

The Windows Serial Port Programming Handbook

Ying Bai



Table of Contents

About the Author	xv
Acknowledgments	xvii

Chapter 1

The Fundamentals of Serial Port Communications	1
1.1 Introduction.....	1
1.2 Why Serial Port Communications Are Necessary.....	2
1.3 What Is Serial Port Communication?	3
1.3.1 RS-232	3
1.3.2 RS-422	3
1.3.3 RS-485	4
1.3.4 Universal Serial Bus (USB)	5
1.3.5 Controller Area Network (CAN).....	6
1.3.5.1 CAN Standard Frame.....	8
1.3.5.2 CAN Extended Frame.....	8
1.3.5.3 Detecting and Signaling Errors.....	8
1.3.6 Firewire.....	9
1.4 Serial Port Communication Protocols.....	11
1.4.1 ASCII Code	11
1.4.2 DTE and DCE	12
1.4.3 Serial Data Format in TTL.....	12
1.4.4 Serial Data Format in Transmission Lines	14
1.4.5 Baud Rate	15
1.4.6 Parity.....	15
1.4.7 Serial Signal Handshaking and the Physical Connector	16
1.4.7.1 DB-9 Connector	18
1.4.7.2 DB-25 Connector	21
1.4.8 Serial Signal Timing.....	23
1.5 Serial Port Cabling	24
1.5.1 PC-to-Modem Cabling	24
1.5.2 Null Modem Cabling.....	25
1.6 The Universal Asynchronous Receiver Transmitter (UART).....	26
1.6.1 Two Types of UARTs.....	28
1.6.2 UART Model Numbers	30
1.6.3 The UART Transmitter.....	30
1.6.4 The UART Receiver	32
1.6.5 Addressing the UART	33
1.6.6 The 8250 UART	33
1.6.6.1 8250 Architecture	34
1.6.6.2 8250 Internal Registers	35
1.6.6.3 8250 Register Functionality.....	37
1.6.7 The 8250 UART Interrupt Operations	45
1.6.8 The 16550 UART	50
1.6.8.1 The Receiver Buffer Register (RBR)	50

1.6.8.2	The FIFO Control Register (FCR)	51
1.6.8.3	The Line Status Register (LSR)	51
1.7	Modems and Flow Control	52
1.7.1	Modem and Modem Control.....	52
1.7.1.1	Internal Modem and External Modem	54
1.7.1.2	Modulation and Demodulation	54
1.7.1.3	Amplitude Modulation	54
1.7.1.4	Frequency Modulation	55
1.7.1.5	Phase Modulation.....	55
1.7.1.6	Other Modulations	56
1.7.1.7	Modem Control	57
1.7.2	Flow Control and File Transfer Control	57
1.7.2.1	Hardware Flow Control	57
1.7.2.2	Software Flow Control.....	58
1.7.2.3	File Transfer Control.....	59
1.7.2.4	The XMODEM Protocol	59
1.7.2.5	The XMODEM-CRC Protocol	61
1.7.2.6	The XMODEM-1K Protocol	62
1.7.2.7	The YMODEM Protocol.....	63
1.7.2.8	The YMODEM-G Protocol.....	64
1.7.2.9	The ZMODEM Protocol.....	64
1.7.2.10	The Kermit Protocol	65
1.8	Serial Communication Errors and Error Detection	67
1.8.1	Block Redundancy—Checksum.....	67
1.8.2	The Classical CRC Algorithm	68
1.8.3	Variations of CRC	70
1.9	Serial Communications with the RS-422 and RS-485	70
1.9.1	Basics of the RS-422 Standard	72
1.9.2	Basics of the RS-485 Standard	73
1.9.3	The Operational Principle of the RS-485.....	73

Chapter2

Serial Port Programming for MS-DOS in ANSI C and Assembly Languages.....89

2.1	Introduction	89
2.1.1	Virtual Machines	89
2.1.2	MS-DOS-Compatible ANSI C Programming.....	89
2.2	A Loopback Serial Port Testing Program Developed in ANSI C.....	91
2.2.1	A Loopback Testing Program Developed in C.....	92
2.2.1.1	The _outp() and _inp() Functions.....	92
2.2.1.2	The Detailed Program Code	92
2.3	Embedding Assembly Code into C Programming.....	95
2.3.1	Inline Assembly Code	96
2.3.2	The _asm Keyword	97
2.3.3	Using C/C++ in _asm Blocks	98
2.3.4	Using Operators and Symbols in _asm Blocks	98
2.3.5	Accessing C/C++ Data in _asm Blocks	99
2.3.6	Using and Preserving Registers in Inline Assembly Code.....	100
2.3.7	Jumping to Labels in _asm Blocks.....	100
2.3.8	Calling C/C++ Functions in _asm Blocks.....	100
2.3.9	Defining _asm Blocks as C Macros.....	102

2.3.10	Embedding Inline Assembly Code Within C Code.....	103
2.4	A Serial Port Communication Program Developed in ANSI C.....	112
2.4.1	The Serial Port Communication Program on the Master Side	114
2.4.2	The Serial Port Communication Program on the Slave Side.....	125
2.4.3	Testing the Serial Port Communication Program Using Two Computers	132
2.5	A Serial Port Communication Program Developed in ANSI C and Inline Assembly Code.....	136
2.5.1	Embedding Inline Assembly Code with the Master and the Slave Computers.....	137
2.6	An Interrupt-Driven Serial Communications Program.....	139
2.6.1	The Interrupt Mechanism of the 8250 and 16550 UARTs	140
2.6.2	A Sample Interrupt Program.....	141
2.7	Programming the Interface Between PCs and A/D Converters	145
2.7.1	An Eight-Bit A/D Serial Interface Developed in ANSI C	146
2.7.1.1	The TLC548 Analog-to-Digital Converter	146
2.7.1.2	The TLC548 Serial Interface Program.....	148
2.7.2	An Eight-Bit A/D Serial Interface Developed in ANSI C and Inline Assembly Code	154
2.7.3	A 12-Bit A/D Serial Interface Developed in ANSI C	160
2.7.3.1	The MAX187—12-Bit Serial A/D Converter	160
2.7.3.2	The MAX220—Multichannel RS-232 Drivers and Receivers	162
2.7.3.3	The 12-Bit Serial A/D Converter Interface Circuit.....	163
2.7.3.4	The 12-Bit Serial A/D Converter Interface Program	165
2.7.4	A 12-Bit A/D Serial Interface Developed in C and Inline Assembly Code	173
2.8	Chapter Summary.....	180

Chapter 3

Serial-Port Interfaces Developed in VC++ 6.0		183
3.1	Introduction.....	183
3.1.1	Configuring a Serial Port	184
3.1.2	Writing Data to the Serial Port.....	186
3.1.3	Reading Data from the Serial Port.....	187
3.2	A Single-Loop Serial Port Communication Test in C/C++	190
3.2.1	Hardware Installation	190
3.2.2	Developing a Console Application Testing Program.....	190
3.2.3	A Serial Port Application in Visual C++	205
3.2.3.1	Developing the Document Class.....	209
3.2.3.2	Developing the View Class.....	212
3.2.3.3	Developing the Dialog Box Classes	220
3.3	A Double-Loop Serial Port Test in Visual C++	243
3.3.1	Hardware Connection.....	243
3.3.2	A Console-Based Double-Loop Serial-Port-Testing Project	245
3.3.3	A Double-Loop Serial-Port-Testing Project Using MFC	260
3.4	RS-485 Serial Port Communication.....	288
3.4.1	Overview.....	288
3.4.2	An RS-485 Application for Real-Time Control	289
3.4.2.1	Installing and Setting Up the NI-485	290
3.4.2.2	NI-485 Serial Port Setup and Installation	291
3.4.2.3	Software Implementation with the NI-485.....	293
3.5	Chapter Summary.....	293

Chapter 4

Serial Port Programming in Visual BASIC	295
4.1 Introduction.....	295
4.2 Calling Windows API Functions to Interface The Serial Ports.....	297
4.2.1 Windows API Functions.....	297
4.2.1.1 Mapping to a Subroutine	300
4.2.1.2 Mapping to a Function.....	301
4.2.2 The API Viewer	301
4.2.3 The API Functions, Structures and Constants in Serial Communications.....	304
4.2.3.1 Nonoverlapped I/O	305
4.2.3.2 Overlapped I/O	306
4.2.4 A Visual Basic Program Using Win32 API Functions.....	307
4.2.4.1 Developing Two Graphical User Interfaces.....	309
4.2.4.2 Adding Win32 API Functions to the VBAPISerial Project	312
4.2.4.3 Developing the Setup Form	316
4.2.4.4 Developing the frmSerial Form.....	318
4.2.5 Testing and Running the VBAPISerial Project.....	328
4.3 Using the Active-X MSComm Control to Interface with the Serial Ports	331
4.3.1 Overview of the Active-X MSComm Control.....	331
4.3.1.1 Configuration Properties for the MSComm Control	332
4.3.1.2 Data Transfer Properties for the MSComm Control	333
4.3.1.3 Handshaking Properties for the MSComm Control.....	333
4.3.1.4 Identification Properties for the MSComm Control.....	335
4.3.1.5 The Operation of the MSComm Control	335
4.3.2 A Serial Port Communication Program Developed with MSComm	337
4.3.2.1 The Serial Interface Program for the Master Computer	338
4.3.2.2 The Serial Interface Program for the Slave Computer	360
4.3.3 A Serial Interface for the File Flow Control Between Two Computers.....	376
4.3.3.1 The File Transfer Program for the Master Computer	376
4.3.3.2 The File Transfer Program for the Slave Computer	398
4.3.4 Developing a Serial Interface For the TLC548 8-Bit A/D Converter.....	411
4.3.4.1 The Interface Circuit of the 8-Bit Serial A/D Converter	411
4.3.4.2 The Interface Program Design.....	412
4.3.4.3 Implementation of the Serial Interface for the 8-Bit Serial A/D Converter.....	425
4.3.5 Developing a Serial Interface for the MAX187 12-Bit A/D Converter.....	427
4.3.5.1 The Interface Circuit of the MAX-187 A/D Converter	428
4.3.5.2 Designing the Graphical User Interfaces.....	429
4.3.5.3 Coding the Project	430
4.3.5.4 Implementation of the Serial Interface for a 12-Bit Serial A/D Converter.....	442
4.4 Calling Dynamic Link Library to Interface with the Serial Ports	444
4.4.1 Review of the DLL.....	444
4.4.2 General Requirement for Calling a User-Defined DLL	445
4.4.3 An Example of Calling DLL to Interface the Serial Port.....	446
4.4.3.1 Configuring the Hardware for the Loop-Back Test	447
4.4.3.2 Developing a Dynamic Link Library in Visual C++	447
4.4.3.3 Developing a Visual Basic Testing Project.....	460
4.5 Chapter Summary	472

Chapter 5

Serial Port Programming in LabVIEW	475
5.1 Introduction.....	475
5.2 A Basic Serial Port Interface for Writing and Reading Data	475
5.2.1 Designing the Front Panel for the Loopback Testing Program.....	476
5.2.2 Designing a Block Diagram for the Loopback Testing Program.....	477
5.2.3 Running and Testing the Loopback Testing Program	480
5.3 Advanced Serial Port Interfaces.....	481
5.3.1 Using VISA to Interface with an 8-Bit Serial A/D Converter, TLC548.....	481
5.3.1.1 Designing a Front Panel for the Main Program.....	483
5.3.1.2 Develop a Block Diagram for the Main Program.....	485
5.3.1.3 Designing a Front Panel for the Data Collection SubVI.....	488
5.3.1.4 Developing a Block Diagram for the Data Collection SubVI.....	490
5.3.1.5 Testing and Running the Project	497
5.3.2 Using VISA to Interface with an 12-Bit Serial A/D Converter MAX187.....	499
5.3.2.1 Designing a Front Panel for the Main Program.....	501
5.3.2.2 Developing a Block Diagram for the Main Program.....	502
5.3.2.3 Designing a Front Panel for the GetMAXData SubVI	505
5.3.2.4 Developing a Block Diagram for the GetMAXData SubVI	507
5.3.2.5 Configuring the GetMAXData VI as a SubVI.....	514
5.3.2.6 Testing and Running the Project	515
5.4 Calling the DLL from LabVIEW to Interface with the Serial Port.....	517
5.4.1 Using Call Library Function and the Code Interface Node.....	517
5.4.2 Using the Call Library Function to Access DLLs.....	517
5.4.2.1 The Calling Conventions	519
5.4.2.2 The Calling Parameters.....	520
5.4.2.3 Calling Functions That Expect Other Data Types	521
5.4.2.4 The Create .c File.....	522
5.4.2.5 Multiple Calls to the Shared DLL Function	522
5.4.3 Using the Call Library Function to Interface with the TLC548 Serial A/D Converter.....	523
5.4.3.1 Interface Circuit of the TLC548 Serial A/D Converter	523
5.4.3.2 Building the Function Protocol in LabVIEW	524
5.4.3.3 Building the Block Diagram in LabVIEW	528
5.4.3.4 Building DLL Functions in Visual C++.....	530
5.5 Calling the CIN from LabVIEW to Interface with the Serial Port.....	547
5.5.1 The Calling Procedure of the CIN.....	548
5.5.1.1 Creating a CIN.....	548
5.5.1.2 Creating a .c File.....	550
5.5.1.3 Using the Visual C++ IDE to Compile the CIN Source Code.....	551
5.5.1.4 Loading the CIN Object Code.....	552
5.5.2 Using CIN to Interface with a Serial A/D Converter.....	552
5.5.2.1 The Hardware Interface Circuit.....	552
5.5.2.2 Designing of a Front Panel for the Project	553
5.5.2.3 Using CIN to Develop a Block Diagram	553
5.5.2.4 Using the Visual C++ 6.0 IDE to Develop the CIN Object Code.....	559
5.5.2.5 Loading the CIN Object Code and Running the Project.....	582
5.6 Other Methods for Interfacing with the Serial Port	585

Chapter 6

Serial Port Programming in MATLAB.....	587
6.1 Introduction.....	587
6.2 Using MEX-files to Interface with Serial Ports	587
6.2.1 The MEX-File Format.....	588
6.2.2 System Setup and Configuration.....	589
6.2.2.1 Select a Compiler.....	589
6.2.3 The Ingredients of a MEX-file.....	591
6.2.3.1 Header File mex.h.....	591
6.2.3.2 The mxArray	591
6.2.3.3 Using the Gateway Function mexFunction in C/C++	592
6.2.3.4 API Functions	595
6.2.4 Creating a MEX-file in C/C++	596
6.2.5 Using a MEX-file to Interface with the MAX187 ADC.....	597
6.2.5.1 Configuring the C/C++ MEX-file.....	599
6.2.5.2 Designing the Header File for the MEX-file	600
6.2.5.3 Designing the DEF File	603
6.2.5.4 Designing the Source File of the MEX-file	603
6.2.5.5 Compiling and Building the Target MEX-file.....	617
6.2.5.6 The Design of the MATLAB M-Function	618
6.2.5.7 Testing and Running the Project	619
6.2.6 Creating a MEX-file to Interface with the TLC548 ADC	621
6.3 Using the Shared DLL to Interface with the Serial Ports.....	622
6.3.1 Installing the Loadlibrary Interface.....	622
6.3.2 Loading and Unloading the Shared Library	624
6.3.3 Obtaining Information from the Library.....	624
6.3.4 Calling Library Functions and Passing Arguments.....	625
6.3.5 Converting Data Between MATLAB and External Functions.....	626
6.3.5.1 Primitive Data Types.....	627
6.3.5.2 Converting Data to Other Primitive Data Types	627
6.3.5.3 Converting Data to References	628
6.3.5.4 Converting to Strings	628
6.3.5.5 Converting and Passing Structures	629
6.3.5.6 Creating References	631
6.3.5.7 Creating a Structure Reference.....	633
6.3.5.8 Creating Reference Pointers	634
6.3.6 Calling a Shared DLL	635
6.3.6.1 Developing a Standard Win32 Dynamic Link Library	635
6.3.6.2 Developing a MATLAB M-Function to Call the DLL.....	638
6.3.6.3 Testing and Running the DLL Project	645
6.4 Using the Serial Object to Interface with the Serial Ports.....	647
6.4.1 The Instrument Control Toolbox.....	647
6.4.2 Creating and Configuring a Serial Port Object	648
6.4.3 Writing and Reading the Serial Port Object.....	649
6.4.4 Event and Callback Functions.....	650
6.4.4.1 The BytesAvailable Event and Its Callback Function BytesAvailableFcn.....	651
6.4.4.2 The Output Empty Event and Its Callback Function OutputEmptyFcn	651
6.4.4.3 The PinStatus Event and Its Callback Function PinStatusFcn ..	651

6.4.4.4	The Timer Event and Its Callback Function <code>TimerFcn</code>	652
6.4.4.5	The Break Interrupt Event and Its Callback Function <code>BreakProcess()</code>	652
6.4.5	Using the Serial Port Object to Perform Data Transmission	652
6.4.5.1	Using the Graphical Tool to Create and Configure a Serial Port	652
6.4.5.2	Developing a User-Defined Callback Function.....	656
6.4.5.3	Developing the Main Serial Port Interface Program.....	656
6.4.5.4	Testing and Running the Main Serial Port Interface Program	658

Chapter 7

Serial Port Programming in Smalltalk.....		659
7.1	Introduction.....	659
7.2	Overview of VisualWorks.....	659
7.2.1	The VisualWorks Application Framework	660
7.2.2	Installing and Starting VisualWorks.....	661
7.3	A Simple Serial Port Interface Program	664
7.3.1	Serial Port Testing Configuration.....	664
7.3.2	Developing a Domain Model Class	665
7.3.3	Developing an Application Model Class and a GUI.....	668
7.3.4	Developing an External Interface Class.....	669
7.3.5	Finish Coding of the <code>SerialPort</code> Project in VisualWorks.....	674
7.3.5.1	Code for the Application Model.....	675
7.3.5.2	Code for the Domain Model.....	677
7.3.6	Parceling and Filing Out the Project Files	680
7.3.7	Develop a Dynamic Link Library in the Visual C++ Domain.....	681
7.3.7.1	Creating the Header File for the DLL.....	681
7.3.7.2	Developing the Source File for the DLL	681
7.3.7.3	Developing the Definition File for the DLL	690
7.3.8	Finishing Coding of the <code>SerialPort</code> Project in VisualWorks.....	691
7.4	An Advanced Serial Port Interface Program	694
7.4.1	The Interface Circuit	695
7.4.2	Developing the Dynamic Link Library.....	696
7.4.2.1	The Header File for the DLL	696
7.4.2.2	Code for the Source Files of the DLL	698
7.4.2.3	Developing the Definition File for the DLL	707
7.4.2.4	Building and Installing the DLL Target File.....	708
7.4.3	Developing a Domain Model Class	708
7.4.4	Developing an Application Model Class and a GUI.....	712
7.4.5	Developing an External Interface Class.....	715
7.4.6	Finish Coding of the <code>SmallMAXDLL</code> Project in VisualWorks	719
7.4.6.1	Code of the Application Model Class	719
7.4.6.2	Code for the Domain Model Class.....	721
7.4.7	Testing and Running the Project.....	724
7.4.8	Parceling and Filing Out the Project Files	726

Chapter 8

Serial Port Programming in Java.....		729
8.1	Introduction.....	729
8.2	Overview of the Java Native Interface.....	729

8.2.1	Why We Need an Interface Between Java and the Native Code	729
8.2.2	The JNI Development Environment	730
8.2.3	How to Develop an InterFACE	731
8.3	A Simple Serial Port Testing Program Using the JNI	732
8.3.1	Setting Up the Java Development Environment in Windows 95/98/Me.....	732
8.3.2	Setting Up the Java Development Environment in Windows 2000	733
8.3.3	Setting Up the Java Development Environment in Windows XP	734
8.3.4	Setting Up the Hardware for the Single-Port Loopback Test	734
8.3.5	The Operation of the Interface Program.....	735
8.3.6	Developing a GUI in Java.....	736
8.3.7	Developing the Model Class File.....	741
8.3.8	Developing the Interface Class File.....	743
8.3.9	Developing the MSG Class File.....	745
8.3.10	Developing a JNI-Style Header File	746
8.3.11	Mapping Variables and Objects Between Java and C/C++.....	747
8.3.11.1	Mapping String Variables.....	749
8.3.11.2	Mapping Array Variables	751
8.3.12	Developing a Dynamic Link Library as the Native Library.....	754
8.3.12.1	Developing the Header File	755
8.3.12.2	Developing the Source File	757
8.3.13	Building and Installing the Native Library.....	766
8.3.14	Running and Testing the Project.....	767
8.4	An Advanced Interface Between the Serial A/D and Java.....	769
8.4.1	Developing the View Class—Java GUI Window	770
8.4.2	Developing the Model Class	773
8.4.3	Developing the Interface Class	775
8.4.4	Creating a JNI-Style Header File.....	775
8.4.5	Developing the Native Library (the DLL Target File)	777
8.4.5.1	Developing the DLL Header File	778
8.4.5.2	Developing the DLL Source File	778
8.4.6	Building and Installing the DLL Target File	789
8.4.7	Testing and Running the MAX187 Project	790
8.5	Chapter Summary.....	792
Appendix		795
Index.....		797