AN2511
Application note

PMBus™ interface using ST7 I²C

Introduction

The PMBus™ (power management bus) is an open standard protocol that defines a means of communicating with power conversion and other devices. The PMBus protocol helps to establish the first truly open communications standard for the digital control of power systems. Implemented over the industry-standard SMBus (system management bus) serial interface, the PMBus protocol facilitates the programming, control and real-time monitoring of compliant power conversion products.

This application note describes how to use the ST7 I²C peripheral for PMBus communication. The firmware of this application performs the PMBus bus protocols mentioned in PMBusTM power system management protocol specification v1.0. The device chosen here is ST72264G1 which has multi-master I²C capability. This microcontroller acts as the PMBus master. It controls the PMBus compatible slaves. The firmware described in this application note is in C language.

To show the PMBus capabilities of ST7, a dedicated demonstration board is developed. This board consists of the ST72F264G1 microcontroller and it works with PC hyperterminal. The objective of this demonstration board is to show to the user the features and capabilities of PMBus features using ST7 I²C peripheral, to support the standard PMBus commands. The results of this demonstration board interfaced with Artesyn's PMBus module are shown in this application note.

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1 PMBus introduction

1.1 PMBus protocol description

The PMBus protocol is intended to cover a wide range of power system architectures and converters.

PMBus devices must use the system management bus (SMBus), version 1.1. Implemented over the industry-standard SMBus serial interface, the PMBus protocol facilitates the programming, control and real-time monitoring of compliant power conversion products.

1.1.1 SMBus version 1.1

The system management bus (SMBus) is a two-wire interface through which various system component chips can communicate with each other and with the rest of the system. It is based on the principles of operation of I^2C.

For more information about SMBus, refer to *AN1713*, available from *www.st.com*.

1.1.2 Extensions to SMBus version 1.1 specification

1. Block write-block-read process call

   To support certain commands of the PMBus command language, PMBus devices must support the "Block write-block-read process call" described in *Section 5.5.8* of *Version 2.0 of the SMBus Specification*.

2. Host notify protocol

   PMBus devices may support the host notify protocol described in *Section 5.5.9* of *Version 2.0 of the SMBus Specification*. If a PMBus device supports the host notify protocol, the two data bytes sent to the host are the same as the data bytes returned by the STATUS_WORD command.

3. Group command protocol

   PMBus devices must support the group command protocol. The group command protocol is used to send commands to more than one PMBus device. The commands are received in one transmission. When the devices detect the STOP condition that ends the command, they all begin executing the command they received.

4. Addressing

   PMBus devices use seven bit addresses.

5. Packet error checking (PEC)

   Support for the SMBus packet error checking (PEC) protocol is optional.

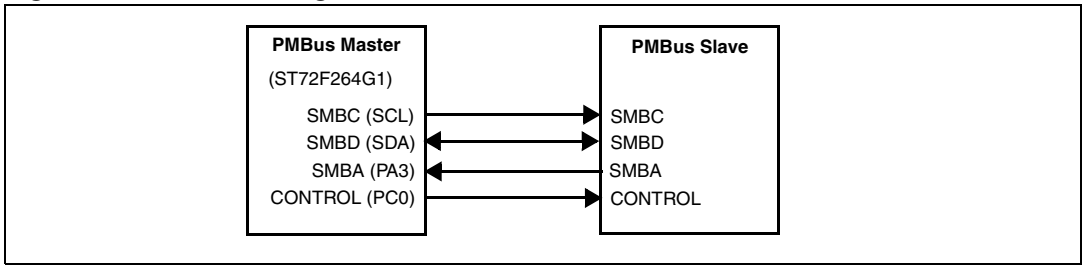
1.2 Hardwired signals

1.2.1 Electrical interface

The following diagram shows the interface between different PMBus devices. ST72264G1 is the selected microcontroller, which has a multi-master I^2C interface. This microcontroller acts as PMBus master. It communicates with any compatible PMBus slave using a 4-pin interface. SMBC is the clock from the master. SMBD is the data pin. Both SMBC and SMBD should be pulled up with a 4.7 kΩ resistor. SMBALERT is the SMBus alert pin, which helps

the slave to alert the master whenever it wants to communicate. The control pin is used to switch ON or OFF a PMBus slave.

Figure 1. Interface diagram



The CONTROL signal is an input signal on a power converter. It is used to turn the unit on and off in conjunction with commands received via the serial bus. It can be configured as an active high or active low signal through the ON_OFF_CONFIG command (refer to *Section 3.1*).

This signal is optional but recommended.

1.2.2 Timing

No specific requirements are made when a PMBus device must respond to a state change of a hardwired signal.

2 Implementation of PMBus using ST7 I²C

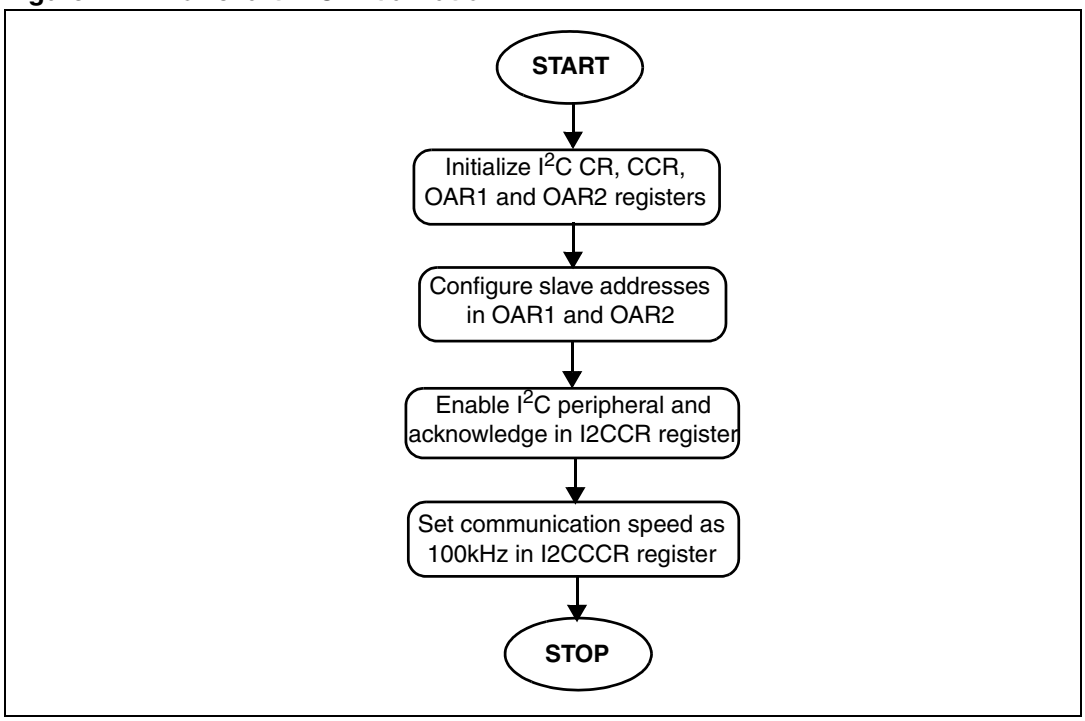
2.1 Firmware architecture

This section explains sequence of operation for different software modules.

2.1.1 I²C initialization

To use ST7 I²C for PMBus communication, the peripheral is initialized for 100 kHz communication speed. The I²C is configured with an address of 0x30, as it can act as a slave due to its multi-master capability. The following flowchart shows the sequence.

Figure 2. Flowchart: I²C initialization



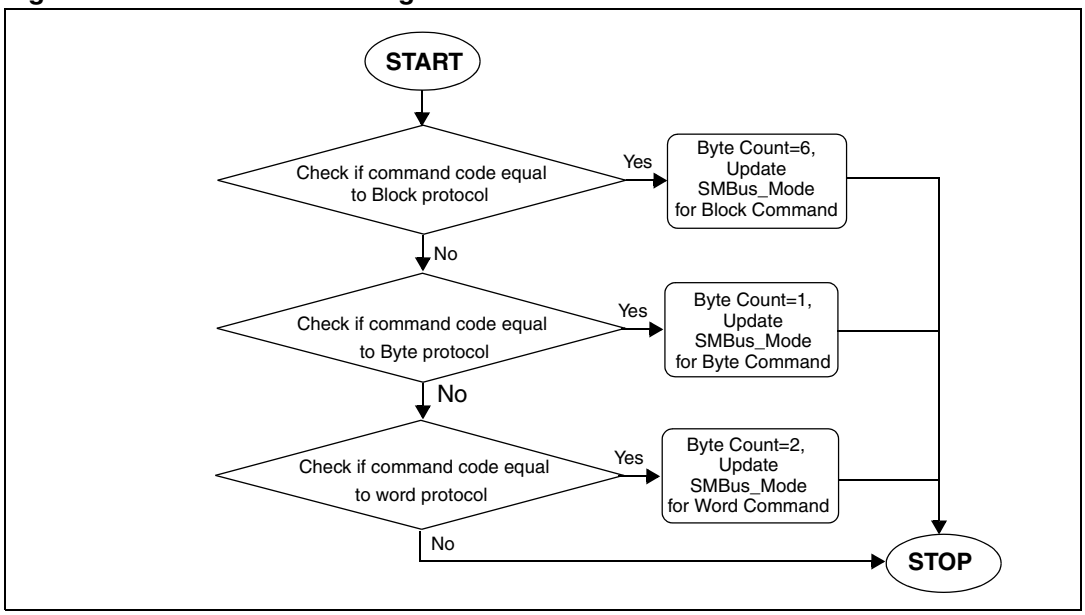
The above flowchart is implemented in the function PMBus_Init.

2.1.2 Slave address and command code

The PMBus master addresses the slave with a 7-bit address. Once the slave device acknowledges the address, the command code is sent corresponding to the PMBus command and SMBus protocol (refer to *Section 3.1*).

Then, the microcontroller decodes the command code as shown in the following sequence. Simultaneously, the `SMBus_Mode` variable is updated.

Figure 3. Flowchart: data length calculation



Inside both `PMBus_CommandRead` and `PMBus_CommandWrite` functions, `PMBus_DataLengthCalc` is called which calculates the data length based on the command code received.

2.1.3 Read and write operation

PMBus master performs read/ write operations with the slave device. Depending on the command code, either `PMBus_CommandRead` or `PMBus_CommandWrite` is called. Inside this function, the SMBus transaction type is selected as shown in the following sequence.

Figure 4. Flowchart: read operation

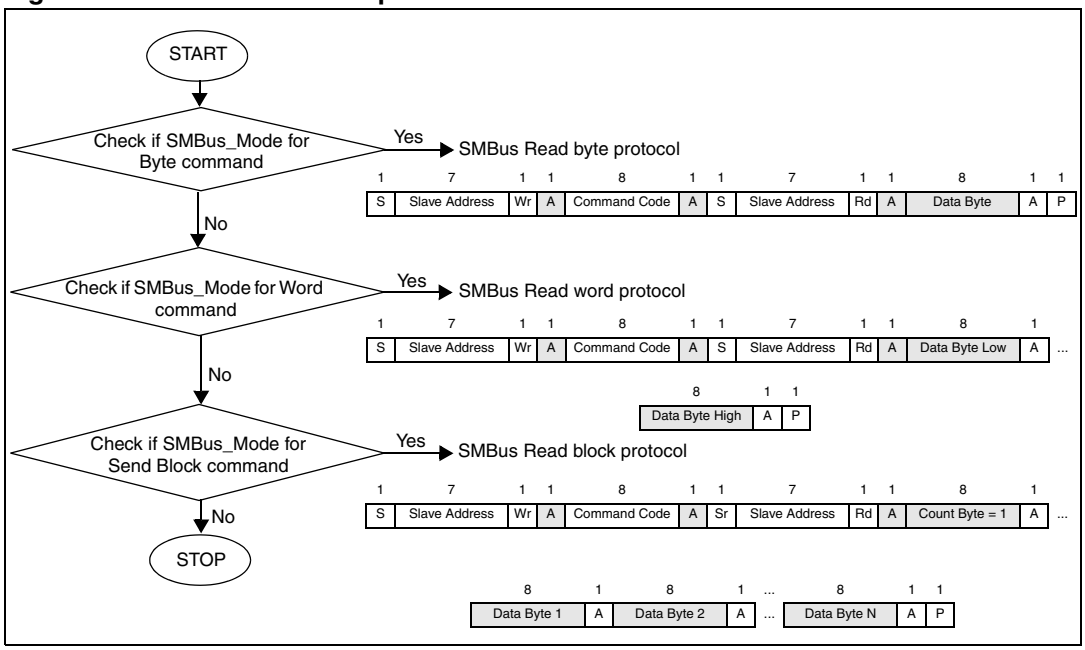
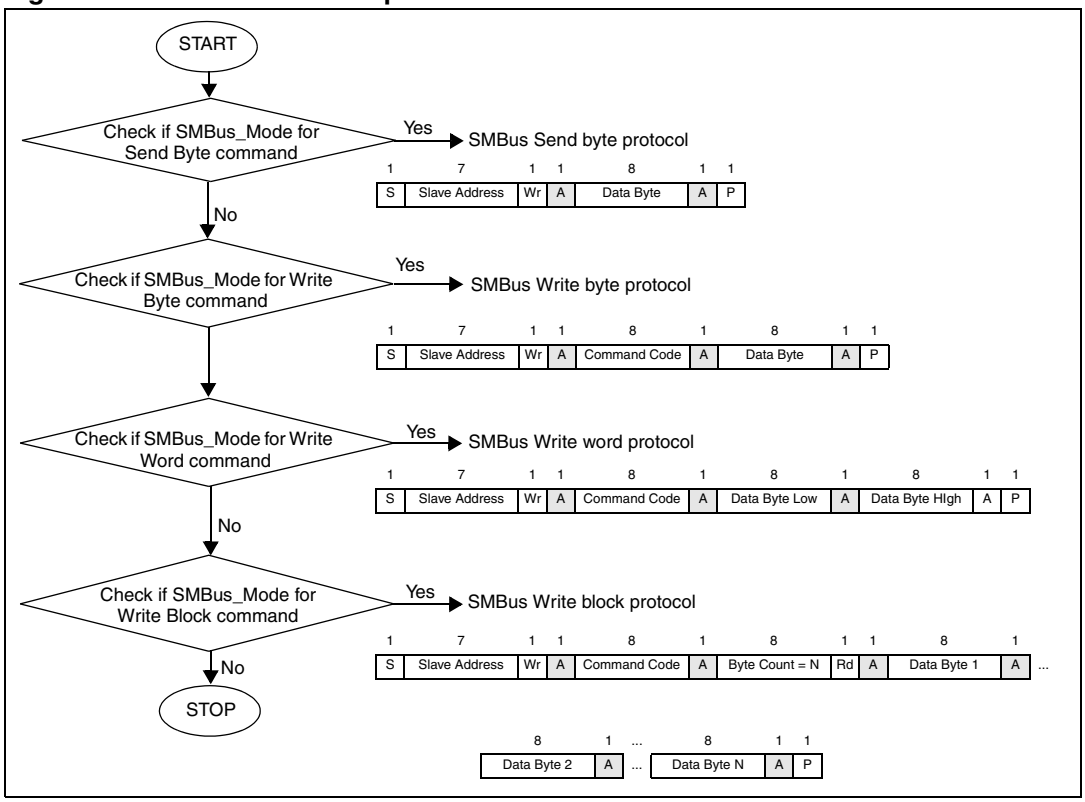


Figure 5. Flowchart: write operation



During the PMBus communication, if there are any errors in communication (acknowledge failure, arbitration loss, bus error or SMBus timeout), the I^2C peripheral is disabled. It is re-initialized again inside the PMBus write/ read functions.

In case the SMBus Alert pin is pulled low by the slave to inform the master that it wants to communicate, the slave address is programmed with the alert response address (0x18). This is acknowledged by the slave that alerted the master. After the communication between the master and slave is complete, the slave address is programmed with the user-defined slave address. The default value of this user-defined address is 0x30.

In case of group operation, the write operation flowchart is followed without the stop condition.

3 PMBus commands and source code

3.1 PMBus commands

The *Part II - command language* document of *PMBus™ Power System Management Protocol Specification v1.0* provides the list of PMBus commands. This driver supports the following list of commands. For each command a table is given.

Table 1. Operation

Command name	OPERATION
Command code	01h
Description	The OPERATION command is used to turn the unit on and off in conjunction with the input from the CONTROL (OUTEN) pin.
SMBus transaction type	Read/ Write byte
Number of data bytes	1

Table 2. ON_OFF_CONFIG

Command name	ON_OFF_CONFIG
Command code	02h
Description	The ON_OFF_CONFIG command configures the combination of CONTROL (OUTEN) pin input and serial bus commands needed to turn the unit on and off.
SMBus transaction type	Read/ Write byte
Number of data bytes	1

Table 3. CLEAR_FAULTS

Command name	CLEAR_FAULTS
Command code	03h
Description	CLEAR_FAULTS is used to clear any fault bits that have been set.
SMBus transaction type	Send byte
Number of data bytes	0

Table 4. RESTORE_DEFAULT_ALL

Command name	RESTORE_DEFAULT_ALL
Command code	12h
Description	The RESTORE_DEFAULT_ALL command instructs the PMBus device to copy the entire contents of the non-volatile default store memory to the matching locations in the operating memory. Any items in default store that do not have matching locations in the operating memory are ignored.
SMBus transaction type	Send byte
Number of data bytes	0

Table 5. STORE_USER_ALL

Command name	STORE_USER_ALL
Command code	15h
Description	The STORE_USER_ALL command instructs the PMBus device to copy the entire contents of the operating memory to the matching locations in the non-volatile user store memory. Any items in operating memory that do not have matching locations in the user store are ignored.
SMBus transaction type	Send byte
Number of data bytes	0

Table 6. VOUT_MODE

Command name	VOUT_MODE
Command code	20h
Description	VOUT_MODE command, used for commanding and reading output voltage, consists of a three bit mode (only linear format is supported.) and a five-bit parameter representing the exponent used in output voltage Read/Writes.
SMBus transaction type	Read/ Write byte
Number of data bytes	1

Table 7. VOUT_COMMAND

Command name	VOUT_COMMAND
Command code	21h
Description	VOUT_COMMAND is used to set the output voltage, in volts (linear format).
SMBus transaction type	Read/ Write word
Number of data bytes	2

Table 8. VOUT_MAX

Command name	VOUT_MAX
Command code	24h
Description	The VOUT_ MAX command sets an upper limit on the output voltage the unit can command regardless of any other commands or combinations.
SMBus transaction type	Read/ Write word
Number of data bytes	2

Table 9. VOUT_MARGIN_HIGH

Command name	VOUT_MARGIN_HIGH
Command code	25h
Description	This VOUT_MARGIN_HIGH command loads the unit with the voltage to which the output is to be changed when the OPERATION command is set to "Margin High".
SMBus transaction type	Read/ Write word
Number of data bytes	2

Table 10. VOUT_MARGIN_LOW

Command name	VOUT_MARGIN_LOW
Command code	26h
Description	This VOUT_MARGIN_LOW command loads the unit with the voltage to which the output is to be changed when the OPERATION command is set to "Margin Low".
SMBus transaction type	Read/ Write word
Number of data bytes	2

Table 11. VOUT_OV_WARN_LIMIT

Command name	VOUT_OV_WARN_LIMIT
Command code	42h

Table 11. VOUT_OV_WARN_LIMIT (continued)

Description	The VOUT_OV_WARN_LIMIT command sets the value of the output voltage at the sense or output pins that causes an output voltage high warning. This value is typically less than the output overvoltage threshold.
SMBus transaction type	Read/ Write word
Number of data bytes	2

Table 12. VOUT_UV_WARN_LIMIT

Command name	VOUT_UV_WARN_LIMIT
Command code	43h
Description	The VOUT_UV_WARN_LIMIT command sets the value of the output voltage at the sense or output pins that causes an output voltage low warning. This value is typically greater than the output undervoltage fault threshold
SMBus transaction type	Read/ Write word
Number of data bytes	2

Table 13. IOUT_OC_FAULT_LIMIT

Command name	IOUT_OC_FAULT_LIMIT
Command code	46h
Description	The IOUT_OC_FAULT_LIMIT command sets the value of the sense output current, in amps (literal format), that causes an overcurrent fault.
SMBus transaction type	Read/ Write word
Number of data bytes	2

Table 14. IOUT_OC_WARN_LIMIT

Command name	IOUT_OC_WARN_LIMIT
Command code	4Ah
Description	The IOUT_OV_WARN_LIMIT command sets the value of the output current that causes an output overcurrent warning.
SMBus transaction type	Read/ Write word
Number of data bytes	2

Table 15. OT_FAULT_LIMIT

Command name	OT_FAULT_LIMIT
Command code	4Fh
Description	The OT_FAULT_LIMIT command sets the value of the sense temperature, in °C (literal format), that causes an overtemperature fault

Table 15. OT_FAULT_LIMIT (continued)

SMBus transaction type	Read/ Write word
Number of data bytes	2

Table 16. OT_FAULT_RESPONSE

Command name	OT_FAULT_RESPONSE
Command code	50h
Description	The OT_FAULT_RESPONSE command instructs the device on what action to take in response to an overtemperature fault.
SMBus transaction type	Read/ Write byte
Number of data bytes	1

Table 17. OT_WARN_LIMIT

Command name	OT_WARN_LIMIT
Command code	51h
Description	The OT_WARN_LIMIT command sets the value of the sense temperature, in °C (literal format), that causes an overtemperature warning.
SMBus transaction type	Read/ Write word
Number of data bytes	2

Table 18. TON_DELAY

Command name	TON_DELAY
Command code	60h
Description	The TON_DELAY sets the time, in ms, from when a start condition is received (CONTROL signal asserted and a valid OPERATION command received) until the output voltage starts to rise.
SMBus transaction type	Read/ Write word
Number of data bytes	2

Table 19. TON_RISE

Command name	TON_RISE
Command code	61h
Description	The TON_RISE sets the time, in ms, from when the output starts to rise until the voltage has entered the regulation band.
SMBus transaction type	Read/ Write word
Number of data bytes	2

Table 20. TOFF_DELAY

Command name	TOFF_DELAY
Command code	64h

Table 20. TOFF_DELAY (continued)

Description	The TOFF_DELAY sets the time, in ms, from when a stop condition is received (CONTROL signal negated or a valid OPERATION command received) until the unit stops transferring energy to the output.
SMBus transaction type	Read/ Write word
Number of data bytes	2

Table 21. TOFF_FALL

Command name	TOFF_FALL
Command code	65h
Description	The TOFF_FALL sets the time, in ms, from the end of the turnoff delay time until the voltage is commanded to zero. Note that this command can only be used with a device whose output can sink enough current to cause the output voltage to decrease at a controlled rate.
SMBus transaction type	Read/ Write word
Number of data bytes	2

Table 22. STATUS_BYTE

Command name	STATUS_BYTE
Command code	78h
Description	The STATUS_BYTE command returns one byte of information with a summary of the most critical faults
SMBus transaction type	Read byte
Number of data bytes	1

Table 23. STATUS_WORD

Command name	STATUS_WORD
Command code	79h
Description	The STATUS_WORD command returns two bytes of information with a summary of the units fault condition.
SMBus transaction type	Read word
Number of data bytes	2

Table 24. STATUS_VOUT

Command name	STATUS_VOUT
Command code	7Ah
Description	The STATUS_VOUT commands returns one byte with status information on Vout.

Table 24. STATUS_VOUT (continued)

SMBus transaction type	Read byte
Number of data bytes	1

Table 25. STATUS_IOUT

Command name	STATUS_IOUT
Command code	7Bh
Description	STATUS_IOUT commands returns one byte with status information on Iout.
SMBus transaction type	Read byte
Number of data bytes	1

Table 26. STATUS_TEMPERATURE

Command name	STATUS_TEMPERATURE
Command code	7Dh
Description	STATUS_TEMPERATURE commands returns one byte with status information on temperature.
SMBus transaction type	Read byte
Number of data bytes	1

Table 27. STATUS_MFR_SPECIFIC

Command name	STATUS_MFR_SPECIFIC
Command code	80h
Description	STATUS_MFR_SPECIFIC commands returns one byte with the manufacturer specific status information.
SMBus transaction type	Read byte
Number of data bytes	1

Table 28. READ_VOUT

Command name	READ_VOUT
Command code	8Bh
Description	The READ_VOUT command returns the actual measured output voltage in the same format as set by the VOUT_MODE command.
SMBus transaction type	Read word
Number of data bytes	2

Table 29. READ_IOUT

Command name	READ_IOUT
Command code	8Ch
Description	The READ_IOUT command returns the measured output current in amperes.
SMBus transaction type	Read word
Number of data bytes	2

Table 30. READ_TEMPERATURE

Command name	READ_TEMPERATURE
Command code	8Dh
Description	Up to three temperature readings can be returned for each device.
SMBus transaction type	Read word
Number of data bytes	2

Table 31. PMBUS_REVISION

Command name	PMBUS_REVISION
Command code	98h
Description	PMBUS_REVISION command stores or reads the revision of the PMBus to which the device is compliant.
SMBus transaction type	Read byte
Number of data bytes	1

Table 32. MFR_ID

Command name	MFR_ID
Command code	99h
Description	The MFR_ID commands loads the unit with ASCII characters that contain the manufacturer's ID (name, abbreviation or symbol that identifies the unit's manufacturer). This is typically only done once at the time of manufacture.
SMBus transaction type	Read/Write block
Number of data bytes	7

Table 33. MFR_MODEL

Command name	MFR_MODEL
Command code	9Ah
Description	The MFR_MODEL command loads the unit with ASCII characters that contain the manufacturer's model number. This is typically done once at the time of manufacture.
SMBus transaction type	Read/Write block
Number of data bytes	6

Table 34. MFR_REVISION

Command name	MFR_REVISION
Command code	9Bh
Description	The MFR_REVISION command loads the unit with ASCII characters that contain the manufacturer's revision number. This is typically done once at the time of manufacture.
SMBus transaction type	Read/Write block
Number of data bytes	2

Table 35. MFR_LOCATION

Command name	MFR_LOCATION
Command code	9Ch
Description	The MFR_REVISION command loads the unit with ASCII characters that contain the manufacturer's revision number. This is typically done once at the time of manufacture.
SMBus transaction type	Read/Write block
Number of data bytes	2

Table 36. MFR_DATE

Command name	MFR_DATE
Command code	9Dh
Description	The MFR_DATE command loads the unit with ASCII characters that identify the unit's date of manufacture. This is typically done once at the time of manufacture.
SMBus transaction type	Read/Write block
Number of data bytes	6

Table 37. MFR_SERIAL

Command name	MFR_SERIAL
Command code	9Eh
Description	The MFR_SERIAL command loads the unit with a serial number to uniquely identify the unit
SMBus transaction type	Read/Write block
Number of data bytes	6

Table 38. MFR_SPECIFIC_00

Command name	MFR_SPECIFIC_00
Command code	D0h
Description	The MFR_SPECIFIC_00 command provides access control for NVM register writes.
SMBus transaction type	Read byte
Number of data bytes	1

Table 39. MFR_SPECIFIC_01

Command name	MFR_SPECIFIC_01
Command code	D1h
Description	The MFR_SPECIFIC_01 command provides access control for configuration register writes.
SMBus transaction type	Read byte
Number of data bytes	1

Table 40. MFR_SPECIFIC_02

Command name	MFR_SPECIFIC_02
Command code	D2h
Description	The MFR_SPECIFIC_02 is a manufacturer defined command.
SMBus transaction type	Read byte
Number of data bytes	1

3.2 Source code

The source code is attached in the zip file along with the application note. This source code is organized as shown below.

```
' Workspace directory
      ' Debug
         ' object files, list files, map files, executable files (.elf), hex code
(.s19)
      ' Sources
         ' Main.c: Contains main source code. In this file, PMBus interface functions
are          called (refer to section 3.3).
         ' Main.h: Contains prototype of all functions used in Main.c.
         ' PMBus.c: Contains functions for PMBus write and read operation. The data
            length calculator function and I2C and Alert signal interrupt sub-
               routines are also written inside this file.
         ' PMBus.h: Contains prototype of all functions and enumerated data
                  types used in PMBus.c.
         ' SMBus_Master.c: Contains source code for differnet SMBus master
               transaction bus protocols.
         ' SMBus_Master.h: Contains prototype of all functions and enumerated data
               types used in SMBus_Master.c.
         ' st72264g1.h: Contains register mapping for ST72F264G1 device.
         ' ST7_hr.h: Contains hardware register bit definitions for ST7 MCU
         ' ST7_Config.h: Contains compiler selection, peripheral register inclusion,
               header files inclusion for linking, macros for assembly instructions
            and Fcpu Definition.
      ' interrupt_vector.c: Contains general Interrupt vector table for ST7 devices
```

3.3 Example

This section explains how to use the PMBus driver. An example operation of write/ read commands are shown.

```
/******************************************************************************
COPYRIGHT 2005 STMicroelectronics
Source File Name : Main.c
Group            : IMS Systems Lab
Author           : Telecom Team
Date First Issued: 01/09/2006
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-

    THE SOFTWARE INCLUDED IN THIS FILE IS FOR GUIDANCE ONLY. STMicroelectronics
    SHALL NOT BE HELD LIABLE FOR ANY DIRECT, INDIRECT OR CONSEQUENTIAL
    DAMAGES WITH RESPECT TO ANY CLAIMS ARISING FROM USE OF THIS SOFTWARE.

-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
********************************Documentation*********************************
General Purpose - Contains main source code. In this file, the PMBus command files
are written.
******************************************************************************/

#include "ST7_config.h"                             /* Fcpu defined as 8MHz */
#include "main.h"       /* Contains the global variables used in main.c */
#include "ST7_hr.h"            /* Contains the register and flags for ST7 */

extern volatile unsigned int SMB_TimeCount;               /* Time count variable */

#pragma space extern [] @tiny    /* To force following variables into short
addressing memory */
extern unsigned char Data_Buff [32] ;       /* Buffer to store data */

               /* Variables to differentiate the different SMBus transaction types */
extern volatile unsigned char SMBus_Mode ;

extern volatile unsigned char SMB_Err_Status ;                    /* Error status */
                                               /* Master to address slave with this
address */
static volatile unsigned char PMBus_SlaveAdd = 0x80;
                                               /* Master to address slave with this
address */
static volatile unsigned char PMBus_SlaveAdd = 0x80;

/*-----------------------------------------------------------------------------
ROUTINE NAME : Main
INPUT        : None
OUTPUT       : None
DESCRIPTION  : Using this file, user can write/ read PMBus commands.
COMMENTS     : Programs jumpts into this routine when microcontroller is reset
-----------------------------------------------------------------------------*/
void main()
{
   unsigned char temp ;
   SMBs_Address_t PMBus_Err ;  /* To check errors in PMBus communication */

   /*----------------------- Port A configuration ----------------------------*/
   PADDR &= (unsigned char)~PORTA_DEFAULT;
        PADDR = PORTA_DEFAULT ;         /* Other pins configured as floating input */
   PAOR = (unsigned char)(PORTA_DEFAULT) ;

        /*----------------------- Port C configuration ----------------------------*/
        PCDDR = CONTROL ;     /* PC0 floating input, others push pull output */
```

```
        PCOR = CONTROL ;
        PCDR = CONTROL ;

       /*------------------------ Alert Interrupt configuration ----------------------
----------*/
   EnableInterrupts;                              /* Resets interrupt mask */

   MISCR1 = 0x10 ;            /* EI0 on falling edge low level for Alert interrupt */

   /*---------------------PMBus communication configuration-------------------*/
   while (1)
   {
           /* I2C configuration: ST7 I2C address 0x30, communication speed 100kHz */
      PMBus_Init (SMBs_MISC, SLAVEADD, 0x40, 0x23);

                            /* Checking if an alert signal is received from slave */
      if (SMBus_Mode & SMB_ARA)
      {
                     /* ST7 I2C sends the alert response address to check which slave
alerted */
         PMBus_Err = SMBm_ReceiveByte (ALERTRESPONSEADD, Data_Buff);

      /* Alerted slave address will be used for any further communication */
             PMBus_SlaveAdd = *Data_Buff ;
         SMBus_Mode &= (unsigned char) ~SMB_ARA ;
      }
      Command_Code =  0x01;   /* User should enter the PMBus command code here */

      PMBus_CommandWrite (Command_Code);  /* Writes data from Data_Buff */


      Command_Code =  0x02;   /* User should enter the PMBus command code here */
                     /* Read data and store it in Data_Buff */
      PMBus_CommandRead (Command_Code);

      if (SMB_Err_Status)
      {                                    /* I2C status register read to clear any
errors  */
         SMB_Err_Status = I2CSR2 ;
         SMB_Err_Status = 0 ;
      }
   }                                                          /* End of while (1) */
}                                                                /* End of main */
```

3.4 Limitations

1. The SMBus driver used in this application note is tested only for write word, read word and write block protocols with PEC disabled.
2. The SMBus driver doesn't meet the clock low extending feature of *SMBus v1.1* due to the limitation of the I^2C peripheral.
3. In case of PEC, when slave is acting as receiver, the ACK bit is not disabled if the PEC received from master transmitter is different from slave. It is stored in the user address as the last byte. It is the responsibility of the user to check the master PEC with the slave PEC to decide on data validity.

4 PMBus interfacing results

This section describes the results of interfacing the demonstration board with Artesyn and SiLabs modules.

4.1 Interfacing with Artesyn module

The following table shows the different PMBus commands and ST demonstration board results compared to the Artesyn DPL20C PMbus module.

Table 41. PMBus interfacing with Artesyn module: results

Command code	PMBus command	SMBus transaction type	Number of data bytes	Data (Si8250)	Data (ST7)
01	OPERATION	Read/ write byte	1	80	80
02	ON_OFF_CONFIG	Read/ write byte	1	14	14
03	CLEAR_FAULTS	Send byte	0		
12	RESTORE_DEFAULT_ALL	Send byte	0		
15	STORE_USER_ALL	Send byte	0		
20	VOUT_MODE	Read/ write byte	1	1 A	1 A
21	VOUT_COMMAND	Read/ write word	2	00 60	00 60
24	VOUT_MAX	Read/ write word	2	01 60	01 60
25	VOUT_MARGIN_HIGH	Read/ write word	2	00 6 A	00 6 A
26	VOUT_MARGIN_LOW	Read/ write word	2	00 56	00 56
42	VOUT_OV_WARN_LIMIT	Read/ write word	2	00 6E	00 6E
43	VOUT_UV_WARN_LIMIT	Read/ write word	2	00 56	00 56
46	IOUT_OC_FAULT_LIMIT	Read/ write word	2	00 19	00 19
4A	IOUT_OC_WARN_LIMIT	Read/ write word	2	00 17	00 17
4F	OT_FAULT_LIMIT	Read/ write word	2	00 78	00 78
50	OT_FAULT_RESPONSE	Read/ write byte	1	B1	B1
51	OT_WARN_LIMIT	Read/ write word	2	00 6E	00 6E
60	TON_DELAY	Read/ write word	2	00 00	00 00
61	TON_RISE	Read/ write word	2	00 0A	00 0A
64	TOFF_DELAY	Read/ write word	2	00 00	00 00
65	TOFF_FALL	Read/ write word	2	00 00	00 00

Table 41. PMBus interfacing with Artesyn module: results (continued)

Command code	PMBus command	SMBus transaction type	Number of data bytes	Data (Si8250)	Data (ST7)
78	STATUS_BYTE	Read byte	1	41	41
79	STATUS_WORD	Read word	2	00 41	00 41
7A	STATUS_VOUT	Read byte	1	00	00
7B	STATUS_IOUT	Read byte	1	00	00
7D	STATUS_TEMPERATURE	Read byte	1	00	00
80	STATUS_MFR_SPECIFIC	Read byte	1	02	02
8B	READ_VOUT	Read word	2	00 01	00 01
8C	READ_IOUT	Read word	2	D7 C3	D7 C3
8D	READ_TEMPERATURE	Read word	2	00 20	00 1D
98	PMBUS_REVISION	Read byte	1	01	01
99	MFR_ID	Read block	7	41 52 54 45 53 59 4E	41 52 54 45 53 59 4E
9A	MFR_MODEL	Read block	6	44 50 4C 32 30 43	44 50 4C 32 30 43
9B	MFR_REVISION	Read/ write block	2	31 02	31 41
9C	MFR_LOCATION	Read/ write block	2	5A 02	5A 53
9D	MFR_DATE	Read/ write block	6	32 34 30 33 36 06	32 34 30 33 36 36
9E	MFR_SERIAL	Read/ write block	6	31 32 33 34 35 06	31 32 33 34 35 36
D0	MFR_SPECIFIC_00	Read byte	1	28	28
D1	MFR_SPECIFIC_01	Read byte	1	10	10
D2	MFR_SPECIFIC_02	Read byte	1	0A	0A

4.2 Interfacing with SiLabs module

The following table shows the different PMBus commands and ST demonstration board results compared to Silicon Labs Si8250 - TB module.

Table 42. PMBus interfacing with SiLabs module: results

Command code	PMBus command	SMBus transaction type	Number of data bytes	Data (Si8250)	Data (ST7)
01	OPERATION	Read/ write byte	1	C0	C0
02	ON_OFF_CONFIG	Read/ write byte	1	1E	1E

Table 42. PMBus interfacing with SiLabs module: results (continued)

Command code	PMBus command	SMBus transaction type	Number of data bytes	Data (Si8250)	Data (ST7)
03	CLEAR_FAULTS	Send byte	0		
12	RESTORE_DEFAULT_ALL	Send byte	0		
15	STORE_USER_ALL	Send byte	0		
20	VOUT_MODE	Read/ write byte	1	11	11
21	VOUT_COMMAND	Read/ write word	2	7F F6	7F F6
24	VOUT_MAX	Read/ write word	2	89 94	89 94
25	VOUT_MARGIN_HIGH	Read/ write word	2	00 6A	00 6A
25	VOUT_MARGIN_HIGH	Read/ write word	2	86 5C	86 5C
26	VOUT_MARGIN_LOW	Read/ write word	2	79 90	79 90
42	VOUT_OV_WARN_LIMIT	Read/ write word	2	89 94	89 94
43	VOUT_UV_WARN_LIMIT	Read/ write word	2	76 58	76 58
4F	OT_FAULT_LIMIT	Read/ write word	2	EB 20	EB 20
50	OT_FAULT_RESPONSE	Read/ write byte	1	00	00
51	OT_WARN_LIMIT	Read/ write word	2	EA D0	EA D0
60	TON_DELAY	Read/ write word	2	00 0A	00 0A
61	TON_RISE	Read/ write word	2	00 32	00 32
64	TOFF_DELAY	Read/ write word	2	00 0A	00 0A
65	TOFF_FALL	Read/ write word	2	00 C8	00 C8
78	STATUS_BYTE	Read byte	1	04	04
79	STATUS_WORD	Read word	2	00 04	00 04
7A	STATUS_VOUT	Read byte	1	00	00
7B	STATUS_IOUT	Read byte	1	00	00
7D	STATUS_TEMPERATURE	Read byte	1	20	20
80	STATUS_MFR_SPECIFIC	Read byte	1	00	00
8B	READ_VOUT	Read word	2	80 4E	80 76
8C	READ_IOUT	Read word	2	D7 C3	00 00
8D	READ_TEMPERATURE	Read word	2	EF 56	EF 56
98	PMBUS_REVISION	Read byte	1	00	00
D0	MFR_SPECIFIC_00	Read byte	1	67	67
D1	MFR_SPECIFIC_01	Read byte	1	EF	EF
D2	MFR_SPECIFIC_02	Read byte	1	08	08

5 PMBus demonstration board

To show the features of the ST7 I^2C working as a PMBus, a demonstration board is available on request. Please contact the nearest ST office to get this board. The evaluation board has an ST72F264G1 MCU that has 4 KBytes Flash memory. All PMBus functionalities are not shown, as this evaluation board has hyperterminal interface which requires lot of messages to be stored in program memory.

5.1 System requirements

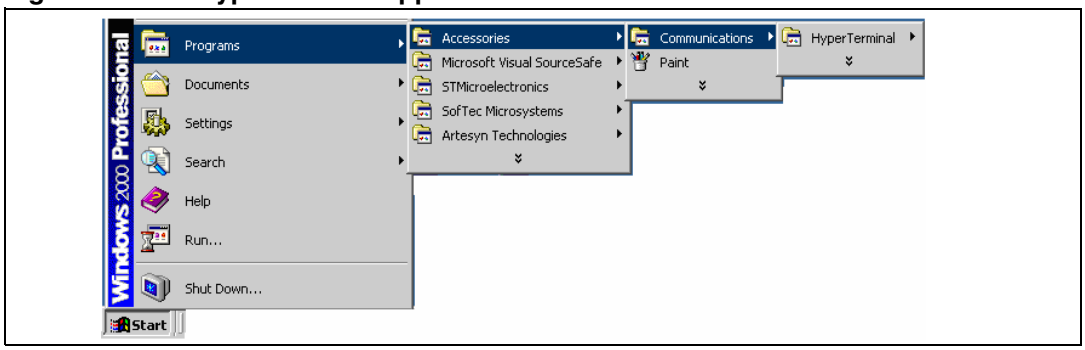
In order to use the PMBus demonstration board with the Windows operating system. The PC should support hyperterminal software and RS232 communication using DB9 connector.

5.2 Software setup

To configure the PC hyperterminal software, the user should follow the steps as mentioned below.

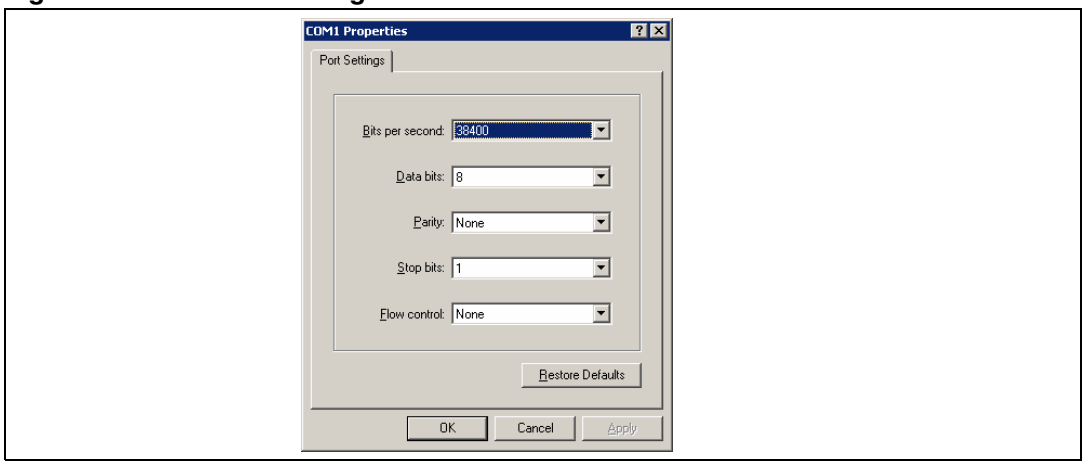
1. Click on **Start** -> **Programs** -> **Accessories** -> **Communications** -> **HyperTerminal** as shown below.

Figure 6. PC hyperterminal application



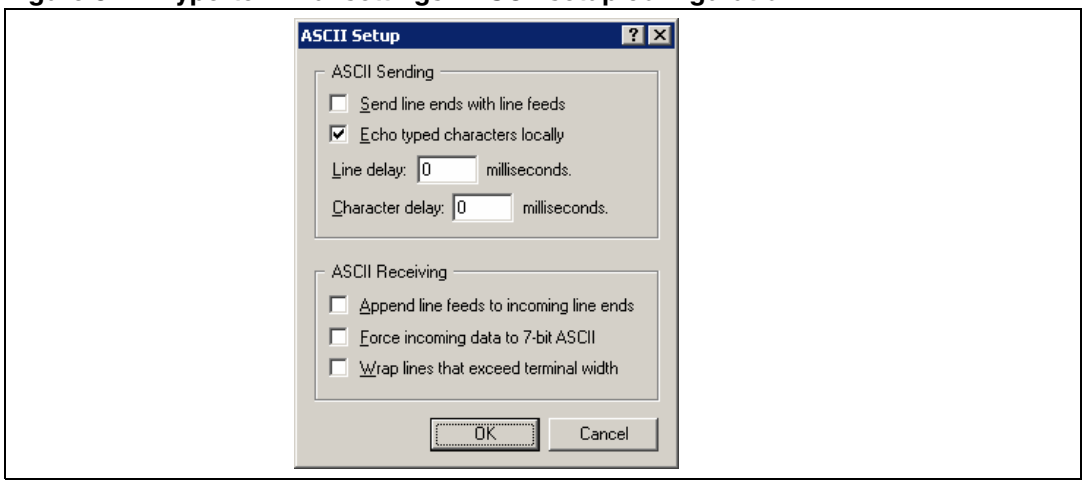
2. Select the correct port in which RS232 (9-pin cable) is connected (refer to *Section 3*).
3. Configure the following baud rate (bits per second) in hyperterminal: **File** -> **Properties** -> **Connect to** -> **Configure**. If the user configures any baud rate other than 38400, then RS232 communication fails.

Figure 7. Baud rate configuration



4. Configure the following settings in hyperterminal: **File** -> **Properties** -> **Settings** -> **ASCII setup**

Figure 8. Hyperterminal settings - ASCII setup configuration



5. Press call in hyperterminal to establish a connection with the board.

5.3 Hardware setup

To configure the hardware board, the user should follow these steps:

1. Jumper settings: There are four jumpers (JP1, JP2, JP3 and JP4) available on the board. The detail of these connectors is as follows:
   a) JP1: JP1 pins should be connected using the jumper if there is no pull-up connected in the clock line of the I^2C bus. Once connected, the I^2C clock line is pulled up with a resistor value of 4.7 kΩ.
   b) JP2: JP2 pins should be connected using the jumper if there is no pull-up connected in the data line of the I^2C bus. Once connected, the I^2C data line is pulled up with a resistor value of 4.7 kΩ.
   c) JP3: JP3 is used to select the clock source for the ST7 microcontroller. From the JP3 side, if the jumper is connected between pins 1 and 2 then the application

runs using the resonator clock (16 MHz). If the jumper is connected between pins 2 and 3 then the application is stopped and ST7 MCU can be re-programmed.

d) JP4: JP4 is used to select the power supply as described below. From the JP4 side, if the jumper is connected between pins 2 and 3 then the application runs using the direct supply given from `POWER' connector. If the jumper is connected between pins 1 and 2 then the application runs using the DC adapter supply given from J1.

2. Power settings: The demonstration board can be powered by one of the following options:

a) DC adapter: Connect a DC adapter to J1. The DC adapter should supply a minimum of 7 V and maximum of 18 V, 1 A. This supply is regulated to 5 V supply using an L7805 regulator.

b) Regulated supply: The user can use a direct 3 V to 5 V supply. The supply and Gnd points should be connected to the `POWER' connector pins 1 and 2. Here, `POWER' connector pin 1 is referred from the JP4 jumper side (from the right side).

6 Using the demonstration board

After installing the setup as explained in *Section 1*, the following message appears in hyperterminal.

Figure 9. Hyperterminal message to show company name and selection of communication speed

If there is any problem in getting the message, press the switch provided in the demonstration board. This switch re-starts the application.

6.1 Normal operation

The following sections explain how to initiate PMBus communication and how to read/ write PMBus commands with hyperterminal.

6.1.1 Selection of communication speed

After the message appears as shown in *Figure 9*, the user should enter 1 or 2 to select the PMBus communication speed as 100 kHz or 400 kHz respectively. The default speed value selected is 100 kHz.

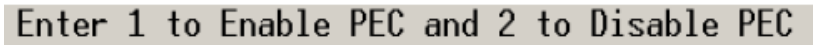
If the user enters any other value other than 1 and 2, the previous speed value is retained.

6.1.2 Selection of packet error checking

After the message appears as shown in *Figure 10*, the user should enter 1 or 2 to enable PEC and disable PEC respectively. If PEC is enabled, all address, command code and data communications are checked through CRC-8 check. The default PEC value is PEC disabled.

If the user enters any other value other than 1 and 2, the previous speed value is retained.

Figure 10. PEC selection

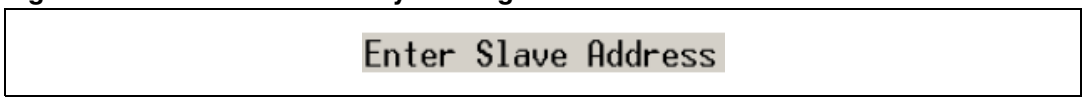


6.1.3 Selection of slave address

The user should enter the slave address of the PMBus device. The slave address should be in hexadecimal format. The slave addresses of different competitor's module are given below. Artesyn DPL20C module: 0x30 SiLabs Si8250-TB module : 0x80.

The slave address could change from one device to another device. The user must refer to the product datasheet and development kit documents to decide on the slave address. An example entry of slave address with Artesyn DPL20C module is shown below.

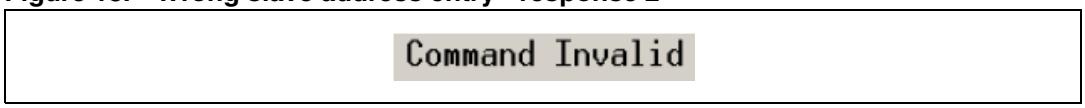
Figure 11. Slave address entry message



If the user enters a wrong slave address then one of the following error messages shown in *Figure 12* or *Figure 13* appears.

Figure 12. Wrong slave address entry - response 1

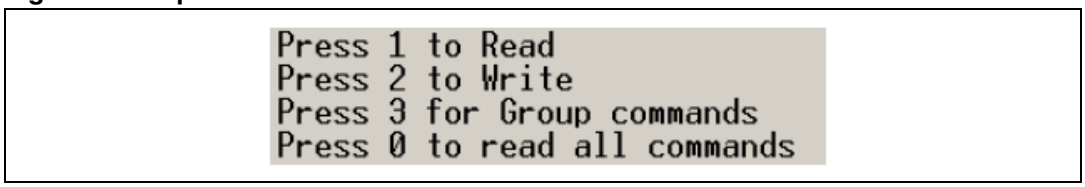
Figure 13. Wrong slave address entry - response 2



6.1.4 Selection of read/write mode

Data can be written into or data can be read back from the PMBus salve device connected. The following figure provides the key option to select one of the modes.

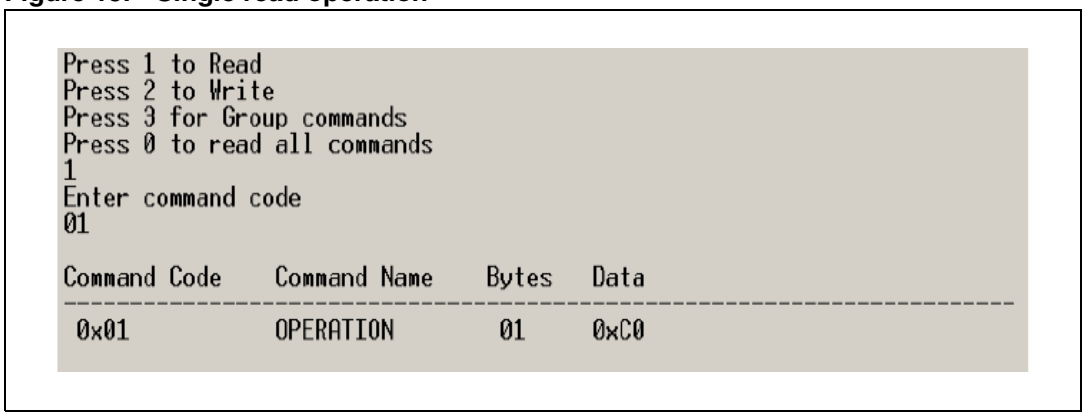
Figure 14. Options to select read/ write mode



6.1.5 Single read mode

The user can press 1 to select read mode. Then the user can enter any command code with reference to *Section 3* to read byte/ word/ block of data. An example of this is shown below.

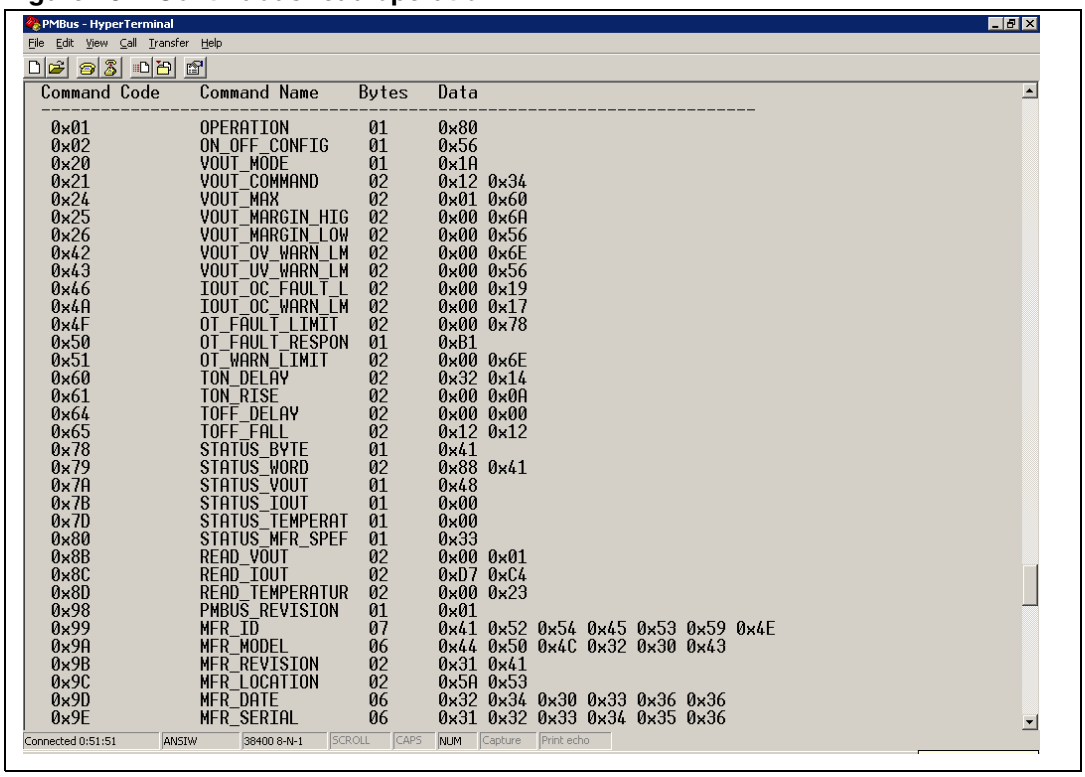
Figure 15. Single read operation



6.1.6 Continuous read mode

The user can press 0 to read all PMBus commands. The lists of supported commands are shown in the following figure.

Figure 16. Continuous read operation



Command codes 0xD0, 0xD1 and 0xD2 are not supported in continuous read mode. If the user wants to read these commands, they can be read by using single read mode.

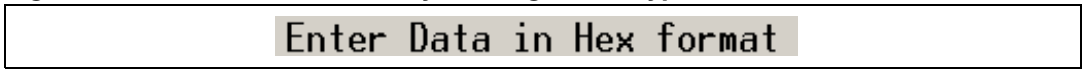
6.1.7 Write mode

The user can press 2 to select write mode. After the following figure appears, the user can enter any command code with reference to *Section 2.1 on page 8* to write byte/ word/ block of data.

Figure 17. Write mode command code entry message from hyperterminal

Then the user can enter any command code with reference to *Section 4* to write byte/ word/ block of data. The user can enter data after the following message.

Figure 18. Write mode data entry message from hyperterminal



Data should be entered in hex format. If the user wants to enter date/ serial numbers, they should be entered in ASCII format.

For example, to enter a date as “15 -12-1991”, then data should be entered as 313531323931 (where 31h=ASCII ”1”, 35h=ASCII “5”, etc., and the date will read “151291”).

An example of this operation is shown below.

Figure 19. Write mode operation example

```
------------------------------------------------------------------------
                        ST MICROELECTRONICS PMBUS DEMO
------------------------------------------------------------------------
Press 1 to Read
Press 2 to Write
Press 3 for Group commands
Press 0 to read all commands
2
Enter command code
24
Enter Data in Hex format
8994
```

When reading back the date written using single read commands, the following message is displayed:

Figure 20. Read operation to check data writing

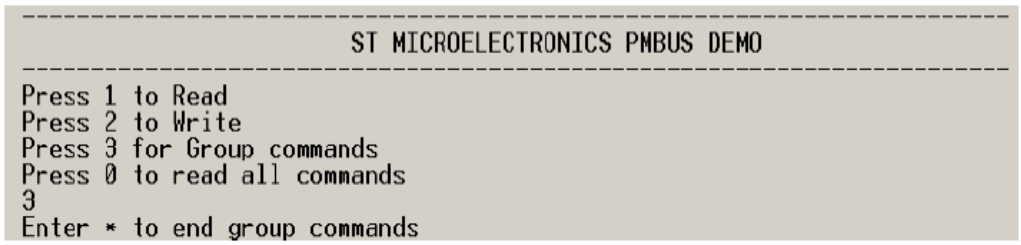
```
------------------------------------------------------------------------
                        ST MICROELECTRONICS PMBUS DEMO
------------------------------------------------------------------------
Press 1 to Read
Press 2 to Write
Press 3 for Group commands
Press 0 to read all commands
1
Enter command code
24

Command Code    Command Name    Bytes   Data
------------------------------------------------------------------------
 0x24           VOUT_MAX         02     0x89 0x94
```

6.1.8 Group command

The user can press 3 to select group command mode. In this demonstration board, the user can write multiple commands for multiple slave addresses.

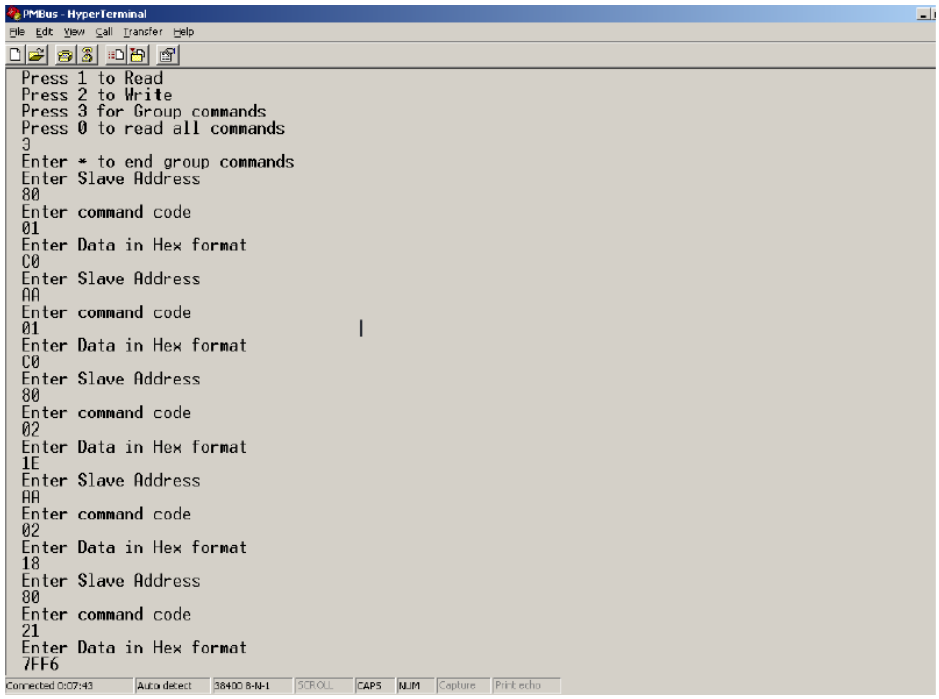
After *Figure 21* appears, the user can enter any command code and data with reference to *Section 3.1: PMBus commands* to write byte/ word/ block of data. The user can enter 5 commands and data for the group command. If the user wants to write less than 5 commands, the user can press * to terminate the group command operation.

Figure 21. Group command code entry message from hyperterminal



An example of this operation is shown below.

Figure 22. Group command operation example



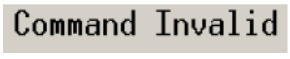
6.2 Error conditions

The following error conditions may be encountered during PMBus communication.

6.2.1 Invalid command code

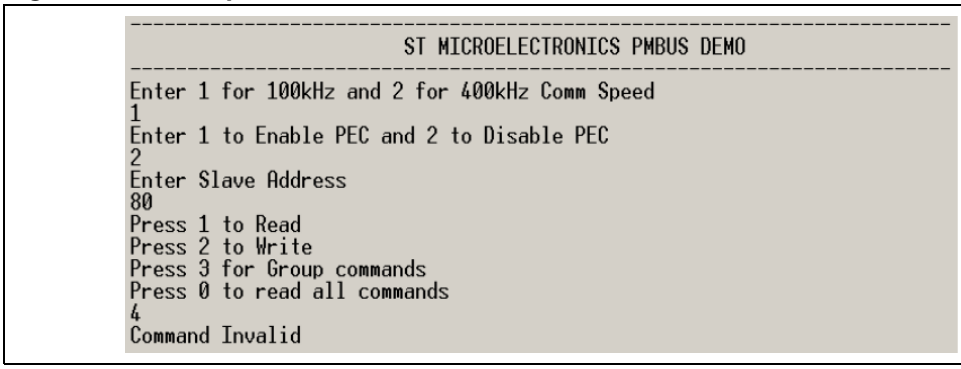
If the user enters a command code that is not available in the list or enters an incorrect option to select read/write options, the following error message appears:

Figure 23. Invalid command message



An example is shown in *Figure 24*.

Figure 24. Example of invalid command



6.2.2 Communication timeout

This error appears when the PMBus communication fails due to one of the following reasons:

- The slave device doesn't acknowledge the master
- The clock low interval exceeds the value of TTIMEOUT,MIN as defined by (*SMBus Specification 1.1*)
- TLOW:SEXT and TLOW:MEXT conditions are not met
- Bus error or arbitration errors in PMBus communication

In these conditions, the following error message appears:

Figure 25. Communication timeout message

7 Hardware description

This section provides schematics, BOM (bill of materials), layout and picture of the demonstration board.

7.1 Schematic and layout

The following figures show the schematic and layouts of the demonstration board.

Figure 26. Demonstration board schematic

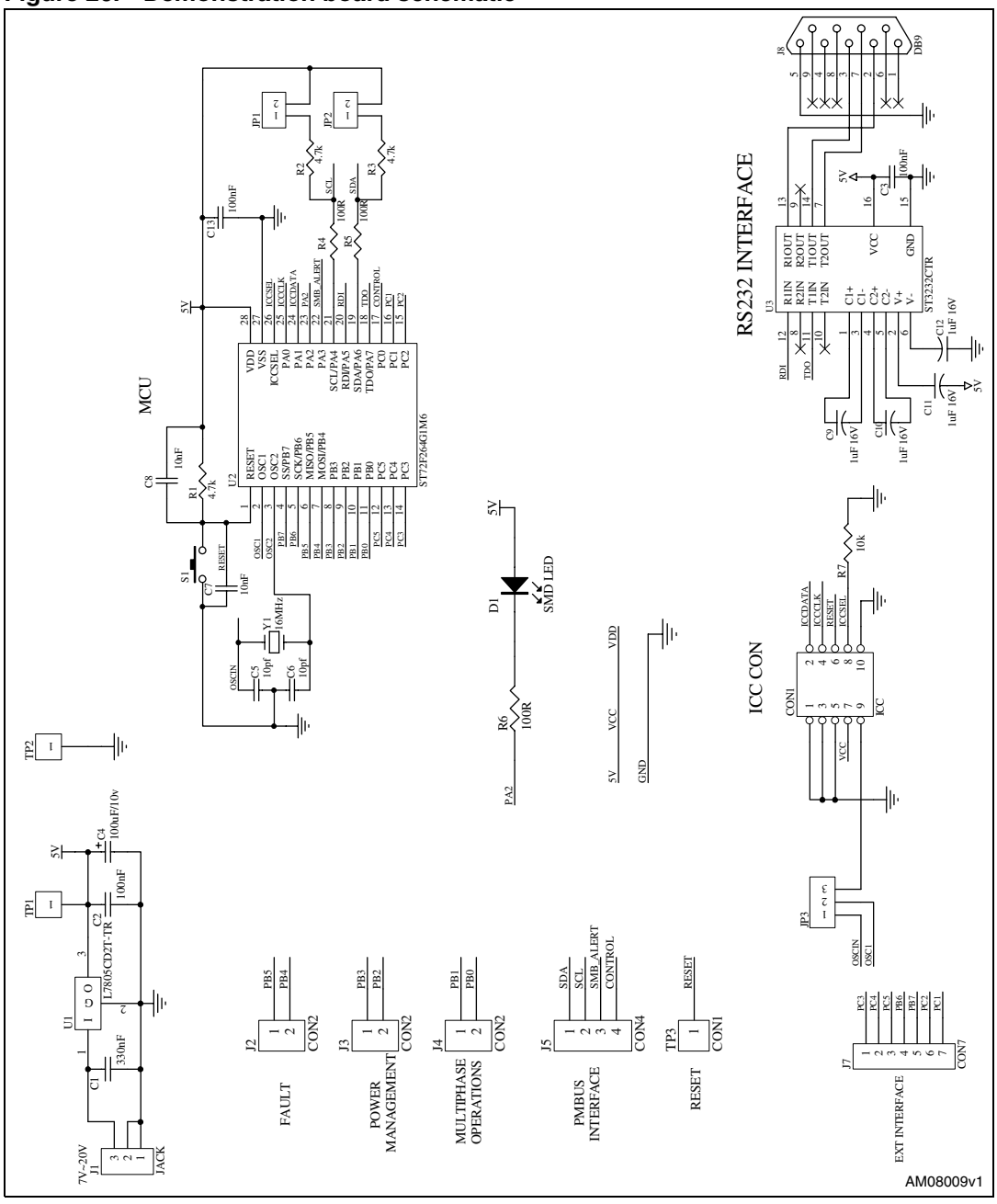


Figure 27. Top view layout of the demonstration board

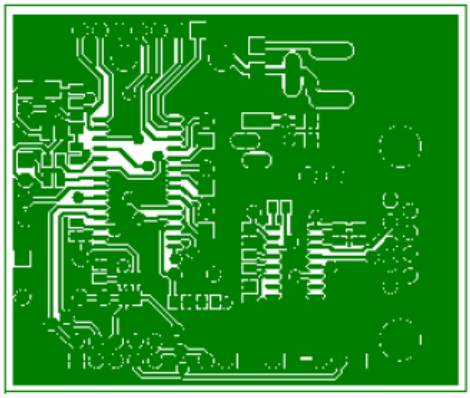
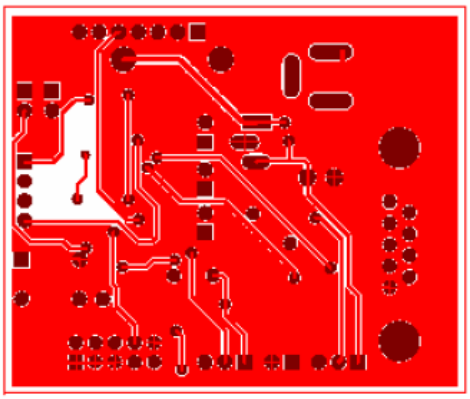


Figure 28. Bottom view layout of the demonstration board



7.2 Bill of materials (BOM)

The following table shows the BOM of the demonstration board.

Table 43. Bill of material

Reference	Value / generic part number	Package	Manufacturer	Manufacturer's ordering code / orderable part number	Supplier
Capacitors: C2, C3, C9, C10, C11, C12, C13	100 nF	805	Any		
Capacitors: C7, C8	10 nF	805	Any		
Capacitors: C5, C6	10 pF	805	Any		
Capacitors: C1	330 nF	805	Any		
Polarized capacitor (Axial): C4	100 µF/ 10 V	RB-5.5	Any		
Resistors: R1, R2, R3	4.7 kΩ	805	Any		
Resistors: R4, R5	100 Ω	805	Any		
Resistors: R6	220 Ω	805	Any		
Resistors: R7	10 kΩ	805	Any		
Connector: TP3	CON1	SIP-1	Any		
Connectors: J2, J3, J4, JP1, JP2, POWER	CON2	SIP-2	Any		
Connectors: JP3, JP4	CON3	SIP-3	Any		
Connector: J5	CON4	SIP-4	Any		
Connector J7	CON7	SIP-7	Any		
9 pin female RS232 connector: J6	DB9	DB9/F			GM (801-036)
Crystal: Y1	16 MHz (KDS)	XTAL-1	Any		
Header: CON1	ICC	IDC-10B	Any		
Power Jack connector: J1	JACK	TAP_2.5 mm			GM: K375A
Regulator: U1	L7805CD2T-TR	TO-220	STMicroelectronics	L7805CD2T-TR	
SMD LED: D1	SMD LED	LED-SMD	Faichild		

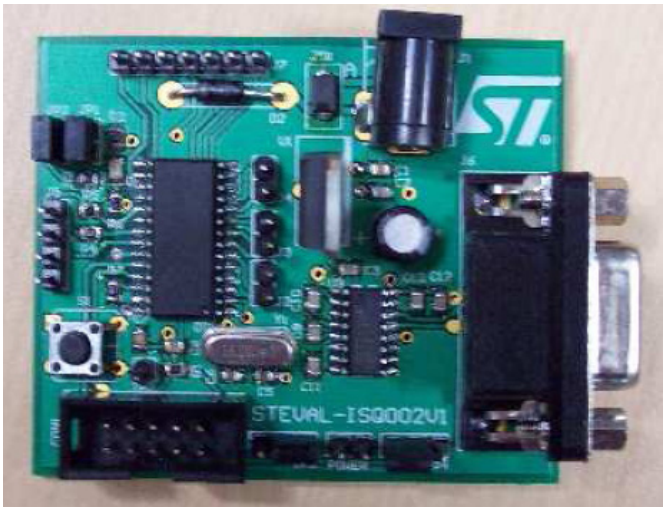
Table 43. Bill of material (continued)

Reference	Value / generic part number	Package	Manufacturer	Manufacturer's ordering code / orderable part number	Supplier
MCU U2	ST72F264G1M6	SOL-28	STMicroelectronics	ST72F264G1M6	
RS232 level translator: U3	ST3232CTR	SO-16	STMicroelectronics	ST3232CTR	
Switch S1	TACT SWITCH	PUSH-4	Any		
Diode: D2	1N5817	DO41	STMicroelectronics		
ZENER diode: ZD1	SMAJ	TO220	STMicroelectronics		

7.3 Demonstration board photo

The following figure shows the picture of the demonstration board.

Figure 29. STEVAL-ISQ002V1

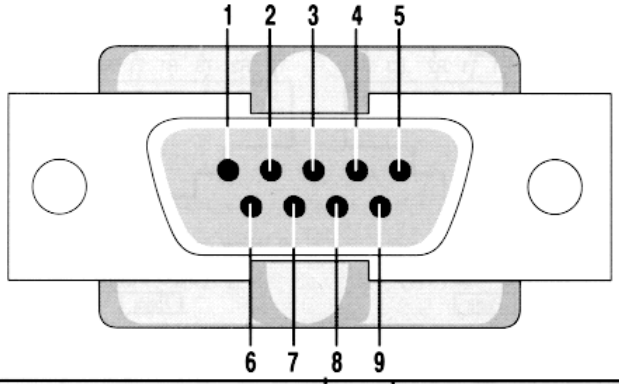


Appendix A Configuration

A.1 RS232 configuration

The following figure shows the pin description of the RS232 D9 connector.

Figure 30. Pin description of RS232 D9 connector



Pin	Signal	Pin	Signal
1	Data Carrier Detect	6	Data Set Ready
2	Received Data	7	Request to Send
3	Transmitted Data	8	Clear to Send
4	Data Terminal Ready	9	Ring Indicator
5	Signal Ground		

Revision history

Table 44. Document revision history

Date	Revision	Changes
17-Apr-2007	1	Initial release.
25-Aug-2010	2	– Modified: *Figure 9*, *10*, *16*, *17*, *18*, *19*, *20*, *23*, *24*, *25*, *26*, *29*, *Table 43* – Added: *Figure 27*, *28* – Minor text changes