

## RL78/F23, F24

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Rev.1.00

### Setup Procedure for LIN Communication in Slave Mode (Guidance)

2022.09.30

#### Introduction

This application note describes setup procedures for LIN communication, in which a device operates in slave mode of the UART/LIN module (hereinafter, RLIN3) in the RL78/F23, F24.

Under certain use conditions, the operations of the microcontroller might be different from examples that this document provides. Customers are required to sufficiently evaluate the use of the RLIN3 in their environment. Customers are also required to refer to the user's manual corresponding to their products for detailed functions of the RLIN3, clock generator, and interrupts.

#### Target Devices

- RL78/F23, F24 products

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## 1. Specifications of LIN Communication in Slave Mode

### 1.1 LIN Slave Mode Usage Conditions

The conditions for use of LIN communication in slave mode that this application note describes are shown below.

**Table 1-1 LIN Slave Mode Usage Conditions**

| Item                                                  |                              | Description                                           |
|-------------------------------------------------------|------------------------------|-------------------------------------------------------|
| CPU/peripheral hardware clock frequency ( $f_{CLK}$ ) |                              | 40 MHz                                                |
| LIN clock source ( $f_{LIN}$ )                        |                              | $f_{CLK}$                                             |
| LTXD0                                                 |                              | P13/LTXD0                                             |
| LRXD0                                                 |                              | P14/LRXD0                                             |
| Baud rate                                             |                              | 19200 bps                                             |
| Mode                                                  |                              | Slave mode (Fixed baud rate or auto baud rate)        |
| Noise filter                                          |                              | Enabled                                               |
| LIN interrupts                                        |                              | INTLIN0TRM, INTLIN0RVC, INTLIN0STA, INTLIN0WUP        |
| Checksum type                                         |                              | Classic checksum or Enhanced checksum (User selected) |
| Error detection                                       | Bit error                    | Enabled                                               |
|                                                       | Frame/Response timeout error | Auto baud rate mode: Disabled                         |
|                                                       |                              | Fixed baud rate mode: Enabled                         |
|                                                       | Framing error                | Enabled                                               |
|                                                       | Sync field error             | Enabled                                               |
|                                                       | Checksum error               | Enabled                                               |
|                                                       | ID parity error              | Enabled                                               |
| Response preparation error                            |                              | Enabled                                               |
| Number of bytes in frame's data field                 |                              | 0 to 8 bytes                                          |
| Response space                                        |                              | 1 Tbit                                                |
| Inter-byte space                                      |                              | 1 Tbit                                                |

## 1.2 LIN Network Connection Example

The LIN network connection is shown below.

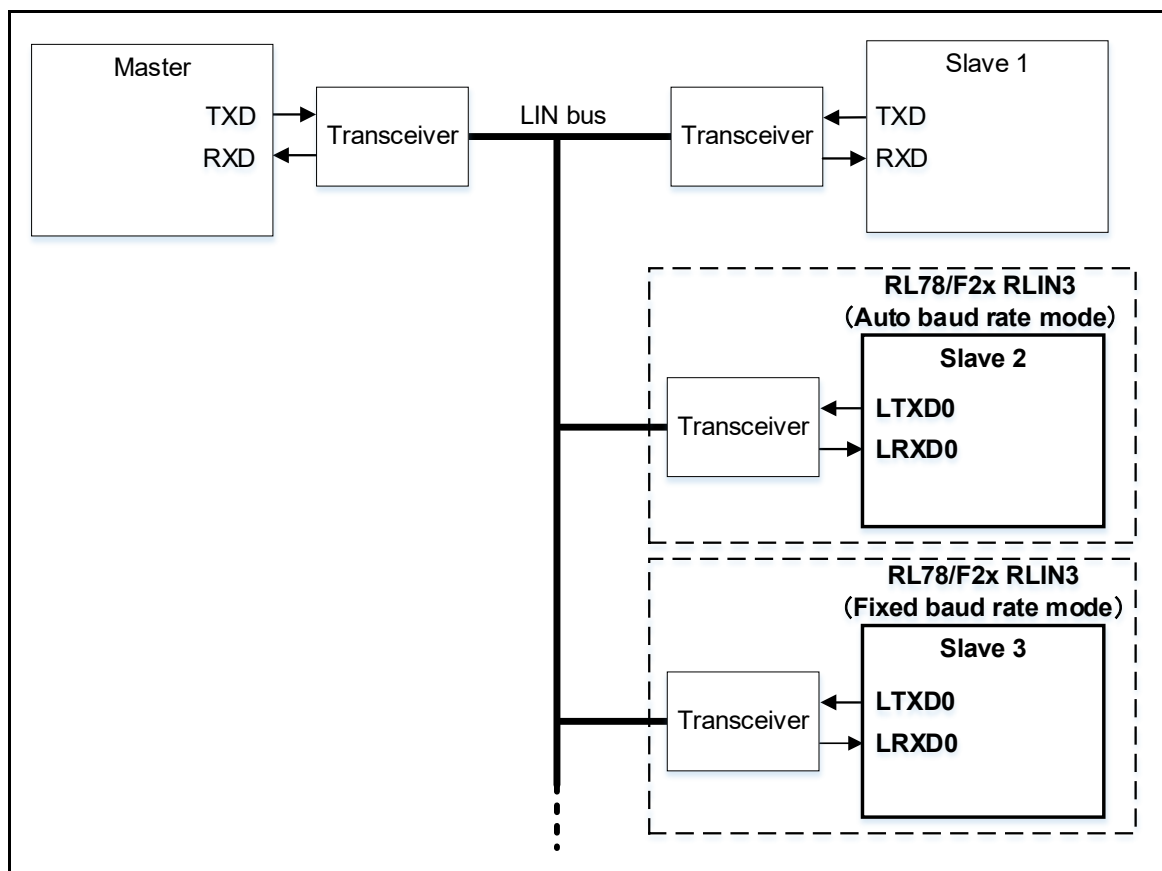


Figure 1-1 LIN Master - Slaves Network Connection (example)

### 1.3 SFR

The setting of the SFR used for LIN slave communication is shown below.

**Table 1-2 SFRs Used for LIN Communication in Slave Mode (1/2)**

| Register                                      |          | Setting Value                                          | Conditions                                                                                                                                                                                                                                                                                     |
|-----------------------------------------------|----------|--------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Name                                          | Symbol   |                                                        |                                                                                                                                                                                                                                                                                                |
| Peripheral enable register 2                  | PER2     | LIN0EN = 0 or 1                                        | 0: Stop LIN0 clock supply, 1: LIN0 clock supply                                                                                                                                                                                                                                                |
| LIN clock select register                     | LINCKSEL | 10H                                                    | LIN0MCK=0 (LIN0 communication clock = f <sub>CLK</sub> <sup>Note</sup> )<br>LIN0MCKE=1 (LIN0 communication clock supply)                                                                                                                                                                       |
| LIN channel select register                   | LCHSEL   | 00H                                                    | LSEL0=0 (Enable LIN0 register access)                                                                                                                                                                                                                                                          |
| LIN wake-up baud rate select register 0       | LWBR0    | Auto baud rate mode: 74H                               | LPRS[2:0]=010B (LIN0 prescaler clock: 1/4 (10MHz))<br>NSPB[3:0]=0111B (Bit sampling: 8 sampling)                                                                                                                                                                                               |
|                                               |          | Fixed baud rate mode: 00H                              | LPRS[2:0]=000B (LIN0 prescaler clock: 1/1 (40MHz))<br>NSPB[3:0]=0000B (Bit sampling: 16 sampling)                                                                                                                                                                                              |
| LIN/UART baud rate prescaler register 0       | LBRP0    | 0081H                                                  | 19200bps<br>In auto baud rate mode: Updated with sync field reception                                                                                                                                                                                                                          |
| LIN self-test control register 0              | LSTC0    | 00H                                                    | LSTM=0 (LIN self-test mode is disabled)                                                                                                                                                                                                                                                        |
| LIN/UART mode register 0                      | LMD0     | Auto baud rate mode: 12H<br>13H (Wake-up transmission) | LMD[1:0]=10B (LIN slave mode [auto baud rate])<br>LIOS=1 (Enable LIN0 transmission/reception/status interrupt)<br>LRDNFS=0 (LRXD0 noise filter enabled)                                                                                                                                        |
|                                               |          | Fixed baud rate mode: 13H                              | LMD[1:0]=11B (LIN slave mode [fixed baud rate])<br>LIOS=1 (Enable LIN0 transmission/reception/status interrupt)<br>LRDNFS=0 (LRXD0 noise filter enabled)                                                                                                                                       |
| LIN/UART break field configuration register 0 | LBFC0    | 00H                                                    | BLT=0 (Break (low width) detection: 10 Tbit)                                                                                                                                                                                                                                                   |
| LIN/UART space configuration register 0       | LSC0     | 10H                                                    | RS[2:0]=000B (Response space: 0 Tbit)<br>IBS[1:0]=01B (Inter-byte space: 1 Tbit)                                                                                                                                                                                                               |
| LIN wake-up configuration register 0          | LWUP0    | 40H                                                    | WUTL[3:0]=0100B (Wake-up transmission low width: 5 Tbit)                                                                                                                                                                                                                                       |
| LIN interrupt enable register 0               | LIE0     | 0FH                                                    | FTCIE=1 (Frame / Wake-up transmission completion interrupt: Enabled)<br>FRCIE=1 (Frame / Wake-up reception completion interrupt: Enabled)<br>ERRIE=1 (Error detection interrupt: Enabled)<br>SHIE=1 (Header reception completion interrupt: Enabled)                                           |
| LIN/UART error detection enable register 0    | LEDE0    | Auto baud rate mode: D9H                               | BERE=1 (Bit error detection: Enabled)<br>TERE=0 (Response timeout error detection: Disabled)<br>FERE=1 (Framing error detection: Enabled)<br>SFERE=1 (Sync field error detection: Enabled)<br>IPERE=1 (ID parity error detection: Enabled)<br>LTES=1 (Timeout selection bit: Response timeout) |
|                                               |          | Fixed baud rate mode: DDH                              | BERE=1 (Bit error detection: Enabled)<br>TERE=1 (Response timeout error detection: Enabled)<br>FERE=1 (Framing error detection: Enabled)<br>SFERE=1 (Sync field error detection: Enabled)<br>IPERE=1 (ID parity error detection: Enabled)<br>LTES=1 (Timeout selection bit: Response timeout)  |
| LIN/UART control register 0                   | LCUC0    | 00H, 01H, 03H                                          | LCUC0=00H (LIN reset mode transition)<br>LCUC0=01H (LIN wake-up mode transition)<br>LCUC0=03H (LIN operation mode transition)                                                                                                                                                                  |
| LIN/UART transmission control register 0      | LTRC0    | 01H, 02H, 04H                                          | LTRC0=01H (Start Header reception / Wake-up transmission)<br>LTRC0=02H (Start response transmission/reception)<br>LTRC0=04H (No response request)                                                                                                                                              |
| LIN/UART mode status register 0               | LMST0    | Read<br>(00H, 01H, 03H)                                | LMST0=00H (LIN reset mode status)<br>LMST0=01H (LIN wake-up mode status)<br>LMST0=03H (LIN operation mode status)                                                                                                                                                                              |
| LIN/UART status register 0                    | LST0     | Read<br>00H (Status clear)                             | Read status flag<br>Bit 0: FTC (1: Frame / Wake-up transmission completion)<br>Bit 1: FRC (1: Response reception completion)<br>Bit 3: ERR (1: Status error detection)<br>Bit 6: D1RC (1: Data[1] reception completion)<br>Bit 7: HTRC (1: Header reception completion)                        |

**Note:** For fixed baud rate mode, select X1 oscillator or PLL clock (source=X1) for communication clock (f<sub>CLK</sub>).

Table 1-2 SFRs Used for LIN Communication in Slave Mode (2/2)

| Register                                                       |               | Setting Value             | Conditions                                                                                                                                                                                                                                                                                                                                                                              |
|----------------------------------------------------------------|---------------|---------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Name                                                           | Symbol        |                           |                                                                                                                                                                                                                                                                                                                                                                                         |
| LIN/UART error status register 0                               | LEST0         | Read<br>00H (Error clear) | Read error status flag<br>Bit 0: BER (1: Bit error detection)<br>Bit 2: TER (1: Response timeout error detection in fixed baud rate mode)<br>Bit 3: FER (1: Framing error detection)<br>Bit 4: SFER (1: Sync field error detection)<br>Bit 5: CSER (1: Checksum error detection)<br>Bit 6: IPER (1: ID parity error detection)<br>Bit 7: RPER (1: Response preparation error detection) |
| LIN/UART data field configuration register 0                   | LDFO0         | xxH                       | RFDL[3:0]: Response data length (0 to 8)<br>RCDS: Response direction (0: Reception, 1: Transmission)<br>LCS: Checksum type (0: Classic checksum, 1: Enhanced checksum)<br>LSS=0 (Next transmission/reception data group is the last one)                                                                                                                                                |
| LIN/UART ID buffer register 0                                  | LIDB0         | Read                      | Received ID + ID parity                                                                                                                                                                                                                                                                                                                                                                 |
| LIN checksum buffer register 0                                 | LCBR0         | xxH                       | Read reception checksum <sup>Note</sup>                                                                                                                                                                                                                                                                                                                                                 |
| LIN/UART data buffer [1-8] registers                           | LDB01 – LDB08 | xxH                       | Set transmit DATA[n], or read reception DATA[n]                                                                                                                                                                                                                                                                                                                                         |
| LIN break and sync field detection status register 0           | LBSS0         | -                         | LIN break and sync field detection flag<br>Bit 0: BRKC (1: Break field signal detection) <sup>Note</sup><br>Bit 1: SYCC (1: Sync field signal detection) <sup>Note</sup>                                                                                                                                                                                                                |
| LIN response space dominant signal detection status register 0 | LRSS0         | -                         | LIN response space dominant signal detection flag<br>Bit 0: RSDD (1: Detected dominant level in response space) <sup>Note</sup>                                                                                                                                                                                                                                                         |

**Note:** LCBR0, LBSS0, and LRSS0 registers are not used in this application note. Checksum error is checked by checksum error detection.

Table 1-3 SFRs Used for LIN Communication in Slave Mode (Port related registers)

| Register                                |        | Setting Value  | Conditions                                              |
|-----------------------------------------|--------|----------------|---------------------------------------------------------|
| Name                                    | Symbol |                |                                                         |
| Input switch control register           | ISC    | ISC2=1         | LRXD0 input pin interrupt enabled                       |
| Peripheral I/O redirection register 4   | PIOR4  | PIOR44=0       | LRXD0: P14, LTXD0: P13 selected                         |
| Port register 1                         | P1     | P13=1          | Port P1.3 output latch = High                           |
| Port mode register 1                    | PM1    | PM13=0, PM14=1 | Port P1.3: output direction, Port P1.4: input direction |
| Port output mode register 1             | POM1   | POM13=0        | Port P1.3: CMOS output                                  |
| Port input mode register 1              | PIM1   | PIM14=0        | Port P1.4: CMOS input                                   |
| Port input threshold control register 1 | PITHL1 | PITHL14=0      | Port P1.4: Schmitt1 input type selected                 |
| Pull-up resistor option register 1      | PU1    | PU14=1         | Port P1.4: Internal pull-up enabled                     |

**Table 1-4 SFRs Used for LIN Communication in Slave Mode (Interrupt related registers)**

| Register                                          |              | Setting Value | Conditions                                                                                 |
|---------------------------------------------------|--------------|---------------|--------------------------------------------------------------------------------------------|
| Name                                              | Symbol       |               |                                                                                            |
| External interrupt rising edge enable register 1  | EGP1         | EGP11=0       | LRXD0: Falling edge detection enabled                                                      |
| External interrupt falling edge enable register 1 | EGN1         | EGN11=1       |                                                                                            |
| Interrupt request flag register 0H                | IF0H         | LIN0TRMIF=0   | Clear the LIN0 transmission interrupt request flag                                         |
| Interrupt request flag register 1L                | IF1L         | LIN0RVCIF=0   | Clear the LIN0 reception interrupt request flag                                            |
|                                                   |              | LIN0STAIF=0   | Clear the LIN0 error status interrupt request flag                                         |
| Interrupt request flag register 2L                | IF2L         | LIN0WUPIF=0   | Clear the LRXD0 falling edge detection interrupt request flag                              |
| Interrupt mask flag register 0H                   | MK0H         | LIN0TRMMK=0,1 | LIN0 transmission interrupt mask flag (0: Interrupt enabled, 1: Interrupt mask)            |
| Interrupt mask flag register 1L                   | MK1L         | LIN0RVCMK=0,1 | LIN0 reception interrupt mask flag (0: Interrupt enabled, 1: Interrupt mask)               |
|                                                   |              | LIN0STAMK=0,1 | LIN0 status interrupt mask flag (0: Interrupt enabled, 1: Interrupt mask)                  |
| Interrupt mask flag register 2L                   | MK2L         | LIN0WUPMK=0,1 | LRXD0 falling edge detection interrupt mask flag (0: Interrupt enabled, 1: Interrupt mask) |
| Priority specification flag registers 10H/00H     | PR10H, PR00H | LIN0TRMPR=01B | LIN0 transmission interrupt priority level flag 0, 1 (01B: Level-1)                        |
| Priority specification flag registers 11L/01L     | PR11L, PR01L | LIN0RVCPR=01B | LIN0 reception interrupt priority level flag 0, 1 (01B: Level-1)                           |
|                                                   |              | LIN0STAPR=01B | LIN0 status interrupt priority level flag 0, 1 (01B: Level-1)                              |
| Priority specification flag registers 12L/02L     | PR12L, PR02L | LIN0WUPPR=01B | LRXD0 falling edge detection interrupt priority level flag 0, 1 (01B: Level-1)             |

## 2. Overview of LIN Slave Communication

### 2.1 LIN Slave Communication Processing Overview

LIN slave communication example flow is shown below.

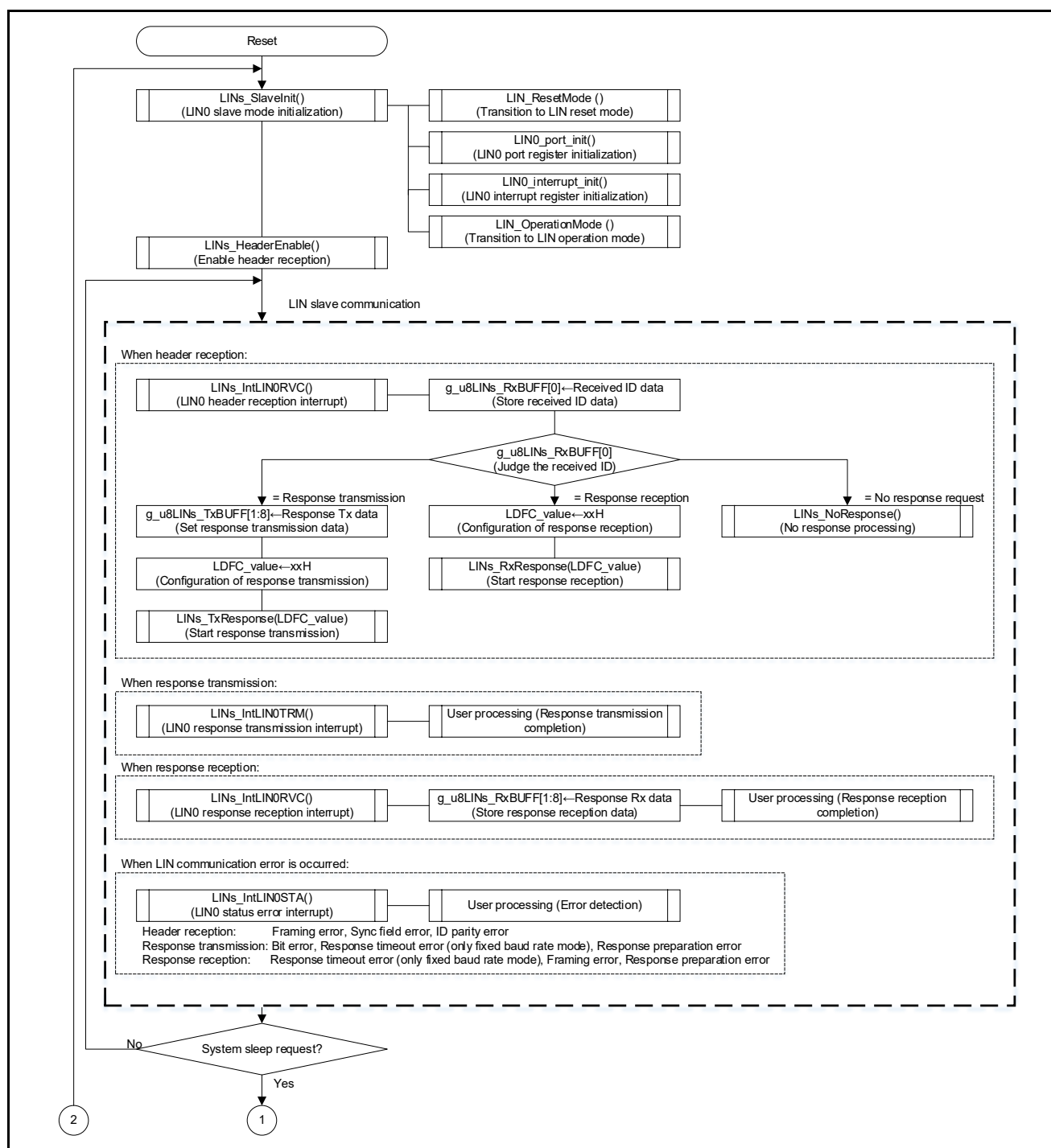


Figure 2-1 LIN Communication Process in Slave Mode (1/2)

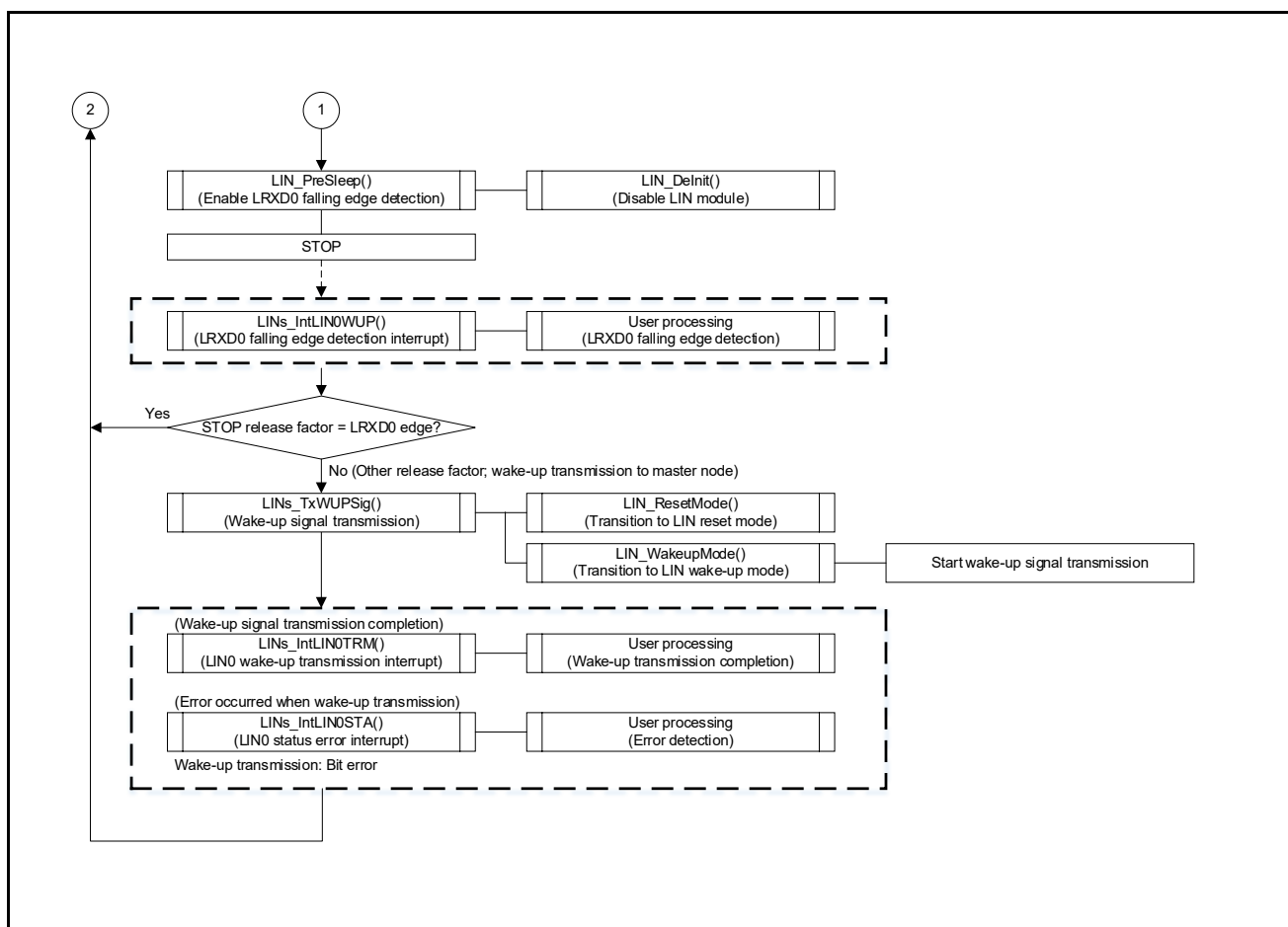
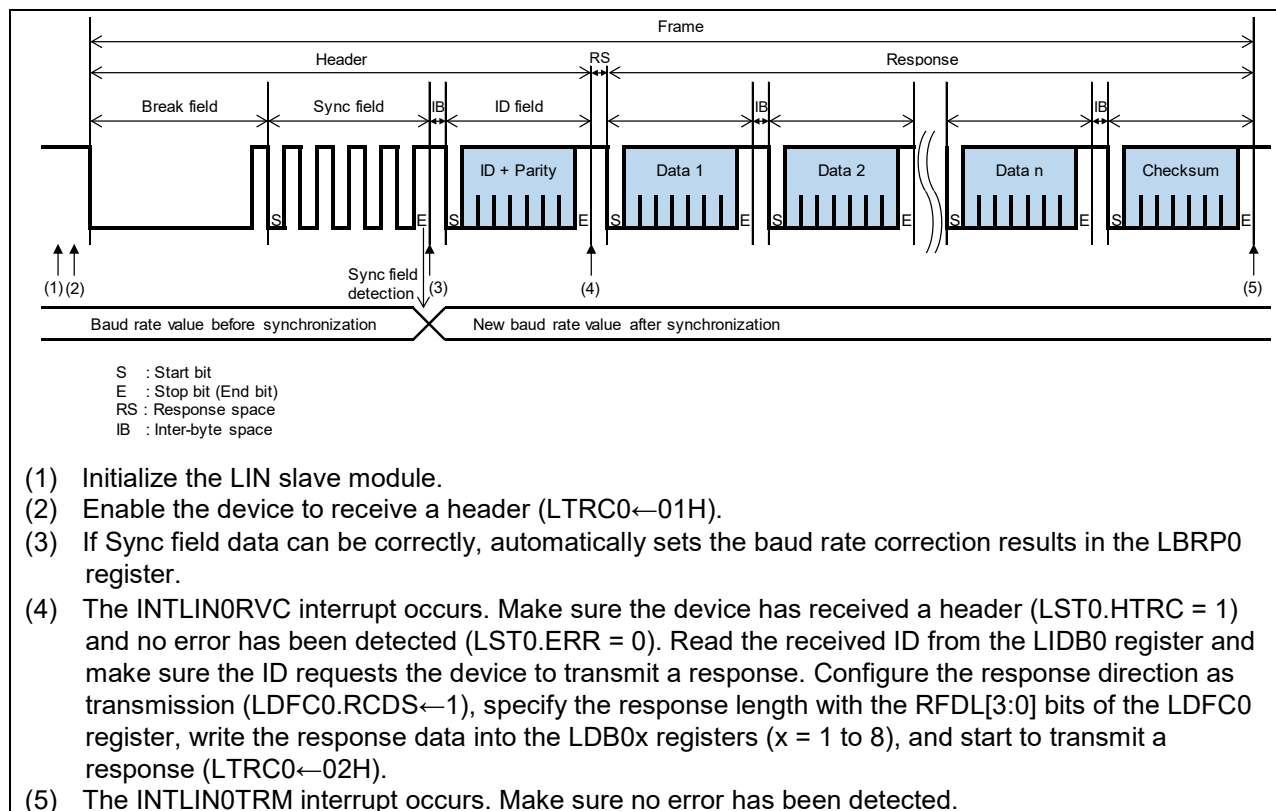


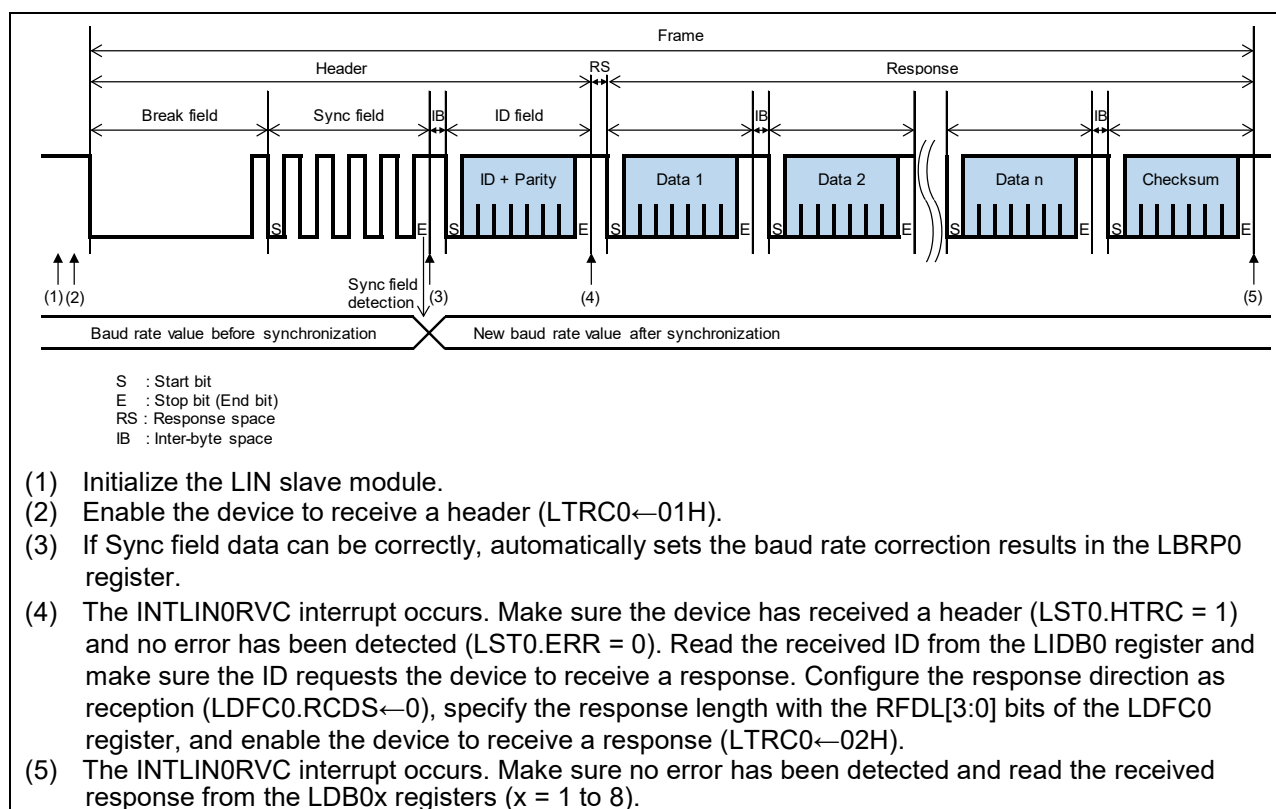
Figure 2-1 LIN Communication Process in Slave Mode (2/2)

## 2.2 LIN Frame Timings

The timing diagram for response transmission and reception in the LIN slave are shown below for each of the Auto baud rate and Fixed baud rate.



**Figure 2-2 Timing Diagram of LIN Response Transmission in Slave Mode (Auto Baud Rate)**



**Figure 2-3 Timing Diagram of LIN Response Reception in Slave Mode (Auto Baud Rate)**

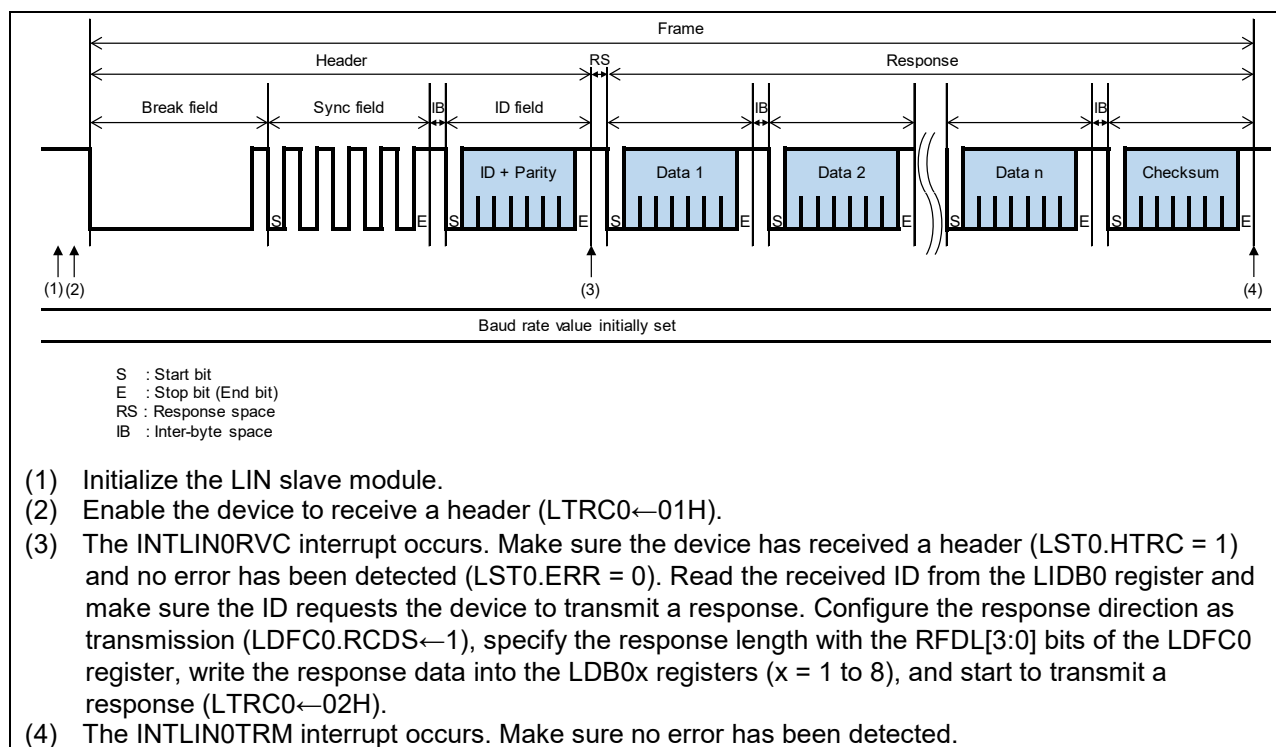


Figure 2-4 Timing Diagram of LIN Response Transmission in Slave Mode (Fixed Baud Rate)

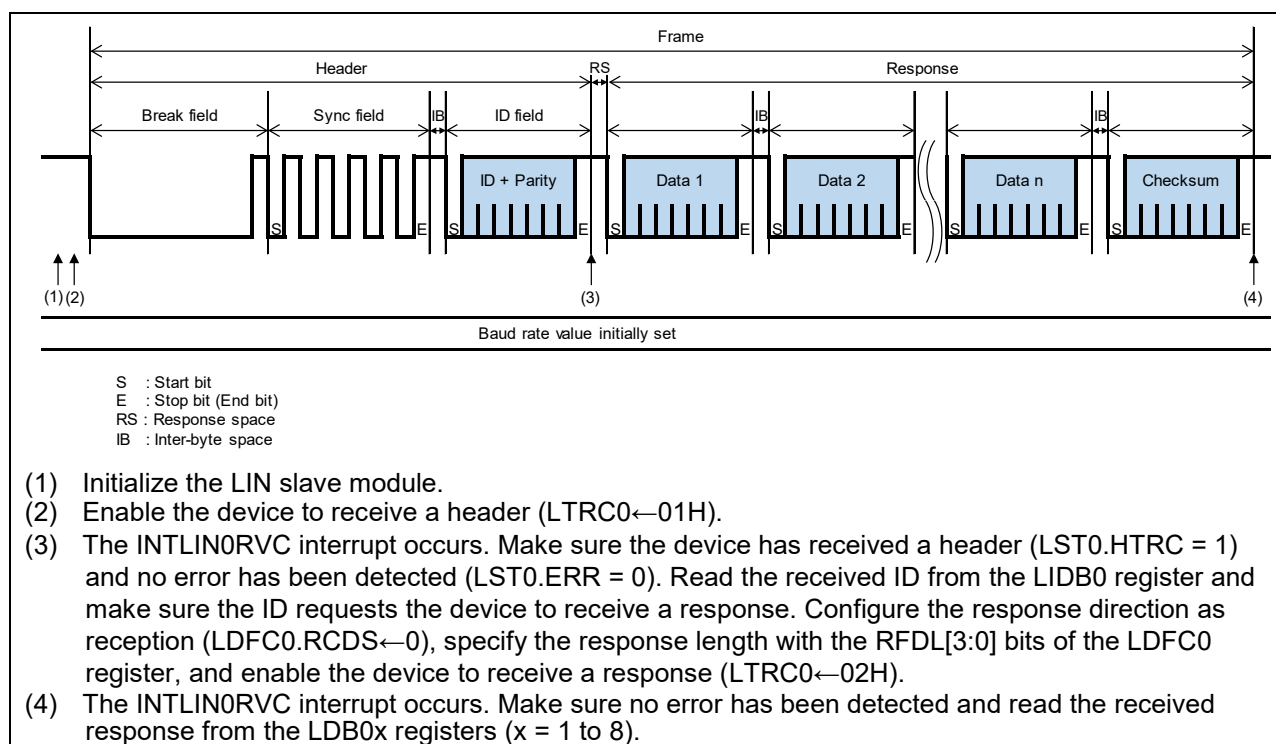


Figure 2-5 Timing Diagram of LIN Response Reception in Slave Mode (Fixed Baud Rate)

## 2.3 LIN Slave Communication Status and SFR

The LIN/UART module (RLIN3) generates LINn successful transmission interrupt, LINn successful reception interrupt, and LINn reception status interrupt. Also, each interrupt has multiple interrupt factors. For details, refer to the user's manual of the target products. In this application note, the status register of RLIN3 module is read to determine the interrupt source. Connections between LIN slave communication status and SFRs are shown below.

After receiving a header, if a dominant level is detected in the LIN bus during the response space until the start of response transmission/reception, the RSDD bit of the LRSSn register becomes to "1" (dominant level detected in the response space). Error handling can also be performed by judging the RSDD bit at the start of response transmission/reception. RSDD bit is not used in this application note.

**Table 2-1 LIN Communication State and SFRs (LINn successful reception interrupt)**

| LIN Communication State<br>Reception                            | SFRs      |            |           |
|-----------------------------------------------------------------|-----------|------------|-----------|
|                                                                 | LST0      |            |           |
|                                                                 | bit3(ERR) | bit7(HTRC) | bit1(FRC) |
| Communication error<br>(Processed in the LIN0 status interrupt) | 1         | -          | -         |
| Header reception completion                                     | 0         | 1          | -         |
| Response reception completion                                   |           | 0          | 1         |
| Illegal interrupt occurred                                      |           |            | 0         |

**Remarks** 1. -: Not judged by software.  
2. For details, see section 3.4.1.

**Table 2-2 LIN Communication State and SFRs (LINn successful transmission interrupt)**

| LIN Communication State<br>Transmission                         | SFRs      |           |       |
|-----------------------------------------------------------------|-----------|-----------|-------|
|                                                                 | LST0      |           | LMST0 |
|                                                                 | bit3(ERR) | bit0(FTC) |       |
| Communication error<br>(Processed in the LIN0 status interrupt) | 1         | -         | -     |
| Response transmission completion                                | 0         | 1         | 01H   |
| Wake-up transmission completion                                 |           | 0         | ≠01H  |
| Illegal interrupt occurred                                      |           |           | -     |

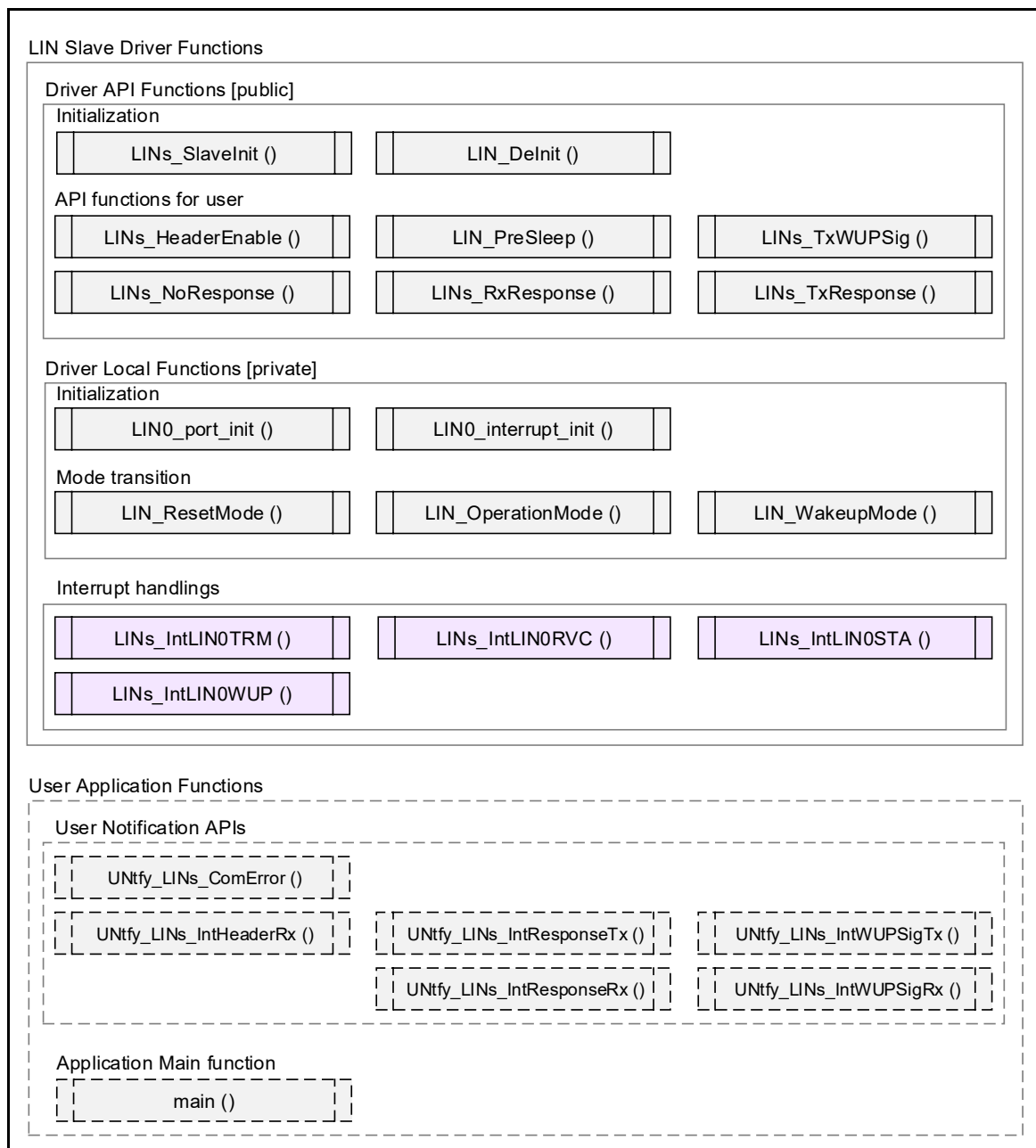
**Remarks** 1. -: Not judged by software.  
2. For details, see section 3.4.2.

### 3. LIN Slave Driver Functions

The LIN slave communication driver program example shown in this application note is explained below.

#### 3.1 Function list

The function list of this driver program and the variables used are shown below.



**Figure 3-1 Functions of LIN Communication in Slave Mode**

Table 3-1 Function List for LIN Communication in Slave Mode

| Function Name                                        | Description                                                                                                                                                                                                                                                                                              | Public / Private |
|------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| void LINs_SlaveInit (void)                           | Initialization for LIN (slave mode)                                                                                                                                                                                                                                                                      | public           |
| void LIN_DeInit (void)                               | Disables LIN module                                                                                                                                                                                                                                                                                      | public           |
| void LINs_HeaderEnable (void)                        | Enable header reception                                                                                                                                                                                                                                                                                  | public           |
| void LIN_PreSleep (void)                             | Process before transition to sleep mode                                                                                                                                                                                                                                                                  | public           |
| void LINs_TxWUPSig (void)                            | LIN wake-up signal transmission request                                                                                                                                                                                                                                                                  | public           |
| void LINs_TxResponse ( unsigned char u8a_LDFC_value) | Response transmission request                                                                                                                                                                                                                                                                            | public           |
| void LINs_RxResponse ( unsigned char u8a_LDFC_value) | Response reception request                                                                                                                                                                                                                                                                               | public           |
| void LINs_NoResponse (void)                          | No response request                                                                                                                                                                                                                                                                                      | public           |
| void LIN0_port_init (void)                           | Initialization for LIN related port function                                                                                                                                                                                                                                                             | private          |
| void LIN0_interrupt_init (void)                      | Initialization for LIN related interrupt function                                                                                                                                                                                                                                                        | private          |
| void LIN_ResetMode (void)                            | This function transitions to LIN reset mode.                                                                                                                                                                                                                                                             | private          |
| void LIN_OperationMode (void)                        | This function transitions to LIN operation mode.                                                                                                                                                                                                                                                         | private          |
| void LIN_WakeupMode (void)                           | This function transitions to LIN wake-up mode.                                                                                                                                                                                                                                                           | private          |
| void LINs_IntLIN0RVC (void)                          | This function is the LIN0 reception completion interrupt processing. (Header reception / Response reception / Wake-up reception <sup>Note</sup> )                                                                                                                                                        | public           |
| void LINs_IntLIN0TRM (void)                          | This function is the LIN0 transmission completion interrupt processing. (Response transmission / Wake-up transmission)                                                                                                                                                                                   | public           |
| void LINs_IntLIN0STA (void)                          | This function is the interrupt processing when LIN0 status error is occurred.<br>- Response transmission: Bit error or Response timeout error detection<br>- Header reception / Response reception: Response timeout error, Framing error, Sync field error, Checksum error or ID parity error detection | public           |
| void LINs_IntLIN0WUP (void)                          | This function is the LRXD0 falling edge detection interrupt processing.                                                                                                                                                                                                                                  | public           |

**Note:** In this application note, wake-up detection is detected in LRXD0 falling edge. Wake-up reception interrupt is not used.

Table 3-2 Variables Used for LIN Communication in Slave Mode

| Variable Name                    | Description                                                                                          |
|----------------------------------|------------------------------------------------------------------------------------------------------|
| unsigned char g_u8LINs_TxBUFF[9] | g_u8LINs_TxBUFF[0]: Not used<br>g_u8LINs_TxBUFF[1 to 8]: Set response transmission data              |
| unsigned char g_u8LINs_RxBUFF[9] | g_u8LINs_RxBUFF[0]: Store received ID data<br>g_u8LINs_RxBUFF[1 to 8]: Store response reception data |

Table 3-3 User Notification Function APIs for LIN Slave Driver

| Function API Name                                         | Description                                                                                                                                                                                                                                                          |
|-----------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| void UNTfy_LINs_ComError ( unsigned short u16a_errorinfo) | User's processing for error detections.<br>bit[7:0]: Store the LEST0 register value (When INTLIN0STA occurred)<br>bit[15:0]: When INTLIN0STA occurred: 00H<br>When INTLIN0RVC occurred: 80H (illegal interrupt)<br>When INTLIN0TRM occurred: 40H (illegal interrupt) |
| void UNTfy_LINs_IntHeaderRx (void)                        | User's processing for header reception completion.                                                                                                                                                                                                                   |
| void UNTfy_LINs_IntResponseTx (void)                      | User's processing for response transmission completion.                                                                                                                                                                                                              |
| void UNTfy_LINs_IntResponseRx (void)                      | User's processing for response reception completion.                                                                                                                                                                                                                 |
| void UNTfy_LINs_IntWUPSigTx (void)                        | User's processing for wake-up signal transmission completion.                                                                                                                                                                                                        |
| void UNTfy_LINs_IntWUPSigRx (void)                        | User's processing for wake-up signal reception completion.                                                                                                                                                                                                           |

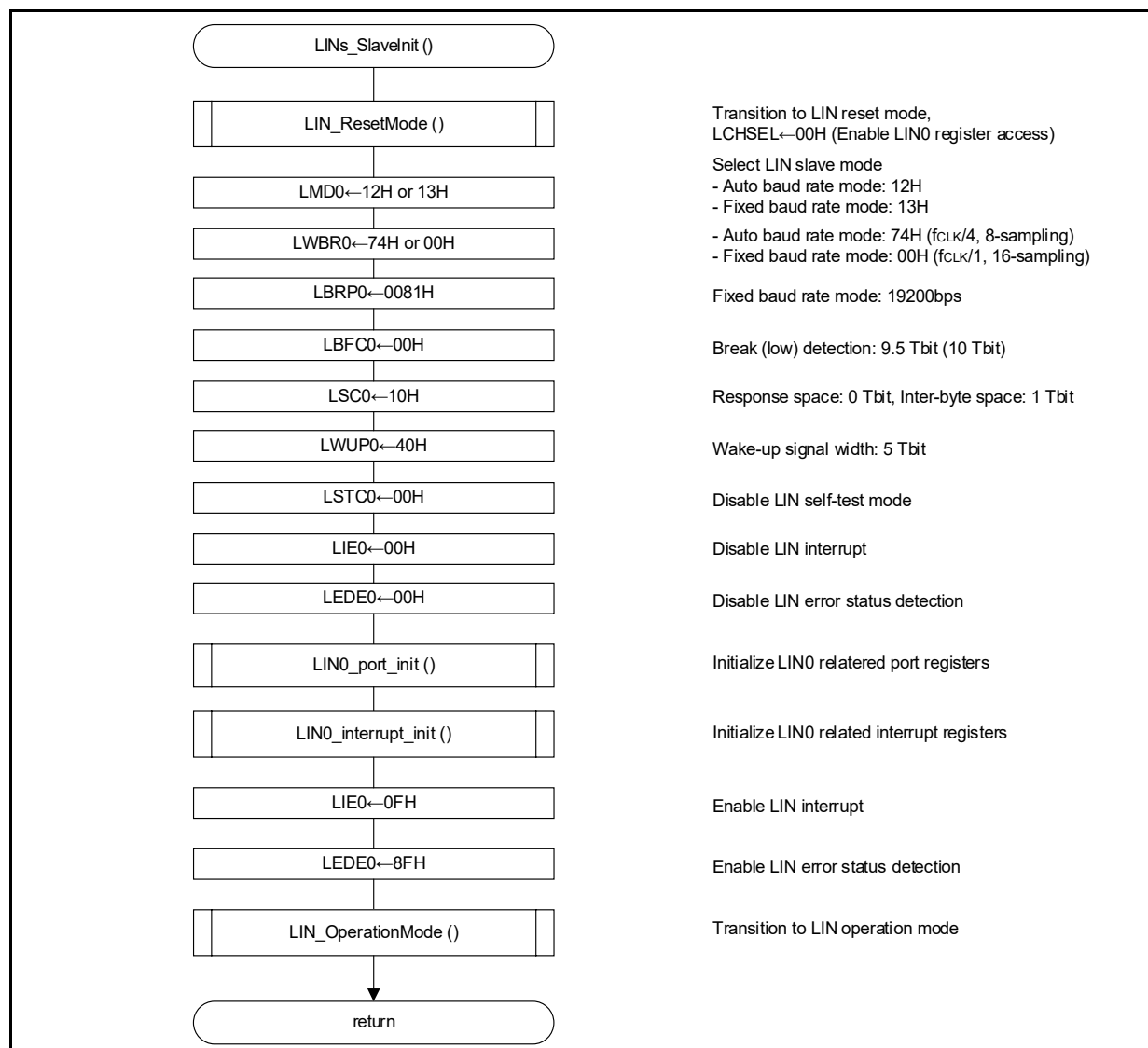
## 3.2 Driver API Functions [Public]

Each public function APIs of the LIN slave communication driver program example shown in this application note is explained below.

### 3.2.1 LIN Slave Module Initialization

**Table 3-4 LIN Slave Initialization Function (LINs\_SlaveInit)**

|                 |                                                                                                                                                                                                                                        |      |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| Syntax          | void LINs_SlaveInit (void)                                                                                                                                                                                                             |      |
| Parameters      | In                                                                                                                                                                                                                                     | None |
|                 | Out                                                                                                                                                                                                                                    | None |
| Local variables | None                                                                                                                                                                                                                                   |      |
| Return value    | None                                                                                                                                                                                                                                   |      |
| Call functions  | LIN_ResetMode (): Transition to LIN reset mode.<br>LIN0_port_init (): LIN0 port function initialization.<br>LIN0_interrupt_init (): LIN0 interrupt function initialization.<br>LIN_OperationMode (): Transition to LIN operation mode. |      |
| Description     | This function initializes LIN (slave mode), port and interrupt functions.                                                                                                                                                              |      |
| Note            | Call from upper layer with interrupt disabled.                                                                                                                                                                                         |      |

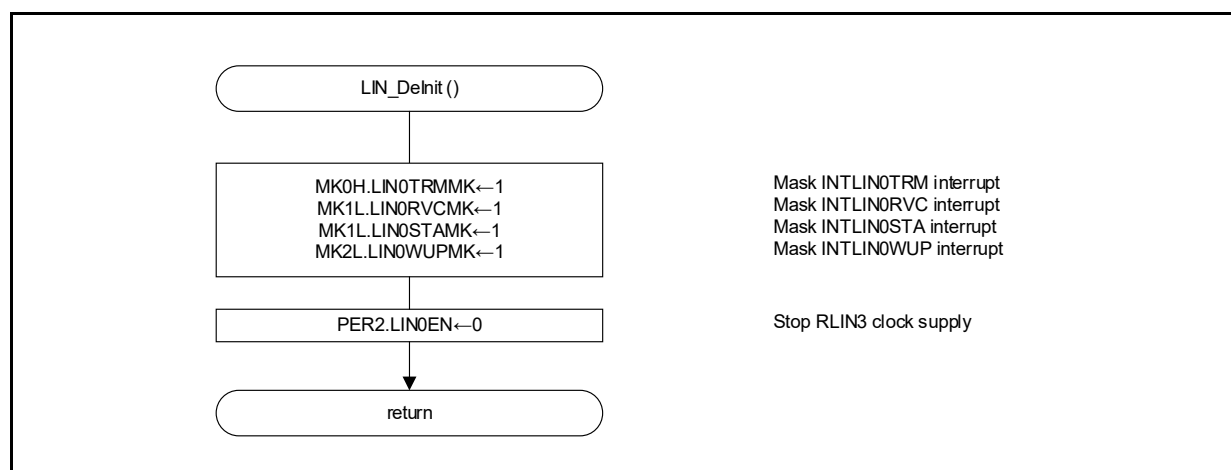


**Figure 3-2 LIN Slave Initialization Procedure (LINs\_SlaveInit)**

### 3.2.2 LIN Module De-Initialization

**Table 3-5 LIN De-Initialization Function (LIN\_DeInit)**

|                 |                                                                      |      |
|-----------------|----------------------------------------------------------------------|------|
| Syntax          | void LIN_DeInit (void)                                               |      |
| Parameters      | In                                                                   | None |
|                 | Out                                                                  | None |
| Local variables | None                                                                 |      |
| Return value    | None                                                                 |      |
| Call functions  | None                                                                 |      |
| Description     | This function disables LIN module.                                   |      |
| Note            | Call this function when GCSC and GINT bits of IAWCTL register are 0. |      |

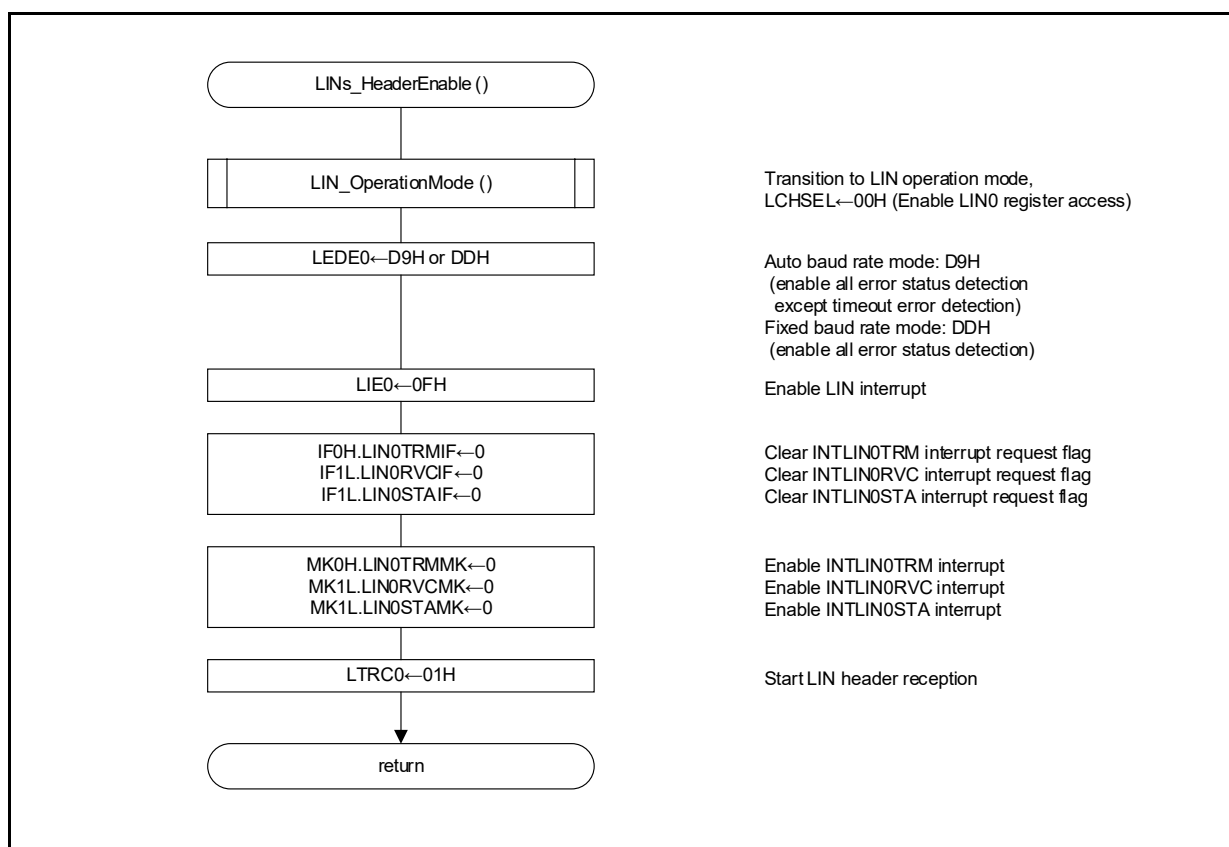


**Figure 3-3 LIN De-Initialization Procedure (LIN\_DeInit)**

### 3.2.3 LIN Slave Header Reception Enable

**Table 3-6 LIN Slave Header Reception Enable Function (LINs\_HeaderEnable)**

|                 |                                                           |      |
|-----------------|-----------------------------------------------------------|------|
| Syntax          | void LINs_HeaderEnable (void)                             |      |
| Parameters      | In                                                        | None |
|                 | Out                                                       | None |
| Local variables | None                                                      |      |
| Return value    | None                                                      |      |
| Call functions  | None                                                      |      |
| Description     | This function is used to enable header reception.         |      |
| Note            | Call this function when GINT bit of IAWCTL register is 0. |      |

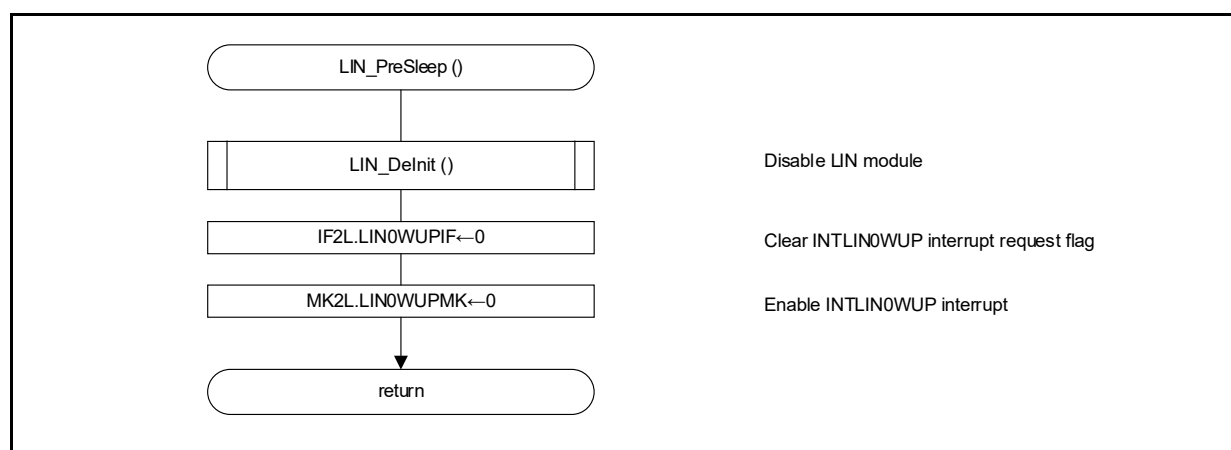


**Figure 3-4 LIN Slave Header Reception Enable Procedure (LINs\_HeaderEnable)**

### 3.2.4 Before Sleep Mode Transition Processing

**Table 3-7 Before Sleep Mode Transition Processing Function (LIN\_PreSleep)**

|                 |                                                           |      |
|-----------------|-----------------------------------------------------------|------|
| Syntax          | void LIN_PreSleep (void)                                  |      |
| Parameters      | In                                                        | None |
|                 | Out                                                       | None |
| Local variables | None                                                      |      |
| Return value    | None                                                      |      |
| Call functions  | LIN_DeInit (): Disable LIN module function                |      |
| Description     | This function is process before transition to sleep mode. |      |
| Note            | Call from upper layer with interrupt disabled.            |      |
|                 | Call this function when GINT bit of IAWCTL register is 0. |      |

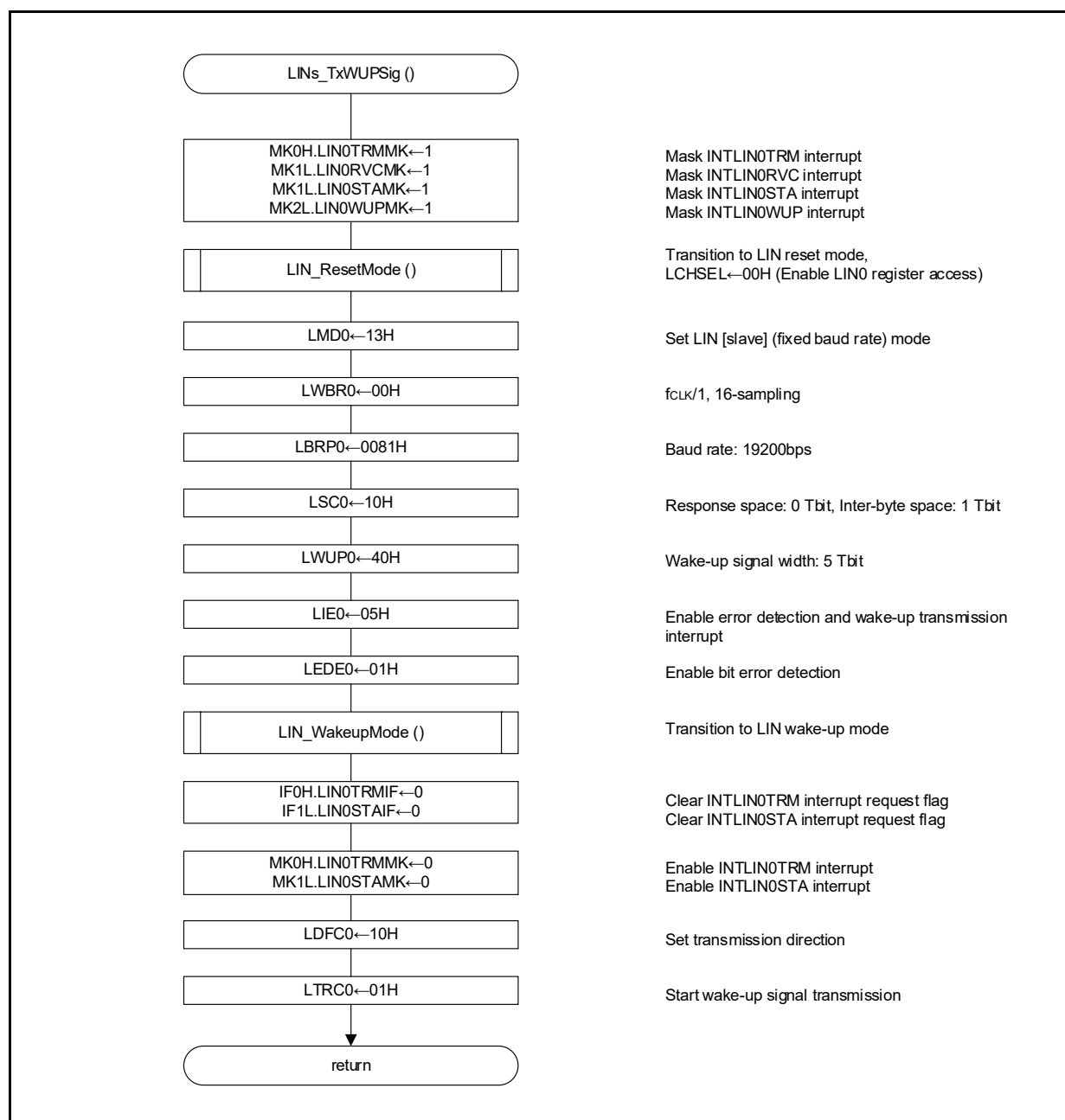


**Figure 3-5 Before Sleep Mode Transition Processing Procedure (LIN\_PreSleep)**

### 3.2.5 LIN Slave Wake-up Signal Transmission

**Table 3-8 LIN Slave Wake-up Signal Transmission Function (LINs\_TxWUPSig)**

|                 |                                                           |                                      |
|-----------------|-----------------------------------------------------------|--------------------------------------|
| Syntax          | void LINs_TxWUPSig (void)                                 |                                      |
| Parameters      | In                                                        | None                                 |
|                 | Out                                                       | None                                 |
| Local variables | None                                                      |                                      |
| Return value    | None                                                      |                                      |
| Call functions  | LIN_ResetMode ():                                         | LIN reset mode transition function   |
|                 | LIN_WakeupMode ():                                        | LIN wake-up mode transition function |
| Description     | This function transmits the LIN wake-up signal.           |                                      |
| Note            | Call this function when GINT bit of IAWCTL register is 0. |                                      |

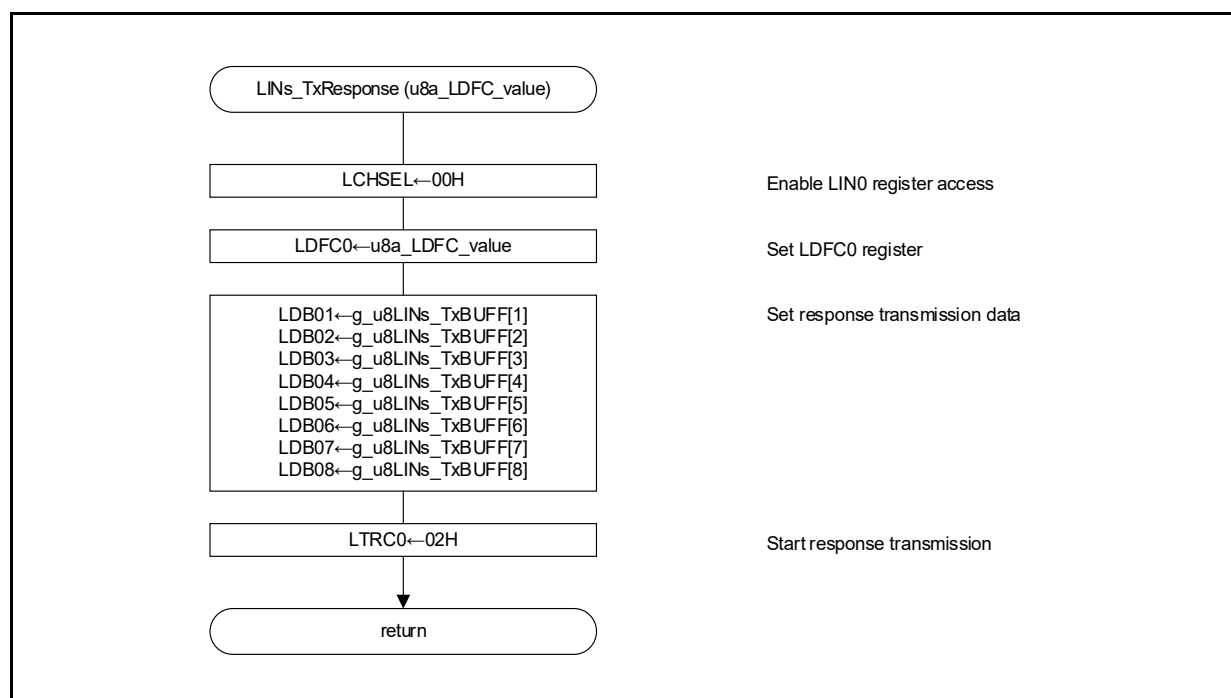


**Figure 3-6 LIN Slave Wake-up Signal Transmission Procedure (LINs\_TxWUPSig)**

### 3.2.6 LIN Slave Response Transmission Start

**Table 3-9 LIN Slave Response Transmission Start Function (LINs\_TxResponse)**

|                 |     |                                                                           |                                                          |
|-----------------|-----|---------------------------------------------------------------------------|----------------------------------------------------------|
| Syntax          |     | void LINs_TxResponse (unsigned char u8a_LDFC_value)                       |                                                          |
| Parameters      | In  | unsigned char                                                             | u8a_LDFC_value: LDFC0 setting value                      |
|                 |     | - bit3-0 (RFDL[3:0]): Response field length [0 to 8]                      |                                                          |
|                 |     | - bit4 (RCDS): Response direction [1: Transmission]                       |                                                          |
|                 |     | - bit5 (LCS): Checksum type [0: classical-checksum, 1: enhanced-checksum] |                                                          |
|                 |     | - bit6: Set to 0                                                          |                                                          |
|                 |     | - bit7 (LSS): 0: Next transmission/reception data group is the last one   |                                                          |
|                 |     | unsigned char                                                             | g_u8LINs_TxBUFF[1:8]: Response transmission data setting |
|                 | Out | None                                                                      |                                                          |
| Local variables |     | None                                                                      |                                                          |
| Return value    |     | None                                                                      |                                                          |
| Call functions  |     | None                                                                      |                                                          |
| Description     |     | LIN response transmission start procedure                                 |                                                          |

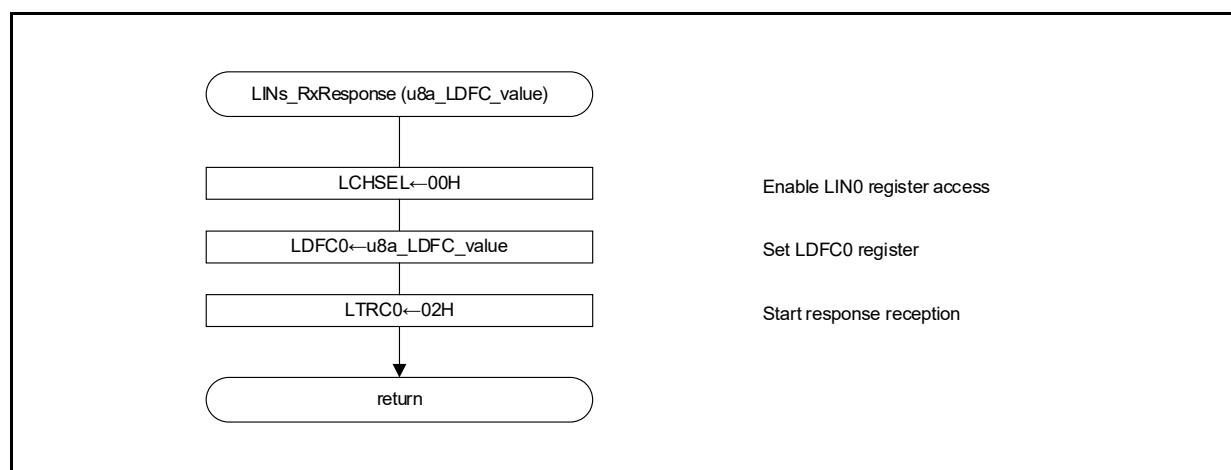


**Figure 3-7 LIN Slave Response Transmission Start Procedure (LINs\_TxResponse)**

### 3.2.7 LIN Slave Response Reception Start

**Table 3-10 LIN Slave Response Reception Start Function (LINS\_RxResponse)**

|                 |     |                                                     |                                                             |
|-----------------|-----|-----------------------------------------------------|-------------------------------------------------------------|
| Syntax          |     | void LINs_RxResponse (unsigned char u8a_LDFC_value) |                                                             |
| Parameters      | In  | unsigned char                                       | u8a_LDFC_value: LDFC0 setting value                         |
|                 |     | - bit3-0 (RFDL[3:0]):                               | Response field length [0 to 8]                              |
|                 |     | - bit4 (RCDS):                                      | Response direction [0: Reception]                           |
|                 |     | - bit5 (LCS):                                       | Checksum type [0: classical-checksum, 1: enhanced-checksum] |
|                 |     | - bit6:                                             | Set to 0                                                    |
|                 |     | - bit7 (LSS):                                       | 0: Next transmission/reception data group is the last one   |
|                 | Out | None                                                |                                                             |
| Local variables |     | None                                                |                                                             |
| Return value    |     | None                                                |                                                             |
| Call functions  |     | None                                                |                                                             |
| Description     |     | LIN response reception start procedure              |                                                             |

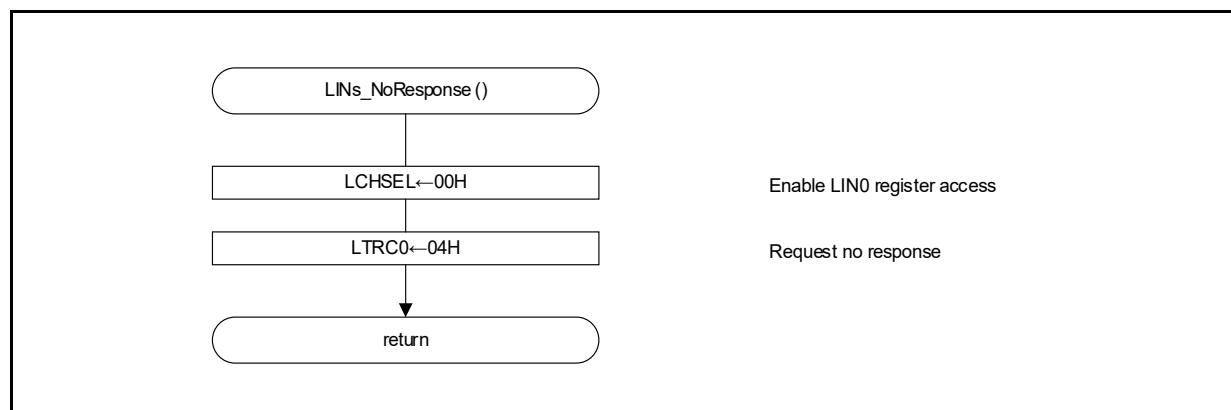


**Figure 3-8 LIN Slave Response Reception Start Procedure (LINS\_RxResponse)**

### 3.2.8 LIN Slave No Response Request

**Table 3-11 LIN Slave No Response Request Function (LINS\_NoResponse)**

|                 |                                   |      |
|-----------------|-----------------------------------|------|
| Syntax          | void LINS_NoResponse (void)       |      |
| Parameters      | In                                | None |
|                 | Out                               | None |
| Local variables | None                              |      |
| Return value    | None                              |      |
| Call functions  | None                              |      |
| Description     | LIN no response request procedure |      |



**Figure 3-9 LIN Slave No Response Request Procedure (LINS\_NoResponse)**

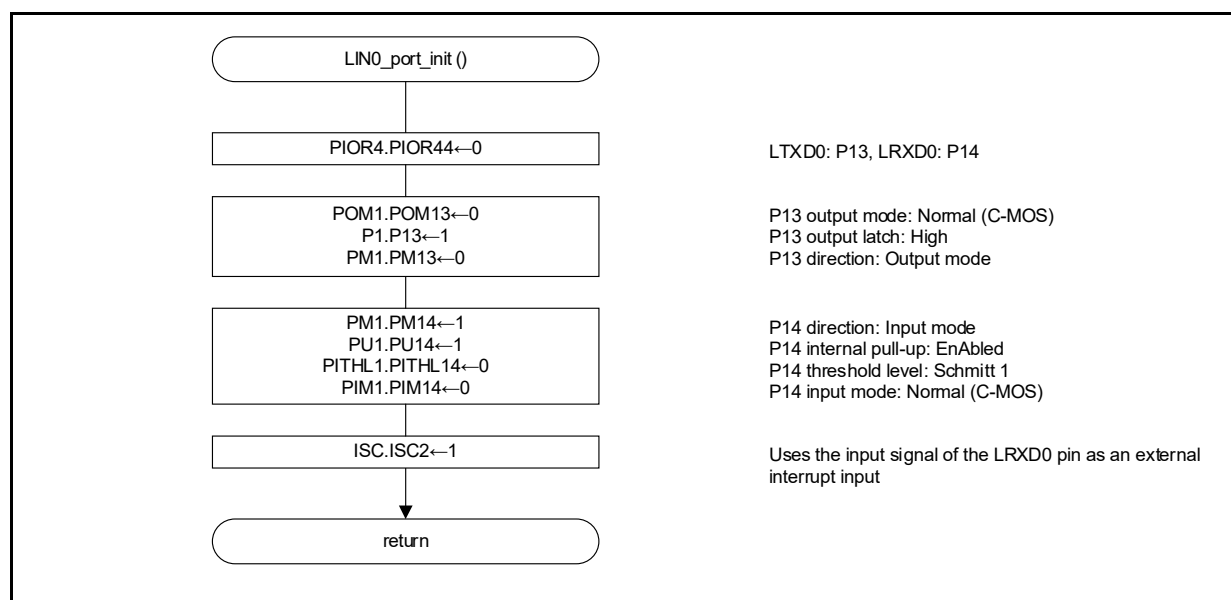
### 3.3 Driver Local Functions [Private]

Each local functions of the LIN slave communication driver program example shown in this application note is explained below.

#### 3.3.1 LIN0 Port Initialization

**Table 3-12 LIN0 Port Initialization Function (LIN0\_port\_init)**

|                 |                                                            |      |
|-----------------|------------------------------------------------------------|------|
| Syntax          | void LIN0_port_init (void)                                 |      |
| Parameters      | In                                                         | None |
|                 | Out                                                        | None |
| Local variables | None                                                       |      |
| Return value    | None                                                       |      |
| Call functions  | None                                                       |      |
| Description     | This function initializes LIN0 related ports.              |      |
| Note            | Call this function when GPORT bit of IAWCTL register is 0. |      |

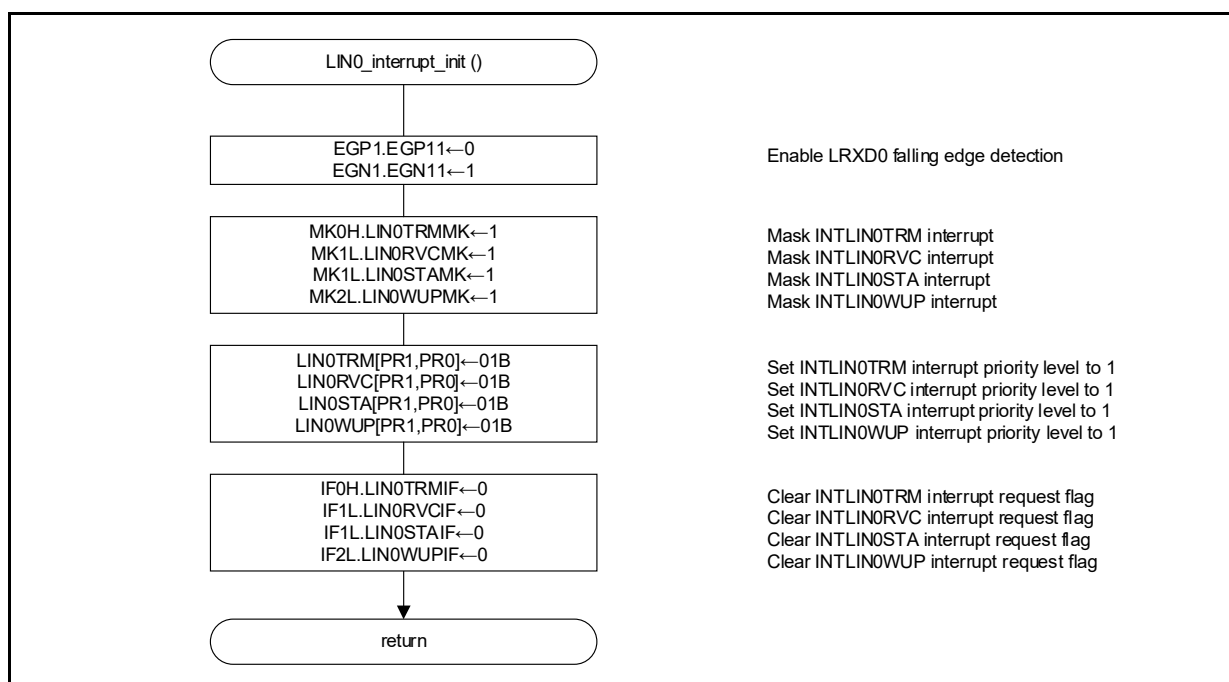


**Figure 3-10 LIN0 port Initialization Procedure (LIN0\_port\_init)**

### 3.3.2 LIN0 Interrupt Initialization

**Table 3-13 LIN0 Interrupt Initialization Function (LIN0\_interrupt\_init)**

|                 |                                                           |      |
|-----------------|-----------------------------------------------------------|------|
| Syntax          | void LIN0_interrupt_init (void)                           |      |
| Parameters      | In                                                        | None |
|                 | Out                                                       | None |
| Local variables | None                                                      |      |
| Return value    | None                                                      |      |
| Call functions  | None                                                      |      |
| Description     | This function initializes LIN0 related interrupts.        |      |
| Note            | Call this function when GINT bit of IAWCTL register is 0. |      |

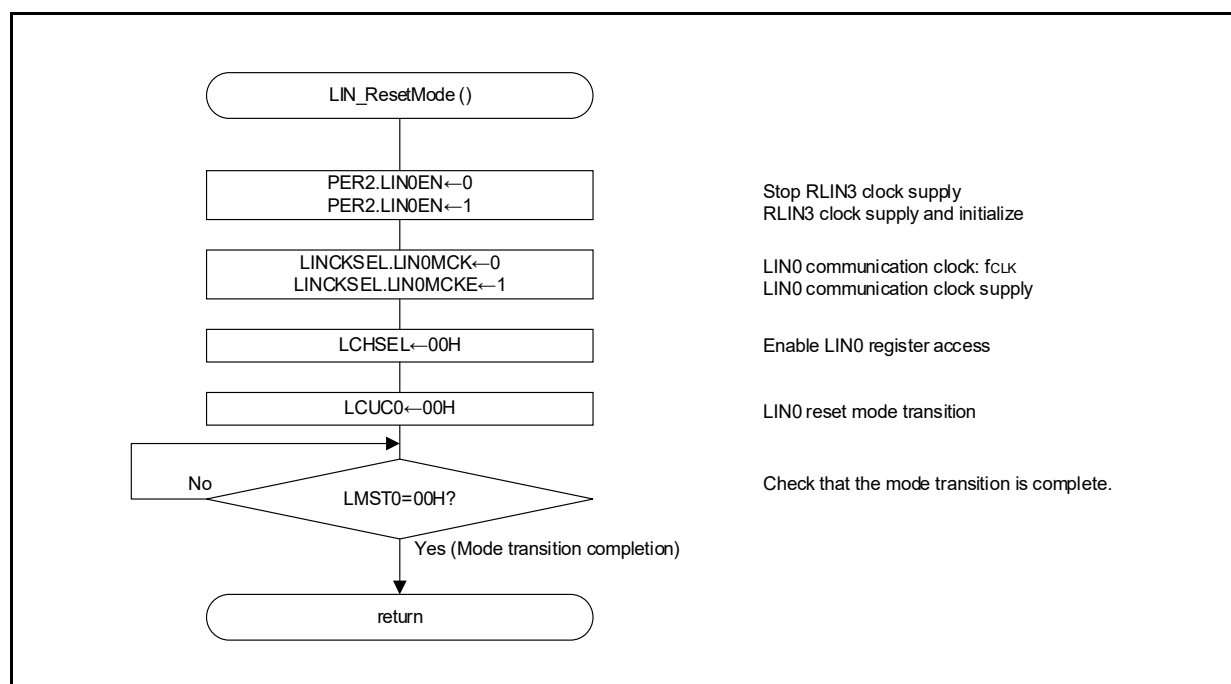


**Figure 3-11 LIN0 Interrupt Initialization Procedure (LIN0\_interrupt\_init)**

### 3.3.3 Transition to LIN Reset Mode

**Table 3-14 Transition to LIN Reset Mode Function (LIN\_ResetMode)**

|                 |                                                           |      |
|-----------------|-----------------------------------------------------------|------|
| Syntax          | void LIN_ResetMode (void)                                 |      |
| Parameters      | In                                                        | None |
|                 | Out                                                       | None |
| Local variables | None                                                      |      |
| Return value    | None                                                      |      |
| Call functions  | None                                                      |      |
| Description     | This function transitions to LIN reset mode.              |      |
| Note            | Call this function when GCSC bit of IAWCTL register is 0. |      |

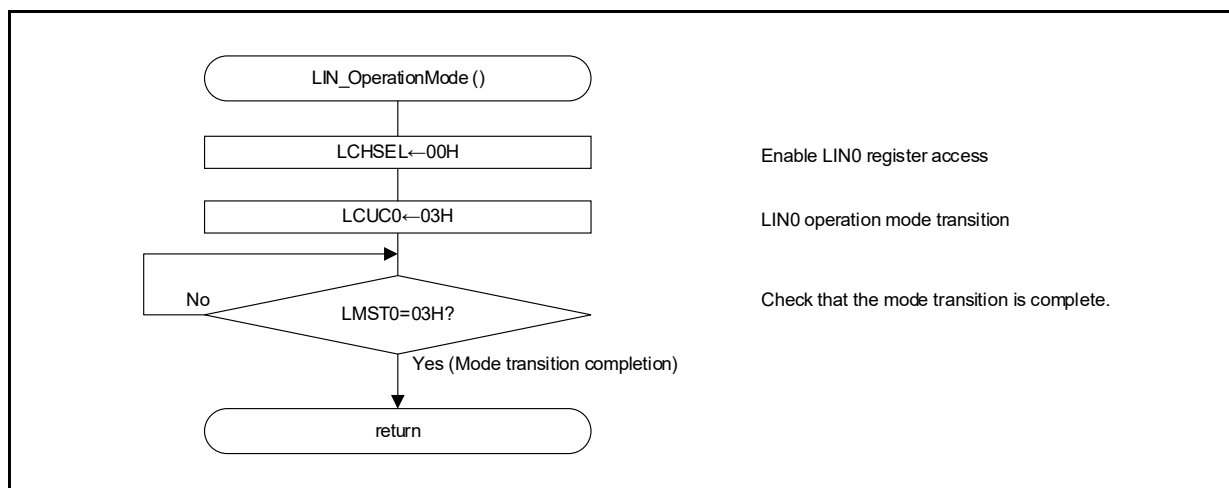


**Figure 3-12 Transition to LIN Reset Mode Procedure (LIN\_ResetMode)**

### 3.3.4 Transition to LIN Operation Mode

**Table 3-15 Transition to LIN Operation Mode Function (LIN\_OperationMode)**

|                 |                                                  |      |
|-----------------|--------------------------------------------------|------|
| Syntax          | void LIN_OperationMode (void)                    |      |
| Parameters      | In                                               | None |
|                 | Out                                              | None |
| Local variables | None                                             |      |
| Return value    | None                                             |      |
| Call functions  | None                                             |      |
| Description     | This function transitions to LIN operation mode. |      |

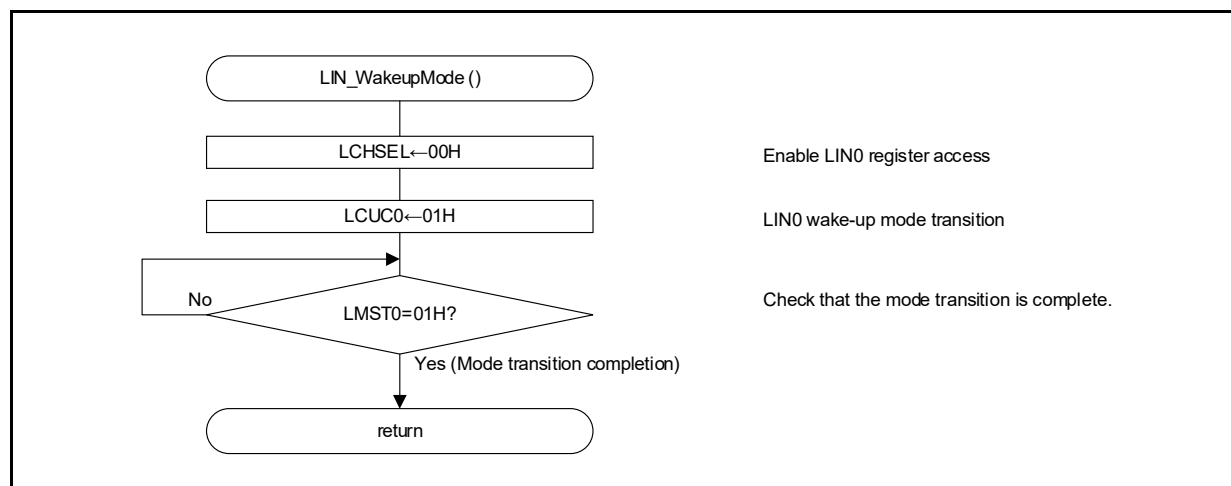


**Figure 3-13 Transition to LIN Operation Mode Procedure (LIN\_OperationMode)**

### 3.3.5 Transition to LIN Wake-up Mode

**Table 3-16 Transition to LIN Wake-up Mode Function (LIN\_WakeupMode)**

|                 |                                                |      |
|-----------------|------------------------------------------------|------|
| Syntax          | void LIN_WakeupMode (void)                     |      |
| Parameters      | In                                             | None |
|                 | Out                                            | None |
| Local variables | None                                           |      |
| Return value    | None                                           |      |
| Call functions  | None                                           |      |
| Description     | This function transitions to LIN wake-up mode. |      |



**Figure 3-14 Transition to LIN Wake-up Mode Procedure (LIN\_WakeupMode)**

### 3.4 Interrupt Processing Functions

Each interrupt processing functions of the LIN slave communication driver program example shown in this application note is explained below.

#### 3.4.1 LIN Slave Reception Completion Interrupt Processing

**Table 3-17 LIN Slave Reception Completion Interrupt Processing Function (LINs\_IntLIN0RVC)**

|                 |     |                                                                                                                                                                                                   |                                               |
|-----------------|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|
| Syntax          |     | void LINs_IntLIN0RVC (void)                                                                                                                                                                       |                                               |
| Parameters      | In  | None                                                                                                                                                                                              |                                               |
|                 | Out | unsigned char g_u8LINs_RxBUFF[0]:                                                                                                                                                                 | Store the received ID when receiving a header |
|                 |     | unsigned char g_u8LINs_RxBUFF[1:8]:                                                                                                                                                               | Store received data when receiving a response |
| Local variables |     | unsigned char u8a_RD_LST0:                                                                                                                                                                        | Store LST0 register                           |
|                 |     | - bit1 (FRC):                                                                                                                                                                                     | Response reception completion                 |
|                 |     | - bit3 (ERR):                                                                                                                                                                                     | LIN communication error detection             |
|                 |     | - bit7 (HTRC):                                                                                                                                                                                    | Header reception completion                   |
|                 |     | unsigned short u16a_errorinfo:                                                                                                                                                                    | 8000H (Illegal interrupt has occurred)        |
| Return value    |     | None                                                                                                                                                                                              |                                               |
| Call functions  |     | UNTfy_LINs_IntHeaderRx ():                                                                                                                                                                        | Header reception completion processing        |
|                 |     | UNTfy_LINs_IntResponseRx ():                                                                                                                                                                      | Response reception completion processing      |
|                 |     | UNTfy_LINs_ComError (u16a_errorinfo):                                                                                                                                                             | Illegal interrupt processing                  |
| Description     |     | INTLIN0RVC interrupt service routine<br>- LIN0 header reception completion<br>- LIN0 response reception completion<br>(Also refer to section. 3.5.2 for the UNTfy_LINs_IntHeaderRx () processing) |                                               |

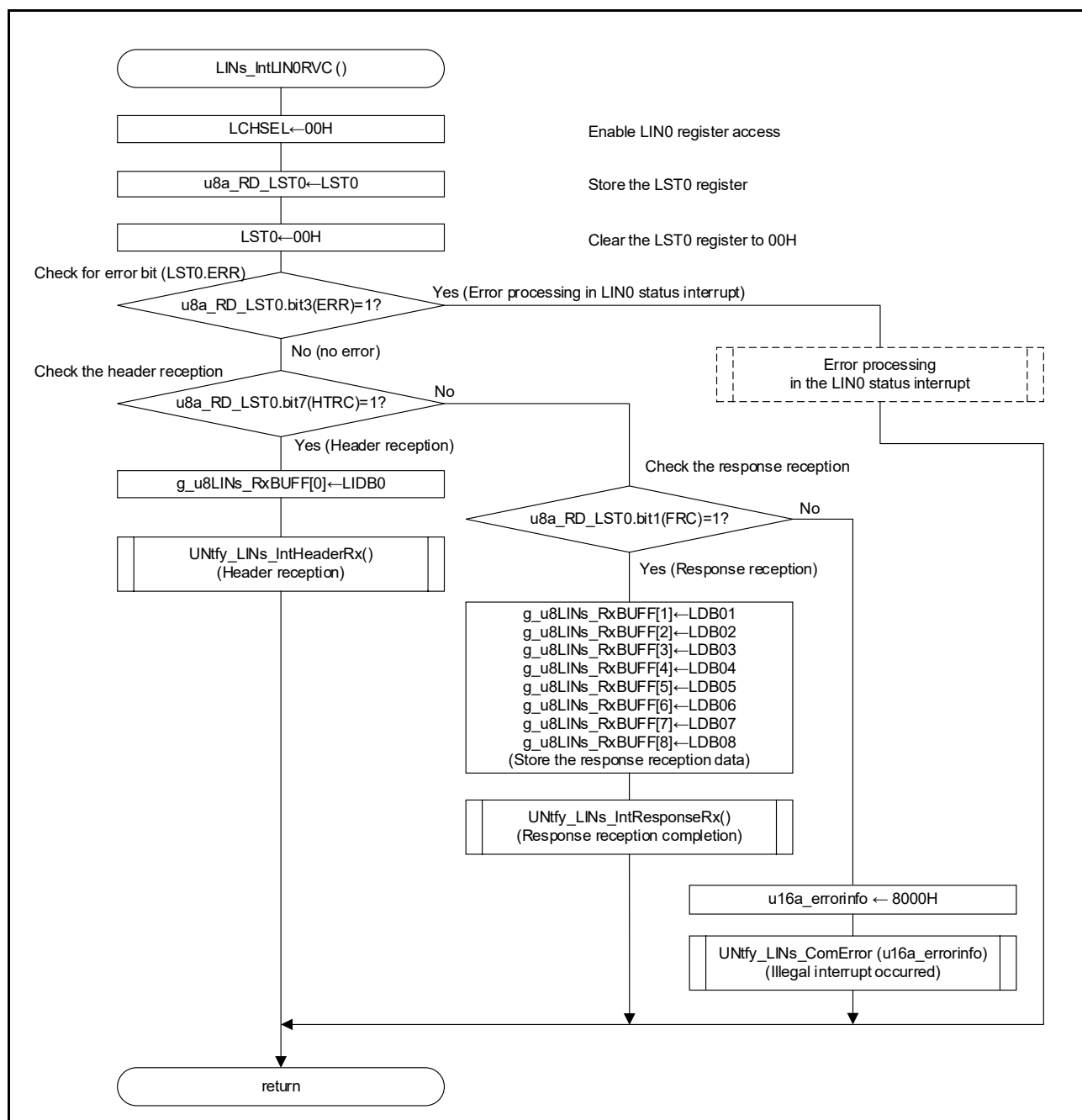
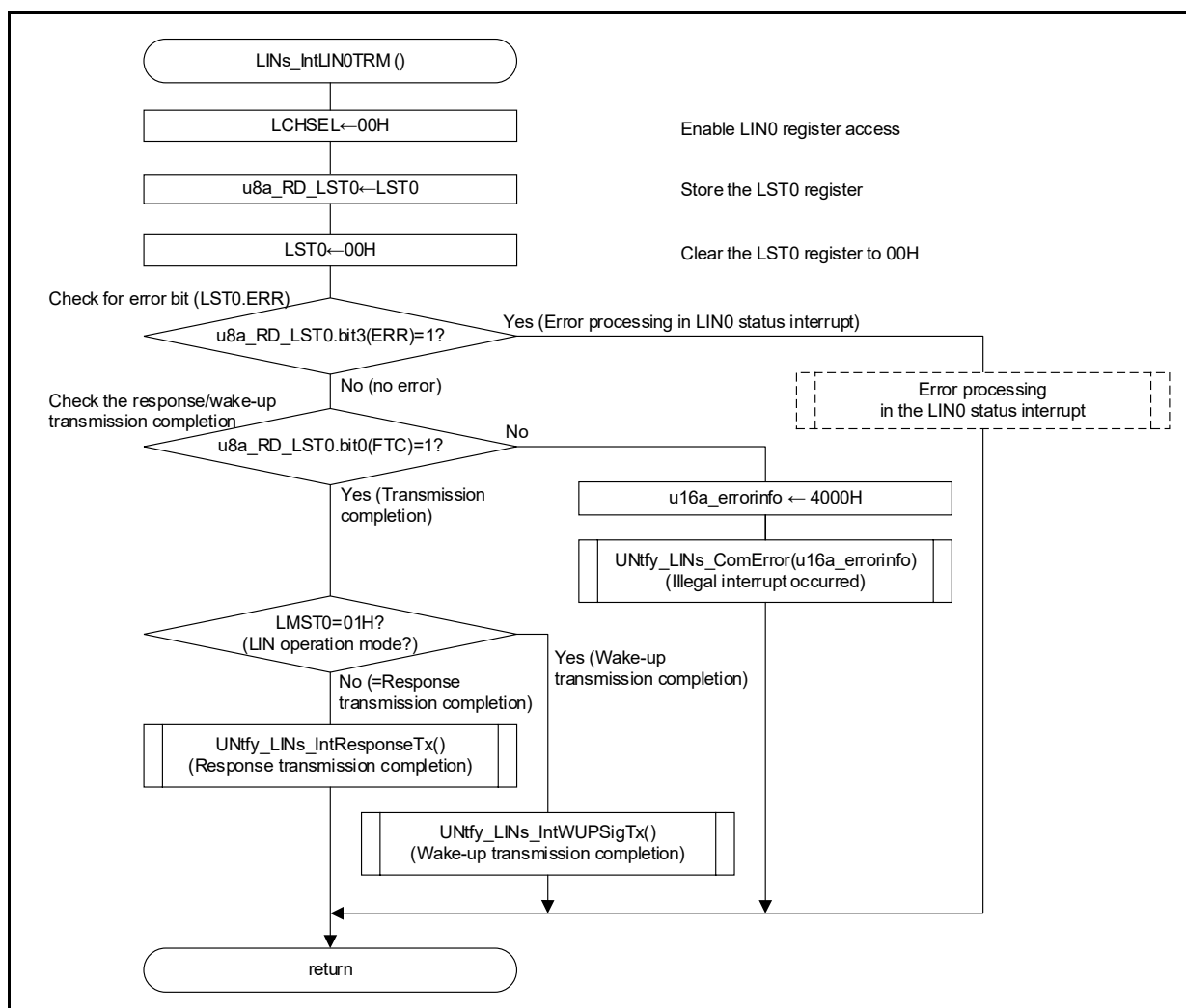


Figure 3-15 LIN Slave Reception Completion Interrupt Processing Procedure (LINs\_IntLIN0RVC)

### 3.4.2 LIN Slave Transmission Completion Interrupt Processing

**Table 3-18 LIN Slave Transmission Completion Interrupt Processing Function (LINs\_IntLIN0TRM)**

|                 |     |                                               |                                             |                                        |
|-----------------|-----|-----------------------------------------------|---------------------------------------------|----------------------------------------|
| Syntax          |     | void LINs_IntLIN0TRM (void)                   |                                             |                                        |
| Parameters      | In  | None                                          |                                             |                                        |
|                 | Out | None                                          |                                             |                                        |
| Local variables |     | unsigned char                                 | u8a_RD_LST0:                                | Store LST0 register                    |
|                 |     | - bit0 (FTC):                                 | Response / Wake-up transmission completion  |                                        |
|                 |     | - bit3 (ERR):                                 | LIN communication error detection           |                                        |
|                 |     | unsigned short                                | u16a_errorinfo:                             | 4000H (Illegal interrupt has occurred) |
| Return value    |     | None                                          |                                             |                                        |
| Call functions  |     | UNtfy_LINs_IntResponseTx ():                  | Response transmission completion processing |                                        |
|                 |     | UNtfy_LINs_IntWUPSigTx ():                    | Wake-up transmission completion processing  |                                        |
|                 |     | UNtfy_LINs_ComError (u16a_errorinfo):         | Illegal interrupt processing                |                                        |
| Description     |     | INTLIN0TRM interrupt service routine          |                                             |                                        |
|                 |     | - LIN0 response transmission completion       |                                             |                                        |
|                 |     | - LIN0 wake-up signal transmission completion |                                             |                                        |

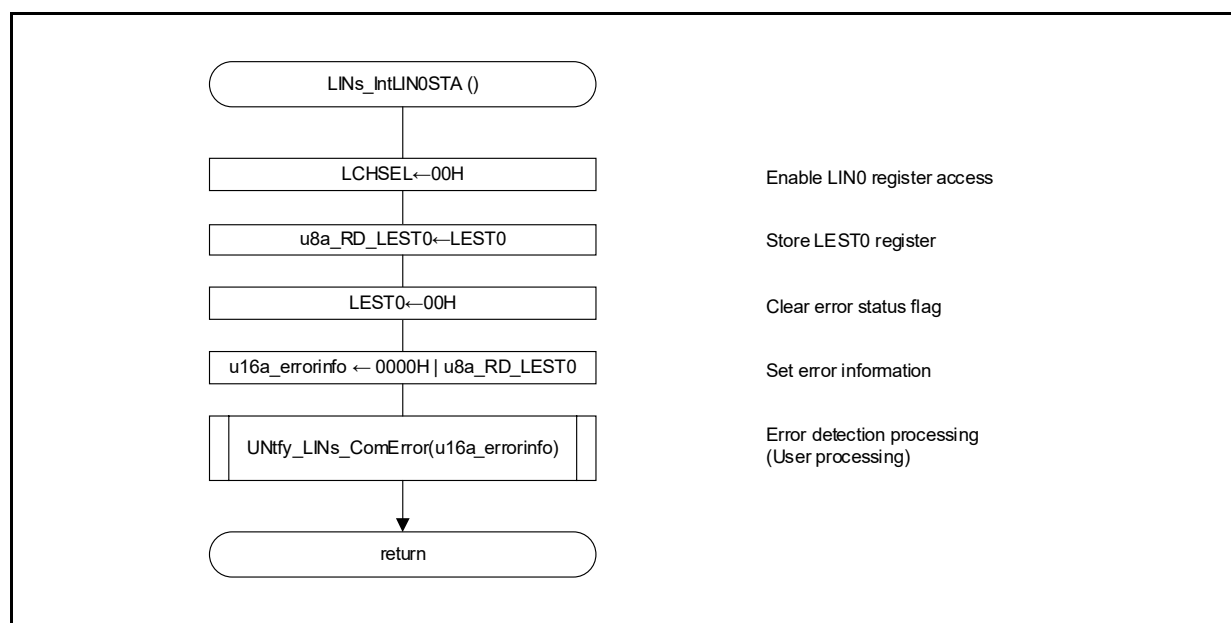


**Figure 3-16 LIN Slave Transmission Completion Interrupt Processing Procedure (LINs\_IntLIN0TRM)**

### 3.4.3 LIN Slave Status Error Interrupt Processing

**Table 3-19 LIN Slave Status Error Interrupt Processing Function (LINS\_IntLIN0STA)**

|                 |                                                                               |                                                                    |
|-----------------|-------------------------------------------------------------------------------|--------------------------------------------------------------------|
| Syntax          | void LINS_IntLIN0STA (void)                                                   |                                                                    |
| Parameters      | In                                                                            | None                                                               |
|                 | Out                                                                           | None                                                               |
| Local variables | unsigned char                                                                 | u8a_RD_LEST0: Store LEST0 register                                 |
|                 | - bit0 (BER):                                                                 | Bit error detected during response/wake-up transmission            |
|                 | - bit2 (TER):                                                                 | Response timeout error detected in fixed baud rate mode            |
|                 | - bit3 (FER):                                                                 | Framing error detected during header/response reception            |
|                 | - bit4 (SFER):                                                                | Sync field error detected during sync field reception              |
|                 | - bit5 (CSER):                                                                | Checksum error detected when response reception                    |
|                 | - bit6 (IPER):                                                                | ID parity error detected when ID field reception                   |
|                 | - bit7 (RPER):                                                                | Response preparation error detected when response data 1 reception |
|                 | unsigned short                                                                | u16a_errorinfo: Error information value                            |
|                 | - bit[7:0]:                                                                   | u8a_RD_LEST0 value                                                 |
|                 | - bit[15:8]:                                                                  | 00H                                                                |
| Return value    | None                                                                          |                                                                    |
| Call functions  | UNtfy_LINs_ComError (u16a_errorinfo): Error detection processing              |                                                                    |
| Description     | This function is the interrupt processing when LIN0 status error is occurred. |                                                                    |

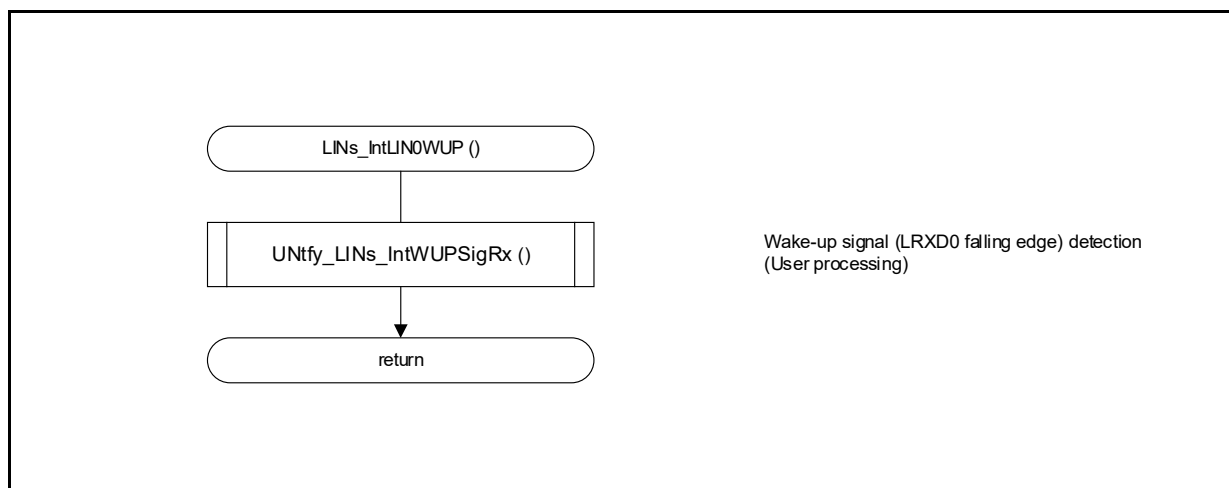


**Figure 3-17 LIN Slave Status Error Interrupt Processing Procedure (LINS\_IntLIN0STA)**

### 3.4.4 LIN Slave Wake-up Signal Detection Interrupt Processing

**Table 3-20 LIN Slave Wake-up Signal Detection Interrupt Processing Function (LINS\_IntLIN0WUP)**

|                 |                                                                    |      |
|-----------------|--------------------------------------------------------------------|------|
| Syntax          | void LINS_IntLIN0WUP (void)                                        |      |
| Parameters      | In                                                                 | None |
|                 | Out                                                                | None |
| Local variables | None                                                               |      |
| Return value    | None                                                               |      |
| Call functions  | UNtfy_LINS_IntWUPSigRx (): LRXD0 falling edge detection processing |      |
| Description     | INTLIN0WUP interrupt service routine                               |      |



**Figure 3-18 LIN Slave Wake-up Signal Detection Interrupt Processing Procedure (LINS\_IntLIN0WUP)**

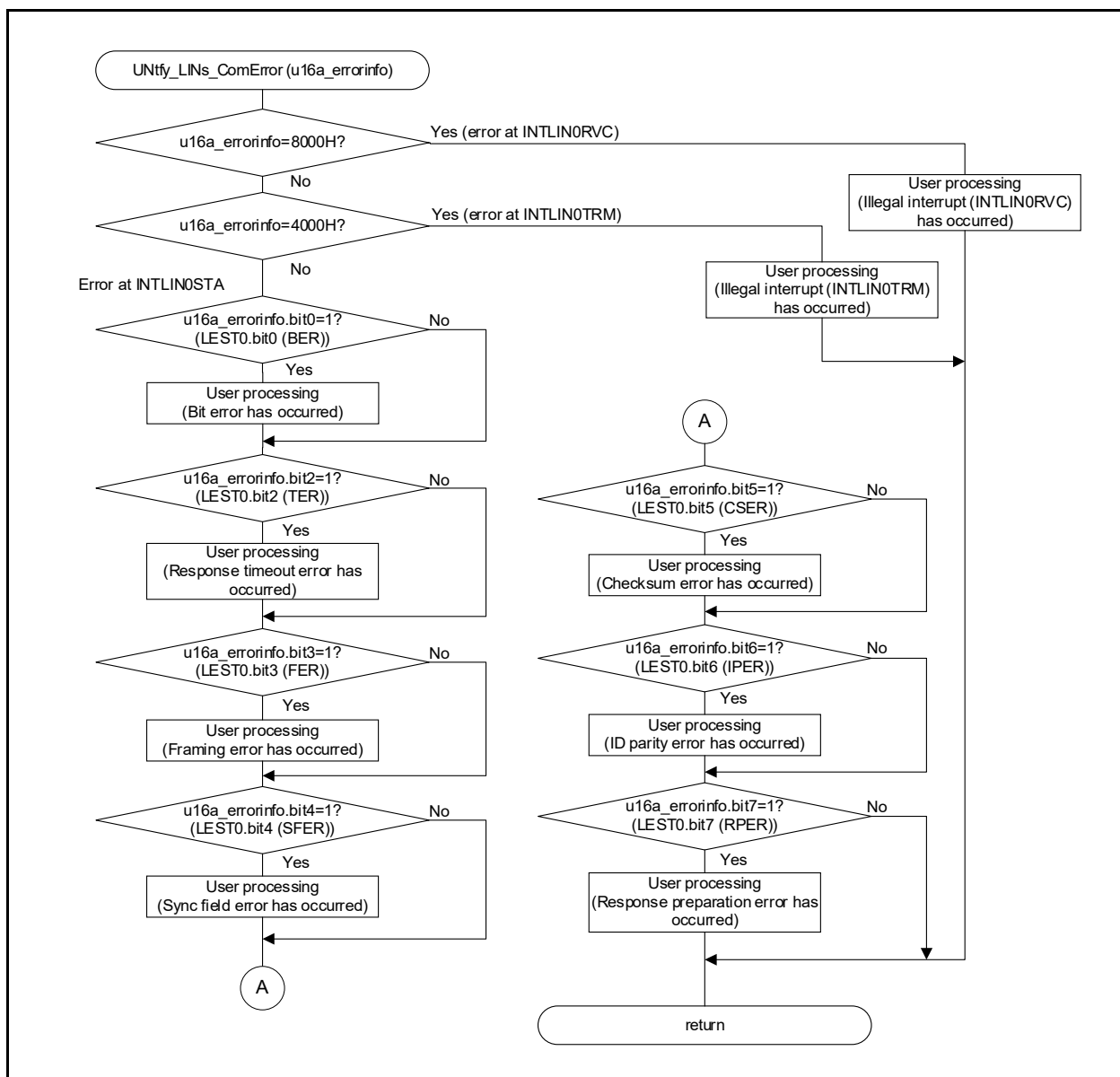
### 3.5 User Notification Function APIs

Each user notification function APIs of the LIN slave communication driver program example shown in this application note is explained below.

#### 3.5.1 Error Notification

**Table 3-21 Error Notification Function API (UNtfy\_LINs\_ComError)**

|                 |     |                                                          |                                                               |
|-----------------|-----|----------------------------------------------------------|---------------------------------------------------------------|
| Syntax          |     | void UNtfy_LINs_ComError (unsigned short u16a_errorinfo) |                                                               |
| Parameters      | In  | unsigned short u16a_errorinfo:                           | Error information value                                       |
|                 |     | - 00xxH:                                                 | Communication error has occurred. "xxH": LEST0 register value |
|                 |     | - 4000H:                                                 | Illegal interrupt (INTLIN0TRM) has occurred.                  |
|                 |     | - 8000H:                                                 | Illegal interrupt (INTLIN0RVC) has occurred.                  |
|                 | Out | None                                                     |                                                               |
| Local variables |     | - (User processing)                                      |                                                               |
| Return value    |     | - (User processing)                                      |                                                               |
| Call functions  |     | - (User processing)                                      |                                                               |
| Description     |     | This function notifies that an error has occurred.       |                                                               |

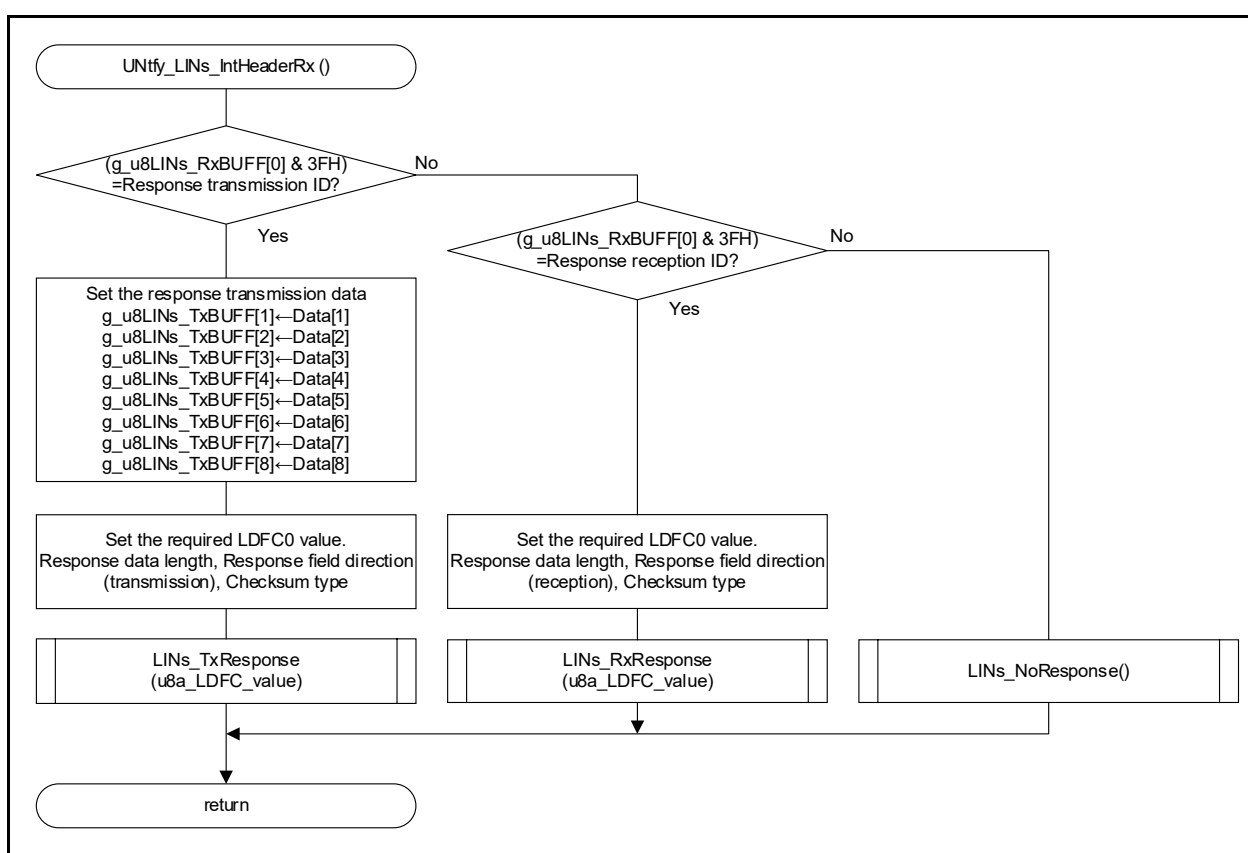


**Figure 3-19 Example of Error Notification Procedure (UNtfy\_LINs\_ComError)**

### 3.5.2 Header Reception Completion Notification

**Table 3-22 Header Reception Completion Notification Function API (UNtfy\_LINs\_IntHeaderRx)**

|                 |     |                                                                |                                |
|-----------------|-----|----------------------------------------------------------------|--------------------------------|
| Syntax          |     | void UNtfy_LINs_IntHeaderRx (void)                             |                                |
| Parameters      | In  | unsigned char        g_u8LINs_RxBUFF[0]:                       | Received ID data               |
|                 | Out | None                                                           |                                |
| Local variables |     | - (User processing)                                            |                                |
| Return value    |     | - (User processing)                                            |                                |
| Call funxtiona  |     | - (User processing)                                            |                                |
|                 |     | LINs_TxResponse (u8a_LDFC_value):                              | Response transmission function |
|                 |     | LINs_RxResponse (u8a_LDFC_value):                              | Response reception function    |
|                 |     | LINs_NoResponse ():                                            | No response request function   |
| Description     |     | This function notifies that the header reception is completed. |                                |

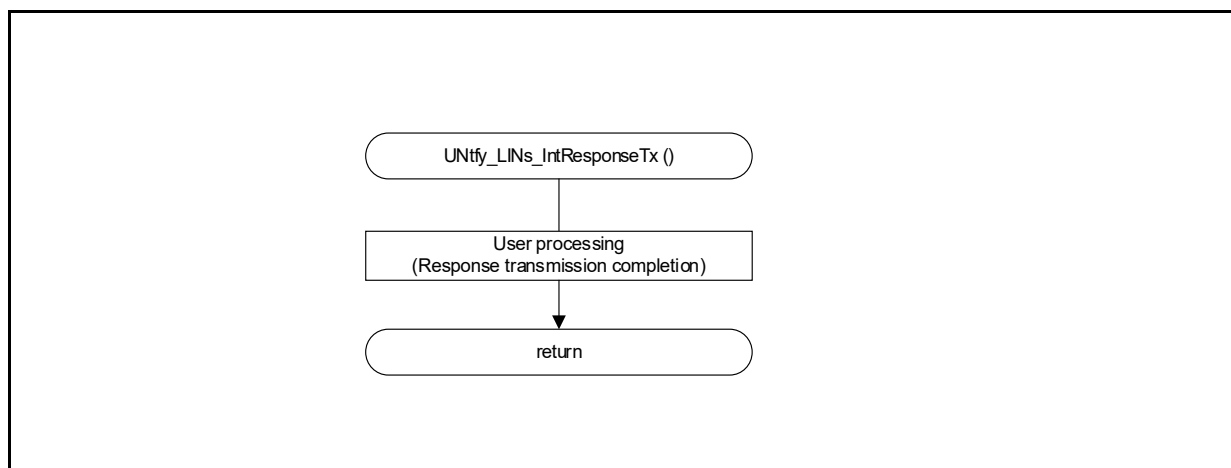


**Figure 3-20 Example of Header Reception Completion Notification Procedure (UNtfy\_LINs\_IntHeaderRx)**

### 3.5.3 Response Transmission Completion Notification

**Table 3-23 Response Transmission Completion Notification Function API  
(UNtfy\_LINs\_IntResponseTx)**

|                 |     |                                                                     |
|-----------------|-----|---------------------------------------------------------------------|
| Syntax          |     | void UNtfy_LINs_IntResponseTx (void)                                |
| Parameters      | In  | None                                                                |
|                 | Out | None                                                                |
| Local variables |     | - (User processing)                                                 |
| Return value    |     | - (User processing)                                                 |
| Call functions  |     | - (User processing)                                                 |
| Description     |     | This function notifies that the response transmission is completed. |

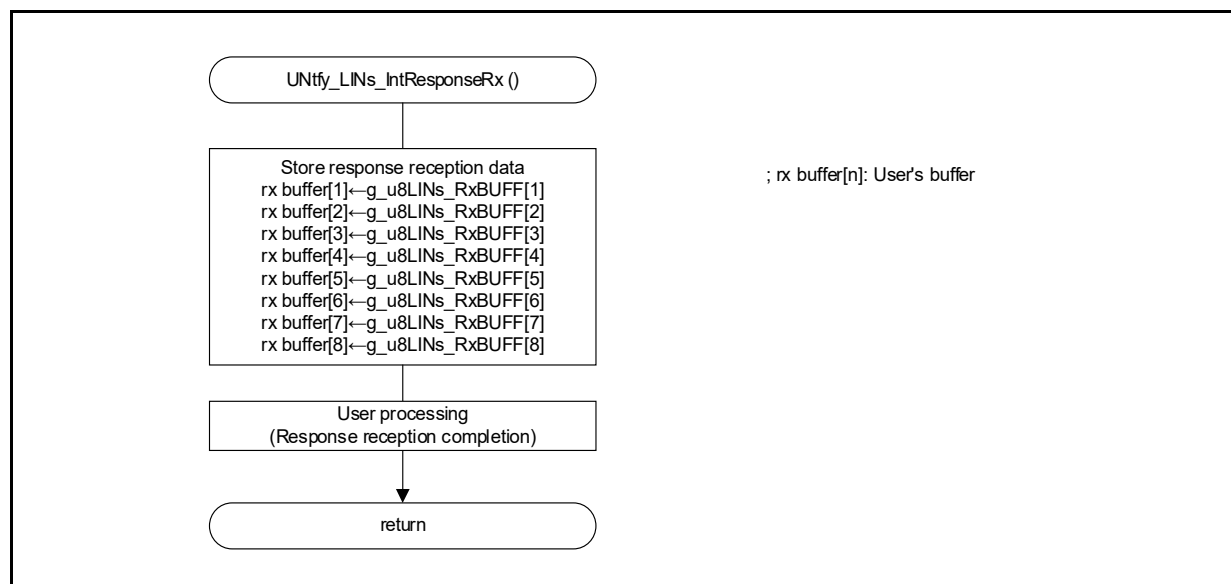


**Figure 3-21 Example of Response Transmission Completion Notification Procedure  
(UNtfy\_LINs\_IntResponseTx)**

### 3.5.4 Response Reception Completion Notification

**Table 3-24 Response Reception Completion Notification Function API (UNtfy\_LINs\_IntResponseRx)**

|                 |     |                                                                  |                         |
|-----------------|-----|------------------------------------------------------------------|-------------------------|
| Syntax          |     | void UNtfy_LINs_IntResponseRx (void)                             |                         |
| Parameters      | In  | unsigned char      g_u8LINs_RxBUFF[1:8]:                         | Response reception data |
|                 | Out | None                                                             |                         |
| Local variables |     | - (User processing)                                              |                         |
| Return value    |     | - (User processing)                                              |                         |
| Call functions  |     | - (User processing)                                              |                         |
| Description     |     | This function notifies that the response reception is completed. |                         |

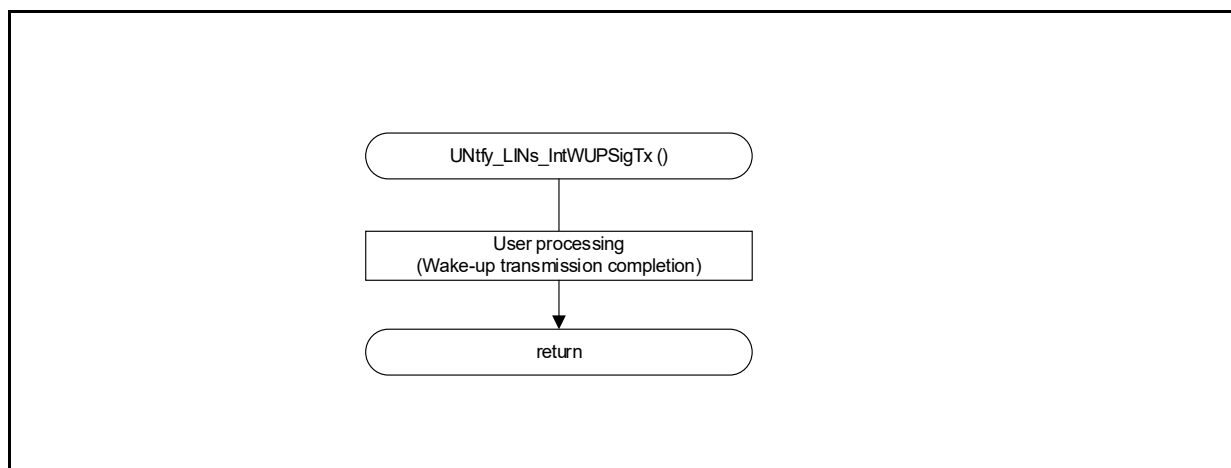


**Figure 3-22 Example of Response Reception Completion Notification Procedure (UNtfy\_LINs\_IntResponseRx)**

### 3.5.5 Wake-up Signal Transmission Completion Notification

**Table 3-25 Wake-up Signal Transmission Completion Notification Function API  
(UNtfy\_LINs\_IntWUPSigTx)**

|                 |                                                                           |      |
|-----------------|---------------------------------------------------------------------------|------|
| Syntax          | void UNtfy_LINs_IntWUPSigTx (void)                                        |      |
| Parameters      | In                                                                        | None |
|                 | Out                                                                       | None |
| Local variables | - (User processing)                                                       |      |
| Return value    | - (User processing)                                                       |      |
| Call functions  | - (User processing)                                                       |      |
| Description     | This function notifies that the wake-up signal transmission is completed. |      |

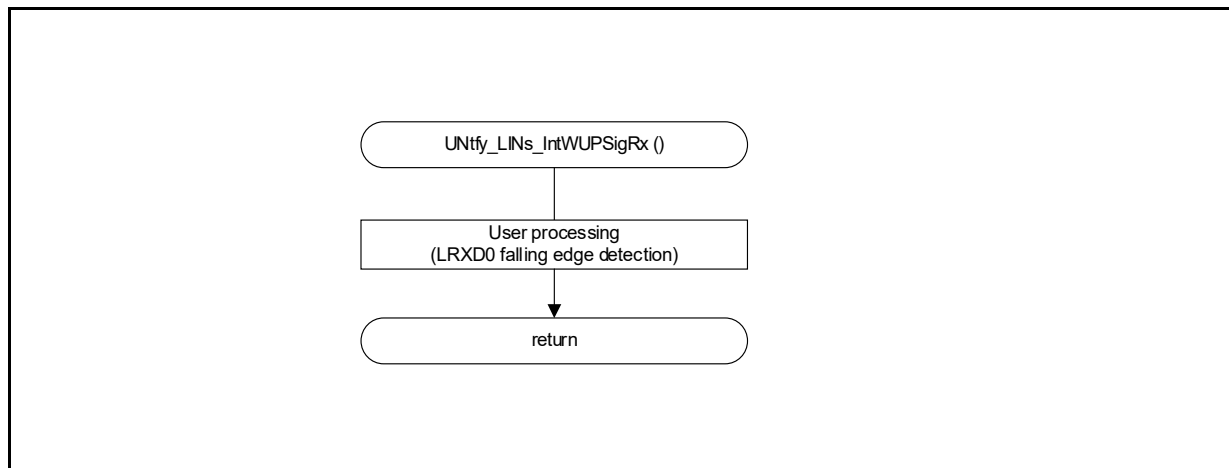


**Figure 3-23 Example of Wake-up Signal Transmission Completion Notification Procedure  
(UNtfy\_LINs\_IntWUPSigTx)**

### 3.5.6 Wake-up Signal Reception Notification

**Table 3-26 Wake-up Signal Reception Notification Function API (UNtfy\_LINs\_IntWUPSigRx)**

|                 |                                                                 |      |
|-----------------|-----------------------------------------------------------------|------|
| Syntax          | void UNtfy_LINs_IntWUPSigRx (void)                              |      |
| Parameters      | In                                                              | None |
|                 | Out                                                             | None |
| Local variables | - (User processing)                                             |      |
| Return value    | - (User processing)                                             |      |
| Call functions  | - (User processing)                                             |      |
| Description     | This function notifies that the LRXD0 falling edge is detected. |      |



**Figure 3-24 Example of Wake-up Signal Reception Notification Procedure (UNtfy\_LINs\_IntWUPSigRx)**

#### 4. Operation Mode Transition of LIN / UART Module (RLIN3)

Operation mode transition can be confirmed with OMM0, OMM1 bits of LMSTn register, after setting OM0, OM1 bits of LCUCn register as operation mode selection.

When setting LIN related registers after mode transition, be sure to confirm the completion of mode transition.

The maximum time of the mode transitions are shown below.

**Table 4-1 LIN / UART Module (RLIN3) Mode Transition Times**

| Mode Transition                     | Transition Conditions                                     | Transition Time <sup>Note</sup>                                          |
|-------------------------------------|-----------------------------------------------------------|--------------------------------------------------------------------------|
| LIN reset mode → LIN operation mode | Set: LCUCn.[OM1,OM0]=11B<br>Check: LMSTn.[OMM1, OMM0]=11B | (Max.) $3 \cdot f_{CLK} + 4 \cdot LINn$<br>communication clock<br>source |
| LIN reset mode → LIN wake-up mode   | Set: LCUCn.[OM1,OM0]=01B<br>Check: LMSTn.[OMM1, OMM0]=01B |                                                                          |
| LIN operation mode → LIN reset mode | Set: LCUCn.[OM1,OM0]=00B                                  |                                                                          |
| LIN wake-up mode → LIN reset mode   | Check: LMSTn.[OMM1, OMM0]=00B                             |                                                                          |

**Note.** The time it takes for LMSTn.[OMM1,OMM0] to change after setting LCUCn.[OM1,OM0].

## 5. References

The documents referenced in this application note are shown below. When referring to these documents, make sure to obtain the latest version of each document from Renesas Electronics website.

- RL78/ F23, F24 User's Manual: Hardware Rev. 1.00
- RL78 family User's Manual: Software Rev. 2.30

**Revision History**

| Rev. | Date       | Description |                       |
|------|------------|-------------|-----------------------|
|      |            | Page        | Summary               |
| 1.00 | 2022.09.30 | -           | First edition issued. |
|      |            |             |                       |

# General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

## 1. Precaution against Electrostatic Discharge (ESD)

A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.

## 2. Processing at power-on

The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.

## 3. Input of signal during power-off state

Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.

## 4. Handling of unused pins

Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.

## 5. Clock signals

After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.

## 6. Voltage application waveform at input pin

Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between  $V_{IL}$  (Max.) and  $V_{IH}$  (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between  $V_{IL}$  (Max.) and  $V_{IH}$  (Min.).

## 7. Prohibition of access to reserved addresses

Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.

## 8. Differences between products

Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

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