Application Note

AN2633/D
Rev. 1, 3/2004

LIN Drivers for SLIC Module on the MC68HC908QL4

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Overview

This application note describes three versions of a slave LIN driver developed for the slave LIN interface controller (SLIC) module on the MC68HC908QL4 (QL4) microcontroller unit (MCU). The slave driver comes with the Motorola QL4 LIN kit evaluation board, which also contains AN2573/D: *LIN Kits LIN Evaluating Boards*, which demonstrates the functionality of the driver.

The slave driver also comes with the M68EVBQL4 evaluation board (EVB) from Metrowerks, along with a compatible version of the application code for the EVB. The software for the LIN kit, including this driver, can be downloaded from the Motorola LIN website: http://motorola.com/semiconductors/LIN

Local Interconnect Network (LIN)

LIN (local interconnect network) is a low-cost communication protocol often used in automotive applications that do not require the bandwidth and versatility of CAN. The LIN bus uses only a single data wire and can communicate at speeds up to 20 kbps. A LIN network has a single master and multiple slaves, so bus arbitration is not required.

The driver and application was developed from the LIN Specification Package. (See **References** for this and other useful resources.)

NOTE: *With the exception of mask set errata documents, if any other Motorola document contains information that conflicts with the information in the device data sheet, the data sheet should be considered to have the most current and correct data.*

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SLIC Module

The SLIC module automates many LIN bus functions, allowing more of the CPU and memory resources to be used for the user application. This application note compares CPU and memory usage details among timer-based, UART-based solutions, and SLIC-based solutions.

Other SLIC module features include:

- Automatic LIN frame synchronization
- Autobauding up to and well exceeding LIN standard bus speeds
- LIN error detection
- LIN message handling
- Automatic checksum generation and verification (for both types)
- ID parity checking

The SLIC module is compatible with LIN 1.3 and LIN 2.0 and requires almost no configuration code and very minimal driver code. More details of the SLIC module are explained in **SLIC Module Operation, Features, and Benefits**.

The driver has been evaluated at 9.615 kbps, 10.417 kbps, and 19.230 kbps.

LIN Communication

A LIN network consists of a single master node and up to 15 slave nodes. Information sent on the LIN bus is in the form of message frames, which can be of selectable length but always have the same format. A message frame has between 1 and 8 bytes of data in addition to the 3 bytes of control and data security information.

Each message frame starts with the master sending out a synchronization break signal (synchbreak field), followed by a synchronization field and a message identifier field. The slave then responds with the data field (which can be between 1 and 8 bytes) and then the checksum field. The synchbreak field identifies the beginning of a new message frame and provides a regular opportunity for the slave to synchronize on the bus clock. The synch field contains the information for the clock synchronization and is always 0x55.

An acknowledgement procedure for correctly received LIN messages is not defined in the LIN protocol.

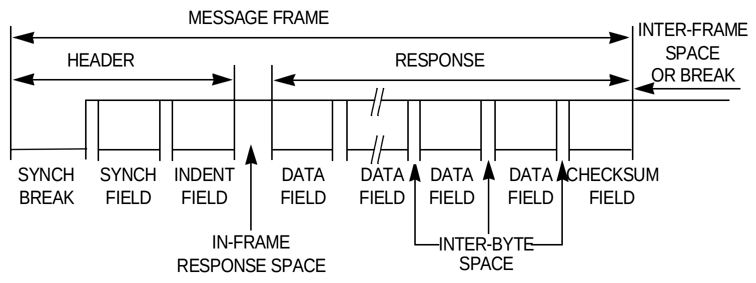


Figure 1. LIN Message Frame

SLIC Module Operation, Features, and Benefits

The SLIC module on the QL4 represents a level of hardware support for LIN slave applications that offers unparalleled performance. This increased performance enables LIN slave node designers to do much more with smaller devices than possible with UART-based solutions.

True Autobauding up to 120 kbps with No Software Changes

The SLIC module automatically performs two very important—but distinctly separate—functions while establishing communication on the LIN bus:

- Autosynchronization
- Autobauding

Automatic LIN message frame synchronization (autosynchronization) is the ability to detect an idle bus and correctly determine when a LIN message frame header has begun.

In many standard UART solutions, this operation can prove problematic, because it is possible to erroneously detect a 0x00 data character as a break symbol, even when within LIN timing specifications. This can happen if the driver software uses the standard UART break-detection circuitry without actually measuring the length of the break symbol. (The ESCI on many Motorola HC08 MCUs contains a feature controlled by a bit called the LINR bit which prevents this error.)

Autobauding is the ability to derive the LIN bus speed from the synchronization byte in the header. Autobauding is possible only if the header is synchronized to the beginning of the message frame. The SLIC handles autobauding and sets up to transmit or receive the rest of the message frame at this speed. Then, the SLIC receives the identifier for the message frame and checks the parity bits to ensure the data integrity of the identifier byte. No software intervention is required until this point, when the ID is presented to the application or driver software. The software performs a lookup and then decides what to do for this message frame.

Because LIN was designed to use inexpensive RC oscillators, the SLIC module was designed to allow an input clock tolerance of about ±50% and ensure that the accuracy of LIN communication is ±1% or less. This wide range of clock accuracy means that in any LIN slave application, it is not necessary to trim the internal oscillator to establish and maintain LIN communications. (Motorola internal RC oscillators, such as the one on the HC908QL4 device, typically come from the factory with a guaranteed tolerance of ±25% before trimming.) This also means that ROM devices are perfectly suited to be used without any nonvolatile memory at all, because they would never need to store a trim value.

High-Speed Communications and Factory Programming

The SLIC is also capable of high-speed operations without the need to change driver code. It will automatically synchronize to LIN messages, up to 120 kbps (depending on CPU speed and filter settings). This is especially useful for downloading code in a factory programming environment.

To accommodate higher speed messages, changes may be required to ensure:

- that the digital receive filter is adjusted, which prevents filtering out valid high-speed data
- that the physical layer device (such as a MC33661 enhanced LIN transceiver) slew rate control is adjusted to prevent attenuating the bits of the high speed message

Smaller, Faster Driver Code

Automation of many standard LIN communication functions allows for much smaller and more efficient driver code, which frees up vital CPU and memory resources. Smaller driver code means that devices with less memory can be used in some applications. Applications that require a 4K FLASH when using an ESCI or timer module might easily fit in a 2K FLASH device if using the SLIC module. Even in a 2K FLASH device (such as HC908QL2), more than 90% of the FLASH memory is available for the application to use.

Fewer Interrupts to Service

Many applications, especially motor control systems, often have stringent timing requirements to maintain adequate control.

To service the LIN communications, the SLIC module requires a maximum of two interrupts for any standard LIN message frame (1 to 8 data bytes). If a message header that the application does not need to handle arrives, the SLIC module would require only one interrupt.

Compared to a UART-based solution, this reduction in interrupts can mean eliminating as many as 10 interrupts per message frame. **Figure 2** shows the interrupts required for servicing an 8-byte LIN request frame using both the SLIC module and a traditional UART-based solution. Channel 1 (third trace from top) of the scope capture shows the ISR firing on the SLIC module (two interrupts required). Channel 4 (fourth trace from top — inverted polarity) shows that 12 interrupts are required to service the same message with a UART-based controller.

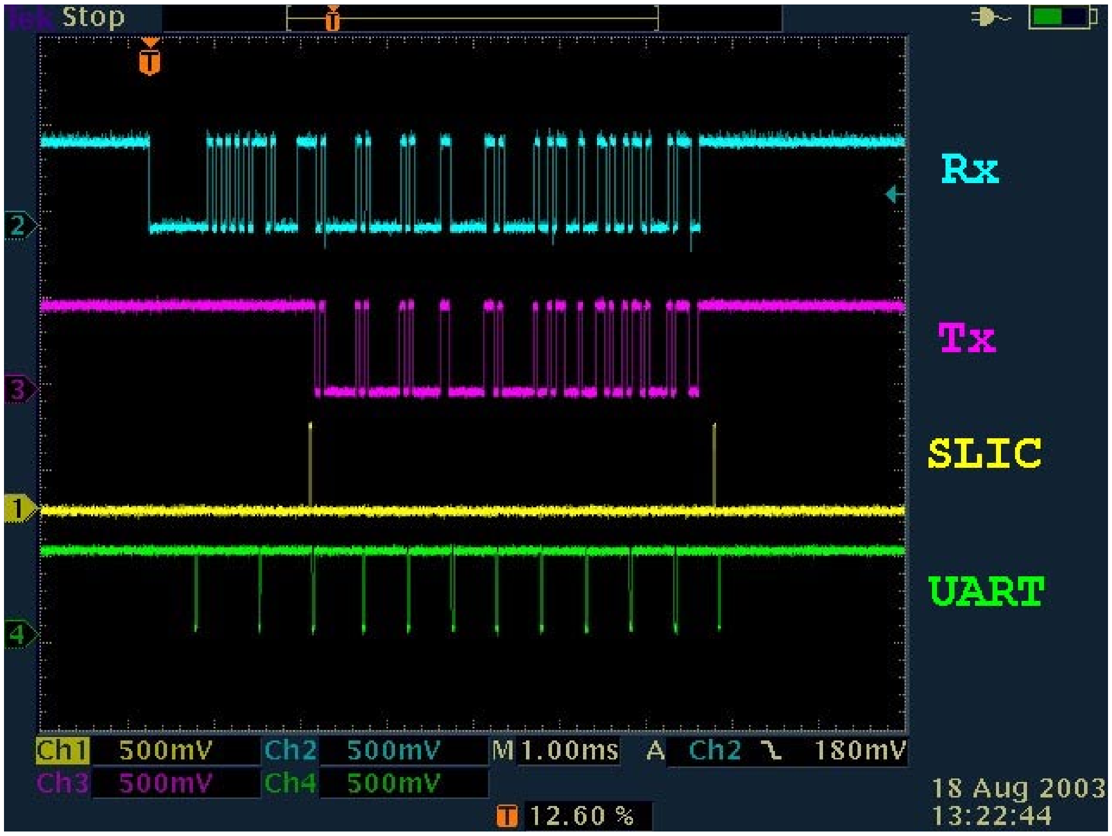


Figure 2. SLIC versus UART-Based Interrupt Handling

With 10 fewer interrupts to service (an 83.3% reduction in interrupts), the CPU is free for a much greater amount of time. Using the SLIC module instead of a UART-based solution significantly reduces the chance of an interrupt interfering with other application operations.

Faster, More Efficient Interrupt Servicing

In addition to reducing the number of interrupts required to service a LIN frame (two interrupts only), the SLIC module has been designed to maximize the efficiency of the interrupt service routine (ISR), which minimizes the CPU requirements for LIN communications. A patented encoding method is used to allow the ISR to service all SLIC interrupts in a short, fixed, and predictable amount of time. Details of this are explained in **CodeWarrior Project — Assembly Source Code Basic SLIC Driver**.

Because the SLIC module automates standard LIN communication functions, less time is spent inside the ISR. Checksum calculations have been automated, which eliminates the extra instructions that would be needed to perform this calculation in a UART solution. This further reduces the amount of time spent inside the communications interrupt handlers. This time is valuable because other interrupts cannot be handled during this time.

Hardware — LIN Kit Demo Board

The LIN kit demo board is made from a QL4 with an added LIN interface, which consists of an MC33399 LIN transceiver and a 5-V regulator (an LT1121 chip). The board can be programmed using either the RS-232 MON08 interface or a Cyclone® or MultiLink® tool.

The board requires three jumpers (J2, J4, and J5) for programming it using the RS-232 MON08 interface. The jumper J2 is however not needed when using a MultiLink or Cyclone tool to program or debug.

NOTE: *If you plan to use MON08 tools for debugging, you must avoid manipulating pin PTA0 since that will disturb the communication with the tool.*

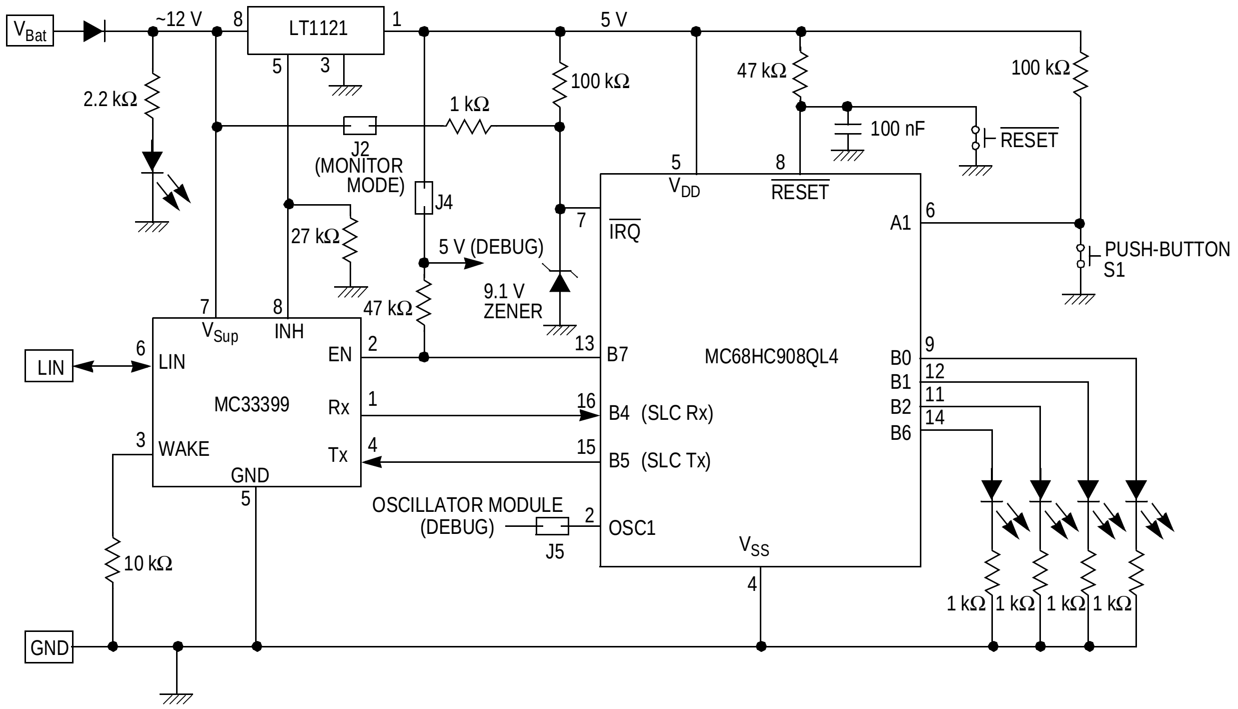


Figure 3. Schematic of QL4 LIN Kit Board

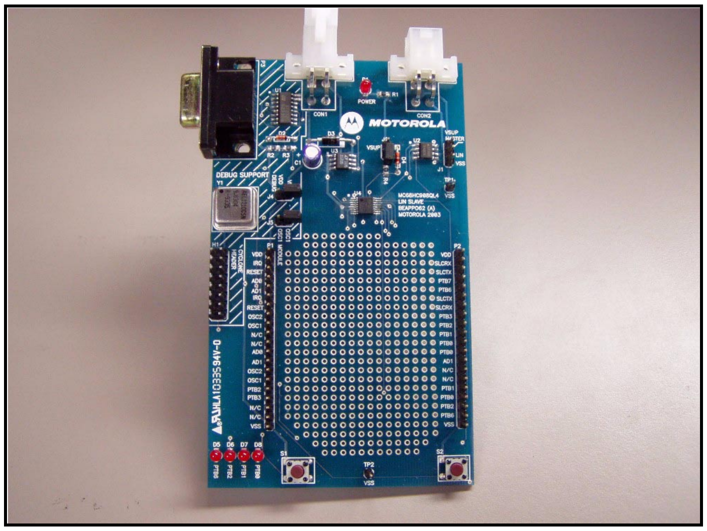


Figure 4. QL4 LIN Kit Board

NOTE: *If the application is designed to be powered down in sleep mode, there are some things to consider when using the QL4 LIN kit board. Because the voltage regulator is connected to the INH pin of the MC33399 physical layer, if the EN pin (connected to PTB7 of the MCU) is driven low in software, it will power down the MCU. LIN network activity would then cause a power-on reset (POR) and code will begin again from scratch.*

Hardware — M68EVB908QL4 Evaluation Board

The QL4 evaluation board is made from a QL4 with an added enhanced LIN interface, which consists of an MC33661 enhanced LIN transceiver and a 5-V regulator (an LT1121 chip). The board can be programmed either using the RS-232 MON08 interface or a Cyclone/MultiLink tool.

The primary difference between the EVB and the LIN kit board is the connection of inputs and outputs. There is only one LED (D1) on the EVB, which is used for displaying the least significant data bit. This bit is inverted in software to accommodate the circuitry differences in the boards, keeping the interface consistent so that a logic 1 turns on the LED.

The other three bits of data, which are output to LEDs D7, D6, and D5 on the LIN kit board, are still brought out to PTB1, PTB2, and PTB6, respectively.

The input button is used differently on the LIN kit board and EVB. Because there is not a dedicated button for the application on the EVB, the reset button is reused. Because the reset function on the QL4 device isn’t active unless activated by software in user mode, there is no problem using this button for the application.

Another major difference with running application code on the EVB is the presence of the enhanced LIN transceiver (MC33661). This allows the possibility of controlling the physical layer slew rate through software control of the enable (EN) pin of the device. Operation of this feature is beyond the scope of this application note. Refer to the documentation for the MC33661 device for more information.

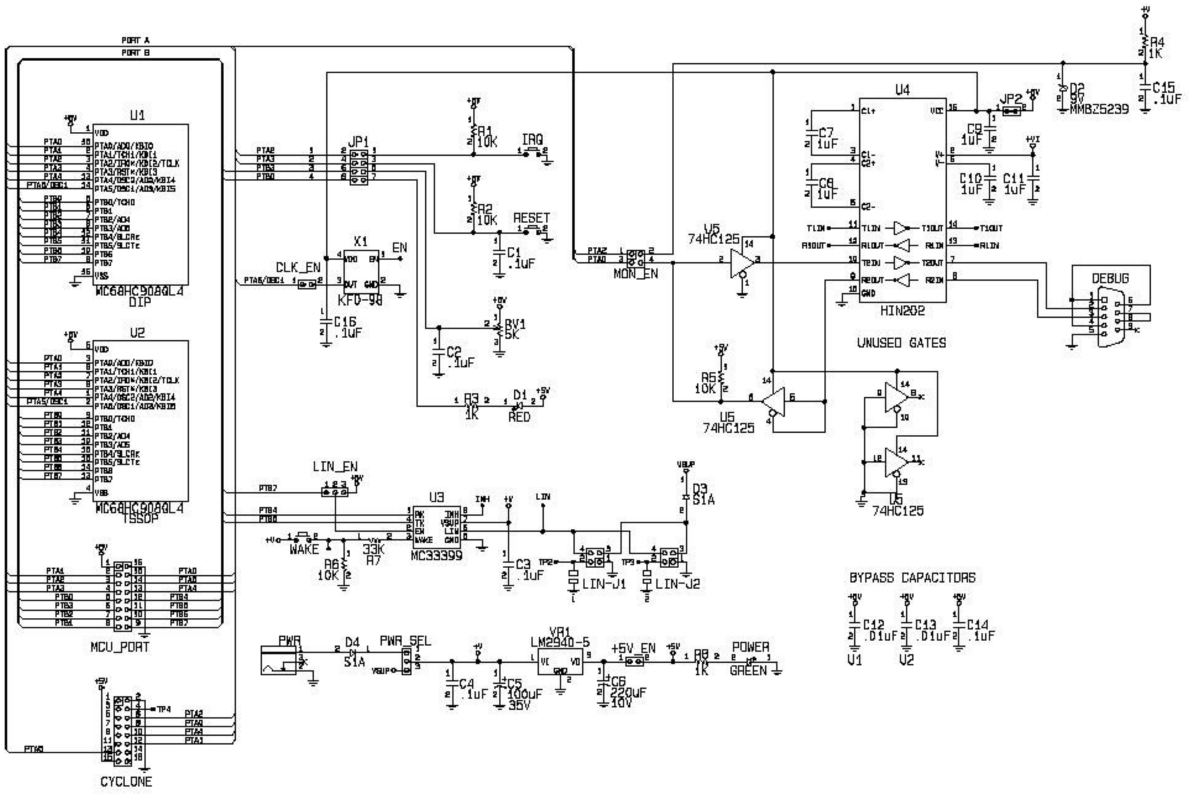


Figure 5. Schematic of M68EVB908QL4 Evaluation Board

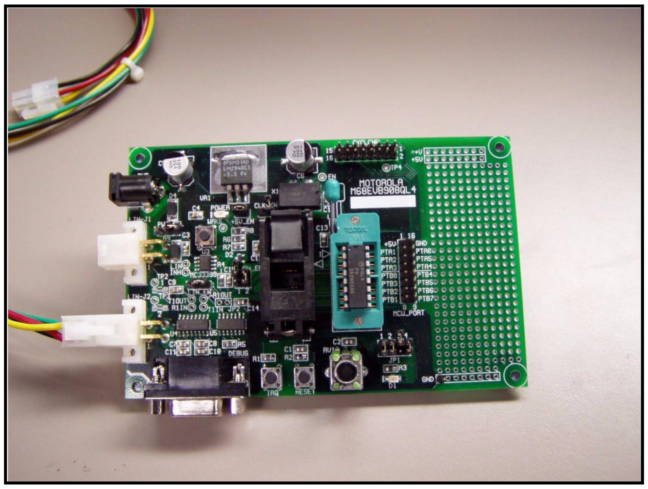


Figure 6. M68EVB908QL4 Evaluation Board

The EVB does not support the regulator inhibit function by the physical layer, so this must be taken into account when using software that handles sleep mode. Care must be taken to ensure that the SLIC module is disabled before disabling the physical layer because recovery from sleep will not result in POR. Sleep mode recovery would then need to re-enable the physical layer first, then re-enable the SLIC module. Details of this are beyond the scope of this application note.

SLIC Driver Code – Three Versions

Three different versions of the SLIC driver code are included in this application note to illustrate several different ways to implement software drivers for this module. All methods serve the same basic purpose, but every method is a different balance of code portability, readability, and efficiency. The primary difference between each version of the driver code is how the SLIC module ISR is written.

The three basic versions of the code are:

- Assembly code version of the SLIC ISR
- Basic C-based version of the same ISR
- C-based driver with a standardized application programmers interface (API). The API is designed to match the API for the QT/QY LIN slave drivers described in AN2599/D.

All versions of the code include a sample application designed for use with either the LIN kit QL4 slave evaluation board or the M68EVB908QL4 evaluation board. To indicate which hardware will be used, uncomment the appropriate `#define` statement at the beginning of the ‘slave.c’ file in the project.

```
// -Use only one of the following define statements --
//#define QL4LINKit       // Use this define for the QL4 LINkit Board
#define QL4EVB            // Use this define for the QL4 EVB Board
```

The sample application responds to message IDs designed for the LIN kit application demo boards. The messaging and details regarding this are explained more fully in AN2573/D: *LIN Kits LIN Evaluation Boards*. The ASM and C versions are designed to respond to only the default IDs. The API version allows the user to dynamically change the ID at runtime (as described in AN2573/D).

One key feature in all versions is a sleep mode function, which turns off the LEDs when no activity has been detected on the bus or button for a long time. Sleep mode is implemented by regularly calling the *Check_LIN_Sleep()* routine in the *main()* routine. This monitors LINSleep flag and sets power states accordingly. Due to differences in hardware between the EVB and LIN kit board, this routine only turns off the LEDs to indicate the sleep mode condition. In actual applications, it is likely the designer would power down the node for sleep mode for energy conservation.

Exact procedures for putting the SLIC to sleep and waking it up again are beyond the scope of this note, but it is important to remember a few basic concepts. Like many communication peripheral modules, the SLIC contains a state machine that synchronizes to the LIN message traffic. It is important to safely disable the SLIC by writing the INITREQ bit **before** turning off the physical layer. Doing this will avoid confusing the state machine and inducing potentially undesirable side effects.

Depending on external circuitry, turning off the physical layer device can have different effects on the rest of the system. On the LIN kit board, for example, disabling the physical layer will activate the inhibit function (INH pin) on the voltage regulator and power down the MCU. LIN bus activity will then restore power to the MCU and the code will go through a POR.

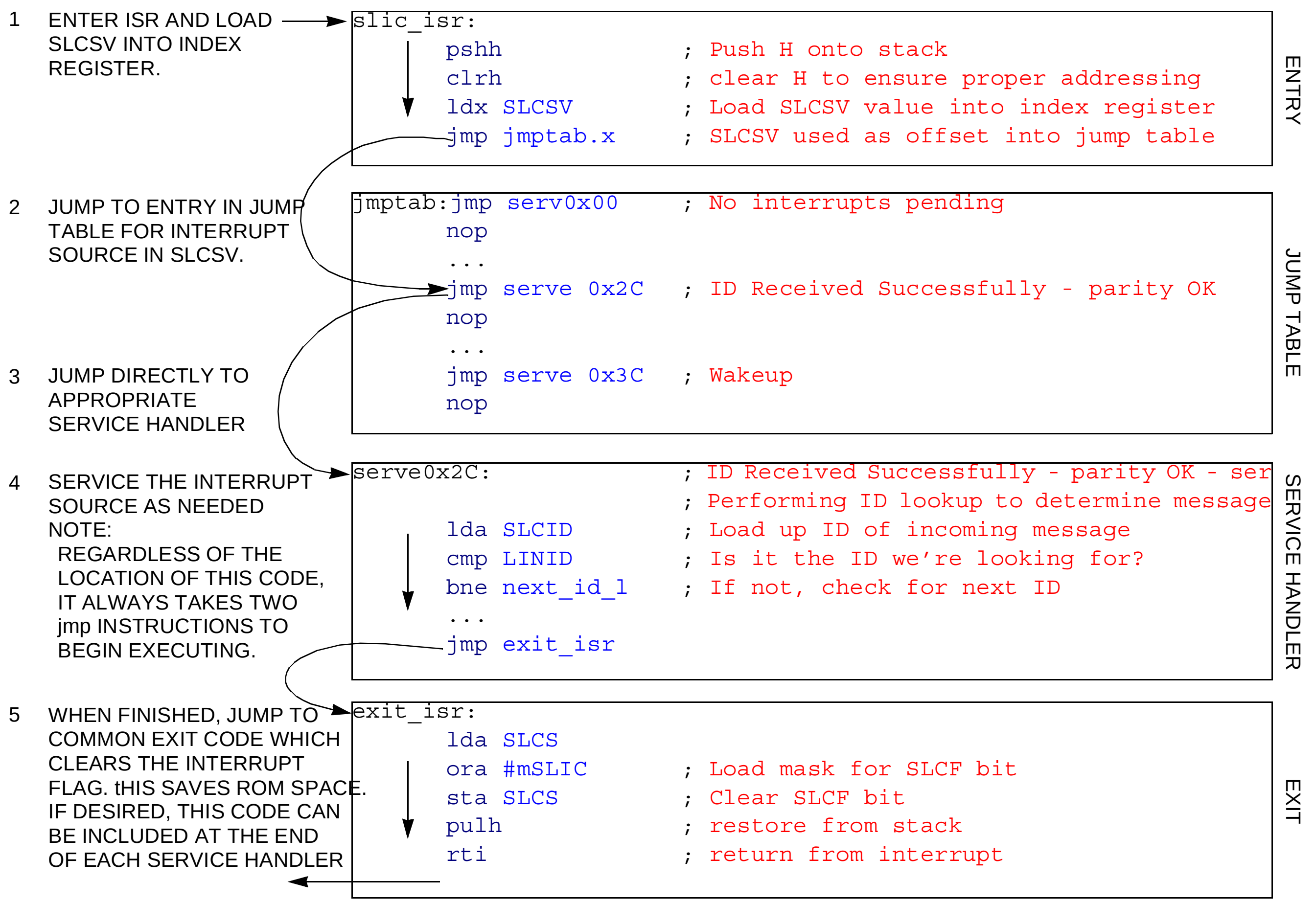
On the EVB, however, the INH pin of the physical layer is not connected to the regulator at all. Turning off the physical layer on the EVB will result in the Rx line to the SLIC being driven to a low state. The SLIC should be disabled first, to prevent it from trying to interpret this as a break symbol. Do NOT try to disable the SLIC from within the SLIC ISR. Disable the SLIC only in a code location outside the ISR such as the *Check_LIN_Sleep()* routine, where the LINSleep flag is recognized and before the physical layer is disabled.

CodeWarrior Project — Assembly Source Code Basic SLIC Driver

The first project described shows a basic C-based LIN slave application with a SLIC ISR written in assembly code. Writing the ISR in assembly allows the greatest degree of control over the performance and the size of the final code. In very small embedded systems, such as those used in LIN slave nodes, code size and performance efficiency are critical to getting the most out of very few resources.

One of the key features of handling the ISR in assembly code is to use the design of the SLIC module to ensure maximum execution efficiency. The SLIC state vector register (SLCSV) is encoded to allow the user to build a jump table. When using a jump table, no matter what interrupt source is being serviced, the ISR will begin servicing the interrupt in a fixed amount of time.

The SLCSV register value is loaded into the index register, then used as an offset into the jump table. The entries in the jump table point to service handler subroutines which handle each SLCSV value accordingly. Figure 7 shows the flow of the assembly based ISR with a SLCSV value of 0x2C (ID Received).


1 ENTER ISR AND LOAD SLCSV INTO INDEX REGISTER.
2 JUMP TO ENTRY IN JUMP TABLE FOR INTERRUPT SOURCE IN SLCSV.
3 JUMP DIRECTLY TO APPROPRIATE SERVICE HANDLER
4 SERVICE THE INTERRUPT SOURCE AS NEEDED NOTE: REGARDLESS OF THE LOCATION OF THIS CODE, IT ALWAYS TAKES TWO jmp INSTRUCTIONS TO BEGIN EXECUTING.
5 WHEN FINISHED, JUMP TO COMMON EXIT CODE WHICH CLEARS THE INTERRUPT FLAG. tHIS SAVES ROM SPACE. IF DESIRED, THIS CODE CAN BE INCLUDED AT THE END OF EACH SERVICE HANDLER
ENTRY
JUMP TABLE
SERVICE HANDLER
EXIT

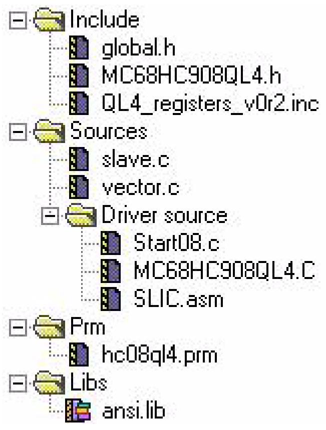
```
slic_isr:
            pshh                ; Push H onto stack
            clrh                ; clear H to ensure proper addressing
            ldx SLCSV           ; Load SLCSV value into index register
            jmp jmptab.x        ; SLCSV used as offset into jump table

jmptab:jmp serv0x00             ; No interrupts pending
            nop
            ...
            jmp serve 0x2C      ; ID Received Successfully - parity OK
            nop
            ...
            jmp serve 0x3C      ; Wakeup
            nop

serve0x2C:                      ; ID Received Successfully - parity OK - ser
                                ; Performing ID lookup to determine message
            lda SLCID           ; Load up ID of incoming message
            cmp LINID           ; Is it the ID we're looking for?
            bne next_id_l       ; If not, check for next ID
            ...
            jmp exit_isr

exit_isr:
            lda SLCS
            ora #mSLIC          ; Load mask for SLCF bit
            sta SLCS            ; Clear SLCF bit
            pulh                ; restore from stack
            rti                 ; return from interrupt
```

Figure 7. SLIC Assembly ISR Flowchart

The jump table serves the same purpose as a `switch(temp_SLCSV)` statement would in a C-based ISR, but the jump table always executes in fixed time. In a `switch(var)` statement, cases near the end of the list might take longer to execute, because all cases must be searched. This may be optimized by the C compiler to minimize execution time, but execution time will still vary based on which case is taken.

It is possible to further optimize this assembly routine by grouping all unused service handlers together so that they can share a common exit point. The entries in the jump table for unused services could even be made to jump directly to the exit code.

As mentioned before, this driver is included in the LIN Kit demo software, which can be downloaded free from the Motorola web site. It also comes with the M68EVB908QL4 evaluation board. It comes in the form of a Metrowerks CodeWarrior 3.0 project (LINQL4-ASM.mcp). The project structure can be seen below:



```
Include
    global.h
    MC68HC908QL4.h
    QL4_registers_v0r2.inc
Sources
    slave.c
    vector.c
    Driver source
        Start08.c
        MC68HC908QL4.C
        SLIC.asm
Prm
    hc08ql4.prm
Libs
    ansi.lib
```

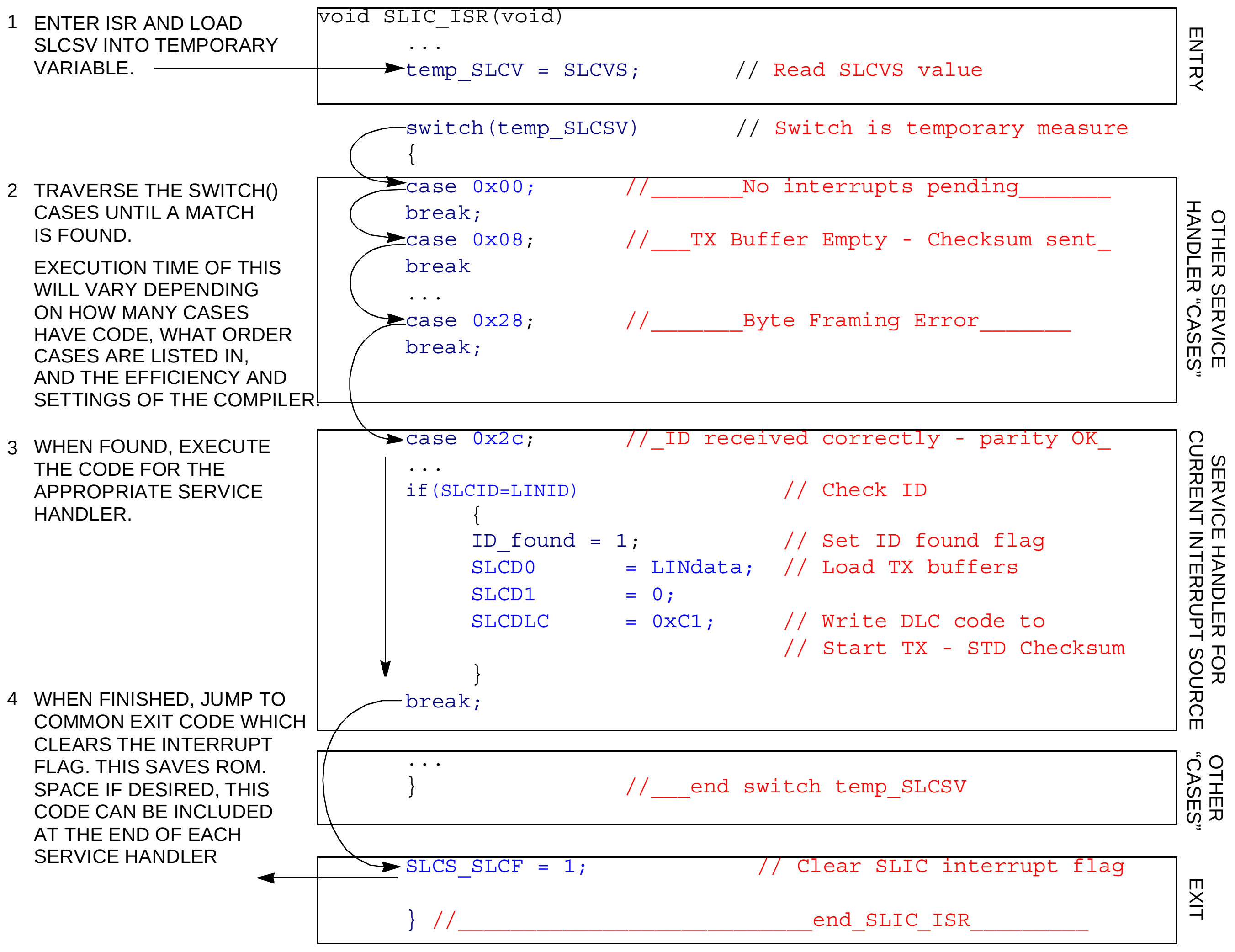
Figure 8. CodeWarrior Project (LINQLY-ASM.mcp) Assembly Source Code

Table 1. Files in LINQL4-ASM.mcp Sample Project

File	Description
SLIC.asm	Contains the main driver code (The LIN driver is contained in the one file)
global.h	Global variable declarations (not used heavily)
MC68HC908QL4.h	MCU register definition header file (non-standard)
QL4_registers_v0r2.inc	ASM register definitions file
slave.c	Main application code
vector.c	MCU vector definitions
Start08.c	Standard HC08 startup code
MC68HC908QL4.C	MCU register data structure instantiations file (also non-standard)
hc08ql4.prm	CodeWarrior parameter file for defining memory locations (ROM and RAM) in the MCU

CodeWarrior Project — C Source Code Basic SLIC Driver

In the C and ASM versions of this code, the same basic functions are performed. The C ISR, in this case, is just a few bytes smaller than the ASM ISR. This is primarily due to the efficiency of the CodeWarrior compiler and the fact that there is not much code to handle many of the different cases. The *switch()statement* in the C ISR is very sparsely populated and the compiler is able to optimize very heavily. In more elaborate driver code, with support for more messages and features, it is likely that the C version would become larger than the ASM version. **Figure 9** shows the flow of the C based ISR with a SLCSV value of 0x2C (ID Received).



1 ENTER ISR AND LOAD SLCSV INTO TEMPORARY VARIABLE.

2 TRAVERSE THE SWITCH() CASES UNTIL A MATCH IS FOUND.

EXECUTION TIME OF THIS WILL VARY DEPENDING ON HOW MANY CASES HAVE CODE, WHAT ORDER CASES ARE LISTED IN, AND THE EFFICIENCY AND SETTINGS OF THE COMPILER.

3 WHEN FOUND, EXECUTE THE CODE FOR THE APPROPRIATE SERVICE HANDLER.

4 WHEN FINISHED, JUMP TO COMMON EXIT CODE WHICH CLEARS THE INTERRUPT FLAG. THIS SAVES ROM. SPACE IF DESIRED, THIS CODE CAN BE INCLUDED AT THE END OF EACH SERVICE HANDLER

```
void SLIC_ISR(void)
      ...
      temp_SLCV = SLCVS;        // Read SLCVS value

      switch(temp_SLCSV)        // Switch is temporary measure
      {
      case 0x00;        //_______No interrupts pending_______
      break;
      case 0x08;        //___TX Buffer Empty - Checksum sent_
      break
      ...
      case 0x28;        //_______Byte Framing Error_______
      break;

      case 0x2c;        //_ID received correctly - parity OK_
      ...
      if(SLCID=LINID)                   // Check ID
           {
           ID_found = 1;                // Set ID found flag
           SLCD0        = LINdata;      // Load TX buffers
           SLCD1        = 0;
           SLCDLC       = 0xC1;         // Write DLC code to
                                        // Start TX - STD Checksum
           }
      break;

      ...
      }                 //___end switch temp_SLCSV

      SLCS_SLCF = 1;            // Clear SLIC interrupt flag

      } //___________________________end_SLIC_ISR_________
```

ENTRY
OTHER SERVICE HANDLER "CASES"
SERVICE HANDLER FOR CURRENT INTERRUPT SOURCE
OTHER "CASES"
EXIT

Figure 9. SLIC-Based ISR Flowchart

An additional feature of the C version of the basic driver is that it will accept a 2-byte message with an ID of 0x97. This is shown as an example of how to handle a LIN command message, where data is coming from the master node.

As mentioned before, this driver is included in the LIN kit demo software, which can be downloaded free from the Motorola web site. It also comes with the M68EVB908QL4 evaluation board. It comes in the form of a Metrowerks CodeWarrior 3.0 project (LINQL4-C.mcp). The project structure can be seen in **Figure 10**.

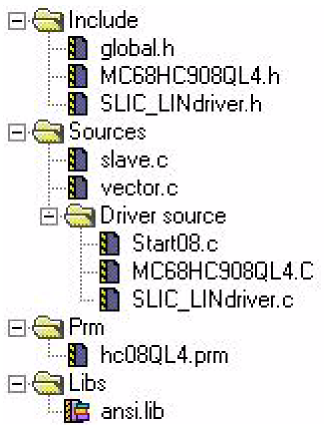


Figure 10. CodeWarrior Project (LINQL4-C.mcp) C Source Code

The LIN driver consists of two files:

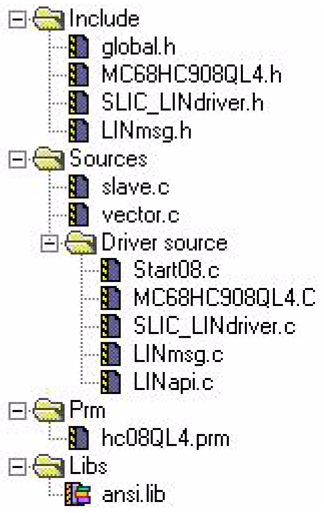
- SLIC_LINdriver.c — contains the main driver code
- SLIC_LINdriver.h — header file for the driver

The other files serve the same functions as they do in the assembly version project.

CodeWarrior Project — C Source Code SLIC Driver with API

The API version of the code is designed to provide essentially the same interface as the one contained in AN2599/D for QT/QY LIN slave drivers.

As mentioned before, this driver is included in the LIN kit demo software, which can be downloaded free from the Motorola web site. It also comes with the M68EVB908QL4 evaluation board. It comes in the form of a Metrowerks CodeWarrior 3.0 project (LINQL4-API.mcp). The project structure can be seen below:



```
Include
    global.h
    MC68HC908QL4.h
    SLIC_LINdriver.h
    LINmsg.h
Sources
    slave.c
    vector.c
    Driver source
        Start08.c
        MC68HC908QL4.C
        SLIC_LINdriver.c
        LINmsg.c
        LINapi.c
Prm
    hc08QL4.prm
Libs
    ansi.lib
```

Figure 11. CodeWarrior Project (LINQL4-API.mcp) — C Source Code with Standard API

The LIN driver consists of four files:

Table 2. Files in LIN Driver

File	Description
SLIC_LINdriver.c	contains the main driver code[1]
LINapi.c	contains all the driver API functions
LINmsg.c	where all LIN message frames are defined
SLIC_LINdriver.h	header file for the driver

1. This is a different file than the one in the C project

The SLIC_LINdriver.c file used in the API version is different and more generic for the API project than for the C project. It is designed to work with the LINmsg.c file to search for messages, rather than hard coding them directly into the interrupt service routine as the C project does.

The structure of LINmsg.c is very similar to the one used in AN2599/D with one important difference. The SLIC module contains a register called the SLIC Data Length Code register (SLCDLC) which encodes the number of bytes in a message frame, the type of checksum calculation to be used (standard or enhanced), and whether the SLIC is to transmit or receive this frame. To simplify the ISR code for the API version, a data structure in LINmsg.c called `MessageDLCTbl[]` contains the appropriate value for this register for each message defined. This `MessageDLCTbl[]` replaces the function of `MessageCountTbl[]` in the AN2599/D drivers.

The other files serve the same functions as they do in the assembly and C projects.

How to Use the API Driver

The easiest way to begin developing a new application is to use the API sample project. To do this, simply replace the sample application file slave.c with your own application code. You can also begin developing by creating a new project in a CodeWarrior development environment and adding the four LIN driver files to the project. Then:

1. Define the messages you want to use, in the LINmsg.c file, as described below.
2. Make sure the vectors (*_Startup()* uses vector 0 and *SLIC_ISR()* uses vector 10) are set up properly, either in the vector.c file or in a parameter file.
3. Don't forget to #include the file LINdriver.h in your application code file.

API Driver Configuration

The driver configuration file, LINmsg.c, can be edited by the user. It contains definitions of all messages to be recognized by the application and is set up for the demo code to recognize all four possible IDs for the demo application. Setting up this file is all that is needed for configuration of the API driver for normal LIN applications.

Message File Configuration

All LIN message frames that the slave node is to use in the application must be defined in the LINmsg.c file.

- **Message buffers** — Define one array for each message frame that either requires a response or must be received. When defining, it is good practice to include the frame ID in the name (for example, “Message0xID”, where ID is the message identifier in hexadecimal with the parity bits included).

  This buffer is for the frame data field for each message. The data field can be 1 to 8 bytes. The array size must equal the number of data bytes for that message. An example of a 2-byte message could be:
  `U8 volatile Message0xD8[2];`

After message buffer storage has been created for all messages that will be recognized by the node, these must be included in a number of additional arrays. The order of the messages must be consistent in all arrays. The following three arrays are required:

- **MessagePointerTbl[]** — Consists of pointers to all message buffers defined above.

  Example: `U8 volatile * MessagePointerTbl[] = {Message0xD8, Message0x99,…};`

- **IdTbl[]** — Contains all IDs relevant to this node. It is very important that the ID includes the parity bits. The order of the messages must be the same as in MessagePointerTbl[] and MessageDLCTbl[].

  Example: `U8 const near IdTbl[] = {0xD8, 0x99,…};`

- **MessageDLCTbl[]** — Defines the SLIC data length code register values for each message. This control register in the SLIC module tells the hardware how many bytes of data are in the message, shows if the message should be sent or received by the slave, and what method of checksum calculation should be used to ensure data integrity. LIN 2.0 allows for standard or enhanced checksum, where the ID byte is included in the calculation. This DLC register value is copied directly to the SLCDLC register at the appropriate time during the message interrupt handling to send or receive data for this message frame with the proper checksum calculation method.

  Example: `U8 volatile near MessageDLCTbl[] = {0xC1,0x44,0x47,…};`

  This example shows that the message with ID 0xD8 (in IdTbl above) is 2 bytes long (plus checksum), uses standard checksum (ID not included), and it is defined for sending.

Remember that the order of the messages must be consistent in all previous tables. All the arrays (except the message buffers) must to be named as described above.

NOTE: *The data type U8 frequently used in the driver and its API is defined as an unsigned 8-bit number. For this compiler this is done as “unsigned char.”*

API

The API that comes with the driver makes it easier for the application developer to interface to the driver, as it is not necessary to know anything about the communications protocol behind how messages are sent and received. Most of this is handled by the SLIC module autonomously, so there is not much behind the API, but it does provide an abstraction layer between low-level driver and application. This section describes an overview of the functions and constants used in the API.

The API includes status constants that describe:

- Status of the service calls (such as sending or receiving)
- Status of individual messages (such as empty, updated, or overrun)

Table 3. LIN Message Status Constants

Constant	Description	Value
LIN_OK	Service call succeeded without any error	0x00
LIN_ INVALID_ID	The ID requested is defined for the node, but for the opposite direction (sending/receiving)	0x80
LIN_NO_ID	The message ID requested is not defined for this node	0x7F
LIN_INVALID_MODE	The service couldn’t be called in the current driver state	0x16

Table 4. LIN Message Status Flow

Constant	Description	Value
LIN_MSG_NODATA	The data buffer for this message is empty, i.e,. data has not been initialized or received yet	0x01u
LIN_MSG_OK	Message data OK, i.e. not overrun and not empty	0x10u
LIN_MSG_NOCHANGE	The message data has not changed since last read/written	0x02u
LIN_MSG_UPDATED	Message data has been updated	0x20u
LIN_MSG_OVERRUN	The message data has not been read and was overwritten	0x04u

LIN Message Status Flow

The message status is stored in the table called LinMsgStatus[]. When the LIN driver is initialized all messages will get the status LIN_MSG_NODATA. Message status will change when the message is being sent, received, or updated.

Table 5 demonstrates the change of status after *PutMsg()* is called or a message is received at a node.

Table 5. Status Change after *PutMsg()* is Called

Previous State	Next State
LIN_MSG_NODATA	LIN_MSG_UPDATED
LIN_MSG_OK	
LIN_MSG_NOCHANGE	
LIN_MSG_UPDATED	LIN_MSG_OVERRUN
LIN_MSG_OVERRUN	

Table 6 demonstrates the change of status after *GetMsg()* is called or data is sent from a node.

Table 6. Status Change after *GetMsg()* is Called

Previous State	Next State
LIN_MSG_UPDATED	LIN_MSG_OK
LIN_MSG_OVERRUN	
LIN_MSG_OK	LIN_MSG_NOCHANGE
LIN_MSG_NOCHANGE	
LIN_MSG_NODATA	LIN_MSG_NODATA

API Functions

LIN_Init()

This function initializes the LIN driver and makes the driver ready to detect LIN communication. Initialization of the driver includes:

- Initializing the SLIC module
- Clearing error flags
- Clearing the sleep flag
- Initializing the message buffer status

LIN_Init() must be called before any other LIN API function is called. It takes no parameters and returns nothing.

Usage example: `LIN_Init();`

LIN_GetMsg()

This function is used for getting the data of the message with a certain ID and copying its message data into a buffer. The parameters for this function are the ID of the message (with parity) and a pointer to the buffer where to put the message data.

LIN_GetMsg() returns a status constant describing whether the call was successful (LIN_OK, LIN_INVALID_ID, LIN_NO_ID).

If the status is not LIN_OK, no data will have been retrieved from the buffer. If the message data has been copied into the buffer, the status of the message will be changed to show that the message has been read. Frame-level atomic operation is automatically guaranteed by the fact that while the SLIC_ISR is transferring data from the SLIC module to the message buffer, interrupts are suspended.

Usage example: `status = LIN_GetMsg (0x99, MsgData);`

LIN_PutMsg()

This function is used for copying data to send from a temporary buffer into the message data of the message with a certain ID. The parameters for this function are the ID of the message (with parity) and a pointer to the buffer where the data to send can be found. The function returns a status constant describing whether the call was successful or not (LIN_OK, LIN_INVALID_ID, LIN_NO_ID). When the message data has been updated, the message status will be changed to show that the message has been written. The call itself does not send any data on the LIN bus, however the next time the master requests this ID, the updated data will be sent. Frame-level atomic operation is guaranteed because the *LIN_PutMsg()* routine disables interrupts during the buffer copy operation.

Usage example: `status = LIN_PutMsg (0x1A, MsgData);`

LIN_MsgStatus()

This function returns the current status of the specified message. It takes the message ID (with parity) as a parameter. If the ID is not defined, the function will return LIN_NO_ID.

Usage example: `msgstatus = LIN_MsgStatus (0x1A);`

LIN_GotoRun()

This function changes the current driver state from SLEEP to RUN by clearing the LINSleep flag. If the driver state is RUN (LINSleep = 0), the function does nothing. It takes no parameters and returns nothing.

Note: This function should be called before calling *LIN_Wakeup()*.

Usage example: `LIN_GotoRun();`

LIN_Wakeup()

LIN_Wakeup() issues the LIN wake-up signal, which consists of eight dominant bits (including start bit) followed by at least four recessive bits (including stop bit and a recessive pause).

This function uses the WAKETX bit feature of the SLIC module to send a single wake-up signal on the bus. No wake-up signal is sent if the driver is in SLEEP state (the LINSleep flag is set) because the *LIN_GotoRun()* function should have been called before, which changes the state to RUN (clear LINSleep = 0). After the wake-up signal is sent, there should be a SynchBreak and communication should resume from the master.

LIN_Wakeup() takes no parameters. There are two possible return values, either LIN_OK (the wake-up signal was successfully sent) or LIN_INVALID_MODE (if the current driver state is SLEEP).

Usage example: `status = LIN_Wakeup();`

Error Handling

The driver detects two types of errors in the LIN message — bit errors and checksum errors.

A bit error is detected when a recessive bit is sent and a dominant bit is detected on the bus. This indicates that the bus is controlled by another node or shorted to GND. In either case, the transmission is aborted and the BitERROR flag is set.

The SLIC automatically detects bit errors and this function in the ISR simply sets the BitERROR flag in the API. The user must then clear the flag when the BitERROR condition is handled (generally setting up for a re-transmission of the corrupted error frame).

The node receiving data will calculate the checksum by doing a modulo-256 sum of the message data bits. This checksum must match the received checksum. If not, the message is corrupt, and the receiving node will set the ChecksumERROR flag and ignore the received data.

As with the bit error, checksum errors are automatically detected by the SLIC module, then the ISR simply sets the ChecksumERROR flag. Note that a checksum error might occur if the message DLC value in the MessageDLCTbl[] array in LINmsg.c was set incorrectly.

The error flags are single bit field values that are set by the driver (set to 1) and cleared by the application code (set to 0). The flags are global and can be polled in the application to check whether there is an error during send or receive.

Table 7 provides a description of bit errors and checksum errors.

Table 7. Error Descriptions

Flag	Description
BitERROR	Set if there is a bit error when sending
ChecksumERROR	Set if there is a checksum error while receiving

Sleep Mode

The LIN protocol includes a sleep mode, which reduces system power consumption. A message with ID 0x3C and first data byte of 0x00 is used to broadcast the Sleep Mode command. The API driver will respond to this sleep mode message by setting the sleep flag (LINSleep). As stated before, the method of putting the module in sleep mode is hardware/design dependent and is therefore handled by the application code.

Driver Performance — Timer, UART, and SLIC Compared

The following performance data compares various methods of implementing LIN communications with different hardware and software options. All are based on using the same basic application found in the LIN kits demonstration software (modified to accommodate an 8-byte message). This data allows the developer to balance cost, performance, and other MCU features for a specific application.

One of the key advantages to the SLIC module is its ability to simplify user application code. **Table 8** shows the RAM and ROM usage of the various implementations, along with the QY bit-banged driver using a timer channel and an ESCI version. These numbers show the memory usage for the LIN kit application.

Table 8. Driver Performance Metrics

	Version	Std API	Feature Level	Driver Code Resource Required		
				RAM (Bytes)	ROM (Bytes)	Stack (Bytes)
TIM08	QY/QT bit-banged drivers AN2503/D(1)	N	MIN	24 (+ 8 per 8 byte msg)	536 (+ 3 per msg)	22
			MAX		836 (+ 3 per msg)	22
	QY/QT bit-banged drivers AN2599/D	Y	—	32 (+12 per 8 byte msg)	1103 (driver) 487 (API)	35
ESCI	EY16 ESCI drivers AN2575/D(2)	Y	—	19 (+1 per 8 byte msg)	1130 (driver + API)	< 25
SLIC	LINQL4-ASM	N	—	11 (+ 8 per 8 byte msg)	172	7
	LINQL4-C	N	—	18 (+ 8 per 8 byte msg)	120	20
	LINQL4-API	Y	—	32 (+ 12 per 8 byte msg)	838 (driver) 420 (API)	35

1. AN2503/D driver assumptions:
   MIN = external OSC, 9600 bps, no SLEEP mode, no parity check, no bit error checking
   MAX = internal OSC, 19200 bps, SLEEP, parity checking, and bit error checking enabled
   Each also has 7 messages defined, using 26 bytes of RAM

2. AN2575/D memory usage data comes from LIN08 driver manual for EY16.

Another key advantage to the SLIC is its ability to dramatically reduce the number of required interrupts and the time spent in servicing those interrupts. **Table 9** shows a relative comparison of the CPU and interrupt loading impacts of the SLIC and various other driver implementations. All have been normalized to 3.2 MHz operation and 8-byte messages to accurately compare the relative performance of each hardware and software combination.

In the QL4 MCU, the internal oscillator speed may be increased to 6.4 MHz by setting the bus frequency select bit (BFS) in the oscillator status register (OSCSTAT). This will further reduce the CPU loading by cutting ISR execution times in half. This means that it is possible to reduce the average CPU usage on the QL4 to below 0.1% and peak usage to 17 μs for an 8-byte LIN message at 9615 bps.

Table 9. Driver Performance Metrics

	Version	Std API	No. of Interrupts/ Msg Frame (8-byte msg)	LIN Bus Speed	CPU Speed (MHz)	CPU Usage[1]	
						Average[2]	Peak
TIM08	QY/QT bit-banged drivers AN2503/D	N	111 Rx[3] 120 Tx	9,615	3.2	14% (rx) 20% (tx)	193 µs
				19,230		29% (rx) 40% (tx)	
	QY/QT bit-banged drivers AN2599/D	Y	97 Rx 106 Tx	9,615		20% (rx) 20% (tx)	272 µs
				19,230		38% (rx) 44% (tx)	
ESCI + TIM08	EY16 ESCI drivers AN2575/D	N	12	9,615	3.2[4] (calculated)	2% (rx) 4% (tx)	39 µs
				19,230		4% (rx) 7% (tx)	
SLIC	LINQL4-ASM AN2633/D	N	2	9,615	3.2	0.3 (rx) 0.2 (tx)	34 µs
				19,230		0.5 (rx) 0.5 (tx)	
	LINQL4-C AN2633/D	N		9,615		0.4 (rx) 0.4 (tx)	61 µs
				19,230		0.8 (rx) 0.8 (tx)	
	LINQL4-API AN2633/D	Y		9,615		0.8 (rx) 0.8 (tx)	123 µs
				19,230		1.6 (rx) 1.7 (tx)	

1. CPU usage represents the time spent in the communication ISR(s) vs. time spent doing other tasks. API functions and handling performed outside of the ISR(s) is not counted against this metric. Average value is reported as a percentage of times, but is still a function of CPU speed, as LIN communications is asynchronous to CPU operations. CPU usage numbers are approximate. Peak time represents the longest single interrupt that must be processed.

2. *From LIN08 Driver User's Manual:* CPU performance is calculated as: L = T active / T frame * 100%
where:
- L is the CPU load in percent;
- T active is the amount of CPU time expended in executing the driver code during T frame;
- T frame is the amount of time required to transmit or receive a regular LIN bus frame of maximum length, containing 8 bytes of data (124 bits). The required LIN message budget of 40% is also taken into account. For Reference: T frame (9615 bps) = 18.055 ms; T frame (19230 bps) = 9.028 ms.

3. For received data (command) messages, 0x55 data and checksum used for worst case ISR load.

4. EY16 CPU usage information was measured based on 4.9152 MHz CPU frequency, then recalculated for a 3.2 MHz CPU frequency.

The difference in the number of interrupts serviced is best seen on an oscilloscope showing the ISR pulses. Figure 12 shows the interrupts required to service an 8-byte request message at 9600bps.

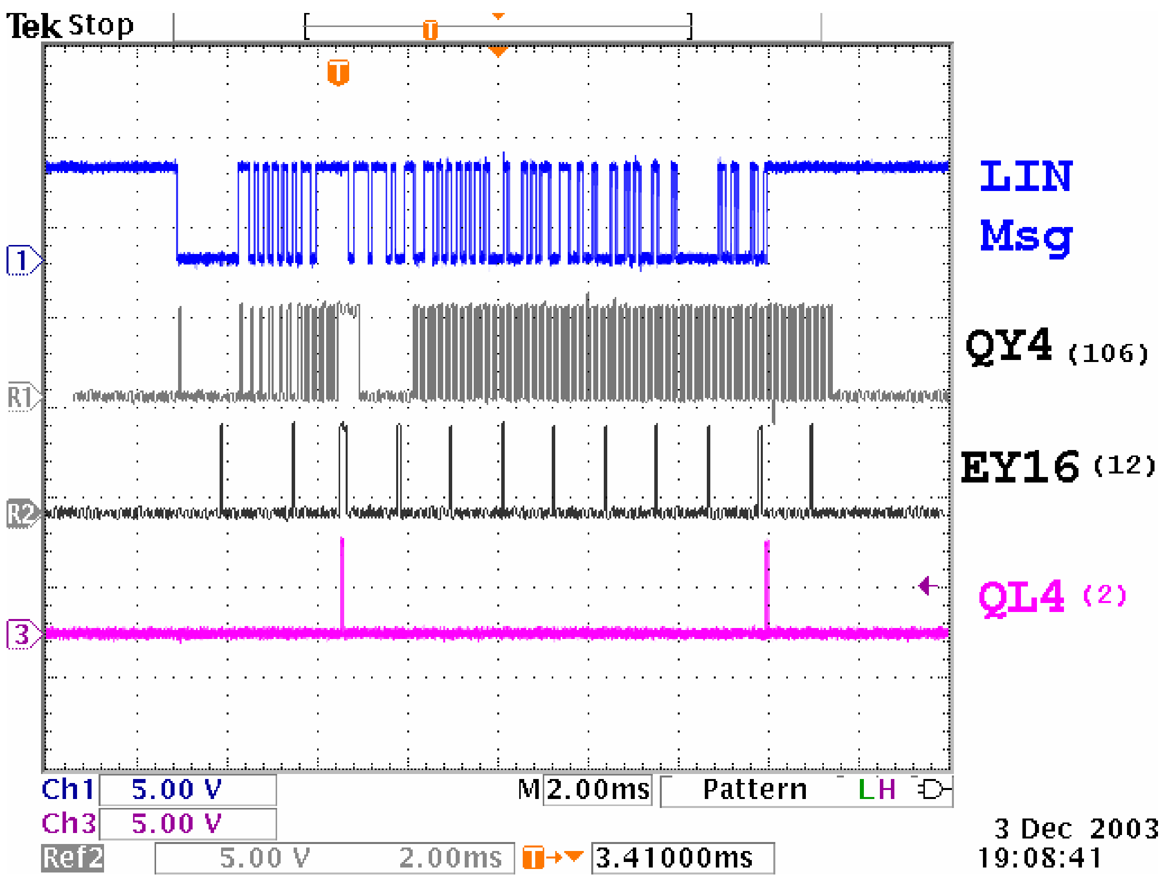


Figure 12. 8-Byte LIN Request Message and Interrupt Handling for HC908QY4, HC908EY16, and HC908QL4

Channel 1 shows the LIN message as seen at the RX pin of the QL4 slave device. Channel R1 is a stored waveform showing the 106 interrupts required to bit bang the message. The interrupts seem to extend past the end of the message frame, but this is due to the delay between the ID lookup and the beginning of the slave's response. Channel R2 is also a stored waveform showing the 12 interrupts required for an EY16 based slave. Channel 3 shows the 2 interrupts required by the QL4 slave node with the SLIC module.

This performance data suggests that the QL4 and EY16 MCUs are better suited for CPU-intensive applications (such as motor control). For simpler, less time-critical applications (such as contact monitoring), the QY4 should be sufficient. MCU selection must be made by balancing cost and resource requirements of CPU and memory.

References

MC68HC908QL Data Sheet, Motorola Document Number: MC68HC908QL4/D

LIN Specification Package, Rev.1.3, Dec. 12, 2002

LIN Specification Package, Rev.2.0, Sept. 16, 2003

AN2503/D: *Slave LIN Driver for the MC68HC908QT/QY MCU*

AN2573/D*: LIN Kits LIN Evaluation Boards*

AN2599/D: *Generic LIN Driver for MC68HC908QY4*

AN2575/D: *MC68HC908EY16 ESCI LIN Drivers*

M68EVB908QL4_SCH_D.pdf – M68EVB908QL4 board schematics

LIN08 Driver User's Manual, Rev 1.1, March 13, 2001

Appendix A: Software Listings — SLIC.asm

```
;/___________________________________________________________________________
;/ Title: SLIC.asm                                    Copyright (c) Motorola 2003
;/
;/ Assembler:  P&E Microcomputer Systems - CASM08Z  (v3.16)
;/ Compiler:   Codewarrior....
;/
;/ Revision History:
;/ Rev #      Date       Who     Comments
;/ ------  -----------   ------  -----------------------------------------------
;/  0.1     28-Oct-03    MR      Initial release -
;/
;/ Filename:     LINQL4-ASM/src/SLIC.asm
;/ Author:       Matt Ruff
;/ Revision:     0.1
;/
;/ Functions:    SLIC module routines
;/
;/ History:
;/
;/ Description:
;/
;/ Notes:
;/
;/____________________________________________________________________________
```

```
            Include 'QL4_registers_v0r2.inc'    ; MC68HC908QL4

            XDEF slic_isr
            XDEF slic_init                      ; Routine to initialize the SLIC

MyData:     SECTION  SHORT
            XREF LINdata                        ; Global varibles use XREF
            XREF LINID
            XREF BusOff
            XREF LINSleep

MyCode:     SECTION
;/+------------------------------------------------------------------------------+
;/|  SLIC_Init - Initializes SLIC module                                         |
;/|                                                                              |
;/|  Configures SLIC for:                                                        |
;/|        1. LIN or BTM mode operation                                          |
;/|        2. Clock Operation in MCU Wait Mode                                   |
;/|        3. Receive filter prescaler adjustment for data rate                  |
;/|        4. Bit timing setting (BTM mode)                                      |
;/+------------------------------------------------------------------------------+
slic_init:
    lda        #mINITREQ                    ;
    coma                                    ; Invert mask
    and        SLCC1                        ; AND with SLCC1
    sta        SLCC1
wait:
    lda        #mINITACK                    ; Wait for INITACK to clear
    and        SLCS                         ;
    cmp        #0                           ; See if INITACK set
    bne        wait                         ; Branch if INITACK still set
    lda        #$80                         ;
    sta        SLCP                         ; Set filter prescaler
    lda        SLCC2                        ;
    ora        #mSLCE
    sta        SLCC2                        ; Enable SLIC module
    rts


;/+------------------------------------------------------------------------------+
;/|                                                                              |
;/|  SLIC_ISR - Interrupt Service Routine                                        |
;/|                                                                              |
;/|  Main handler for SLIC interrupts                                            |
;/|                                                                              |
;/+------------------------------------------------------------------------------+
slic_isr:
        pshh                         ; Push H onto stack
        clrh                         ; Clear H to ensure proper addressing

        ldx SLCSV                    ; Load SLCSV value into index register
        jmp jmptab,x                 ; SLCSV used as offset into jump table

jmptab: jmp serve0x00                ; No interrupts pending
        nop
        jmp serve0x04                ; No-Bus-Activity
        nop
        jmp serve0x08                ; TX Buffer Empty - Checksum sent
        nop
        jmp serve0x0C                ; TX Buffer Empty
        nop
        jmp serve0x10                ; RX Buffer Full - Checksum OK
        nop
        jmp serve0x14                ; RX Buffer Full
        nop
        jmp serve0x18                ; Bit-Error
        nop
        jmp serve0x1C                ; RX Buffer Overrun
        nop
        jmp serve_none               ; <reserved>
        nop
        jmp serve0x24                ; Checksum Error
        nop
        jmp serve0x28                ; Byte Framing Error
        nop
        jmp serve0x2C                ; ID Received Successfully - parity OK
        nop
        jmp serve0x30                ; ID Parity Error
        nop
        jmp serve0x34                ; Inconsistent-Synch-Field Error
        nop
        jmp serve_none               ; <reserved>
        nop
        jmp serve0x3C                ; Wakeup
        nop
serve0x00:                           ; No interrupts pending - service handler
        jmp exit_isr
serve0x04:                           ; No-Bus-Activity - service handler
        inc BusOff                   ; Add 1 to BusOff
        lda BusOff
        cmpa #$02                    ;
        bne end0x04                  ;
        inc LINSleep                 ; Set LINSleep flag
        lda #0
        sta BusOff                   ; Reset BusOff counter
end0x04:
        jmp exit_isr
serve0x08:                           ; TX Buffer Empty - Checksum sent - service handler
;        jmp exit_isr                 ; --- uncomment to terminate service routine code
serve0x0C:                           ; TX Buffer Empty - service handler
        jmp exit_isr
serve0x10:                           ; RX Buffer Full - Checksum OK - service handler
        jmp exit_isr
serve0x14:                           ; RX Buffer Full - service handler
;        jmp exit_isr                 ; --- uncomment to terminate service routine code
serve0x18:                           ; Bit-Error - service handler
;        jmp exit_isr                 ; --- uncomment to terminate service routine code
serve0x1C:                           ; RX Buffer Overrun - service handler
;        jmp exit_isr                 ; --- uncomment to terminate service routine code
serve0x24:                           ; Checksum Error - service handler
```

```
;        jmp exit_isr                 ; --- uncomment to terminate service routine code
serve0x28:                           ; Byte Framing Error - service handler
        jmp exit_isr
serve0x2C:                           ; ID Received Successfully - parity OK - service handler
                                     ; Performing ID lookup to determine message meaning
        lda SLCID                    ; Load up ID of incoming message
        cmp LINID                    ; Is it the ID we're looking for?
        bne next_id_1                ; If not, check next for next ID
        lda LINdata
        sta SLCD0                    ; Load data byte 0
        lda #$00
        sta SLCD1                    ; Load data byte 1
        lda #$C1
        sta SLCDLC                   ; Write DLC - TX, STD Checksum, 2 bytes
        bra id_lookup_done
next_id_1:                          ; If additional IDs to be searched for, enter handler here
not_found:                           ; ID not found - Ignore message frame
        lda #0
       sta SLCDLC                      ; Alpha sample workaround - write 00 to DLC before IMSG
        lda SLCC1
        ora #mIMSG
        sta SLCC1                    ; Set IMSG bit
id_lookup_done:
        lda #0                       ;
        sta LINSleep                 ; Clear LINSleep - saw bus traffic
        jmp exit_isr
serve0x30:                           ; ID Parity Error - service handler
;        jmp exit_isr                 ; --- uncomment to terminate service routine code
serve0x34:                           ; Inconsistent-Synch-Field Error - service handler
;        jmp exit_isr                 ; --- uncomment to terminate service routine code
serve0x3C:                           ; Wakeup - service handler
;        jmp exit_isr                 ; --- uncomment to terminate service routine code
serve_none:                          ; default - service handler
exit_isr:
        lda SLCS
        ora #mSLCF                   ; Load mask for SLCF bit
        sta SLCS                     ; Clear SLCF bit
        pulh                         ; restore from stack
        rti                          ; return from interrupt
```

Appendix B – Software Listings – SLIC_LINdriver.c

```
;**************************************************************************************
//_____________________________________________________________________________
// Title: SLIC_LINdriver.c                    Copyright (c) Motorola 2003
//
// Assembler:  P&E Microcomputer Systems - CASM08Z  (v3.16)
// Compiler:   Codewarrior....
//
// Revision History:
// Rev #      Date       Who     Comments
// ------  -----------   ------  ------------------------------------------------
//  0.1     11-Aug-03    MR      Initial release -
//
// Filename:     LINQL4-C/src/SLIC_LINdriver.c
// Author:       Matt Ruff
// Revision:     0.1
//
// Functions:    SLIC module routines
//
// History:
//
// Description:
//
// Notes:
//
//_____________________________________________________________________________

#include "global.h"
#include "MC68HC908QL4.h"
#include "SLIC_LINdriver.h"

extern unsigned char temp_msg_buffer[8];    // Temporary storage of SLIC buffer contents
extern unsigned char LINdata;
extern unsigned char LINID;
extern unsigned char BusOff;
extern unsigned char LINSleep;

//+------------------------------------------------------------------------+
//|  SLIC_Init - Initializes SLIC module                                    |
//|                                                                         |
//|  Configures SLIC for:                                                   |
//|        1. LIN or BTM mode operation                                     |
//|        2. Clock Operation in MCU Wait Mode                              |
//|        3. Receive filter prescaler adjustment for data rate             |
//|        4. Bit timing setting (BTM mode)                                 |
//+------------------------------------------------------------------------+
void SLIC_Init(void)
    {
    SLCC1_INITREQ = 0;                   // Clear INITREQ bit in SLIC
    while(SLCS_INITACK==1){;;}           // Wait for INITACK to clear
    SLCC2_SLCWCM = 0;                    // Wait Clock Mode
```

```
                                            //  0 - SLIC clocks continue in CPU WAIT
                                            //  1 - SLIC clocks stop in CPU WAIT
//    SLCP = 0x80;                          // RX Filter Prescaler
                                            //   This is only used if a value other
                                            //   than the default is desired.
                                            //   00 - div 1
                                            //   01 - div 2
                                            //   10 - div 3  (default setting)
                                            //   11 - div 4
    SLCC2_SLCE = 1;                      // Enable SLIC module
    }

//+----------------------------------------------------------------------------+
//|                                                                            |
//|  SLIC_ISR - Interrupt Service Routine                                      |
//|                                                                            |
//|  Main handler for SLIC interrupts                                          |
//|                                                                            |
//+----------------------------------------------------------------------------+
//______________________________SLIC_ISR_____________
#pragma TRAP_PROC
void SLIC_ISR(void)
    {
    unsigned char temp_SLCSV = 0;
             char ID_found = 0;            // If ID not found, set IMSG
             char temp = PTB_PTB0;

    temp_SLCSV = SLCSV;                    // Read SLCSV value

    switch(temp_SLCSV)                     // switch is temporary measure
        {
        case 0x00:    //___________No Interrupts Pending__________________
        break;

        case 0x04:    //___________No Bus Activity________________________
            BusOff++;
            if (BusOff == 2)
                {
                LINSleep = 1;          // Set LINSleep flag
                BusOff = 0;            // Reset BusOff counter
                }
        break;

        case 0x08:    //___________TX Buffer Empty - Checksum Sent_______
        break;

        case 0x0C:    //___________TX Buffer Empty_______________________
        break;

        case 0x10:    //___________RX Buffer Full - Checksum OK__________

            //________________________________________________________________________TEST___
            if(SLCID==0x97)                        // Test message from master
                {                                  // --------- test code....
                temp_msg_buffer[0] = SLCD0;        // Load RAM from RX buffers
        temp_msg_buffer[1] = SLCD1;        // Load RAM from RX buffers
        }
    //_______________________________________________________________________TEST___
break;

case 0x14:    //___________RX Buffer Full - No errors____________
break;

case 0x18:    //___________Bit-Error_____________________________
break;

case 0x1C:    //___________RX Buffer Overrun_____________________
break;

case 0x20:    //___________<reserved>____________________________
break;

case 0x24:    //___________Checksum Error________________________
break;

case 0x28:    //___________Byte Framing Error____________________
break;

case 0x2C:    //___________ID received correctly - parity OK_____
              //           Perform ID lookup
    //_________________________________________________________________________
    if(SLCID==LINID)            // Check ID
        {
        ID_found = 1;           // Set ID found flag
        SLCD0      = LINdata;  // Load TX buffers
        SLCD1    = 0;
        SLCDLC   = 0xC1;        // Write DLC code to start TX - STD CHECKSUM
        }
     //_________________________________________________________________________
     if(SLCID==0x97)            // Test message from master
         {                      // --------- test code....
         ID_found = 1;          // Set ID found flag
         SLCDLC = 0x41;         // Write DLC code = RX, STANDARD CHECKSUM, 2 bytes
         }
     //_________________________________________________________________________

      if (ID_found == 0)
          {
                              #warning "ALPHA SAMPLE WORKAROUND"
         SLCDLC = 0x00;      // Alpha sample workaround - write DLC = 0 before IMSG=1;
          SLCC1_IMSG = 1;    // Set IMSG bit to ignore ID if not found!
          }

     ID_found = 0;                      // reset ID_found
                                        // (should do anyway on re-entry into ISR)
     LINSleep = 0;                      // Clear LINSleep flag-due to bus activity

break;
case 0x30:    //___________ID Parity Error______________________
break;
```

```
        case 0x34:    //___________Inconsistent-Synch-Field Error_______
        break;

        case 0x38:    //___________<reserved>___________________________
        break;

        case 0x3C:    //___________Wakeup_______________________________
        break;
        }            //___ end switch temp_SLCSV

    SLCS_SLCF = 1;                // Clear SLIC interrupt flag
    } //_______________________________________________end_SLIC_ISR_______

;*****************************************************************************************
```

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