Local Interconnect Network (LIN) Demonstration

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1 Introduction

This application note describes a LIN demo that was designed for the SAE show in March 2000. The project was intended to demonstrate the LIN protocol, tools and Motorola products that were available. Although the demo is purely visual and does not represent any particular application, it does introduce many features that would be implemented in actual applications, such as CAN-LIN gateway, sleep mode, messaging scheme, LIN drivers and LIN tools. The hardware was designed to be flexible and can easily be configured to drive many real applications.

An introduction to the LIN protocol and general description of the demo is presented first, followed by a detailed description of the hardware and software, including schematics and flow diagrams. All code listings are included in the Appendix.

2 Local Interconnect Network Bus (LIN)

The LIN bus is an inexpensive serial communications protocol, which effectively supports remote application within a car’s network. It is particularly intended for mechatronic nodes in distributed automotive applications, but is equally suited to industrial applications. It is intended to complement the existing CAN network leading to hierarchical networks within cars. The protocol’s main features are listed below:

- Single master, multiple slave (i.e. no bus arbitration)
• Single wire communications up to 20Kbit/s
• Guaranteed latency times
• Variable length of data frame (2, 4 and 8 byte)
• Configuration flexibility
• Multi-cast reception with time synchronization, without crystals or ceramic resonators.
• Data checksum and error detection
• Detection of defect nodes
• Low cost silicon implementation based on standard UART/SCI hardware
• Enabler for hierarchical networks

Data is transferred across the bus in fixed form messages of selectable lengths. The master task transmits a header that consists of a break signal followed by synchronization and identifier fields. The slaves respond with a data frame that consists of between 2, 4 and 8 data bytes plus 3 bytes of control information. Figure 1 shows the communication concept of message transfer and the message format.

Figure 1  LIN Message frame
The master controls all bus traffic on the network. The master initiates communication by transmitting a header frame with synchronization and identifier information. Any slave, including the slave task in the master control unit, can respond with a data frame. Only one slave can respond to each identifier. However, any number of slaves can be configured to recognize a particular identifier driven on the bus. The master control unit can transfer data to any number of slaves through its slave task. i.e. the master’s slave task responds to a header (sent by the master) and transmits data on to the bus. All other slaves can simultaneously receive the data frame.

2.1 Header Frame

The header frame consists of 3 main parts: a SYNCH BREAK signal, a SYNCH FIELD and an IDENTIFIER. The SYNCH BREAK is used to identify the beginning of a message frame and allow the slaves to synchronise to the master’s bus clock. It is a unique signal that has 2 parts: a Dominant SYNCH BREAK that is longer than any regular dominant bit stream, and a synchronisation delimiter that is required to enable the detection of the start bit of the following SYNCH FIELD. Figure 2 shows the SYNCH BREAK field.

![Figure 2 SYNCH BREAK field](image)

The timing specification for the SYNCH_BREAK field is dependent on the tolerance of the slave node’s clock source. The master is always required to transmit a dominant $T_{\text{SYNBRK}}$ signal, that is a minimum 13 bits, measured in the master’s time base. The slave detects a break signal if it is dominant for longer than any regular bit stream. If the slave’s clock source has a tolerance lower than $\pm 15\%$ ($F_{\text{TOL_UNSYNCH}}$) the SYNCH BREAK THRESHOLD is 11 bit times (number of dominant bits required to be recognised as a SYNCH BREAK FIELD) measured in the slave’s time base. If the clock source’s tolerance is less than $\pm 2\%$ ($F_{\text{TOL_SYNCH}}$) the threshold is reduced to 9 dominant bits.

The second part of the header is the SYNCH FIELD that contains the pattern 0x55 to allow the slave to synchronize with the master. This
allows low cost microcontrollers with internal RC oscillators to be used in slave nodes.

**NOTE:** Internal oscillators have a low tolerance that requires to be trimmed (actively changed) if reliable communication is to be maintained.

The final part of the header is the IDENTIFIER FIELD that denotes the content and length of a message. The content is represented by 6 identifier bits and 2 parity bits. Identifier bits ID4 and ID5 specify the number of data fields in a message. Figure 3 shows the identifier field.

The parity information is calculated using a mixed parity algorithm that prevents all bits being recessive or dominant.

### 2.2 Response Frame

The response frame is always transmitted by the slave task (this can be the slave in the master). It consists between 2, 4 or 8 data fields and a checksum field. The data fields consist of 8 bits of data transmitted LSB first. The checksum contains an inverted modulo 256 sum over all data bytes.

### 2.3 Sleep Mode Frame

A reserved Sleep Mode Frame with a fixed 0x80 identifier was specified in the original version of the LIN specification. In version 1.2 or later the Sleep Mode Frame has been removed and replaced by reserved identifiers, which are described in section 2.4. However, as the demo software was developed to the original specification it uses the fixed identifier 0x80 as the Sleep Mode Frame.

**NOTE:** Any slave node can bring the bus out of sleep mode (by transmitting the WAKE_UP signal). However, it is only the master that is allowed to put the network to sleep.

Refer to LIN specifications for further details.
2.4 Reserved Identifiers

Version 2.1 of the LIN specification contains reserved identifiers; Command frame identifiers and Extended frame identifiers.

2.4.1 Command Frame Identifiers

Two COMMAND FRAME IDENTIFIERS have been reserved to broadcast general command requests from master to all bus participants. The frame structure is identical to regular 8-byte message frames with the following reserved IDENTIFIER FIELDS:

- 0x3C – Download frame
- 0x7D – Upload frame

The download frame is used to send commands and data from master to the slave nodes. The upload frame is used to trigger one of the slave nodes (being addressed by a prior download frame) to send data to the master.

Additionally, command frames with their first byte containing 0x00 to 0x7F are reserved for specific use by the LIN consortium. The remaining frames are free to be assigned by the user.

2.4.2 Sleep Mode Command

The SLEEP MODE COMMAND is used to broadcast the sleep mode to all bus nodes. The SLEEP MODE COMMAND is a download COMMAND FRAME with the first data byte set to 0x00.

2.4.3 Extended Frame Identifier

Two EXTENDED FRAME IDENTIFIERS have been reserved to allow the embedding of user defined message formats and for future expansion without violating the specification. The frame structure is identical to regular 8-byte message frames with the following reserved IDENTIFIER FIELDS:

- 0xFE – User defined extended frame
- 0xBF – Future LIN extension

The identifier can be followed by an arbitrary number of LIN BYTE FIELDS. The frame length, communication concept and data content are not specified. Also, the length coding within the ID field does not apply to the EXTENDED frame identifiers.
3 SAE Demo Description

The LIN Demo consists of a single master node and twelve slave nodes mounted on a ‘clock face’ (see Figure 4 for details). The master controls all slave nodes. It schedules messages that flash the slave’s LEDs in a predetermined sequence. In addition, on a request from the master, each slave node responds with a status messages. The status returned is the value of 2 HEX switches mounted on the slave hardware. The value can be changed, in real time, and monitored on the LIN and CAN buses.

The demo has several modes of operation that are described below. Each mode is selected by a CAN message or by a switch on the master node, when operated in standalone mode. Finally, the master node can be removed and the demo can be driven using a VCT LINspector configured in emulation mode.

![Figure 4 Clock Face Hardware](image-url)
NOTE: The LINspector is a cost effective LIN tool that can be used in a variety of situations, including development, testing and verification. It is driven from a LIN configuration description file, which contains all details of the network. It can be used to monitor all traffic, provide detailed timing information and advanced triggering functions. Additionally, it enables basic and advanced emulation features that allow the user to ‘replace’ any number of nodes on the network. Refer to VCT’s web page for more details. The URL is http://www.vct.se

3.1 Demo Configuration:

3.1.1 Standard: Software on master node used to control the demo. VCT LINspector used to monitor all bus activity. CAN node used to activate different demo modes and display status messages.

3.1.2 Standalone: Software on master node used to control the demo. VCT LINspector used to monitor bus activity. HEX switches on master used to select modes

3.1.3 Emulator: VCT LINspector used to control the demo and display all bus activity.

3.2 Modes of operation:

3.2.1 Default Mode: In this mode, the master sequentially transmits messages to the slave nodes that control their LEDs. The slaves respond with the settings of their HEX switches. The switch settings are translated to a CAN message and transmitted onto the CAN bus. If a slave node is removed a NO_NODE code (0x00) is transmitted on to the CAN bus

3.2.2 Broadcast Mode: In this mode, the master periodically transmits a messages that each slave node simultaneously receives. The transmitted messages switch on the slave’s LEDs. The master node controls the LED pattern.
3.2.3 Ident Mode: This mode is primarily used to set-up the demo. The master transmits a broadcast message that each slave node receives. On reception of this message, the slaves output their IDs to the LEDs.

3.2.4 Sleep Mode: This is the demo’s low power mode. The master transmits a sleep command that signals to the slaves to enter sleep mode by disabling their voltage regulators. The master also enters sleep mode once the sleep command has been successfully transmitted. Any slave can wake-up the demo by pressing the red buttons around the perimeter of the ‘clock face’. The slave node that is woken up wakes up the entire network by transmitting a wake-up sequence on the LIN bus.

The LIN physical interface (MC33399) supports wake-up from the bus and from an external source. On the detection of a valid wake-up signal, the physical interface drives its inhibit output signal low, enabling an external voltage regulator (if this feature is used). Alternatively, the inhibit output can be used to drive the IRQ of the microcontroller. Refer to MC33399 data sheet for specific application details.

3.3 LIN Messaging Scheme

A simple data driven messaging scheme was used to control the demo. Each slave node is statically configured to recognize 3 LIN message identifiers. These are a NodeX_Write, a NodeX_Read and a Broadcast message, where X denotes the node number. This allows the master to transmit commands and data to individual nodes and for each node to transmit status responses back to the master. The broadcast message identifier is common to each slave node. It allows the master to transmit data to all the nodes simultaneously. Table 1 lists the messages that were used for the demo.

<table>
<thead>
<tr>
<th>Message Name</th>
<th>Message ID (LIN ID)</th>
<th>Slave Response Source</th>
<th>Slave Response Destination</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Node1_Write</td>
<td>LINMsg01 (0xC1)</td>
<td>Master</td>
<td>Slave_ID 1</td>
<td>Master transmits node1 control command</td>
</tr>
<tr>
<td>Node2_Write</td>
<td>LINMsg02 (0x42)</td>
<td>Master</td>
<td>Slave_ID 2</td>
<td>Master transmits node2 control command</td>
</tr>
<tr>
<td>Node3_Write</td>
<td>LINMsg03 (0x03)</td>
<td>Master</td>
<td>Slave_ID 3</td>
<td>Master transmits node3 control command</td>
</tr>
<tr>
<td>Node4_Write</td>
<td>LINMsg04 (0xC4)</td>
<td>Master</td>
<td>Slave_ID 4</td>
<td>Master transmits node4 control command</td>
</tr>
<tr>
<td>Node5_Write</td>
<td>LINMsg05 (0x85)</td>
<td>Master</td>
<td>Slave_ID 5</td>
<td>Master transmits node5 control command</td>
</tr>
<tr>
<td>Node6_Write</td>
<td>LINMsg06 (0x06)</td>
<td>Master</td>
<td>Slave_ID 6</td>
<td>Master transmits node6 control command</td>
</tr>
</tbody>
</table>
The messages selected for the demo are all 2 bytes long. The first byte is a command byte and the second is data. Table 2 details the NodeX_Write Message Format.
NodeX_Write Message Format

Table 2 NodeX_Write Messages

<table>
<thead>
<tr>
<th>Identifier = See table</th>
<th>Byte1 = Command Byte</th>
<th>Byte2 = LED Pattern</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Command</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLAVE_LEDS_COMMAND</td>
<td>0x01</td>
</tr>
<tr>
<td>CLOCK_LEDS_COMMAND</td>
<td>0x03</td>
</tr>
</tbody>
</table>

Broadcast_Message Format

Table 3 Broadcast Messages

<table>
<thead>
<tr>
<th>Identifier = See table</th>
<th>Byte1 = Command Byte</th>
<th>Byte2 = LED Pattern</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Command</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>BROADCAST_COMMAND</td>
<td>0x02</td>
</tr>
<tr>
<td>IDENT_COMMAND</td>
<td>0x04</td>
</tr>
<tr>
<td>SLEEP_COMMAND</td>
<td>0x80</td>
</tr>
</tbody>
</table>

NOTE: LED pattern sent with command byte. Pattern written to slave node LEDs. IDENT and SLEEP commands the LED pattern is ignored.

NodeX_Read Message Format

Table 4 NodeX_Read Messages

<table>
<thead>
<tr>
<th>Identifier = See table</th>
<th>Byte1 = NodeID</th>
<th>Byte2 = Hex Switch</th>
</tr>
</thead>
</table>

The message format was adopted to allow flexibility within the demo. Additional commands can be added without too much effort. The slaves can also easily decode the various commands and act accordingly. Another benefit is that the master node software has total control over the LED pattern that the slaves output. In order to change the LED’s sequence, only the master software has to be changed.
In actual LIN applications a signal-based messaging scheme should be adopted. Refer to section Section 4.1 Motorola LIN Drivers and API for details of Motorola’s signal-based LIN API.

3.4 Hardware Description

The demo consists of 13 LIN nodes; a single master and 12 slaves. The hardware for each node is identical as shown in the schematic (see appendix for schematic details). Identical hardware was used to enable a universal master/slave board to be designed. This makes the slaves more flexible and reduces demo cost. The main drawback of adopting this common solution is that the microcontroller required for the master node, MC68HC908AZ60, is not suitable for slave nodes because of its additional functionality (particularly CAN). This makes it too expensive for a typical slave node. Figure 5 shows a block diagram of the hardware. Table 5 details more suitable slave microcontrollers. Contact Motorola for further details (www.mcu.motsp.com).

Figure 5 Master/Slave Hardware
The hardware has several functions that make the design flexible and suitable for other general CAN and LIN applications.

### Table 5 LIN Slave Devices

<table>
<thead>
<tr>
<th>Device ROM</th>
<th>FLASH</th>
<th>RAM</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>68HC908JK3</td>
<td>–</td>
<td>4K</td>
<td>128</td>
</tr>
<tr>
<td>68HC908JL3</td>
<td>–</td>
<td>4K</td>
<td>128</td>
</tr>
<tr>
<td>68HC908JK1</td>
<td>–</td>
<td>1.5K</td>
<td>128</td>
</tr>
<tr>
<td>68HC08AB16</td>
<td>16K</td>
<td>–</td>
<td>512</td>
</tr>
<tr>
<td>68HC908EY8</td>
<td>–</td>
<td>8K</td>
<td>256</td>
</tr>
</tbody>
</table>

### 3.4.1 Monitor Mode
The hardware has the additional circuitry included to allow the microcontroller to communicate with a PC via its monitor mode. This enables in-circuit Flash programming and simple debugging to be performed. Hiware's MON08 target was used in the application development.

### 3.4.2 LIN Physical Interface (MC33399)
The MC33399 was used in the demo. This interface is a serial link bus interface designed to provide bi-directional, half-duplex communication interfacing in automotive applications. It is similar to the ISO9141 interface, but has additional features specific to the LIN protocol. These features are wake-up from the LIN bus, wakeup from an external source and slew rate control to reduce EMI emissions. Refer to the MC33399 data sheet for a detailed description and application diagrams.

### 3.4.3 CAN Physical Interface
In addition to the LIN interface, each node has a CAN physical interface (MC33388). This is required for the master node, as a simple CAN to LIN gateway is implemented.

### 3.4.4 LEDs and HEX Switch interface
Each node has 8 LEDs (4 red and 4 green) and 2 HEX switches. The LEDs are driven directly from Port B, configured as output, and used to demonstrate the LIN protocol and sequencing of messages from the...
master. The switches are input to Port D and allow each node to have a status and identifier value that can be changed in real time and transmitted on the LIN bus.

The LEDs and switches are positioned at the edge of the boards and can easily be removed and the board used to drive an actual application. For example, the port lines that interface to the LEDs and switches could be connected to a power drive board and could be used to control motors of a mirror module. This makes the board very flexible and allows quick prototyping of LIN applications.

### 3.4.5 Motorola Components used

- MC68HC908AZ60 – General purpose flash MCU with CAN.
- MC33399 – LIN Physical interface.
- MC33388 – Low speed, fault tolerant, CAN physical interface.

### 4 Software Description

The demo comprises a single master and 12 slave nodes. The master software is responsible for scheduling LIN messages, providing a CAN to LIN gateway and general communications. The slave software interrogates all header frames transmitted on the bus and either receives a response frame from another slave or transmits a response frame on to the bus. Each slave waits for a pre-configured message, decodes the command and either outputs the data to its LED port, if it is a NodeX_Write or broadcast message, or transmits a status message to the LIN network, if a NodeX_Read message was detected. The code for each slave is practically identical, the only difference being the messages configured are specific to individual nodes. See Table 1 for details.

The master and slave code implementations both use the Motorola HC08 LIN low level drivers to manage all the LIN communications. The drivers and the application code for the demo are described in this section. All data flow diagrams and flow charts are included. Refer to the appendix for code listing.

### 4.1 Motorola LIN Drivers and API

The driver provides the full LIN protocol eliminating the application code from implementing the LIN low level kernel. The user interfaces with the drivers, statically at compile time and dynamically at run time through an API. Two versions of the drivers exist: one with a custom Motorola API and the second with the LIN API. The project used the Motorola API drivers.
The Motorola API is entirely message based. The message identifiers for a specific node are configured at compile time through header files. The application accesses the data transmitted using the LIN_GetMsg() and LIN_PutMsg() services. The application retrieves or transmits the data associated with the identifier. (The address of a buffer that contains the data to be transmitted or received and the message identifier are passed to the driver, by the application). The drivers are easily used with no additional tools and are linked with the application code.

The main difference of the LIN API is that it is signal based. The application code does not access the entire message data, but only specific signals. A signal consists of one or more bits of data. The drivers provide services to access particular signals of varying lengths. (1 bit, 2-8bits and 9-16bits). In order to use the drivers an additional description file is required that describes all the signals that are specific for a particular node. This description file is then converted to header files (an additional tool is required for this) and included with the application. Every node on the network requires a separate description file that contains its specific signals. This file is also used with the LINspector tool for development and evaluation. The LIN API has provision to connect to several hardware interfaces (more than one SCI).

The LIN Drivers are currently available for the HC05, HC08 and HC12 families of microcontrollers. Details of the HC08 implementation are given below.

<table>
<thead>
<tr>
<th>Node</th>
<th>LINBaud Rate(bps)</th>
<th>MCU bus frequency</th>
<th>MCU load</th>
<th>RAM (bytes)</th>
<th>ROM (bytes)</th>
<th>Stack (bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master</td>
<td>20000</td>
<td>4</td>
<td>&lt;9%</td>
<td>23</td>
<td>1391</td>
<td>&lt;34</td>
</tr>
<tr>
<td>Slave</td>
<td>20000</td>
<td>4</td>
<td>&lt;5%/6%</td>
<td>20/21</td>
<td>1071/689</td>
<td>&lt;34/19</td>
</tr>
</tbody>
</table>

Note 1: Figures exclude per message overhead
Note 2: Motorola API/LIN API

Contact Motorola Software Systems for further information.
software.systems@helpline.sps.mot.com
4.1.1 Static Configuration

The drivers are statically configured through 2 header files, lincfg.h and linmsgid.h. The lincfg.h file is used to provide general LIN configuration information, such as baud rate and timer pre-scalers. The information in this file is the same for each node on the network, assuming they are all the same target hardware. The linmsgid.h file is used to define the node’s messages and whether they are to be received or transmitted. This file is usually unique to every node on the network. For further details refer to the LIN drivers manual and the demo configuration files.

4.1.2 Driver API

The API is the interface with the drivers. The application code calls the run time services provided by the driver, during execution. The services used in the demo software are described below. Refer to driver manual for full descriptions of the Motorola and LIN API.

4.1.2.1 LIN_Init:

The LIN_Init service performs initialization of the driver. The function must be called before any other API service call is made. The service initializes the following functions:

- Sets baud rate (Information entered in lincfg.h file)
- Assigns physical interface pins
- Sets Tx to idle state
- Clears all error flags and counters
- Clears all data buffers
- Change state of drivers to run
- Initializes all variables

Syntax: unsigned char LIN_Init (void);
Applicable: Master, Slave
Parameters: None
Return: LIN_OK
4.1.2.2 LIN_GetMsg:
The LIN_GetMsg service retrieves the current content of the specified message buffer to an application defined buffer.

Syntax: unsigned char LIN_GetMsg (unsigned char MsgId, unsigned char * Data);

Applicable: Master, Slave

Parameters: MsgId – Message identifier
Data – Pointer to memory buffer where received data is to be stored.

Return: LIN_OK, LIN_NO_ID, LIN_INVALID_ID and LIN_MSG_NODATA

4.1.2.3 LIN_PutMsg:
The LIN_PutMsg service transmits current contents of specified message buffer to an application specified message buffer.

Syntax: unsigned char LIN_PutMsg (unsigned char MsgId, unsigned char * Data);

Applicable: Master, Slave

Parameters: MsgId – Message identifier
Data – Pointer to memory buffer where data is to be transmitted.

Return: LIN_OK, LIN_NO_ID and LIN_INVALID_ID

4.1.2.4 LIN_RequestMsg:
The LIN_RequestMsg service transmits the message identifiers header frame

Syntax: unsigned char LIN_RequestMsg (unsigned char MsgId);

Applicable: Master

Parameters: MsgId – Message identifier

Return: LIN_OK, LIN_REQ_PENDING and LIN_MSG_SLEEP
4.1.2.5 LIN_MsgStatus: The LIN_MsgStatus service returns the current status of the specified message buffer.

Syntax: unsigned char LIN_MsgStatus (unsigned char MsgId);
Applicable: Master, Slave
Parameters: MsgId – Message identifier
Return: LIN_NO_ID, LIN_OK, LIN_MSG_NOCHANGE and LIN_MSG_NODATA

4.2 Master code implementation

The master software has 2 main tasks that schedule LIN messages and provide a CAN to LIN gateway. The scheduler operates from a periodic tick, driven from Timer B overflow, and transmits a header frame every 150ms. The gateway function is driven from the CANRx interrupt and either changes the demo mode or transmits a LIN message to a specific slave node. Figure 6 shows the data flow diagram of the master software.

Figure 6 Master Data flow Diagram
4.2.1 Demo Modes

As discussed the demo has several modes of operation that are user selectable. The mode is controlled by a CAN message or by the HEX switch on the master PEC, when operated in standalone mode. The mode can be changed at any time. Table 6 shows the CAN messages and switch positions that select different modes.

<table>
<thead>
<tr>
<th>Mode</th>
<th>CAN Message</th>
<th>Switch Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default</td>
<td>ID 0x00, Byte0=0x0E, 0x00</td>
<td>0</td>
</tr>
<tr>
<td>Broadcast</td>
<td>ID 0x00, Byte0=0x0E, 0x01</td>
<td>1</td>
</tr>
<tr>
<td>Ident</td>
<td>ID 0x00, Byte0=0x0E, 0x02</td>
<td>2</td>
</tr>
<tr>
<td>Sleep</td>
<td>ID 0x00, Byte0=0x0E, 0x03</td>
<td>3</td>
</tr>
</tbody>
</table>

The mode select is controlled in the ScheduleMessage function. The software reads a demomode control variable and depending on its value calls a default message handler, broadcast message handler, ident message handler or a sleep message handler. The control variable is initialized to DEFAULT mode out of reset, but can be updated directly from the hex switch (on Port D) or from a CAN message.
Software Description
Master code implementation

Figure 7 ScheduleMessage Flow Diagram

1. Start
2. Transmit ALIVE Message
3. Standalone Mode
   - Y: Update demomode variable with mode select switch settings
   - N: DEFAULT Mode
4. DEFAULT Mode
   - Y: Call DefaultMsgHandler
   - N: BROADCAST Mode
5. BROADCAST Mode
   - Y: Call BroadcastMsgHandler
   - N: IDENT Mode
6. IDENT Mode
   - Y: Call IdentMsgHandler
   - N: SLEEP Mode
7. SLEEP Mode
   - Y: Call SleepMsgHandler
   - N: End
Each mode and its software are described below:

4.2.1.1 Default mode

In default mode the software executes in a loop that sequentially transmits 2 messages to each slave node. See Table 7 for sequence. The first message is a NodeX_Read message that requests a status response from the slave to indicate that it is present. If the master does not receive the slave response within a 10mS timeout it is assumed that the node is not present and a NO_NODE code (0x00) is transmitted on the CAN bus. The second message transmitted (assuming a node is present) is a NodeX_Write message that transmits a command byte and a data byte to a specific slave. The slave decodes the command and outputs the data to its LED port.

The status response message is checked to see if it has changed since the last interrogation. If it has changed it is translated to a CAN message and transmitted onto the CAN bus. The status information is updated before the function is exited.

**NOTE:** The CAN transmission is not performed if the demo is in standalone mode.

The scheduler software exits this function then waits in the main loop before transmitting to the next node in the sequence. The node number to be transmitted is controlled in the TIMBOVF_ISR. See main loop for further details.
The default message table shows the order that the nodes are written to and the data that is transmitted.
Start

N

Index within range (1 to 12) Y

Reset Index to 1

Index 6 or 12 N

Y

Call Transmit Function and pass ScheduleIndex, ALL_LEDS_ON data &MsgReadBuf

N

Status Changed Y

Transmit new status on CAN bus

Update Status

End

Figure 8 Default Mode Flow Diagram
Figure 9 Default Transmit Function
4.2.1.2 Broadcast Mode

In this mode, the master software periodically transmits a broadcast message which is received by every slave node. The first byte of the message contains the broadcast command, and the second byte contains the data byte that each slave outputs to its LED port. A single 1 is shifted through the data byte from bit0 to bit7, the sequence is then reversed and repeated. The data bytes to be broadcast are stored in a lookup table. See Table 8 below for details.

### Table 8 Broadcast Table

<table>
<thead>
<tr>
<th>Value</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0x01</td>
<td></td>
</tr>
<tr>
<td>0x03</td>
<td></td>
</tr>
<tr>
<td>0x07</td>
<td></td>
</tr>
<tr>
<td>0x0F</td>
<td></td>
</tr>
<tr>
<td>0x1F</td>
<td></td>
</tr>
<tr>
<td>0x3F</td>
<td></td>
</tr>
<tr>
<td>0x7F</td>
<td></td>
</tr>
<tr>
<td>0xFF</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** A lookup table was used to allow the pattern sequence to be changed with ease
Figure 10  Broadcast Mode Flow Diagram
4.2.1.3 IDENT Mode

In this mode, the master software periodically transmits a broadcast message with an IDENT command. Each slave node receives this command and outputs its individual identifier to its LED port.

**NOTE:** The slave is pre-programmed with its identifier.

![Ident Mode Flow Diagram](Image)

**Figure 11 Ident Mode Flow Diagram**
4.2.1.4 Sleep Mode

In this mode, the demo enters its low power state by switching off its voltage regulator. The master node transmits a SLEEP command that is received by all slave nodes. Once the SLEEP command has been successfully transmitted, the master disables its voltage regulator by driving the LIN interface into its Sleep mode. The software then waits in an infinite loop until the regulator is disabled. The master is the only node that can issue a SLEEP command.

The master is woken by a wake-up request initiated by one of the slave nodes. The LIN I/F device recognizes a specific wake-up message driven onto the bus. The LIN I/F brings the node out of sleep mode by turning on the voltage regulator.

![Figure 12 Sleep Mode Flow Diagram](image_url)
4.2.2 CAN Communication

The master software also provides CAN communication and implements a simple CAN to LIN gateway.

The CAN receive and the transmit functions are described below:

NOTE: CAN communication do not occur when the demo is configured in standalone mode.

4.2.2.1 Receiving CAN Messages

The receiver function is interrupt driven. If a message passes the CAN filters it is written into the CAN receive buffer and a receive interrupt request is issued. The CANRx ISR sets a msgtxd flag that indicates that a new message has been received and clears the interrupt flag to enable further interrupts. The main routine, discussed below, polls the msgtxd flag, waiting until it is set. When a new CAN message is received, the code calls a MsgHandlerTable (array of pointers to functions) and jumps to the appropriate MsgHandlerFunction. The function that is executed is dependent on the first byte of the received CAN message. This byte, masked off with 0x0F, determines the index of the MsgHandlerTable and subsequently the handler that the code executes.

4.2.2.2 CAN Message Handlers

The basis of the CAN communication and gateway function is performed using a series of message handlers. These are described below:

4.2.2.2.1 Common Message Handler

This handler is used to transmit a LIN message to a particular slave node. The node that the message is transmitted to is determined by an index (CanMsgINDEX). The index is calculated from the CAN message that was received. The slaves receive the LIN messages and control the external button LED around the circumference of the ‘clock face’.

Start

Transmit CLOCK_LED_COMMAND to slave node X

X denotes node number (0 <= x <=12)

End

Figure 13 Message Handler (1-12) flow diagrams
4.2.2.2.2 **SleepHandler**

See sleep mode description

4.2.2.2.3 **ModeSelect Handler**

This function decodes the CAN mode select message and writes the appropriate value to the demomode variable.

![ModeSelectHandler flow diagrams](image)

**Figure 14 ModeSelectHandler flow diagrams**

4.2.2.2.4 **DefaultHandler**

This handler consists of the function prototype. This is included for expandability and to ensure that the code does not ‘run away’ even if an invalid entry in the message handler vector table is accessed, i.e. all unused entries in the table jump to DefaultMessage handler.
4.2.2.3 Transmitting CAN Messages

The CAN transmitter function is called from the initialisation and default mode functions. The identifier and data to be transmitted are written to TxBuffer0 and transmitted when the bus is idle. The function that transmits the message, TxCANBuffer(), receives a pointer to a structure that contains the id and data to be transmitted and the TxBuffer number as arguments.

Figure 15  CAN Transmit flow diagrams
4.2.2.4 Master Node

Main Loop

The main routine is essentially a simple infinite loop that waits for either a msgrxd system flag to be set or a loopcontrol system flag to be cleared. The msgrxd flag is set in the CANRx_ISR when a CAN message is received. If the flag is set, the MsgHandlerTable is called and the appropriate handler routine executed as described in the Receiving CAN Messages section. The loopcontrol flag is cleared periodically in the TIMBOVF_ISR, which overflows every 150ms. When the flag is cleared, the ScheduleMsg function is called and the selected mode executed. Once the CAN message is received or the mode executed, the main function resets the appropriate flags and returns to the infinite loop waiting for a flag to change again.

The main loop also performs initialization, by calling the appropriate initialization function, before the infinite loop is entered. Initialisation of the MCU registers, LIN drivers and application is also performed.
Figure 16 Main Loop flow diagram
4.3 Slave Code description

The slave code is entirely message driven. The software for each node is practically identical, the only difference being the messages the node is configured to recognize and the nodeID.

The individual slaves are configured to react to 3 preprogrammed message identifiers: a NodeX_Write, a NodeX_Read and a common broadcast message (NodeX_Write message that every slave is programmed to receive). See Table 1 for details. Each slave monitors every header that the master drives on the bus, but only reacts to its configured identifiers. If a NodeX_Write message is detected, it receives the message data, decodes the command, and either writes to its LED output port or the external output LED or enters SLEEP mode. If a NodeX_Read message is detected, the slave automatically transmits its status information bytes (i.e. Its ID and the HEX switch settings) on to the LIN bus.

Received messages are handled in exactly the same way as the master code handles CAN messages. When a new LIN message is received (NodeX_Write) the code calls a MsgHandlerTable (array of pointers to functions) and jumps to the appropriate MsgHandlerFunction.

Figure 17 Slave code data flow diagram
4.3.1 Slave Code Main Function

The slave code's main function is very similar to the master's in that it performs some initialization before entering an infinite loop. During an iteration of the loop, the code updates the status message buffer by writing the HEX switch settings to the NodeX_Read message buffer using the LIN_PUTMsg() service and checks to see if a new received message has been detected. If a new message has been detected, the MsgHandlerTable is called and the appropriate handler function is executed. Several housekeeping tasks are also performed in the main loop, such as control of timeouts etc. Once the iteration is complete, the code jumps back to the start of the loop and performs the tasks again.
Software Description
Slave Code description

Figure 18  Main Loop flow diagram
### 4.3.2 Receiving LIN messages

Each slave node is configured to receive 2 LIN messages: a broadcast message and a NodeX_Write message. The first byte of the message is a command. The main function polls the message status flags of the configured messages and transfers the received data to the application receive buffer, MsgRcvd, when a valid message is received. The command byte is decoded and the appropriate handler function is executed. Each message handler is described below:

#### 4.3.2.1 Rotating Handler

This handler is entered when the demo is configured for default mode (SLAVE_LEDS command transmitted by the master). The handler decodes the LED data received, to see if it is to illuminate the RED or GREEN LEDs, resets the appropriate time out counter and then outputs the data to its LED output port.
Figure 19  Rotating Message Handler flow diagram
4.3.2.2 Broadcast Handler

This handler is entered when the demo is configured for broadcast mode (BROADCAST command transmitted by the master). The handler disables the time out and then outputs the data to its LED output port.

![Broadcast Message Handler flow diagram](image)

4.3.2.3 External Handler

This handler is entered when the demo is configured for external mode (CLOCK_LEDS_COMMAND command transmitted by the master). The handler enables the time out and then outputs the data to its external output port (PortE, bit4)

![External Message Handler flow diagram](image)
4.3.2.4 Identify Handler

This handler is entered when the demo is configured for IDENT mode (IDENT command transmitted by the master). The handler disables the time out and then outputs the data to its LED output port.

![Identify Message Handler flow diagram](image)

**Figure 22 Identify Message Handler flow diagram**

4.3.2.5 Default Handler

This handler consists of the function prototype. This is included for expandability and to ensure that the code does not 'run away' even if an invalid entry in the message handler vector table is accessed. I.e. All unused entries in the table jump to DefaultMessage handler.

4.3.2.6 SleepHandler

See sleep mode description
4.3.3  
Sleep Mode

Sleep mode is the demo’s low power mode. It is entered when the master transmits the SLEEP identifier (0x80). Each slave receives the command and jumps to the sleep message handler. The handler disables the voltage regulator by driving the LIN I/F into sleep mode.

Any node can be brought out of sleep mode by an external switch (switches around the circumference of the clock face) or a wake-up message (see protocol specification for details) detected on the LIN bus. The slave that is woken up transmits the wake-up message onto the bus, which wakes up the master and the other nodes.

Each slave distinguishes between a wake-up (switch on voltage regulator) and a normal power up sequence, by detecting if the master is present on the bus (master will be communicating on bus for standard power up sequence). The master transmits an ALIVE (0x0F) message every 150ms to signal its presence. If a slave detects an ALIVE message it assumes that it is a power up sequence. If the ALIVE is not detected within 200ms the slave assumes that it has woken up and subsequently transmits a wake-up message to the network.
5 Code Listings

5.1 Master Code – Master08.C

#include <linapi.h> // LIN Drivers Header file

#include <master08CodeReview.h> // Master08 header file
#include <common.h> // Common data structure
#include <port.h> // Port register definitions
#include <timer.h> // Timer register definitions
#include <sim.h> // SIM Register definitions
#include <si.h> // Serial Interface Register definitions
#include <kbd.h> // Keyboard wakeup Register definitions
#include <mscan08.h> // msCAN Register definitions

const SlaveNodeMsgType SlaveMsg[] =
{
  {0x0F,0x0F}, // Broadcast message *
  {0x01,0x11}, // Node1 Write messageID, Node1 Read messageID
  {0x02,0x12}, // Node2 Write messageID, Node2 Read messageID
  {0x03,0x13}, // Node3 Write messageID, Node3 Read messageID
}
{0x04,0x14}, // Node4 Write messageID, Node4 Read messageID
{0x05,0x15}, // Node5 Write messageID, Node5 Read messageID
{0x06,0x16}, // Node6 Write messageID, Node6 Read messageID
{0x07,0x17}, // Node7 Write messageID, Node7 Read messageID
{0x08,0x18}, // Node8 Write messageID, Node8 Read messageID
{0x09,0x19}, // Node9 Write messageID, Node9 Read messageID
{0x0A,0x1A}, // Node10 Write messageID, Node10 Read messageID
{0x0B,0x1B}, // Node11 Write messageID, Node11 Read messageID
{0x0C,0x1C} // Node12 Write messageID, Node12 Read messageID
};

/** Broadcast table settings */
const tU08 BroadcastTable [] =
{
  0x01,
  0x03, // Data bytes transmitted when in broadcast mode
  0x07,
  0x0F,
  0x1F,
  0x3F,
  0x7F,
  0xFF
};

/***************************************************************************/
/* Message handler vector table */
/***************************************************************************/

void (* const MsgHandlerTable[])() =
{
  CommonMsgHandler,
  CommonMsgHandler, // If required different handlers can be used
  CommonMsgHandler,
  CommonMsgHandler,
  CommonMsgHandler,
  CommonMsgHandler,
  CommonMsgHandler,
  CommonMsgHandler,
  CommonMsgHandler,
  CommonMsgHandler,
  SleepHandler,
  ModeSelect,
  DefaultHandler
};

/******************************** Global Variables ***************************/
SlaveMsgBufferType CurrentSlaveStatus [12]; // Current slave node status
DemoModeType_t DemoMode = DEFAULT; // Current demo mode (DEFAULT,BROADCAST,IDENT,SLEEP)
tFLAG SystemFlags; // System flags
tXBUF StatusMsg;

tU08 MgwWriteBuf [2]; // Temp write buffer used with LIN Drivers
tU08 ScheduleIndex = 0x01; // Slave node index
tU08 AltScheduleIndex = 0x00;
tU08 BroadcastIndex = 0x00; // Broadcast control index
tU08 MsgReadBuff1[2] = {0x00,0x00}; // Temp read buffer used with LIN Drivers
tU08 MsgReadBuff2[2] = {0x00,0x00};
tU08 CanMsgIndex = 0x00;
tU08 TimeoutCount = 0x00;
tU08 LoopControlTime = 0x00;
******************************************************************************/
Function Name : Main
Engineer : R29414
Date : 09/02/2000
Parameters : none
Returns : none
Notes : Main loop
*******************************************************************************/

void main(void)
{
    /* Local variables */
    tU08 i; // loop control
    MCUInitialisation(); // Initialisation of MCU register
    LIN_Init(); // LIN Drivers Initialisation service

    /***************************************************************************/
    LIN drivers TOC attached to output ports
    Disabled on production software
    /***************************************************************************/

    /***************************************************************************/
    LIN drivers TOC attached to output ports
    Disabled on production software
    /***************************************************************************/

    /***************************************************************************/
    Disable timer channels from ports */
    AZ60_TIMER.tasc0.byte = AZ60_TIMER.tasc0.byte & 0xF3;
    AZ60_TIMER.tasc1.byte = AZ60_TIMER.tasc1.byte & 0xF3;
    /***************************************************************************/
    Enable MC33399 device */
    AZ60_PORT.pte.bit.pte3 = 1;
    AZ60_PORT.ddre.bit.ddre3 = 1;

    for (i=0; i<0xff; ++i)   // Wait for LIN to switch ON
    {
        // Enable Global Interrupts */
        asm
        {
            cli
        }

        /* Transmit Alive Message */
        MsgWriteBuf[0] = ALIVE_COMMAND;
        MsgWriteBuf[1] = ALIVE_BYTE;
        LIN_PutMsg(SlaveMsg[0].WriteMsg, MsgWriteBuf); // Copy transmit data to LIN buffers
        LIN_RequestMsg(SlaveMsg[0].WriteMsg); // Transmit LIN message
    }
    if ((AZ60_PORT.ptd.byte & 0xF0) != 0x00) // Standalone mode or CAN mode
    {
        SystemFlags.bit.canmode=1; // CAN mode
    }
    ScheduleTableInit(); // Initialise schedule table
}
SystemFlags.bit.loopcontrol=1; // Initialise loop control

/* Main Loop */
while(1) {
    /* Wait for timer interrupt or CAN receive message */
    while ((SystemFlags.bit.loopcontrol==1) && (SystemFlags.bit.msgrxd==0))
        
        if ((SystemFlags.bit.loopcontrol==0) && (SystemFlags.bit.msgrxd==0))
            
            ScheduleMsg(); // Timer interrupt
            SystemFlags.bit.loopcontrol = 1; // Set up for next loop iteration
        
        else // CAN message received
            
            CanMsgIndex = (AZ60_MSCAN08.rxbuf.dsr[0] & 0x0F);
           (MsgHandlerTable[CanMsgIndex]()); // Jump to message handler table
            SystemFlags.bit.msgrxd = 0; // Set up for next CAN message

        }
    }
    // end of while (1)
} // end of main

/**********************************************************
Function Name : ScheduleTableInit
Engineer :   R29414
Date : 09/02/2000
Parameters : none
Returns : none
Notes : Initialise the schedule table. It identifies the slave
on the LIN bus
***********************************************************/
void ScheduleTableInit (void)
{
    /* Local variables */
    tU08 i; /* Index counter */
    tU08 msgTempBuffer[] = {0x00, 0x00}; /* Initialise temp buffer */

    /* LIN Schedule table Initialisation */
    for (i=0 ; i<12 ; i++)
        
        /* Clear all elements in Slave table array*/
        CurrentSlaveStatus [i].Byte0 = NO_NODE; // NO_NODE = 0x00
        CurrentSlaveStatus [i].Byte1 = NO_NODE;

    }

    /* Check nodes on Bus */ /* Nodes 1 to 12 */
    for (i=1 ; i<13 ; i++)
        
        while (LIN_RequestMsg(SlaveMsg[i].ReadMsg) != LIN_OK) // Transmit LIN header
            
            TimeoutCount = 0x00; // Initialise Timeout count
            SystemFlags.bit.linmsgtimeout=0; // Initialise timeout flag
SystemFlags.bit.starttimeout=1; // Start timeout

while (LIN_MsgStatus(SlaveMsg[i].ReadMsg) !=LIN_OK && SystemFlags.bit.linmsgtimeout==0)
{
    // Wait for new data or timeout
    SystemFlags.bit.starttimeout=0; // Stop timeout. Disables timeout in TIMBOVF_ISR
}

if (SystemFlags.bit.linmsgtimeout==0) // No Timeout
{
    // Valid message received
    LIN_GetMsg (SlaveMsg[i].ReadMsg, msgTempBuffer); // Transfer Node status to Temp buffer */
    /* Update Current slave status */
    CurrentSlaveStatus[i-1].Byte0 = msgTempBuffer[0]; // l=< i <13
    CurrentSlaveStatus[i-1].Byte1 = msgTempBuffer[1];
}

/* Transmit initial status via CAN if not in standalone mode */
if (SystemFlags.bit.canmode==1) // Standalone mode canmode= 0
{
    (tU16) i; // i is the CANId
    TxCANMsg(msgTempBuffer,i); // Transmit CAN message */
} // end of for
} // End of scheduleTableInit function

/****************************************************************************
Task Name : ScheduleMsg
Engineer : R29414
Date : 
Parameters : none
Returns : none
Notes : Determine mode of demo and calls handler
******************************************************************************/

void ScheduleMsg(void)
{
    /* Transmit Alive Message */
    MsgWriteBuf[0] = ALIVE_COMMAND;
    MsgWriteBuf[1] = ALIVE_BYTE;
    LIN.PutMsg(SlaveMsg[0].WriteMsg, MsgWriteBuf);
    LIN_RequestMsg(SlaveMsg[0].WriteMsg); // Transmit message
    while (LIN_MsgStatus(SlaveMsg[0].WriteMsg) !=LIN_OK) // Wait for message request complete
{
    if (SystemFlags.bit.canmode==0) // Check mode
    {
        DemoMode = AZ60_PORT.pkd.byte & 0x03; // Stand alone mode
    }
    switch (DemoMode)
    {
        case DEFAULT:
            DefaultMsgHandler(); // Call NodeMsgHandler
            break;

        case BROADCAST:
BroadcastMsgHandler(); // Call BroadcastMsgHandler  
break;

case IDENT:  
    IdentMsgHandler(); // Call IdentMsgHandler  
break;

case SLEEPMODE:  // Call SleepHandler  
    SleepHandler();  
break;

default:  
    break;
} // End of switch
} // End scheduleMsg

/*-------------------------------------------------------------------------------*/
Task Name : DefaultMsgHandler
Engineer : R29414
Date : 26/07/2000
Parameters : none
Returns : none
Notes :
/*-------------------------------------------------------------------------------*/
void DefaultMsgHandler(void)
{
    if ((ScheduleIndex <1) || (ScheduleIndex >= 13)) // Check index is within range 1 to 12
    {
        ScheduleIndex = 1; // Out of range
        // make index = 1
    }

    /* Within range */
    if (((ScheduleIndex == 12) || (ScheduleIndex == 6)) // Valid ScheduleIndex
    {
        /* Node 12 or 6 */
        LINTransmit(ScheduleIndex, ALL_LEDS_ON, MsgReadBuf1); // Transmit specified message header frame
    }
    else
    {
        AltScheduleIndex = 12 - ScheduleIndex; // Calculate alternate index
        LINTransmit(ScheduleIndex, RED_LEDS_ON, MsgReadBuf1); // Transmit specified message header frame
        LINTransmit(AltScheduleIndex, GREEN_LEDS_ON, MsgReadBuf2); // Transmit specified message header frame
    }

    /* Compare status data with previous data */
    if ((CurrentSlaveStatus[(ScheduleIndex - 1).Byte0 != MsgReadBuf1[0]]) ||
        (CurrentSlaveStatus[(ScheduleIndex - 1).Byte1 != MsgReadBuf1[1]])
    {
        if (SystemFlags.bit.canmode==1) // Do not transmit if standalone mode
        {
            (tU16) ScheduleIndex; // ScheduleIndex is the CANId
            TxCANMsg(MsgReadBuf1,ScheduleIndex); // Transmit CAN message
        }
        CurrentSlaveStatus[(ScheduleIndex - 1).Byte0 = MsgReadBuf1[0]; // Update status data
    }
CurrentSlaveStatus[ScheduleIndex - 1].Byte1 = MsgReadBuf1[1];
}
} // End DefaultMsgHandler

 /**************************************************************************
 Task Name : LINTransmit
 Engineer : R29414
 Date : 26/07/2000
 Parameters : index, ledcommand, &msgbuffer
 Returns : none
 Notes :
**************************************************************************/

void LINTransmit(tU08 index, tU08 ledcommand, tU08 *msgbuffer)
{
  TimeoutCount = 0x00; // Initialise Timeout count
  SystemFlags.bit.linmsgtimeout=0; // Initialise Timeout
  LIN_RequestMsg(SlaveMsg[index].ReadMsg); // Transmit specified message header frame
  SystemFlags.bit.starttimeout=1; // Start Timeout

  /* Wait for new data or timeout */
  while (LIN_MsgStatus(SlaveMsg[index].ReadMsg) !=LIN_OK && SystemFlags.bit.linmsgtimeout==0)
  {
    SystemFlags.bit.starttimeout=0; // Stop timeout
    if (SystemFlags.bit.linmsgtimeout==0) // Check if valid LIN message received
    {
      LIN_GetMsg(SlaveMsg[index].ReadMsg, msgbuffer); // Store status information
      MsgWriteBuf[0] = SLAVE_LEDS_COMMAND;
      MsgWriteBuf[1] = ledcommand; //Set up write buffer to transmit command to node
      LIN_PutMsg(SlaveMsg[index].WriteMsg, MsgWriteBuf);
      LIN_RequestMsg(SlaveMsg[index].WriteMsg);
      while (LIN_MsgStatus(SlaveMsg[index].WriteMsg) !=LIN_OK) // Wait for transmission to complete
      {
      }
    } else
    {
      msgbuffer[0] = NO_NODE; // Timeout
      msgbuffer[1] = NO_NODE;
    }
  }
} /* End LINTransmit */

 /**************************************************************************
 Task Name : BroadcastMsgHandler
 Engineer : R29414
 Parameters : none
 Returns : none
 Notes :
**************************************************************************/

void BroadcastMsgHandler(void)
if (BroadcastIndex < 0 || BroadcastIndex > 7) // Don't let Index outwith range
{
    BroadcastIndex = 0;
}

MsgWriteBuf[0] = BROADCAST_COMMAND;
MsgWriteBuf[1] = BroadcastTable[BroadcastIndex];
LIN_PutMsg(SlaveMsg[0].WriteMsg, MsgWriteBuf);
LIN_RequestMsg(SlaveMsg[0].WriteMsg);
while (LIN_MsgStatus(SlaveMsg[0].WriteMsg) != LIN_OK) // Wait for message complete
{
    if (BroadcastIndex == 0)
    {
        SystemFlags.bit.updowncontrol = 0; // Up Counter
    }
    if (BroadcastIndex == 7)
    {
        SystemFlags.bit.updowncontrol = 1; // Down Counter
    }
}
} // End of BroadcastMsgHandler

void IdentMsgHandler(void)
{
    MsgWriteBuf[0] = IDENT_COMMAND;
    MsgWriteBuf[1] = AZ60_PORT.prd.byte; // Hex switch input
    LIN_PutMsg(SlaveMsg[0].WriteMsg, MsgWriteBuf);
    LIN_RequestMsg(SlaveMsg[0].WriteMsg);
    while (LIN_MsgStatus(SlaveMsg[0].WriteMsg) != LIN_OK); // Wait for message complete
}
} // End of BroadcastMsgHandler

void MCUInitialisation(void)
{
    /* Device configuration */
    AZ60_KBD.config1.bit.copd = 1; // Disable Watchdog
    AZ60_SIM.config2.byte = 1; // AZ Mode and CAN enabled

    /* Ports Initialisation */
    AZ60_PORT.ddrd.byte = 0x00; // PortD i/p for HEX switches
A260_PORT.ptb.byte = 0xFF;
A260_PORT.ddrb.byte = 0xFF;  // Port B o/p for LEDs
A260_PORT.ptc.bit.ptc0 = 0;
A260_PORT.ddrc.bit.ddrc0 = 1;

/* CAN I/F Configuration */
SetMC33388Mode(NORMAL);  // put MC33388 into normal mode
AZ60_PORT.ddrf.byte = PTF4|PTF3;  // PTF3=EN and PTF4=STB pins on MC33388

SystemFlags.byte = 0;  // reset all system flags

InitialiseMSCAN08();  // MSCAN Initialisation

StatusMsg.id.w[0] = 0x0000;  // standard 11-bit ID = 1
StatusMsg.dlr = 0;  // 0 data bytes
StatusMsg.tbpr = 0;  // set CAN status message ID, DLR and priority

/* Initialise TIMB Overflow */
AZ60_TIMER.tbsc.byte = 0x30;  // Reset TIMB
AZ60_TIMER.tbmod.word = 0x3E8;  // 1ms overflow when 1Meg Bus and pre-scale=0
AZ60_TIMER.tbsc.byte = 0x40;  // Enable TIMB OVR Interrupt & Start timer
}

ErrMsg = (((MsgBuffer[0] << 8) & 0xFF00) | (MsgBuffer[1] << 16));  // Calculate msg ID

/* End of MCU Initialisation */

******************************************************************************/
Function Name : TXCANDump
Engineer : R38917
Date : 11/02/00
Parameters : *MsgBuffer, CANId
Returns : None
Notes :
******************************************************************************/
void TXCANDump (tU08 *MsgBuffer, tU16 CANId)
{
    tU08 i;
    StatusMsg.id.w[0] = ((CANId <<5) & 0xFFE0);  // Calculate id
    StatusMsg.dlr = sizeof(MsgBuffer);  // Calculate number of data bytes in buffer
    for (i=0 ; i < StatusMsg.dlr ; i++ )  // Transfer data bytes to CAN message buffer
    {  
        StatusMsg.dsr[i] = MsgBuffer[i];
    }
    TXCANDump(&StatusMsg,MSCAN_TX0);
}

******************************************************************************/
Function Name : TXCANSend
Engineer : R29414
Date : 22/02/00
Parameters : *MsgBuffer, CANId
Returns : None
Notes :
******************************************************************************/
void TXCANSend (tU08 *MsgBuffer, tU16 CANId)
{
    tU08 i;
    StatusMsg.id.w[0] = ((CANId <<5) & 0xFFE0);  // Calculate id
    StatusMsg.dlr = sizeof(MsgBuffer);  // Calculate number of data bytes in buffer
    for (i=0 ; i < StatusMsg.dlr ; i++ )  // Transfer data bytes to CAN message buffer
    {  
        StatusMsg.dsr[i] = MsgBuffer[i];
    }
    TXCANDump(&StatusMsg,MSCAN_TX0);
}

******************************************************************************/
Function Name : TXCANBuffer
Engineer : R38917
Date : 11/02/00
Parameters : *MsgBuffer, CANId
Returns : None
Notes :
******************************************************************************/
void TXCANBuffer(tTXBUF *MsgBuffer, tU08 TxBufferID)
{
    tU08 i;
}

******************************************************************************/
Function Name : TXCANDump
Engineer : R38917
Date : 11/02/00
Parameters : *MsgBuffer, CANId
Returns : None
Notes :
******************************************************************************/
void TXCANDump (tU08 *MsgBuffer, tU16 CANId)

while(!(AZ60_MSCAN08.ctflg.byte & TxBufferID))
{
    /***
    Timeout Period And Abort Stuff ?
    ***/
    AZ60_MSCAN08.txbuf[(TxBufferID >> 1)].id.l = Buffer -> id.l;
    for(i=0 ; i < Buffer -> dlr ; i++)
        AZ60_MSCAN08.txbuf[(TxBufferID >> 1)].dsr[i] = Buffer -> dsr[i];
    AZ60_MSCAN08.txbuf[(TxBufferID >> 1)].dlr = Buffer -> dlr;
    AZ60_MSCAN08.txbuf[(TxBufferID >> 1)].tbpr = Buffer -> tbpr;
    AZ60_MSCAN08.ctflg.byte = TxBufferID;
}

/****************************************************************************
Function Name : SetMC33388Mode
Engineer : R38917
Date : 11/02/00
Parameters : Mode
Returns : None
Notes :
******************************************************************************/
void SetMC33388Mode(enum tMC33388 Mode)
{
    switch(Mode)
    {
        case SLEEP:
            AZ60_PORT.ptf.byte = 0; //STB=EN=0
            break;
        case SLEEP_RQ:
            AZ60_PORT.ptf.byte = PTF3; //STB=0,EN=1
            break;
        case RX_ONLY:
            AZ60_PORT.ptf.byte = PTF4; //STB=1,EN=0
            break;
        case NORMAL:
            AZ60_PORT.ptf.byte = PTF4|PTF3; //STB=EN=1
            break;
        default:
            ;
    }
}

/****************************************************************************
Function Name : CommonMsgHandler
Engineer : R38917
Date : 20/07/00
Parameters : None
Returns : None
Notes : This handler is common to the 12 messages as only the index is different.
******************************************************************************/
void CommonMsgHandler(void) // Common handler replaces Node1 - Node12 handlers
{ 
    tU08 msgSent[] = {CLOCK_LEDS_COMMAND, ALL_LEDS_OFF}; // Local Declaration
    LIN_PutMsg(SlaveMsg[CanMsgIndex].WriteMsg, msgSent); // Transfer data to LIN Msg buffer
    LIN_RequestMsg(SlaveMsg[CanMsgIndex].WriteMsg); // Request a message
    while (LIN_MsgStatus(SlaveMsg[CanMsgIndex].WriteMsg) != LIN_OK); // Wait a while
} 

/**************************************************************************
Function Name : SleepHandler
Engineer : R38917
Date : 11/02/00
Parameters : None
Returns : None
Notes :
**************************************************************************/

void SleepHandler(void) 
{ 
    /* Send out LIN Sleep command */
    MsgWriteBuf[0] = SLEEP_COMMAND;
    MsgWriteBuf[1] = 0x00;
    LIN_PutMsg(SlaveMsg[0].WriteMsg, MsgWriteBuf);
    LIN_RequestMsg(SlaveMsg[0].WriteMsg);
    while (LIN_MsgStatus(SlaveMsg[0].WriteMsg) !=LIN_OK) // Wait for message complete
    ;
    A260_PORT.pte.bit.pte3 = 0; // Disable UPL
    SetMC33388Mode(SLEEP_RQ);
    SetMC33388Mode(SLEEP);
    while(1) 
    ; //placing MC33388 into SLEEP mode switches off the Vreg }

/**************************************************************************
Function Name : ModeSelect
Engineer : R38917
Date : 10/02/00
Parameters : None
Returns : None
Notes :
**************************************************************************/

void ModeSelect(void) 
{ 
    switch(A260_MSCAN08.rxbuf.dsr[1])  // Demo mode in byte1
    {
    case DEFAULT:
        DemoMode = DEFAULT; // Put demo in default mode
        break;
    case BROADCA

DemoMode = BROADCAST; // Put demo in broadcast mode
BroadcastIndex = 0;
break;

case IDENT:
    DemoMode = IDENT; // Put demo in IDENT mode
    break;

default:
    ;
}

/****************************************************************************
Function Name : DefaultHandler
Engineer : R38917
Date : 11/02/00
Parameters : None
Returns : None
Notes : 
******************************************************************************/
void DefaultHandler(void)
{
}

/****************************************************************************
Function Name : InitialiseMSCAN08
Engineer : R38917
Date : 10/02/00
Parameters : None
Returns : None
Notes : 
******************************************************************************/
void InitialiseMSCAN08(void)
{
AZ60_MSCAN08.cmcr0.bit.sftres = 1; //put CAN module in soft reset
AZ60_MSCAN08.cbtr0.byte = CBT0_125K;
AZ60_MSCAN08.cbtr1.byte = CBT1_125K;
AZ60_MSCAN08.cid.mr.l = 0xFFFFFFFF; //accept all messages
AZ60_MSCAN08.cmcr0.bit.sftres = 0; //release CAN module from soft reset
AZ60_MSCAN08.crier.bit.rxfie = 1; //enable CAN receive interrupts
while(!AZ60_MSCAN08.cmcr0.bit.synch) ; //wait for CAN bus to synchronize
}

/****************************************************************************
Task Name : TimerB Overflow
Engineer : R29414
Date :
Parameters : none
Returns : none
Notes : Overflow period set at 1ms.
******************************************************************************/
/ * Hiware compiler */

#pragma TRAP_PROC

void TIMBOVF_ISR (void)
{
    // Loop control timer timeout
    if (LoopControlTime<LOOP_CONTROL_PERIOD)
    {
        LoopControlTime++;
    }
    else
    {
        LoopControlTime=0x00; // Reset LoopControlTime
        SystemFlags.bit.loopcontrol =0; // Clear system flag
        ScheduleIndex++; // Increment Schedule Table Index
    
    if (ScheduleIndex >=13)
    {
        ScheduleIndex = 0x01; // Reset Schedule Index
    }

    if (DemoMode == BROADCAST)
    {
        if (SystemFlags.bit.updowncontrol == 0)
        {
            BroadcastIndex++;
        }
        else
        {
            BroadcastIndex--;
        }
    }
}

if (SystemFlags.bit.starttimeout == 1)
{
    if (TimeoutCount<TIMEOUT_PERIOD) // Timeoutperiod set in header file
    {
        TimeoutCount++; // Timeout period set in header file
    }
    else
    {
        SystemFlags.bit.linmsgtimeout =1; // Set Timeout flag
    }

    /* Clear Interrupt flag */
    AZ60_TIMER.tbsc.byte &= ~TOF; // Read TBSC0 and write 0 to CH0F
}

} // End of ISR

سائر

Function Name : CANRxISR
Engineer : R38917
Date : 10/02/00
Parameters : None
#pragma TRAP_PROC

void CANRx_ISR(void)
{
    SystemFlags.bit.msgrxd = 1;
    A260_MSCAN08.crflg.bit.rxf = 1;  //clear interrupt flag
} // End ISR

5.2 Master Code – MASTER08.H

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#include "c:\header_files\hc08\common.h"    // common data structure
#include "c:\header_files\hc08\mscan08.h"   // common data structure

#ifndef MASTER08CODEREVIEW_H
#define MASTER08CODEREVIEW_H

#define LOOP_CONTROL_PERIOD 150
#define TIMEOUT_PERIOD 10

#endif /* MASTER08CODEREVIEW_H */
```c
#ifndef _H_MSCAN_RS485_H
#define _H_MSCAN_RS485_H

#define __MSCAN_RS485__

typedef struct SlaveNodeMsgStruct
{
    tU08 WriteMsg;
    tU08 ReadMsg;
} SlaveNodeMsgType;

typedef struct SlaveMsgBufferStruct
{
    tU08 Byte0;
    tU08 Byte1;
} SlaveMsgBufferType;

typedef union
{
    tU08 byte;
    struct
    {
        tU08 msgrxd:1; // target connection established
        tU08 loopcontrol :1; // Loop control flag
        tU08 updowncontrol :1; // Broadcast message up down flag 0 = Up, 1 = Down
        tU08 canmode :1; // Flag indicates mode. Standalone = 1 CAN = 0
        tU08 linmsgtimeout :1; // LIN timeout. Timeout = 1, OK = 0
        tU08 starttimeout :1; // LIN timeout. Timeout = 1, OK = 0
        tU08 :2; // not used
    } bit;
} tFLAG;

typedef enum
{
    DEFAULT,
    BROADCAST,
    IDENT,
    SLEEPMODE
} DemoModeType_t;

typedef enum_tMC33388
{
    SLEEP,
    SLEEP_RQ,
    RX_ONLY,
    NORMAL
};

#ifndef _H_MSCAN_RS485_H
define NODE_CONNECTED 0x80
#define NO_NODE 0x00
#define CBT0_125K 0xC0
#define CBT1_125K 0xD8 // based on a 4MHz xtal, 3 sampling points, SJW = 4
#define MSCAN_TX0 0x01
#endif
```

# define MSCAN_TX1 0x02
# define MSCAN_TX2 0x04

# define LED0_ON 0x01
# define LED1_ON 0x02
# define LED2_ON 0x04
# define LED3_ON 0x08
# define LED4_ON 0x10
# define LED5_ON 0x20
# define LED6_ON 0x40
# define LED7_ON 0x80
# define ALL_LEDS_ON 0x00
# define ALL_LEDS_OFF 0xFF
# define RED_LEDS_ON 0xF0
# define GREEN_LEDS_ON 0x0F

/* command bytes */
# define SLAVE_LEDS_COMMAND 0x01
# define BROADCAST_COMMAND 0x02
# define CLOCK_LEDS_COMMAND 0x03
# define IDENT_COMMAND 0x04
# define SLEEP_COMMAND 0x08
# define ALIVE_COMMAND 0x0F
# define ALIVE_BYTE 0xAD

/************************* Macros *********************************************/

/************************* Prototypes ****************************************/

void MCUInitialisation (void);
void ScheduleTableInit (void);
void ScheduleMsg (void);
void DefaultMsgHandler (void);
void BroadcastMsgHandler (void);
void IdentMsgHandler(void);
void TxCANMsg (tU08 *, tU16);

void CommonMsgHandler(void);
void TxCANBuffer(tTXBUF *,tU08);
void SetMC33388Mode(enum tMC33388);
void SleepHandler(void);
void StatusRequestHandler(void);
void ModeSelect(void);
void DefaultHandler(void);
void InitialiseMSCAN08(void);
void LINTransmit(tU08, tU08, tU08 *);

#endif/* End of Header file ifndef*/

5.3 Slave Code – SLAVE08.C

뱯nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;nbsp;
Date Created : 27 January 2000
Current Revision : $Revision:1.0$

Functions :
Tasks :

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*******************************************************************************

/************************* System Include Files ******************************/
#include "SAEdemo.h"    //demo header file
#include <linapi.h>   //lin driver api
#include <port.h>     //port registers definitions
#include <sim.h>      //system register definitions
#include <kbd.h>      //register definitions
#include <si.h>       //register definitions
#include <timer.h>    //register definitions

/************************* Declarations **************************************/
/*************************** # defines ***************************************/
#define AZ60 (*(tPORT *)(0x0000))
#define SIM (*(tSIM *)(0xFE00))
#define KBD (*(tKBD *)(0x001A))
#define SI (*(tSI *)(0x0010))
#define TIMER (*(tTIMER *)(0x0020))

/************************* typedefs *******************************************/
typedef union
{
    tU08 byte;
    struct
    {
        tU08 enableTimeout :1;  //enable default mode timeout
        tU08 enableExternal :1;  //enable external timeout
        tU08 disableWaketime :1;
        tU08 :5;   //not used
    }bit;
}tFLAG;

/******* Slave Code – SLAVE08.C *******/

Date Created : 27 January 2000
Current Revision : $Revision:1.0$

Functions :
Tasks :

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*******************************************************************************
enum tMC33388
{
    SLEEP,
    SLEEP_RQ,
    RX_ONLY,
    NORMAL
};

/****************************************************************************
Function Name : SetMC33388Mode
Engineer : r38917
Date : 11/02/00
Parameters : Mode
Returns : None
Notes :
******************************************************************************/
void SetMC33388Mode(enum tMC33388 Mode)
{
    switch(Mode)
    {
    case SLEEP:
        AZ60.ptf.byte = 0; //STB=EN=0
        break;
    case SLEEP_RQ:
        AZ60.ptf.byte = PTF3; //STB=0,EN=1
        break;
    case RX_ONLY:
        AZ60.ptf.byte = PTF4; //STB=1,EN=0
        break;
    case NORMAL:
        AZ60.ptf.byte = PTF4|PTF3; //STB=EN=1
        break;
    default:
    ;
    }
}
Date: 10/02/00

Parameters: None
Returns: None
Notes:

******************************************************************************/
void RotatingHandler(void)
{
    if((MsgRcvd[1] & RED_LED_MASK) != RED_LED_MASK)
        REDTIMticks = 0; //reset red timeout period
    if((MsgRcvd[1] & GREEN_LED_MASK) != GREEN_LED_MASK)
        GREENTIMticks = 0; //reset green timeout period
    SystemFlags.bit.enableTimeout = 1;
    AZ60.ptb.byte = MsgRcvd[1]; //send data to portb to switch on LEDs
}

/*******************************************************************************
Function Name: Broadcast message
Engineer: TTZ740
Date: 10/02/00

Parameters: None
Returns: None
Notes:
*******************************************************************************
void BroadcastHandler(void)
{
    SystemFlags.bit.enableTimeout = 0;
    AZ60.ptb.byte = ~MsgRcvd[1]; //output data byte to port
}

/*******************************************************************************
Function Name: External LED message
Engineer: TTZ740
Date: 10/02/00

Parameters: None
Returns: None
Notes:
*******************************************************************************
void ExternalHandler(void)
{
    EXTERNTIMticks = 0; //reset external timeout period
    SystemFlags.bit.enableExternal = 1;
    AZ60.pte.bit.pte4 = 1; //switch on external LED
}

*******************************************************************************
Function Name: MsgHandler4
Engineer: TTZ740
Date: 10/02/00

Parameters: None
Returns: None
Notes:
*******************************************************************************
void IdentifyHandler(void)

{  
SystemFlags.bit.enableTimeout = 0;
AZ60.ptb.byte = ~nodeID;  //display node ID on LEDs
}

/**********************************************************
Function Name : SleepHandler
Engineer : r38917
Date : 11/02/00
Parameters : None
Returns : None
Notes :
**********************************************************/
void SleepHandler(void)
{
AZ60.ddrf.byte = DDRF3|DDRF4;  //enable PTF pins as output
AZ60.pte.bit.pte3 = 0;  //disable UPL interface
SetMC33388Mode(NORMAL);  //MC33388 can't be put to sleep from Vbat
//standby mode
SetMC33388Mode(SLEEP_RQ);
SetMC33388Mode(SLEEP);
while(1)
{
    while(1)  //placing MC33388 into SLEEP mode switches off the Vreg
}
}

/**********************************************************
Function Name : DefaultHandler
Engineer : r38917
Date : 11/02/00
Parameters : None
Returns : None
Notes :
**********************************************************/
void DefaultHandler(void)
{
}

/**********************************************************
Message handler vector table
**********************************************************/
void (* const MsgHandlerTable[]()) =
{
    DefaultHandler,
    RotatingHandler,
    BroadcastHandler,
    ExternalHandler,
    IdentifyHandler,
    DefaultHandler,
    DefaultHandler,
    DefaultHandler,
    DefaultHandler,
    DefaultHandler,
    DefaultHandler,
    DefaultHandler,
    DefaultHandler,
    DefaultHandler,
DefaultHandler,
DefaultHandler
};

/***************************************************************************/
Task Name : LINInitialise
Engineer : TTZ740
Date : 

Parameters : none
Returns : none
Notes : LIN driver timer setup causes output compare pins to toggle
which creates a conflict with the hardware design
***************************************************************************/

void LINInitialise(void)
{
    LIN_Init(); // initialise LIN driver
    TIMER.tasc0.byte = TIMER.tasc0.byte & 0xF3;
    TIMER.tasc1.byte = TIMER.tasc1.byte & 0xF3;
}

/***************************************************************************/
Task Name : LINWakeup
Engineer : TTZ740
Date : 

Parameters : none
Returns : none
Notes : Initial hardware design used the UPL interface, which is
not compatible with the LIN protocol for bus wakeup, hence
a custom wakeup routine is required for the UPL interface
***************************************************************************/

void LINWakeup(void)
{
    SI.sci.scc1.bit.ensci = 0; // disable SCI
    SI.sci.scbr.bit.scr = 1; // 10400 baud
    SI.sci.scbr.bit.scp = 1; // 10400 baud
    SI.sci.scc1.bit.ensci = 1; // enable SCI
    SI.sci.scc2.bit.te = 1; // enable transmit

    while (SI.sci.scc1.bit.scte == 0)
    {
        SI.sci.scdr = 0xAA; // send wake up
        while (SI.sci.scc1.bit.tc == 0)
        {
        }
    }
    LINInitialise(); // initialise LIN driver
}

/***************************************************************************/
Task Name : initialise
Engineer : TTZ740
Date : 

Parameters : none
Returns : none

AN2103
MOTOROLA
void initialise (void) {
    u8 i = 0;
    SIM.config2.byte = 0x11; //disable CAN module, enable A2 mode
    KBD.config1.byte = 0x71; //disable COP
    AZ60.ptb.byte = ALL_LEDS_OFF; //port b LEDs switch off
    AZ60.ddrb.byte = 0xFF; //set port b to output
    SystemFlags.byte = 0; //reset the system flags
    LINInitialise();
    TIMER.tsc.byte = 0x54; //enable ovf interrupt, rst counter and /16 prescaler
    TIMER.tmod.word = 0x003E; //1mS overflow based on 4MHz xtal
    AZ60.pte.byte = PTE3; //enable UPL device, switch off external LED
    AZ60.ddre.byte = DDRE3|DDRE4;
    for (i = 0; i < 0xFF; ++i) ; //delay for UPL to switch on
}

******************************************************************************/

Task Name : main
Engineer : TTZ740
Date :
Parameters : none
Returns : none
Notes :
******************************************************************************/

void main( void ) {
    initialise(); //initialisation routine
    asm cli; //enable global interrupts
    while( 1 ) {
        MsgSent[0] = nodeID; //data byte1 to be sent is node ID
        MsgSent[1] = AZ60.ptd.byte; //Data byte1 to be sent is switch status
        LIN_PutMsg(MESSAGESEND, MsgSent); //send data to data buffer
        if (LIN_MsgStatus(MESSAGESEND) != LIN_MSG_NOCHANGE) {
            WakeupTimeout = 0; //reset wakeup timeout
        }
        if (LIN_MsgStatus(MESSAGERECEIVE) == LIN_OK)//if new message
            LIN_GetMsg(MESSAGERECEIVE, MsgRcvd); //read the message
            MsgHandlerTable[(MsgRcvd[0] & 0x0F)];//call subroutine for appropriate command
            WakeupTimeout = 0; //reset wakeup timeout
        }
        if (LIN_MsgStatus(BROADCASTRECEIVE) == LIN_OK)//if new broadcast message
            LIN_PutMsg(MESSAGESEND, MsgSent); //send broadcast message to data buffer
    }
}
LIN_GetMsg(BROADCASTRECEIVE, MsgRcvd); //read the message
MsgHandlerTable[(MsgRcvd[0] & 0x0F)](); //call subroutine for appropriate command

WakeupTimeout = 0; //reset wakeup timeout
}
}
}

/**************************************************************************
Task Name : PIT_ISR
Engineer : TTZ740
Date :
Parameters : none
Returns : none
Notes :
******************************************************************************/

#pragma TRAP_PROC

void PIT_ISR(void)
{

if(SystemFlags.bit.enableTimeout)
{
    if(REDTIMticks < REDTIMPeriod) //check if timeout period for red LEDs has expired
        REDTIMticks++; //increment ticks
    else
        AZ60.ptb.byte |= RED_LED_MASK; //switch off red LEDs

    if(GREENTIMticks < GREENTIMPeriod) //check if timeout period for green LEDs has expired
        GREENTIMticks++; //increment ticks
    else
        AZ60.ptb.byte |= GREEN_LED_MASK; //switch off green LEDs

    if(AZ60.ptb.byte == ALL_LEDS_OFF)
        SystemFlags.bit.enableTimeout = 0;
}

if(SystemFlags.bit.enableExternal)
{
    if(EXTERNTIMticks < EXTERNTIMPeriod) //check if timeout period for external LEDs has expired
        EXTERNTIMticks++; //increment ticks
    else
        AZ60.pte.bit.pte4 = 0; //switch off external LED

    if(!AZ60.pte.bit.pte4)
        SystemFlags.bit.enableExternal = 0;
}

if (!SystemFlags.bit.disableWaketime)
if(WakeupTimeout < TXWAKEUPMSG)
    WakeupTimeout++;
else
{
    static tU08retry = 0;
    if (retry < 3)
    {
        WakeupTimeout = 0; //reset wakeup timeout
        LINWakeup(); //attempt to wake up network
        retry++;
    }
    else
        SystemFlags.bit.disableWaketime = 1;
}

TIMER.tsc.bit.tof = 0; //clear the overflow flag

5.4 Slave Code – SLAVE08.H

/****************************************************************************
Copyright (c) Motorola 1998
File Name : SLAVE08.C
Engineer : TTZ740
Location : EKB
Date Created : 07/02/2000
Current Revision : $Revision:1.0 $
Notes : LIN driver header file
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*****************************************************************************/
 ifndef SLAVE08_H
#define SLAVE08_H

                        /*******************************************************************/
/* standarddefs that may be defined by compiler */
 ifndef SLAVE08_H
#define SLAVE08_H

                        /*******************************************************************/
/* standarddefs that may be defined by compiler */
#if !defined(TRUE)
define TRUE 0x01
#define FALSE 0x00
#endif

#define ON TRUE
#define OFF FALSE
#define YES TRUE
#define NO FALSE

#define RED_LED_MASK 0x0F
#define GREEN_LED_MASK 0xF0
#define RED_LEDS_ON 0xF0
#define GREEN_LEDS_ON 0x0F
#define ALL_LEDS_OFF 0xFF
#define ALL_LEDS_ON 0x00

#define REDTIMPeriod 150 //generates 150mS timeout (4MHz xtal)
define GREENTIMPeriod 150 //generates 150mS timeout (4MHz xtal)
define EXTERNTIMPeriod 150 //generates 150mS timeout (4MHz xtal)
#define TXWAKEUPMSG 200

/ *********************** Prototypes ***********************/
#endif /* End of Header file ifndef */

/* End of Header file ifdef */