



LIN\_EA  
DSD\_LIN\_EA

Division  
I B&S

## **LIN Driver**

**Title: SW Component LIN\_EA v1.7**

| <b>History</b>                 |  |                             |                                    |  |
|--------------------------------|--|-----------------------------|------------------------------------|--|
| <b>Issue status</b><br>(Index) | <b>Maturity/Date</b><br>(draft/invalid/valid)<br>(dd-mmm-yyyy) | <b>Author</b><br>Department | <b>Check/Release</b><br>Department | <b>Description</b>   |
| 1.0                            | Draft<br>27-Oct-15   | Edgar Escayola              | Adrián Zacarías                    | Creation of the document   |
| 1.1                            | Draft<br>28-Oct-15   | Edgar Escayola              | Adrián Zacarías                    | Changes at: Purpose, References, and realization constraints and targets.  |
| 1.2                            | Draft<br>29-Oct-15   | Adrián Zacarías             | Edgar Escayola                     | Addition of abbreviations and definitions, diagrams and descriptions.  |
| 1.3                            | Draft<br>30-Oct-15   | Adrián Zacarías             | Edgar Escayola                     | Class diagram and functions definitions.   |
| 1.4                            | Draft<br>30-Oct-15   | Edgar Escayola              | Adrián Zacarías                    | Implementation of traceability in the document.  |
| 1.5                            | Release<br>1-Dec-15  | Edgar Escayola              | Adrián Zacarías                    | Changes from the review implemented.   |
| 1.6                            | Draft<br>2-Dec-15  | Edgar Escayola              | Adrián Zacarías                    | Implementation of the comments from the coach: Architecture diagram, use case diagram, sequence diagram, functional decomposition and definitions of new functions.  |
| 1.7                            | Draft<br>6-Dec-15  | Adrián Zacarías             | Edgar Escayola                     | Functional decomposition and sequence diagram updated. Addition of the following functions: Header_handler, Data_reception, Led_OFF_State, Led_ON_State, Led_TOGGING_State, Slave_FALSE_State and Slave_TRUE_State. LIN transceiver, master's features and error handling added. |

## Table of Contents

|          |   |           |
|----------|---|-----------|
| <b>1</b> | <b>PURPOSE .....</b>                                | <b>5</b>  |
| 1.1      | Definitions and abbreviations .....                 | 5         |
| 1.2      | Definitions .....                                   | 5         |
| 1.3      | Type name definition .....                          | 5         |
| <b>2</b> | <b>REALIZATION CONSTRAINTS AND TARGETS .....</b>    | <b>6</b>  |
| 2.1      | TRK-MPC5606B's features .....                       | 6         |
| 2.2      | Master's features .....                             | 6         |
| 2.3      | LIN transceiver .....                               | 7         |
| <b>3</b> | <b>SW CONCEPTUAL DESIGN .....</b>                   | <b>8</b>  |
| 3.1      | Architecture design .....                           | 8         |
| 3.2      | Deployment Diagram .....                            | 8         |
| 3.3      | Use case diagram .....                              | 9         |
| 3.4      | Sequence diagram .....                              | 10        |
| 3.5      | Error handling .....                                | 11        |
| <b>4</b> | <b>SW COMPONENT INTERNAL BREAKDOWN .....</b>        | <b>12</b> |
| 4.1      | Functional Decomposition .....                      | 12        |
| 4.2      | LIN .....   | 14        |
| 4.2.1    | Function void Init_LIN (void) .....                 | 14        |
| 4.2.2    | Function void RX_ISR (void) .....                   | 14        |
| 4.2.3    | Function void Header_handler (void) .....           | 15        |
| 4.2.4    | Function void Data_reception (void) .....           | 16        |
| 4.3      | LIN_EA .....  | 16        |
| 4.3.1    | Function void LED_status (void) .....               | 16        |
| 4.3.2    | Function void Set_SlaveState (T_UBYTE) .....        | 17        |
| 4.3.3    | Function T_UBYTE Led_OFF_State (T_UBYTE) .....      | 18        |
| 4.3.4    | Function T_UBYTE Led_ON_State (T_UBYTE) .....       | 18        |
| 4.3.5    | Function T_UBYTE Led_TOGGLING_State (T_UBYTE) ..... | 18        |
| 4.3.6    | Function T_UBYTE Slave_FALSE_State (T_UBYTE) .....  | 18        |
| 4.3.7    | Function T_UBYTE Slave_TRUE_State (T_UBYTE) .....   | 18        |
| 4.4      | TASKS .....   | 19        |
| 4.4.1    | Function void Task0_SlaveState (void) .....         | 19        |



|             |   |           |
|-------------|---|-----------|
| 4.4.2       | Function void Task1_LED (void).....                 | 19        |
| <b>4.5</b>  | <b>Init_Tasks .....</b>                             | <b>19</b> |
| 4.5.1       | Function void Global_Init (void).....               | 19        |
| <b>4.6</b>  | <b>TIMER.....</b>                                   | <b>20</b> |
| 4.6.1       | Function void InitPIT (void).....                   | 20        |
| 4.6.2       | Function void InitPITChannel (T_UBYTE).....         | 20        |
| <b>4.7</b>  | <b>LED .....</b>                                    | <b>21</b> |
| 4.7.1       | Function void Init_LED (void).....                  | 21        |
| 4.7.2       | Function T_UBYTE Get_LED_Status (void) .....        | 21        |
| 4.7.3       | Function void Set_LED_Status (T_UBYTE) .....        | 21        |
| <b>4.8</b>  | <b>GPIO .....</b>                                   | <b>21</b> |
| 4.8.1       | Function void Set_Pin_State (T_UBYTE, T_UBYTE)..... | 21        |
| 4.8.2       | Function void Set_Pin_Mode (T_UBYTE, T_UBYTE) ..... | 22        |
| 4.8.3       | Function T_UBYTE Get_Pin_State (T_UBYTE) .....      | 22        |
| <b>4.9</b>  | <b>KERNEL.....</b>                                  | <b>22</b> |
| 4.9.1       | Function void Tick_ISR (void).....                  | 22        |
| 4.9.2       | Function void main_Scheduler (void) .....           | 22        |
| <b>4.10</b> | <b>Main .....</b>                                   | <b>23</b> |
| 4.10.1      | Function void main (void).....                      | 23        |
| <b>4.11</b> | <b>System_Initialization .....</b>                  | <b>23</b> |
| 4.11.1      | Function void System_Init (void).....               | 23        |
| 4.11.2      | Function void ModeEntry (void).....                 | 23        |

## 1 Purpose

This document has been created to describe the design specifications of the application LIN Driver. It consists on the implementation of the LIN protocol in the TRK-MPC5606B development board and an application, which will be a slave number 1 in a group of one master and four slaves.

Req. Id. 1.0, 1.1, 1.2

### 1.1 Definitions and abbreviations

#### 1.2 Definitions

|                         |  |
|-------------------------|--|
| <b>Cmd_NONE</b>         | Command to do nothing.   |
| <b>Cmd_LED_on</b>       | Command to turn the LED on.  |
| <b>Cmd_LED_off</b>      | Command to turn the LED off.   |
| <b>Cmd_LED_toggling</b> | Command to trigger the blinking LED of the sequence.   |
| <b>Cmd_disable_slv</b>  | Command to disable the slave mode in the slave node.   |
| <b>Data</b>             | The response of a frame carries one to eight data bytes, collectively called data.   |
| <b>Dominant</b>         | A zero value in the LIN bus.   |
| <b>Frame</b>            | A frame consists of a header and a response. The reply frame for a node configuration or a diagnostic request is a response. |
| <b>Header</b>           | A header is the first part of a frame; it is always sent by the master task.   |
| <b>ISR</b>              | Interrupt Service Routine  |
| <b>LED</b>              | Light Emitting Diode   |
| <b>LFDIV</b>            | LINFlex Divider. Intermediate variable for Baud Rate calculation.  |
| <b>LIN</b>              | Local interconnect Network   |
| <b>LIN_EA</b>           | Name of the system designed in this project.   |
| <b>LINFBRR</b>          | LIN Fractional Baud Rate Register  |
| <b>LINFlex</b>          | Local Interconnect Network Flexible controller.  |
| <b>LINIBRR</b>          | LIN Integer Baud Rate Register   |
| <b>Node</b>             | A node is an ECU (electronic control unit). However, a single ECU may be connected to multiple LIN clusters.                 |
| <b>PIT</b>              | Periodic Interrupt Timer   |
| <b>Recessive</b>        | A one value in the LIN bus.  |
| <b>Rx</b>               | Reception.   |
| <b>Slave node</b>       | A node that contains a slave task only, i.e. it does not contain a master task.  |
| <b>TOGGLING</b>         | Status where the LED blinks.   |
| <b>Tx</b>               | Transmission.  |

Req. Id. 1.13, 1.14, 1.15, 1.17, 1.18

#### 1.3 Type name definition

| Type Name        | Elements |            |             |                  |                 |                |
|------------------|----------|------------|-------------|------------------|-----------------|----------------|
|                  | 0        | 1          | 2           | 3                | 4               | 5              |
| <b>t_cmdType</b> | cmd_NONE | cmd_LED_on | cmd_LED_off | cmd_LED_toggling | cmd_disable_slv | cmd_enable_slv |
| <b>t_LEDstat</b> | OFF      | ON         | TOGGLING    |                  |                 |                |
| <b>t_boolean</b> | FALSE    | TRUE       |             |                  |                 |                |
| <b>array</b>     | AZSEEV   |            |             |                  |                 |                |
| <b>Scalar</b>    | 1        |            |             |                  |                 |                |

Req. Id. 1.12, 1.16, 1.19, 1.20, 1.21

## References

| N° | Document name                                    | Reference   | Revision |
|----|--|---|----------|
| 1  | LIN Specification Package                        | LIN/Documents/LIN-Spec_2-2A.pdf                                 | 2.2A     |
| 2  | Traceability Matrix – LIN_EA                     | LIN/Documents/1.0 Requirements/Traceability Matrix – LIN_EA.xls | 1.7      |
| 3  | MPC5607B Microcontroller Reference Manual        | LIN/Documents/MPC5607BRM_Reference_Manual.pdf                   | 7.2      |
| 4  | Quick Start Guide TRK-MPC5606B                   | LIN/Documents/Quick_Start_Guide.pdf                             | 3        |
| 5  | LIN Network Definition                           | LIN/Documents/LIN_Network_Database.xls                          | 1.0      |
| 6  | MCP2050 - LIN Transceiver with Voltage Regulator | LIN/Documents/MCP2050.pdf                                       | 1.0      |
| 7  | AVT-718 User's manual                            | LIN/Documents/AVT-718.pdf                                       | C1       |

## 2 Realization constraints and targets

### 2.1 TRK-MPC5606B's features

- MPC5606B MCU (144-pin LQFP).
- On-board JTAG connection via open source OSBDM circuit using the MPC9S08JM MCU.
- MCZ3390S5EK system basis chip with advanced power management and integrated CAN transceiver and LIN 2.0 interface.
- CAN interface.
- LIN interface with 1.3, 2.0, 2.1, and J2602 protocol versions supported.
- Analog interface with potentiometer.
- High-efficiency green LEDs.
- 4 PushButtons.
- Serial communication interface.
- External power 9V DC to 12V DC regulated down to 5V DC.

Req. Id. 3.3

### 2.2 Master's features

The master node was implemented using the AVT-718 Multiple Protocol Interface unit, which supports, among others, the LIN protocol specification 1.2.

#### Specifications

Overall size (inches): 7.3 x 6.1 x 2.0.

Weight: 18 oz.

Operating temperature range: 0 to +70 degrees C.

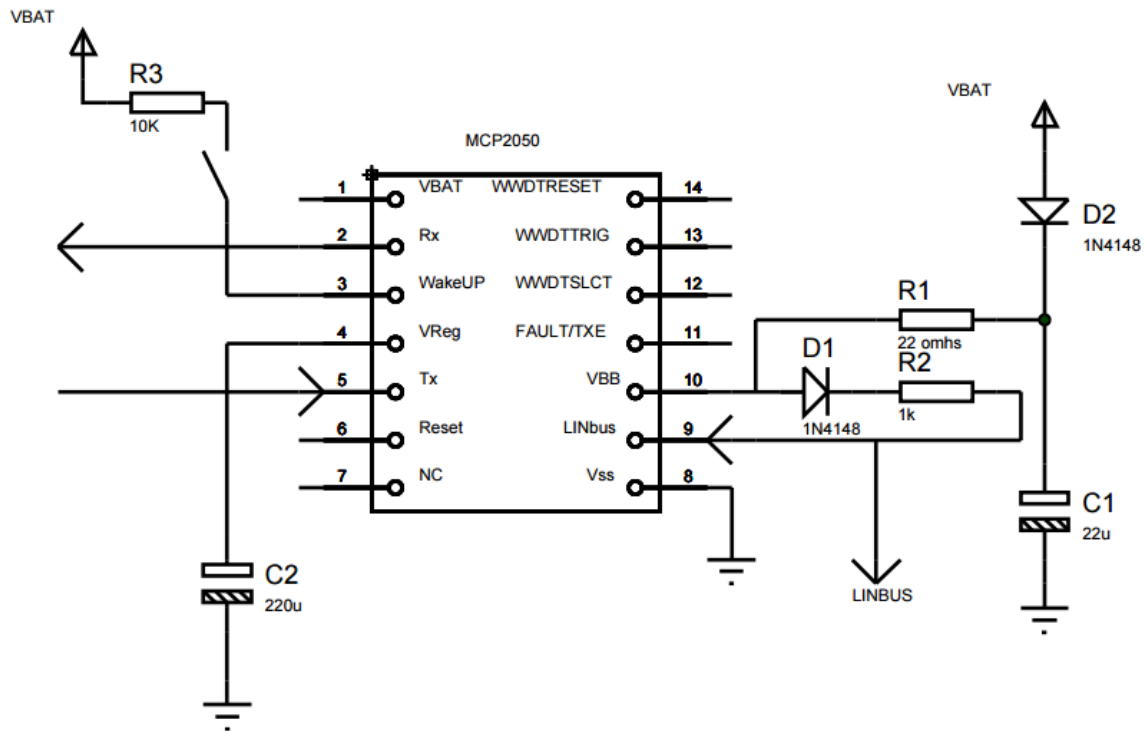
Input voltage range: +9.0 VDC to +30.0 VDC.

Power dissipation: 3.0 watts (nominal).

The factory default setting for the AVT-718 is 19.2 kbaud.

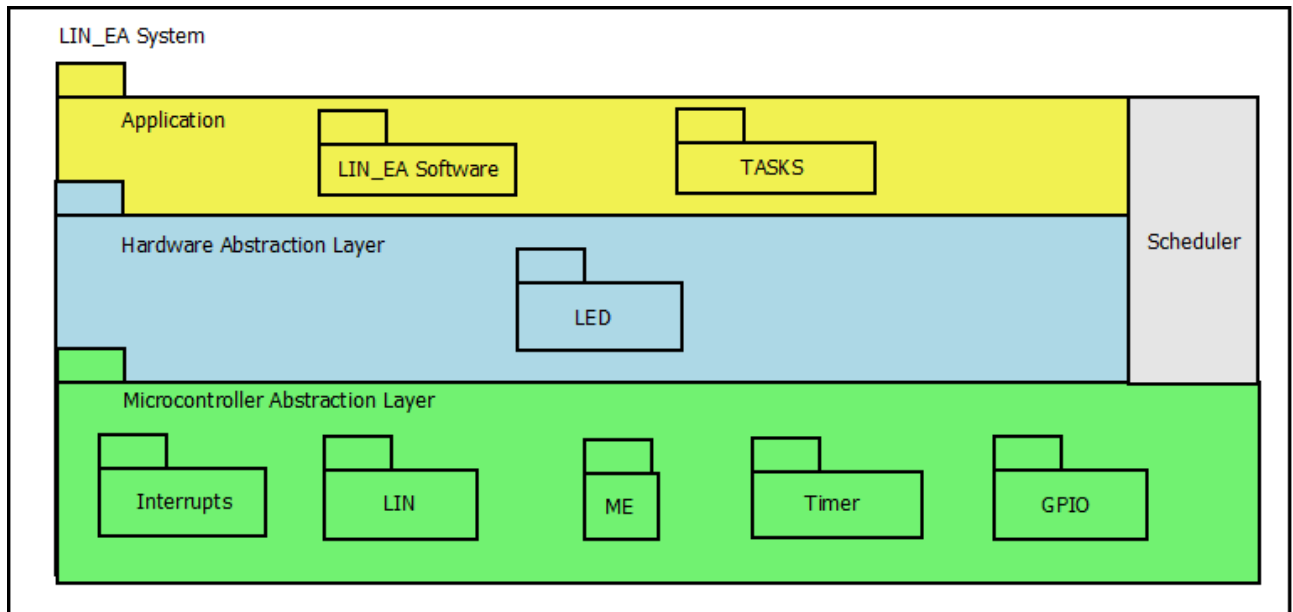
## 2.3 LIN transceiver

A LIN transceiver was implemented in order to connect the 5 volts logic of the Tx and Rx pins of the microcontroller to the 12 volts LIN-bus. The following diagram illustrates the circuit used.



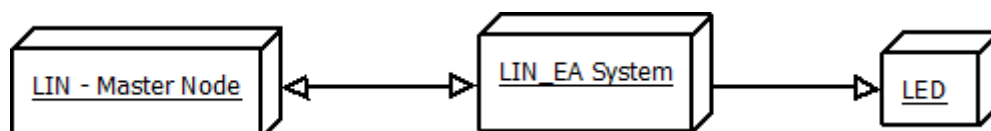
### 3 SW Conceptual design

#### 3.1 Architecture design



The architecture diagram shows the layers in which the system is divided. In the Microcontroller Abstraction Layer, there are the modules where the interrupts, timers, GPIO, LIN interface and general configurations are handled. In the Hardware Abstraction Layer, the system manages the external modules as LEDs. In the Application layer, there is the main software and the tasks from the scheduler. Parallel to the hardware and application layer there is the scheduler, which communicates with each of the layers.

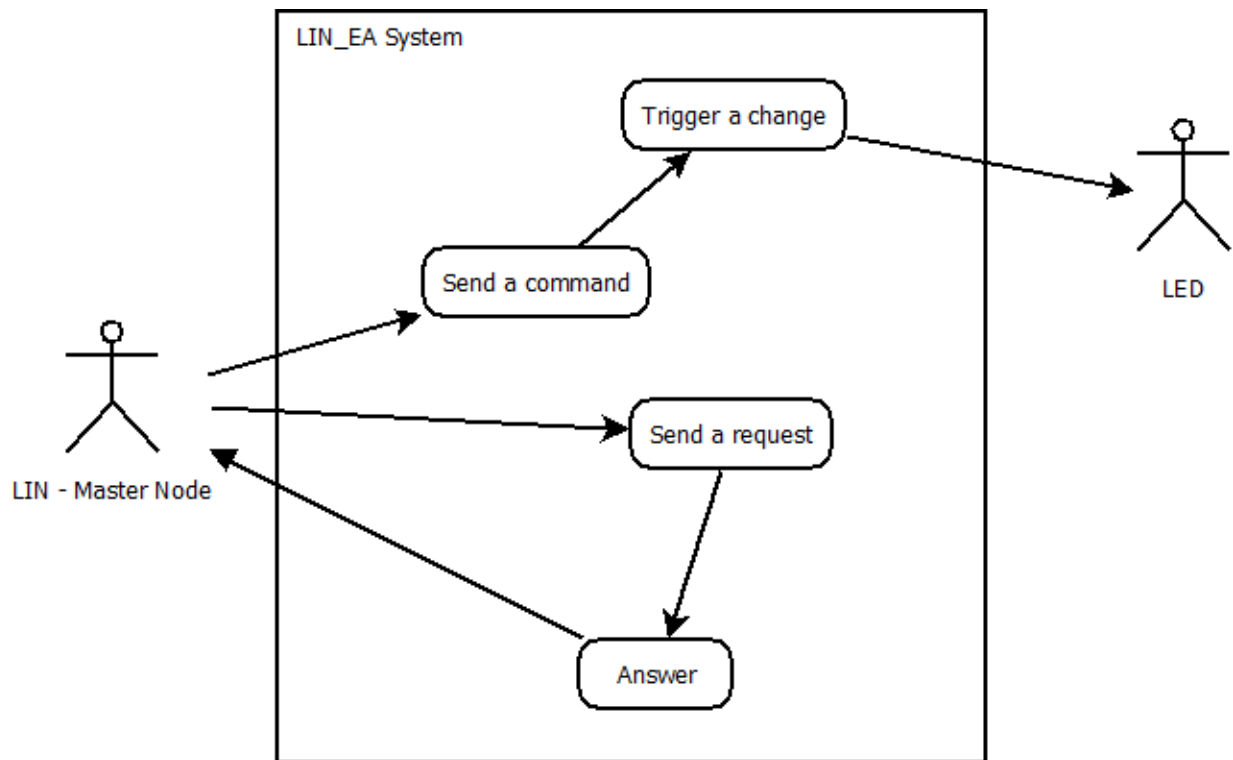
#### 3.2 Deployment Diagram



The deployment diagram shows the interaction of the LIN\_EA system with external systems. There is a bidirectional communication with a LIN master node and an output to a LED. The master node sends commands, which can affect the system and LED state.



### 3.3 Use case diagram



#### Users

**LIN – Master Node**

#### Description

The master node sends data to the slave in order to affect the system.

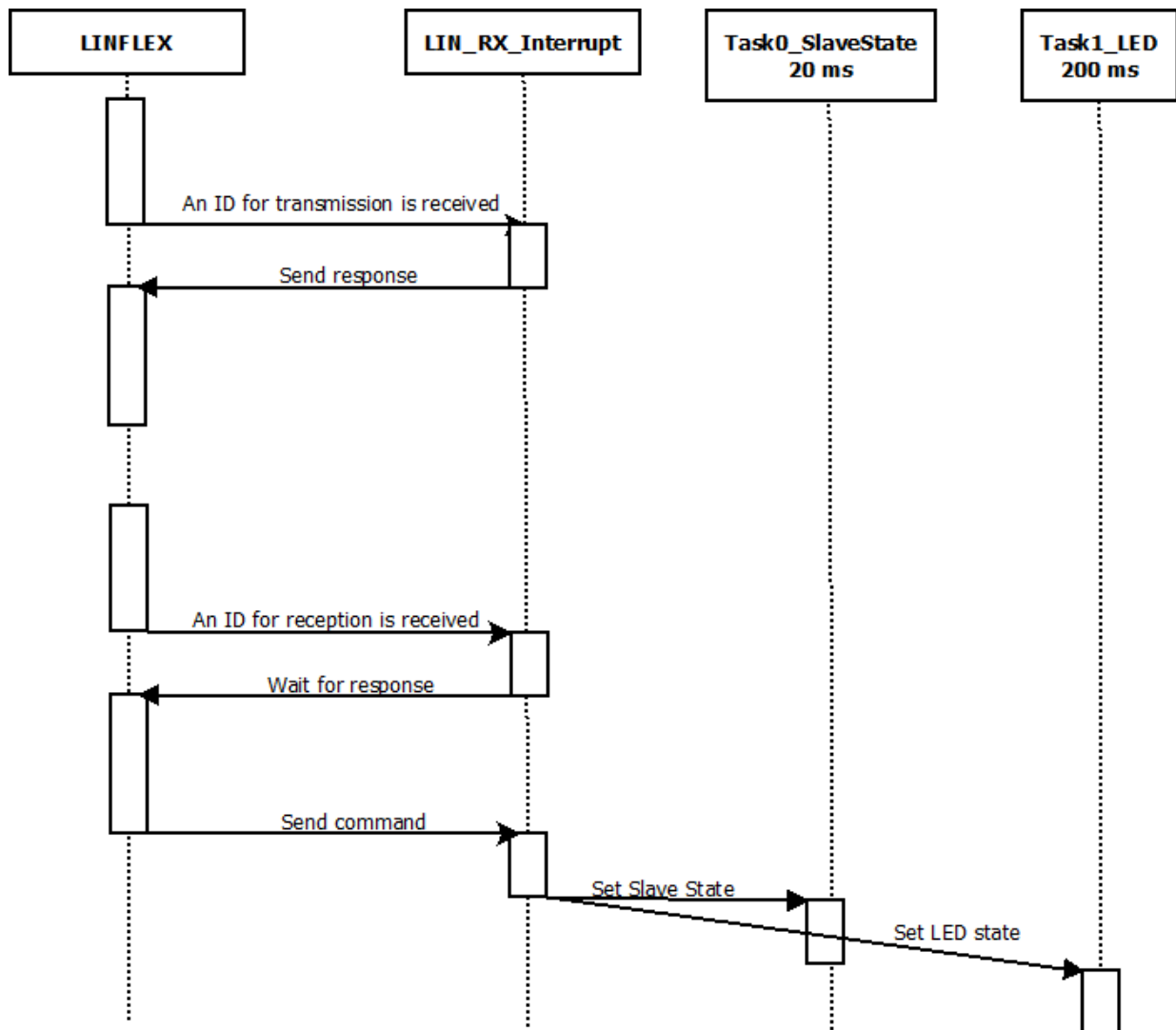
**LED**

There is a LED which is controlled by the system.

| Case                    | Description   |
|-------------------------|---|
| <b>Send a command</b>   | This case triggers a transmission by the master in order to communicate a command to be executed.       |
| <b>Trigger a change</b> | This case evaluates the command sent.   |
| <b>Send a request</b>   | This case triggers a transmission by the master to communicate a request to receive status information. |
| <b>Answer</b>           | This case triggers the transmission to the LIN – Master Node of the solicited information.              |



### 3.4 Sequence diagram



This diagram describes the interaction between different modules of the software and the microcontroller. The LINFLEX controller from the microcontroller is in charge of receiving the messages that arrive to the system through the LIN protocol. Then it sends them to the interrupt. If it matches for transmission, the LIN\_RX\_interrupt fills the buffer and triggers the transmission of the data. Lastly, LINFLEX sends the data and checksum. If it matches for reception, the LIN\_RX\_interrupt sets the length of the data that will be received. After the reception is done, the data is taken by the interrupt and marks them as available for task0\_SlaveState and task1\_LED.

### 3.5 Error handling

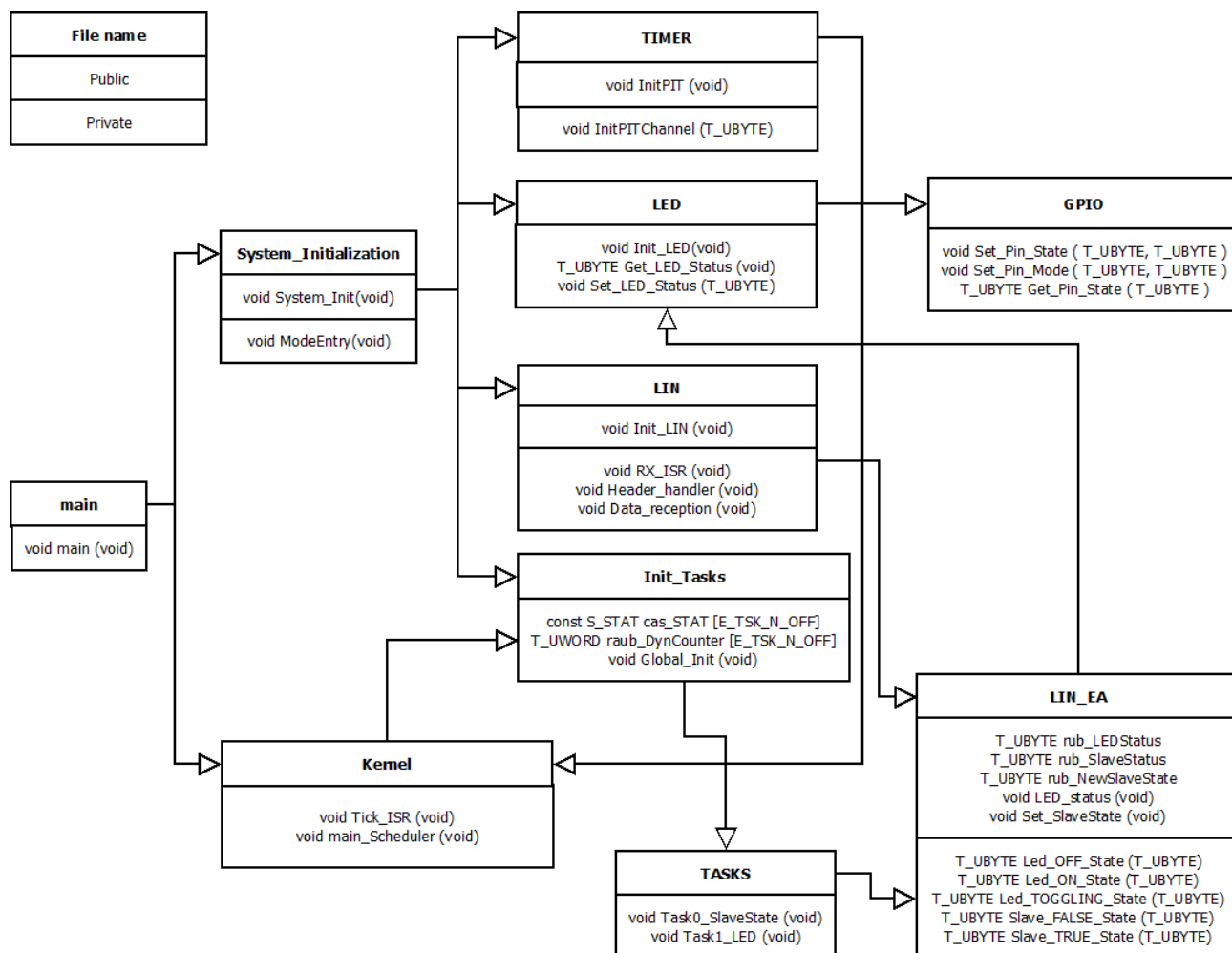
In order to consume less CPU resources, the hardware of the MPC5606B handles the signals of the LIN-bus, managing the errors and only generating interrupts when the software needs to specify the length of the response field, specify the data that is going to be sent or when the data is ready to be read. The following errors alter the internal state machine of the LINFlex controller of the MPC5606B.

| Error                 | Description   | LINFlex response  |
|-----------------------|---|---|
| <b>Bit error</b>      | During transmission, the value read back from the bus differs from the transmitted value.                                 | <ul style="list-style-type: none"> <li>Stops the transmission of the frame after the corrupted bit.</li> <li>Returns to idle state.</li> </ul>  |
| <b>Framing error</b>  | A dominant state has been sampled on the bit of the currently received character (Sync field, identifier, or data field). | If encountered during reception: <ul style="list-style-type: none"> <li>Discards the current frame.</li> <li>Returns immediately to idle state.</li> </ul>  |
| <b>Checksum error</b> | The computed checksum does not match the received checksum.   | If encountered during reception: <ul style="list-style-type: none"> <li>Discards the received frame.</li> <li>Returns to idle state.</li> </ul>   |
| <b>Header error</b>   | An error occurred during header reception (break delimiter error, inconsistent sync field, header timeout)                | If encountered during header reception, a break field error, an inconsistent sync field, or a timeout: <ul style="list-style-type: none"> <li>Discards the header.</li> <li>Returns to idle state.</li> </ul> |

In case that a received signal is longer than expected, it only takes the bytes that the software was expecting. Since the checksum would not be the real checksum but another byte of data, the checksum would be incorrect, generating a checksum error, discarding the received frame and returning the internal state machine to idle state.

## 4 SW Component internal breakdown

### 4.1 Functional Decomposition



| File                         | Description  |
|------------------------------|--|
| <b>Main</b>                  | Main module that runs the main function. It is divided in system's initialization and execution of the scheduler.  |
| <b>System_Initialization</b> | The function of this module is to call the functions that initializes the mode of operation, peripherals, and the scheduler.   |
| <b>LIN_EA</b>                | It is in charge of executing the main application of the program. It contains two main functions, which also contain the state machines to control the LED status and the slave state. |
| <b>Kernel</b>                | The scheduler is being executed here. It handles the main configurations and the tick interrupt.   |
| <b>TASKS</b>                 | This module contains the periodic tasks that are executed by the   |

|                   |  |
|-------------------|--|
|                   | scheduler.   |
| <b>Init_Tasks</b> | This module contains the global initializations which are needed for the correct execution of the scheduler.                     |
| <b>LIN</b>        | This module contains the LIN driver. It consists of an initialization of the LIN controller and an interrupt for reception.      |
| <b>TIMER</b>      | This file contains the configurations that must be done to achieve the periodic interrupt that gives the Ticks to the scheduler. |
| <b>GPIO</b>       | This module handles the registers needed to configure ports and change state of pins.  |
| <b>LED</b>        | This module configures and handles the state of the LED.   |

## Function Description and Dynamic Behavior

### 4.2 LIN

#### 4.2.1 Function void Init\_LIN (void)

|                         |  |
|-------------------------|--|
| <b>Description</b>      | This function initializes the LIN controller of the board. |
| <b>Parameter 1</b>      | Void   |
| <b>Return Value</b>     | Void   |
| <b>Precondition</b>     | Does not apply   |
| <b>Post condition</b>   | Does not apply   |
| <b>Error Conditions</b> | Does not apply   |

The LIN controller must be set to initialization mode in order to set its configurations. First the RX and TX pin are set as INPUT and OUTPUT, respectively. The break detection threshold is set to 11 dominant local slave bit times. Another configuration is to set the endianness to Little Endian, the initial baud rate is set and the interrupt is configured. Before leaving the function, the software sets the LIN controller to normal mode.

In order to calculate the initial Baud Rate (BR) the following formula is used :

$$LFDIV = LINIBRR + \frac{LINFBR}{16}$$

$$BR = \frac{f}{16 * LFDIV}$$

If  $f = 64 \text{ MHz}$ ,  $LINIBRR = 416$ , and  $LINFBR = 11$ , then:

$$LFDIV = LINIBRR + \frac{LINFBR}{16} = 416 + \frac{11}{16} = 416.6874$$

$$BR = \frac{f}{16 * LFDIV} = \frac{64 \times 10^6}{16 * 416.6874} = 9599.51 \approx 9600 \text{ Symbols/second}$$

Req. Id. 1.3, 1.30, 2.0, 2.1, 2.7.

#### 4.2.2 Function void RX\_ISR (void)

|                         |   |
|-------------------------|---|
| <b>Description</b>      | This function is called every time a reception interrupt is generated from the LINFlex controller. It calls the Header_handler or Data_reception function if the Header Reception Flag or Data Received Flag are set, respectively. |
| <b>Parameter 1</b>      | Void  |
| <b>Return Value</b>     | Void  |
| <b>Precondition</b>     | Basic configuration of LINFlex must be done and the interrupt must be initialize in order to run this function.   |
| <b>Post condition</b>   | Does not apply  |
| <b>Error Conditions</b> | Does not apply  |

### 4.2.3 Function void Header\_handler (void)

|                         |  |
|-------------------------|--|
| <b>Description</b>      | This function is called every time a header is received. It is in charge of discard an invalid ID or setting the parameters to receive or send the response. |
| <b>Parameter 1</b>      | Void   |
| <b>Return Value</b>     | Void   |
| <b>Precondition</b>     | Does not apply   |
| <b>Post condition</b>   | Does not apply   |
| <b>Error Conditions</b> | Does not apply   |

The following messages ID (considering parity) are valid for reception:

| Message name           | Msg ID | Msg Data Length (byte) | Message publisher | Message subscriber | Signal length (bits) | Signal type | Signal Description    |
|------------------------|--------|------------------------|-------------------|--------------------|----------------------|-------------|-----------------------|
| <b>MASTER_CMD_ALL</b>  | 0xCF   | 1                      | Master            | Slave 1, 2, 3, 4.  | 4                    | T_cmdType   | Command for all nodes |
| <b>MASTER_CMD_SLV1</b> | 0x50   | 1                      | Master            | Slave 1            | 4                    | T_cmdType   | Command for node 1.   |

Req. Id. 1.3, 1.4, 1.5, 1.6, 1.7, 2.0, 2.1.

The following messages ID (considering parity) are valid for transmission. After the reception of one of those IDs, the function fills the buffer with the data described below and triggers the transmission.

| Message name      | Msg ID | Msg Data Length (byte) | Message publisher | Message subscriber | Signal length (bits) | Signal type | Signal Description              |
|-------------------|--------|------------------------|-------------------|--------------------|----------------------|-------------|---------------------------------|
| <b>SLAVE1_RSP</b> | 0x20   | 2                      | Slave 1           | Master             | 2                    | T_LEDstat   | Return LED status               |
|                   |        |                        |                   |                    | 1                    | T_boolean   | Return node status              |
| <b>SLAVE1_ID</b>  | 0xF0   | 7                      | Slave 1           | Master             | 8                    | Scalar      | Return team number              |
|                   |        |                        |                   |                    | 48                   | Array       | Return initials of team members |

Req. Id. 1.3, 1.8, 1.9, 1.10, 1.11, 2.0, 2.1.

#### 4.2.4 Function void Data\_reception (void)

|                         |  |
|-------------------------|--|
| <b>Description</b>      | This function is called every time a Data Reception Flag is set. It is in charge of setting flags depending on the command received in the response. |
| <b>Parameter 1</b>      | Void   |
| <b>Return Value</b>     | Void   |
| <b>Precondition</b>     | Does not apply   |
| <b>Post condition</b>   | Does not apply   |
| <b>Error Conditions</b> | Does not apply   |

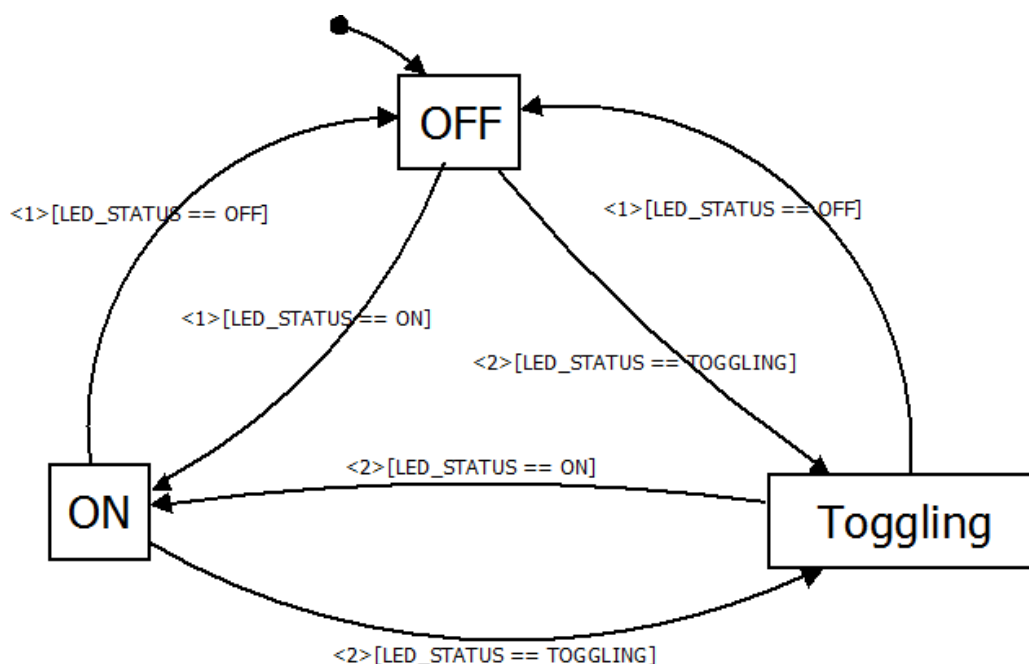
### 4.3 LIN\_EA

#### 4.3.1 Function void LED\_status (void)

|                         |   |
|-------------------------|---|
| <b>Description</b>      | This function is called every time the task 1 is executed. It has a state machine, which controls the response's reception after a valid command is received. |
| <b>Parameter 1</b>      | Void  |
| <b>Return Value</b>     | Void  |
| <b>Precondition</b>     | Basic configuration of LINFlex must be done and the interrupts must be initialize in order to run this function.  |
| <b>Post condition</b>   | Does not apply  |
| <b>Error Conditions</b> | Does not apply  |

Req. Id. 3.0, 3.1

**Dynamic Behavior**  
State Chart





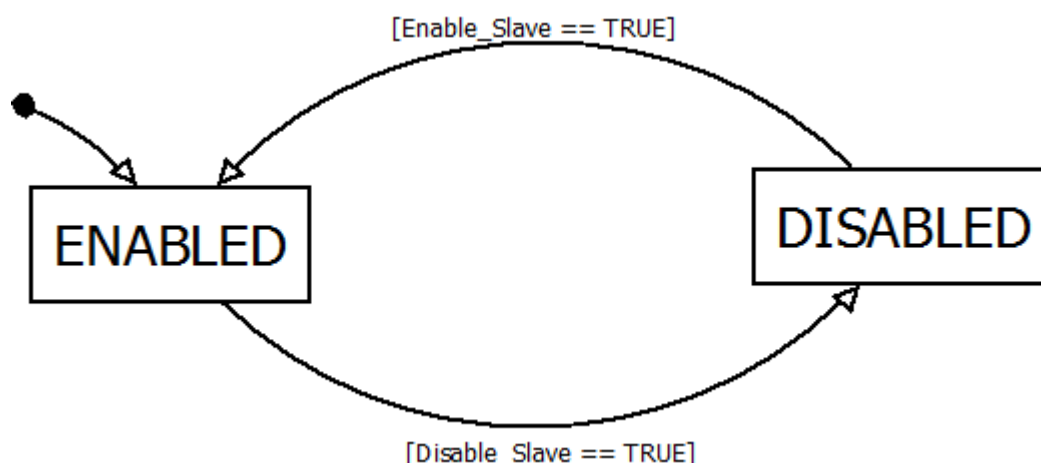
| State           | Description                                   |
|-----------------|---|
| <b>OFF</b>      | State in which the LED is OFF. Req. Id. 1.24  |
| <b>ON</b>       | State in which the LED is ON. Req. Id. 1.23   |
| <b>Toggling</b> | State in which the LED toggles. Req. id. 1.25 |

#### 4.3.2 Function void Set\_SlaveState (T\_UBYTE)

|                         |   |
|-------------------------|---|
| <b>Description</b>      | This function is executed every 20 milliseconds in the task 0. It has a state machine, which controls the response's reception after a valid command is received. |
| <b>Parameter 1</b>      | T_UBYTE. Flag that might trigger a change in the internal state machine.  |
| <b>Return Value</b>     | Void  |
| <b>Precondition</b>     | Does not apply  |
| <b>Post condition</b>   | Does not apply  |
| <b>Error Conditions</b> | Does not apply  |

Req. Id. 3.2

**Dynamic Behavior**  
State Chart



| State           | Description  |
|-----------------|--|
| <b>Enabled</b>  | State in which the slave node acts fully in slave mode. The state transition is triggered by the command cmd_disable_slv. The command cmd_none shall not trigger any change. Req. Id. 1.26, 1.28 |
| <b>Disabled</b> | State in which the system will not accept any other command than the command cmd_enable_slv. The command cmd_none shall not trigger any change. Req. Id. 1.29                                    |

Req. Id. 1.22

#### 4.3.3 Function T\_UBYTE Led\_OFF\_State (T\_UBYTE)

|                         |   |
|-------------------------|---|
| <b>Description</b>      | Function that implements the OFF state in the state machine of the function LED_status. |
| <b>Parameter 1</b>      | T_UBYTE. Receives the state variable so it could change it.                             |
| <b>Return Value</b>     | T_UBYTE. Returns the state variable.  |
| <b>Precondition</b>     | Does not apply  |
| <b>Post condition</b>   | Does not apply  |
| <b>Error Conditions</b> | Does not apply  |

#### 4.3.4 Function T\_UBYTE Led\_ON\_State (T\_UBYTE)

|                         |  |
|-------------------------|--|
| <b>Description</b>      | Function that implements the ON state in the state machine of the function LED_status. |
| <b>Parameter 1</b>      | T_UBYTE. Receives the state variable so it could change it.                            |
| <b>Return Value</b>     | T_UBYTE. Returns the state variable.   |
| <b>Precondition</b>     | Does not apply   |
| <b>Post condition</b>   | Does not apply   |
| <b>Error Conditions</b> | Does not apply   |

#### 4.3.5 Function T\_UBYTE Led\_TOGGLING\_State (T\_UBYTE)

|                         |  |
|-------------------------|--|
| <b>Description</b>      | Function that implements the TOGGLING state in the state machine of the function LED_status. |
| <b>Parameter 1</b>      | T_UBYTE. Receives the state variable so it could change it.                                  |
| <b>Return Value</b>     | T_UBYTE. Returns the state variable.   |
| <b>Precondition</b>     | Does not apply   |
| <b>Post condition</b>   | Does not apply   |
| <b>Error Conditions</b> | Does not apply   |

#### 4.3.6 Function T\_UBYTE Slave\_FALSE\_State (T\_UBYTE)

|                         |   |
|-------------------------|---|
| <b>Description</b>      | Function that implements the FALSE state in the state machine of the function Set_SlaveState. |
| <b>Parameter 1</b>      | T_UBYTE. Receives the state variable so it could change it.                                   |
| <b>Return Value</b>     | T_UBYTE. Returns the state variable.  |
| <b>Precondition</b>     | Does not apply  |
| <b>Post condition</b>   | Does not apply  |
| <b>Error Conditions</b> | Does not apply  |

#### 4.3.7 Function T\_UBYTE Slave\_TRUE\_State (T\_UBYTE)

|                         |  |
|-------------------------|--|
| <b>Description</b>      | Function that implements the TRUE state in the state machine of the function Set_SlaveState. |
| <b>Parameter 1</b>      | T_UBYTE. Receives the state variable so it could change it.                                  |
| <b>Return Value</b>     | T_UBYTE. Returns the state variable.   |
| <b>Precondition</b>     | Does not apply   |
| <b>Post condition</b>   | Does not apply   |
| <b>Error Conditions</b> | Does not apply   |

## 4.4 TASKS

### 4.4.1 Function void Task0\_SlaveState (void)

|                         |  |
|-------------------------|--|
| <b>Description</b>      | This task is executed every 20 milliseconds. Its main function is to call the state machine that handles the slave status of the system. |
| <b>Parameter 1</b>      | Void   |
| <b>Return Value</b>     | Void   |
| <b>Precondition</b>     | Does not apply   |
| <b>Post condition</b>   | Does not apply   |
| <b>Error Conditions</b> | Does not apply   |

### 4.4.2 Function void Task1\_LED (void)

|                         |  |
|-------------------------|--|
| <b>Description</b>      | This task is executed every 200 milliseconds. Its main function is to call the state machine that handles the status of the LED. |
| <b>Parameter 1</b>      | Void   |
| <b>Return Value</b>     | Void   |
| <b>Precondition</b>     | Does not apply   |
| <b>Post condition</b>   | Does not apply   |
| <b>Error Conditions</b> | Does not apply   |

## 4.5 Init\_Tasks

### 4.5.1 Function void Global\_Init (void)

|                         |  |
|-------------------------|--|
| <b>Description</b>      | This function initializes the scheduler.                       |
| <b>Parameter 1</b>      | Void   |
| <b>Return Value</b>     | Void   |
| <b>Precondition</b>     | This function should be called before executing the scheduler. |
| <b>Post condition</b>   | The scheduler's functionalities can be used.                   |
| <b>Error Conditions</b> | Does not apply.  |

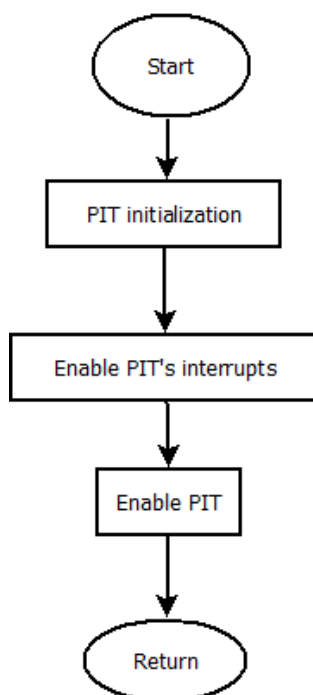
## 4.6 TIMER

### 4.6.1 Function void InitPIT (void)

|                         |   |
|-------------------------|---|
| <b>Description</b>      | PIT is initialized.   |
| <b>Parameter 1</b>      | Void  |
| <b>Return Value</b>     | Void  |
| <b>Precondition</b>     | This function is called in the beginning of the main program to initialize the PIT. |
| <b>Post condition</b>   | The interrupts every 10ms will be generated.  |
| <b>Error Conditions</b> | Does not apply  |

#### Dynamic Behavior

Activity diagram



### 4.6.2 Function void InitPITChannel (T\_UBYTE)

|                         |  |
|-------------------------|--|
| <b>Description</b>      | This function configures the given channel of the PIT timer.             |
| <b>Parameter 1</b>      | T_UBYTE PIT channel which must be configured.                            |
| <b>Parameter 2..n</b>   | Does not apply   |
| <b>Return Value</b>     | Void   |
| <b>Precondition</b>     | This function should be called in the beginning of the main application. |
| <b>Post condition</b>   | The initialized channel of the PIT will be ready to use.                 |
| <b>Error Conditions</b> | Does not apply.  |

## 4.7 LED

### 4.7.1 Function void Init\_LED (void)

|                         |   |
|-------------------------|---|
| <b>Description</b>      | This function initializes the pin used for the LED. |
| <b>Parameter 1</b>      | Void  |
| <b>Return Value</b>     | Void  |
| <b>Precondition</b>     | Does not apply                                      |
| <b>Post condition</b>   | The LED will be able to be changed.                 |
| <b>Error Conditions</b> | Does not apply                                      |

### 4.7.2 Function T\_UBYTE Get\_LED\_Status (void)

|                         |   |
|-------------------------|---|
| <b>Description</b>      | This function returns the state of the LED.   |
| <b>Parameter 1</b>      | Void  |
| <b>Return Value</b>     | T_UBYTE. Corresponds to the logic state of the LED. It can be either 0 or 1, meaning off or on, respectively. |
| <b>Precondition</b>     | Does not apply  |
| <b>Post condition</b>   | Does not apply  |
| <b>Error Conditions</b> | Does not apply  |

### 4.7.3 Function void Set\_LED\_Status (T\_UBYTE)

|                         |   |
|-------------------------|---|
| <b>Description</b>      | This function changes the LED status depending on the parameter received. |
| <b>Parameter 1</b>      | T_UBYTE. It can receive either 0 or 1 to turn it off or on respectively.  |
| <b>Return Value</b>     | Void  |
| <b>Precondition</b>     | The function Init_LED should be executed before.                          |
| <b>Post condition</b>   | The LED status will change to the one received in the parameter.          |
| <b>Error Conditions</b> | Does not apply  |

## 4.8 GPIO

### 4.8.1 Function void Set\_Pin\_State (T\_UBYTE, T\_UBYTE)

|                         |   |
|-------------------------|---|
| <b>Description</b>      | Changes the logic level of the output pin selected.                                     |
| <b>Parameter 1</b>      | T_UBYTE. Corresponds to the pin number that should be affected.                         |
| <b>Parameter 2</b>      | T_UBYTE. It can receive either 0 or 1 to turn the pin off or on respectively.           |
| <b>Return Value</b>     | Void  |
| <b>Precondition</b>     | The mode of the pin selected should be OUTPUT.  |
| <b>Post condition</b>   | The logic level for the selected pin, will be the one selected in the second parameter. |
| <b>Error Conditions</b> | Does not apply  |

#### 4.8.2 Function void Set\_Pin\_Mode (T\_UBYTE, T\_UBYTE)

|                         |  |
|-------------------------|--|
| <b>Description</b>      | This function changes the pin mode of the selected pin to the selected mode.   |
| <b>Parameter 1</b>      | T_UBYTE. Corresponds to the pin number that should be affected.  |
| <b>Parameter 2</b>      | T_UBYTE. It can receive a value according to the following definitions: 0 -> OUTPUT, 1 -> INPUT, 2 -> LIN_TX, 3 -> LIN_RX. |
| <b>Return Value</b>     | Void   |
| <b>Precondition</b>     | Does not apply   |
| <b>Post condition</b>   | The selected pin will act as the selected pin mode.  |
| <b>Error Conditions</b> | Does not apply   |

#### 4.8.3 Function T\_UBYTE Get\_Pin\_State (T\_UBYTE)

|                         |   |
|-------------------------|---|
| <b>Description</b>      | This function returns the state of the given pin.   |
| <b>Parameter 1</b>      | T_UBYTE. Corresponds to the pin number which state is unknown.  |
| <b>Return Value</b>     | T_UBYTE. Corresponds to the logic state of the pin. It can be either 0 or 1, meaning off or on, respectively. |
| <b>Precondition</b>     | Does not apply  |
| <b>Post condition</b>   | Does not apply  |
| <b>Error Conditions</b> | Does not apply  |

### 4.9 KERNEL

#### 4.9.1 Function void Tick\_ISR (void)

|                         |  |
|-------------------------|--|
| <b>Description</b>      | This function is the one that handles the clock Ticks in order to trigger the tasks. This interrupt runs periodically every 10 milliseconds according to the configuration of the PIT. |
| <b>Parameter 1</b>      | Void   |
| <b>Return Value</b>     | Void   |
| <b>Precondition</b>     | This function is called when a PIT interrupt is generated.   |
| <b>Post condition</b>   | It will literally interrupt the flow of the program to implement its code.   |
| <b>Error Conditions</b> | Does not apply   |

#### 4.9.2 Function void main\_Scheduler (void)

|                         |  |
|-------------------------|--|
| <b>Description</b>      | This function contains the main function of the scheduler which controls the timing for each of the tasks. |
| <b>Parameter 1</b>      | Void   |
| <b>Return Value</b>     | Void   |
| <b>Precondition</b>     | The Global_Init function should be executed before.  |
| <b>Post condition</b>   | Does not apply   |
| <b>Error Conditions</b> | Does not apply   |

## 4.10 Main

### 4.10.1 Function void main (void)

|                         |   |
|-------------------------|---|
| <b>Description</b>      | This function runs first by default. It is divided in system initialization and execution of the scheduler. |
| <b>Parameter 1</b>      | Void  |
| <b>Parameter 2</b>      | Does not apply.   |
| <b>Return Value</b>     | Void  |
| <b>Precondition</b>     | Does not apply.   |
| <b>Post condition</b>   | Does not apply.   |
| <b>Error Conditions</b> | Does not apply.   |

## 4.11 System\_Initialization

### 4.11.1 Function void System\_Init (void)

|                         |   |
|-------------------------|---|
| <b>Description</b>      | This function calls the functions that initializes the mode of operation, peripherals, and the scheduler. |
| <b>Parameter 1</b>      | Void  |
| <b>Parameter 2</b>      | Does not apply.   |
| <b>Return Value</b>     | Void  |
| <b>Precondition</b>     | This should be the first function called in the main program.   |
| <b>Post condition</b>   | It will be possible to use the microcontroller with the configurations done.                              |
| <b>Error Conditions</b> | Does not apply.   |

### 4.11.2 Function void ModeEntry (void)

|                         |  |
|-------------------------|--|
| <b>Description</b>      | It initializes the mode of operation.  |
| <b>Parameter 1</b>      | Void   |
| <b>Parameter 2</b>      | Does not apply.  |
| <b>Return Value</b>     | Void   |
| <b>Precondition</b>     | This should be the first function called in the main program.                |
| <b>Post condition</b>   | It will be possible to use the microcontroller with the configurations done. |
| <b>Error Conditions</b> | Does not apply.  |