User's Manual

R-IN32M3 Series

User's Manual: Modbus stack

- R-IN32M3-EC
- R-IN32M3-CL

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Instructions for the use of product

In this section, the precautions are described for over whole of CMOS device.
Please refer to this manual about individual precaution.
When there is a mention unlike the text of this manual, a mention of the text takes first priority

1. Handling of Unused Pins

Handle unused pins in accord 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 LSI, associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible. Unused pins should be handled as described under Handling of Unused Pins in the manual.

2. Processing at Power-on

The state of the product is undefined at the moment 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 moment 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 moment 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 moment when power is supplied until the power reaches the level at which resetting has been specified.

3. Prohibition of Access to Reserved Addresses

Access to reserved addresses is prohibited.

- The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.

4. Clock Signals

After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has 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. Moreover, 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.

How to use this manual

Purpose and target readers

This manual is intended for users who wish to understand the functions of Industrial Ethernet network LSI "R-IN32M3-EC/CL" for designing application of it.

It is assumed that the reader of this manual has general knowledge in the fields of electrical engineering, logic circuits, and microcontrollers.

Particular attention should be paid to the precautionary notes when using the manual. These notes occur within the body of the text, at the end of each section, and in the Usage Notes section.

The revision history summarizes the locations of revisions and additions. It does not list all revisions. Refer to the text of the manual for details.
The mark "<R>" means the updated point in this revision. The mark "<R>" let users search for the updated point in this document.

Related Documents

The related documents indicated in this publication may include preliminary versions. However, preliminary versions are not marked as such. Please be understanding of this beforehand. In addition, because we make document at development, planning of each core, the related document may be the document for individual customers. Last four digits of document number(described as ****) indicate version information of each document. Please download the latest document from our web site and refer to it.

The document related to R-IN32M3 Series

Document name	Document number
R-IN32M3 Series Datasheet	R18DS0008EJ****
R-IN32M3-EC User's Manual	R18UZ0003EJ****
R-IN32M3-CL User's Manual	R18UZ0005EJ****
R-IN32M3 Series User's Manual Peripheral function	R18UZ0007EJ****
R-IN32M3 Series Programming Manual (Driver edition)	R18UZ0009EJ****
R-IN32M3 Series Programming Manual (OS edition)	R18UZ0011EJ****
R-IN32M3 Series User's Manual TCP/IP stack	R18UZ0019EJ****
R-IN32M3 Series User's Manual Modbus stack	This Manual

Notation of Numbers and Symbols

Weight in data notation : Left is high-order column, right is low-order column

Active low notation:

xxxZ (capital letter Z after pin name or signal name)

or xxx_N (capital letter _N after pin name or signal name)

or xxnx (pin name or signal name contains small letter n)

Note:

explanation of (Note) in the text

Caution:

Item deserving extra attention

Remark:

Supplementary explanation to the text

Numeric notation:

Binary ⋯ xxxx , xxxxB or n'bxxxx (n bits)

Decimal ⋯ xxxx

Hexadecimal ⋯ xxxxH or n'hxxxx (n bits)

Prefixes representing powers of 2 (address space, memory capacity):

K (kilo)⋯ $2^{10} = 1024$

M (mega)⋯ $2^{20} = 1024^2$

G (giga)⋯ $2^{30} = 1024^3$

Data Type:

Word ⋯ 32 bits

Halfword ⋯ 16 bits

Byte ⋯ 8 bits

Contents

1. Overview

This document explains Modbus protocol stacks for R-IN32M3 series. In here, Modbus protocol is meant as Modbus TCP which is an Ethernet based protocol and Modbus RTU, and Modbus ASCII protocol, which is based on serial communication like as RS-485, RS-232C, and RS-422.

This document is intended to be read by users who are developing a Modbus application using the R-IN32M3 Modbus protocol stack. This document will thus serve as a guide in implementing a Modbus application using the R-IN32M3 Modbus protocol stack. So the function summary and Application Programming Interface (API) and application samples of Modbus protocol stack are described in this document.

1.1 Features

R-IN32M3 Modbus protocol stack allows fast and easy development of the following applications.

- Modbus RTU slave
- Modbus ASCII slave
- Modbus RTU master
- Modbus ASCII master
- Modbus TCP server
- Modbus TCP gateway

Supported classes and function codes are followings.

- Support of the Modbus conformance classes 0, 1 and part of class 2
- Supported function codes:
  - Read Coils (FC 1)
  - Read Discrete Inputs (FC 2)
  - Read Holding Registers (FC 3)
  - Read Input Registers (FC 4)
  - Write Single Coil (FC 5)
  - Write Single Register (FC 6)
  - Write Multiple Coils (FC 15)
  - Write Multiple Registers (FC 16)
  - Read/Write Multiple Registers (FC 23)

1.2 Sample soft's varieties

User can use the 2 types of sample software of Modbus stack, named "limited version" and "official version".

For both, the contents and supported level are same. The differences are mainly binarization of code and some restrictions for setting.

The following is the overview of the difference between "limited version" and "official version".

Table 1.1 Difference for version

Items	Limited version	Official version
Supported protocol	Supported Modbus TCP server , RTU/ASCII master, or slave	
Function	- For TCP, gateway Since based on TCP/IP "evaluation version", There are some restriction (e.g. Protocol stack configurations) Note1 - For RTU/ASCII No difference functionally	- For TCP, gateway Since based on TCP/IP "commercial version", there are no restriction. - For RTU/ASCII No difference functionally
Code binarization	Core part of Modbus stack is object code. And TCP/IP, UDP/IP part is same as evaluation version of TCP/IP stack from Renesas.	Source code except for the core of TCP/IP, UDP/IP part.
How to get	Download from Renesas's website Note2	Please contact to Renesas.

Note1 The detail is written in the chapter 1 of User's manual TCP/IP stack.

Note2 Limited version is available to download from the following site.
http://www.renesas.com/products/soc/assp/fa_lsi/multi_protocol_communication/r-in32m3/peer/sample_software.jsp

The limited version is suitable for initial evaluation and realizes easy to touch, but for mass production, please ask to get the official version.

1.3 Development environment

The development environment of Modbus protocol stack is described here.

1.3.1 Development tools

Development tools for this stack are shown in Table 1.2.

Table 1.2 Development tools

Tool Chain	IDE	Compiler	Debugger	ICE
ARM	-	RealView Developer Suite V4.1 (ARM)	microVIEW-PLUS Ver.5.11PL3 (Yokogawa Digital Computer Corporation)	adviceLUNA 2.03-00 (Yokogawa Digital Computer Corporation)
GNU	-	Sourcery G++ Lite 2012.09-63 (Mentor Graphics)	microVIEW-PLUS Ver.5.11PL3 (Yokogawa Digital Computer Corporation)	adviceLUNA 2.03-00 (Yokogawa Digital Computer Corporation)
KEIL	MDK-ARM (KEIL)	MDK-ARM (KEIL)	MDK-ARM (KEIL)	ULINK (KEIL)
IAR	Embedded Workbench for ARM V7.30.1 (IAR Systems)	Embedded Workbench for ARM V7.30.1 (IAR Systems)	Embedded Workbench for ARM V7.30.1 (IAR Systems)	i-Jet JTAGjet-Trace-CM (IAR Systems)

1.3.2 Evaluation board

Modbus stack sample application can be worked on the following evaluation boards for R-IN32M3. Regarding a more information for each evaluation boards, please look Renesas or IAR or TESSERA TECHNOLOGY INC.s' web site.

[Supported evaluation board]

- Modbus TCP protocol
  - TS-R-IN32M3-EC : by TESSERA TECHNOLOGY INC.
  - TS-R-IN32M3-CL : by TESSERA TECHNOLOGY INC.
  - TS-R-IN32M3-CEC : by TESSERA TECHNOLOGY INC.
  - KSK-RIN32M3EC-LT-IL : by IAR KickStart kit by IAR AB.

- Modbus RTU/ASCII protocol
  - TS-R-IN32M3-EC : by TESSERA TECHNOLOGY INC.
  - TS-R-IN32M3-CL : by TESSERA TECHNOLOGY INC.
  - TS-R-IN32M3-CEC : by TESSERA TECHNOLOGY INC.

Caution For RS-485 communication with Modbus RTU/ASCII protocol, user should prepare the RS485 transceiver IC or module, and connect related signal as follows.
P20 (RXD0) : to TX, P21 (TXD0) : to RX, RP17(GPIO) : to DE(/RE)

For Modbus RTU/ASCII communication, the example of hardware connection is described in Chapter 7. Please refer its chapter.

1.4 Resource Requirements

- The hardware RTOS must be available to run the stack.
- The code running along with the Modbus Serial Stacks must not use the one timer channel, as it is used by the stack for packet timing. If user wants to assign some other timer channel for the stack it has to be done by the stack initialization.
- The stack uses one channel the UART in the Modbus serial communications. If the user wants to change the UART channel it has to be done by the stack initialization.
- The user has to assign a GPIO Pin for controlling the RS485 transceiver and it must be available to the stack. It has to be done by the stack initialization.

1.5 Networking Aspects

- The Modbus Serial stack can communicate over standard RS485 networks.
- The Modbus TCP Stack is capable of communicating over standard Ethernet networks.

1.6 Concurrency Issues

- The stack uses a UART channel, a timer channel and a GPIO pin of the chip while running in serial mode. These interfaces will not be available to other programs when the stack is running.
- The stack consumes some capabilities of the hardware RTOS.
- If the stack is running in the Slave mode, the user has to ensure the proper handshaking of the stack and the task that updates the Modbus application objects.
  - In Slave mode, the user has to write the function for accessing the Modbus objects and map it to the Modbus function codes by using the function ‘Modbus_slave_map_init()’.
  - While writing the function the user has to ensure that two or more tasks will not access the memory at a time.

2. Basic concepts of R-IN32M3 Modbus stack

2.1 Supported Protocol standards

This stack has got the capability to address the requirements of both Modbus Master/Client and Modbus Slave/Server. Along with these the stack has got the capability to communicate with Modbus RTU, Modbus ASCII and Modbus TCP networks. But it doesn't have the capability to function as a Modbus TCP Client stack.

Based on the different modes, the stack can be considered as the composition of the following six stacks,

- Modbus RTU Master Stack.
- Modbus RTU Slave Stack.
- Modbus ASCII Master Stack.
- Modbus ASCII Slave Stack.
- Modbus TCP Server Stack.
- Modbus TCP Server Gateway Stack

Provision is given to the user to select the stack mode in their project. Along with this, nine Modbus function codes are also supported in these stacks. Following are the function codes supported in these stacks,

- 1(0x01) – Read coils
- 2(0x02) – Read discrete input
- 3(0x03) – Read holding registers
- 4(0x04) – Read input registers
- 5(0x05) – Write single coil
- 6(0x06) – Write single register
- 15(0x0F) – Write multiple coils
- 16(0x10) – Write multiple registers
- 23(0x17) – Read/Write multiple registers

2.2 Design Methodology

1. Choose a necessary in order to implement functions on network, a protocol stack is a prescribed hierarchy of software layers. The following figure shows hiearachy in this stack.
2. This stack creates a task by using the capability of the hardware RTOS. The stack is to use in the multi threaded projects using the RTOS.
3. This stack must not use more than one timer channel for Modbus frame timing.

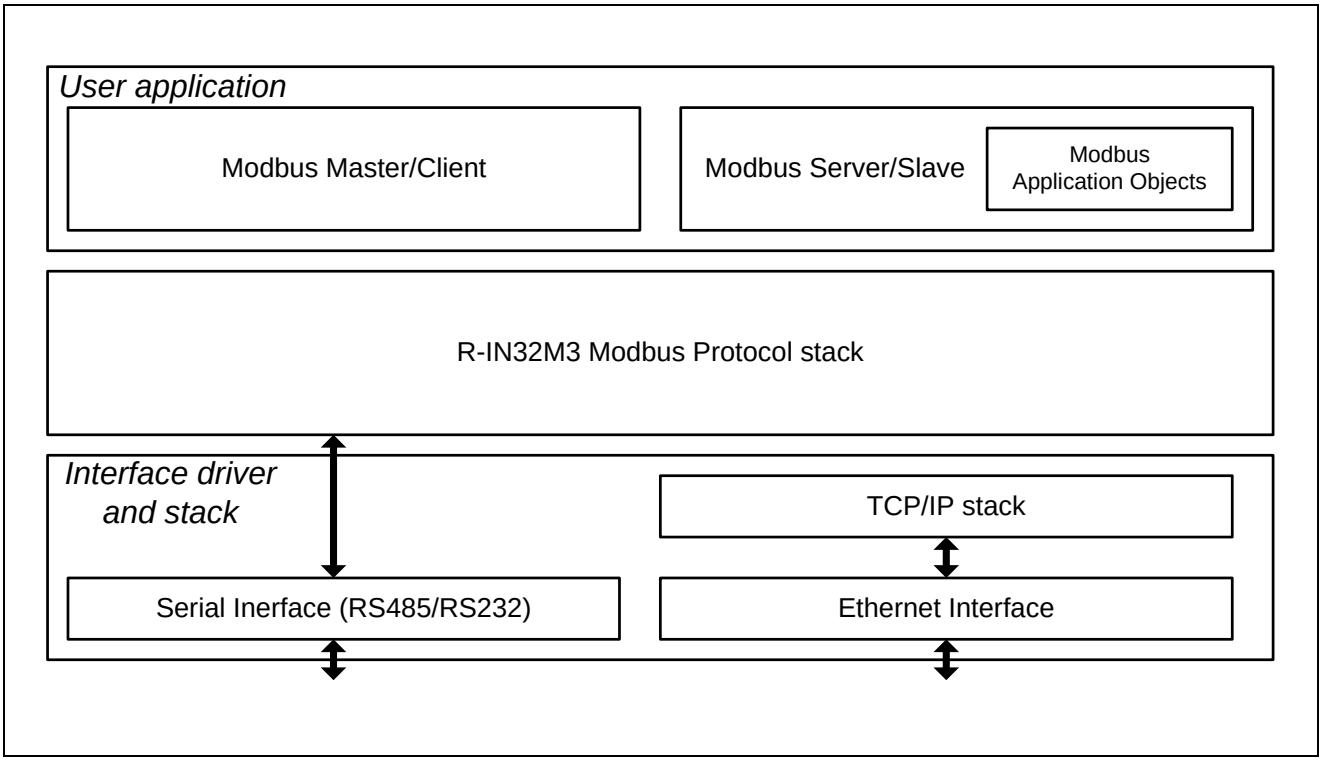


Figure 2.1 Overview of R-IN32M3 Modbus stack <R>

3. System Architecture – Modbus Serial Protocol Stacks

Figure 3.1 shows the overall architecture of the Modbus Protocol Stack. As shown in the diagram the stack is divided in to four functional layers.

The stack is designed in such a way that it can be used to realize both server/slave and client/master applications by setting the required configuration. The stack can be configured to support any one of Modbus RTU and Modbus ASCII modes at a time. For selecting the desired stack mode and client / server functions, initialization API is provided which the user can modify.

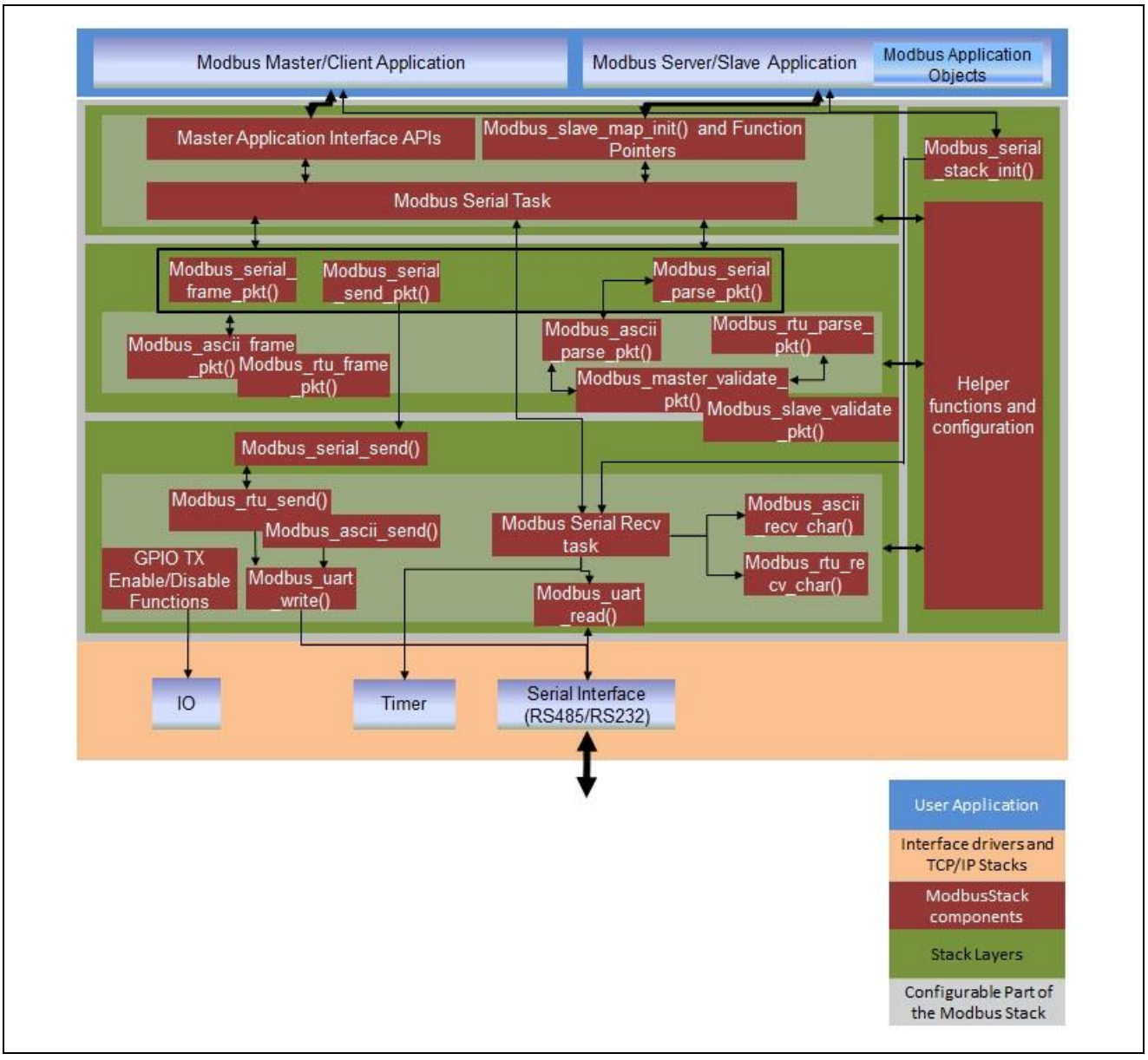


Figure 3.1 Modbus Stack Architecture <R>

Subsequent sections contain the information of the layered architecture.

3.1 Module Decomposition

Based on the functionality, the stack is divided in to the following layers

Application Interface Layer as the top layer, which directly interacts with the user application in both master and slave modes.

Packet Framing and Parsing Layer as the middle layer, this layer is responsible for framing, parsing and validating the Modbus frames.

Connection management, Frame Send and Receive Layer as the bottom layer, which manages the logical connections and sending and receiving of the Modbus frames.

Across these three layers lies the Configuration Layer, this is the layer which contains the necessary configuration APIs. Below sections detail the different layers and design of these layers.

3.1.1 Application Interface Layer

Application interface layer contains the necessary functions to interact with the user application. It also contains a thread that maintains the stack states. Based on the configured stack mode, either Master or Slave, the thread works in different ways and makes it possible to provide, to the user, the functionalities required in that mode. This layer of the stack is same for the communication modes RTU and ASCII.

The main ‘Application Interface Layer’ components, specific to the Modbus Server/Slave mode, are the Serial task and the Modbus_serial_slave_map_init() function. Using the Modbus_serial_slave_map_init() API, the user application registers the callback functions to be invoked when a valid Modbus request with a particular function code is received.

The parsing of the request message and framing the response are running in the context of the Serial task. When a valid Modbus request is received, the task will invoke the appropriate call back handler function. The task is designed such that the response is passed back to the master only on receiving the response from the callback handler.

Remark **The call back handler is user application provided and care must be taken to ensure that the function returns within a stipulated maximum interval. If the function does not return due to some error, there are chances that Modbus server will no longer be able to accept new commands.**

The main ‘Application Interface Layer’ components, specific to the Modbus Master/Client mode are the Serial task and the User Application Interface APIs. Serial task starts to run when the user initialized the stack, and the user application calls the interface API for Modbus transactions.

The user application calls User Application Interface APIs to request the stack to send Modbus requests to the Modbus slave devices. The Serial task receives the request and processes it.

Calls to these APIs can be blocking or non-blocking. If the user provided a call-back function in the arguments, the function call will be non-blocking and the serial task calls the user provided function on reception of a response or timeout occur. If the user didn’t provide a call-back function, these APIs block till receiving a replay from slave device or timeout occur.

3.1.1.1 Modbus Serial Task

A common task named serial task is used for both Modbus Master and Slave Stack irrespective of mode (RTU/ASCII). Depending on the configured stack mode, the task functions as either Master or Slave task.

For example, if the stack mode is defined as Modbus RTU Master, then the serial task will function as master task. This is done by switching between two states defined for Master and Slave.

The Figure 3.2 shows the state transition diagram of the Serial task functioning as slave. The function Modbus_serial_stack_init() initializes the Serial Task, on successful initialization the task waits for a message using a mailbox. Depending on the message type received in mailbox it functions either as Master or Slave. The task remains in that state till receiving a Modbus request from the Modbus Master when it functions as a Slave task.

On receiving a request from the client, the task does the following activities,

- Parse and validate the received packet.
- If successful verification of the packet integrity, frames a response packet and sends it to the master device.

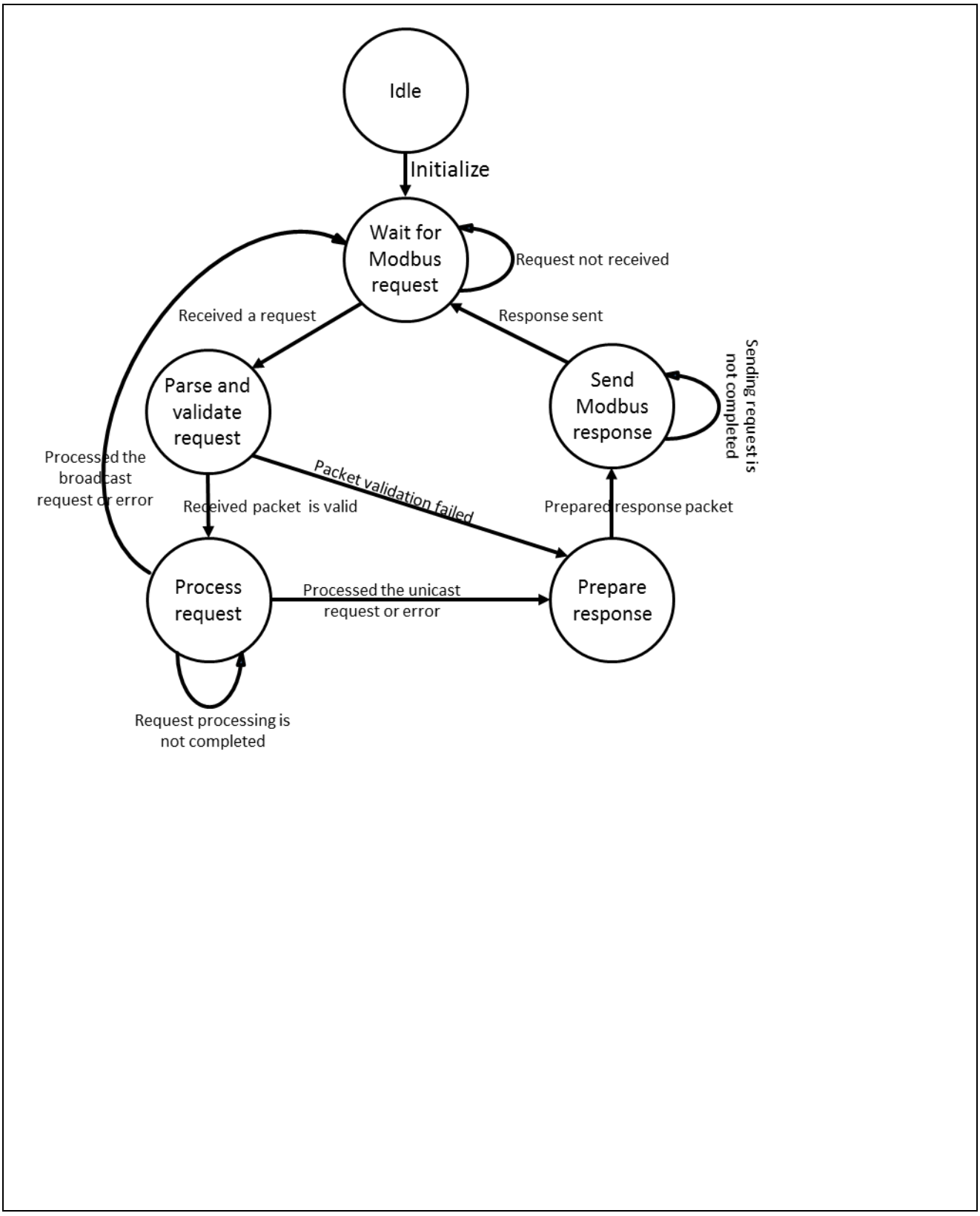


Figure 3.2 Functioning of Modbus Serial Task as Slave <R>

The Figure 3.3 Figure 3.2 shows the state transition diagram of the Serial task functioning as master. Modbus Serial Task starts running when the user initializes the stack by calling the function named ‘Modbus_serial_stack_init ()’. After initialization serial task will wait for the message. The user application calls the User Application Interface APIs, to request the serial task for Modbus transactions with the slave devices. When the task received a request, it does the following activities.

- Prepare a Modbus request packet and send it to the Modbus Slave device.
- If the request sent was a broadcast request, the task waits up to the ‘Turnaround Delay’ and start to wait for another request from the user.
- If the request sent was a unicast request, the task waits for a response from the slave device until 'Response Timeout' interval.
- If the task received a valid response from the slave device within the ‘Response timeout’ expires, it updates the received data to the user application.
- If the task didn’t receive a response within ‘Response Timeout’ interval, the task retries the same request up to a configured number of max retry counts.
- If the task didn’t receive a response to the retries also, then the task updates the user application with the timeout information.

The user application can provide a callback handler along with the function call if it requires notification when the command request processing is completed. In this case, the function call will not block and application developer can perform other tasks while the request is completed. If a callback function is not provided, the function call will be a blocking call.

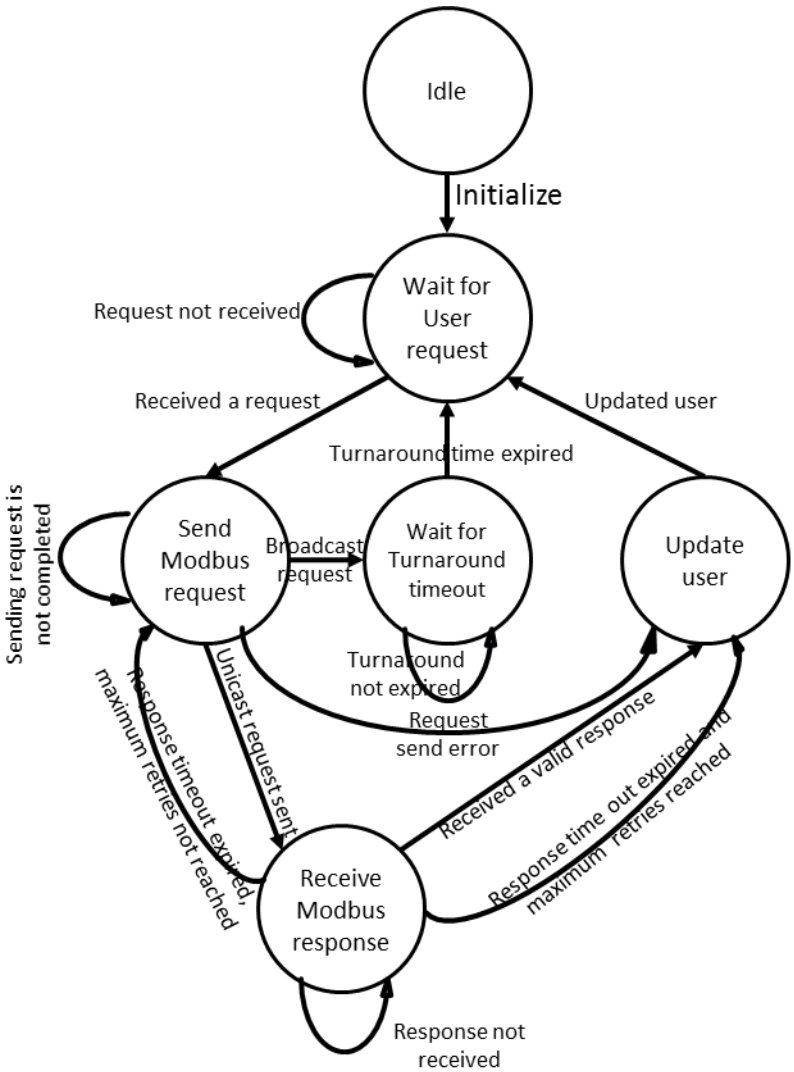


Figure 3.3 Functioning of Modbus Serial Task as Master <R>

3.1.1.2 Error identification and reporting

(1) Modbus RTU/ASCII Slave

- For unicast requests, the Serial task will generate an exception response and send it back to the Master, when received a request for a function code to which the user has not registered a callback function.
- The call-back function written by the user has to generate exceptions for the requests for registers or coils those are not implemented.
- The initialization API performs a basic level validation on the initialization parameters and returns the status, while initializing the stack.
- For broadcast requests, response will not be sent to client for all requests.

(2) Modbus RTU/ASCII Master

- The API functions will perform a basic level validation on the parameters given to it.
- The task returns timeout error if it doesn't receive a response to the request after a number of retries.
- Memory is allocated dynamically for packet construction. Error is reported if the memory can not be ensured.

3.1.2 Packet Framing and Parsing Layer

This is the stack layer which does the required packet framing and parsing activities. It contains functions and data structures for framing the Modbus packets, parsing the packet, sending packet, receiving packet, and validating the received packets. The implementation of these functions is different for Modbus RTU and Modbus ASCII modes, but functions of a particular communication mode are used in both Master and Slave modes. Also, since Modbus packet is processed internally in RTU format, it will be processed is converted to RTU format even in the case of ASCII mode.

(1) Parsing receive packet

- In the case of ASCII mode, perform the packet conversion from ASCII format to RTU format.
- If length check, packet integrity and slave ID checks fail, discards the received packet.
- After successful verification of the packet integrity, slave ID and the request data, invokes the user registered function to process the request.
- When received a unicast request, prepares an exception response and sends it to the master on failure of function code and request data validation.
- When received a broadcast request, the received packet is accepted as a normal packet if the write function code, but it does not send a response message to the master device. On the other, the received packet is if read function code, and discards the request packet as invalid slave ID.

(2) Framing send packet

In the case of master mode, the request packet will be constructed based on the content generated by the API. In the case of slave mode, the response packet will be constructed based on the content generated by the API. CRC / LRC will be added to constructed packet. In the case of ASCII mode, since the stack is processing internally in RTU format, converted to ASCII is done from the RTU.

3.1.2.1 Error Identification and Reporting

- Packet length and specified data and slave ID in the Receive and Transmit packets are verified whether they comply with the protocol based on the function code.
- Packet validation function verifies the integrity of the received packet using CRC/LRC filled in the packet.
- Memory is allocated dynamically for framing packet. Error is reported if the memory can not be ensured.

3.1.3 Connection management, Frame Send and Receive Layer

This is the layer which contains the functions and data structures for sending and receiving data through the communication interface. Management of frame timing in the case of serial interface comes in this layer.

3.1.3.1 Serial Receive Task

The serial receive task starts running when the Modbus Serial Stack is initialized. An event is being registered in the Hardware ISR table for UART and Timer interrupts. The serial receive task waits for the event flag to be set with the pattern defined in the hardware ISR.

If the UART interrupt occurred, each byte is read using the driver function uart_read(). After the successful reception of character, depending on the stack mode either Modbus_ascii_recv_char() or Modbus_rtu_recv_char() is invoked. The characters are stored in a buffer within these functions.

If the timer interrupt occurred, Modbus_timer_handler() is invoked. Determining the frame timing is done in this function.

3.1.3.2 Modbus Serial Interface Configuration

- In this mode, UART interface of the chip is configured to send and receive packets as per the configuration parameters provided while initializing the stack.
- If an error occurs during the reception operation, and has caused the interrupt event status. Please refer to the "User's Manual peripheral function edition" about reception error detail.
- A timer channel will be utilized to measure the inter character delay.
- The RS485 mode switching will be done by using a GPIO pin.

3.1.3.3 Error identification and reporting

If an error occurs during the reception, discard the received packet, and continues processing.

3.1.4 Stack Configuration and Management Module

This is the software module comes across the three layers of the stack. Macros and defines for stack and mode selection, time out selection, global variables, data structures and configuration APIs come under this block.

Sections below details the different components in this layer,

3.1.4.1 Error Codes

Along with the response, the error code is also mentioned to inform the user application about the command processing status. For this different error codes are generated while processing the request/response. Following are the different error codes used:

Table 3.1 Description for each error

ERR_OK	Specifies success code
ERR_ILLEGAL_FUNCTION	Specifies the function code received in the request is not an allowable action for the server (or slave) or the function code is not implemented. This value must be a constant, cannot change the value from 0x01.
ERR_ILLEGAL_DATA_ADDRESS	Specifies the data address received in the request is not an allowable address for the server (or slave) or the addressed register is not implemented. This value must be a constant, cannot change the value from 0x02
ERR_ILLEGAL_DATA_VALUE	Specifies a value contained in the request data field is not an allowable value for the server (or slave). This value must be a constant, cannot change the value from 0x03.
ERR_SLAVE_DEVICE_FAILURE	Specifies an unrecoverable error occurred while the server (or slave) was attempting to perform the requested action. This value must be a constant, cannot change the value from 0x04.
ERR_STACK_INIT	In stack initialization failure
ERR_ILLEGAL_SERV_BSY	Specifies the maximum transaction reached. This value must be a constant, cannot change the value from 0x06
ERR_CRC_CHECK	Specifies the CRC check has failed
ERR_LRC_CHECK	Specifies the LRC check has failed
ERR_INVALID_SLAVE_ID	Specifies the slave ID is invalid
ERR_TCP_SND_MBX_FULL	Specifies that the mailbox is full
ERR_STACK_TERM	In stack termination failure
ERR_TIME_OUT	Timeout error added
ERR_MEM_ALLOC	Memory allocation failure
ERR_SYSTEM_INTERNAL	Mailbox send or receive failure
ERR_ILLEGAL_NUM_OF_COILS	Specifies the number of coils provided is not within the specified limit
ERR_ILLEGAL_NUM_OF_INPUTS	Specifies the number of inputs provided is not within the specified limit
ERR_ILLEGAL_NUM_OF_REG	Specifies the number of registers provided is not within the specified limit
ERR_ILLEGAL_OUTPUT_VALUE	Specifies the value of the registers is invalid
ERR_ILLEGAL_NUM_OF_OUTPUTS	Specifies the number of outputs is invalid
ERR_INVALID_STACK_INIT_PARAMS	Specifies invalid stack init information from user
ERR_INVALID_STACK_MODE	Stack mode specified is invalid
ERR_FUN_CODE_MISMATCH	Master receives a response for another function code(not for the requested function code)
ERR_SLAVE_ID_MISMATCH	Master receives a response from another slave (not from the requested slave)
ERR_OK_WITH_NO_RESPONSE	Return status for broadcast requests

3.1.4.2 Stack Selection

The development scope includes 6 Modbus stacks modes and one among the following is selected by the us er. In case of TCP Server Gateway design, user shall select either MODBUS_RTU_MASTER_MODE or MOD BUS_ASCII_MASTER_MODE as the stack mode of the device connected serially to the TCP gateway device.

3.1.4.3 Function code selection

Modbus Stack invokes user registered function when a request is received from client side.

If this function pointer is set to NULL means the corresponding function code is not implemented or supported by application/device. So in this way, we can enable and disable function codes.

3.1.4.4 Error identification and reporting

Verification of configuration parameters is carried out within the API function that is referenced. If there is an error in the specified, an error is reported from the API.

4. System Architecture – Modbus TCP Protocol Stacks

This section details the software design of Modbus TCP Server and Modbus TCP-Serial Gateway stacks. The Figure 4.1 shows the architecture of the stack. As shown in the diagram the stack can be used as a Modbus TCP Server Stack and a Modbus TCP Server stack with Gateway functionality. It is possible for the user to use the stack only for gateway functionality also.

In Modbus TCP – Serial Gateway mode the stack will be using the Modbus RTU/ASCII Master Stack as the gateway to the serial network. Initialization of the Modbus RTU/ASCII Master Stack will be done inside the function which initializes the Modbus Gateway Stack. The user can select either one of the Modbus RTU or Modbus ASCII gateway stacks.

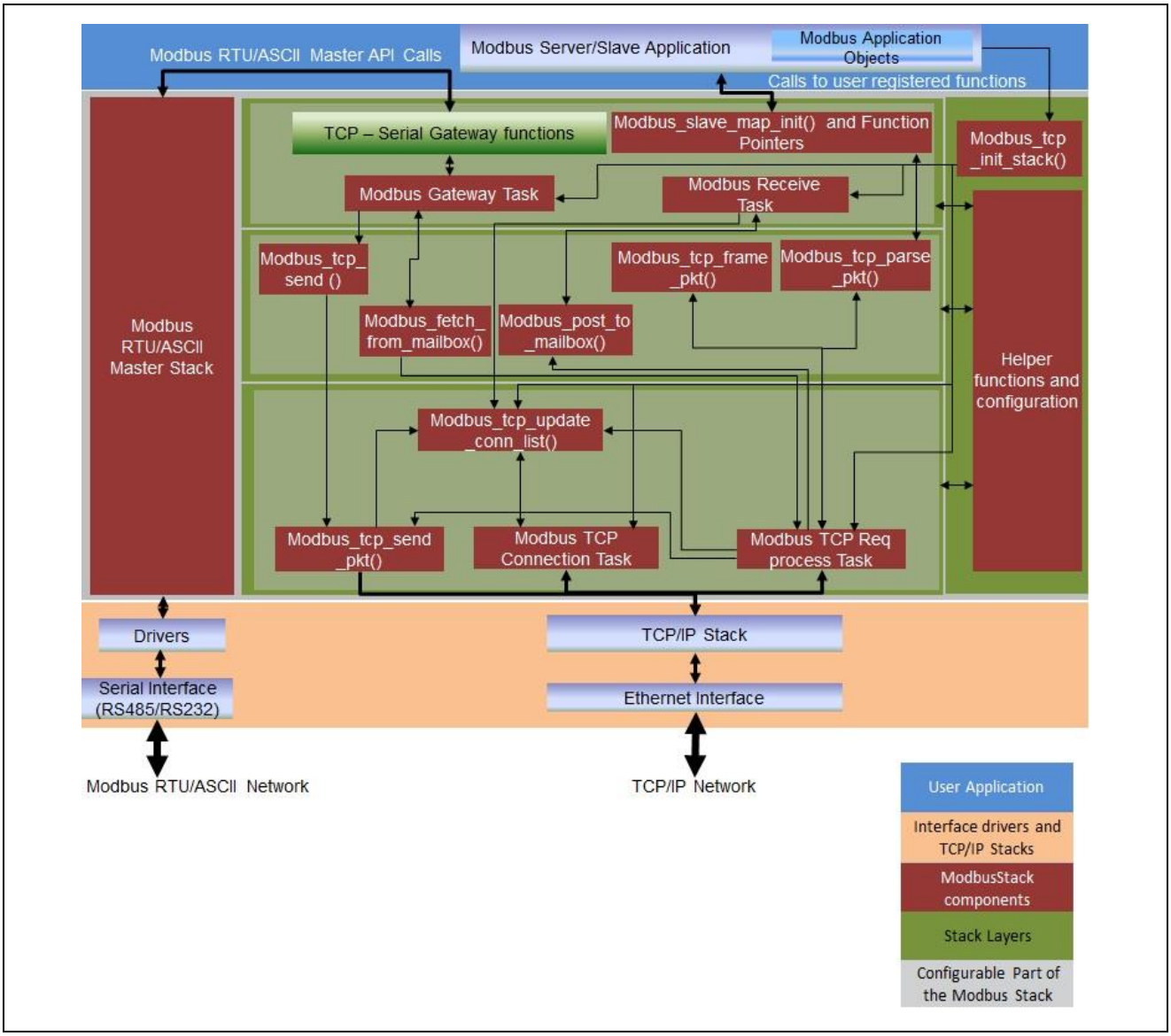


Figure 4.1 Modbus TCP and Gateway Stack Architecture <R>

As shown in the Figure 4.1 , the TCP Server and the Gateway stacks can be split into layers based on functionality.

The top layer Application Interface Layer consists of two tasks and callback function mapping API.

The middle layer Framing and Parsing Layer consist of functions and queues to frame packets, parse packets, read and write mailbox and helper functions. All these functions run in the context of the tasks in the upper layer.

The bottom layer Connection Management, Frame Send and Receive layer contains functions and tasks to handle TCP Connections and sending and receiving of TCP packets along with the helper functions. All functions in this layer, except the one for sending the response TCP message, runs in the context of the tasks in this layer itself. The response TCP packet will be send after processing the request received from server task in case of TCP packet and gateway task in case of serial packet.

The Configuration layer is the one which comes across the three layers and contains the necessary functions along with the configuration API.

4.1 Module Decomposition

4.1.1 Application Interface Layer

This layer contains two tasks and some functions, based on the selected mode the tasks and functions gets activated.

If the stack is used only as a server, then the Modbus Gateway task will not be running and the functions, called only by the gateway task, will not be used. The server task will be running even if the stack is used only for implementing gateway functionality.

4.1.1.1 Modbus TCP Server Task

This is the task which handles activities as the Modbus server. The task waits for getting data from the mailbox in which the ‘Modbus TCP Receive Data Task’ posts the received Modbus requests. When a packet arrived in the mailbox, this task copies it and processes. There will be a slight change in the activities of this task when switching between the modes of the stack with gateway functionality and without gateway functionality.

If the gateway functionality of the stack is disabled, this task will drop the Modbus packets with slave ID other than ‘0xFF’ and processes the packets with slave ID ‘0xFF’. Whereas, in the mode with the gateway functionality, this task posts the requests with the slave ID other than ‘0xFF’ to the mailbox on which the ‘Modbus TCP-Serial gateway task’ waits for getting request packets.

Figure 4.2 and Figure 4.3 show the state machine of this task when the stack working without gateway functionality and with gateway functionality, respectively.

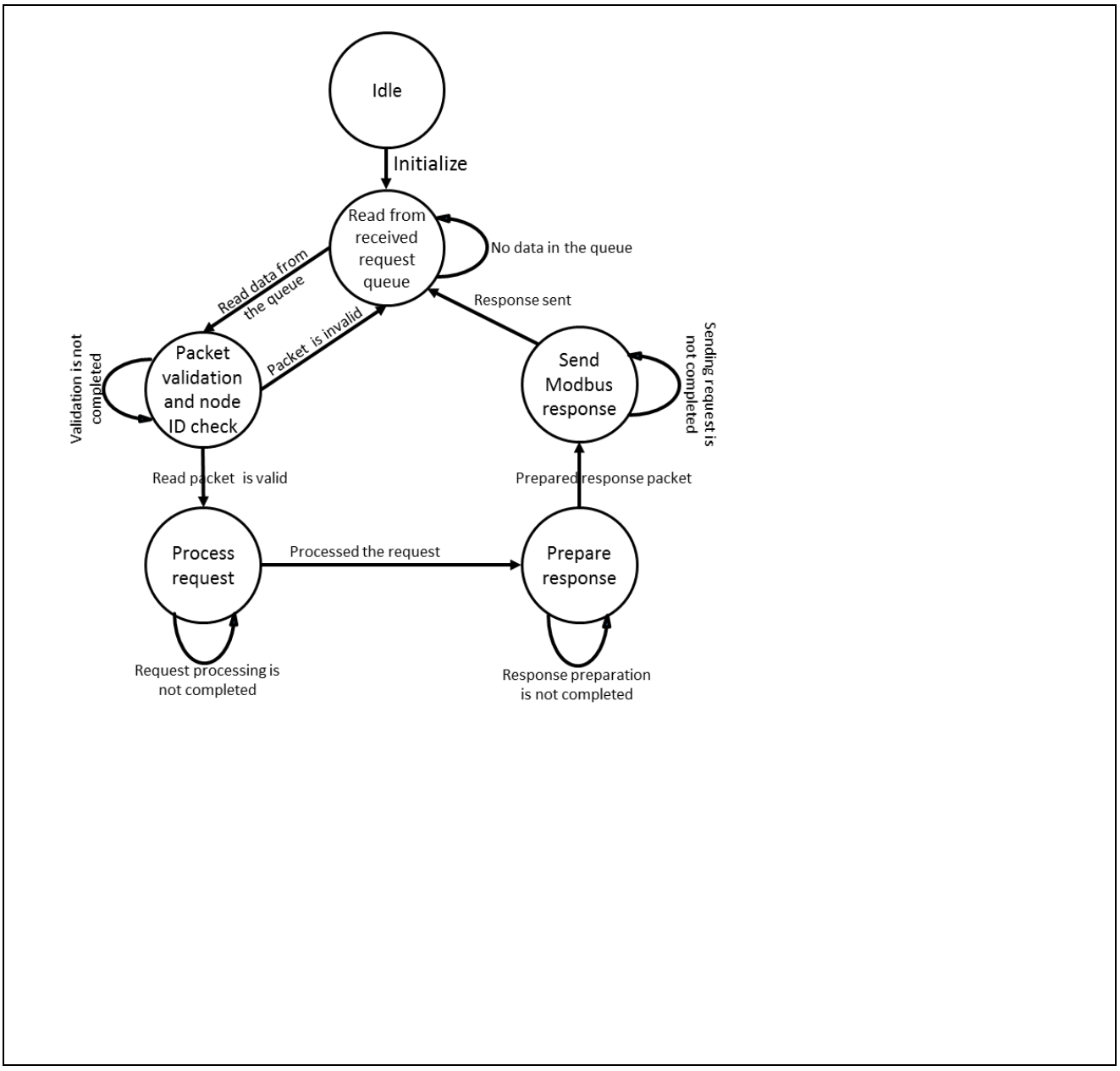


Figure 4.2 Modbus TCP Server Task (without gateway) <R>

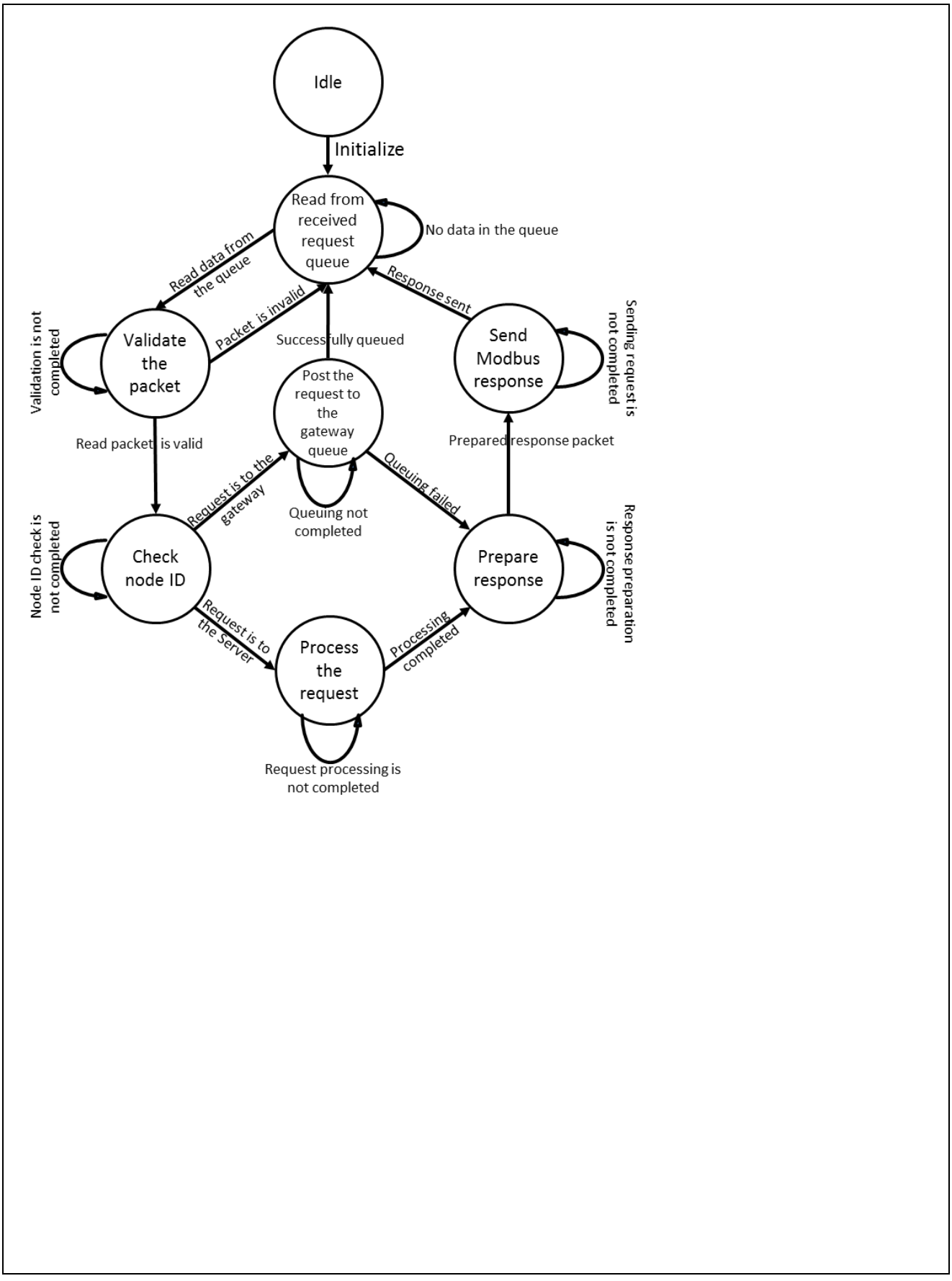


Figure 4.3 Modbus TCP Server Task (with gateway) <R>

4.1.1.2 Modbus TCP – Serial Gateway task

This is the task responsible for communicating with the Modbus Serial interface, for that, the Modbus RTU/ASCII Master Stack will be available. The Figure 4.4 shows the state main chain of this task. As the figure shows the task waits for data in the mailbox in which the 'Modbus TCP Server task' posts the requests when a request from client received with slave ID other than '0xFF'. When a request is received from the mailbox the task verifies it and sends it to the Modbus RTU/ASCII Master Stack by invoking the Modbus Gateway functions. This task calls the gateway functions based on the functions code in the received packet and sends a reply back to the Modbus TCP connection when a response is received from the master task. Meantime, the Modbus RTU/ASCII Master Task communicates with the slave devices in the serial networks and gets a response to give it to this task.

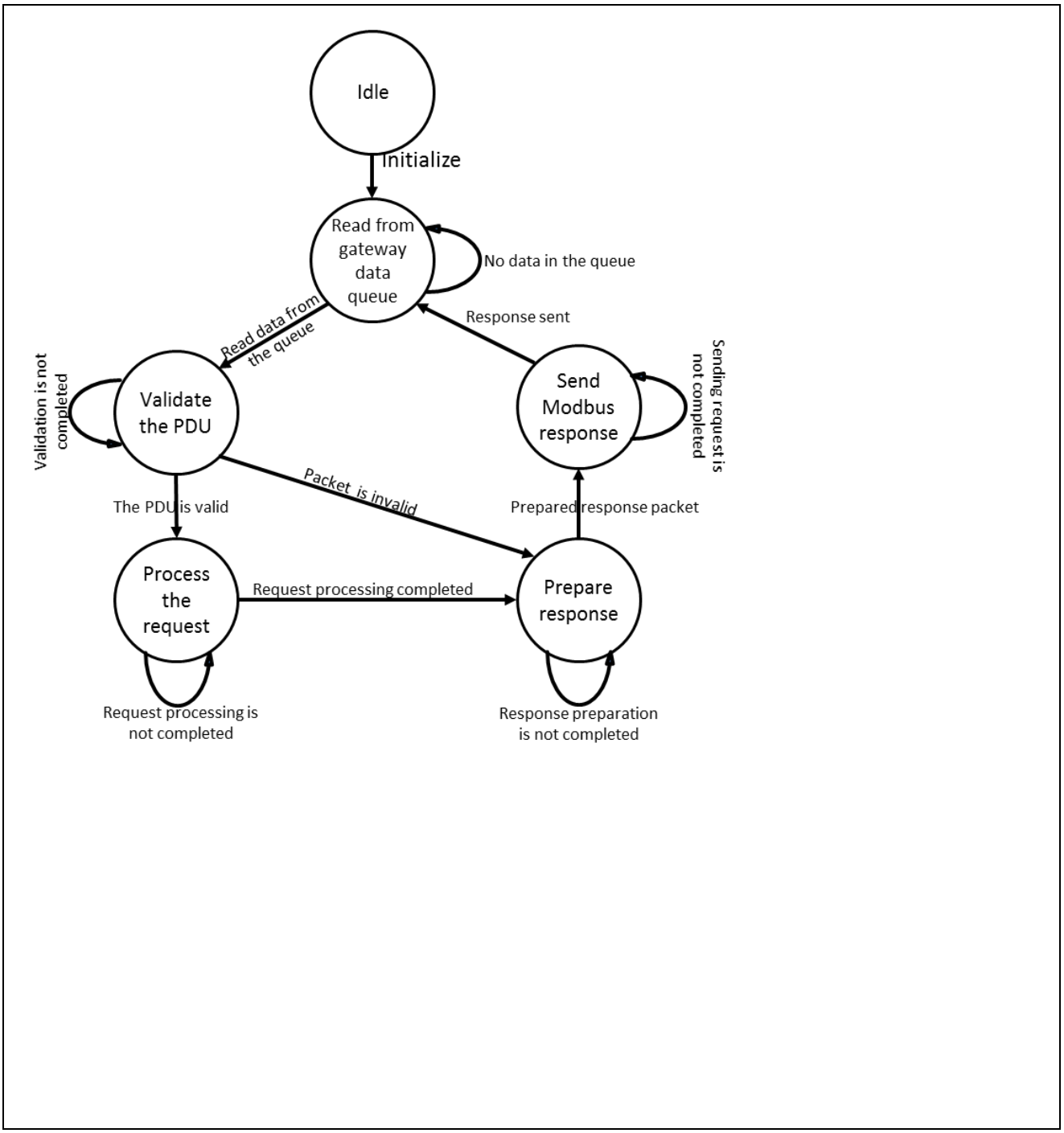


Figure 4.4 MODBUS TCP-Serial Gateway Task <R>

4.1.1.3 Error Identification and Reporting

- Memory is allocated dynamically for framing packet. Error is reported if the memory can not be ensured.
- Gateway task queues the message up to maximum number MAX_GW_MBX_SIZE. If the Gateway task can not be queued, the TCP server task will reply the exception code 6(Server Busy) as a response packet for the request packet.

4.1.2 Packet Framing and Parsing Layer

This is the stack layer which does the required packet framing and parsing activities. It contains functions and data structures for framing the Modbus packets, parsing the packet, sending packet, receiving packet, and validating the received packets.

(1) Parsing receive packet

If length check and packet integrity checks fail, discards the received packet. If the received packet is normally, the callback function that the user has registered is invoked in order to process the request.

(2) Framing send packet

Task sends back a response packet is built the based on execution result of the callback function. If the unsupported function code is specified, it is necessary to return the Exception code, and sends it to build a response packet.

4.1.2.2 Error Identification and Reporting

- Packet length and specified data in the receive packets are verified whether they comply with the protocol based on the function code.
- Memory is allocated dynamically for framing packet. Error is reported if the memory can not be ensured.

4.1.3 Connection management, Frame Send and Receive Layer

This layer contains tasks and functions to accept connections from clients, receive data from clients and sent data back.

4.1.3.1 Modbus TCP Accept Connection Task

This task gets initialized when the user initialized the stack and starts waiting for the connection requests to the port 502 from clients and at a user configured port (if provided by user during stack initialization). When the task received a connection request it checks the IP against allowed IP list and active connection list and accepts the connection. After accepting the connection adds it to the active connection list. The Figure 4.5 shows the state diagram of this task. The total number of connections allowed is restricted to MAXIMUM_NUMBER_OF_CLIENTS.

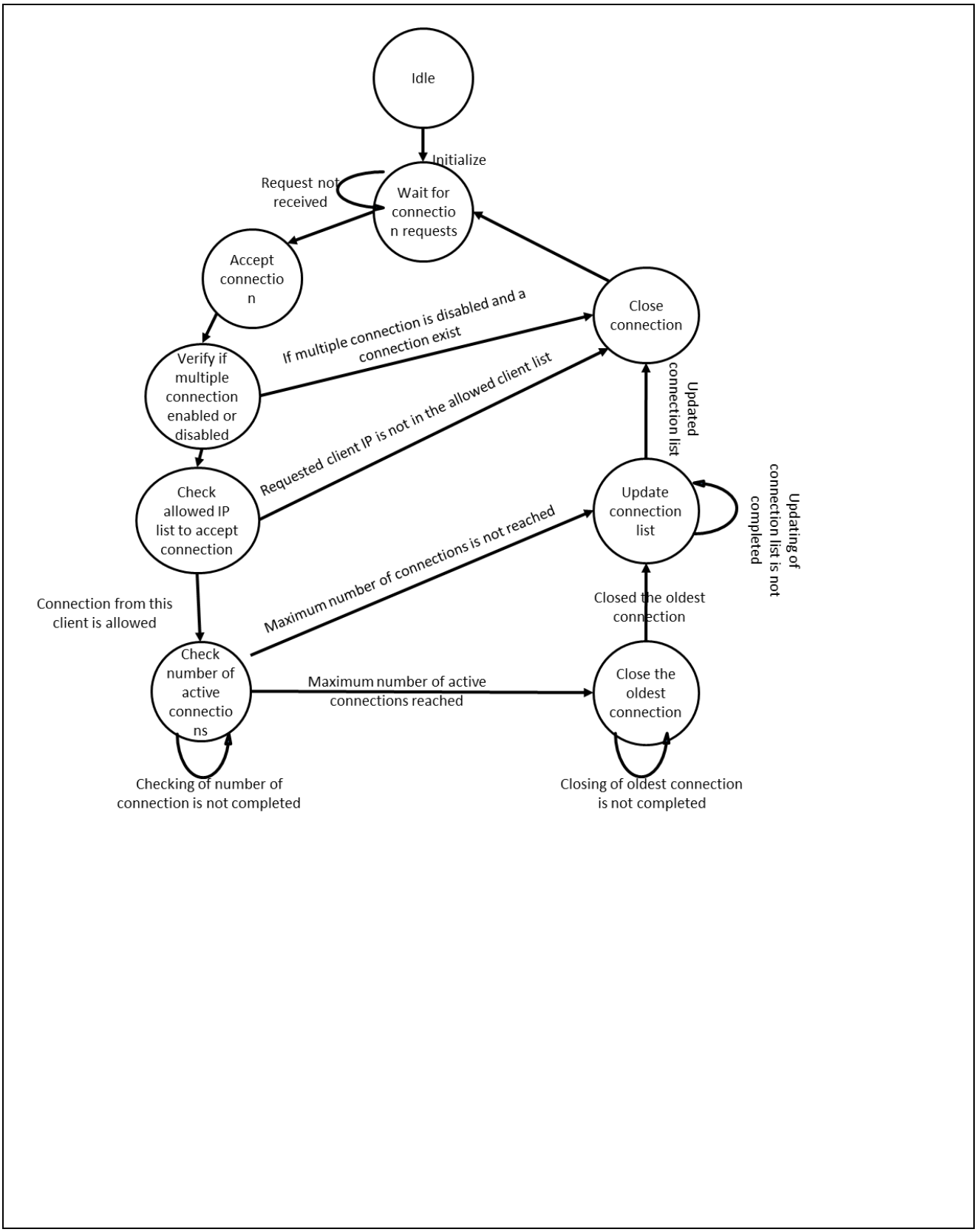


Figure 4.5 Modbus TCP Accept Connection Task <R>

4.1.3.2 Modbus TCP Receive Data Task

This task gets initialized when the user initialized the stack. The task waits for data from the clients connected and posts it to a mailbox when a valid packet is received. The Figure 4.6 shows the state diagram of this task.

When received a request from a client the ‘Modbus TCP Receive Data Task’ calls the function ‘Modbus_post_to_mailbox()’ to post the request to a mailbox. This mail message is read by the ‘Modbus TCP Server Task’ with the function ‘Modbus_fetch_from_mailbox()’.

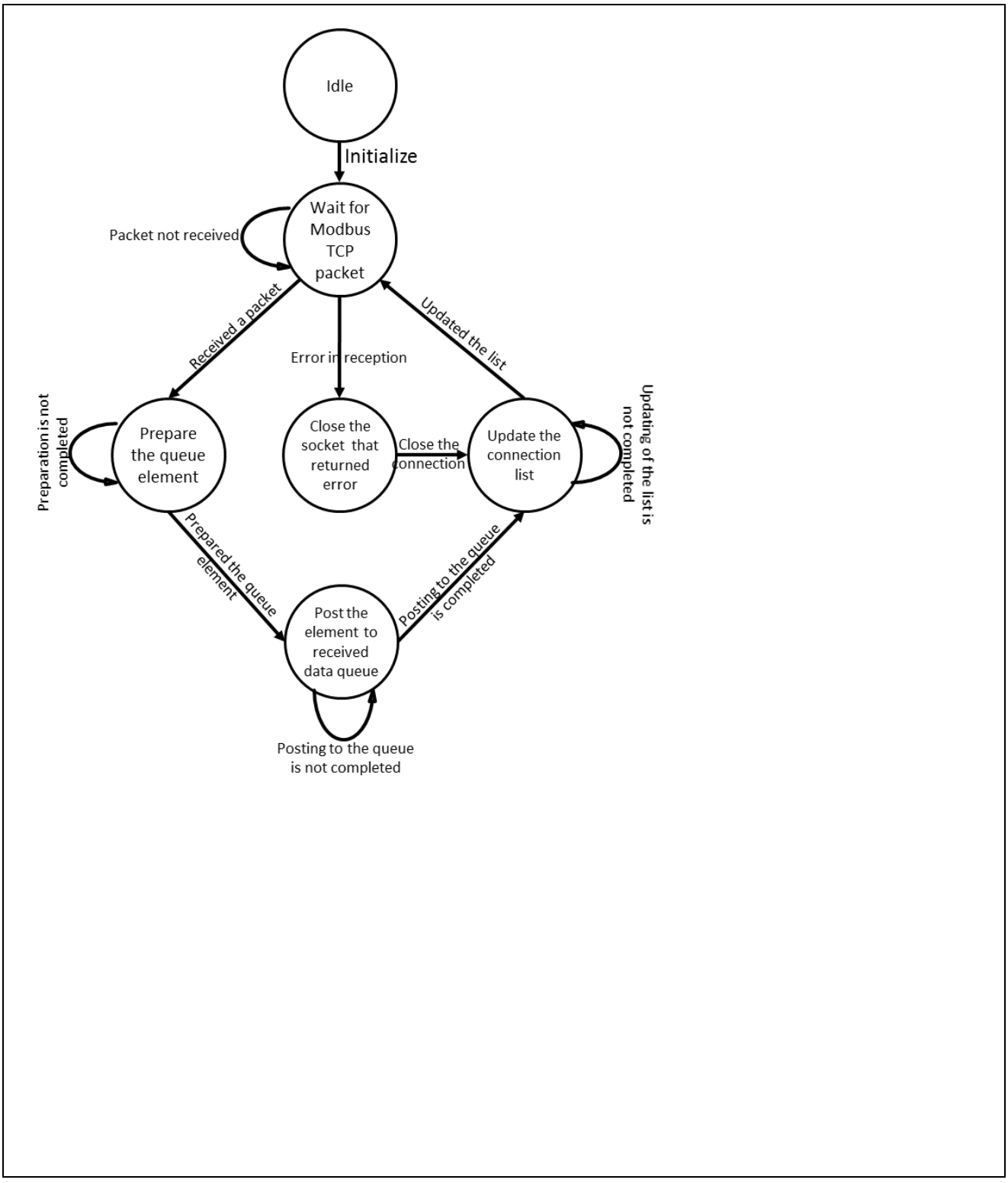


Figure 4.6 Modbus TCP Receive Data task <R>

4.1.3.3 Error Identification and Reporting

- Memory is allocated dynamically for parsng packet. Error is reported if the memory can not be ensured.
- TCP server task queues the message up to maximum number MAX_RCV_MBX_SIZE. If the TCP server task can

not be queued, the TCP receive data task will reply the exception code 6(Server Busy) as a response packet for the request packet.

5. Description of application programming interface

This chapter explains the detailed specifications of the Application Programming Interface.

5.1 User Interface API

This chapter explains the APIs to be used in User Application.

5.1.1 Modbus TCP/IP

5.1.1.1 Initialization of protocol stack

The following API is used in initialization of protocol stack.

Modbus_tcp_init_stack	Modbus TCP stack initialization API

【Format】

```
uint32_t Modbus_tcp_init_stack(uint8_t u8_stack_mode,
                               uint8_t u8_tcp_gw_slave,
                               uint8_t u8_tcp_multiple_client,
                               uint32_t u32_additional_port,
                               p_serial_stack_init_info_t pt_serial_stack_init_info,
                               p_serial_gpio_cfg_t pt_serial_gpio_cfg_t);
```

【Parameter】

uint8_t	u8_stack_mode	Variable to store the stack mode
uint8_t	u8_tcp_gw_slave	Status whether gateway enabled as TCP server
uint8_t	u8_tcp_multiple_client	Status whether multiple client is enabled
uint32_t	u32_additional_port	Additional port configured by user
p_serial_stack_init_info_t	pt_serial_stack_init_info	Structure pointer to serial stack initialization parameters
p_serial_gpio_cfg_t	pt_serial_gpio_cfg_t	Pointer to the structure with hardware configuration parameters.

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On successful initialization
ERR_STACK_INIT	On failure

【Explanation】

This API initialize Modbus stack based on the user provided information. If the serial stack information structure is NULL, Modbus_tcp_server_init_stack() is invoked. If the serial stack information structure is provided by user, Modbus_tcp_init_gateway_stack() is invoked with the required serial parameter configuration.

For this few initializing parameters are provided in the APIs.

a. u8_stack_mode of type uint8_t is an argument in order to select the Modbus TCP stack type. The user specifies the following macro in this parameter. If user wants to use the gateway mode, please specify the mode to be used to communicate with the serial device.

Stack mode parameter code	Meaning
MODBUS_RTU_MASTER_MODE	Used to select Modbus Stack RTU master mode
MODBUS_RTU_SLAVE_MODE	Used to select Modbus Stack RTU slave mode
MODBUS_ASCII_MASTER_MODE	Used to select Modbus Stack ASCII master mode
MODBUS_ASCII_SLAVE_MODE	Used to select Modbus Stack ASCII slave mode
MODBUS_TCP_SERVER_MODE	Used to select Modbus Stack TCP server mode

b. u8_tcp_gw_slave of type uint8_t is an argument in order to select the Modbus gateway mode type. The user specifies the following macro in this parameter.

Stack gateway parameter code	Meaning
MODBUS_TCP_GW_SLAVE_DISABLE	Modbus stack gateway slave disable
MODBUS_TCP_GW_SLAVE_ENABLE	Modbus stack gateway slave enable

c. u8_tcp_multiple_client of type uint8_t is an argument in order to select whether accept communication from multiple clients. The user specifies the following macro in this parameter.

Multiple client connection parameter code	Meaning
DISABLE_MULTIPLE_CLIENT_CONNECTION	By setting this value, multiple client connection is disabled
ENABLE_MULTIPLE_CLIENT_CONNECTION	By setting this value, multiple client connection is enabled

d. Additional port (other Modbus default port 502) provided by user for MODBUS communication can also be used. If user does not want to add the port, please specify 0.

e. Structure of type p_serial_stack_init_info_t is an argument in order to provide information specific to serial communication. If want to use in TCP server mode, please specify NULL to this argument.

・Structure of serial stack initialization parameters (serial_stack_init_info_t)

```
typedef struct _stack_init_info{
    uint32_t    u32_baud_rate;          /* Baud rate for serial port configuration */
    uint8_t     u8_parity;              /* Parity for serial port configuration */
    uint8_t     u8_stop_bit;            /* Stop bit for serial port configuration */
    uint8_t     u8_uart_channel;        /* The hardware UART channel to be used by the Modbus serial
                                           stack */
    uint8_t     u8_timer_channel;       /* The hardware timer channel to be used by the Modbus serial
                                           stack */
    uint32_t    u32_response_timeout_ms; /* Response shall be received within this time out */
    uint32_t    u32_turnaround_delay_ms; /* Delay in between consecutive requests in broadcast mode */
    uint32_t    u32_interframe_timeout_us; /* Inter frame delay for the RTU packet */
    uint32_t    u32_interchar_timeout_us; /* Inter char delay for the ASCII packet */
    uint8_t     u8_retry_count;         /* Number of retries to be done in case of an error */
}serial_stack_init_info_t, *p_serial_stack_init_info_t;
```

Use the following macro to the parameters of the structure.

Boud rate parameter code	Meaning
UART_BAUD_9600	Use to select 9600bps
UART_BAUD_19200	Use to select 19200bps
UART_BAUD_31250	Use to select 31250bps
UART_BAUD_38400	Use to select 38400bps
UART_BAUD_76800	Use to select 76800bps
UART_BAUD_115200	Use to select 115200bps
UART_BAUD_153600	Use to select 153600bps

Parity parameter code	Meaning
UART_PARITY_NONE	No parity
UART_PARITY_ODD	Odd parity
UART_PARITY_EVEN	Even parity

Stop bit parameter code	Meaning
UART_STOPBIT_1	One stop bit
UART_STOPBIT_2	Two stop bit

Uart channel parameter code	Meaning
UART_CHANNEL_0	Use to select channel 0
UART_CHANNEL_1	Use to select channel 1

Timer channel parameter code	Meaning
TIMER_CHANNEL_0	Use to select channel 0
TIMER_CHANNEL_1	Use to select channel 1

f. Structure of type p_serial_gpio_cfg_t is an argument in order to provide function pointers to control the GPIO port for RS485 communication. If want to use in TCP server mode, please specify NULL to this argument.

・Structure of I/O port configuration information (serial_gpio_cfg_t)

```
typedef struct _serial_gpio_cfg_t{
    fp_gpio_callback_t    fp_gpio_init_ptr;    /* Callback function pointer to invoke the initialize the GPIO used
                                                  for RS485 direction control */
    fp_gpio_callback_t    fp_gpio_set_ptr;     /* Callback function pointer to set the GPIO used for RS485
                                                  direction control */
    fp_gpio_callback_t    fp_gpio_reset_ptr;   /* Callback function pointer to reset the GPIO used for RS485
                                                  direction control */
}serial_gpio_cfg_t, *p_serial_gpio_cfg_t;
```

Modbus_slave_map_init	Modbus function code mapping API

【Format】

uint32_t Modbus_slave_map_init(p_slave_map_init_t p_serial_slave_map_init_t);

【Parameter】

p_slave_map_init_t	p_serial_slave_map_init_t	structure pointer to function code mapping table

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On success
ERR_INVALID_STACK_INIT_PARAMS	If parameter is null
ERR_MEM_ALLOC	If memory allocation failed

【Explanation】

This API does the mapping of user defined functions for processing requests from clients depending on function code. When the Modbus Slave stack receives a request, it invokes the corresponding handler function registered.

This API is only valid when the Modbus stack is configured as Slave mode.

・Structure of function code mapping table (slave_map_init_t)

```
typedef struct _slave_map_init{
    fp_function_code1_t     fp_function_code1;     /* Call back function pointer for Modbus function code 1
                                                      (Read Coils) operation */
    fp_function_code2_t     fp_function_code2;     /* Call back function pointer for Modbus function code 2
                                                      (Read Discrete Inputs) operation */
    fp_function_code3_t     fp_function_code3;     /* Call back function pointer for Modbus function code 3
                                                      (Read Holding Registers) operation */
    fp_function_code4_t     fp_function_code4;     /* Call back function pointer for Modbus function code 4
                                                      (Read Input Registers) operation */
    fp_function_code5_t     fp_function_code5;     /* Call back function pointer for Modbus function code 5
                                                      (Write Single Coil) operation */
    fp_function_code6_t     fp_function_code6;     /* Call back function pointer for Modbus function code 6
                                                      (Write Single Register) operation */
    fp_function_code15_t    fp_function_code15;    /* Call back function pointer for Modbus function code 15
                                                      (Write Multiple Coils) operation */
    fp_function_code16_t    fp_function_code16;    /* Call back function pointer for Modbus function code 16
                                                      (Write Multiple Registers) operation */
    fp_function_code23_t    fp_function_code23;    /* Call back function pointer for Modbus function code 23
                                                      (Read/Write Multiple Registers) operation */
}slave_map_init_t, *p_slave_map_init_t;
```

Callback function corresponding to each function code, to the definition in the following format. For more information on the structure to be used in the callback function, please refer to each API of Chapter 5.1.2.2.

fp_function_code1_t	Call back function pointer for Modbus function code 1(Read Coils) processing

【Format】

uint32_t (*fp_function_code1_t)(p_req_read_coils_t pt_req_read_coils,
p_resp_read_coils_t pt_resp_read_coils);

【Parameter】

p_req_read_coils_t	pt_req_read_coils	structure pointer from stack to user with read coils request information
p_resp_read_coils_t	pt_resp_read_coils	structure pointer to stack from user with read coils response data

【Return value】

uint32_t	0 : success ,1 : failure

fp_function_code2_t	Call back function pointer for Modbus function code 2(Read Discrete Inputs) processing

【Format】

uint32_t (*fp_function_code2_t)(p_req_read_inputs_t pt_req_read_inputs,
p_resp_read_inputs_t pt_resp_read_inputs);

【Parameter】

p_req_read_inputs_t	pt_req_read_inputs	structure pointer from stack to user with read discrete inputs request information
p_resp_read_inputs_t	pt_resp_read_inputs	structure pointer to stack from user with read discrete inputs response data

【Return value】

uint32_t	0 : success ,1 : failure

fp_function_code3_t	Call back function pointer for Modbus function code 3(Read Holding Registers) processing

【Format】

uint32_t (*fp_function_code3_t)(p_req_read_holding_reg_t pt_req_read_holding_reg,
p_resp_read_holding_reg_t pt_resp_read_holding_reg);

【Parameter】

p_req_read_holding_reg_t	pt_req_read_holding_reg	structure pointer from stack to user with read holding registers request information
p_resp_read_holding_reg_t	pt_resp_read_holding_reg	structure pointer to stack from user with read holding registers response data

【Return value】

uint32_t	0 : success ,1 : failure

fp_function_code4_t	Call back function pointer for Modbus function code 4(Read Input Registers) processing

【Format】

```
uint32_t (*fp_function_code4_t)(p_req_read_input_reg_t pt_req_read_input_reg,
                                p_resp_read_input_reg_t pt_resp_read_input_reg);
```

【Parameter】

p_req_read_input_reg_t	pt_req_read_input_reg	structure pointer from stack to user with read input registers request information
p_resp_read_input_reg_t	pt_resp_read_input_reg	structure pointer to stack from user with read input registers response data

【Return value】

uint32_t	0 : success ,1 : failure

fp_function_code5_t	Call back function pointer for Modbus function code 5(Write Single Coil) processing

【Format】

```
uint32_t (*fp_function_code5_t)(p_req_write_single_coil_t  pt_req_write_single_coil,
                                p_resp_write_single_coil_t  pt_resp_write_single_coil );
```

【Parameter】

p_req_write_single_coil_t	pt_req_write_single_coil	structure pointer from stack to user with write single coil request information
p_resp_write_single_coil_t	pt_resp_write_single_coil	structure pointer to stack from user with write single coil response

【Return value】

uint32_t	0 : success ,1 : failure

fp_function_code6_t	Call back function pointer for Modbus function code 6(Write Single Register) processing

【Format】

```
uint32_t (*fp_function_code6_t)(p_req_write_single_reg_t  pt_req_write_single_reg,
                                p_resp_write_single_reg_t  pt_resp_write_single_reg);
```

【Parameter】

p_req_write_single_reg_t	pt_req_write_single_reg	structure pointer from stack to user with write single register request information
p_resp_write_single_reg_t	pt_resp_write_single_reg	structure pointer to stack from user with write single register response

【Return value】

uint32_t	0 : success ,1 : failure

fp_function_code15_t	Call back function pointer for Modbus function code 15(Write Multiple Coils) processing

【Format】

uint32_t (*fp_function_code15_t) (p_req_write_multiple_coils_t pt_req_write_multiple_coils,
p_resp_write_multiple_coils_t pt_resp_write_multiple_coils);

【Parameter】

p_req_write_multiple_coils_t	pt_req_write_multiple_coils	structure pointer from stack to user with write multiple coils request information
p_resp_write_multiple_coils_t	pt_resp_write_multiple_coils	structure pointer to stack from user with write multiple coils response

【Return value】

uint32_t	0 : success ,1 : failure

fp_function_code16_t	Call back function pointer for Modbus function code 16(Write Multiple Registers) processing

【Format】

uint32_t (*fp_function_code16_t) (p_req_write_multiple_reg_t pt_req_write_multiple_reg,
p_resp_write_multiple_reg_t pt_resp_write_multiple_reg);

【Parameter】

p_req_write_multiple_reg_t	pt_req_write_multiple_reg	structure pointer from stack to user with write multiple registers request information
p_resp_write_multiple_reg_t	pt_resp_write_multiple_reg	structure pointer to stack from user with write multiple registers response

【Return value】

uint32_t	0 : success ,1 : failure

fp_function_code23_t	Call back function pointer for Modbus function code 23(Read/Write Multiple Registers) processing

【Format】

uint32_t (*fp_function_code23_t) (p_req_read_write_multiple_reg_t pt_req_read_write_multiple_reg,
p_resp_read_write_multiple_reg_t pt_resp_read_write_multiple_reg);

【Parameter】

p_req_read_write_multiple_reg_t	pt_req_read_write_multiple_reg	structure pointer from stack to user with read/write multiple registers request information
p_resp_read_write_multiple_reg_t	pt_resp_read_write_multiple_reg	structure pointer to stack from user with read/write multiple registers response

【Return value】

uint32_t	0 : success ,1 : failure

5.1.1.2 IP management

The following API is used in IP management.

Modbus_tcp_init_ip_table	Modbus set host IP list properties

【Format】

```
void_t Modbus_tcp_init_ip_table(ENABLE_FLAG e_flag,
                                TABLE_MODE e_mode);
```

【Parameter】

ENABLE_FLAG	e_flag	Status is whether the connection table enabled or disabled enabled: ENABLE, disabled: DISABLE
TABLE_MODE	e_mode	Status indicating the list contain IP to be accepted or rejected accepted: ACCEPT, rejected: REJECT

【Return value】

void_t

【Error code】

—

【Explanation】

This function is used for specifying mode (accept/reject) and to Enable or Disable the list of IP address by the user. By default the host IP list is disabled.

Modbus_tcp_add_ip_addr	Modbus add an IP to host IP list

【Format】

```
uint32_t Modbus_tcp_add_ip_addr(pchar_t pu8_add_ip);
```

【Parameter】

pchar_t	pu8_add_ip	Host IP address in numbers and dots notation ex. 192.168.1.100

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On successful addition.
ERR_IP_ALREADY_PRESENT	If address already present in list.
ERR_MAX_CLIENT	If maximum connections reached.
TABLE_DISABLED	If list is disabled.

【Explanation】

This function is used for adding a IP to the host IP list.

Modbus_tcp_delete_ip_addr	remove an IP from host IP list

【Format】

uint32_t Modbus_tcp_delete_ip_addr(pchar_t pu8_del_ip);

【Parameter】

pchar_t	pu8_del_ip	Host IP address in numbers and dots notation

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On successful search.
ERR_IP_NOT_FOUND	If IP is not in the list
ERR_TABLE_EMPTY	If the list is empty
ERR_TABLE_DISABLED	If the table is disabled, i.e., server accepts connection request from any host

【Explanation】

This function is used for removing a host IP from the list.

5.1.1.3 Task

The following function is the main processing task operates in the protocol stack.

Modbus_tcp_recv_data_task	TCP Receive data Task

【Format】

void_t Modbus_tcp_recv_data_task(void_t);

【Parameter】

void_t

【Return value】

void_t

【Error code】

—

【Explanation】

This task waits for a request received in the selected socket ID. It verifies the packet is for Modbus protocol. If so, write the request to the receive mailbox. If the mailbox is found full, send an error server busy to the client.

Modbus_tcp_req_process_task	TCP server task

【Format】

void_t Modbus_tcp_req_process_task(void_t);

【Parameter】

void_t

【Return value】

void_t

【Error code】

—

【Explanation】

This task wait for a request in the queue. Verify the slave ID in the request packet to determine the packet is for the TCP server or the device connected to it serially. If the packet is for the TCP server process the request read from the queue, prepare the response packet and send it to the TCP client. If the packet is for the serial device connected, write the request to the gateway mailbox.

Modbus_gateway_task	TCP – Serial Gateway task

【Format】

void_t Modbus_gateway_task(void_t);

【Parameter】

void_t

【Return value】

void_t

【Error code】

—

【Explanation】

This task wait for a request in the gateway queue for processing the data in the serial device connected to the TCP server. It process the request read from the queue, prepare the response packet and send it to the TCP client.

Modbus_tcp_soc_wait_task	TCP accept connection task

【Format】

void_t Modbus_tcp_soc_wait_task(void_t);

【Parameter】

void_t

【Return value】

void_t

【Error code】

—

【Explanation】

This task waits for a connection from a client in the default Modbus port (502) and an additional port if configured by user. Verify whether the IP table is enabled or not. If enabled, verify the list contains the IP list to accepted or rejected. Accordingly save the socket descriptor to the connection list.

Modbus_tcp_terminate_stack	Modbus terminate TCP stack API

【Format】

uint32_t Modbus_tcp_terminate_stack(void_t);

【Parameter】

void_t	

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On successful termination
ERR_STACK_TERM	If termination failed

【Explanation】

This API terminate Modbus stack. Depending upon the stack mode, corresponding APIs are invoked. If the stack mode is MODBUS_TCP_SERVER_MODE, Modbus_tcp_terminate_stack() is invoked. If stack mode is gateway, Modbus_tcp_terminate_gateway_stack() is invoked.

5.1.2 Modbus Serial

5.1.2.1 Initialization of protocol stack

The following API is used in initialization of protocol stack.

Modbus_serial_stack_init	Modbus Serial Stack initialization API

【Format】

```
uint32_t Modbus_serial_stack_init(p_serial_stack_init_info_t pt_serial_stack_init_info,
                                  p_serial_gpio_cfg_t    pt_serial_gpio_cfg_t,
                                  uint8_t   u8_stack_mode,
                                  uint8_t   u8_slave_id);
```

【Paramter】

p_serial_stack_init_info_t	pt_serial_stack_init_info	Pointer to the structure with serial configuration parameters.
p_serial_gpio_cfg_t	pt_serial_gpio_cfg_t	Pointer to the structure with GPIO configuration parameters.
uint8_t	u8_stack_mode	Mode in which the stack should be initialized(RTU/ASCII master/slave)
uint8_t	u8_slave_id	Slave ID of device; valid only for slave mode

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On successful initialization of serial stack
ERR_INVALID_STACK_MODE	If stack mode specified is invalid
ERR_INVALID_SLAVE_ID	If slave id specified is invalid
ERR_INVALID_STACK_INIT_PARAMS	If invalid stack init information from user
ERR_STACK_INIT	If stack activation or clear flag fails

【Explanation】

This API is to initialize the serial stack as per the user provided configuration parameters. By providing different configurations, stack could function in the way user requires.

For this few initializing parameters are provided in the APIs.

a. Structure of type p_serial_stack_init_info_t is an argument in order to provide information specific to serial communication.

b. Structure of type p_serial_gpio_cfg_t is an argument in order to provide function pointers to control the GPIO port for RS485 communication.

c. u8_stack_mode of type uint8_t is an argument in order to select the Modbus serial stack type. According to the value assigned for this parameter, stack works in either of the following mode:

Stack mode parameter code	Meaning
MODBUS_RTU_MASTER_MODE	Used to select Modbus Stack RTU master mode
MODBUS_RTU_SLAVE_MODE	Used to select Modbus Stack RTU slave mode
MODBUS_ASCII_MASTER_MODE	Used to select Modbus Stack ASCII master mode
MODBUS_ASCII_SLAVE_MODE	Used to select Modbus Stack ASCII slave mode

d. u8_slave_id of type uint8_t is an argument in order to set the device ID in slave mode. This parameter is used when the stack is in either ASCII/RTU Slave mode. This parameter can hold any value within the range 1 to 247.

Please refer to Chapter 5.1.1.1 for detail of the parameters.

Modbus_slave_map_init	Modbus function code mapping API

【Format】

uint32_t Modbus_slave_map_init (p_slave_map_init_t p_tcp_slave_map_init_t);

【Parameter】

p_slave_map_init_t	p_tcp_slave_map_init_t	Structure pointer to function code mapping table

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On success
ERR_INVALID_STACK_INIT_PARAMS	If parameter is null
ERR_MEM_ALLOC	If memory allocation failed

【Explanation】

This API is the same function as when the Modbus TCP. Please refer to Chapter 5.1.1.1 for detail of the function.

5.1.2.2 Master Mode API

The following API is used in master mode.

Modbus_read_coils	Modbus read coils

【Format】

```
uint32_t Modbus_read_coils(p_req_read_coils_t pt_req_read_coils,
                           p_resp_read_coils_t pt_resp_read_coils,
                           fp_callback_notify_t fp_callback_notify);
```

【Parameter】

p_req_read_coils_t	pt_req_read_coils	Structure pointer to read coil request
p_resp_read_coils_t	pt_resp_read_coils	Structure pointer to read coil response
fp_callback_notify_t	fp_callback_notify	Function pointer argument for the call back notification in non blocking API mode. If this argument is set to NULL API become blocking.

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	If coil read successful
ERR_SYSTEM_INTERNAL	For mailbox send or receive failure
ERR_ILLEGAL_NUM_OF_COILS	If the number of coils provided is not within the specified limit
ERR_INVALID_SLAVE_ID	If the slave ID is not valid
ERR_MEM_ALLOC	If the memory allocation fail
ERR_SLAVE_ID_MISMATCH	If master receives a response from another slave (not from the requested slave)
ERR_CRC_CHECK	If CRC validation fails for RTU stack mode
ERR_LRC_CHECK	If LRC validation fails for ASCII stack mode
ERR_FUN_CODE_MISMATCH	If master receives a response for another function code(not for the requested function code)
ERR_ILLEGAL_FUNCTION	If the function code is invalid or if function code is disabled in the stack
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid

【Explanation】

This API is used to read data from coils when requested.If this API returns an error, the data field in the response structure will be invalid.

・Structure of read coils request (req_read_coils_t)

```
typedef struct _req_read_coils{
    uint16_t    u16_transaction_id;     /* Specifies the transaction ID */
    uint16_t    u16_protocol_id;        /* Specifies the protocol ID */
    uint8_t     u8_slave_id;            /* Identification of a remote slave connected */
    uint16_t    u16_start_addr;         /* Specifies address of the first coil */
    uint16_t    u16_num_of_coils;       /* Specifies the number of coils to be read */
}req_read_coils_t, *p_req_read_coils_t;
```

・Structure of read coils response (resp_read_coils_t)

```
struct _resp_read_coils{
    uint16_t    u16_transaction_id;     /* Specifies the transaction ID */
    uint16_t    u16_protocol_id;        /* Specifies the protocol ID */
    uint8_t     u8_slave_id;            /* Identification of a remote slave connected(Own ID) */
    uint8_t     u8_exception_code;      /* Error detected during processing the request. On
                                           success the exception code should  be zero, if the
                                           exception code is non zero the aru8_data will be null */
    uint8_t     u8_num_of_bytes;        /* Specifies the number of bytes of data */
    uint8_t     aru8_data[MAX_DISCRETE_DATA]; /* Data to be read */
}resp_read_coils_t, *p_resp_read_coils_t;
```

Modbus_read_discrete_inputs	Modbus read discrete inputs

【Format】

```
uint32_t Modbus_read_discrete_inputs(p_req_read_inputs_t pt_req_read_inputs,
                                     p_resp_read_inputs_t pt_resp_read_inputs,
                                     fp_callback_notify_t fp_callback_notify);
```

【Parameter】

p_req_read_inputs_t	pt_req_read_inputs	Structure pointer to read input request
p_resp_read_inputs_t	pt_resp_read_inputs	Structure pointer to read input response
fp_callback_notify_t	fp_callback_notify	Function pointer argument for the call back notification in non blocking API mode. If this argument is set to NULL API become blocking.

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	If input read successful
ERR_SYSTEM_INTERNAL	For mailbox send or receive failure
ERR_ILLEGAL_NUM_OF_INPUTS	If the number of inputs provided is not within the specified limit
ERR_INVALID_SLAVE_ID	If the slave ID is not valid
ERR_MEM_ALLOC	If the memory allocation fail
ERR_SLAVE_ID_MISMATCH	If master receives a response from another slave (not from the requested slave)
ERR_CRC_CHECK	If CRC validation fails for RTU stack mode
ERR_LRC_CHECK	If LRC validation fails for ASCII stack mode
ERR_FUN_CODE_MISMATCH	If master receives a response for another function code(not for the requested function code)
ERR_ILLEGAL_FUNCTION	If the function code is invalid or if function code is disabled in the stack
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid

【Explanation】

This API is used to read data from discrete input when requested. If this API returns an error, the data field in the response structure will be invalid.

・Structure of read inputs request (req_read_inputs_t)

```
typedef struct _req_read_inputs{
    uint16_t    u16_transaction_id;     /* Specifies the transaction ID */
    uint16_t    u16_protocol_id;        /* Specifies the protocol ID */
    uint8_t     u8_slave_id;            /* Identification of a remote slave connected */
    uint16_t    u16_start_addr;         /* Specifies address of the first discrete input */
    uint16_t    u16_num_of_inputs;      /* Specifies the number of discrete inputs to be read */
}req_read_inputs_t, *p_req_read_inputs_t;
```

・Structure of read inputs response (resp_read_inputs_t)

```
typedef struct _resp_read_inputs{
    uint16_t    u16_transaction_id;     /* Specifies the transaction ID */
    uint16_t    u16_protocol_id;        /* Specifies the protocol ID */
    uint8_t     u8_slave_id;            /* Identification of a remote slave connected */
    uint8_t     u8_exception_code;      /* Error detected during processing the request. On
                                           success the exception code should  be zero, if the
                                           exception code is non zero the aru8_data will be null */
    uint8_t     u8_num_of_bytes;        /* Specifies the number of bytes of data */
    uint8_t     aru8_data[MAX_DISCRETE_DATA]; /* Buffer to store the read data */
}resp_read_inputs_t, *p_resp_read_inputs_t;
```

Modbus_read_holding_registers	Modbus read holding registers.

【Format】

```
uint32_t Modbus_read_holding_registers(p_req_read_holding_reg_t pt_req_read_holding_reg,
                                       p_resp_read_holding_reg_t pt_resp_read_holding_reg,
                                       fp_callback_notify_t fp_callback_notify);
```

【Parameter】

p_req_read_holding_reg_t	pt_req_read_holding_reg	Structure pointer to read holding reg. request
p_resp_read_holding_reg_t	pt_resp_read_holding_reg	Structure pointer to read holding reg. response
fp_callback_notify_t	fp_callback_notify	Function pointer argument for the call back notification in non blocking API mode. If this argument is set to NULL API become blocking.

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	If holding register read successful
ERR_SYSTEM_INTERNAL	For mailbox send or receive failure
ERR_ILLEGAL_NUM_OF_REG	If the number of registers provided is not within the specified limit
ERR_INVALID_SLAVE_ID	If the slave ID is not valid
ERR_MEM_ALLOC	If the memory allocation fail
ERR_SLAVE_ID_MISMATCH	If master receives a response from another slave (not from the requested slave)
ERR_CRC_CHECK	If CRC validation fails for RTU stack mode
ERR_LRC_CHECK	If LRC validation fails for ASCII stack mode
ERR_FUN_CODE_MISMATCH	If master receives a response for another function code(not for the requested function code)
ERR_ILLEGAL_FUNCTION	If the function code is invalid or if function code is disabled in the stack
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid

【Explanation】

This API is used to read data from holding registers when requested. If this API returns an error, the data field in the response structure will be invalid.

・Structure of read holding registers request (req_read_holding_reg_t)

```
typedef struct _req_read_holding_reg{
    uint16_t    u16_transaction_id;     /* Specifies the transaction ID */
    uint16_t    u16_protocol_id;        /* Specifies the protocol ID */
    uint8_t     u8_slave_id;            /* Identification of a remote slave connected */
    uint16_t    u16_start_addr;         /* Specifies address of the first holding register */
    uint16_t    u16_num_of_regs;        /* Specifies the number of registers to be read */
}req_read_holding_reg_t, *p_req_read_holding_reg_t;
```

・Structure of read holding registers response (resp_read_holding_reg_t)

```
typedef struct _resp_read_holding_reg{
    uint16_t    u16_transaction_id;     /* Specifies the transaction ID */
    uint16_t    u16_protocol_id;        /* Specifies the protocol ID */
    uint8_t     u8_slave_id;            /* Identification of a remote slave connected */
    uint8_t     u8_exception_code;      /* error detected during processing the request. On success
                                           the exception code should  be zero, if the exception code is
                                           non zero the aru16_data will be null */
    uint8_t     u8_num_of_bytes;        /* specifies the number of bytes of data */
    uint16_t    aru16_data[MAX_REG_DATA];   /* buffer to store the read data */
}resp_read_holding_reg_t, p_resp_read_holding_reg_t;
```

Modbus_read_input_registers	Modbus read input registers.

【Format】

```
uint32_t Modbus_read_input_registers(p_req_read_input_reg_t pt_req_read_input_reg,
                                     p_resp_read_input_reg_t pt_resp_read_input_reg,
                                     fp_callback_notify_t fp_callback_notify);
```

【Parameter】

p_req_read_input_reg_t	pt_req_read_input_reg	Structure pointer to read input reg. request
p_resp_read_input_reg_t	pt_resp_read_input_reg	Structure pointer to read input reg. response
fp_callback_notify_t	fp_callback_notify	Function pointer argument for the call back notification in non blocking API mode. If this argument is set to NULL API become blocking.

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	If input register read successful
ERR_SYSTEM_INTERNAL	For mailbox send or receive failure
ERR_ILLEGAL_NUM_OF_REG	If the number of registers provided is not within the specified limit
ERR_INVALID_SLAVE_ID	If the slave ID is not valid
ERR_MEM_ALLOC	If the memory allocation fail
ERR_SLAVE_ID_MISMATCH	If master receives a response from another slave (not from the requested slave)
ERR_CRC_CHECK	If CRC validation fails for RTU stack mode
ERR_LRC_CHECK	If LRC validation fails for ASCII stack mode
ERR_FUN_CODE_MISMATCH	If master receives a response for another function code(not for the requested function code)
ERR_ILLEGAL_FUNCTION	If the function code is invalid or if function code is disabled in the stack
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid

【Explanation】

This API is used to read data from input registers when requested. If this API returns an error, the data field in the response structure will be invalid.

・Structure of read input registers request (req_read_input_reg_t)

```
typedef struct _req_read_input_reg{
    uint16_t    u16_transaction_id;     /* Specifies the transaction ID */
    uint16_t    u16_protocol_id;        /* Specifies the protocol ID */
    uint8_t     u8_slave_id;            /* Identification of a remote slave connected */
    uint16_t    u16_start_addr;         /* Specifies address of the first input register */
    uint16_t    u16_num_of_regs;        /* Specifies the number of registers to be read */
}req_read_input_reg_t, *p_req_read_input_reg_t;
```

・Structure of read input registers response (resp_read_input_reg_t)

```
typedef struct _resp_read_input_reg{
    uint16_t    u16_transaction_id;     /* Specifies the transaction ID */
    uint16_t    u16_protocol_id;        /* Specifies the protocol ID */
    uint8_t     u8_slave_id;            /* Identification of a remote slave connected */
    uint8_t     u8_exception_code;      /* Error detected during processing the request. On success
                                           the exception code should be zero, if the exception code is
                                           non zero the aru16_data will be null */
    uint8_t     u8_num_of_bytes;        /* Specifies the number of bytes of data */
    uint16_t    aru16_data[MAX_REG_DATA]; /* Buffer to store the read data */
}resp_read_input_reg_t, p_resp_read_input_reg_t;
```

Modbus_write_single_coil	Modbus write single coil

【Format】

```
uint32_t Modbus_write_single_coil(p_req_write_single_coil_t pt_req_write_single_coil,
                                  p_resp_write_single_coil_t  pt_resp_write_single_coil,
                                  fp_callback_notify_t fp_callback_notify);
```

【Parameter】

p_req_write_single_coil_t	pt_req_write_single_coil	Structure pointer to write single coil request
p_resp_write_single_coil_t	pt_resp_write_single_coil	Structure pointer to write single coil response
fp_callback_notify_t	fp_callback_notify	Function pointer argument for the call back notification in non blocking API mode. If this argument is set to NULL API become blocking.

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	If single coil write is successful
ERR_SYSTEM_INTERNAL	For mailbox send or receive failure
ERR_ILLEGAL_OUTPUT_VALUE	If the value of the registers is invalid
ERR_INVALID_SLAVE_ID	If the slave ID is not valid
ERR_MEM_ALLOC	If the memory allocation fail
ERR_SLAVE_ID_MISMATCH	If master receives a response from another slave (not from the requested slave)
ERR_CRC_CHECK	If CRC validation fails for RTU stack mode
ERR_LRC_CHECK	If LRC validation fails for ASCII stack mode
ERR_FUN_CODE_MISMATCH	If master receives a response for another function code(not for the requested function code)
ERR_ILLEGAL_FUNCTION	If the function code is invalid or if function code is disabled in the stack
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid

【Explanation】

This API is used to write data to single coil when requested.

・Structure of write single coil request (req_write_single_coil_t)

```
typedef struct _req_write_single_coil
    uint16_t    u16_transaction_id;     /* Specifies the transaction ID */
    uint16_t    u16_protocol_id;        /* Specifies the protocol ID */
    uint8_t     u8_slave_id;            /* Identification of a remote slave connected */
    uint16_t    u16_output_addr;        /* Specifies address of the coil */
    uint16_t    u16_output_value;       /* Data to be written */
}req_write_single_coil_t, *p_req_write_single_coil_t;
```

・Structure of write single coil response (resp_write_single_coil_t)

```
typedef struct _resp_write_single_coil{
    uint16_t    u16_transaction_id;     /* Specifies the transaction ID */
    uint16_t    u16_protocol_id;        /* Specifies the protocol ID */
    uint8_t     u8_slave_id;            /* Identification of a remote slave connected */
    uint8_t     u8_exception_code;      /* Error detected during processing the request. On success the
                                           exception code should be zero */
    uint16_t    u16_output_addr;        /* Specifies address of the coil */
    uint16_t    u16_output_value;       /* Data to be written */
}resp_write_single_coil_t, *p_resp_write_single_coil_t;
```

Modbus_write_single_reg	Modbus write single register

【Format】

```
uint32_t Modbus_write_single_reg(p_req_write_single_reg_t  pt_req_write_single_reg,
                                 p_resp_write_single_reg_t  pt_resp_write_single_reg,
                                 fp_callback_notify_t  fp_callback_notify);
```

【Parameter】

p_req_write_single_reg_t	pt_req_write_single_reg	Structure pointer to write single reg. request
p_resp_write_single_reg_t	pt_resp_write_single_reg	Structure pointer to write single reg. response
fp_callback_notify_t	fp_callback_notify	Function pointer argument for the call back notification in non blocking API mode. If this argument is set to NULL API become blocking.

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	If single register write is successful
ERR_SYSTEM_INTERNAL	For mailbox send or receive failure
ERR_INVALID_SLAVE_ID	If the slave ID is not valid
ERR_MEM_ALLOC	If the memory allocation fail
ERR_SLAVE_ID_MISMATCH	If master receives a response from another slave (not from the requested slave)
ERR_CRC_CHECK	If CRC validation fails for RTU stack mode
ERR_LRC_CHECK	If LRC validation fails for ASCII stack mode
ERR_FUN_CODE_MISMATCH	If master receives a response for another function code(not for the requested function code)
ERR_ILLEGAL_FUNCTION	If the function code is invalid or if function code is disabled in the stack
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid

【Explanation】

This API is used to write data to single register when requested.

・Structure of write single register request (req_write_single_reg_t)

```
typedef struct _req_write_single_reg{
    uint16_t    u16_transaction_id;    /* Specifies the transaction ID */
    uint16_t    u16_protocol_id;       /* Specifies the protocol ID */
    uint8_t     u8_slave_id;           /* Identification of a remote slave connected */
    uint16_t    u16_register_addr;     /* Specifies address of the register */
    uint16_t    u16_register_value;    /* Data to be written */
}req_write_single_reg_t, *p_req_write_single_reg_t;
```

・Structure of write single register response (resp_write_single_reg_t)

```
typedef struct _resp_write_single_reg{
    uint16_t    u16_transaction_id;    /* Specifies the transaction ID */
    uint16_t    u16_protocol_id;       /* Specifies the protocol ID */
    uint8_t     u8_slave_id;           /* Identification of a remote slave connected */
    uint8_t     u8_exception_code;     /* Error detected during processing the request. On success the
                                          exception code should be zero */
    uint16_t    u16_register_addr;     /* Specifies address of the register */
    uint16_t    u16_register_value;    /* Data to be written */
}resp_write_single_reg_t, *p_resp_write_single_reg_t;
```

Modbus_write_multiple_coils	Modbus write multiple coils

【Format】

uint32_t Modbus_write_multiple_coils(p_req_write_multiple_coils_t pt_req_write_multiple_coils,
p_resp_write_multiple_coils_t pt_resp_write_multiple_coils,
fp_callback_notify_t fp_callback_notify);

【Parameter】

p_req_write_multiple_coils_t	pt_req_write_multiple_coils	Structure pointer to write multiple coils request
p_resp_write_multiple_coils_t	pt_resp_write_multiple_coils	Structure pointer to write multiple coils response
fp_callback_notify_t	fp_callback_notify	Function pointer argument for the call back notification in non blocking API mode. If this argument is set to NULL API become blocking.

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	If write multiple coil write successful
ERR_SYSTEM_INTERNAL	For mailbox send or receive failure
ERR_ILLEGAL_NUM_OF_OUTPUTS	If the number of outputs is invalid
ERR_INVALID_SLAVE_ID	If the slave ID is not valid
ERR_MEM_ALLOC	If the memory allocation fail
ERR_SLAVE_ID_MISMATCH	If master receives a response from another slave (not from the requested slave)
ERR_CRC_CHECK	If CRC validation fails for RTU stack mode
ERR_LRC_CHECK	If LRC validation fails for ASCII stack mode
ERR_FUN_CODE_MISMATCH	If master receives a response for another function code(not for the requested function code)
ERR_ILLEGAL_FUNCTION	If the function code is invalid or if function code is disabled in the stack
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid

【Explanation】

This API is used to write data to multiple coils when requested.

・Structure of write multiple coils request (req_write_multiple_coils_t)

```
typedef struct _req_write_single_reg{
    uint16_t    u16_transaction_id;          /* Specifies the transaction ID */
    uint16_t    u16_protocol_id;             /* Specifies the protocol ID */
    uint8_t     u8_slave_id;                 /* Identification of a remote slave connected */
    uint16_t    u16_start_addr;              /* Specifies address of the first coil */
    uint16_t    u16_num_of_outputs;          /* Specifies the number of coils to be written */
    uint8_t     u8_num_of_bytes;             /* Specifies the number of bytes of data */
    uint8_t     aru8_data[MAX_DISCRETE_DATA]; /* Data to be written */
}req_write_single_reg_t, *p_req_write_single_reg_t;
```

・Structure of write multiple coils response (resp_write_multiple_coils_t)

```
typedef struct _resp_write_multiple_coils{
    uint16_t    u16_transaction_id;          /* Specifies the transaction ID */
    uint16_t    u16_protocol_id;             /* Specifies the protocol ID */
    uint8_t     u8_slave_id;                 /* Identification of a remote slave connected */
    uint8_t     u8_exception_code;           /* Error detected during processing the request. On
                                                success the exception code should be zero */
    uint16_t    u16_start_addr;              /* Specifies address of the coils */
    uint16_t    u16_num_of_outputs;          /* Specifies the number of coils to be written */
}resp_write_multiple_coils_t, *p_resp_write_multiple_coils_t;
```

Modbus_write_multiple_reg	Modbus write multiple registers

【Format】

```
uint32_t Modbus_write_multiple_reg(p_req_write_multiple_reg_t pt_req_write_multiple_reg,
                                   p_resp_write_multiple_reg_t pt_resp_write_multiple_reg,
                                   fp_callback_notify_t fp_callback_notify);
```

【Parameter】

p_req_write_multiple_reg_t	pt_req_write_multiple_reg	Structure pointer to write multiple reg. request
p_resp_write_multiple_reg_t	pt_resp_write_multiple_reg	Structure pointer to write multiple reg. response
fp_callback_notify_t	fp_callback_notify	Function pointer argument for the call back notification in non blocking API mode. If this argument is set to NULL API become blocking.

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	If write multiple register write successful
ERR_SYSTEM_INTERNAL	For mailbox send or receive failure
ERR_ILLEGAL_NUM_OF_REG	If the number of registers is invalid
ERR_INVALID_SLAVE_ID	If the slave ID is not valid
ERR_MEM_ALLOC	If the memory allocation fail
ERR_SLAVE_ID_MISMATCH	If master receives a response from another slave (not from the requested slave)
ERR_CRC_CHECK	If CRC validation fails for RTU stack mode
ERR_LRC_CHECK	If LRC validation fails for ASCII stack mode
ERR_FUN_CODE_MISMATCH	If master receives a response for another function code(not for the requested function code)
ERR_ILLEGAL_FUNCTION	If the function code is invalid or if function code is disabled in the stack
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid

【Explanation】

This API is used to write data to multiple registers when requested.

・Structure of write multiple registers request (req_write_multiple_reg_t)

```
typedef struct _req_write_multiple_reg{
    uint16_t    u16_transaction_id;          /* Specifies the transaction ID */
    uint16_t    u16_protocol_id;             /* Specifies the protocol ID */
    uint8_t     u8_slave_id;                 /* Identification of a remote slave connected */
    uint16_t    u16_start_addr;              /* Specifies address of the first register */
    uint16_t    u16_num_of_reg;              /* Specifies the number of registers to be written */
    uint8_t     u8_num_of_bytes;             /* Specifies the number of bytes of data */
    uint16_t    aru16_data[MAX_REG_DATA];    /* Data to be written */
}req_write_multiple_reg_t, *p_req_write_multiple_reg_t;
```

・Structure of write multiple registers response (resp_write_multiple_reg_t)

```
typedef struct _resp_write_multiple_reg{
    uint16_t    u16_transaction_id;          /* Specifies the transaction ID */
    uint16_t    u16_protocol_id;             /* Specifies the protocol ID */
    uint8_t     u8_slave_id;                 /* Identification of a remote slave connected */
    uint8_t     u8_exception_code;           /* Error detected during processing the request. On success the
                                                exception code should be zero */
    uint16_t    u16_start_addr;              /* Specifies address of the first register */
    uint16_t    u16_num_of_reg;              /* Specifies the number of registers to be written */
}resp_write_multiple_reg_t, *p_resp_write_multiple_reg_t;
```

Modbus_read_write_multiple_reg	Modbus read and write multiple registers

【Format】

uint32_t Modbus_read_write_multiple_reg(p_req_read_write_multiple_reg_t pt_req_read_write_multiple_reg,
p_resp_read_write_multiple_reg_t pt_resp_read_write_multiple_reg,
fp_callback_notify_t fp_callback_notify);

【Parameter】

p_req_read_write_multiple_reg_t	pt_req_read_write_multiple_reg	Structure pointer to read and write multiple reg request
p_resp_read_write_multiple_reg_t	pt_resp_read_write_multiple_reg	Structure pointer to read and write multiple reg response
fp_callback_notify_t	fp_callback_notify	Function pointer argument for the call back notification in non blocking API mode. If this argument is set to NULL API become blocking.

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	If read/write multiple register is successful
ERR_SYSTEM_INTERNAL	For mailbox send or receive failure
ERR_ILLEGAL_OUTPUT_VALUE	If the value of the registers is invalid
ERR_INVALID_SLAVE_ID	If the slave ID is not valid
ERR_MEM_ALLOC	If the memory allocation fail
ERR_SLAVE_ID_MISMATCH	If master receives a response from another slave (not from the requested slave)
ERR_CRC_CHECK	If CRC validation fails for RTU stack mode
ERR_LRC_CHECK	If LRC validation fails for ASCII stack mode
ERR_FUN_CODE_MISMATCH	If master receives a response for another function code(not for the requested function code)
ERR_ILLEGAL_FUNCTION	If the function code is invalid or if function code is disabled in the stack
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid

【Explanation】

This API is used to read and write data to multiple registers when requested. If this API returns an error, the data field in the response structure will be invalid.

・Structure of read and write multiple registers request (req_read_write_multiple_reg_t)

```
typedef struct _req_read_write_multiple_reg{
    uint16_t    u16_transaction_id;          /* Specifies the transaction ID */
    uint16_t    u16_protocol_id;             /* Specifies the protocol ID */
    uint8_t     u8_slave_id;                 /* Identification of a remote slave connected */
    uint16_t    u16_read_start_addr;         /* Specifies address of the first register to be read from */
    uint16_t    u16_num_to_read;             /* Specifies the number of registers to be read */
    uint16_t    u16_write_start_addr;        /* Specifies address of the first register to be written */
    uint16_t    u16_num_to_write;            /* Specifies the number of registers to be written */
    uint8_t     u8_write_num_of_bytes;       /* Specifies the number of bytes of data */
    uint16_t    aru16_data[MAX_REG_DATA];    /* Data to be written */
}req_read_write_multiple_reg_t, *p_req_read_write_multiple_reg_t;
```

・Structure of read and write multiple registers response (resp_read_write_multiple_reg_t)

```
typedef struct _resp_read_write_multiple_reg{
    uint16_t    u16_transaction_id;          /* Specifies the transaction ID */
    uint16_t    u16_protocol_id;             /* Specifies the protocol ID */
    uint8_t     u8_slave_id;                 /* Identification of a remote slave connected */
    uint8_t     u8_exception_code;           /* Error detected during processing the request. On
                                                success the exception code should  be zero, if the
                                                exception code is non zero the aru16_read_data will be
                                                null */
    uint16_t    u8_num_of_bytes;             /* Specifies the number of complete bytes of data */
    uint16_t    aru16_read_data[MAX_REG_DATA];  /* Data to be read */
}resp_read_write_multiple_reg_t, *p_resp_read_write_multiple_reg_t;
```

Modbus_callback_notify	Call back function for notification

【Format】

void Modbus_callback_notify(uint32_t u32_resp_code);

【Parameter】

uint32_t	u32_resp_code	Response code

【Return value】

void_t

【Error code】

—

【Explanation】

This is the default call back function invoked by the master stack if the caller has not registered their own call back handler. It is only applicable in master mode configuration of Modbus stack.

Stack invokes the registered call back function when read/write request get response from slave side.

5.1.2.3 Task

The following function is the main processing of task.

Modbus_serial_task	Modbus serial task

【Format】

```
void_t Modbus_serial_task(void_t);
```

【Parameter】

void_t

【Return value】

void_t

【Error code】

—

【Explanation】

This task runs either as slave task or as master task depending on the stack mode when the stack is in master mode, this task waits for a request from the user. Validate the information provided by the user. If validation is successful, frame the packet and send the packet to the slave device. It waits for the response from the slave. If the callback is provided by the user, task invokes the callback when the response data is received.

When the stack is in slave mode, this task waits for a request. If so process the packet and send the response.

Modbus_serial_recv_task	Modbus serial receive task

【Format】

```
void_t Modbus_serial_recv_task(void_t);
```

【Parameter】

void_t

【Return value】

void_t

【Error code】

—

【Explanation】

This task is used for receiving character from UART. Watching each interrupt event that was registered in hardware ISR, invoke the process according to the event that occurred.

When the UART receive interrupt is detected, read the received data from the UART, and invoke buffering process corresponding to the RTU / ASCII each mode.

When the UART status interrupt is detected, invoke driver function for UART status interrupt. Please refer to “User’s manual (Peripheral function edition)” for UART status interrupt details.

When the Timer interrupt is detected, invoke the buffering stop process.

Modbus_serial_stack_terminate	Modbus terminate serial stack API

【Format】

uint32_t Modbus_serial_stack_terminate(void_t);

【Parameter】

void_t

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On successful
ERR_STACK_TERM	if termination failed

【Explanation】

This API terminate MODBUS serial stack.

5.2 Internal API

This chapter explains the interface of the API that is used internally.

5.2.1 Packet Framing and Parsing API

5.2.1.1 Serial Connection Management

The following API has been used in the packet processing of serial communication.

Modbus_serial_frame_pkt	Modbus serial frame packet	

【Format】

```
void_t Modbus_serial_frame_pkt(puint8_t  pu8_mb_snd_pkt,
                               puint32_t pu32_snd_pkt_len,
                               p_mbserial_queue_elmnt_t pt_mbserial_queue_elmnt);
```

【Parameter】

puint8_t	pu8_mb_snd_pkt	Pointer to the array storing packet to be send
puint32_t	pu32_snd_pkt_len	Length of the packet framed
pt_mbserial_queue_elmnt	pt_mbserial_queue_elmnt	Structure pointer containing user information

【Return value】

void_t

【Error code】

—

【Explanation】

This function frames a packet with the information provided by the user application. Depending on the mode of the stack, structure is passed to corresponding functions.

For master mode, Modbus_master_frame_request() is invoked. Similarly for slave mode, Modbus_slave_frame_response() is invoked, and then collect the necessary information.

For RTU mode, Modbus_rtu_frame_pkt() is invoked. Similarly for ASCII mode, ,Modbus_ascii_frame_pkt() is invoked, and generate a packet.

・Structure of serial packet queue (mbserial_queue_elmnt_t)

```
typedef struct _mbserial_queue_elmnt{
    fp_callback_notify_t    fpt_callback_notify;            /* Function pointer for the call back
                                                               notification in non blocking API mode.If this
                                                               argument is set to NULL then it is in blocking
                                                               mode. */
    void*                   pu8_output_response;            /* Pointer to the response structure from the
                                                               API */
    void*                   pu8_input_request;              /* Pointer to the request structure from the
                                                               API */
    uint32_t                u32_num_of_bytes;               /* Specifies the number of bytes in the data
                                                               packet field */
    uint8_t                 aru8_data_packet[MAX_DATA_SIZE]; /* Contains the data provided by the user
                                                               application */
    uint8_t                 u8_cmd_mode;                    /* Contains whether the stack is in unicast or
                                                               broadcast mode */
    uint8_t                 u8_slave_id;                    /* Contains slave id in the request */
    uint8_t                 u8_func_code;                   /* Contains function code in the request */
}mbserial_queue_elmnt_t, *p_mbserial_queue_elmnt_t;
```

This structure is the following macro is used.

Packet processing mode	Meaning
UNICAST_MODE	This packet is processed as a Unicast packet
BROADCAST_MODE	This packet is processed as a Broadcast packet

Modbus_rtu_frame_pkt	Modbus RTU frame packet

【Format】

```
void_t Modbus_rtu_frame_pkt(puint8_t  pu8_mb_snd_pkt,
                            puint32_t pu32_snd_pkt_len,
                            p_mbserial_queue_elmnt_t pt_mbserial_queue_elmnt);
```

【Paramter】

puint8_t	pu8_mb_snd_pkt	Pointer to the array storing packet to be send
puint32_t	pu32_snd_pkt_len	Length of the packet framed
pt_mbserial_queue_elmnt	pt_mbserial_queue_elmnt	Structure pointer containing user information

【Return value】

void_t

【Error code】

—

【Explanation】

This function frames a packet for RTU device with the information provided by the user application. For calculating CRC, calculate_crc() is used.

Modbus_ascii_frame_pkt	Modbus ASCII frame packet

【Format】

```
void_t Modbus_ascii_frame_pkt(puint8_t  pu8_mb_snd_pkt,
                              puint32_t   pu32_snd_pkt_len,
                              p_mbserial_queue_elmnt_t  pt_mbserial_queue_elmnt);
```

【Parameter】

puint8_t	pu8_mb_snd_pkt	Pointer to the array storing packet to be send
puint32_t	pu32_snd_pkt_len	Length of the packet framed
pt_mbserial_queue_elmnt	pt_mbserial_queue_elmnt	Structure pointer containing user information

【Return value】

void_t

【Error code】

—

【Explanation】

This function frames a packet for ASCII device with the information provided by the user application. For calculating LRC, calculate_lrc() is used.

Modbus_serial_send_pkt	Modbus serial send packet

【Format】

```
void_t Modbus_serial_send_pkt(puint8_t pu8_mb_snd_pkt,
                              uint32_t u32_snd_pkt_len);
```

【Parameter】

puint8_t	pu8_mb_snd_pkt	Pointer to the MODBUS send packet array
uint32_t	u32_snd_pkt_len	Length of the MODBUS send packet

【Return value】

void_t

【Error code】

—

【Explanation】

This function is the wrapper function of Modbus_serial_send ().

Modbus_serial_send	Modbus serial send packet

【Format】

```
void_t Modbus_serial_send(puint8_t u8_mb_snd_pkt,
                          uint32_t u32_snd_pkt_len);
```

【Parameter】

puint8_t	pu8_mb_snd_pkt	Pointer to the MODBUS send packet array
uint32_t	u32_snd_pkt_len	Length of the MODBUS send packet

【Return value】

void_t

【Error code】

—

【Explanation】

This function sends the prepared packet through UART. During transmission, by RS485 control function that has been registered in the stack initialization function, communication direction is switched to the sender.

Modbus_serial_parse_pkt	MODBUS serial parse packet

【Format】

```
uint32_t Modbus_serial_parse_pkt(puint8_t pu8_mb_recv_pkt,
                                 puint32_t  pu32_recv_pkt_len,
                                 p_mbserial_queue_elmnt_t  pt_mbserial_queue_elmnt);
```

【Parameter】

puint8_t	pu8_mb_recv_pkt	Pointer to the Modbus receive packet array.
uint32_t	u32_recv_pkt_len	Length of the Modbus receive packet
p_mbserial_queue_elmnt_t	pt_mbserial_queue_elmnt	Structure pointer that contains information to be provided to the user

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On parsing of packet received is successful
ERR_MEM_ALLOC	If memory allocation fails
ERR_SLAVE_ID_MISMATCH	If master receives a response from another slave (not from the requested slave)
ERR_CRC_CHECK	If CRC validation fails for RTU stack mode
ERR_LRC_CHECK	If LRC validation fails for ASCII stack mode
ERR_FUN_CODE_MISMATCH	If master receives a response for another function code(not for the requested function code)
ERR_ILLEGAL_FUNCTION	If the function code is invalid or if function code is disabled in the stack
ERR_INVALID_SLAVE_ID	If the slave ID is invalid
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid
ERR_OK_WITH_NO_RESPONSE	Return status for broadcast requests

【Explanation】

This function parses the received packet and updates the structure that contains information to be provided to the user.

Depending on the mode of the stack, the corresponding functions are invoked. For RTU, Modbus_rtu_parse_pkt() is invoked. Similarly for ASCII, Modbus_ascii_parse_pkt() is invoked.

Modbus_rtu_parse_pkt	Modbus RTU parse packet

【Format】

```
uint32_t Modbus_rtu_parse_pkt(puint8_t  pu8_mb_recv_pkt,
                              puint32_t   pu32_recv_pkt_len,
                              p_mbserial_queue_elmnt_t   pt_mbserial_queue_elmnt);
```

【Parameter】

puint8_t	pu8_mb_recv_pkt	Pointer to the Modbus receive packet array
uint32_t	pu32_recv_pkt_len	Length of the Modbus receive packet
p_mbserial_queue_elmnt_t	pt_mbserial_queue_elmnt	Structure pointer that contains information to be provided to the user

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On parsing of packet received is successful
ERR_MEM_ALLOC	If memory allocation fails
ERR_SLAVE_ID_MISMATCH	If master receives a response from another slave (not from the requested slave)
ERR_FUN_CODE_MISMATCH	If master receives a response for another function code(not for the requested function code)
ERR_CRC_CHECK	Validation fails for RTU stack mode
ERR_ILLEGAL_FUNCTION	If the function code is invalid or if function code is disabled in the stack
ERR_INVALID_SLAVE_ID	If the slave ID is invalid
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid
ERR_OK_WITH_NO_RESPONSE	Return status for broadcast requests

【Explanation】

This API parses the packet received from UART. Depending on the mode of the stack, Modbus_master_parse_pkt() is invoked for master mode, Modbus_slave_parse_pkt() is invoked for slave mode.

Modbus_ascii_parse_pkt	Modbus ASCII parse packet

【Format】

```
uint32_t Modbus_ascii_parse_pkt (puint8_t pu8_mb_recv_pkt,
                                 puint32_t pu32_recv_pkt_len,
                                 p_mbserial_queue_elmnt_t pt_mbserial_queue_elmnt);
```

【Parameter】

puint8_t	pu8_mb_recv_pkt	Pointer to the Modbus receive packet array
uint32_t	pu32_recv_pkt_len	Length of the Modbus receive packet
p_mbserial_queue_elmnt_t	pt_mbserial_queue_elmnt	Structure pointer that contains information to be provided to the user

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On parsing of packet received is successful
ERR_MEM_ALLOC	If memory allocation fails
ERR_SLAVE_ID_MISMATCH	If master receives a response from another slave (not from the requested slave)
ERR_FUN_CODE_MISMATCH	If master receives a response for another function code(not for the requested function code)
ERR_CRC_CHECK	Validation fails for RTU stack mode
ERR_ILLEGAL_FUNCTION	If the function code is invalid or if function code is disabled in the stack
ERR_INVALID_SLAVE_ID	If the slave ID is invalid
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid
ERR_OK_WITH_NO_RESPONSE	Return status for broadcast requests

【Explanation】

This API parses the packet received from UART. In this function, after converting the specified ASCII packet to RTU packet, call each packet analysis APIs corresponding to the stack mode.

Modbus_master_parse_pkt	Modbus Master parse packet

【Format】

```
uint32_t Modbus_master_parse_pkt(puint8_t   pu8_mb_recv_pkt,
                                 puint32_t   pu32_recv_pkt_len,
                                 p_mbserial_queue_elmnt_t   pt_mbserial_queue_elmnt);
```

【Parameter】

puint8_t	pu8_mb_recv_pkt	Pointer to the Modbus receive packet array
uint32_t	pu32_recv_pkt_len	Length of the Modbus receive packet
p_mbserial_queue_elmnt_t	pt_mbserial_queue_elmnt	Structure pointer that contains information to be provided to the user

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On parsing of packet received is successful
ERR_SLAVE_ID_MISMATCH	If master receives a response from another slave (not from the requested slave)
ERR_FUN_CODE_MISMATCH	If master receives a response for another function code(not for the requested function code)
ERR_LRC_CHECK	If LRC validation fails for ASCII master stack mode
ERR_CRC_CHECK	If CRC validation fails for RTU master stack mode
ERR_ILLEGAL_FUNCTION	If the function code is invalid or if function code is disabled in the stack
ERR_INVALID_SLAVE_ID	If the slave ID is invalid
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid

【Explanation】

This API parses the packet received from UART. The structure that contains information to be provided to the user is updated.

Modbus_slave_parse_pkt	Modbus Slave parse packet

【Format】

```
uint32_t Modbus_slave_parse_pkt(puint8_t  pu8_mb_recv_pkt,
                                puint32_t   pu32_recv_pkt_len,
                                p_mbserial_queue_elmnt_t   pt_mbserial_queue_elmnt);
```

【Parameter】

puint8_t	pu8_mb_recv_pkt	Pointer to the Modbus receive packet array
uint32_t	pu32_recv_pkt_len	Length of the Modbus receive packet
p_mbserial_queue_elmnt_t	pt_mbserial_queue_elmnt	Structure pointer that contains information to be provided to the user

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On parsing of packet received is successful
ERR_LRC_CHECK	If LRC validation fails for ASCII slave stack mode
ERR_CRC_CHECK	If CRC validation fails for RTU slave stack mode
ERR_ILLEGAL_FUNCTION	If the function code is invalid or if function code is disabled in the stack
ERR_INVALID_SLAVE_ID	If the slave ID is invalid
ERR_MEM_ALLOC	If memory allocation fails
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid
ERR_OK_WITH_NO_RESPONSE	Return status for broadcast requests

【Explanation】

This API parse the specified packet, perform the callback function corresponding to each function code that the user has registered. After callback perform, API updates the structure of serial queue(pt_mbserial_queue_elmnt) based on the execution results. In this function, dynamically allocate memory request and response table for each callback perform. Request table will be released within this function, but response table will be released at the stage of generating a response packet.

Modbus_master_validate_pkt	Modbus master validate packet

【Format】

uint32_t Modbus_master_validate_pkt(p_mbserial_queue_elmnt_t pt_mbserial_queue_elmnt);

【Paramter】

p_mbserial_queue_elmnt_t	pt_mbserial_queue_elmnt	Structure pointer that contains information to be provided to the user

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On parsing of packet received is successful
ERR_SLAVE_ID_MISMATCH	If master receives a response from another slave (not from the requested slave)
ERR_FUN_CODE_MISMATCH	If master receives a response for another function code(not for the requested function code)
ERR_LRC_CHECK	If LRC validation fails for ASCII slave stack mode
ERR_CRC_CHECK	If CRC validation fails for RTU slave stack mode
ERR_ILLEGAL_FUNCTION	If the function code is invalid or if function code is disabled in the stack
ERR_INVALID_SLAVE_ID	If the slave ID is invalid
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid

【Explanation】

This function validates the packet received from UART and returns error if validation fails. Slave ID and function code in the packet is verified in this function.

Modbus_slave_validate_pkt	Modbus slave validate packet

【Format】

uint32_t Modbus_slave_validate_pkt(p_mbserial_queue_elmnt_t pt_mbserial_queue_elmnt);

【Parameter】

p_mbserial_queue_elmnt_t	pt_mbserial_queue_elmnt	Structure pointer that contains information to be provided to the user

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On validation of packet received is successful
ERR_LRC_CHECK	If LRC validation fails for ASCII slave stack mode
ERR_CRC_CHECK	If CRC validation fails for RTU slave stack mode
ERR_ILLEGAL_FUNCTION	If the function code is invalid or if function code is disabled in the stack
ERR_INVALID_SLAVE_ID	If the slave ID is invalid
ERR_SLAVE_ID_MISMATCH	If the slave id in the request is not its own slave id or broadcast id
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid
ERR_OK_WITH_NO_RESPONSE	Return status for broadcast requests

【Explanation】

This function validates the packet received from UART and returns error if validation fails. Slave ID in the packet is verified in this function.

Modbus_master_frame_request	Modbus Master frame response

【Format】

void_t Modbus_master_frame_request(p_mbserial_queue_elmnt_t pt_mbserial_queue_elmnt);

【Parameter】

p_mbserial_queue_elmnt_t	pt_mbserial_queue_elmnt	Structure pointer that contains information to be provided to the user

【Return value】

void_t

【Error code】

—

【Explanation】

This function is invoked when the stack is in master mode. The mb_serial structure is updated using the information from response structure provided by the user Application.

Modbus_slave_frame_response	Modbus Slave frame response

【Format】

void_t Modbus_slave_frame_response(p_mbserial_queue_elmnt_t pt_mbserial_queue_elmnt);

【Parameter】

p_mbserial_queue_elmnt_t	pt_mbserial_queue_elmnt	Structure pointer containing user information

【Return value】

void_t

【Error code】

—

【Explanation】

This function is invoked when the stack is in slave mode. The mb_serial structure is updated using the information from response structure provided by the user Application.

Modbus_uart_write	Modbus uart write

【Format】

```
void_t Modbus_uart_write(puint8_t   pu8_mb_snd_data,
                         uint32_t   u32_data_size);
```

【Parameter】

puint8_t	pu8_mb_snd_data	Starting address of the data to be send
uint32_t	u32_data_size	Length of data to send in bytes

【Return value】

void_t

【Error code】

—

【Explanation】

This function writes the specified number of characters to the configured UART channel. It uses Renesas driver function - uart_write using the channel number defined by MB_UART_CHANNEL.

Modbus_uart_read	Modbus uart read

【Format】

```
uint32_t Modbus_uart_read(puint8_tpu8_mb_read_char);
```

【Parameter】

puint8_t	pu8_mb_read_char	Pointer to the location to read the 8bit character

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On successful.
ERR_UART_RECV_OPERATION	Read operation failed

【Explanation】

This function reads a single character from UART channel specified. It is a wrapper function to Renesas driver function - uart_read using the channel number defined by MB_UART_CHANNEL.

Modbus_rtu_crc_calculate	Modbus serial cyclic Redundancy check calculation

【Format】

```
uint32_t Modbus_rtu_crc_calculate(puint8_t pu8_mb_pkt,
                                  uint32_t u32_pkt_len);
```

【Parameter】

puint8_t	pu8_mb_pkt	Pointer to the Modbus packet array
uint32_t	u32_pkt_len	Length of the Modbus packet

【Return value】

uint32_t	Calculated CRC value

【Error code】

—

【Explanation】

This function calculates the CRC of the packet.

Modbus_rtu_crc_validate	Modbus serial cyclic Redundancy check validation

【Format】

```
uint32_t Modbus_rtu_crc_validate(puint8_t pu8_mb_pkt,
                                 uint32_t u32_pkt_len);
```

【Parameter】

puint8_t	pu8_mb_pkt	Pointer to the Modbus packet array
uint32_t	u32_pkt_len	Length of the Modbus packet

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	If validation of CRC is successful
ERR_CRC_CHECK	If validation fails

【Explanation】

This function validates the CRC of the received packet. The CRC of the received packet is calculated and compared with the value present in the packet. If both values are same, CRC validation is successful.

Modbus_ascii_lrc_calculate	Modbus serial longitudinal Redundancy check calculation

【Format】

```
uint8_t Modbus_ascii_lrc_calculate(puint8_t pu8_mb_pkt,
                                   uint32_t u32_pkt_len);
```

【Parameter】

puint8_t	pu8_mb_pkt	Pointer to the Modbus packet array
uint32_t	u32_pkt_len	Length of the Modbus packet

【Return value】

uint32_t	Calculated LRC value

【Error code】

—

【Explanation】

This function calculates the LRC of the packet.

Modbus_ascii_lrc_validate	Modbus serial longitudinal Redundancy check validation

【Format】

```
uint32_t Modbus_ascii_lrc_validate(puint8_t pu8_mb_pkt,
                                   uint32_t u32_pkt_len);
```

【Parameter】

puint8_t	pu8_mb_pkt	Pointer to the Modbus packet array
uint32_t	u32_pkt_len	Length of the Modbus packet

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On validation of LRC is successful
ERR_LRC_CHECK	If LRC validation fails for ASCII stack mode

【Explanation】

This function validates the LRC of the received packet. The LRC of the received packet is calculated and compared with the value present in the packet. If both values are same, LRC validation is successful.

Modbus_rtu_to_ascii	Modbus RTU to ASCII Conversion

【Format】

```
void_t Modbus_rtu_to_ascii(puint8_t  pu8_rtu_pkt,
                           uint32_t u32_rtu_pkt_size,
                           puint8_t pu8_ascii_pkt,
                           puint32_t pu32_ascii_pkt_size);
```

【Parameter】

puint8_t	pu8_rtu_pkt	Pointer to the input RTU array
uint32_t	u32_rtu_pkt_size	Number of bytes in the in the input RTU array
puint8_t	pu8_ascii_pkt	Pointer to the output ASCII array
puint32_t	pu32_ascii_pkt_size	Pointer to return number of bytes in the in the output ASCII array

【Return value】

void_t

【Error code】

—

【Explanation】

This function converts the modbus PDU in hex form to its ASCII values.

Modbus_ascii_to_rtu	Modbus ASCII to RTU Conversion

【Format】

```
void_t Modbus_ascii_to_rtu(puint8_t  pu8_ascii_pkt,
                           uint32_t u32_ascii_pkt_size,
                           puint8_t pu8_rtu_pkt,
                           puint32_t pu32_rtu_pkt_size);
```

【Parameter】

puint8_t	pu8_ascii_pkt	Pointer to the input ASCII array
uint32_t	u32_ascii_pkt_size	Number of bytes in the input ASCII array
puint8_t	pu8_rtu_pkt	Pointer to return the output RTU array
puint32_t	pu32_rtu_pkt_size	Pointer to return the number of bytes in the in the output RTU array

【Return value】

void_t

【Error code】

—

【Explanation】

This function converts the array of ASCII values to its equivalent hex values.

Modbus_RS485_TX_enable RS485 Transmit enable

【Format】

void_t Modbus_RS485_TX_enable(void_t);

【Parameter】

void_t

【Return value】

void_t

【Error code】

—

【Explanation】

This function switches RS485 transceiver to transmission mode.

Modbus_RS485_TX_disable RS485 Transmit disable

【Format】

void_t Modbus_RS485_TX_enable(void_t);

【Parameter】

void_t

【Return value】

void_t

【Error code】

—

【Explanation】

This function switches RS485 transceiver to reception mode.

Modbus_ascii_recv_char	Receive character for Modbus ASCII

【Format】

void_t Modbus_ascii_recv_char(uint8_t u8_read_char);

【Parameter】

uint8_t	u8_read_char	received character

【Return value】

void_t

【Error code】

—

【Explanation】

This function is responsible for buffering of the received data to Modbus ASCII mode. Buffering is done until process detects termination character or process gets the maximum number of characters (MAX_ASCII_PACKET_LEN). Upon detecting the termination character, the packet to each task depending on the stack mode will report to the effect that could be received.

When this function is invoked, the timer is started by specified Inter frame delay at stack initialization in order to measure non-communicate time.

Modbus_rtu_recv_char	Receive character for Modbus RTU

【Format】

void_t Modbus_rtu_recv_char(uint8_t u8_recv_char)

【Parameter】

uint8_t	u8_recv_char	received character

【Return value】

void_t

【Error code】

—

【Explanation】

This function is responsible for buffering of the received data to Modbus RTU mode. Buffering is done until process gets the maximum number of characters (MAX_RTU_PACKET_LEN). Termination decision of packets is done in the timer handler to detect the non-communication time.

When this function is invoked, the timer is started by specified Inter frame delay at stack initialization in order to measure non-communicate time.

Modbus_timer_handler	Timer handler

【Format】

void Modbus_timer_handler(void);

【Parameter】

void_t

【Return value】

void_t

【Error code】

—

【Explanation】

This function is invoked when the timer interrupt event has occurred in the serial data receive task.

For ASCII mode, reset the buffering process of the receiving data. If this function is invoked before the end character is detected, packet will be discarded.

For RTU mode, Stop buffering of the received data, according to the stack mode, it reports that the packet reception has been completed to each task.

5.2.1.2 TCP/IP Connection Management

The following API has been used in the TCP/IP packet processing.

Modbus_tcp_send_pkt	Modbus TCP send packet

【Format】

```
uint32_t Modbus_tcp_send_pkt(puint8_t pu8_mb_snd_pkt,
                             uint32_t u32_snd_pkt_len,
                             uint8_t u8_soc_id);
```

【Parameter】

puint8_t	pu8_mb_snd_pkt	Pointer to the Modbus send packet array
uint32_t	u32_snd_pkt_len	Length of the Modbus send packet
uint8_t	u8_soc_id	Socket ID to which the data is to be transmitted

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On successfully send the packet
ERR_SEND_FAIL	If packet sending failed

【Explanation】

This API writes the specified packet to a connected socket. TCP / IP stack API is used for writing.

Modbus_tcp_frame_pkt	Modbus TCP frame packet

【Format】

```
void_t Modbus_tcp_frame_pkt( puint8_t pu8_mb_snd_pkt,
                             puint32_t pu32_snd_pkt_len,
                             p_mb_tcp_pkt_info_t pt_mb_tcp_pkt_info);
```

【Parameter】

puint8_t	pu8_mb_snd_pkt	Pointer to the array storing packet to be send
puint32_t	pu32_snd_pkt_len	Length of the packet framed
p_mb_tcp_pkt_info_t	pt_mb_tcp_pkt_info	Structure pointer containing response information

【Return value】

void_t

【Error code】

—

【Explanation】

This function is used to update TCP packet information structure from response structure provided by the user application.

Modbus_tcp_parse_pkt	Modbus TCP parse packet

【Format】

```
uint32_t Modbus_tcp_parse_pkt(puint8_t pu8_mb_rcv_pkt,
                              uint32_t u32_recv_pkt_len,
                              p_mb_tcp_pkt_info_t pt_mb_tcp_pkt_info);
```

【Parameter】

puint8_t	pu8_mb_rcv_pkt	Pointer to the array storing the received packet
puint32_t	u32_recv_pkt_len	Length of the Modbus receive packet
p_mb_tcp_pkt_info_t	pt_mb_tcp_pkt_info	Structure pointer containing response information

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On successful parsing the packet
EXP_ILLEGAL_DATA_VALUE	If data value is not in the valid range
ERR_ILLEGAL_FUNCTION	If function code is not supported or enabled
ERR_MEM_ALLOC	If memory allocation fails

【Explanation】

This API parse the specified packet, perform the callback function corresponding to each function code that the user has registered. After callback perform, API updates the structure of TCP packet information (pt_mb_tcp_pck_info) based on the execution results. In this function, dynamically allocate memory request and response table for each callback perform. Request table will be released within this function, but response table will be released at the stage of generating a response packet.

Modbus_tcp_validate_pkt	Modbus TCP validate packet

【Format】

```
uint32_t Modbus_tcp_validate_pkt(p_mb_tcp_pkt_info_t pt_mb_tcp_pkt_info,
                                 uint32_t u32_pdu_len);
```

【Parameter】

p_mb_tcp_pkt_info_t	pt_mb_tcp_pkt_info	Structure pointer containing request information
uint32_t	u32_pdu_len	Length of the PDU received

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On successful validation
EXP_ILLEGAL_DATA_VALUE	If data value is not in the valid range
ERR_ILLEGAL_FUNCTION	If function code is not supported or enabled

【Explanation】

This function validates a packet recevived by the TCP device.

Modbus_tcp_init_socket	function for creating server socket

【Format】

```
int8_t Modbus_tcp_init_socket( uint16_t u16_port,
                               pint32_t ps32_listen_fd);
```

【Parameter】

uint16_t	u16_port	Port number to which socket is to be bound
pint32_t	ps32_listen_fd	Socket descriptor bound

【Return value】

int8_t	Error code

【Error code】

ERR_OK	On successful completion
ERR_SOCK_ERROR	If socket creation fails
ERR_BIND_ERROR	If binding fails
ERR_LISTEN_ERROR	If listening fails

【Explanation】

This function is used for creating the server socket and turns the server to accept mode for monitoring client connections.

Modbus_tcp_frame_response	Modbus TCP frame response

【Format】

uint32_t Modbus_tcp_frame_response(uint8_t u8_fn_code,
p_mb_tcp_pkt_info_t pt_mb_tcp_pkt_info);

【Parameter】

uint8_t	u8_fn_code	Variable storing the function code
p_mb_tcp_pkt_info_t	pt_mb_tcp_pkt_info	Structure pointer containing user information

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On framing packet is successful

【Explanation】

This function is used to update TCP packet information structure from response structure provided by the user application.

5.2.2 Stack Configuration and Management API

5.2.2.1 Initialization of Protocol Stack

The following API has been used in the initialization process of the stack.

Modbus_tcp_server_init_stack	Modbus TCP server (without gateway)stack initialization

【Format】

```
uint32_t Modbus_tcp_server_init_stack(uint32_t u32_additional_port,
                                      uint8_t u8_tcp_multiple_client);
```

【Parameter】		
uint32_t	u32_additional_port	Additional port value configured by user
uint8_t	u8_tcp_multiple_client	Status whether multiple client is enabled
【Return value】		
uint32_t	Error code	
【Error code】		
ERR_OK	On successful initialization of the task or mailbox	
ERR_STACK_INIT	If initialization of the task or mailbox failed	

【Explanation】

This API is used to initialize the TCP stack. Specifically, this function to start the three tasks of the following required for the operation of the stack.

- The task of monitoring the connection from the client using the port number(default 502) that is specified by the user.
- The task of receiving the data sent from the client side.
- The task of analyzes the received data and performs an operation corresponding to each function code provided by the user.

Modbus_tcp_init_gateway_stack	Modbus TCP gateway initialization

【Format】

```
uint32_t Modbus_tcp_init_gateway_stack(uint8_t u8_stack_mode,
                                       uint8_t u8_tcp_gw_slave,
                                       p_serial_stack_init_info_t pt_serial_stack_init_info,
                                       p_serial_gpio_cfg_t     pt_serial_gpio_cfg_t);
```

【Parameter】

uint8_t	u8_stack_mode	Variable to store the stack mode RTU/ASCII
uint8_t	u8_tcp_gw_slave	Status whether gateway enabled as TCP server
p_serial_stack_init_info_t	pt_serial_stack_init_info	Structure pointer to serial stack initialization parameters
p_serial_gpio_cfg_t	pt_serial_gpio_cfg_t	Pointer to the structure with hardware configuration parameters

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On successful initialization of the task or mailbox
ERR_STACK_INIT	If initialization of the task or mailbox failed

【Explanation】

This API is used to initialize the stack with gateway functionality. Initialize Modbus TCP stack along with the serial stack. Activate a gateway task to process the request for serial devices connected to the TCP device. Create a mailbox to communicate with this task.

5.2.2.2 IP management

The following API has been used in the IP management.

Modbus_tcp_search_ip_addr	Modbus search a host IP

【Format】

```
uint32_t Modbus_tcp_search_ip_addr(pchar_t pu8_search_IP,
                                   puint8_t pu8_ip_idx);
```

【Parameter】		
pchar_t	pu8_search_IP	IP address to be searched
puint8_t	pu8_ip_idx	Index at which IP address is placed

【Return value】	
uint32_t	Error code

【Error code】	
ERR_OK	On successful search
ERR_IP_NOT_FOUND	If IP is not in the list
ERR_TABLE_EMPTY	If the list is empty
ERR_TABLE_DISABLED	If the table is disabled, i.e., server accepts connection request from any host

【Explanation】

This function is used for search an IP from the host IP list given.

Modbus_tcp_shift_conn_list	Modbus shift TCP connection list

【Format】

```
void_t Modbus_tcp_shift_conn_list(puint8_t pu8_conn_list,
                                  puint8_t pu8_conn_idx);
```

【Parameter】		
puint8_t	pu8_conn_list	Pointer to array containing the connection list
puint8_t	pu8_conn_idx	Index from which the socket ID is to be shifted

【Return value】
void_t

【Error code】
—

【Explanation】

This API is used to shift the connection list according to the latest active connection.

Modbus_tcp_remove_from_conn_list	Modbus TCP remove from connection list

【Format】

```
void_t Modbus_tcp_remove_from_conn_list(puint8_t pu8_soc_id,
                                        puint8_t pu8_conn_list);
```

【Parameter】

puint8_t	pu8_soc_id	Variable storing the socket ID.
puint8_t	pu8_conn_list	Pointer to array containing the connection list.

【Return value】

void_t

【Error code】

—

【Explanation】

This API is used to remove a connection established, from the connection list kept by the server. Verify the location at which the socket ID is specified and shift the all connection by one.

Modbus_tcp_add_to_conn_list	Modbus add a connection to Modbus TCP connection list

【Format】

```
void_t Modbus_tcp_add_to_conn_list(puint8_t pu8_soc_id,
                                   puint8_t pu8_conn_list);
```

【Parameter】

puint8_t	pu8_soc_id	Variable storing the socket ID
puint8_t	pu8_conn_list	Pointer to array containing the connection list

【Return value】

void_t

【Error code】

—

【Explanation】

This API is used to add a new connection received by the TCP server to the connection list kept by the server. Append the new connection to the array one by one.

Modbus_tcp_get_loc_from_list	Modbus get location of a connection

【Format】

```
uint32_t Modbus_tcp_get_loc_from_list(puint8_t pu8_soc_id,
                                      puint8_t pu8_conn_list,
                                      puint8_t pu8_soc_loc);
```

【Parameter】

puint8_t	pu8_soc_id	Variable storing the socket ID
puint8_t	pu8_conn_list	Pointer to array containing the connection list
puint8_t	pu8_soc_loc	Pointer variable storing the socket location referenced in the connection list

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	If the location of the socket ID obtained
ERR_SOC_NOT_FOUND	If referenced socket not present in the connection array list

【Explanation】

This API is used to obtain the location of a socket ID referenced from the MODBUS TCP connection list.

Modbus_tcp_update_conn_list	Modbus update TCP connection list

【Format】

```
void_t Modbus_tcp_update_conn_list(uint8_t u8_soc_id,
                                   puint8_t pu8_conn_list,
                                   uint8_t u8_add_remove);
```

【Parameter】

uint8_t	u8_soc_id	Variable storing the socket ID
puint8_t	pu8_conn_list	Pointer to array containing the connection list
uint8_t	u8_add_remove	Update type

【Return value】

void_t

【Error code】

—

【Explanation】

This API is used to update the connection list with the latest connection. The latest connection should be placed at the last of the array and the oldest connection is placed initially. In this function, the following macro is used as an argument.

Update type	Meaning
ADD_TO_CONN_LIST	Add socket ID to the connection list
REMOVE_FROM_CONN_LIST	Remove socket ID from the connection list

5.2.2.3 Task terminate

The following API has been used in the task termination processing.

Modbus_tcp_server_terminate_stack	Modbus terminate TCP Server stack API

【Format】

uint32_t Modbus_tcp_server_terminate_stack(void_t)

【Parameter】

void_t

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On successful termination
ERR_STACK_TERM	If termination failed

【Explanation】

This API terminate Modbus TCP stack related task and the mailbox used for the TCP task.

Modbus_tcp_gateway_terminate_stack	Modbus terminate TCP gateway stack API

【Format】

uint32_t Modbus_tcp_gateway_terminate_stack(void_t)

【Parameter】

void_t

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On successful termination
ERR_STACK_TERM	If termination failed

【Explanation】

This API terminate Modbus TCP gateway stack related task and the mailbox used for the TCP gateway task.

5.2.2.4 Mailbox

The following API has been used in the mailbox management.

Modbus_create_mailbox	Modbus create a mailbox

【Format】

uint32_t Modbus_create_mailbox(uint16_t u16_mbx_id);

【Parameter】		
uint16_t	u16_mbx_id	Variable storing the mailbox ID

【Return value】	
uint32_t	Error code

【Error code】	
ERR_OK	On successful creation of mailbox
ERR_MAILBOX	If creation of mailbox failed

【Explanation】

This API is used to create a mailbox for passing message between different tasks.

Modbus_post_to_mailbox	Modbus post a request to the mailbox

【Format】

uint32_t Modbus_post_to_mailbox(uint16_t u16_mbx_id,
p_mb_req_mbx_t pt_req_recvd);

【Parameter】		
uint16_t	u16_mbx_id	Variable containing the mailbox ID to which request is to be posted
p_mb_req_mbx_t	pt_req_recvd	Pointer to the structure containing request information

【Return value】	
uint32_t	Error code

【Error code】	
ERR_OK	On successful write to mailbox
ERR_MAILBOX	If write of mailbox failed
ERR_TCP_SND_MBX_FULL	If mailbox is full

【Explanation】

This API is used to send the request received from the client to the receive mailbox or gateway mailbox. Increment the number of elements in mailbox if the request sent successfully.

・Structure of mailbox queue (mb_req_mbx_t)

```
typedef struct _req_mbx{
    uint32_t    u32_soc_id;     /* Socket ID at which the request arrived */
    puint8_t    pu8_req_pkt;    /* Pointer to the requested packet */
    uint32_t    u32_pkt_len;    /* Packet length */
}mb_req_mbx_t, *p_mb_req_mbx_t;
```

Modbus_fetch_from_mailbox	Modbus read a request from the mailbox.

【Format】

uint32_t Modbus_fetch_from_mailbox(uint16_t u16_mbx_id,
p_mb_req_mbx_t* pt_req_recvd);

【Parameter】		
uint16_t	u16_mbx_id	Variable containing the mailbox ID to which request is read
p_mb_req_mbx_t	pt_req_recvd	Pointer to the structure containing request information

【Return value】	
uint32_t	Error code

【Error code】	
ERR_OK	On successful read from mailbox
ERR_MAILBOX	If read from mailbox failed

【Explanation】

This API is used to read the request posted to the receive mailbox or gateway mailbox depending upon the mailbox ID specified. Decrement the number of elements in mailbox if the request read successfully.

Modbus_check_mailbox	Modbus verify the number of elements in mailbox.

【Format】

uint32_t Modbus_check_mailbox(uint16_t u16_mbx_id);

【Parameter】		
uint16_t	u16_mbx_id	Variable containing the mailbox ID to which request is read.

【Return value】	
uint32_t	Number of mailbox used or error code

【Error code】	
ERR_TCP_SND_MBX_FULL	If mailbox is full

【Explanation】

This API is used to verify the number of elements in mailbox. The maximum number that can be processed by each mailbox is defined by the following macros. If the number of messages being processed has reached the maximum value, it is determined that the message full.

Macro name	Meaning
MAX_RCV_MBX_SIZE	Maximum number of receive mailbox
MAX_GW_MBX_SIZE	Maximum number of gateway mailbox

Modbus_delete_mailbox	Modbus Delete mailbox

【Format】

uint32_t Modbus_delete_mailbox(uint16_t u16_mbx_id);

【Parameter】

uint16_t	u16_mbx_id	Variable storing the mailbox ID.

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On successful deletion of mailbox
ERR_MAILBOX	If deletion of mailbox failed

【Explanation】

This API is used to delete a mailbox specified by the mailbox ID.

5.2.3 Gateway mode API

This chapter describes the function that will be called from the gateway task.

Modbus_gw_read_coils	Modbus gateway function to read the coil

【Format】

```
uint32_t Modbus_gw_read_coils(puint8_t pu8_recvd_pkt,
                              uint32_t u32_recv_pkt_len,
                              p_mb_tcp_pkt_info_t pt_gw_tcp_pkt_info);
```

【Parameter】

puint8_t	pu8_recvd_pkt	Pointer to the array storing the received packet.
uint32_t	u32_recv_pkt_len	Length of received packet
p_mb_tcp_pkt_info_t	pt_gw_tcp_pkt_info	Structure to fill with the response information

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On read coil successful
ERR_SYSTEM_INTERNAL	For mailbox send or receive failure
ERR_ILLEGAL_NUM_OF_COILS	If the number of coils provided is not within the specified limit
ERR_INVALID_SLAVE_ID	If the slave ID is not valid
ERR_MEM_ALLOC	If memory allocation fails
ERR_SLAVE_ID_MISMATCH	If the slave id in the request is not its own slave id or broadcast id
ERR_CRC_CHECK	If CRC validation fails for RTU slave stack mode
ERR_LRC_CHECK	If LRC validation fails for ASCII slave stack mode
ERR_FUN_CODE_MISMATCH	If the function code is not supported by the stack
ERR_ILLEGAL_FUNCTION	If function code is not supported or enabled
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid
ERR_INSUFFICIENT_DATA	If receive packet length is invalid

【Explanation】

This API invokes the function provided in the master to read the data of the coil. In this function, memory is allocated for both request and response structure dynamically and fill the request structure with the information in the received packet. Invoke the serial master API, frame a packet with the response information obtained and send the response packet to the client. After that, the memory allocated for both response and request structures to be freed.

・Structure of response information (mb_tcp_pkt_info_t)

```
typedef struct _mb_tcp_pkt_info{
    puint8_t    pu8_output_response;          /* pointer to the response structure from the API */
    uint16_t    u16_transaction_id;           /* specifies the transaction identifier */
    uint16_t    u16_protocol_id;              /* specifies the protocol ID */
    uint8_t     u8_slave_id;                  /* specifies the slave ID of the device */
    uint16_t    u16_num_of_bytes;             /* specifies the number of bytes in the data packet
                                                 PDU field */
    uint8_t     aru8_data_packet[MAX_DATA_SIZE]; /* contains the function and data */
}mb_tcp_pkt_info_t, *p_mb_tcp_pkt_info_t;
```

Modbus_gw_read_discrete_inputs	Modbus gateway function to read the discrete input

【Format】

```
uint32_t Modbus_gw_read_discrete_inputs(puint8_t pu8_recvd_pkt,
                                        uint32_t u32_recv_pkt_len,
                                        p_mb_tcp_pkt_info_t pt_gw_tcp_pkt_info);
```

【Parameter】

puint8_t	pu8_recvd_pkt	Pointer to the array storing the received packet
uint32_t	u32_recv_pkt_len	Length of received packet
p_mb_tcp_pkt_info_t	pt_gw_tcp_pkt_info	Structure to fill with the response information

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	On discrete input read successful
ERR_SYSTEM_INTERNAL	For mailbox send or receive failure
ERR_ILLEGAL_NUM_OF_INPUTS	If the number of inputs provided is not within the specified limit
ERR_INVALID_SLAVE_ID	If the slave ID is not valid
ERR_MEM_ALLOC	If memory allocation fails
ERR_SLAVE_ID_MISMATCH	If the slave id in the request is not its own slave id or broadcast id
ERR_CRC_CHECK	If CRC validation fails for RTU slave stack mode
ERR_LRC_CHECK	If LRC validation fails for ASCII slave stack mode
ERR_FUN_CODE_MISMATCH	If the function code is not supported by the stack
ERR_ILLEGAL_FUNCTION	If function code is not supported or enabled
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid
ERR_INSUFFICIENT_DATA	If receive packet length is invalid

【Explanation】

This API invokes the function provided in the master to read the data of the discrete input. In this function, memory is allocated for both request and response structure dynamically and fill the request structure with the information in the received packet. After that, the memory allocated for both response and request structures to be freed.

Modbus_gw_read_holding_regs	Modbus gateway function to read the holding register

【Format】

```
uint32_t Modbus_gw_read_holding_regs(puint8_t pu8_recvd_pkt,
                                     uint32_t u32_recv_pkt_len,
                                     p_mb_tcp_pkt_info_t pt_gw_tcp_pkt_info);
```

【Parameter】

puint8_t	pu8_recvd_pkt	Pointer to the array storing the received packet.
uint32_t	u32_recv_pkt_len	Length of received packet
p_mb_tcp_pkt_info_t	pt_gw_tcp_pkt_info	Structure to fill with the response information

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	If holding register read successful
ERR_SYSTEM_INTERNAL	For mailbox send or receive failure
ERR_ILLEGAL_NUM_OF_REG	If the number of registers provided is not within the specified limit
ERR_INVALID_SLAVE_ID	If the slave ID is not valid
ERR_MEM_ALLOC	If memory allocation fails
ERR_SLAVE_ID_MISMATCH	If the slave id in the request is not its own slave id or broadcast id
ERR_CRC_CHECK	If CRC validation fails for RTU slave stack mode
ERR_LRC_CHECK	If LRC validation fails for ASCII slave stack mode
ERR_FUN_CODE_MISMATCH	If the function code is not supported by the stack
ERR_ILLEGAL_FUNCTION	If function code is not supported or enabled
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid
ERR_INSUFFICIENT_DATA	If receive packet length is invalid

【Explanation】

This API invokes the function provided in the master to read the data of the holding register. In this function, memory is allocated for both request and response structure dynamically and fill the request structure with the information in the received packet. After that, the memory allocated for both response and request structures to be freed.

Modbus_gw_read_input_regs	Modbus gateway function to read the input register

【Format】

```
uint32_t Modbus_gw_read_input_regs(puint8_t pu8_recvd_pkt,
                                   uint32_t u32_recv_pkt_len,
                                   p_mb_tcp_pkt_info_t pt_gw_tcp_pkt_info);
```

【Parameter】

puint8_t	pu8_recvd_pkt	Pointer to the array storing the received packet
uint32_t	u32_recv_pkt_len	Length of received packet
p_mb_tcp_pkt_info_t	pt_gw_tcp_pkt_info	Structure to fill with the response information

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	If input register read successful
ERR_SYSTEM_INTERNAL	For mailbox send or receive failure
ERR_ILLEGAL_NUM_OF_REG	If the number of registers provided is not within the specified limit
ERR_INVALID_SLAVE_ID	If the slave ID is not valid
ERR_MEM_ALLOC	If memory allocation fails
ERR_SLAVE_ID_MISMATCH	If the slave id in the request is not its own slave id or broadcast id
ERR_CRC_CHECK	If CRC validation fails for RTU slave stack mode
ERR_LRC_CHECK	If LRC validation fails for ASCII slave stack mode
ERR_FUN_CODE_MISMATCH	If the function code is not supported by the stack
ERR_ILLEGAL_FUNCTION	If function code is not supported or enabled
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid
ERR_INSUFFICIENT_DATA	If receive packet length is invalid

【Explanation】

This API invokes the function provided in the master to read the data of the input register. In this function, memory is allocated for both request and response structure dynamically and fill the request structure with the information in the received packet. After that, the memory allocated for both response and request structures to be freed.

Modbus_gw_write_single_coil	Modbus gateway function to write a single coil

【Format】

```
uint32_t Modbus_gw_write_single_coil(puint8_t pu8_recvd_pkt,
                                     uint32_t u32_recv_pkt_len,
                                     p_mb_tcp_pkt_info_t pt_gw_tcp_pkt_info);
```

【Parameter】

puint8_t	pu8_recvd_pkt	Pointer to the array storing the received packet
uint32_t	u32_recv_pkt_len	Length of received packet
p_mb_tcp_pkt_info_t	pt_gw_tcp_pkt_info	Structure to fill with the response information

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	If single coil write is successful
ERR_SYSTEM_INTERNAL	For mailbox send or receive failure
ERR_ILLEGAL_OUTPUT_VALUE	If the value of the registers is invalid
ERR_INVALID_SLAVE_ID	If the slave ID is not valid
ERR_MEM_ALLOC	If memory allocation fails
ERR_SLAVE_ID_MISMATCH	If the slave id in the request is not its own slave id or broadcast id
ERR_CRC_CHECK	If CRC validation fails for RTU slave stack mode
ERR_LRC_CHECK	If LRC validation fails for ASCII slave stack mode
ERR_FUN_CODE_MISMATCH	If the function code is not supported by the stack
ERR_ILLEGAL_FUNCTION	If function code is not supported or enabled
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid
ERR_INSUFFICIENT_DATA	If receive packet length is invalid

【Explanation】

This API invokes the function provided in the master to write a single coil. In this function, memory is allocated for both request and response structure dynamically and fill the request structure with the information in the received packet. After that, the memory allocated for both response and request structures to be freed.

Modbus_gw_write_single_reg	Modbus gateway function to write a single register

【Format】

```
uint32_t Modbus_gw_write_single_reg(puint8_t pu8_recvd_pkt,
                                    uint32_t u32_recv_pkt_len,
                                    p_mb_tcp_pkt_info_t pt_gw_tcp_pkt_info);
```

【Parameter】

[in]	puint8_t	pu8_recvd_pkt	Pointer to the array storing the received packet
[in]	uint32_t	u32_recv_pkt_len	Length of received packet
[out]	p_mb_tcp_pkt_info_t	pt_gw_tcp_pkt_info	Structure to fill with the response information

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	If single register write is successful
ERR_SYSTEM_INTERNAL	For mailbox send or receive failure
ERR_INVALID_SLAVE_ID	If the slave ID is not valid
ERR_MEM_ALLOC	If memory allocation fails
ERR_SLAVE_ID_MISMATCH	If the slave id in the request is not its own slave id or broadcast id
ERR_CRC_CHECK	If CRC validation fails for RTU slave stack mode
ERR_LRC_CHECK	If LRC validation fails for ASCII slave stack mode
ERR_FUN_CODE_MISMATCH	If the function code is not supported by the stack
ERR_ILLEGAL_FUNCTION	If function code is not supported or enabled
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid
ERR_INSUFFICIENT_DATA	If receive packet length is invalid

【Explanation】

This API invokes the function provided in the master to write a single register. In this function, memory is allocated for both request and response structure dynamically and fill the request structure with the information in the received packet. After that, the memory allocated for both response and request structures to be freed.

Modbus_gw_write_multiple_coils	Modbus gateway function to write multiple coils

【Format】

```
uint32_t Modbus_gw_write_multiple_coils(puint8_t pu8_recvd_pkt,
                                        uint32_t u32_recv_pkt_len,
                                        p_mb_tcp_pkt_info_t pt_gw_tcp_pkt_info);
```

【Parameter】

puint8_t	pu8_recvd_pkt	Pointer to the array storing the received packet
uint32_t	u32_recv_pkt_len	Length of received packet
p_mb_tcp_pkt_info_t	pt_gw_tcp_pkt_info	Structure to fill with the response information

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	If multiple coils write is successful
ERR_SYSTEM_INTERNAL	For mailbox send or receive failure
ERR_ILLEGAL_NUM_OF_OUTPUTS	If the number of outputs is invalid
ERR_INVALID_SLAVE_ID	If the slave ID is not valid
ERR_MEM_ALLOC	If memory allocation fails
ERR_SLAVE_ID_MISMATCH	If the slave id in the request is not its own slave id or broadcast id
ERR_CRC_CHECK	If CRC validation fails for RTU slave stack mode
ERR_LRC_CHECK	If LRC validation fails for ASCII slave stack mode
ERR_FUN_CODE_MISMATCH	If the function code is not supported by the stack
ERR_ILLEGAL_FUNCTION	If function code is not supported or enabled
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid
ERR_INSUFFICIENT_DATA	If receive packet length is invalid

【Explanation】

This API invokes the function provided in the master to write a data to multiple coils. In this function, memory is allocated for both request and response structure dynamically and fill the request structure with the information in the received packet. After that, the memory allocated for both response and request structures to be freed.

Modbus_gw_write_multiple_reg	Modbus gateway function to write multiple registers

【Format】

```
uint32_t Modbus_gw_write_multiple_reg(puint8_t pu8_recvd_pkt,
                                      uint32_t u32_recv_pkt_len,
                                      p_mb_tcp_pkt_info_t pt_gw_tcp_pkt_info);
```

【Parameter】

puint8_t	pu8_recvd_pkt	Pointer to the array storing the received packet
uint32_t	u32_recv_pkt_len	Length of received packet
p_mb_tcp_pkt_info_t	pt_gw_tcp_pkt_info	Structure to fill with the response information

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	If single register write is successful
ERR_SYSTEM_INTERNAL	For mailbox send or receive failure
ERR_ILLEGAL_NUM_OF_REG	If the number of registers is invalid
ERR_INVALID_SLAVE_ID	If the slave ID is not valid
ERR_MEM_ALLOC	If memory allocation fails
ERR_SLAVE_ID_MISMATCH	If the slave id in the request is not its own slave id or broadcast id
ERR_CRC_CHECK	If CRC validation fails for RTU slave stack mode
ERR_LRC_CHECK	If LRC validation fails for ASCII slave stack mode
ERR_FUN_CODE_MISMATCH	If the function code is not supported by the stack
ERR_ILLEGAL_FUNCTION	If function code is not supported or enabled
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid
ERR_INSUFFICIENT_DATA	If receive packet length is invalid

【Explanation】

This API invokes the function provided in the master to write a data to multiple registers. In this function, memory is allocated for both request and response structure dynamically and fill the request structure with the information in the received packet. After that, the memory allocated for both response and request structures to be freed.

Modbus_gw_read_write_multiple_reg	Modbus gateway function to read/write multiple registers

【Format】

```
uint32_t Modbus_gw_read_write_multiple_reg(puint8_t pu8_recvd_pkt,
                                           uint32_t u32_recv_pkt_len,
                                           p_mb_tcp_pkt_info_t pt_gw_tcp_pkt_info);
```

【Parameter】

puint8_t	pu8_recvd_pkt	Pointer to the array storing the received packet
uint32_t	u32_recv_pkt_len	Length of received packet
p_mb_tcp_pkt_info_t	pt_gw_tcp_pkt_info	Structure to fill with the response information

【Return value】

uint32_t	Error code

【Error code】

ERR_OK	If read/write multiple register is successful
ERR_SYSTEM_INTERNAL	For mailbox send or receive failure
ERR_ILLEGAL_OUTPUT_VALUE	If the value of the registers is invalid
ERR_INVALID_SLAVE_ID	If the slave ID is not valid
ERR_MEM_ALLOC	If memory allocation fails
ERR_SLAVE_ID_MISMATCH	If the slave id in the request is not its own slave id or broadcast id
ERR_CRC_CHECK	If CRC validation fails for RTU slave stack mode
ERR_LRC_CHECK	If LRC validation fails for ASCII slave stack mode
ERR_FUN_CODE_MISMATCH	If the function code is not supported by the stack
ERR_ILLEGAL_FUNCTION	If function code is not supported or enabled
ERR_ILLEGAL_DATA_VALUE	If data value given is invalid
ERR_INSUFFICIENT_DATA	If receive packet length is invalid

【Explanation】

This API invokes the function provided in the master to read/write a data from/to multiple registers. In this function, memory is allocated for both request and response structure dynamically and fill the request structure with the information in the received packet. After that, the memory allocated for both response and request structures to be freed.

6. Implementation

This chapter explains the software implementation procedure.

6.1 Modbus TCP

It's explained to Modbus TCP stack in this chapter. In carrying out the implementation of Modbus TCP, TCP / IP protocol stack also must be implement.

Please refer to “programming manual (TCP/IP edition)” for implementation of TCP/IP protocol stack.

6.1.1 Server mode

The following are the items required when using the slave mode.

(1) Task ID definition

To use the following API as a task, and a Task ID defined in any value.

Task API	Function
Modbus_tcp_soc_wait_task	Wait for TCP connection task
Modbus_tcp_recv_data_task	TCP receive data Task
Modbus_tcp_req_process_task	TCP request processing task

(2) Mailbox ID definition

The following Mailbox ID is required.

Mailbox ID	Meaning
ID_MB_TCP_RECV_MBX	TCP receive mailbox

(3) Task generation

It generates a Task to be used in the Modbus stack. Please refer to “programming manual (OS edition)” for description method. Description example is shown in following figure.

```
const TSK_TBL static_task_table[] = {
// CRE_TSK( tskid,          {tskatr,      exinf,    task,                       itskpri,    stksz,   stk});
        …
    {ID_CONN_TASK,    {TA_HLNG,   0,       (FP)Modbus_tcp_soc_wait_task,    8,          0x400,   NULL}},
    {ID_RECV_SOC,   {TA_HLNG,   0,       (FP)Modbus_tcp_recv_data_task,   8,          0x400,   NULL}},
    {ID_SERV_TSK,   {TA_HLNG,   0,       (FP)Modbus_tcp_req_process_task,   8,          0x400,   NULL}},
        …
};
```

(4) Mailbox generation

It generates a Mailbox to be used in the Modbus stack. Please refer to “programming manual (OS edition)” for description method. Description example is shown in following figure.

```
const MBX_TBL static_mailbox_table[] = {
// CRE_MBX(    mbxid,                  {mbxatr,        maxmpri,   mprihd});
      …
         {ID_MB_TCP_RECV_MBX,     {TA_TFIFO,   0,      NULL}},
      …
};
```

(5) Initialization of Modbus stack

It performs various initialization, and then start the Modbus stack. This initialization needs to execute after the initialization of the TCP / IP protocol stack.

TCP server mode must perform the following by each APIs.

- Regisger IP address
- Register callback functions corresponding to each the function code
- Initialize Modbus routine and start up related task

Please refer to Chapter 5.1.1.1 and 5.1.1.2 for description method of each APIs.

Basically initialization is as follows:

```
/* Enable IP table */
Modbus_tcp_init_ip_table(ENABLE, REJECT);

/* register IP address */
ercd = Modbus_tcp_add_ip_addr("192.168.1.100");
if (ercd != ERR_OK){
    return ercd;
}

/* register callback functions */
st_slave_map.fp_function_code1  = cb_func_code01;
st_slave_map.fp_function_code2  = cb_func_code02;
st_slave_map.fp_function_code3  = cb_func_code03;
st_slave_map.fp_function_code4  = cb_func_code04;
st_slave_map.fp_function_code5  = cb_func_code05;
st_slave_map.fp_function_code6  = cb_func_code06;
st_slave_map.fp_function_code15 = cb_func_code15;
st_slave_map.fp_function_code16 = cb_func_code16;
st_slave_map.fp_function_code23 = cb_func_code23;
Modbus_slave_map_init (&st_slave_map);

/* Initialize MODBUS stack by TCP server mode */
ercd = Modbus_tcp_init_stack(MODBUS_TCP_SERVER_MODE,
            MODBUS_TCP_GW_SLAVE_ENABLE,
            ENABLE_MULTIPLE_CLIENT_CONNECTION,
            0,
            NULL,
            NULL);
if (ercd != ERR_OK){
    return ERR_OK;
}
```

(6) Implement call back functions

If the function code is instructed to implements the callback function for performing.

Please refer to the item of Section 5.1.1.1 of the Modbus_slave_map_init API. Interface specification of the callback function has been described.

6.1.2 Gateway mode

Gateway mode is the structure that connects Modbus Serial and Modbus TCP by gateway task. The following are the items required when using the gateway mode.

(1) Task ID definition

To use the following API as a task, and a Task ID defined in any value.

Task API	function
Modbus_gateway_task	TCP server⇔Serial device Gateway task
Modbus_tcp_soc_wait_task	Wait for connection task
Modbus_tcp_recv_data_task	TCP receive data Task
Modbus_tcp_req_process_task	TCP request processing task
Modbus_serial_recv_task	Serial receive data task
Modbus_serial_task	Serial request processing task

(2) Event flag ID definition

The following Event flag ID is required.

Event flag	Meaning
ID_FLG_SERIAL	Timer and UART interrupt event
ID_FLG_RESP_RDY	Response event in Blocking mode
ID_SERIAL_RESP	Recveive response event

(3) Mailbox ID definition

The following Mailbox ID is required.

Mailbox ID	Meaning
ID_MB_GATEWAY_MBX	Receive gateway process mailbox
ID_MB_TCP_RECV_MBX	TCP receive mailbox
ID_MB_SERIAL_MBX	Serial event mailbox

(4) Task generation

It generates a Task to be used in the Modbus stack. Please refer to “programming manual (OS edition)” for description method. Description example is shown in following figure.

```
const TSK_TBL static_task_table[] = {
// CRE_TSK( tskid,                    {tskatr,      exinf,   task,                              itskpri,   stksz,      stk});
        …
            {ID_CONN_TASK,             {TA_HLNG,   0,   (FP)Modbus_tcp_soc_wait_task,        8,      0x400,   NULL}},
            {ID_RECV_SOC,              {TA_HLNG,   0,   (FP)Modbus_tcp_recv_data_task,       8,      0x400,   NULL}},
            {ID_SERV_TSK,              {TA_HLNG,   0,   (FP)Modbus_tcp_req_process_task,     8,      0x400,   NULL}},
            {ID_GATEWAY_TSK,           {TA_HLNG,   0,   (FP)Modbus_gateway_task,             8,      0x400,   NULL}},
            {ID_MB_SERIAL_RECV_TSK,    {TA_HLNG,   0,   (FP)Modbus_serial_recv_task,         8,      0x400,   NULL}},
            {ID_MB_SERIAL_TSK,         {TA_HLNG,   0,   (FP)Modbus_serial_task,              8,      0x400,   NULL}},
        …
};
```

(5) Event flag generation

It generates a Event flag to be used in the Modbus stack. Please refer to “programming manual (OS edition)” for description method. Description example is shown in following figure.

```
const FLG_TBL static_eventflag_table[] = {
// CRE_FLG(     flgid,          {flgatr,      iflgptn});
    …
    {ID_FLG_SERIAL,     {TA_TFIFO,   0}},
    {ID_FLG_RESP_RDY,   {TA_TFIFO,   0}},
    {ID_SERIAL_RESP,    {TA_TFIFO,   0}},
    …
};
```

(6) Mailbox generation

It generates a Mailbox to be used in the Modbus stack. Please refer to “programming manual (OS edition)” for description method. Description example is shown in following figure.

```
const MBX_TBL static_mailbox_table[] = {
// CRE_MBX(   mbxid,          {mbxatr,              maxmpri,    mprihd});
    …
    {ID_MB_SERIAL_MBX,  {TA_TFIFO,      0,     NULL}},
    {ID_MB_GATEWAY_MBX, {TA_TFIFO,      0,     NULL}},
    {ID_MB_TCP_RECV_MBX,{TA_TFIFO,      0,     NULL}},
    …
};
```

(7) Hardware ISR entries

It entries a Hardware ISR to be used in the Modbus stack. Please refer to “programming manual (OS edition)” for description method. Description example is shown in following figure.

```
const HWISR_TBL static_hwisr_table[] = {
// inhno,          hwisr_syscall,    id,             setptn
        …
  {UAJ0TIR_IRQn,    HWISR_SET_FLG, ID_FLG_SERIAL,   RECV_FLG},
  {TAUJ2I1_IRQn,    HWISR_SET_FLG, ID_FLG_SERIAL,   TIMER_FLG},
  {UAJ0TIS_IRQn,    HWISR_SET_FLG, ID_FLG_SERIAL,   UART_STS_FLG},
        …
};
```

The above ISR table entry shows the configuration for UART channel 0 and Timer channel 1. If a separate channel is used, necessary modifications will have to be made.

(8) Initialzation of Modbus stack

This is the initialization as well as the TCP server mode, but with the following exceptions.

- No registration by Modbus_slave_map_init().(But, in order to ensure the internal memory, that needs to be executed.)
- Initialize in gateway mode the Modbus_tcp_init_stack, to add a set of serial communication.

Please refer to Chapter 5.1.1.1 and 5.1.1.2 for description method of each APIs.
Basically initialization is as follows:

```
/* Enable IP table */
Modbus_tcp_init_ip_table(ENABLE, REJECT);

/* register IP address */
ercd = Modbus_tcp_add_ip_addr("192.168.1.100");
if (ercd != ERR_OK){
    return ercd;
}

/* serial connection setting */
st_init_info.u32_baud_rate                  = BAUD_38400;
st_init_info.u8_parity                      = PARITY_NONE;
st_init_info.u8_stop_bit                    = STOP_BIT_ONE;
st_init_info.u8_uart_channel                = UART_CHANNEL_ZERO;
st_init_info.u8_timer_channel               = TIMER_CHANNEL_ONE;
st_init_info.u32_response_timeout_ms    = 1000;
st_init_info.u32_turnaround_delay_ms    = 200;
st_init_info.u32_interframe_timeout_us = 1750;
st_init_info.u32_interchar_timeout_us   = 750;
st_init_info.u8_retry_count                 = 3;

/* register functions that performs RS485 direction control */
st_gpio_cfg.fp_gpio_init_ptr   = gpio_init;
st_gpio_cfg.fp_gpio_set_ptr    = gpio_set;
st_gpio_cfg.fp_gpio_reset_ptr = gpio_reset;

/* register callback functions(only memory allocation) */
Modbus_slave_map_init (&st_slave_map);

/* Initialize Modbus stack by TCP gateway mode */
ercd = Modbus_tcp_init_stack(MODBUS_RTU_MASTER_MODE,
            MODBUS_TCP_GW_SLAVE_ENABLE,
            ENABLE_MULTIPLE_CLIENT_CONNECTION,
            0,
            &st_init_info,
            &st_gpio_cfg);
if (ercd != ERR_OK){
    return ERR_OK;
}
```

6.2 Modbus RTU/ASCII

It's explained to Modbus RTU/ASCII stack in this chapter.

6.2.1 Slave mode

The following are the items required when using the slave mode.

(1) Task ID definition

To use the following API as a task, and a Task ID defined in any value.

Task API	Function
Modbus_serial_recv_task	Serial receive data task
Modbus_serial_task	Serial request processing task

(2) Event flag ID definition

The following Event flag ID is required.

Event flag	Meaning
ID_FLG_SERIAL	Timer and UART interrupt event
ID_FLG_RESP_RDY	Response event in Blocking mode
ID_SERIAL_RESP	Recveive response event

(3) Mailbox ID definition

The following Mailbox ID is required.

Mailbox ID	Meaning
ID_MB_SERIAL_MBX	Serial event mailbox

(4) Task generation

It generates the Task to be used in the Modbus stack. Please refer to “programming manual (OS edition)” for description method. Description example is shown in following figure.

```
const TSK_TBL static_task_table[] = {
// CRE_TSK( tskid,              {tskatr,  exinf,    task,               itskpri,    stksz,   stk});
          …
  {ID_MB_SERIAL_RECV_TSK,   {TA_HLNG,   0,    (FP)Modbus_serial_recv_task, 8,    0x400, NULL}},
  {ID_MB_SERIAL_TSK,        {TA_HLNG,   0,    (FP)Modbus_serial_task,      8,    0x400, NULL}},
          …
};
```

(5) Event flag generation

It generates the Event flag to be used in the Modbus stack. Please refer to “programming manual (OS edition)” for description method. Description example is shown in following figure.

```
const FLG_TBL static_eventflag_table[] = {
// CRE_FLG(     flgid,          {flgatr,      iflgptn});
    …
    {ID_FLG_SERIAL,     {TA_TFIFO,   0}},
    {ID_FLG_RESP_RDY,   {TA_TFIFO,   0}},
    {ID_SERIAL_RESP,    {TA_TFIFO,   0}},
    …
};
```

(6) Mailbox generation

It generates the Mailbox to be used in the Modbus stack. Please refer to “programming manual (OS edition)” for description method. Description example is shown in following figure.

```
const MBX_TBL static_mailbox_table[] = {
// CRE_MBX(   mbxid,          {mbxatr,       maxmpri,   mprihd});
    …
    {ID_MB_SERIAL_MBX,  {TA_TFIFO,   0,     NULL}},
    …
};
```

(7) Hardware ISR entries

It entries the Hardware ISR to be used in the Modbus stack. Please refer to “programming manual (OS edition)” for description method. Description example is shown in following figure.

```
const HWISR_TBL static_hwisr_table[] = {
// inhno,          hwisr_syscall,       id,           setptn
      …
  {UAJ0TIR_IRQn,   HWISR_SET_FLG,    ID_FLG_SERIAL,   RECV_FLG},
  {TAUJ2I1_IRQn,   HWISR_SET_FLG,    ID_FLG_SERIAL,   TIMER_FLG},
  {UAJ0TIS_IRQn,   HWISR_SET_FLG,    ID_FLG_SERIAL,   UART_STS_FLG},
      …
};
```

The above ISR table entry shows the configuration for UART channel 0 and Timer channel 1. If a separate channel is used, necessary modifications will have to be made.

(8) Initialization of Modbus stack

It performs various initialization, and then start the Modbus stack. Serial slave mode must perform the following by each APIs.

- Register callback functions corresponding to each the function code.
- Initialize MODBUS routine and start up related task. Since it also performs this initialization in the serial communication related settings, it set to match the master side.

Please refer to Chapter 5.1.2.1 for description method of each APIs.

Basically initialization is as follows:

```
/* register callback functions */
st_slave_map.fp_function_code1   = cb_func_code01;
st_slave_map.fp_function_code2   = cb_func_code02;
st_slave_map.fp_function_code3   = cb_func_code03;
st_slave_map.fp_function_code4   = cb_func_code04;
st_slave_map.fp_function_code5   = cb_func_code05;
st_slave_map.fp_function_code6   = cb_func_code06;
st_slave_map.fp_function_code15 = cb_func_code15;
st_slave_map.fp_function_code16 = cb_func_code16;
st_slave_map.fp_function_code23 = cb_func_code23;
Modbus_slave_map_init (&st_slave_map);

/* serial connection setting */
st_init_info.u32_baud_rate                  = BAUD_38400;
st_init_info.u8_parity                      = PARITY_NONE;
st_init_info.u8_stop_bit                    = STOP_BIT_ONE;
st_init_info.u8_uart_channel                = UART_CHANNEL_ZERO;
st_init_info.u8_timer_channel               = TIMER_CHANNEL_ONE;
st_init_info.u32_response_timeout_ms    = 1000;
st_init_info.u32_turnaround_delay_ms    = 200;
st_init_info.u32_interframe_timeout_us = 1750;
st_init_info.u32_interchar_timeout_us   = 750;
st_init_info.u8_retry_count                 = 3;

/* register function that performs RS485 direction control */
st_gpio_cfg.fp_gpio_init_ptr   = gpio_init;
st_gpio_cfg.fp_gpio_set_ptr    = gpio_set;
st_gpio_cfg.fp_gpio_reset_ptr = gpio_reset;

/* Initialize Modbus stack by RTU slave mode   */
ercd = Modbus_serial_stack_init(&st_init_info,
            &st_gpio_cfg,
            MODBUS_RTU_SLAVE_MODE,
            1);          /* Slave ID */
```

If ASCII mode is used, API argument will have to change from MODBUS_RTU_SLAVE_MODE to MODBUS_ASCII_SLAVE_MODE.

(9) Implement call back functions

If the function code is instructed to implements the callback function for performing.

Please refer to the item of Section 5.1.1.1 of the Modbus_slave_map_init API. Interface specification of the callback function has been described.

6.2.2 Master mode

Master mode uses the OS resources the same as Slave mode, please refer to (1) ~ (7) in the previous section.The following are the items required when using the Master mode.

(1) Initialzation of Modbus stack

Initialized in master mode will be the only Modbus_serial_stack_init.

Please refer to Chapter 5.1.2.1 for a description method of the API.

Basically initialization is as follows:

```
/* serial connection setting */
st_init_info.u32_baud_rate                  = BAUD_38400;
st_init_info.u8_parity                      = PARITY_NONE;
st_init_info.u8_stop_bit                    = STOP_BIT_ONE;
st_init_info.u8_uart_channel                = UART_CHANNEL_ZERO;
st_init_info.u8_timer_channel               = TIMER_CHANNEL_ONE;
st_init_info.u32_response_timeout_ms    = 1000;
st_init_info.u32_turnaround_delay_ms    = 200;
st_init_info.u32_interframe_timeout_us = 1750;
st_init_info.u32_interchar_timeout_us   = 750;
st_init_info.u8_retry_count                 = 3;

/* register function that performs RS485 direction control */
st_gpio_cfg.fp_gpio_init_ptr   = gpio_init;
st_gpio_cfg.fp_gpio_set_ptr    = gpio_set;
st_gpio_cfg.fp_gpio_reset_ptr = gpio_reset;

/* Modbus stack be initilized in RTU master mode   */
ercd = Modbus_serial_stack_init(&st_init_info,
            &st_gpio_cfg,
            MODBUS_RTU_MASTER_MODE,
            0);
```

If ASCII mode is used, API argument will have to change from MODBUS_RTU_MASTER_MODE to MODBUS_ASCII_MASTER_MODE.

7. Tutorial by sample application

In this chapter, the way to run the Modbus stack sample application is shown, and the behavior of it is confirmed.

7.1 Modbus TCP server communication

7.1.1 Overview of sample project

In here, the setup procedure to see the Modbus TCP server communication with PC is described. And by using a simple application on Windows PC, the user can see a demonstration that LED blinking pattern is changed by using Read coil and write coil command.

7.1.2 Hardware connection

Regarding the evaluation board for setup demonstration, user can use EC, CL, CEC board by TESSERA technology Inc., or IAR KickStart Kit by IAR. Through RJ45 port, user can see connection to PC or PLC.

The following figure is the hardware setup image for Modbus TCP communication with CEC board.

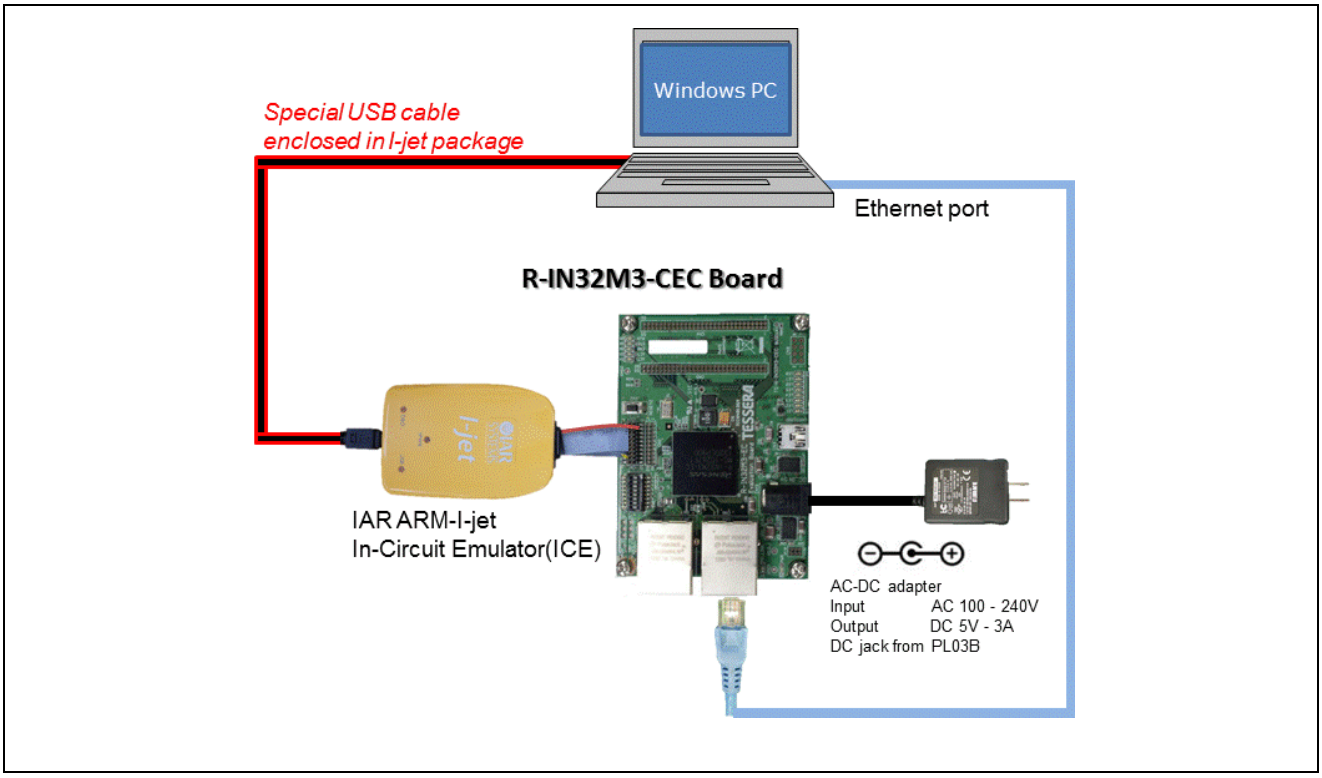


Figure 7.1 Hardware connection for development infrastructure to Modbus TCP with CEC board

7.1.3 Board IP address setting

Please set the IP address in the following procedure.

(1) Set desired server network address setting in net_cfg.c. An example is shown in Figure 7.2

```
/*****************************************
    Define Local IP Address
*****************************************/
T_NET_ADR gNET_ADR[] = {
    {
        0x0,                /* Reserved */
        0x0,                /* Reserved */
        0xC0A80164,         /* IP address (192.168.    1.100) */
        0xC0A80101,         /* Gateway        (192.168.    1.    1) */
        0xFFFFFF00,         /* Subnet mask (255.255.255.    0) */
    }
};
```

Figure 7.2 The example setting of IP address (in case IP address is 192.168.1.100)

(2) Your PC's IP-address need to be in the same domain as the R-IN32M3 board. (Please also refer next page as detail procedure.)

In this example, we will use:

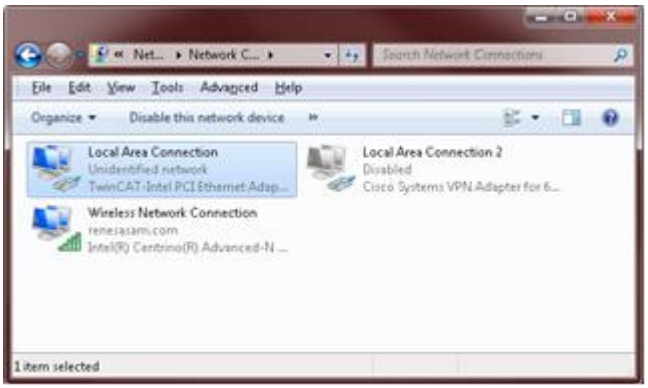
Subnet mask : 255.255.255.0

PC IP-address : 192.168.1.101

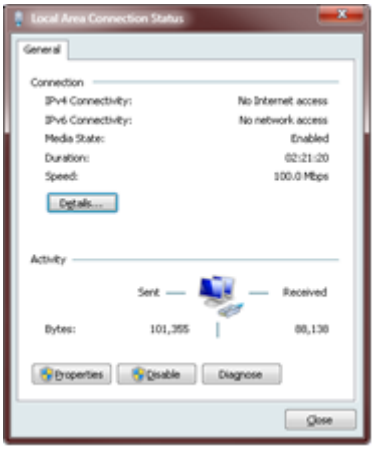
This is so that server and client are in the same domain.

cf. How to set the PC IP-address

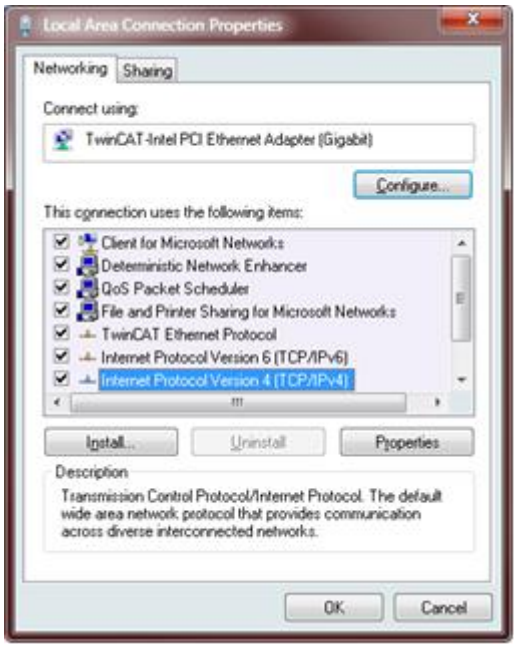
- Open the network connections list.
  In Windows7: Control panel->Network and Sharing Center->Change adapter settings.



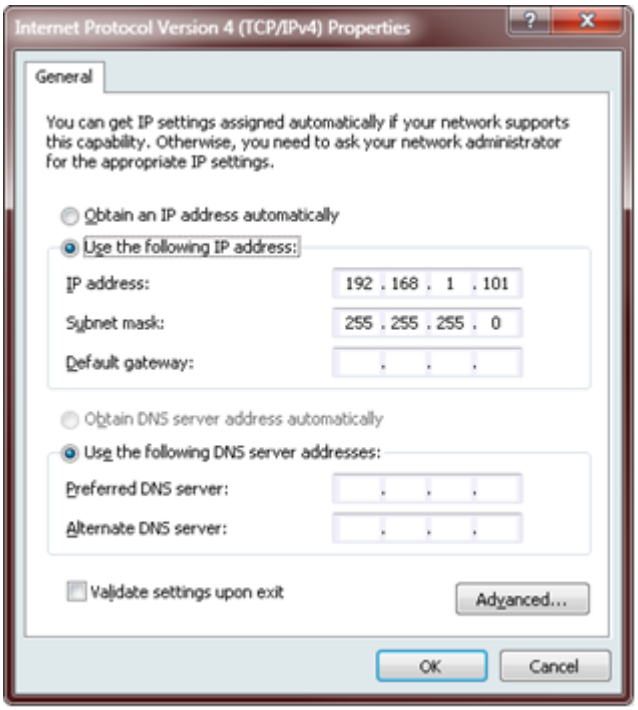
- Double-click (or right-click) on the Local Area Connection, then select "Properties".



- Select TCP/IPv4, and push the Properties button.



- Set IP-address to 192.168.1.101, and sub net mask to 255.255.255.0



7.1.4 Demonstration

User can see the simple demonstration with using the sample project included this stack.

7.1.4.1 Specification of demonstration

By communicating with PC through the Modbus TCP protocol, LED blinking pattern is controlled dynamically. For this control, Read Coil and Write Coil command is used.

As detail, the following sequence is executed.

(1) PC application is checked parities of general input 8bit switch[Note] by using Modbus "Read coil" command,

(2) According input switch setting value, output port status, which is connected to LED, is updated periodically.

Updating span = ([SW setting value] + 1) x 10 [msec] : when SW value is less than 0x7F

Fixed 10msec : when SW value is 0x7F or more

Note - For TS-R-IN32M3-"CEC" board,
the SW is not prepared. Since the setting value will be set to fixed 0xFF, then LED blinking would be updated by 100msec.
- For TS-R-IN32M3-"EC" board,
input SW is named "SW6".
- For TS-R-IN32M3-EC board "Lite" included IAR KickStart kit,
input SW is named "SW3".
- For TS-R-IN32M3-"CL" board,
input SW is SW18 and SW19 of rotarySW. The bit 2-bit8 is assigned to bit0-6 in this value. To make it simple, it might be better to set "0"for SW18 and SW19, at first.

7.1.4.2 How to set up the demonstration

The used workbench file is in the following path.

[IAR project file]

\r-in32m3_samplesoft\Device\Renesas\RIN32M3\Source\Project\modbus_TCP\IAR\main.eww

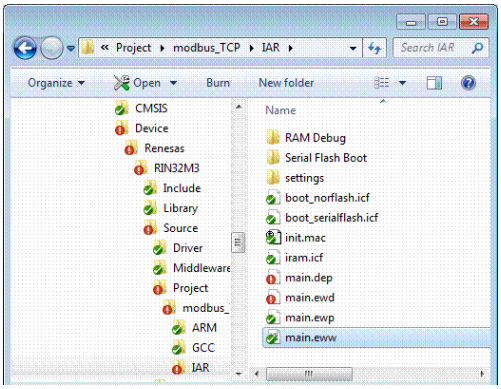


Figure 7.3 demonstration workbench

Next, user need to change the active project from the tab on the left-upper side from RAM Debug, Serial Flash Boot, or NOR boot, according to the hardware Switch setting of the evaluation board.

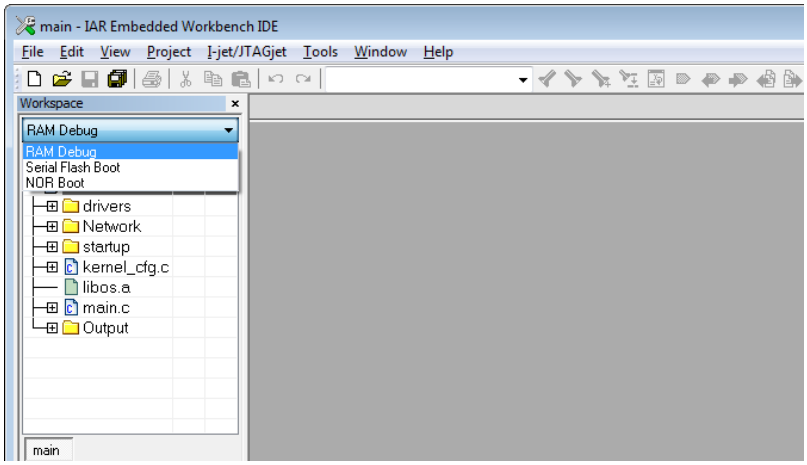


Figure 7.4 selection of project

Please set according to following procedure.

(1) Compile. Download, and run application.

Remark If TS-R-IN32M3-CL board is used, please add "RIN32M3_CL" definition into Defined symbol in the preprocessor tab of C/C++ compiler as option setting.

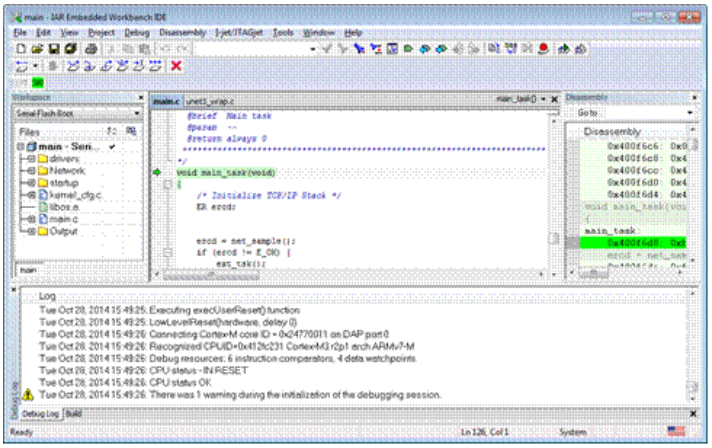


Figure 7.5 IAR IDE capture after downloading to Serial Flash.

(2) Open "ModbusDemoApplication**.exe**" which is included in Modbus stack package.

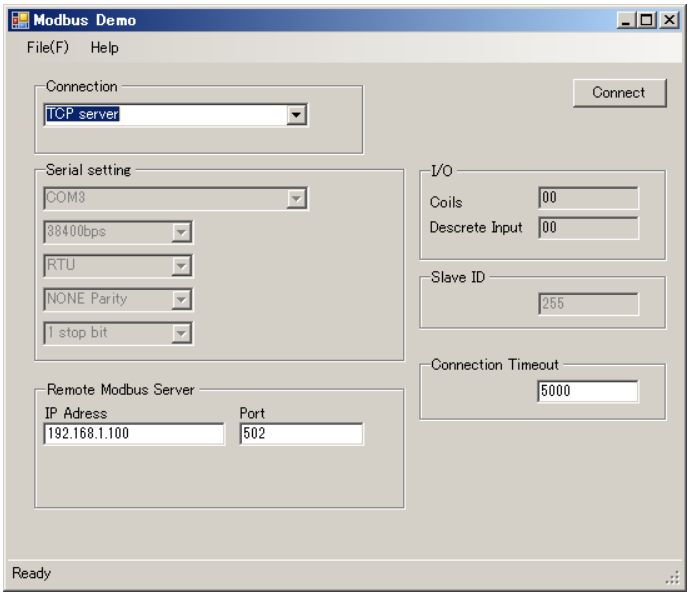


Figure 7.6 Demo Application capture after open.

(3) “Connection” is selected to TCP server, and set server IP address (e.g. “**192.168.1.100**”) and Port No(e.g. “**502**”).

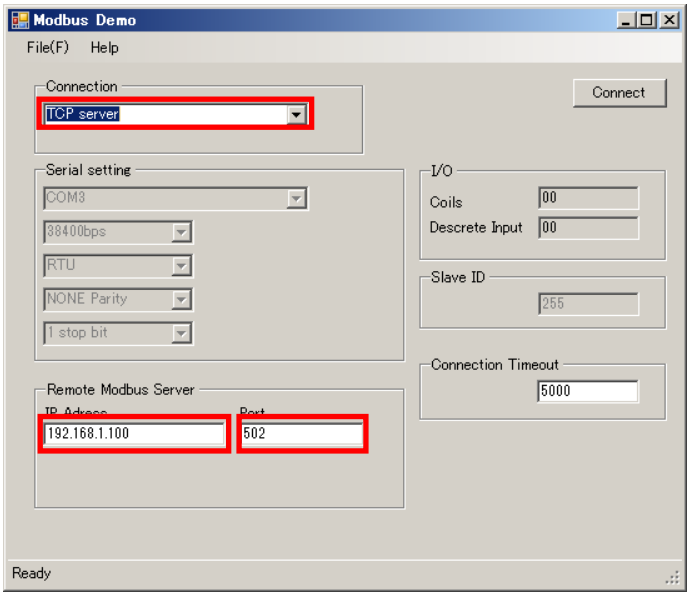


Figure 7.7 After set IP address and Port No.

(4) When “Connect” button is pressed, LED blinking has started with Modbus communication.

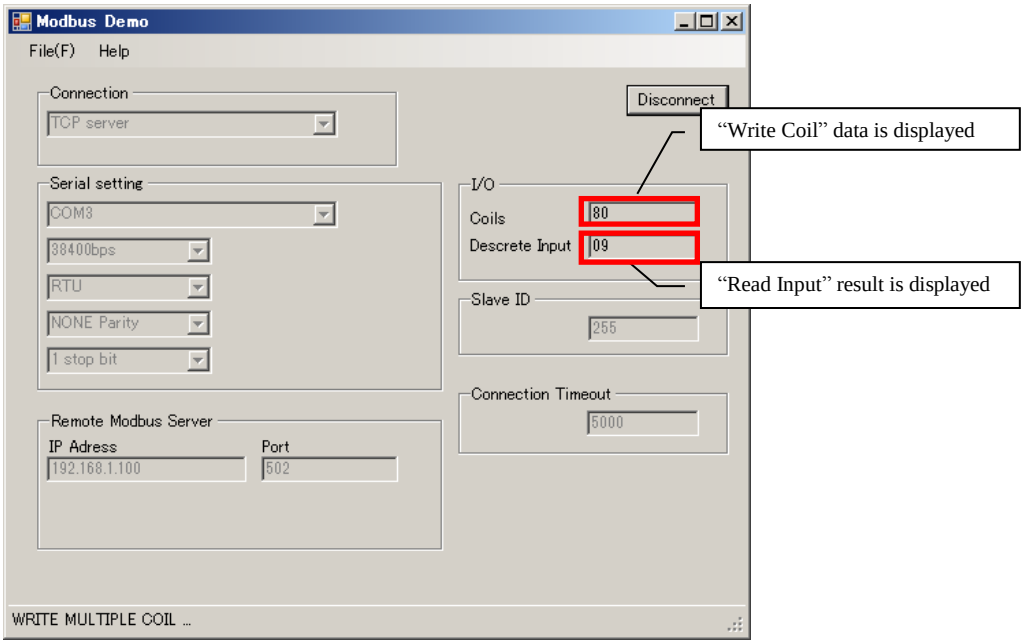


Figure 7.8 After starting demonstration

Figure 7.9 LED blinking demo image

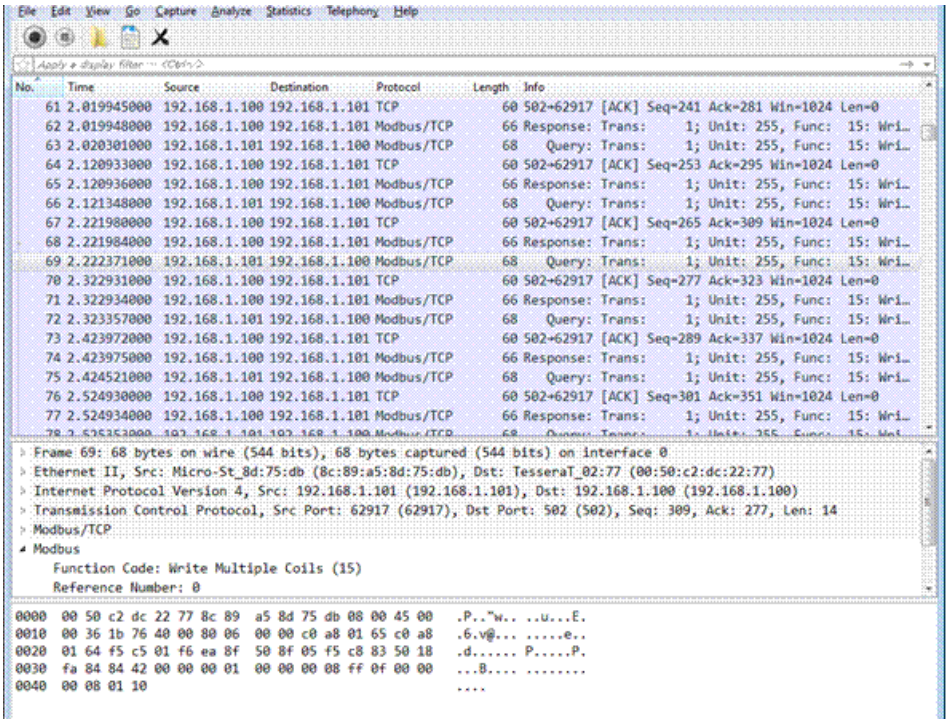


Figure 7.10 Communication log in Wireshark application

7.2 Modbus RTU/ASCII slave communication

7.2.1 Overview of sample project

In here, the setup procedure to see the Modbus RTU/ASCII slave communication with PC is described. And by using a simple application on Windows PC, the user can see a demonstration that LED blinking pattern is changed by using Read coil and write coil command.

7.2.2 Hardware connection

Regarding the evaluation board for setup demonstration, user can use EC, CL, CEC board by TESSERA Technology Inc.. User can see connection to PC or PLC through RS-485 communication.

Remark IAR Kickstart kit cannot support. （because board spec is specially for Ethernet）

Please note that the user **needs to prepare RS485 transceiver module**[Note] for RS-485 communication for RS-485 communication with every board. The Table 7.1 is shown that the expected connection pins to RS-485 transceiver.

The Figure 7.11 is the hardware setup image for Modbus RTU/ASCII communication with CEC board. And Figure 7.12 is the detail to connect pins for RS-485 interface.

Table 7.1 Connection pins for RS-485 I/F for Modbus RTU/ASCII

Connected pin for RS-485 transceiver	Port resource for R-IN32M3	R-IN32M3-EC Evaluation board (TS-R-IN32M3-EC)	R-IN32M3-CL Evaluation board (TS-R-IN32M3-CL)	R-IN32M3-EC Evaluation board (TS-R-IN32M3-CEC)	R-IN32M3-EC KickStart Kit (KSK-RIN32M3EC-LT-IL)
TX	P20 (RXD0)	After removing R125, connect to opposite pin connected LED.	J22 : 1 pin (After removing Jumper)	CN5 : 44 pin	RTU/ASCII is not supported.
RX	P21 (TXD0)	After removing R126, connect to opposite pin connected LED.	J27 : 3 pin (After removing Jumper)	CN5 : 46 pin	
DE(/RE)	P27	CN14 : 13 pin	CN4 : 1 pin	CN5 : 52 pin	
VCC	3.3V	+3.3V	+3.3V	V3.3_1	
GND	GND	GND	GND	GND2	

Note We have confirmed RS485 communication with following module:

[UART-RS485 transration]

- “RS485 breakout” module from Sparkfun

https://www.sparkfun.com/products/10124

[RS485-USB transration]

- USB to RS-485 Converter from Sparkfun

https://www.sparkfun.com/products/9822

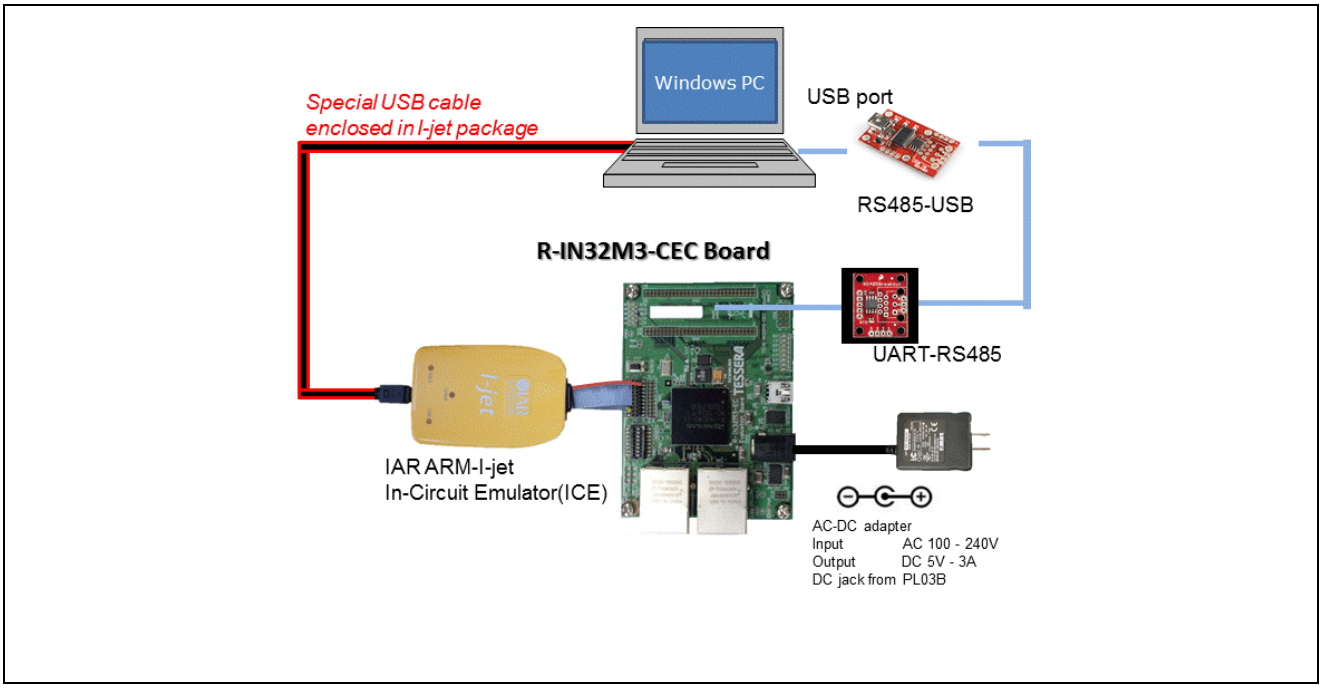


Figure 7.11 Hardware connection for development infrastructure for Modbus RTU/ASCII with CEC board

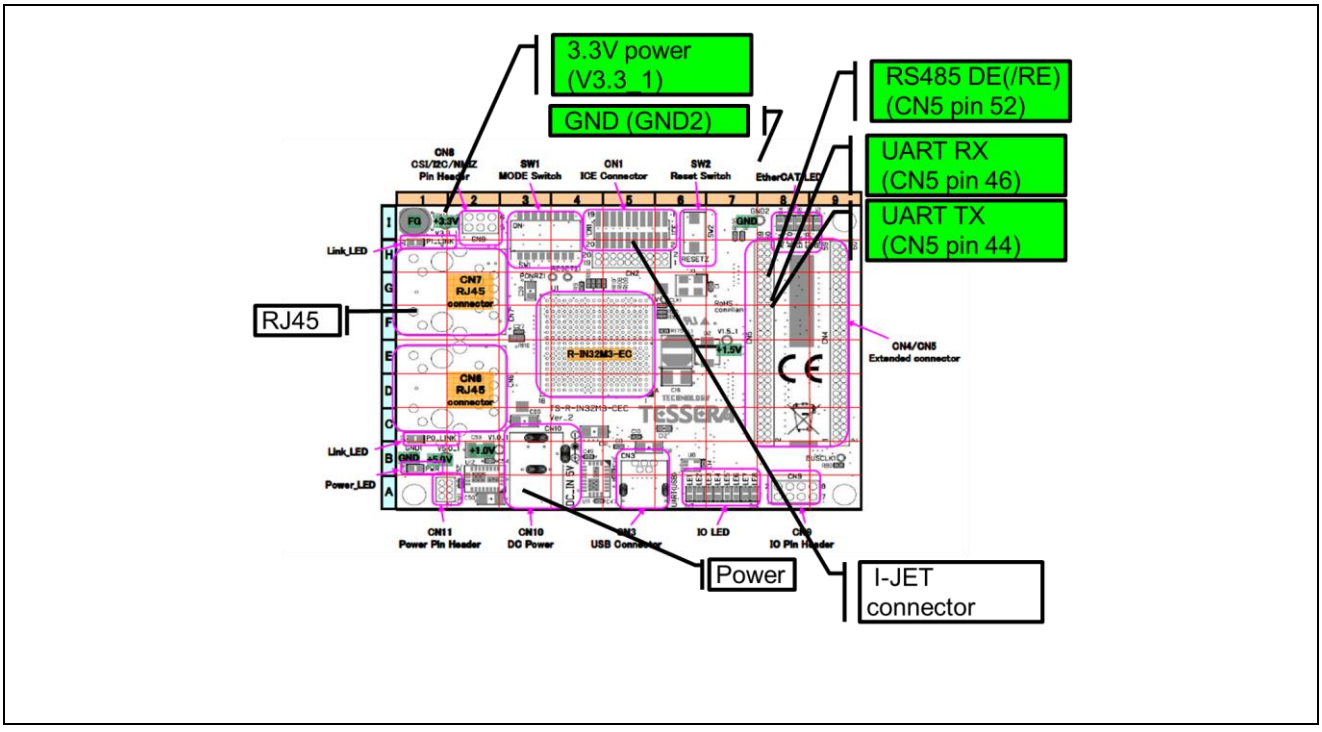


Figure 7.12 The detail for RS-485 related connection pins

7.2.3 Demonstration

User can see the simple demonstration with using the sample project included this stack.

7.2.3.1 Specification of demonstration

By communicating with PC through Modbus RTU/ASCII protocol, LED blinking pattern is controlled dynamically. For this control, Read Coil and Write Coil command is used.

As detail, the following sequence is executed.

(1) PC application is checked parities of general input 8bit switch(Note) by using Modbus "Read coil" command,

(2) According input switch setting value, output port status, which is connected to LED, is updated periodically.

Updating span = ([SW setting value] + 1) x 10 [msec] : when SW value is less than 0x7F

Fixed 10msec : when SW value is 0x7F or more

Note - For TS-R-IN32M3-"CEC" board,
the SW is not prepared. Since the setting value will be set to fixed 0xFF, then LED blinking would be updated by 100msec.
- For TS-R-IN32M3-"EC" board,
input SW is named "SW6".
- For TS-R-IN32M3-EC board "Lite" included IAR KickStart kit,
input SW is named "SW3".
- For TS-R-IN32M3-"CL" board,
input SW is SW18 and SW19 of rotary SW. The bit 2-bit8 is assigned to bit0-6 in this value. To make it simple, it might be better to set "0"for SW18 and SW19, at first.

7.2.3.2 How to set up the demonstration

The used workbench file is in the following path.

[IAR project file]

\r-in32m3_samplesoft\Device\Renesas\RIN32M3\Source\Project\modbus_Serial\IAR\main.eww

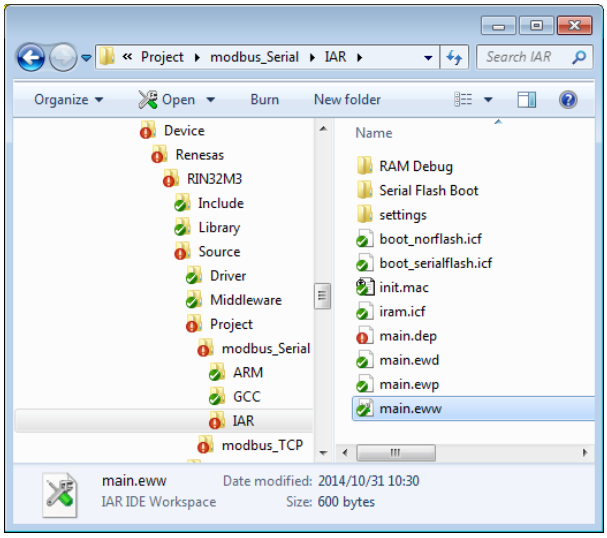


Figure 7.13 Demonstration workbench

Next, user need to change the active project from the tab on the left-upper side from RAM Debug, Serial Flash Boot, or NOR boot, according to the hardware Switch setting of the evaluation board.

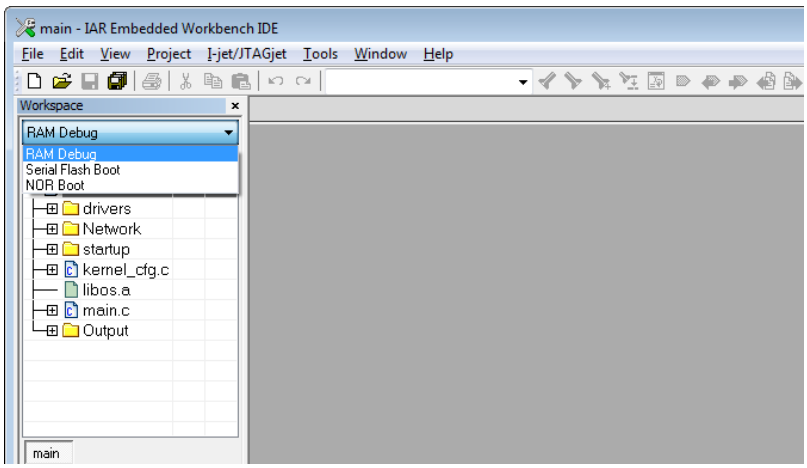


Figure 7.14 Selection of project

And then, for selecting Modbus serial mode from 4 kinds of protocols that is RTU master, RTU slave, ASCII master, and ASCII slave, user needs to select by compile option.

If you are using IAR workbench, please open the IAR workspace and open “option” setting of active project.

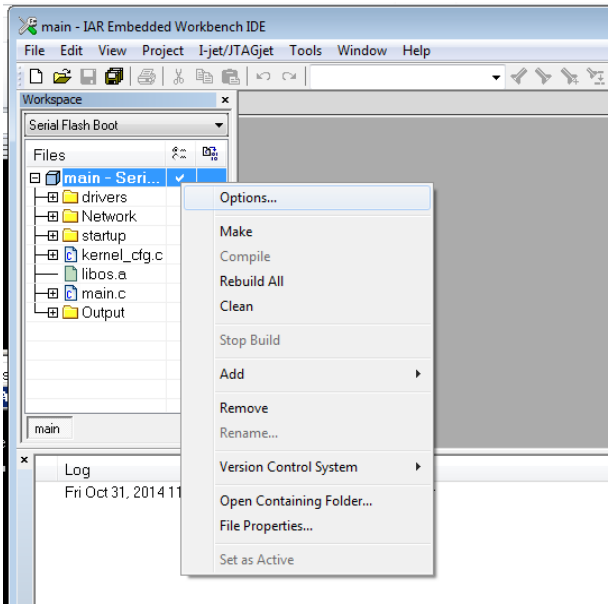


Figure 7.15 Open option setting in IAR EWARM

Select **“C/C++ Compiler”** as the category, and select **“Preprocessor”** tab.

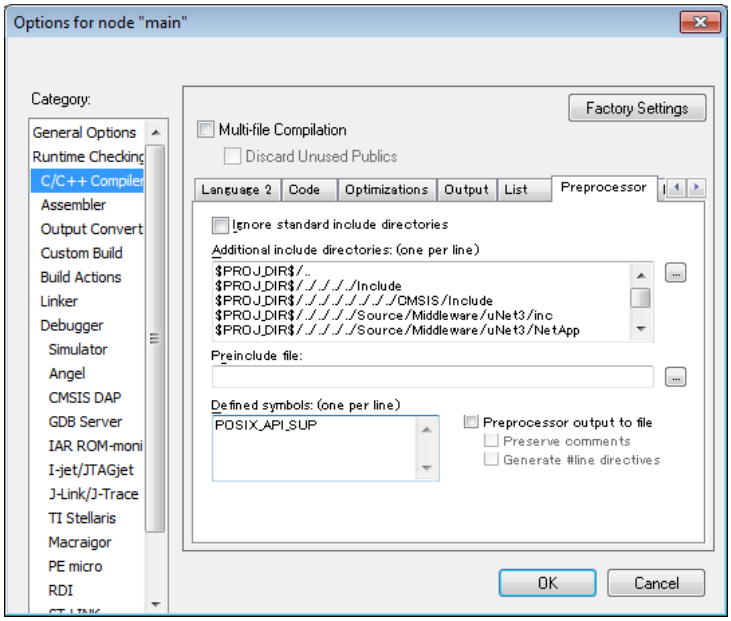


Figure 7.16 Capture of preprocessor setting

According to the following, please add in “Defined symbols”.

[Compile option setting]

- For Modbus RTU slave : (no need to add)
- For Modbus RTU master : add “**MODBUS_MASTER**”
- For Modbus ASCII slave : add “**MODBUS_ASCII**”
- For Modbus ASCII master : add “**MODBUS_MASTER**” , and “**MODBUS_ASCII**”

Next, please set according to following procedure.

(1) Compile. Download, and run application.

Remark If TS-R-IN32M3-CL board is used, please add "RIN32M3_CL" definition into Defined symbol in preprocessor tab of C/C++ compiler as option setting.

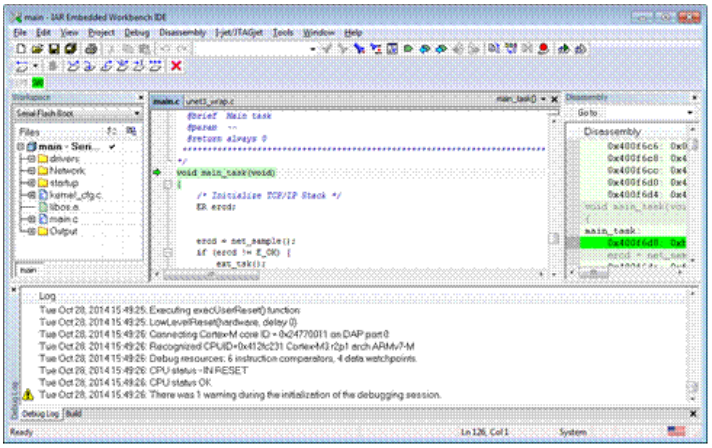


Figure 7.17 IAR IDE capture after downloading to Serial Flash.

(2) Set COM setting (baud-rate, data bits, parity, stop bits, flow control) in device manager on Windows PC to the value which is same as setting in in modbus_init() function.

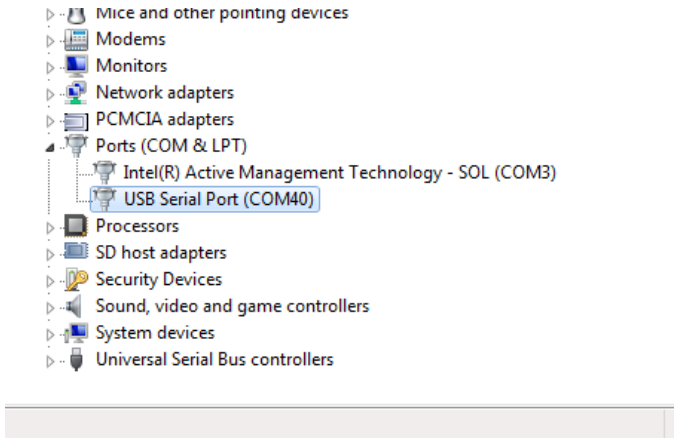
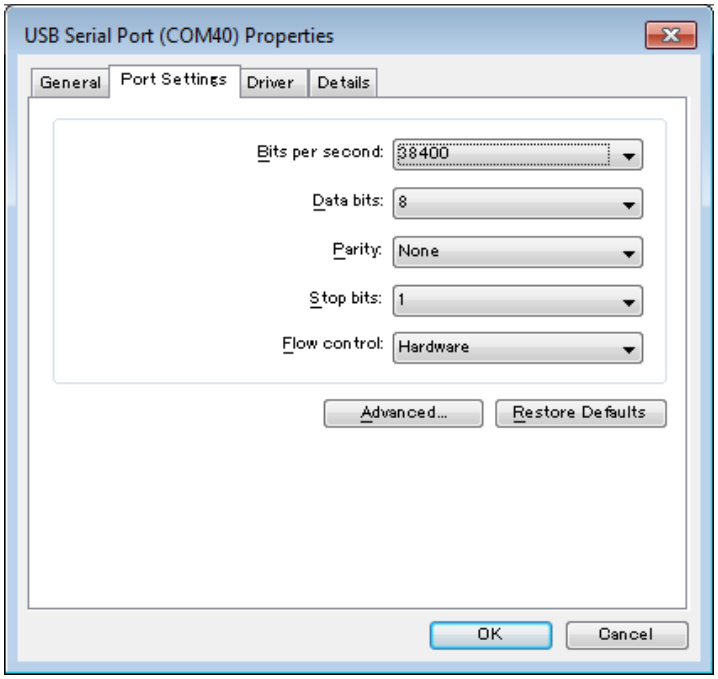


Figure 7.18 Device manager of Windows PC



The setting should be same as following setting in modbus_init() function

```
    Modbus_slave_map_init(&st_slave_map);
#endif

    /* serial connection setting */
    st_init_info.u32_baud_rate             = BAUD_38400;      /* Baud rate for ser
    st_init_info.u8_parity                 = PARITY_NONE;     /* Parity for serial
    st_init_info.u8_stop_bit               = STOP_BIT_ONE;    /* Stop bit for seri
    st_init_info.u8_uart_channel           = UART_CHANNEL_ZERO;  /* The hardware UART
    st_init_info.u8_timer_channel          = TIMER_CHANNEL_ONE;  /* The hardware time
    st_init_info.u32_response_timeout_ms   = 1000;            /* Response shall be
    st_init_info.u32_turnaround_delay_ms   = 200;             /* Delay in between
    st_init_info.u32_interframe_timeout_us = 1750;               /* Inter frame c
    st_init_info.u32_interchar_timeout_us  = 750;          /* Inter char delay for
    st_init_info.u8_retry_count            = 3;               /* Number of retries

    /* register functions that performs RS485 direction control */
    st_gpio_cfg.fp_gpio_init_ptr  = gpio_init;            /* Callback functior
    st_gpio_cfg.fp_gpio_set_ptr   = gpio_set;             /* Callback functior
    st_gpio_cfg.fp_gpio_reset_ptr = gpio_reset;           /* Callback functior
```

Figure 7.19 Serial port setting in device manager of Windows PC

(3) Open "**ModbusDemoApplication.exe**" which is included in Modbus stack package.

(4) "**Connection**" is selected to Serial Slave, and select COM port and serial communication parameters.

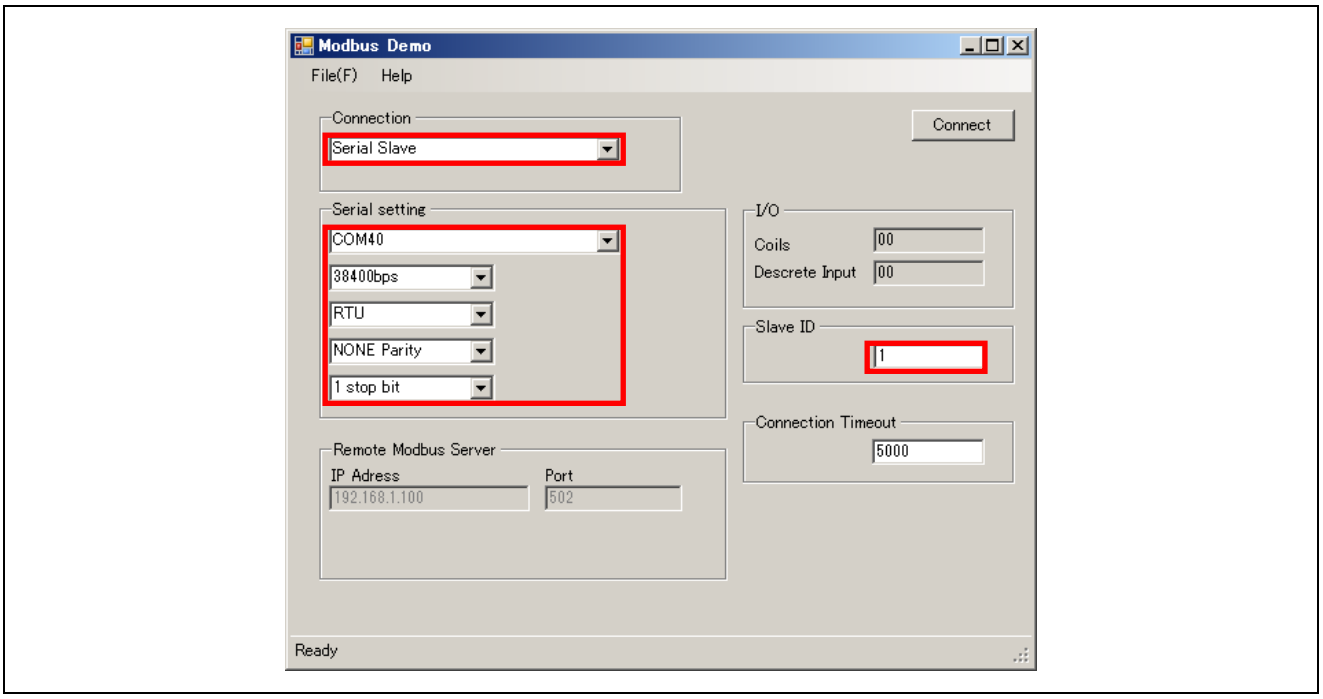


Figure 7.20 After set COM port and serial paramters

(5) When "Connect" button is pressed, LED blinking has started with Modbus communication.

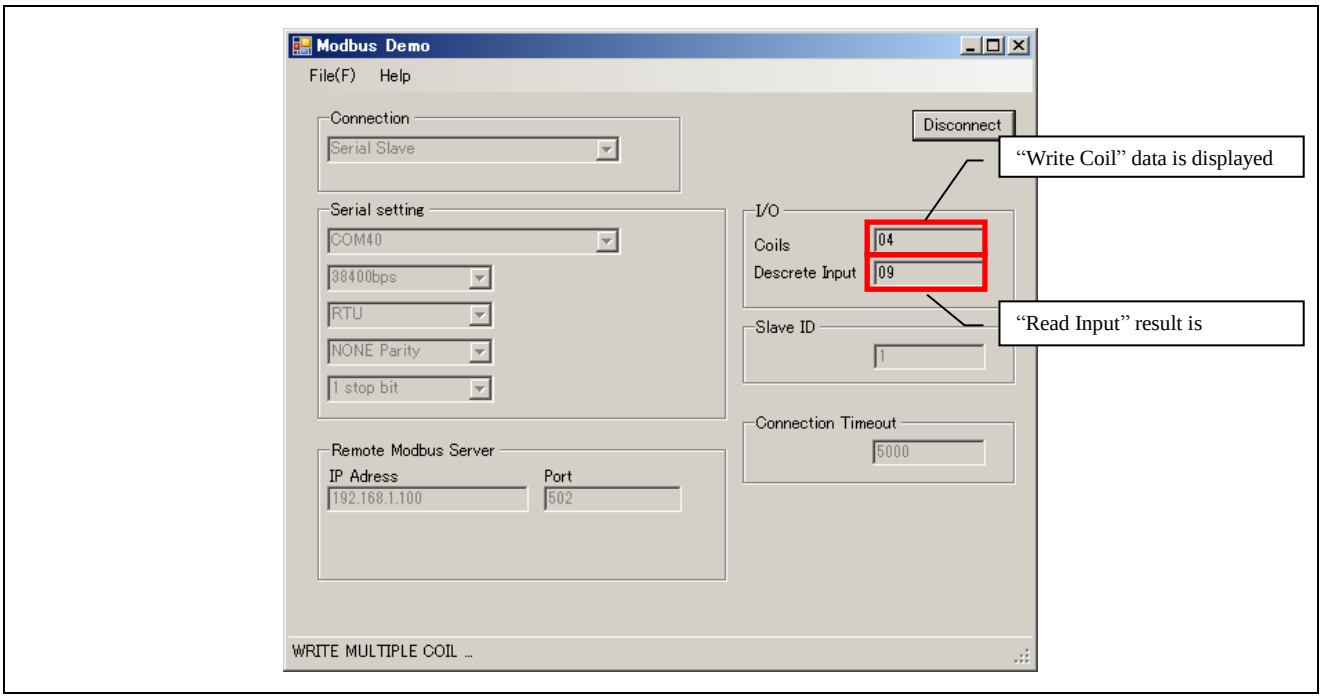


Figure 7.21 After starting demonstration

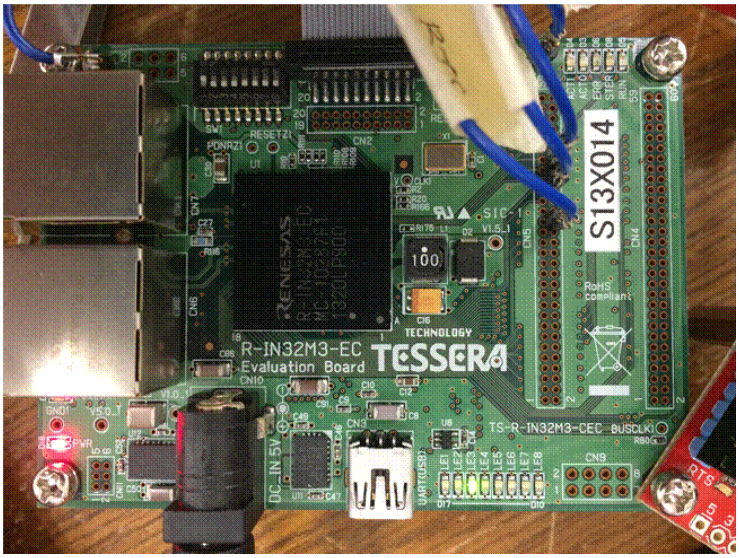


Figure 7.22 LED blinking demo image

7.3 Modbus RTU/ASCII master communication

7.3.1 Overview of sample project

In here, the setup procedure to see the Modbus RTU/ASCII master communication with PC is described. And by using a simple application on Windows PC, the user can see a demonstration that LED blinking pattern is changed by using Read coil and write coil command.

7.3.2 Hardware connection

It is same as for Modbus RTU/ASCII slave. Please refer the section 7.2.2 Hardware connection

7.3.3 Demonstration

7.3.3.1 Specification of demonstration

It is almost same as for Modbus RTU/ASCII slave. Please refer the section 7.2.3.1 Specification of demonstration. The difference is only following.

- LED updating span is fixed to 1 Sec, independent to hardware switch setting.

7.3.3.2 How to set up the demonstration

It is almost same as for Modbus RTU/ASCII slave. Please refer the section 7.2.3.2 How to set up the demonstration the difference is only following.

- For the compiler, please add in “Defined symbols”.

[Compile option setting]

- For Modbus RTU master : add “**MODBUS_MASTER**”
- For Modbus ASCII master : add “**MODBUS_MASTER**” , and “**MODBUS_ASCII**”

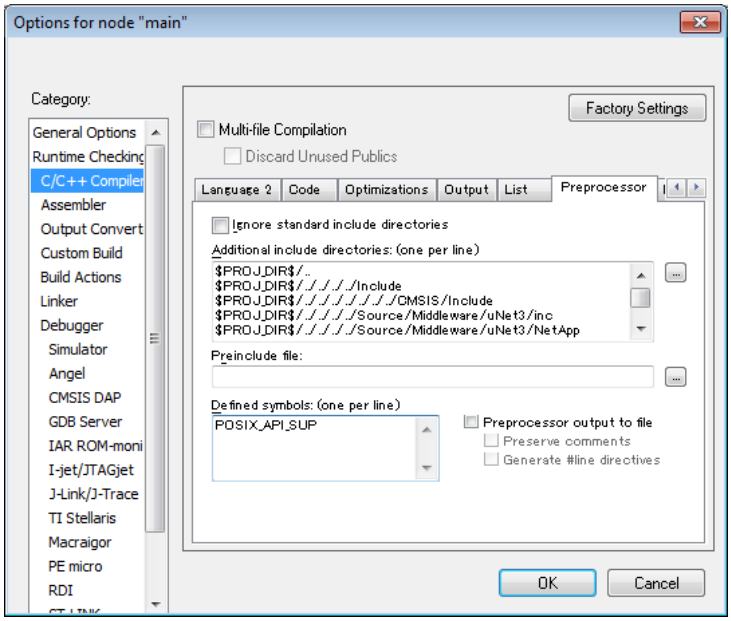


Figure 7.23 Capture of preprocessor setting

(1) Compile. Download, and run application.

(2) Open “ModbusDemoApplication**.exe**” which is included in Modbus stack package.

(3) “Connection” is selected to Serial Master, and select COM port and serial communication parameters

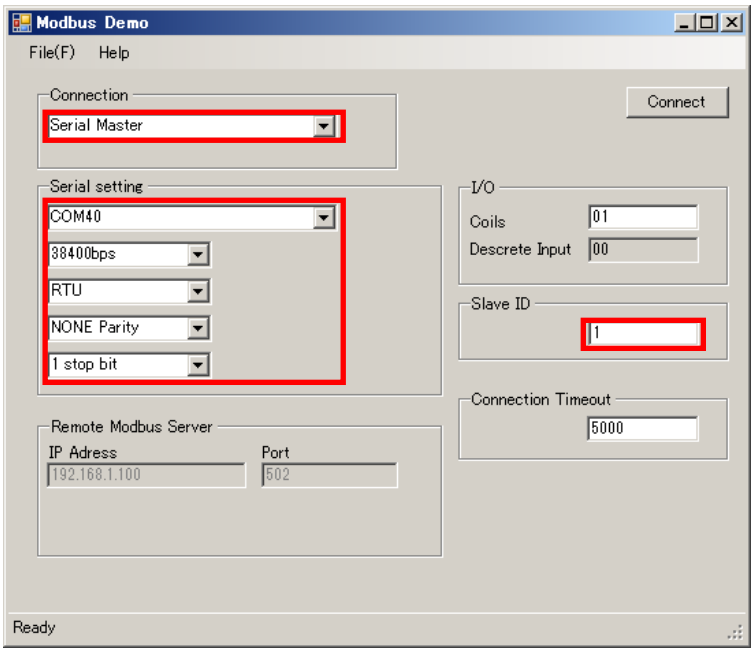


Figure 7.24 After setting port using.

(4) When “Connect” button is pressed, Demo application is ready for Modbus communication.

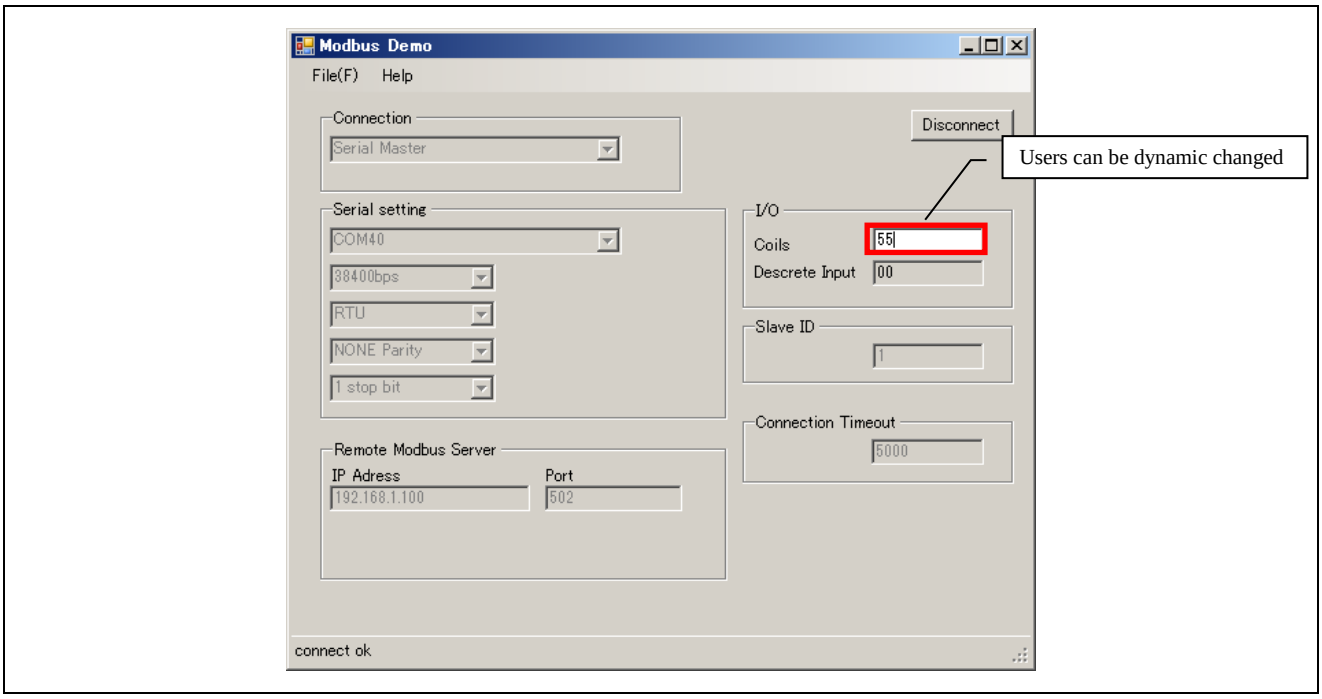


Figure 7.25 After starting demonstration

(5) Once the board is reset, LED blinking will started. <R>

Caution For this demo application, slave device should run before the master program starts to run.

7.4 Modbus TCP server – RTU/ASCII master gateway communication

7.4.1 Overview of sample project

In here, the setup procedure to see the Modbus TCP server – RTU/ASCII master gateway communication with the PC is described. And by using simple application on Windows PC, the user can see a demonstration that LED blinking pattern on RTU/ASCII slave module is changed by using Read coil and write coil command through the gateway module.

7.4.2 Hardware connection

Regarding the evaluation board for setup demonstration, 2 evaluation boards are needed. One is for gateway module, and the other is RTU/ASCII slave device.

The following figure is the hardware setup image for Modbus gateway communication with CEC board.

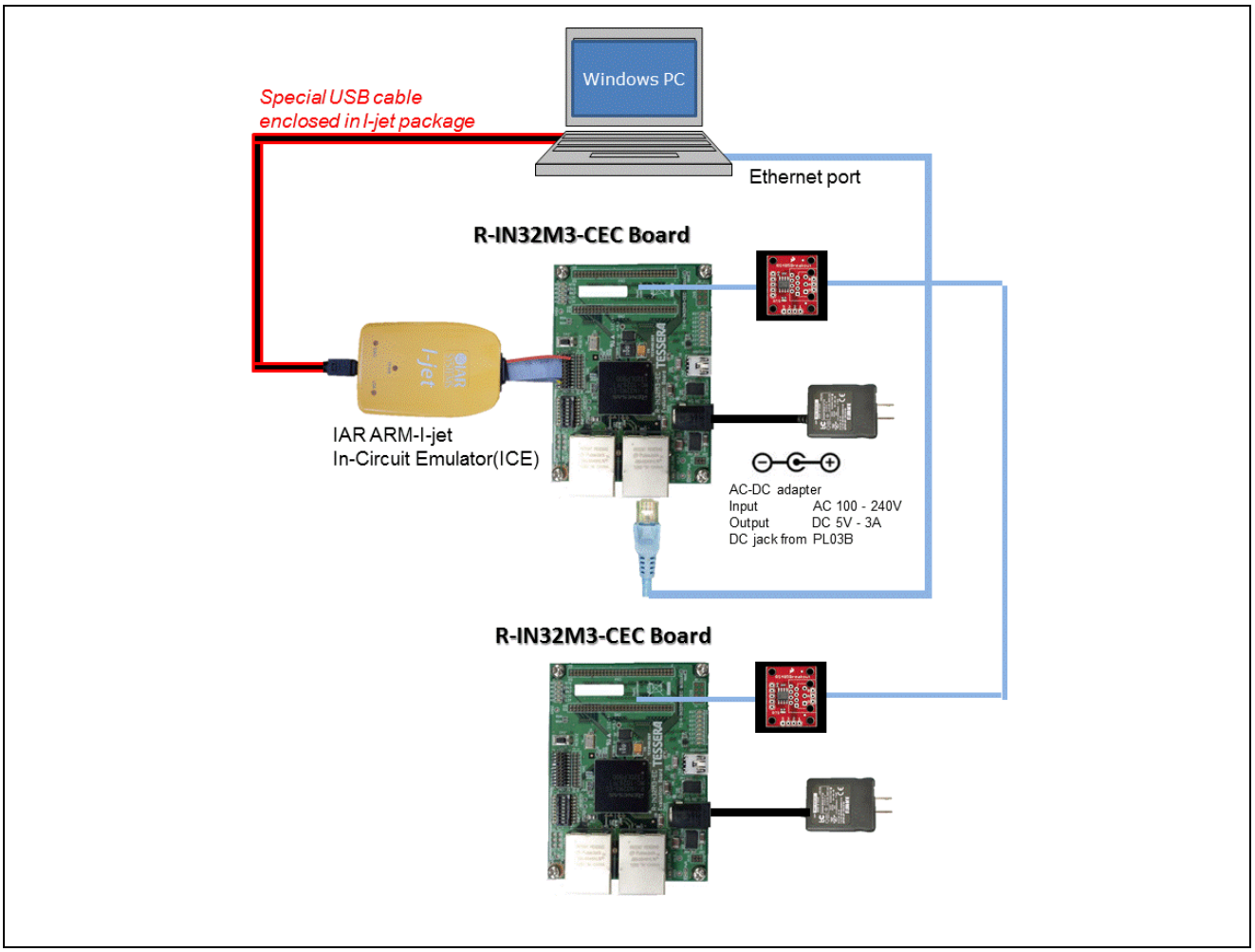


Figure 7.26 Hardware connection for development infrastructure for Modbus gateway with CEC board

7.4.3 Demonstration

User can see the simple demonstration with using the sample project included this stack.

7.4.3.1 Specification of demonstration

Specification is same as for Modbus TCP written in section 7.1.2. By communicating with PC through Modbus TCP protocol, LED blinking pattern is controlled dynamically. For this control, Read Coil and Write Coil command is used.

7.4.3.2 How to set up the demonstration

(1) For Modbus RTU/ASCII slave module

It is same as for Modbus RTU/ASCII slave. Please refer to section 7.2.3.2 How to set up the demonstration.

(2) For Modbus gateway module

It is almost same as for Modbus TCP server. Please refer the section 7.1.4.2 How to set up the demonstration. The difference is only following.

- For the compiler, please add in “Defined symbols”.

[Compile option setting]

- For Modbus gateway : add “**MODBUS_GATEWAY**”

(3) Open “ModbusDemoApplication**.exe**” which is included in Modbus stack package.

(4) “Connection” is selected to TCP gateway, and set server IP (e.g. “**192.168.1.100**”), Port No(e.g. “**502**”) and Slave ID(e.g. “**1**”).

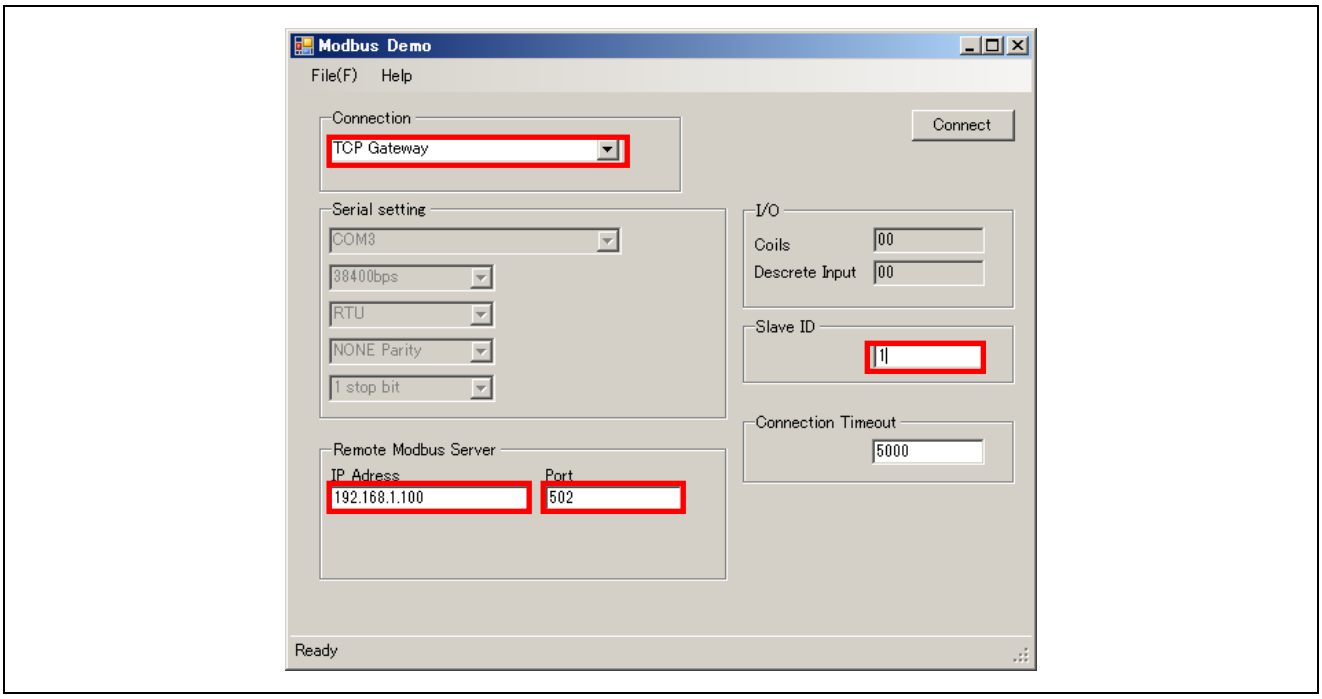


Figure 7.27 After set parameters

(5) When “Connect” button is pressed, LED blinking has started with Modbus communication.

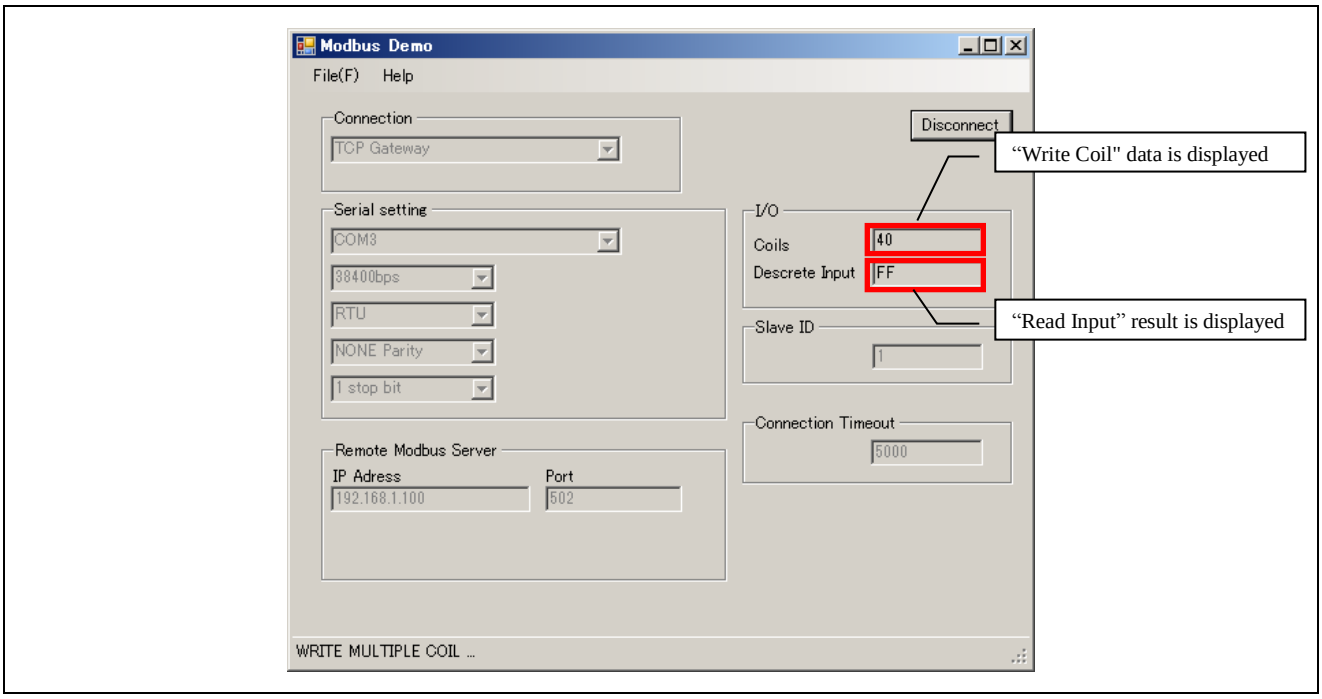


Figure 7.28 After starting demonstration

8. Issue and Limitations

- The gateway functionality uses the MODBUS serial master code. Thus the gateway only allows Modbus transactions with supported function codes by the master.
- There is no priority provided for TCP connections. Upon receiving a new connection request, the oldest connection will be closed.

REVISION HISTORY	R-IN32M3 Series User's Manual: Modbus stack

Rev.	Date	Description	
		Page	Summary
1.00	Apr 08, 2015	-	First edition issued
1.01	Aug 31, 2015	36	Fixed errors in the macro name.
		124 125	Deleted explanation because the DHCP function can not be used.

[Memo]

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R-IN32M3 Series
User's Manual: Modbus stack

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