XMC™ in application - Power Management Bus (PMBus™)

XMC™ microcontrollers

August 2016

Agenda (1/2)

1. Overview
2. Key features
3. Specification
4. System block diagram
5. Hardware overview
6. Software overview
7. Highlight MCU features
8. Get started

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9 Resource listing

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Power Management Bus (PMBus™) – Overview

- The Power Management Bus (PMBus™) is a standard for communication and power management in terms of :
  - Inventory
    - e.g.: Device ID
  - Configuration
    - e.g.: On/Off configuration, fault/warnings
  - Control
    - e.g.: Sequencing delay/rampfault response
  - Telemetry
    - e.g.: V_{out}, I_{out}, power, temperature, peak values
  - Status
    - e.g.: Comms, date, temp

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Power Management Bus (PMBus™) – Key features

- Free and open standard
- Based on I2C:
  - Bi-directional communication between master and slave
- Low cost
- Robust protocol:
  - Timeouts forcing bus reset
  - SMBALERT# line for interrupts
  - Packet error checking (PEC)
  - Host notify
  - CONTROL signal for on/off control

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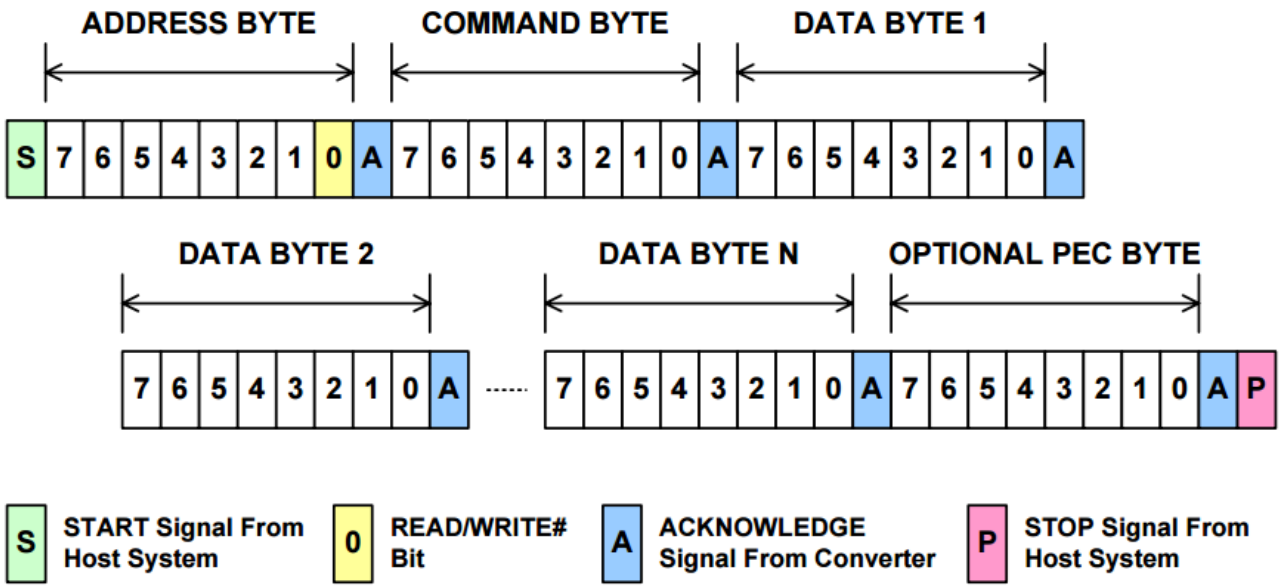
Power Management Bus (PMBus™) – Specification (1/4)



PMBus™ frame structure

Power Management Bus (PMBus™) – Specification (2/4)

- Nominal bus voltage: 2.7 V_{DC} to 5.5 V_{DC}
- Baudrate : 100 Kbit/s or 400 Kbit/s
- Several format frame (protocols) supporting many functional commands

Command Code	Command Name	SMBus Transaction Type	Number Of Data Bytes	Reserved For Future Use	Reserved For Future Use
00h	PAGE	R/W Byte	1		
01h	OPERATION	R/W Byte	1		
02h	ON_OFF_CONFIG	R/W Byte	1		
03h	CLEAR_FAULTS	Send Byte	0		
04h	PHASE	R/W Byte	1		
05h	Reserved				
06h	Reserved				
07h	Reserved				
08h	Reserved				
09h	Reserved				
0Ah	Reserved				
0Bh	Reserved				
0Ch	Reserved				
0Dh	Reserved				
0Eh	Reserved				
0Fh	Reserved				
10h	WRITE_PROTECT	R/W Byte	1		
11h	STORE_DEFAULT_ALL	Send Byte	0		
12h	RESTORE_DEFAULT_ALL	Send Byte	0		
13h	STORE_DEFAULT_CODE	Write Byte	1		
14h	RESTORE_DEFAULT_CODE	Write Byte	1		
15h	STORE_USER_ALL	Send Byte	0		
16h	RESTORE_USER_ALL	Send Byte	0		
17h	STORE_USER_CODE	Write Byte	1		
18h	RESTORE_USER_CODE	Write Byte	1		
19h	CAPABILITY	Read Byte	1		

Send Byte

Receive Byte

Write Byte

Write Word

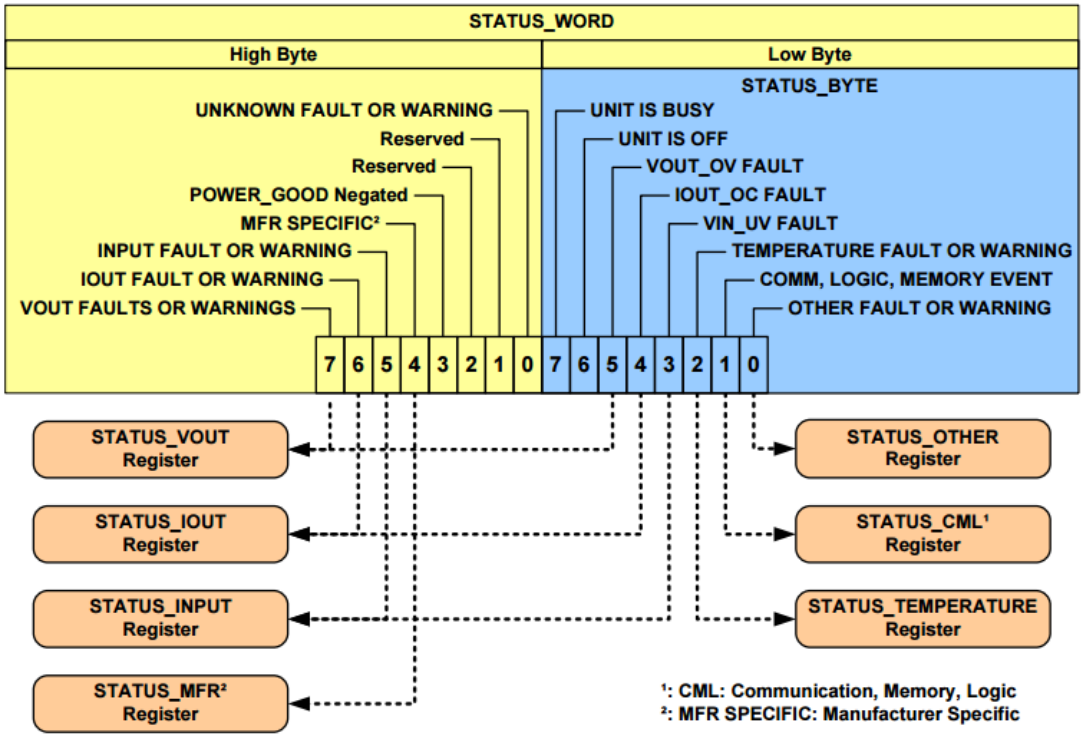
Read Byte

Read Word

Host Notify Protocol

Power Management Bus (PMBus™) – Specification (3/4)

Status Registers



Power Management Bus (PMBus™) – Specification (4/4)

- Parametric information
  - Input voltage
  - Input current
  - Output voltage
  - Output current
  - Temperature (up to 3 sensors)
  - Fan speed (up to 2 fans)
  - Duty cycle
  - Switching frequency

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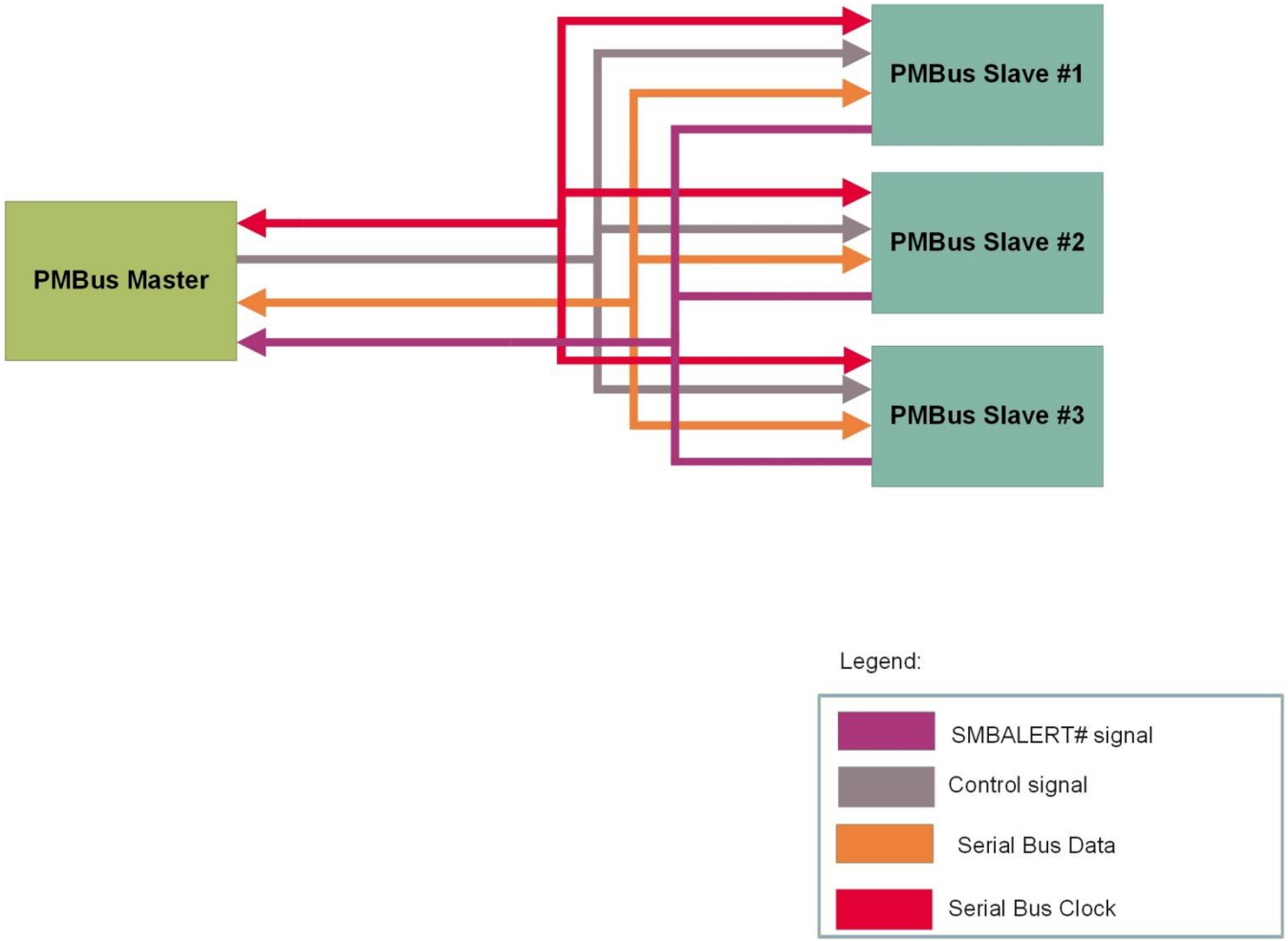
Power Management Bus (PMBus™) – System block diagram (1/2)

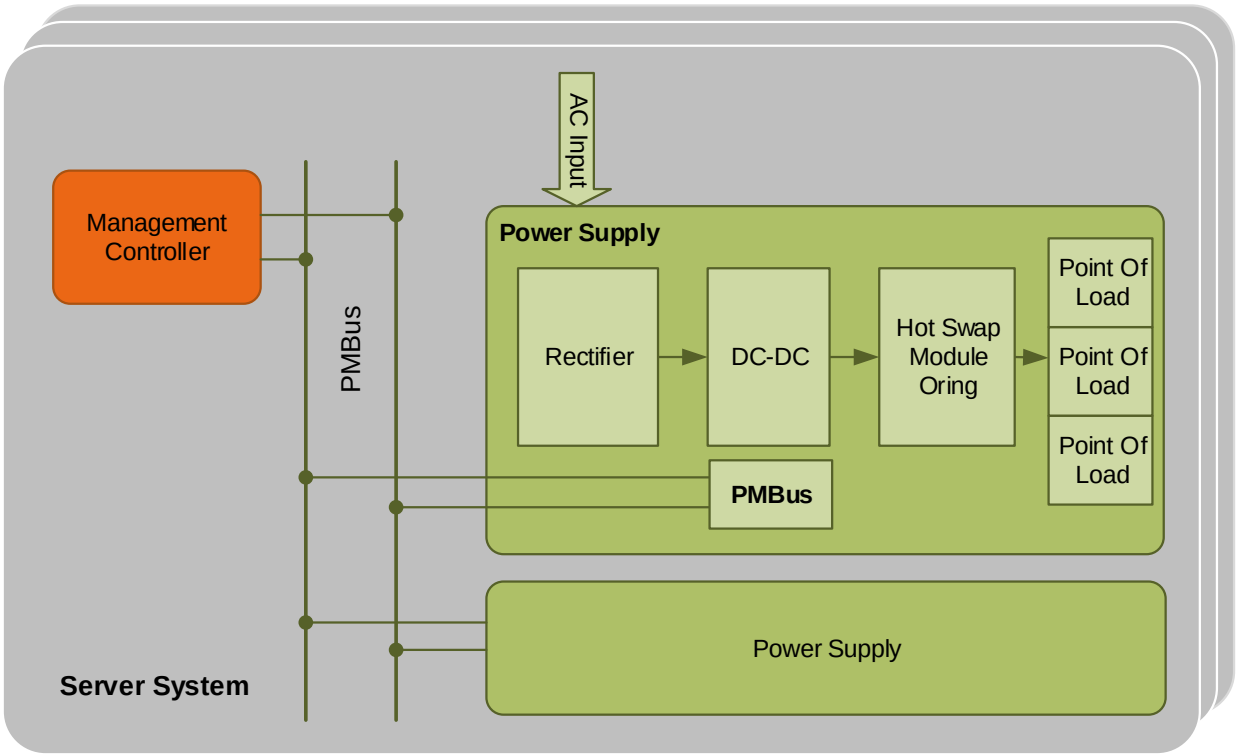


System block diagram: PMBus™

Power Management Bus (PMBus™) – System block diagram (2/2)

Application example – server system

- Power supplies for server application
- Load sharing capability with OR-ing
- Use PMBus™ to turn-on and turn-off one power supply for efficiency purpose



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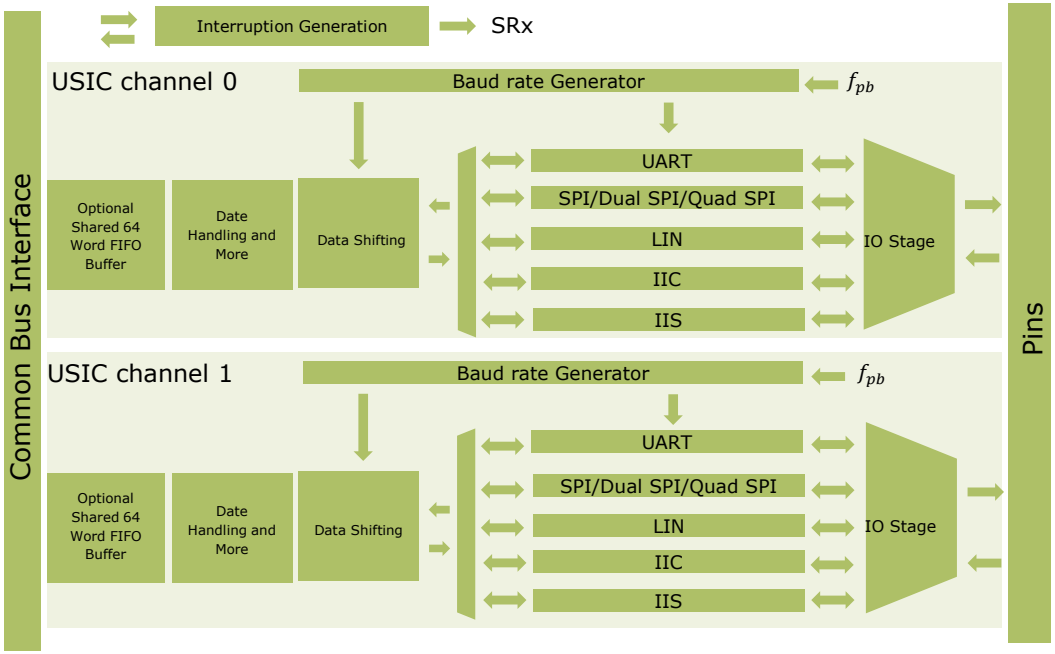
Power Management Bus (PMBus™) – Hardware overview (1/2)

- Several peripherals can are used for supporting the characteristic of the PMBus™:
  - USIC module for the I2C layer
  - NVIC for handling the interrupts
  - ERU for checkings
  - SYSTICK for the timeouts
  - GPIO for SMBALERT# and control signals

Power Management Bus (PMBus™) – Hardware overview (2/2)

- USIC module
  - Each USIC module provides two universal serial communication channels to interface with external devices. It is tailored for various serial protocols like I2C. A shared 64 words FIFO buffer is available in each USIC module



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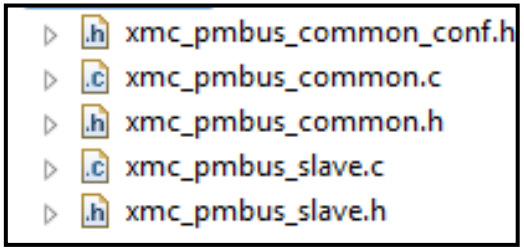
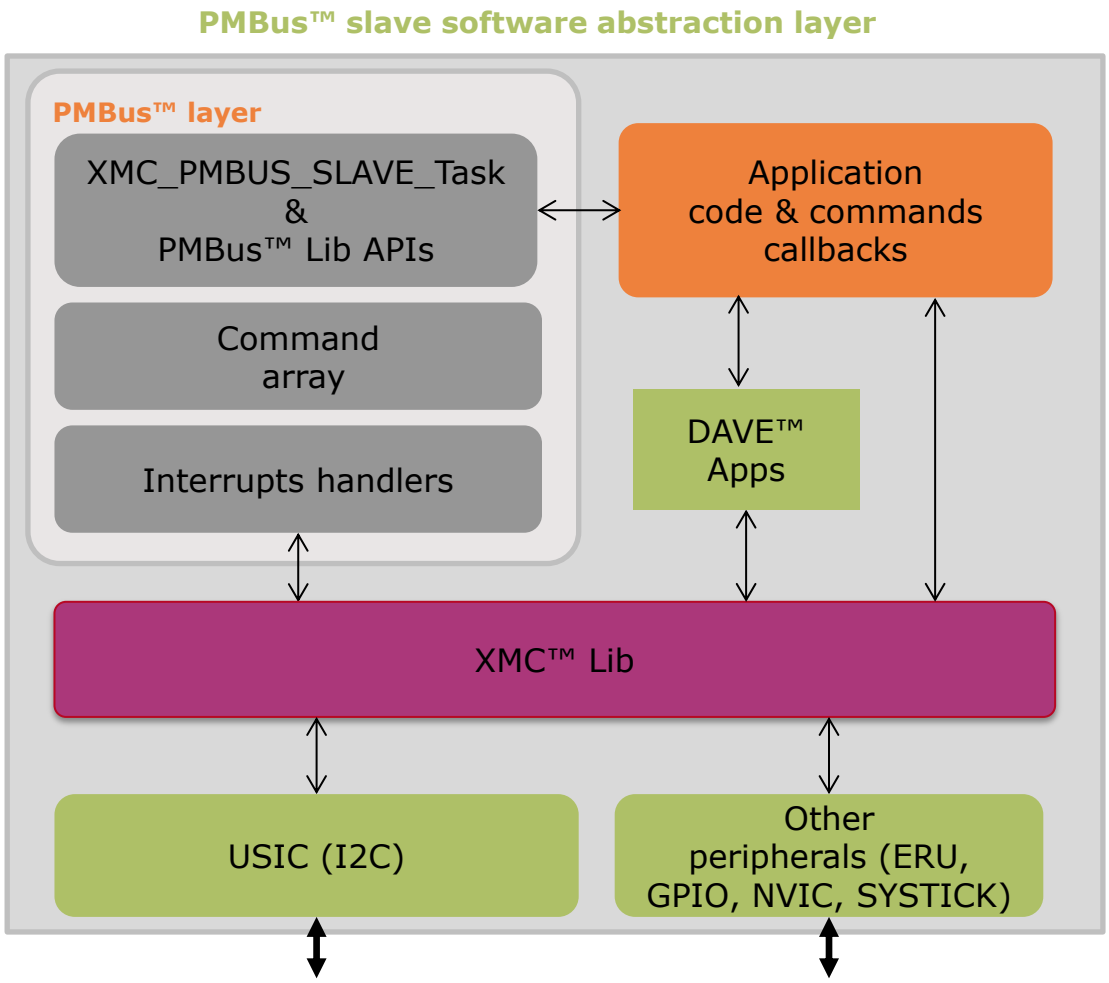
Power Management Bus (PMBus™) – Software overview (1/3)

- Based XMC™ Lib, PMBus™ Lib gives the user all the software utilities for implementing the slave part of the PMBus™ Rev. 1.2 in Infineon XMC™ microcontrollers.
- Commands can be added easily at any time
- Up to 400 kHz I2C
- Files included:
  - xmc_pmbus_common_conf.h
    - General configuration of the library
  - xmc_pmbus_common.h
    - Common APIs and configuration structures
  - xmc_pmbus_common.c
    - Array of commands and common APIs implementation
  - xmc_pmbus_slave.h
    - Slave APIs and configuration structures
  - xmc_pmbus_slave.c
    - Slave APIs implementation



Power Management Bus (PMBus™) – Software overview (2/3)

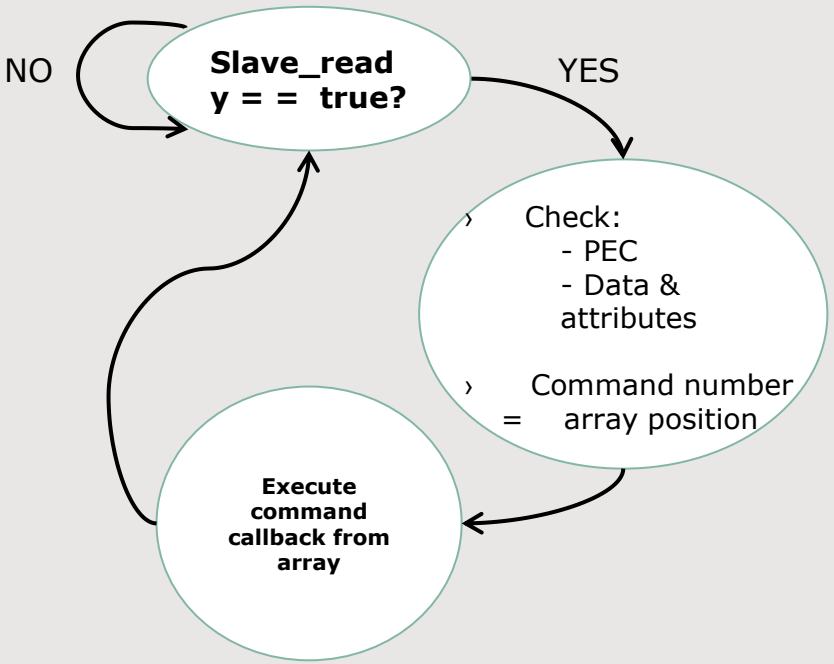


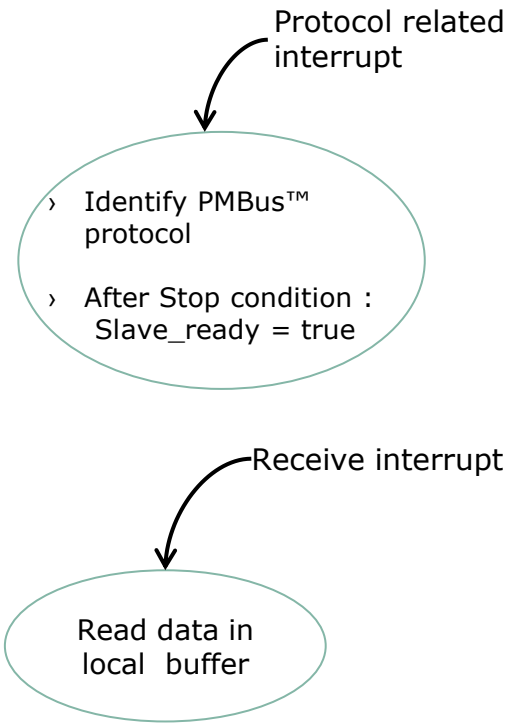
Flow chart: Power Management Bus (PMBus™) – software overview

Power Management Bus (PMBus™) – Software overview (3/3)

Slave task:

Does the needed checkings and executes the respective command callback





Flow chart: Power Management Bus (PMBus™) – software overview

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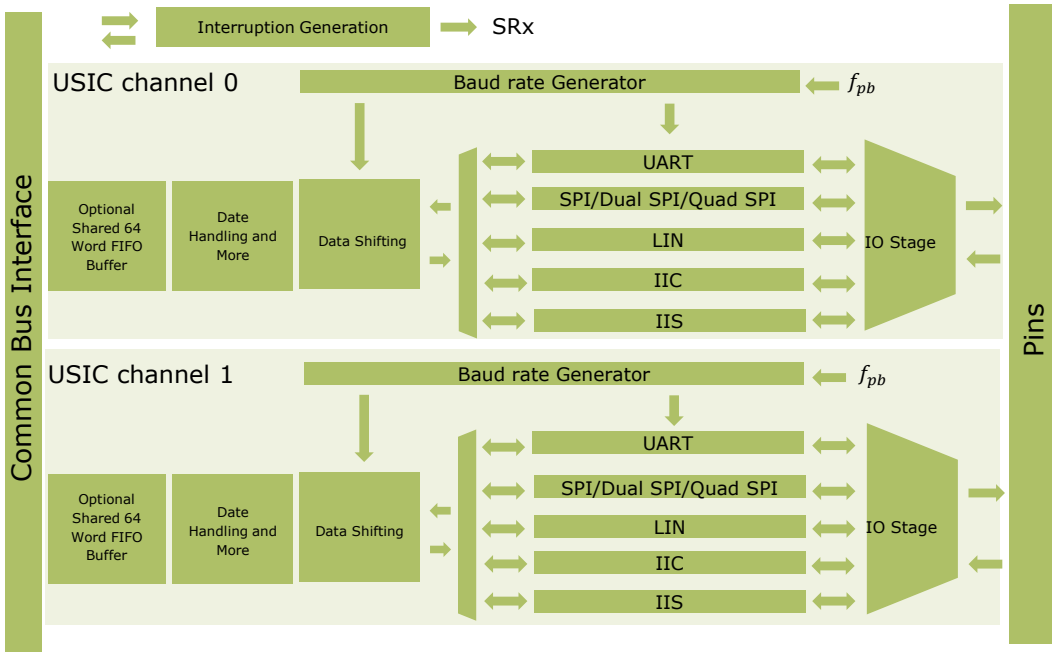
Power Management Bus (PMBus™) – Highlight MCU features – PMBus™ Lib

- Library available supporting main characteristic of the protocol:
  - SMBALERT#
  - Host notify
  - Control signal
  - PEC
  - Timeout
  - Supports all types of PMBus™ data format:
    - Linear
    - DIRECT
    - VID (only for V_{out} commands)

Power Management Bus (PMBus™) – Highlight MCU features - USIC module (1/4)

- USIC module
  - Each USIC module provides two universal serial communication channels to interface with external devices. It is tailored for various serial protocols like I2C. A shared 64 words FIFO buffer is available in each USIC module

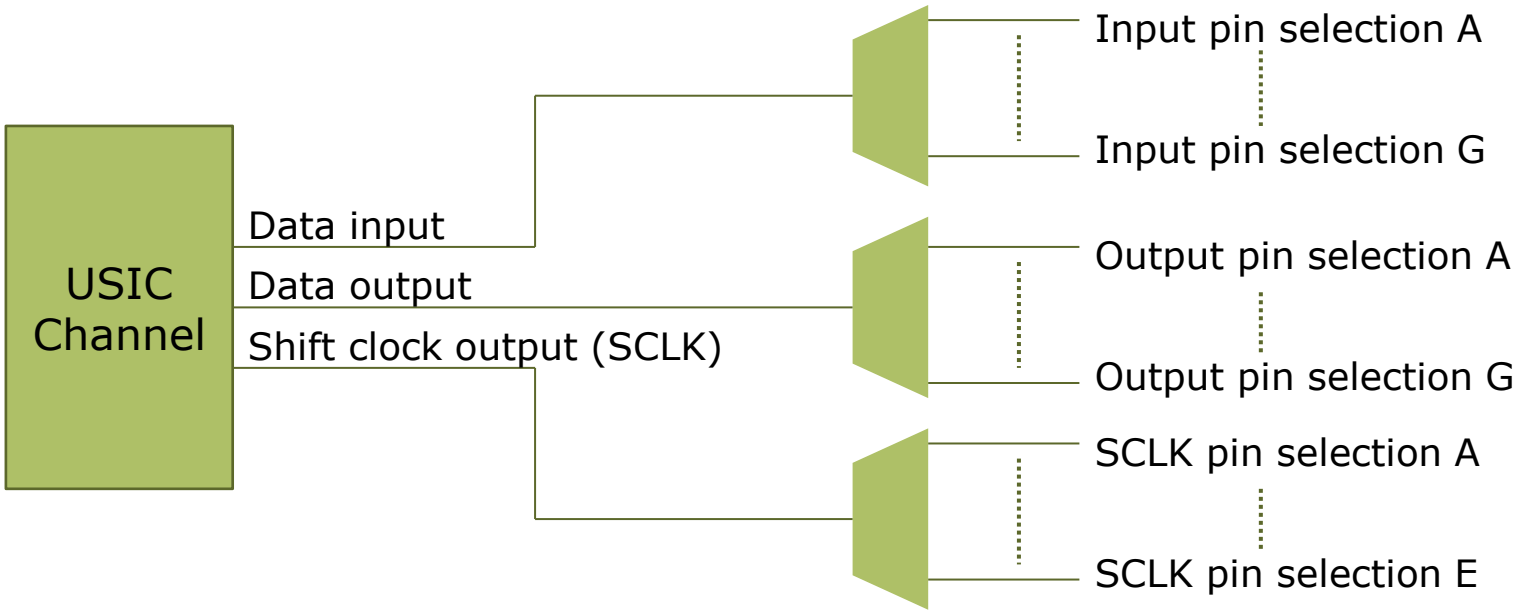


Power Management Bus (PMBus™) – Highlight MCU features - USIC module (2/4)

- USIC module
  - 64-words FIFO buffer available
    - All data need to be transmitted can be pushed into the FIFO
    - This can offload the CPU. It can perform other tasks while the USIC is transmitting
  - Efficient frame handling, low software effort
    - In slave mode, the I2C module decodes and send acknowledgement signal without any software handling
  - Up to 400 kHz I2C

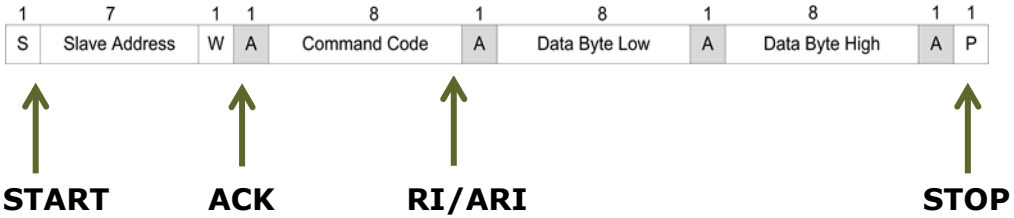
Power Management Bus (PMBus™) – Highlight MCU features - USIC module (3/4)

- Each channel offers several possible input and output pins
- Pin reconfiguration without resetting the device
- Refer to USIC-interconnect chapter in device reference manual on the available pins for USIC transmit and receive pin



Power Management Bus (PMBus™) – Highlight MCU features - USIC module (4/4)

- Interrupts for every protocol
  - Transmit shift interrupt (TSI)
  - Transmit buffer interrupt (TBF)
  - Standard receive interrupt (RI)
  - Received start interrupt (RSI)
  - Alternative receive interrupt(ARI)
  - Data lost interrupt



- I2C protocol related interrupt
  - Start condition (START)
  - Stop condition (STOP)
  - ACK received (ACK)
  - NACK received
  - Slave read request
  - Repeated start condition

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Power Management Bus (PMBus™) – Get started – PMBus™ Lib (1/7)

- Include the library in an existing project

- Configure the library in “xmc_pmbus_common_conf.h”:
  1. Chose the available/s channels:
     - `#define XMC_PMBUS_NODE_USICx_CHy  XMC_PMBUS_ENABLE`
  2. Enable the required library features using the XMC_PMBUS_ENABLE macro:
     - `Timeout, control signal, smbalert and host notify`
  3. Configure the length of the slave buffer and microseconds of timeout if required:
     - `#define XMC_PMBUS_MICRO_SECS (900U)`
     - `#define XMC_PMBUS_SLAVE_MAX_DATA_LENGTH (0x0FU)`

Power Management Bus (PMBus™) – Get started – PMBus™ Lib (2/7)

- Create XMC_PMBUS_NODE_CONFIG_t for the main slave configuration

Example:

```
const XMC_PMBUS_NODE_CONFIG_t slave1_config =
{
  /* Channel of the USIC */
  .channel = XMC_USIC1_CH1,

  /* Pointer to initialization structure I2C protocol */
  .i2c_config = &slave1_i2c_config,

  /* Protocol interrupt config*/
  .protocol_irq_sr = (uint8_t)XMC_PMBUS_USIC1_CH1_PROTOCOL_IRQ_SR,
  .protocol_irq_nvic_node = (IRQn_Type)XMC_PMBUS_USIC1_CH1_PROTOCOL_IRQ_NVIC_NODE,
  .protocol_irq_prio = (uint32_t)XMC_PMBUS_USIC1_CH1_PROTOCOL_IRQ_PRIO,

  /* RX interrupt */
  .rx_fifo_irq_sr = (uint8_t)XMC_PMBUS_USIC1_CH1_RX_FIFO_IRQ_SR,
  .rx_fifo_irq_nvic_node = (IRQn_Type)XMC_PMBUS_USIC1_CH1_RX_FIFO_IRQ_NVIC_NODE,
  .rx_fifo_irq_prio = (uint32_t)XMC_PMBUS_USIC1_CH1_RX_FIFO_IRQ_PRIO,

  /* SCL line config structure */
  .scl_pin_config = &pmbus_scl,

  /*SCL port and pin selection */
  .scl_port = XMC_GPIO_PORT0,
  .scl_pin = 10U,
```

Power Management Bus (PMBus™) – Get started – PMBus™ Lib (3/7)

- Create XMC_PMBUS_NODE_CONFIG_t for the main slave configuration

Example:

```
  /*SCL Input multiplexer selection*/
  .scl_source = (uint8_t)USIC1_C1_DX1_P0_10,

  /* SDA line config structure */
  .sda_pin_config = &pmbus_sda,

  /*SDA port and pin selection */
  .sda_port = XMC_GPIO_PORT4,
  .sda_pin = 2U,

  /*SCL Input multiplexer selection*/
  .sda_source = (uint8_t)USIC1_C1_DX0_P4_2,

  /* CAPABILITY */
  .capability.pec = XMC_PMBUS_DISABLE,
  .capability.smb_alert = XMC_PMBUS_DISABLE,
  .capability.max_bus_speed = XMC_PMBUS_SPEED_400KHZ,

  /* Control signal and timeout disables*/
  .control_io_enable = XMC_PMBUS_DISABLE,
  .timeout_enable = XMC_PMBUS_DISABLE,

  /* Pointer to the array for received data*/
  .data_ptr = slave1_data,
};
```

Power Management Bus (PMBus™) – Get started – PMBus™ Lib (4/7)

- Create XMC_PMBUS_NODE_t structure with a pointer to the configuration structure

  Example:

```
XMC_PMBUS_NODE_t slave1 =
{
   .config_ptr = &slave_config,
};
```

- Add the callbacks for the required commands and the extern declarations in “xmc_pmbus_common.c”

  Example:

```
/* Extern declarations */
extern XMC_PMBUS_STATUS_t XMC_PMBUS_NODE_CmdCapability(XMC_PMBUS_NODE_t *const node);
extern XMC_PMBUS_STATUS_t XMC_PMBUS_NODE_CmdStatusByte(XMC_PMBUS_NODE_t * const node);
extern XMC_PMBUS_STATUS_t XMC_PMBUS_NODE_CmdStatusWord(XMC_PMBUS_NODE_t * const node);
      .
      .
      .
```

Power Management Bus (PMBus™) – Get started – PMBus™ Lib (5/7)

- Add callbacks for required commands and extern declarations in "xmc_pmbus_common.c"

Example:

```
/* Callback functions added to the callback command array */
const XMC_PMBUS_NODE_CMD_INFO_t cmd_info[] =
{
                    .
                    .
                    .
   {.call_back = XMC_PMBUS_NODE_CmdCapability, .no_of_data_bytes = 1U, .attribute = (uint16_t)
   (XMC_PMBUS_PROTOCOL_RD_BYTE)}, /* Command Code - 19h; Command Name = CAPABILITY*/
                    .
                    .
                    .
   {.call_back = XMC_PMBUS_NODE_CmdStatusByte, .no_of_data_bytes = 1U, .attribute = (uint16_t)
   (XMC_PMBUS_PROTOCOL_WR_RD_BYTE)}, /* Command Code - 78h; Command Name = STATUS_BYTE*/
   {.call_back = XMC_PMBUS_NODE_CmdStatusWord, .no_of_data_bytes = 2U, .attribute = (uint16_t)
   (XMC_PMBUS_PROTOCOL_WR_RD_WORD)}, /* Command Code - 79h; Command Name = STATUS_WORD*/
                    .
                    .
                    .
}
```

Power Management Bus (PMBus™) – Get started – PMBus™ Lib (6/7)

- Implements callbacks in application code

Example:

```
/* Capability command callback. It sends back the capabilities of the device*/
XMC_PMBUS_STATUS_t XMC_PMBUS_NODE_CmdCapability(XMC_PMBUS_NODE_t *const node)
{
  uint8_t data[2];
  XMC_PMBUS_STATUS_t status = XMC_PMBUS_STATUS_ERROR;

  if(node->comm_type == XMC_PMBUS_COMM_TYPE_READ)
  {
    data[0] = node->config_ptr->capability.capability_reg;
    XMC_I2C_CH_SlaveTransmit(node->config_ptr->channel, data[0]);
    XMC_PMBUS_STATUS_t status = XMC_PMBUS_STATUS_SUCCESS;
  }
  return (status);
}
```

Power Management Bus (PMBus™) – Get started – PMBus™ Lib (7/7)

- Call Init API at initialization and Task API periodically

Example:

```
int main(void)
{
      .
      .
      .

  /* Init API PMBUS */
  XMC_PMBUS_SLAVE_Init(&slave1);

      .
      .
      .

  while(1U)
  {

    /* slave1 task */
    XMC_PMBUS_SLAVE_Task(&slave1);

  }

}
```

Agenda

9 Resource listing

Power Management Bus (PMBus™) – Resource listing

- PMBus™
  - PMBus™ specification Revision 1.2 Part 1
  - PMBus™ specification Revision 1.2 Part 2

- PMBus™ Lib
  - Documentation
  - Dowload library and examples

Power Management Bus (PMBus™) – Glossary abbreviations (1/2)

PMBus™	Power Management Bus
DAVE™	Free development IDE for XMC™
I2C	Inter-Integrated Circuit protocol
PEC	Packet Error Checking
USIC	Universal Serial Interface Channel
NVIC	Nested Vectored Interrupt Controller
ERU	Event Request Unit
GPIO	General Purpose Input/Output
SYSTICK	System timer
FIFO	First Input First Output

Power Management Bus (PMBus™) – Glossary abbreviations (2/2)

- ACK Acknowledge
- NACK Non-acknowledge

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