling access to EEDATA memory through a custom function.
Bit 4	FDEF_BIT	This bit defines an object that is functionally defined. Typically objects are defined by a function if they have special rules that cannot be defined by a single static type. For example, an object that triggers an event when read should be functionally defined. Or if an object can change read-write access level based on application dependent events or states should also be functionally defined. Also note, if this bit is set then all other bits can be defined within the object handling function, except the FSUB_BIT.
Bit 5	MAP_BIT	This bit defines the mappability of the object. Thus if this bit is set then the object can be mapped into a PDO.
Bit 6	FSUB_BIT	This bit defines whether the entire subindex array is functionally defined. Thus for a particular index there will be only one entry in the dictionary. And all requests to access any subindex are handled by the object’s access handling function. This is useful for objects where all of the subindices have the same functionality but require different parameter values; therefore, only one entry is required in the dictionary file.
Bit 7	reserved	reserved at this time

TABLE 8: LOGIC AND BIT DEFINITIONS

Bits	Description
RD	Allow read
N_RD	Read not allowed
WR	Write allowed
N_WR	Write not allowed
ROM	ROM based object
N_ROM	Not a ROM based object
EE	EEDATA based object
N_EE	Not an EEDATA based object
FDEF	Functionally defined object
N_FDEF	Not a functionally defined object
MAP	Mappable object
N_MAP	Not a mappable object
FSUB	Functionally defined subindex
N_FSUB	Not a functionally defined subindex

TABLE 9: LOGIC OR BIT DEFINITIONS

Bits	Description
CONST	ROM based read-only object
RW	Readable and writable object
RO	Read-only object
WO	Write-only object
RW_EE	Readable and writable EEDATA object
RO_EE	Read-only object in EEDATA
WO_EE	Write-only object in EEDATA
FUNC	Functionally defined object

SIMPLE OBJECTS

The dictionary provides support for simple objects. Simple objects are essentially objects that operate within the realm of a normal data type. This includes any data type supported by the compiler as well as arrays.

A simple object is defined in the object dictionary by referencing the object within the dictionary. This is illustrated by the first dictionary entry in Example 7. A read request to this object will return the data stored in `uCO_DevManufacturerStatReg`; a write request will return an error, since this is a read-only object.

FUNCTIONALLY DEFINED OBJECT

Objects are defined by a function when the object has some properties that do not follow a standard data type or array defined in the C language. For example, a variable unsigned char `MyObj` that has no unusual conditions does not need to be defined by a function; however, if in `MyObj` bit 7 enables the write to `MyObj`, then this would require special handling and must be defined by a function, similar to COB IDs.

An object is defined by a function when the FDEF_BIT is set in its control byte. This is demonstrated with the second dictionary entry in Example 7, which defines the COB ID for the SYNC object. In this case, the function `_CO_COMM_SYNC_COBIDAccessEvent()` is called when there is a request to access the object at index 1005h, subindex 0x00.

WRITING AN OBJECT HANDLING FUNCTION

An object is referenced through an SDO, PDO, or through some application access. If the object is defined by a function then the function defined in the dictionary will be called when the object is referenced. There are three possible events that the object handling function can handle when referenced:

- Read control: Read the control bits defined by the function. This applies to all bits except the FSUB_BIT and FDEF_BIT bits; these bits must be defined for the object within the dictionary.
- Read: Read the object if it is readable.
- Write: Write the object if it is writable.

Example 8 demonstrates what a typical handling function looks like. Example 9 is an example of a handler for the TPDO1 COB ID object.

An object handling function is provided with functions and a structure to process requests to or from. The functions are `mCO_DictGetCmd()` and `mCO_DictSetRet()`. The first is used to retrieve the command, and the second is used to return any errors to the requestor. Table 11 lists the errors that can be returned. In the case of a successful request, then no response is necessary; the dictionary assumes success.

The requestor will set a pointer in the dictionary (`uDict.obj`) to its local DICT_OBJ structure. This structure contains information about the object as well as the requestor. The structure is defined in Table 8. Example 8 demonstrates usage of the structure with an object handling function.

EXAMPLE 7: EXAMPLES OF OBJECT DEFINITIONS

Simple Object Definition:
```
{0x1002,0x00,RO,4,{(rom unsigned char *)&uCO_DevManufacturerStatReg}}
```

Functionally Defined Object:
```
{0x1005,0x00,FUNC | RW,4,{(rom unsigned char *)&_CO_COMM_SYNC_COBIDAccessEvent}
```

TABLE 10: DICT_OBJ UDICT STRUCTURE

Element	Type	Description
`pReqBuf`	unsigned char *	Pointer to the requestor's buffer. This is the pointer to the requestor's data when writing an object. When reading, this is the pointer to the requestor's buffer space.
`reqLen`	unsigned int	Number of bytes requested. This should never exceed the length of the object.
`reqOffst`	unsigned int	Starting point for the request. This is provided to support partial requests due to low buffer space. This is most useful for read requests; for write requests this would be unlikely since partially writing an object is not always desirable. Also, this parameter does not need to be supported if the number of bytes in the object is less than 8.
`index`	unsigned int	CANopen Index.
`subindex`	unsigned char	CANopen subindex.
`ctl`	enum DICT_CTL	Memory access type.
`len`	unsigned int	Size of the object in bytes.
`p`	union DICT_PTRS	Pointers to objects.

TABLE 11: ERROR DEFINITIONS

Name	Description
E_SUCCESS	Success, no error
E_TOGGLE	Toggle bit not alternated
E_SDO_TIME	SDO protocol timed out
E_CS_CMD	Client/server command specifier not valid or unknown
E_MEMORY_OUT	Out of memory
E_UNSUPP_ACCESS	Unsupported access to object
E_CANNOT_READ	Attempt to read a write only object
E_CANNOT_WRITE	Attempt to write a read-only object
E_OBJ_NOT_FOUND	Object does not exist in the object dictionary
E_OBJ_CANNOT_MAP	Object cannot be mapped to the PDO
E_OBJ_MAP_LEN	The number and length of the objects to be mapped would exceed PDO length
E_GEN_PARAM_COMP	General parameter incompatibility
E_GEN_INTERNAL_COMP	General internal incompatibility in the device
E_HARDWARE	Access failure due to a hardware error
E_LEN_SERVICE	Data type does not match, length of service parameter does not match
E_LEN_SERVICE_HIGH	Data type does not match, length of service parameter too high
E_LEN_SERVICE_LOW	Data type does not match, length of service parameter too low
E_SUBINDEX_NOT_FOUND	Subindex does not exist
E_PARAM_RANGE	Value range of parameter exceeded (only for write access)
E_PARAM_HIGH	Value of parameter too high
E_PARAM_LOW	Value of parameter too low
E_MAX_LT_MIN	Maximum value is less than minimum value
E_GENERAL	General error
E_TRANSFER	Data cannot be transferred or stored to the application
E_LOCAL_CONTROL	Data cannot be transferred or stored to the application because of local control
E_DEV_STATE	Data cannot be transferred or stored to the application because of the present device state

EXAMPLE 8: FUNCTIONAL OBJECT HANDLING

```
void MyObjectHandlingFunction(void)
{
    switch (mCO_DictGetCmd())
    {
        case DICT_OBJ_INFO:// Get information about the object
            // Code in this request type should modify the type of access. For
            // example, if the object can change from RO to RW based on a particular
            // state of the application then this would be handled here. In most
            // situations this can be omited since the object info is static;
            // static information is supported directly by the dictionary.
        break;
        case DICT_OBJ_READ: // Read the object
            // This is the object read request. Code in this request type should
            // handle any data movement and/or events based on the Read.
        break;
        case DICT_OBJ_WRITE: // Write the object
            // This is the object write request. Code in this request type should
            // handle any data movement and/or events based on the Write.
        break;
    }
}
```

EXAMPLE 9: FUNCTIONAL OBJECT HANDLING EXAMPLE

```
void CO_COMM_TPDO1_COBIDAccessEvent(void)
{
    switch (mCO_DictGetCmd())
    {
        case DICT_OBJ_READ: // Read the object
            // Translate MCHP COB to CANopen COB
            mTOOLS_MCHP2CO(mTPDOGetCOB(1));

            // Return the COBID
            *(unsigned long *)(uDict.obj->pReqBuf) = mTOOLS_GetCOBID();
            break;

        case DICT_OBJ_WRITE: // Write the object
            // Translate the COB to MCHP format
            mTOOLS_CO2MCHP(*(unsigned long *)(uDict.obj->pReqBuf));

            // If the request is to stop the PDO
            if ((*(UNSIGNED32 *)(&mTOOLS_GetCOBID())).PDO_DIS)
            {
                // And if the COB received matches the stored COB and type then close
                if (!((mTOOLS_GetCOBID() ^ mTPDOGetCOB(1)) & 0xFFFFEFFF))
                {
                    // but only close if the PDO endpoint was open
                    if (mTPDOIsOpen(1)) {mTPDOClose(1);}

                    // Indicate to the local object that this PDO is disabled
                    (*(UNSIGNED32 *)(&mTPDOGetCOB(1))).PDO_DIS = 1;
                }
                else {mCO_DictSetRet(E_PARAM_RANGE);} //error
            }

            // Else if the TPDO is not open then start the TPDO
            else
            {
                // And if the COB received matches the stored COB and type then open
                if (!((mTOOLS_GetCOBID() ^ mTPDOGetCOB(1)) & 0xFFFFEFFF))
                {
                    // but only open if the PDO endpoint was closed
                    if (!mTPDOIsOpen(1)) {mTPDOOpen(1);}

                    // Indicate to the local object that this PDO is enabled
                    (*(UNSIGNED32 *)(&mTPDOGetCOB(1))).PDO_DIS = 0;
                }
                else {mCO_DictSetRet(E_PARAM_RANGE);} //error
            }
            break;
    }
}
```

DICTIONARY SERVICES

There are several services for dictionary management available for use by the SDO endpoint. If necessary, they may also be used for dynamic PDO mapping.

mCO_DictObjectRead

This function reads the object defined by myObj. To use this, the object information must be stored locally as a DICT_OBJ structure then passed to the mCO_DictObjectRead() function. Internally only the reference is used.

Within the DICT_OBJ structure is the information necessary for receiving data from the object. Some of this information must be provided by the calling function and other information must be provided by the dictionary. The mCO_DictObjectDecode() function must be called prior to calling mCO_DictObjectRead() to get the access and reference information stored in the dictionary. Other information must be provided by the user. The following table describes the structure and the source of information for each element.

TABLE 12: DICT_OBJ STRUCTURE

Element	Type	Provided by	Description
pReqBuf	unsigned char *	User	Pointer to the requestors buffer
reqLen	unsigned int	User	Number of bytes requested
reqOffst	unsigned int	User	Starting point for the request
index	unsigned int	User	CANopen Index
subindex	unsigned char	User	CANopen subindex
ctl	enum DICT_CTL	mCO_DictObjectDecode()	Memory access type
len	unsigned int	mCO_DictObjectDecode()	Size of the object in bytes
p	union DICT_PTRS	mCO_DictObjectDecode()	Pointers to objects

Syntax

```
void mCO_DictObjectRead(DICT_OBJ myObj)
```

Parameters

```
DICT_OBJ myObj
```

Return Values

None. Use mCO_DictGetRet() to retrieve the error code.

Example

```
void MyFunc(void)
{
   DICT_OBJ myLocalObj;
   unsigned char localArray[20];
   // Specify the object
   myLocalObj.index = 0x1008L;
   myLocalObj.subindex = 0x00;
   // Get the information stored in the dictionary
   mCO_DictObjectDecode(myLocalObj);
   // Specify the local space and what data to read
   myLocalObj.pReqBuf = localArray;
   myLocalObj.reqLen = 0x8;
   myLocalObj.reqOffst = 0x0;
   // Read the object
   mCO_DictObjectRead(myLocalObj);
}
```

mCO_DictObjectWrite

This function writes the object defined by myObj. To use this, the object information must be stored locally as a DICT_OBJ structure then passed to the mCO_DictObjectWrite() function. Internally only the reference is used.

Syntax

```
void mCO_DictObjectWrite(DICT_OBJ myObj)
```

Parameters

DICT_OBJ myObj: The object structure shown in Table 12.

Return Values

None. Use mCO_DictGetRet() to retrieve the error code.

Example

The basic usage is similar to the example given for mCO_DictObjectRead() (page 43).

mCO_DictObjectDecode

This function is used to fill in any static information for a particular object that resides within the dictionary. An object defined by myObj must be declared locally and passed to the function. The function will take the index and sub index information and search for it within the dictionary. If the object is found then a pointer, length, and some control information will be loaded within the myObj structure; refer to Table 12. Status information is returned and can be retrieved with the mCO_DictGetRet() function.

Syntax

```
void mCO_DictObjectDecode(DICT_OBJ myObj)
```

Parameters

DICT_OBJ myObj: The object structure shown in Table 12.

Return Values

None. Use mCO_DictGetRet() to retrieve the error code.

Example

The basic usage is similar to the example given for mCO_DictObjectRead() (page 43).

`mCO_DictGetCmd`

This function is used to retrieve the command for an object. There are only three commands: `DICT_OBJ_INFO`, `DICT_OBJ_READ`, and `DICT_OBJ_WRITE`.

Syntax

```
enum _DICT_OBJECT_REQUEST mCO_DictGetCmd(void)
```

Parameters

None

Return Values

`DICT_OBJ_INFO`: Read object control information.

`DICT_OBJ_READ`: Read the object.

`DICT_OBJ_WRITE`: Write the object.

Example

Refer to the code in Example 9 (page 42).

`mCO_DictGetRet`

This function is used to get the return status of a dictionary operation.

Syntax

```
unsigned char mCO_DictGetRet(void)
```

Parameters

None

Return Values

All the possible errors are listed in Table 11 (page 40).

Example

None

`mCO_DictSetRet`

This function is used to set the return status of a dictionary operation. This is only used within an object handling function.

Syntax

```
void mCO_DictSetRet(unsigned char retVal)
```

Parameters

`unsigned char retVal`: The return status of the object request. All the possible errors are listed in Table 11 (page 40).

Return Values

None

Example

Refer to the code in Example 9 (page 42).

ECAN™ DRIVER

The functions in this section describe the functional interface of the ECAN driver. Note that the driver provided with the CANopen Stack has been specifically designed for PIC18F devices with ECAN technology. It is also possible to use an external CAN controller, and therefore a different driver with different function calls. In this event, the user will need to provide an appropriate driver.

`mCANEventManager`

This is an event handling function. All queued events are processed from within this function. This function is called within the CANopen Stack when `CO_ProcessAllEvents` is called.

Syntax

```
void mCANEventManager(void)
```

Parameters

None

Return Values

None

Example

None

`mCANReset`

This function resets CAN communications and sets the appropriate bit rate. This function is called from within the CANopen Stack when a Reset request is received either from the application or the NMT master.

Syntax

```
void mCANReset(unsigned char CANBitRate)
```

Parameters

None

Return Values

None

Example

None.

`mCANOpenComm`

This function opens CAN communications. This function should be treated as a request. Depending on the bus activity, communications may not be opened immediately.

Syntax

```
void mCANOpenComm(void)
```

Parameters

None

Return Values

None

Example

None

mCANCloseComm

This function closes CAN communications.

Syntax

```
void mCANCloseComm(void)
```

Parameters

None

Return Values

None

Example

None

mCANIsCommOpen

This function can be used to query the driver to determine if communications are opened or closed.

Syntax

```
BOOL mCANIsCommOpen(void)
```

Parameters

None

Return Values

`TRUE`: Communications are opened.

`FALSE`: Communications are closed.

Example

None.

mCANErrIsOverFlow

This function is used to query the driver for a receive buffer overflow condition. If an overflow condition is found then the condition can be removed by calling the `mCANErrClearOverFlow` function. When an overflow condition has happened one or more messages have been lost. How this is handled depends on the application; the specification does not require a particular method for handling this condition.

Syntax

```
void mCANErrIsOverFlow(void)
```

Parameters

None

Return Values

`TRUE`: A receive buffer has overflowed.

`FALSE`: A receive buffer has not overflowed.

Example

None

mCANErrClearOverFlow

Remove the receive buffer overflow condition.

Syntax

`void mCANErrClearOverFlow(void)`

Parameters

None

Return Values

None

Example

None

mCANSetBitRate

This function sets the current bit rate. The bit rate is not changed immediately; it is actually queued in the driver until the driver and CAN hardware are ready to accept a change. Typically this is only called once at start-up.

Syntax

`void mCANSetBitRate(unsigned char CANBitRate)`

Parameters

`unsigned char CANBitRate`: This can be any value; however, only values 0 through 8 are considered valid. All other values will automatically default to the bit rate identified by option 0. All 9 options are defined in the file `CO_DEFS.DEF`.

Return Values

None

Example

None

mCANGetBitRate

This function returns the current bit rate used by the driver.

Syntax

`unsigned char mCANGetBitRate(void)`

Parameters

None

Return Values

unsigned char: The current bit rate. Only values 0 through 8 are valid; however, the function may return other values if `mCANSetBitRate()` was passed a value other than the valid values.

Example

None

`mCANOpenMessage`

This function scans the available mailbox space for an open slot. The CAN identifier must be passed in along with a unique non-zero handle to that identifier. If a slot is found then all messages containing the provided CAN identifier will be received and the handle will be used to identify the message. The handle will also be returned to the caller if found; otherwise, the return will be zero. The calling function must maintain the handle if the endpoint is to be released at a later time without a Reset.

The CAN identifier is added but not activated until the bus and the driver are ready. In future CAN modules this queuing functionality may be removed, depending on available hardware support.

Syntax

```
void mCANOpenMessage(unsigned char MsgTyp, unsigned long COBID, unsigned char hRet)
```

Parameters

`unsigned char MsgTyp:` The unique handle to the identifier. It must be non-zero.

`unsigned long COBID:` The CAN identifier of the message to be allowed.

Return Values

`unsigned char hRet:`The return status. This will be either 0 or the handle.

Example

None

`mCANCloseMessage`

This function scans the mailbox space for the handle. If found, the CAN identifier is removed from the receive list.

The CAN identifier is only queued to be removed from the list. Thus messages may still be received until the driver can fully remove the CAN identifier from the hardware. In future CAN modules this queuing functionality may be removed depending on hardware support.

Syntax

```
void mCANCloseMessage(unsigned char hMsg)
```

Parameters

`unsigned char hMsg`: The handle to the message.

Return Values

None

Example

None

mCANIsGetRTR

This function queries the driver for the RTR condition of the current message. The function `mCANIsGetReady` should be called prior to this request to set the current message.

Syntax

```
void mCANIsGetRTR(void)
```

Parameters

None

Return Values

None

Example

None

mCANIsGetReady

This function scans for a receive event. If found, it places a handle associated to the receive buffer into an internal register which can be accessed by `mCANFetchRetStat`. Otherwise, it returns zero. If a valid message is waiting, it should be processed prior to calling the function again.

Buffer access on successive receive related calls is assumed, i.e., the handle is not required for associated read functions. For example, calls to `mCANGetDataLen()` and `mCANGetDataByten()` functions assume the most current received message data is being requested.

Syntax

```
void mCANIsGetReady(void)
```

Parameters

None

Return Values

None

Example

None

mCANReadMessage

Calling this function indicates to the driver that the current message has been processed, and the driver is now free to use the buffer for a new message. The function `mCANIsGetReady` should have been called prior to this request to set the current message.

Syntax

```
void mCANReadMessage(void)
```

Parameters

None

Return Values

None

Example

None

`mCANGetPtrRxCOB`

This function retrieves the pointer to the current identifier. It also points to the whole message stored in Microchip format.

Syntax

`unsigned char * mCANGetPtrRxCOB(void)`

Parameters

None

Return Values

`unsigned char *:` Returns a pointer to the received CAN identifier.

Example

None

`mCANGetPtrRxData`

This function retrieves the pointer to the current data.

Syntax

`unsigned char * mCANGetPtrRxData(void)`

Parameters

None

Return Values

`unsigned char *`: Returns a pointer to the received data.

Example

None

`mCANGetDataLen`

This function retrieves the length of the current message or RTR request.

Syntax

`unsigned char mCANGetDataLen(void)`

Parameters

None

Return Values

`unsigned char:` Length of message or RTR request.

Example

None

mCANGetDataByten

This represents a total of eight functions, where the trailing `n` can represents values from 0 to 7. Each will return the corresponding data byte of the message received.

Syntax

`unsigned char mCANGetDataByten(void)`

Parameters

None

Return Values

`unsigned char`: The data byte.

Example

None

mCANIsPutReady

This function scans for an available output buffer. If successful, the handle passed is the same as the handle returned; otherwise a zero is returned. The function `mCANFetchRetStat` must be called to get the return value.

Syntax

`void mCANIsPutReady(putHndl)`

Parameters

`unsigned char putHndl`: The handle of the message.

Return Values

None

Example

None

mCANIsPutFin

This function queries the driver for any message that has been placed on the bus and returns the handle to the message that was sent. The function `mCANFetchRetStat` must be used to get the handle to the message.

This function should only be called one time for a transmit indication. Calling this function a second time after receiving an indication may not return the same handle.

Syntax

`void mCANIsPutFin(void)`

Parameters

None

Return Values

None

Example

None

mCANSendMessage

This function is used to indicate to the driver that the data, length, and CAN identifier have been loaded and are ready to be sent.

Syntax

`void mCANSendMessage(void)`

Parameters

None

Return Values

None

Example

None

mCANGetPtrTxCOB

This function gets the pointer to the transmit CAN identifier buffer.

Syntax

`unsigned char * mCANGetPtrTxCOB(void)`

Parameters

None

Return Values

`unsigned char *`: The pointer to the CAN identifier transmit buffer.

Example

None

mCANGetPtrTxData

This function gets the pointer to the transmit data buffer.

Syntax

`unsigned char * mCANGetPtrTxData(void)`

Parameters

None

Return Values

`unsigned char *`: A pointer to the data transmit buffer.

Example

None

mCANPutDataLen

This function sets the data length or the RTR request length.

Syntax

```
void mCANPutDataLen(unsigned char CANlen)
```

Parameters

`unsigned char CANlen`: The length or the RTR request length of the message.

Return Values

None

Example

None

mCANPutDataByten

This represents a total of eight functions, where the trailing `n` represents values from 0 to 7. Each can be used to set the corresponding byte to be sent.

Syntax

```
void mCANPutDataByten(unsigned char CANDat)
```

Parameters

`unsigned char CANDat`: Data byte.

Return Values

None

Example

None

mCANFetchRetStat

This function is used to get the status of a function that returns status. The functions that return status are noted.

Syntax

```
unsigned char mCANFetchRetStat(void)
```

Parameters

None

Return Values

`unsigned char`: The status of the last operation.

Example

None

FINISHING THE APPLICATION

Of course there are still some CAN specific details that need to be handled. Here are some points to remember:

- Objects: Define and develop all objects and handling functions and link them to the dictionary. Objects that are defined by a function require of course extra coding because of the handling function; however, these types of objects are highly flexible.
- Dictionary: Place all objects within their proper place within the dictionary. Properly define the control, length, and the reference information for the objects.
- PDOs: These still must be defined and developed. Remember that PDOs can be static or dynamic; static methods will always be code and process-efficient but are obviously not flexible like dynamic PDOs. There are also a number of PDO transmission types that depend on the specific application. For these reasons, only a base set of tools are provided so the designer can develop the most efficient code for the application.
- Timing: Provide a time base by using one of the timers or some external time source.
- Initialization: Develop proper initialization code. Many objects need to be initialized from some static source such as ROM, EEPROM, or even switches connected to input pins.
- Main Processing: Develop efficient cooperative design practices in order to properly capture and handle all events.
- Events: There are numerous events. Ensure proper handling is in place where necessary. For example, Reset requests from the network are provided as events to the application. It is left up to the application designer to decide how to handle a Reset request.
- Compile Time Setup: Set up the appropriate compile time options to achieve optimal resource usage and efficiency.

RESOURCE USAGE

Device resources used by the stack are highly dependent on the compile time options, as well as compiler optimizations. The application designer should expect the stack to consume about 7000 to 10,000 bytes of program memory and 300 bytes of data memory with optimization.

Using all of the optimizations available in the MPLAB® C18 Compiler (v2.30.01), the demonstration application provided with this application note requires 7434 bytes of program memory and 314 bytes of data memory.

CONCLUSION

Developing a CANopen device can be an arduous task. By using the CANopen Stack and its tools, a good portion of the work is already accomplished by removing much of the CANopen and CAN specific communications management. This allows the applications designer to focus a much greater percentage of his or her effort on the application, and less on the specifics of CANopen.

REFERENCES

DS-301 (v 4.02), "*CANopen Communication Profile for Industrial Systems Based on CAL*". Erlangen: CAN in Automation e.V., 2002.

M. Farsi and M. Barbosa, *CAN Implementation: Applications to Industrial Networks.* Baldock, Hertfordshire: Research Studies Press, 2000.

APPENDIX A: SOFTWARE DISCUSSED IN THIS APPLICATION NOTE

Because of the number of individual modules and their size, a complete source code listing of the CANopen Stack is not provided here. Interested users are invited to download the.zip archive file, including all source and header files, from the Microchip corporate web site at:

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