

# *embOS/IP*

CPU independent  
TCP/IP stack for  
embedded applications

## User Guide

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## Manual versions

This manual describes the latest software version. If any error occurs, please inform us and we will try to assist you as soon as possible.

For further information on topics or routines not yet specified, please contact us.

SW version / Manual revision	Date	By	Explanation
1.60/00	100324	SK	Chapter "API functions" updated. * "IP_SetSupportedDuplexModes()" added. Chapter "FTP client" added. Minor updates and corrections.
1.58/00	100204	SK	Chapter "SMTP client" updated. Chapter "Configuration" updated. * Section "Required buffers" updated. Minor updates and corrections.
1.56/00	090710	SK	Chapter "API functions" updated. * "IP_DNSC_SetMaxTLL()" added. Chapter "Configuring embOS/IP" updated. * Macro "IP_TCP_ACCEPT_CHECKSUM_FFFF" added.
1.54b/00	090603	SK	Chapter "Web server (Add-on)" updated. * "IP_WEBS_Process()" updated. * "IP_WEBS_ProcessLast()" added. * "IP_WEBS_OnConnectionLimit()" updated.
1.54a/01	090520	SK	Chapter "API functions" updated. * IP_GetAddrMask() updated. * IP_GetGWMask() updated. * IP_GetIPMask() updated. Chapter "Web server (Add-on)" updated. * Section "Changing the file system type" added. * Section "IP_WEBS_SetFileInfoCallback" updated.
1.54a/00	090508	SK	Chapter "Web server (Add-on)" updated. * IP_WEBS_GetNumParas() added. * IP_WEBS_GetParaValue() added. * IP_WEBS_DecodeAndCopyStr() added. * IP_WEBS_DecodeString() added. * IP_WEBS_SetFileInfoCallback() added. * IP_WEBS_CompareFilenameExt() added. * Section "Dynamic content" added * Section "Common Gateway interface" moved into section "Dynamic content". Chapter "Socket interface" * getpeername() corrected. Chapter "Network interface drivers" updated.
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1.42/00	080821	SK	Chapter "Web server (Add-on)": * List of valid values for CGI parameter and values added. Chapter "FTP Server (Add-on)": * Section "FTP server system time" added. * pfGetTimeDate() added.
1.40/00	080731	SK	Chapter "API functions": * IP_TCP_SetConnKeepaliveOpt() added. * IP_TCP_SetRetransDelayRange() added. * IP_SendPacket() added. Chapter "Socket interface": * getsockopt() updated. * setsockopt() updated. Chapter "OS integration": * IP_OS_WaitItemTimed() added.

SW version / Manual revision	Date	By	Explanation
1.30/01	080610	SK	Chapter "FTP server (Add-on)" section "Resource usage" added Chapter "Web server (Add-on)" section "Resource usage" added
1.30/00	080423	SK	Chapter "FTP server (Add-on)" added. Chapter "Web server (Add-on)" updated.
1.24/03	080320	SK	Chapter "Socket interface": * getpeername added. * getsockname added.
1.24/02	080222	SK	Chapter "Device Driver": * NXP LPC23xx/24xx driver added.
1.24/01	080124	SK	Chapter "HTTP server (Add-on)" updated. Chapter "API functions": * IP_UTIL_EncodeBase64() added. * IP_UTIL_DecodeBase64() added.
1.24/00	080124	SK	Chapter "HTTP server (Add-on)" added: Chapter "API functions": * IP_AllowBackPressure() added. * IP_GetIPAddr() added. * IP_SendPing() added. * IP_SetDefaultTTL() added.
1.22/04	071213	SK	Chapter "Introduction": * Section "Components of an Ethernet system" added. Chapter "API functions": * IP_IsIFaceReady() added. * IP_NI_ConfigPHYAddr() added. * IP_NI_ConfigPHYMode() added. * IP_NI_ConfigBasePtr () added. Chapter "Socket interface": * All functions: parameter description enhanced. Chapter "Device drivers" renamed to "Network interface drivers". Chapter "Network interface drivers": * Section "ATMEL AT91SAM7X" added. * Section "ATMEL AT91SAM9260" added. * Section "Davicom DM9000" added. * Section "ST STR912" added.
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1.22/02	071123	SK	Chapter "Socket interface": * gethostbyname() added. * Structure hostent added. Chapter "Core functions": * IP_PrintIPAddr() added. * IP_DNS_SetServer() added.
1.22/01	071122	SK	Chapter "DHCP": * IP_DHCP_Activate() updated. Chapter "Debugging": * Section "Testing stability" added. Chapter "Socket interface": * Section "Error codes" added.

SW version / Manual revision	Date	By	Explanation
1.22/00	071114	SK	<p>Chapter "Introduction":</p> <ul style="list-style-type: none"> <li>* "Request for comments" enhanced.</li> </ul> <p>Chapter "API functions":</p> <ul style="list-style-type: none"> <li>* IP_AddLogFilter() added.</li> <li>* IP_AddWarnFilter() added.</li> <li>* IP_GetCurrentLinkSpeed() added.</li> <li>* IP_TCP_Set2MSLDelay() added.</li> <li>* select() added.</li> </ul> <p>Various function descriptions enhanced.</p> <p>Chapter "API functions" renamed to "core functions".</p> <p>Socket functions removed from chapter "API functions"</p> <p>Chapter "Socket interface" added.</p> <p>Chapter "DHCP" added.</p> <p>Chapter "UDP zero copy" added.</p> <p>Chapter "TCP zero copy" added.</p> <p>Chapter "Glossary" added.</p> <p>Chapter "Index" updated.</p>
1.00/02	071017	SK	<p>Chapter "Introduction":</p> <ul style="list-style-type: none"> <li>* Section "Features" enhanced.</li> <li>* Section "Basic concepts" added.</li> <li>* Section "Task and interrupt usage" added.</li> <li>* Section "Further readings" added.</li> </ul> <p>Chapter "Running embOS/IP" enhanced.</p> <p>Chapter "API functions":</p> <ul style="list-style-type: none"> <li>* IP_Init() added.</li> <li>* IP_Task() added.</li> <li>* IP_RxTask() added.</li> <li>* IP_GetVersion() added.</li> <li>* IP_SetLogFilter() added.</li> <li>* IP_SetWarnFilter() added.</li> <li>* IP_Panic() removed.</li> <li>* Structure sockaddr added.</li> <li>* Structure sockaddr_in added.</li> <li>* Structure in_addr added.</li> </ul> <p>Chapter "Device driver".</p> <ul style="list-style-type: none"> <li>* General information updated.</li> <li>* Section "Writing your own driver" added.</li> </ul> <p>Chapter "Debugging" added.</p> <p>Chapter "Performance and resource usage" added.</p> <p>Chapter "OS integration" updated.</p>
1.00/01	071002	SK	<p>Product name changed to "embOS/IP":</p> <p>Chapter "API functions":</p> <ul style="list-style-type: none"> <li>* IP_X_Prepere() renamed to IP_X_Config().</li> <li>* IP_AddBuffers() added.</li> <li>* IP_ConfTCPSpace() added.</li> </ul>
1.00/00	070927	SK	Initial version.

## Software versions

Refers to *Release.html* for information about the changes of the software versions.



# About this document

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## Assumptions

This document assumes that you already have a solid knowledge of the following:

- The software tools used for building your application (assembler, linker, C compiler)
- The C programming language
- The target processor
- DOS command line.

If you feel that your knowledge of C is not sufficient, we recommend *The C Programming Language* by Kernighan and Richie (ISBN 0-13-1103628), which describes the standard in C-programming and, in newer editions, also covers the ANSI C standard.

## How to use this manual

This manual explains all the functions and macros that embOS/IP offers. It assumes you have a working knowledge of the C language. Knowledge of assembly programming is not required.

## Typographic conventions for syntax

This manual uses the following typographic conventions:

Style	Used for
Body	Body text.
Keyword	Text that you enter at the command-prompt or that appears on the display (that is system functions, file- or pathnames).
Parameter	Parameters in API functions.
Sample	Sample code in program examples.
Sample comment	Comments in program examples.
Reference	Reference to chapters, sections, tables and figures or other documents.
<b>GUIElement</b>	Buttons, dialog boxes, menu names, menu commands.
<b>Emphasis</b>	Very important sections

**Table 1.1: Typographic conventions**



**SEGGER Microcontroller GmbH & Co. KG** develops and distributes software development tools and ANSI C software components (middleware) for embedded systems in several industries such as telecom, medical technology, consumer electronics, automotive industry and industrial automation.

SEGGER's intention is to cut software development-time for embedded applications by offering compact flexible and easy to use middleware, allowing developers to concentrate on their application.

Our most popular products are emWin, a universal graphic software package for embedded applications, and embOS, a small yet efficient real-time kernel. emWin, written entirely in ANSI C, can easily be used on any CPU and most any display. It is complemented by the available PC tools: Bitmap Converter, Font Converter, Simulator and Viewer. embOS supports most 8/16/32-bit CPUs. Its small memory footprint makes it suitable for single-chip applications.

Apart from its main focus on software tools, SEGGER develops and produces programming tools for flash microcontrollers, as well as J-Link, a JTAG emulator to assist in development, debugging and production, which has rapidly become the industry standard for debug access to ARM cores.

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## EMBEDDED SOFTWARE (Middleware)



**emWin**

**Graphics software and GUI**

emWin is designed to provide an efficient, processor- and display controller-independent graphical user interface (GUI) for any application that operates with a graphical display. Starterkits, eval- and trial-versions are available.



**embOS**

**Real Time Operating System**

embOS is an RTOS designed to offer the benefits of a complete multitasking system for hard real time applications with minimal resources. The profiling PC tool embOSView is included.



**emFile**

**File system**

emFile is an embedded file system with FAT12, FAT16 and FAT32 support. emFile has been optimized for minimum memory consumption in RAM and ROM while maintaining high speed. Various Device drivers, e.g. for NAND and NOR flashes, SD/MMC and CompactFlash cards, are available.



**USB-Stack**

**USB device stack**

A USB stack designed to work on any embedded system with a USB client controller. Bulk communication and most standard device classes are supported.

## SEGGER TOOLS

**Flasher**

**Flash programmer**

Flash Programming tool primarily for microcontrollers.

**J-Link**

**JTAG emulator for ARM cores**

USB driven JTAG interface for ARM cores.

**J-Trace**

**JTAG emulator with trace**

USB driven JTAG interface for ARM cores with Trace memory. supporting the ARM ETM (Embedded Trace Macrocell).

**J-Link / J-Trace Related Software**

Add-on software to be used with SEGGER's industry standard JTAG emulator, this includes flash programming software and flash breakpoints.



# Table of Contents

1	Introduction to embOS/IP .....	13
1.1	What is embOS/IP .....	14
1.2	Features .....	14
1.3	Basic concepts .....	15
1.3.1	embOS/IP structure .....	15
1.3.2	Encapsulation .....	16
1.4	Tasks and interrupt usage .....	17
1.5	Background information .....	20
1.5.1	Components of an Ethernet system .....	20
1.6	Further reading .....	23
1.6.1	Request for Comments (RFC) .....	23
1.6.2	Related books .....	24
1.7	Development environment (compiler) .....	25
2	Running embOS/IP on target hardware .....	27
2.1	Step 1: Open an embOS start project .....	29
2.2	Step 2: Adding embOS/IP to the start project .....	30
2.3	Step 3: Build the project and test it .....	32
3	Example applications .....	33
3.1	Overview .....	34
3.1.1	embOS/IP DNS client (OS_IP_DNSClient.c) .....	35
3.1.2	embOS/IP non-blocking connect (OS_IP_NonBlockingConnect.c) .....	35
3.1.3	embOS/IP ping (OS_IP_Ping.c) .....	35
3.1.4	embOS/IP shell (OS_IP_Shell.c) .....	35
3.1.5	embOS/IP simple server (OS_IP_SimpleServer.c) .....	36
3.1.6	embOS/IP speed client (OS_IP_SpeedClient_TCP.c) .....	36
3.1.7	embOS/IP speed client (OS_IP_SpeedClient_UDP.c) .....	37
3.1.8	embOS/IP start (OS_IP_Start.c) .....	37
3.1.9	embOS/IP UDP discover (OS_IP_UDPDiscover.c / OS_IP_UDPDiscoverZeroCopy.c)	37
4	Core functions .....	39
4.1	API functions .....	40
4.2	Configuration functions .....	42
4.3	Management functions .....	63
4.4	Other IP stack functions .....	67
4.5	Stack internal functions, variables and data-structures .....	80
5	Socket interface .....	81
5.1	API functions .....	82
5.2	Socket data structures .....	107
5.3	Error codes .....	111
6	TCP zero-copy interface .....	113
6.1	TCP zero-copy .....	114
6.1.1	Allocating, freeing and sending packet buffers .....	114
6.1.2	Callback function .....	114
6.2	Sending data with the TCP zero-copy API .....	115

6.2.1	Allocating a packet buffer .....	115
6.2.2	Filling the allocated buffer with data .....	115
6.2.3	Sending the packet.....	115
6.3	Receiving data with the TCP zero-copy API .....	116
6.3.1	Writing a callback function.....	116
6.3.2	Registering the callback function .....	116
6.4	API functions .....	117
7	UDP zero-copy interface.....	123
7.1	UDP zero-copy .....	124
7.1.1	Allocating, freeing and sending packet buffers.....	124
7.1.2	Callback function.....	124
7.2	Sending data with the UDP zero-copy API.....	125
7.2.1	Allocating a packet buffer .....	125
7.2.2	Filling the allocated buffer with data .....	125
7.2.3	Sending the packet.....	125
7.3	Receiving data with the UDP zero-copy API.....	126
7.3.1	Writing a callback function.....	126
7.3.2	Registering the callback function .....	126
7.4	API functions .....	127
8	DHCP client .....	139
8.1	DHCP backgrounds .....	140
8.2	API functions .....	141
9	Network interface drivers .....	147
9.1	General information.....	148
9.1.1	MAC address filtering .....	148
9.1.2	Checksum computation in hardware .....	148
9.1.3	Ethernet CRC computation.....	148
9.2	Available network interface drivers .....	149
9.2.1	ATMEL AT91SAM7X .....	150
9.2.2	ATMEL AT91SAM9260 .....	153
9.2.3	DAVICOM DM9000/DM9000A .....	156
9.2.4	FREESCALE ColdFire MCF5329 .....	159
9.2.5	NXP LPC23xx / 24xx.....	162
9.2.6	ST STR912 .....	164
9.3	Writing your own driver .....	165
9.3.1	Device driver functions .....	167
10	Configuring embOS/IP .....	173
10.1	Runtime configuration.....	174
10.1.1	IP_X_Configure() .....	174
10.1.2	Driver handling .....	175
10.1.3	Memory and buffer assignment .....	175
10.2	Compile-time configuration.....	177
10.2.1	Compile-time configuration switches .....	177
10.2.2	Debug level .....	178
11	Web server (Add-on).....	179
11.1	embOS/IP web server .....	180
11.2	Feature list.....	181
11.3	Requirements .....	182
11.4	HTTP backgrounds.....	183
11.4.1	HTTP communication basics.....	183
11.4.2	HTTP status codes.....	184
11.5	Using the web server sample .....	185
11.5.1	Using the Windows sample .....	185
11.5.2	Running the web server example on target hardware .....	185

11.5.3	Changing the file system type .....	186
11.6	Dynamic content .....	187
11.6.1	Common Gateway Interface (CGI) .....	187
11.6.2	Virtual files .....	189
11.7	Authentication.....	191
11.7.1	Authentication example .....	192
11.7.2	Configuration of the authentication .....	193
11.8	Form handling.....	194
11.8.1	Simple form processing sample .....	195
11.9	Configuration .....	198
11.9.1	Compile time configuration switches.....	198
11.10	API functions .....	200
11.11	Web server data structures .....	216
11.12	Resource usage .....	220
11.12.1	ROM usage .....	220
11.12.2	RAM usage: .....	220
<b>12</b>	<b>SMTP client (Add-on).....</b>	<b>221</b>
12.1	embOS/IP SMTP client.....	222
12.2	Feature list .....	223
12.3	Requirements.....	224
12.4	SMTP backgrounds.....	225
12.5	Configuration .....	227
12.5.1	Compile time configuration switches.....	227
12.6	API functions .....	228
12.7	SMTP client data structures.....	230
12.8	Resource usage .....	238
12.8.1	ROM usage .....	238
12.8.2	RAM usage: .....	238
<b>13</b>	<b>FTP server (Add-on) .....</b>	<b>239</b>
13.1	embOS/IP FTP server .....	240
13.2	Feature list .....	241
13.3	Requirements.....	242
13.4	FTP basics .....	243
13.4.1	Active mode FTP.....	244
13.4.2	Passive mode FTP .....	245
13.4.3	FTP reply codes .....	246
13.4.4	Supported FTP commands .....	247
13.5	Using the FTP server sample .....	248
13.5.1	Using the Windows sample.....	248
13.5.2	Running the FTP server example on target hardware .....	248
13.6	Access control .....	249
13.7	Configuration .....	253
13.7.1	Compile time configuration switches.....	253
13.7.2	FTP server system time .....	254
13.8	API functions .....	256
13.9	FTP server data structures .....	259
13.10	Resource usage .....	261
13.10.1	ROM usage .....	261
13.10.2	RAM usage: .....	261
<b>14</b>	<b>FTP client (Add-on).....</b>	<b>263</b>
14.1	embOS/IP FTP client .....	264
14.2	Feature list .....	265
14.3	Requirements.....	266
14.4	FTP basics .....	267
14.4.1	Passive mode FTP .....	268
14.4.2	Supported FTP client commands .....	269
14.5	Configuration .....	270

14.5.1	Compile time configuration switches .....	270
14.6	API functions .....	271
14.7	FTP client data structures .....	278
14.8	Resource usage .....	279
14.8.1	ROM usage.....	279
14.8.2	RAM usage:.....	279
15	Debugging.....	281
15.1	Message output .....	282
15.2	Testing stability .....	283
15.3	API functions .....	284
15.4	Message types .....	290
16	OS integration .....	293
16.1	General information.....	294
16.2	OS layer API functions .....	295
16.2.1	Examples .....	295
17	Performance & resource usage .....	297
17.1	Memory footprint .....	298
17.2	Performance.....	299
18	Appendix A - File system abstraction layer .....	301
18.1	File system abstraction layer.....	302
18.2	File system abstraction layer function table.....	303
18.2.1	emFile interface .....	305
18.2.2	Read-only file system .....	306
18.2.3	Using the read-only file system .....	306
18.2.4	Windows file system interface .....	308
19	Glossary.....	309

# Chapter 1

## Introduction to embOS/IP

---

This chapter provides an introduction to using embOS/IP. It explains the basic concepts behind embOS/IP.

## 1.1 What is embOS/IP

embOS/IP is a CPU-independent TCP/IP stack.

embOS/IP is a high-performance library that has been optimized for speed, versatility and small memory footprint.

## 1.2 Features

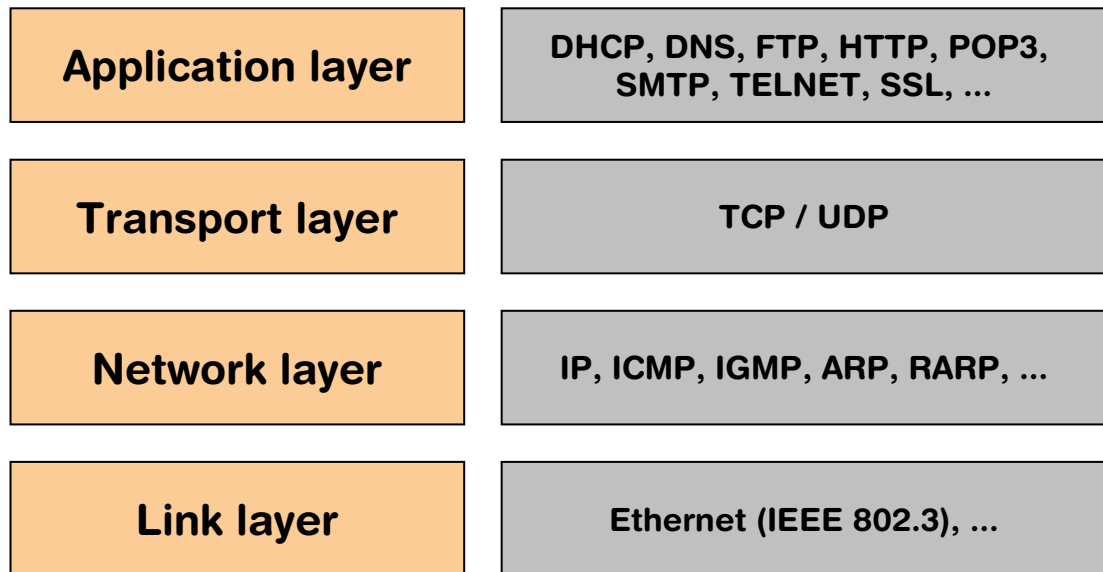
embOS/IP is written in ANSI C and can be used on virtually any CPU.  
Some features of embOS/IP:

- Standard socket interface.
- High performance.
- Small footprint.
- No configuration required.
- Runs "out-of-the-box".
- Very simple network interface driver structure.
- Works seamlessly with embOS in multitasking environment.
- Zero data copy for ultra fast performance.
- Non-blocking versions of all functions.
- Connections limited only by memory availability.
- Delayed ACKs.
- BSD style "keep-alive" option.
- Re-assembly of fragmented packets.
- Support for messages and warnings in debug build.
- Drivers for most common Ethernet controllers available.
- Support for driver side (hardware) checksum computation.
- Royalty-free.

## 1.3 Basic concepts

### 1.3.1 embOS/IP structure

embOS/IP is organized in different layers, as shown in the following illustration.



A short description of each layer's functionality follows below.

#### Application layer

The application layer is the interface between embOS/IP and the user application. It uses the embOS/IP API to transmit data over an TCP/IP network. The embOS/IP API provides functions in BSD (Berkeley Software Distribution) socket style, such as `connect()`, `bind()`, `listen()`, etc.

#### Transport layer

The transport layer provides end-to-end communication services for applications. The two relevant protocols of the Transport layer protocol are the Transmission Control Protocol (TCP) and the User Datagram Protocol (UDP). TCP is a reliable connection-oriented transport service. It provides end-to-end reliability, resequencing, and flow control. UDP is a connectionless transport service.

#### Internet layer

All protocols of the transport layer use the Internet Protocol (IP) to carry data from source host to destination host. IP is a connectionless service, providing no end-to-end delivery guarantees. IP datagrams may arrive at the destination host damaged, duplicated, out of order, or not at all. The transport layer is responsible for reliable delivery of the datagrams when it is required. The IP protocol includes provision for addressing, type-of-service specification, fragmentation and reassembly, and security information.

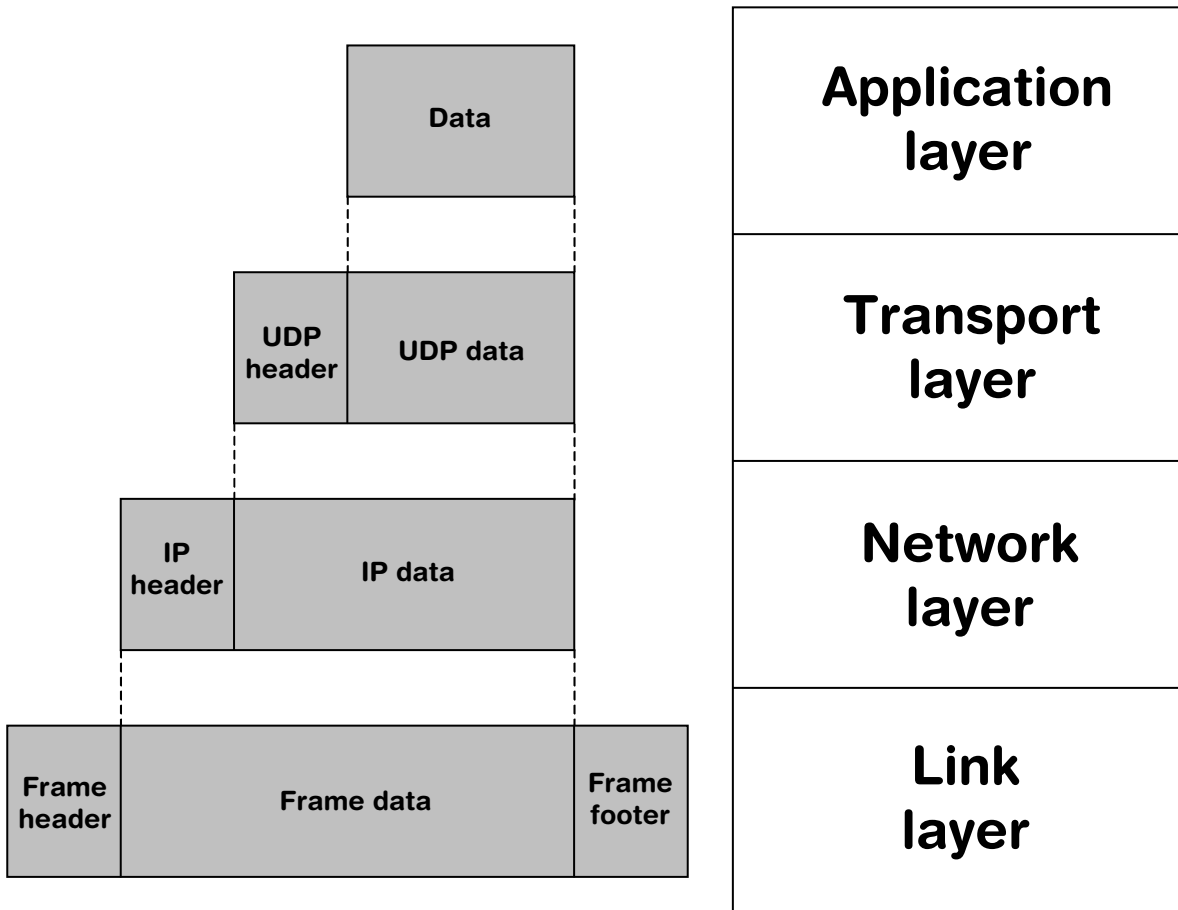
#### Link layer

The link layer provides the implementation of the communication protocol used to interface to the directly-connected network. A variety of communication protocols have been developed and standardized. The most commonly used protocol is Ethernet (IEEE 802.3). In this version of embOS/IP only Ethernet is supported.

## 1.3.2 Encapsulation

The four layers structure is defined in [RFC 1122]. The data flow starts at the application layer and goes over the transport layer, the network layer, and the link layer. Every protocol adds an protocol-specific header and encapsulates the data and header from the layer above as data. On the receiving side, the data will be extracted in the complementary direction. The opposed protocols do not know which protocol on the above and below layers are used.

The following illustration shows the encapsulation of data within an UDP datagram within an IP packet.



## 1.4 Tasks and interrupt usage

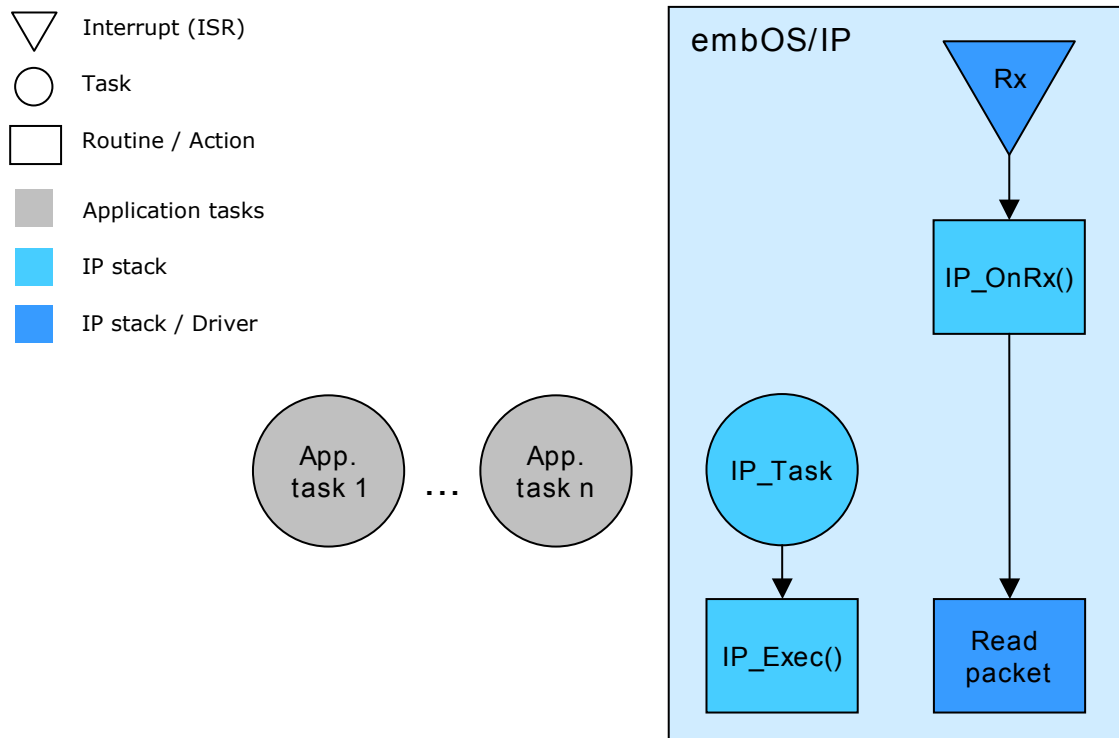
embOS/IP can be used in an application in three different ways.

- One task dedicated to the stack (`IP_Task`)
- Two tasks dedicated to the stack (`IP_Task`, `IP_RxTask`)
- Zero tasks dedicated to the stack (`Superloop`)

The default task structure is one task dedicated to the stack. The priority of the management tasks `IP_Task` (and `IP_RxTask` if available) should be higher than the priority of an application task which uses the stack.

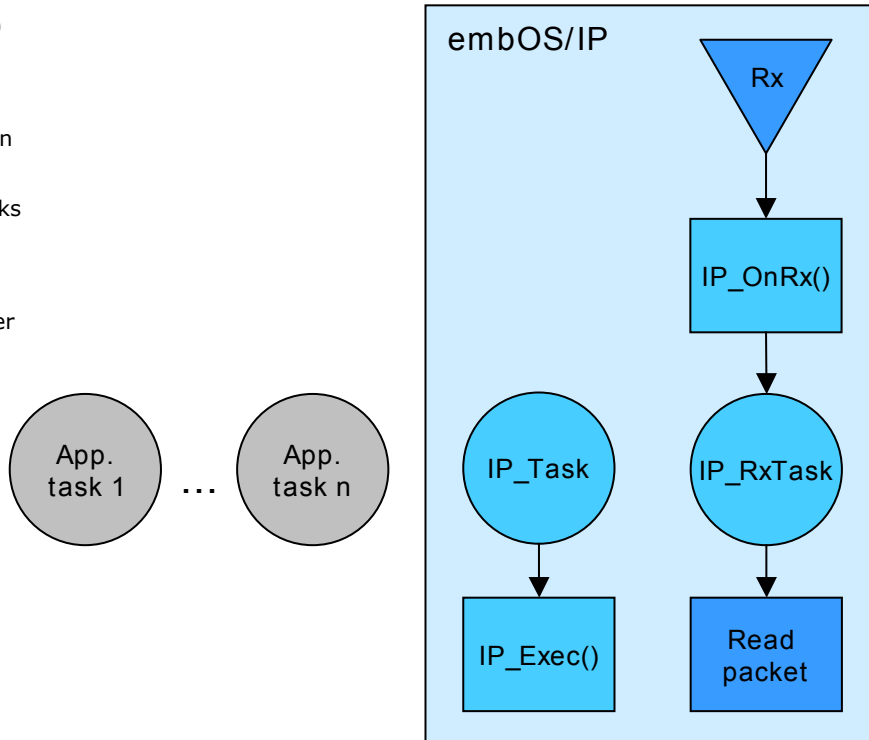
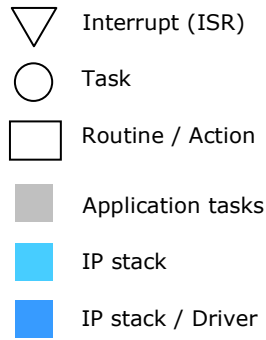
### One task dedicated to the stack

To use one task dedicated to the stack is the simplest way to use the TCP/IP stack. It is called `IP_Task` and handles housekeeping operations, resending and handling of incoming packets. The "Read packet" operation is performed from within the ISR. Because the "Read packet" operation is called directly from the ISR, no additional task is required. The length of the interrupt latency will be extended for the time period which is required to process the "Read packet" operation. Refer to `IP_Task()` on page 64 for more information and an example about how to include the `IP_Task` into your embOS project.



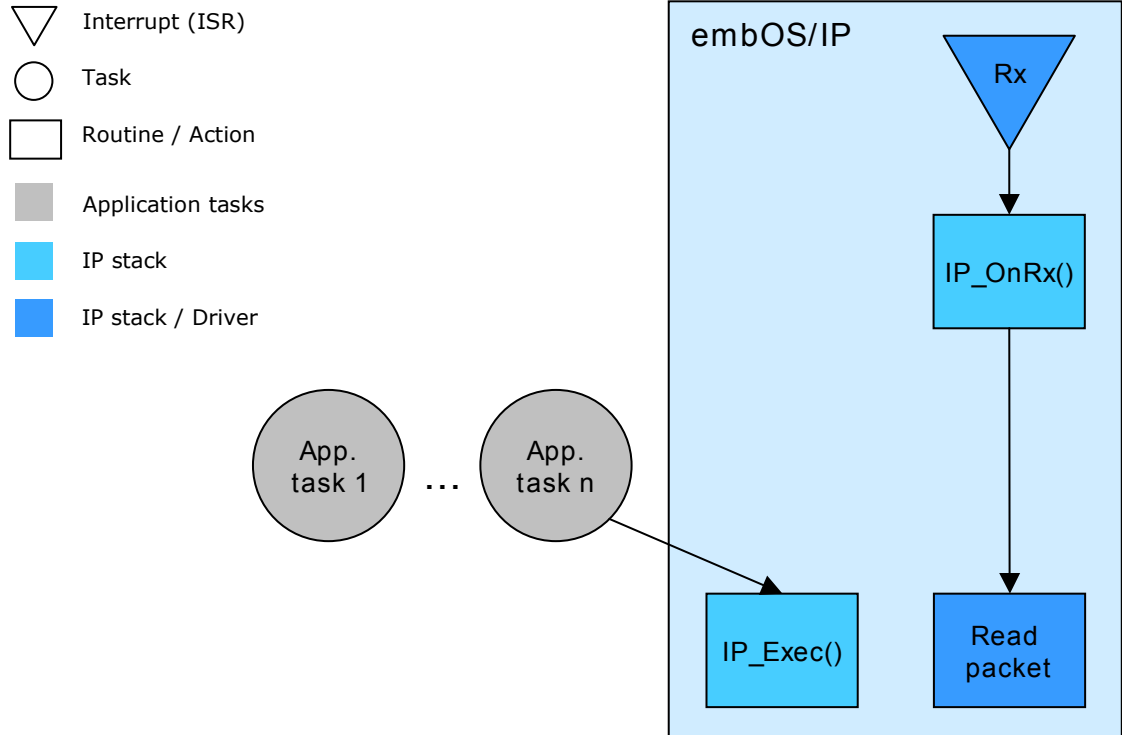
### Two tasks dedicated to the stack

Two tasks are dedicated to the stack. The first task is called the `IP_Task` and handles housekeeping operations, resends, and handling of incoming packets. The second is called `IP_RxTask` and handles the "Read packet" operation. `IP_RxTask` is waked up from the interrupt service routine, if new packets are available. The interrupt latency is not extended, because the "Read packet" operation has been moved from the interrupt service routine to `IP_RxTask`. Refer to `IP_Task()` on page 64 and `IP_RxTask()` on page 65 for more information.



## Zero tasks dedicated to the stack (Superloop)

embOS/IP can also be used without any additional task for the stack, if an application task calls `IP_Exec()` periodically. The "Read packet" operation is performed from within the ISR. Because the "Read packet" operation is called directly from the ISR, no additional task is required. The length of the interrupt latency will be extended for the time period which is required to process the "Read packet" operation.



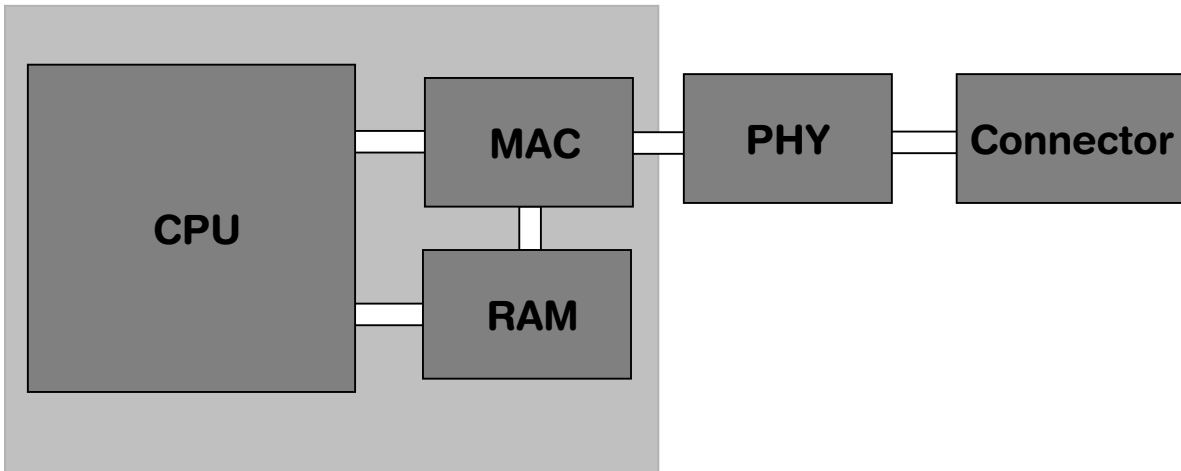
## 1.5 Background information

### 1.5.1 Components of an Ethernet system

Main parts of an Ethernet system are the Media Access Controller (MAC) and the Physical device (PHY). The MAC handles generating and parsing physical frames and the PHY handles how this data is actually moved to or from the wire.

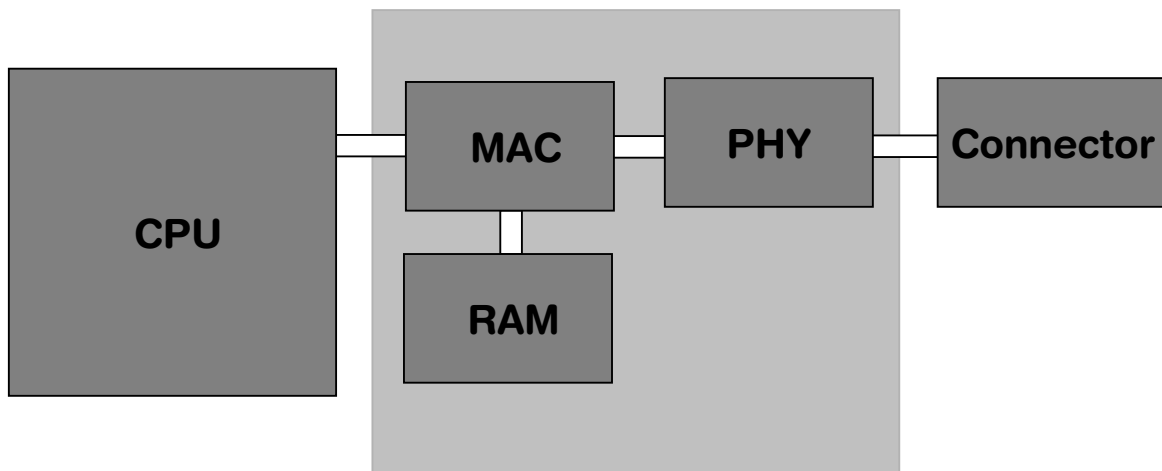
#### MCUs with integrated MAC

Some modern MCUs (for example, the ATMEL SAM7X or the ST STR912) include the MAC and use the internal RAM to store the Ethernet data. The following block diagram illustrates such a configuration.



#### External Ethernet controllers with MAC and PHY

Chips without integrated MAC can use fully integrated single chip Ethernet MAC controller with integrated PHY and a general processor interface. The following schematic illustrates such a configuration.



### 1.5.1.1 MII / RMII: Interface between MAC and PHY

The MAC communicates with the PHY via the Media Independent Interface (MII) or the Reduced Media Independent Interface (RMII). The MII is defined in IEEE 802.3u. The RMII is a subset of the MII and is defined in the RMI specification. The MII/RMII can handle control over the PHY which allows for selection of such transmission criteria as line speed, duplex mode, etc.

In theory, up to 32 PHYs can be connected to a single MAC. In praxis, this is never done; only one PHY is connected. In order to allow multiple PHYs to be connected to a single MAC, individual 5-bit addresses have been assigned to the different PHYs. If only one PHY is connected, the embOS/IP driver automatically finds the address of it.

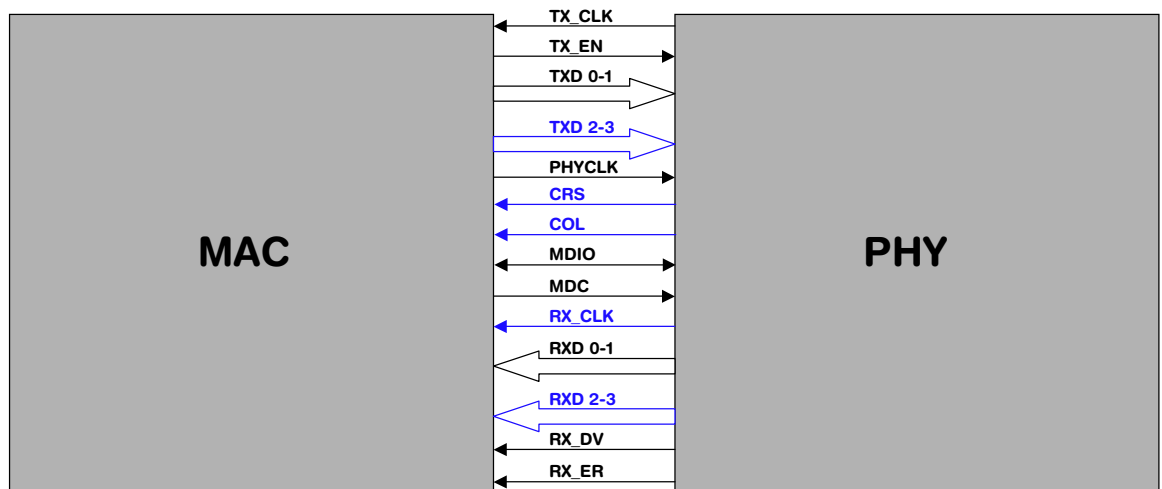
The standard defines 32 16-bit PHY registers. The first 6 are defined by the standard.

Register	Description
BMCR	Basic Mode Control Register
BSR	Basic Mode Status Register
PHYSID1	PHYS ID 1
PHYSID2	PHYS ID 2
ANAR	Auto-Negotiation Advertisement Register
LPAR	Link Partner Ability register

**Table 1.1: Standardized registers of the MAC/PHY interface**

The drivers automatically recognize any PHY connected, no manual configuration of PHY address is required.

The MII and RMII interface are capable of both 10Mb/s and 100Mb/s data rates as described in the IEEE 802.3u standard.



The intent of the RMII is to provide a reduced pin count alternative to the IEEE 802.3u MII. It uses 2 bits for transmit (TXD0 and TXD1) and two bits for receive (RXD0 and RXD1). There is a Transmit Enable (TX\_EN), a Receive Error (RX\_ER), a Carrier Sense (CRS), and a 50 MHz Reference Clock (TX\_CLK) for 100Mb/s data rate. The pins used by the MII and RMII interfaces are described in the following table.

Signal	MII	RMII
TX_CLK	Transmit Clock (25 MHz)	Reference Clock (50 MHz)
TX_EN	Transmit Enable	Transmit Enable
TXD[0:1]	4-bit Transmit Data	2-bit Transmit Data
TXD[2:3]		N/A

**Table 1.2: MII / RMII comparison**

Signal	MII	RMII
PHYCLK	PHY Clock Output	PHY Clock Output
CRS	Carrier Sense	N/A
COL	Collision Detect	N/A
MDIO	Management data I/O	Management data I/O
MDC	Data Transfer Timing Reference Clock	Data Transfer Timing Reference Clock
RX_CLK	Receive Clock	N/A
RXD[0:1]	4-bit Receive Data	2-bit Receive Data
RXD[2:3]		N/A
RX_DV	Data Valid	Carrier Sense/Data Valid
RX_ER	Receive Error	Receive Error

**Table 1.2: MII / RMII comparison**

## 1.6 Further reading

This guide explains the usage of the embOS/IP protocol stack. It describes all functions which are required to build a network application. For a deeper understanding about how the protocols of the internet protocol suite works use the following references.

The following Request for Comments (RFC) define the relevant protocols of the internet protocol suite and have been used to build the protocol stack. They contain all required technical specifications. The listed books are simpler to read as the RFCs and give a general survey about the interconnection of the different protocols.

### 1.6.1 Request for Comments (RFC)

RFC#	Description
[RFC 768]	UDP - User Datagram Protocol Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc768.txt">ftp://ftp.rfc-editor.org/in-notes/rfc768.txt</a>
[RFC 791]	IP - Internet Protocol Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc791.txt">ftp://ftp.rfc-editor.org/in-notes/rfc791.txt</a>
[RFC 792]	ICMP - Internet Control Message Protocol Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc792.txt">ftp://ftp.rfc-editor.org/in-notes/rfc792.txt</a>
[RFC 793]	TCP - Transmission Control Protocol Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc793.txt">ftp://ftp.rfc-editor.org/in-notes/rfc793.txt</a>
[RFC 821]	SMTP - Simple Mail Transfer Protocol Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc826.txt">ftp://ftp.rfc-editor.org/in-notes/rfc826.txt</a>
[RFC 826]	ARP - Ethernet Address Resolution Protocol Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc826.txt">ftp://ftp.rfc-editor.org/in-notes/rfc826.txt</a>
[RFC 951]	BOOTP - Bootstrap Protocol Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc951.txt">ftp://ftp.rfc-editor.org/in-notes/rfc951.txt</a>
[RFC 959]	FTP - File Transfer Protocol Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc959.txt">ftp://ftp.rfc-editor.org/in-notes/rfc959.txt</a>
[RFC 1034]	DNS - Domain names - concepts and facilities Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc1034.txt">ftp://ftp.rfc-editor.org/in-notes/rfc1034.txt</a>
[RFC 1035]	DNS - Domain names - implementation and specification Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc1035.txt">ftp://ftp.rfc-editor.org/in-notes/rfc1035.txt</a>
[RFC 1042]	IE-EEE - Transmission of IP datagrams over IEEE 802 networks Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc1042.txt">ftp://ftp.rfc-editor.org/in-notes/rfc1042.txt</a>
[RFC 1122]	Requirements for Internet Hosts - Communication Layers Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc1122.txt">ftp://ftp.rfc-editor.org/in-notes/rfc1122.txt</a>
[RFC 1123]	Requirements for Internet Hosts - Application and Support Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc1123.txt">ftp://ftp.rfc-editor.org/in-notes/rfc1123.txt</a>
[RFC 1661]	PPP - Point-to-Point Protocol Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc1661.txt">ftp://ftp.rfc-editor.org/in-notes/rfc1661.txt</a>
[RFC 1939]	POP3 - Post Office Protocol - Version 3 Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc1939.txt">ftp://ftp.rfc-editor.org/in-notes/rfc1939.txt</a>
[RFC 2131]	DHCP - Dynamic Host Configuration Protocol Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc2131.txt">ftp://ftp.rfc-editor.org/in-notes/rfc2131.txt</a>
[RFC 2616]	HTTP - Hypertext Transfer Protocol -- HTTP/1.1 Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc2616.txt">ftp://ftp.rfc-editor.org/in-notes/rfc2616.txt</a>

## 1.6.2 Related books

- [Comer] - Computer Networks and Internets, Douglas E Comer and Ralph E. Droms - ISBN: 978-0131433519
- [Tannenbaum] - Computer Networks, Andrew S. Tannenbaum  
ISBN: 978-0130661029
- [StevensV1] - TCP/IP Illustrated, Volume 1, W. Richard Stevens  
ISBN: 978-0201633467.
- [StevensV2] - TCP/IP Illustrated, Volume 2, W. Richard Stevens and Gary R. Wright - ISBN: 978-0201633542.
- [StevensV3] - TCP/IP Illustrated, Volume 3, W. Richard Stevens  
ISBN: 978-0201634952.

## 1.7 Development environment (compiler)

The CPU used is of no importance; only an ANSI-compliant C compiler complying with at least one of the following international standard is required:

- ISO/IEC/ANSI 9899:1990 (C90) with support for C++ style comments (//)
- ISO/IEC 9899:1999 (C99)
- ISO/IEC 14882:1998 (C++)

If your compiler has some limitations, let us know and we will inform you if these will be a problem when compiling the software. Any compiler for 16/32/64-bit CPUs or DSPs that we know of can be used; most 8-bit compilers can be used as well.

A C++ compiler is not required, but can be used. The application program can therefore also be programmed in C++ if desired.



# Chapter 2

## Running embOS/IP on target hardware

---

This chapter explains how to integrate and run embOS/IP on your target hardware. It explains this process step-by-step.

## Integrating embOS/IP

The embOS/IP default configuration is preconfigured with valid values, which matches the requirements of the most applications. embOS/IP is designed to be used with embOS, SEGGER's real-time operating system. We recommend to start with an embOS sample project and include embOS/IP into this project.

We assume that you are familiar with the tools you have selected for your project (compiler, project manager, linker, etc.). You should therefore be able to add files, add directories to the include search path, and so on. In this document the IAR Embedded Workbench® IDE is used for all examples and screenshots, but every other ANSI C toolchain can also be used. It is also possible to use make files; in this case, when we say "add to the project", this translates into "add to the make file".

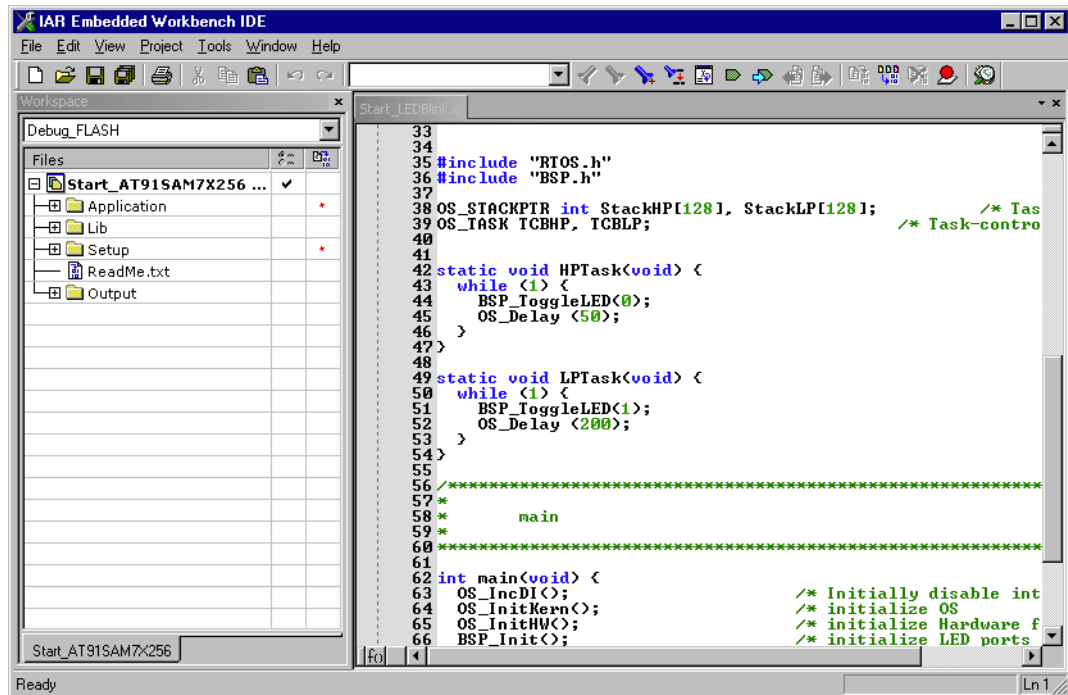
### Procedure to follow

Integration of embOS/IP is a relatively simple process, which consists of the following steps:

- Step 1: Open an embOS project and compile it.
- Step 2: Add embOS/IP to the start project
- Step 3: Compile the project

## 2.1 Step 1: Open an embOS start project

We recommend that you use one of the supplied embOS start projects for your target system. Compile the project and run it on your target hardware.



## 2.2 Step 2: Adding embOS/IP to the start project

Add all source files in the following directory to your project:

- Config
- IP
- UTIL (optional)

The `Config` folder includes all configuration files of embOS/IP. The configuration files are preconfigured with valid values, which match the requirements of most applications. Add the hardware configuration `IP_Config_<TargetName>.c` supplied with the driver shipment.

If your hardware is currently not supported, use the example configuration file and the driver template to write your own driver. The example configuration file and the driver template is located in the `Sample\Driver\Template` folder.

The `Util` folder is an optional component of the embOS/IP shipment. It contains optimized MCU and/or compiler specific files, for example a special memcpy function.

### Replace BSP.c and BSP.h of your embOS start project

Replace the `BSP.c` source file and the `BSP.h` header file used in your embOS start project with the one which is supplied with the embOS/IP shipment. Some drivers require a special functions which initializes the network interface of the driver. This function is called `BSP_ETH_Init()`. It is used to enable the ports which are connected to the network hardware. All network interface driver packages include the `BSP.c` and `BSP.h` files irrespective if the `BSP_ETH_Init()` function is implemented.

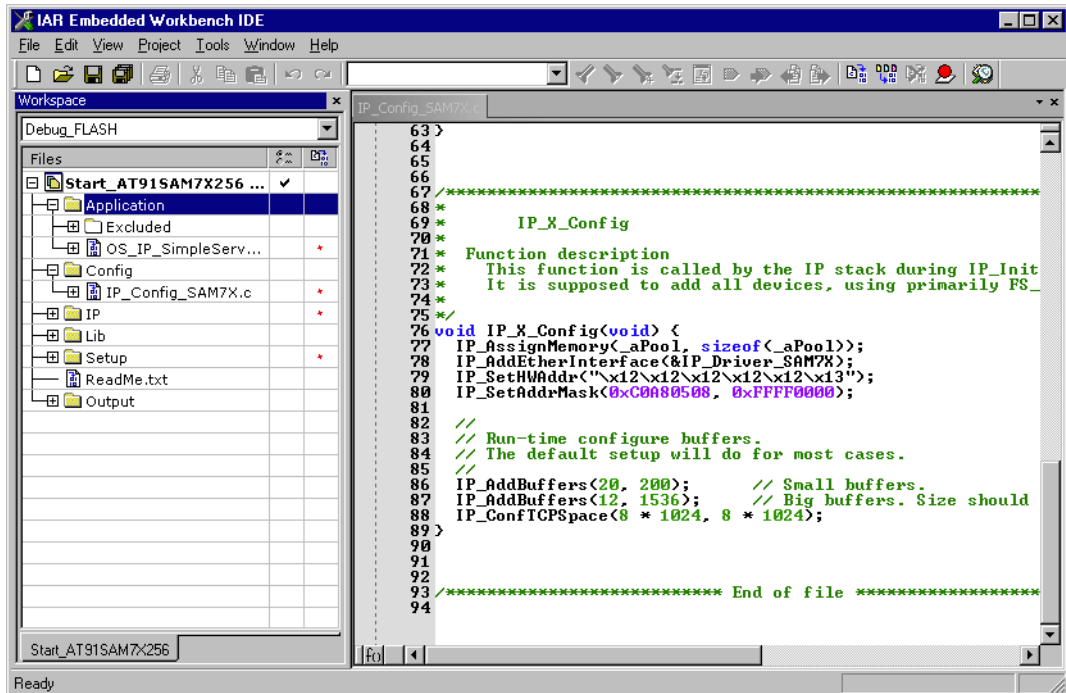
### Configuring the include path

The include path is the path in which the compiler looks for include files. In cases where the included files (typically header files, `.h`) do not reside in the same directory as the C file to compile, an include path needs to be set. In order to build the project with all added files, you will need to add the following directories to your include path:

- Config
- Inc
- IP

## Select the start application

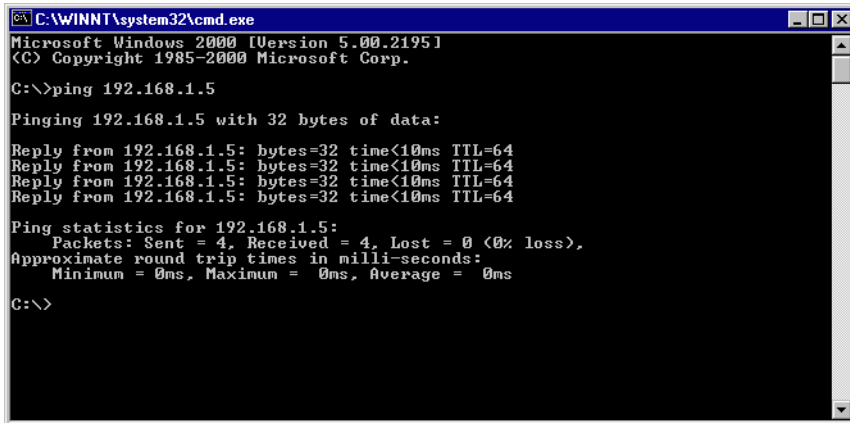
For quick and easy testing of your embOS/IP integration, start with the code found in the folder `Application`. Add one of the applications to your project (for example `OS_IP_SimpleServer.c`).



## 2.3 Step 3: Build the project and test it

Build the project. It should compile without errors and warnings. If you encounter any problem during the build process, check your include path and your project configuration settings. To test the project, download the output into your target and start the application.

By default, ICMP is activated. This means that you could ping your target. Open the command line interface of your operating system and enter `ping <TargetAddress>`, to check if the stack runs on your target. The target should answer all pings without any error.



```
C:\WINNT\system32\cmd.exe
Microsoft Windows 2000 [Version 5.00.2195]
(C) Copyright 1985-2000 Microsoft Corp.

C:\>ping 192.168.1.5

Pinging 192.168.1.5 with 32 bytes of data:

Reply from 192.168.1.5: bytes=32 time<10ms TTL=64
Reply from 192.168.1.5: bytes=32 time<10ms TTL=64
Reply from 192.168.1.5: bytes=32 time<10ms TTL=64
Reply from 192.168.1.5: bytes=32 time<10ms TTL=64

Ping statistics for 192.168.1.5:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 0ms, Maximum = 0ms, Average = 0ms

C:\>
```

# Chapter 3

## Example applications

---

In this chapter, you will find a description of each embOS/IP example application.

## 3.1 Overview

Various example applications for embOS/IP are supplied. These can be used for testing the correct installation and proper function of the device running embOS/IP.

The following start application files are provided:

File	Description
OS_IP_DNSClient.c	Demonstrates the use of the integrated DNS client.
OS_IP_NonBlockingConnect.c	Demonstrates how to connect to a server using non-blocking sockets.
OS_IP_Ping.c	Demonstrates how to send ICMP echo requests and how to process ICMP replies in application.
OS_IP_Shell.c	Demonstrates using the IP-shell to diagnose the IP stack.
OS_IP_SimpleServer.c	Demonstrates setup of a simple server which simply sends back the target system tick for every character received.
OS_IP_SpeedClient_TCP.c	Demonstrates the TCP send and receive performance of the device running embOS/IP. Refer to <i>embOS/IP speed client (OS_IP_SpeedClient_TCP.c)</i> on page 36 for detailed information.
OS_IP_SpeedClient_UDP.c	Demonstrates the UDP send performance of the device running embOS/IP.
OS_IP_Start.c	Demonstrates use of the IP stack without any server or client program. To ping the target, use the command line: <code>ping &lt;target-ip&gt;</code> where <code>&lt;target-ip&gt;</code> represents the IP address of the target, which depends on the configuration and is usually <code>192.168.5.1</code> if the DHCP client is not enabled.
OS_IP_UDPDiscover.c	Demonstrates setup of a simple UDP application which replies to UDP broadcasts. The application sends an answer for every received discover packet. The related host application sends discover packets as UDP broadcasts and waits for the feedback of the targets which are available in the subnet.
OS_IP_UDPDiscoverZeroCopy.c	Demonstrates setup of a simple UDP application which replies to UDP broadcasts. The application uses the embOS/IP zero-copy interface. It sends an answer for every received discover packet. The related host application sends discover packets as UDP broadcasts and waits for the feedback of the targets which are available in the subnet.

**Table 3.1: embOS/IP example applications**

The example applications for the target-side are supplied in source code in the Application directory.

### 3.1.1 embOS/IP DNS client (OS\_IP\_DNSClient.c)

The embOS/IP DNS client resolves a hostname (for example, *www.segger.com*) to an IP address and outputs the resolved address via terminal I/O.

### 3.1.2 embOS/IP non-blocking connect (OS\_IP\_NonBlockingConnect.c)

The embOS/IP non-blocking connect sample demonstrates how to connect to a server using non-blocking sockets. The target tries to connect to TCP server with a non-blocking socket. The sample can be used with any TCP server independent of the application which is listening on the port. The client only opens a TCP connection to the server and closes it without any further communication. The terminal I/O output in your debugger should be similar to the following out:

```
Connecting using non-blocking socket...
Successfully connected after 2ms!
1 of 1 tries were successful.
```

```
Connecting using non-blocking socket...
Successfully connected after 1ms!
2 of 2 tries were successful.
```

### 3.1.3 embOS/IP ping (OS\_IP\_Ping.c)

The embOS/IP ping sample demonstrates how to send ICMP echo requests and how to process received ICMP packets in your application. A callback function is implemented which outputs a message if an ICMP echo reply or an ICMP echo request has been received.

To test the embOS/IP ICMP implementation, you have to perform the following steps:

1. Customize the `Local defines, configurable` section of `OS_IP_Ping.c`. Change the macro `HOST_TO_PING` accordant to your configuration. For example, if the Windows host PC which you want to ping use the IP address 192.168.5.15, change the `HOST_TO_PING` macro to `0xC0A8050F`.
2. Open the command line interface and enter:  

```
ping [IP_ADDRESS _OF_YOUR_TARGET_RUNNING_EMBOSIP]
```

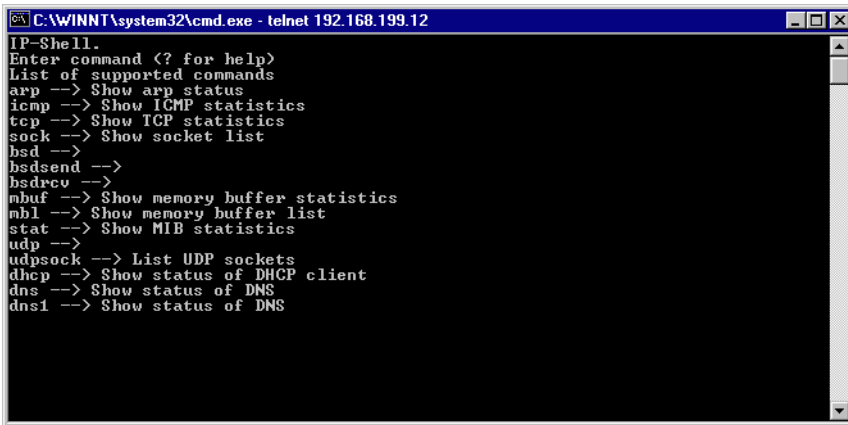
The terminal I/O output in your debugger should be similar to the following out:

```
ICMP echo reply received!
ICMP echo request received!
ICMP echo reply received!
ICMP echo reply received!
ICMP echo reply received!
ICMP echo reply received!
ICMP echo reply received!
ICMP echo request received!
ICMP echo reply received!
ICMP echo reply received!
ICMP echo reply received!
```

### 3.1.4 embOS/IP shell (OS\_IP\_Shell.c)

The embOS/IP shell server is a task which opens TCP-port 23 (telnet) and waits for a connection. The actual shell server is part of the stack, which keep the application program nice and small. The shell server task can be added to any application and should be used to retrieve status information while the target is running. To connect

to the target, use the command line: `telnet <target-ip>` where `<target-ip>` represents the IP address of the target, which depends on the configuration and is usually `192.168.5.230` if the DHCP client is not enabled.



```

C:\WINNT\system32\cmd.exe - telnet 192.168.199.12
IP-Shell.
Enter command (? for help)
List of supported commands
arp --> Show arp status
icmp --> Show ICMP statistics
tcp --> Show TCP statistics
sock --> Show socket list
bsd -->
bsdsend -->
bsdrcv -->
mbuf --> Show memory buffer statistics
mbl --> Show memory buffer list
stat --> Show MIB statistics
udp -->
udpsock --> List UDP sockets
dhcp --> Show status of DHCP client
dns --> Show status of DNS
dns1 --> Show status of DNS

```

### 3.1.5 embOS/IP simple server (OS\_IP\_SimpleServer.c)

Demonstrates setup of a simple server which simply sends back the target system tick for every character received. It opens TCP-port 23 (telnet) and waits for a connection. To connect to the target, use the command line: `telnet <target-ip>` where `<target-ip>` represents the IP address of the target, which depends on the configuration and is usually `192.168.5.230` if the DHCP client is not enabled.

### 3.1.6 embOS/IP speed client (OS\_IP\_SpeedClient\_TCP.c)

The embOS/IP speed client is a small application to detect the TCP send and receive performance of embOS/IP on your hardware.

#### 3.1.6.1 Running the embOS/IP speed client

To test the embOS/IP performance, you have to perform the following steps:

1. Start the Windows speed test server. The example application for the host-side is supplied as executable and in source code in the `Windows\SpeedTestServer\` directory. To run the speed test server, simply start the executable, for example by double-clicking it or open the supplied Visual C project and compile and start the application.
2. Add `OS_IP_SpeedClient.c` to your project.
3. Customize the Local defines, configurable section of `OS_IP_SpeedClient.c`. Change the macro `SERVER_IP_ADDR` accordant to your configuration. For example, if the Windows host PC running the speed test server uses the IP address `192.168.5.15`, change the `SERVER_IP_ADDR` macro to `0xC0A8050F`. If you have changed the port which the Windows host application uses to listen, change the macro `SERVER_PORT` accordingly.
4. Build and download the speed client into your target. The target connects to the

server and starts the transmission.

```

C:\Documents and Settings\Sven\Desktop\SpeedTestServer.exe
Server sent 4194304 bytes.
Total Time: 1359 ms
Bytes per second: 3085465
*****
Server starts sending 4194304 bytes.
*****
Server sent 4194304 bytes.
Total Time: 1359 ms
Bytes per second: 3085465
*****
Server starts sending 4194304 bytes.

```

### 3.1.7 embOS/IP speed client (OS\_IP\_SpeedClient\_UDP.c)

The embOS/IP speed client is a small application to detect the UDP send performance of embOS/IP on your hardware.

### 3.1.8 embOS/IP start (OS\_IP\_Start.c)

Demonstrates use of the IP stack without any server or client program. To ping the target, use the command line: `ping <target-ip>` where `<target-ip>` represents the IP address of the target, which depends on the configuration and is usually 192.168.5.230 if the DHCP client is not enabled.

### 3.1.9 embOS/IP UDP discover (OS\_IP\_UDPDiscover.c / OS\_IP\_UDPDiscoverZeroCopy.c)

To test the embOS/IP UDP discover example, you have to perform the following steps:

1. Start the Windows UDP discover example application. The example application for the host-side is supplied as executable and in source code in the `Windows\UDPDiscover\` directory. To run the UDP discover example, simply start the executable, for example by double-clicking it or open the supplied Visual C project and compile and start the application.
2. Add `OS_IP_UDPDiscover.c` to your project.
3. Customize the `Local defines, configurable` section of `OS_IP_UDPDiscover.c`. By default, the example uses port 50020. If you have changed the port that the Windows host application uses, change the macro `PORT` accordingly.
4. Build and download the UDP discover example into your target. The target sends an answer for every received discover packet. The related host application sends discover packets as UDP broadcasts and waits for the feedback of the targets which are available in the subnet.



# Chapter 4

## Core functions

---

In this chapter, you will find a description of each embOS/IP core function.

## 4.1 API functions

The table below lists the available API functions within their respective categories.

Function	Description
Configuration functions	
<code>IP_AddBuffers()</code>	Adds buffers to the TCP/IP stack.
<code>IP_AddEthernetInterface()</code>	Adds an Ethernet interface to the stack.
<code>IP_AllowBackpressure()</code>	Activates back pressure.
<code>IP_AssignMemory()</code>	Assigns memory.
<code>IP_ConfTCPSpace()</code>	Configures the send and receive space.
<code>IP_DNSC_SetMaxTTL()</code>	Sets the maximum TTL of a DNS entry.
<code>IP_DNS_SetServer()</code>	Sets the DNS server.
<code>IP_NI_ConfigPHYAddr()</code>	Configures the PHY address.
<code>IP_NI_ConfigPHYMode()</code>	Configures the PHY mode.
<code>IP_NI_ConfigPoll()</code>	Select polled mode for the network interface.
<code>IP_NI_SetTxBufferSize()</code>	Configures the Tx buffer size used by the network interface driver.
<code>IP_SetAddrMask()</code>	Sets the address mask of an interface.
<code>IP_SetDefaultTTL()</code>	Sets the TTL of an IP packet.
<code>IP_SetHWAddr()</code>	Sets the hardware address of an interface.
<code>IP_SetMTU()</code>	Sets the maximum transmission unit of an interface.
<code>IP_SetSupportedDuplexModes()</code>	Sets the supported duplex modes.
<code>IP_SOCKET_SetDefaultOptions()</code>	Sets the socket options which should be enabled by default.
<code>IP_SOCKET_SetLimit()</code>	Sets the maximum number of available sockets.
<code>IP_TCP_Set2MSLDelay()</code>	Sets the maximum segment lifetime.
<code>IP_TCP_SetConnKeepaliveOpt()</code>	Sets the keepalive options.
<code>IP_TCP_SetRetransDelayRange()</code>	Sets retransmission delay range.
Management functions	
<code>IP_Init()</code>	Initialization function of the stack.
<code>IP_Task()</code>	Main task for starting the stack.
<code>IP_RxTask()</code>	Reads all available packets and sleeps until a new packet is received.
<code>IP_Exec()</code>	Checks if any packet has been received and handles timers.
Other IP stack functions	
<code>IP_GetAddrMask()</code>	Returns the IP address and the subnet mask of the device.
<code>IP_GetCurrentLinkSpeed()</code>	Returns the current link speed.
<code>IP_GetGWAddr()</code>	Returns the gateway address of the device.
<code>IP_GetHWAddr()</code>	Returns the hardware address (MAC) of the device.
<code>IP_GetIPAddr()</code>	Returns the IP address of the device.
<code>IP_GetIPPacketInfo()</code>	Returns the start address of the data part of an IP packet.
<code>IP_GetVersion()</code>	Returns the version number of embOS/IP.
<code>IP_ICMP_SetRxHook()</code>	Sets a hook function which will be called if target receives a ping packet.
<code>IP_IFaceIsReady()</code>	Checks if the interface is ready.

**Table 4.1: embOS/IP API function overview**

Function	Description
<code>IP_PrintIPAddr()</code>	Convert an 4 byte IP address to a dots-and-number string.
<code>IP_SendPacket()</code>	Sends a user defined packet on the interface.
<code>IP_SendPing()</code>	Sends an ICMP Echo Request.
<code>IP_SetRxHook()</code>	Sets a hook function that handles all received packets.

**Table 4.1: embOS/IP API function overview (Continued)**

## 4.2 Configuration functions

### 4.2.1 IP\_AddBuffers()

#### Description

Adds buffers to the TCP/IP stack. This is a configuration function, typically called from `IP_X_Config()`. It needs to be called 2 times, one per buffer size.

#### Prototype

```
void IP_AddBuffers ( int NumBuffers,  
                    int BytesPerBuffer );
```

#### Parameter

Parameter	Description
<code>NumBuffers</code>	[IN] The number of buffers.
<code>BytesPerBuffer</code>	[IN] Size of buffers in bytes.

**Table 4.2: IP\_AddBuffers() parameter list**

#### Additional information

embOS/IP requires small and large buffers. We recommend to define the size of the big buffers to 1536 to allow a full Ethernet packet to fit. The small buffers are used to store packets which encapsulates no or few application data like protocol management packets (TCP SYNs, TCP ACKs, etc.). We recommend to define the size of the small buffers to 256 bytes.

#### Example

```
IP_AddBuffers(20, 256);           // 20 small buffers, each 256 bytes.  
IP_AddBuffers(12, 1536);        // 12 big buffers, each 1536 bytes.
```

## 4.2.2 IP\_AddEtherInterface()

### Description

Adds an Ethernet interface.

### Prototype

```
void IP_AddEtherInterface ( const IP_HW_DRIVER * pDriver );
```

### Parameter

Parameter	Description
<a href="#">pAddr</a>	[IN] A pointer to a network interface driver structure.

**Table 4.3: IP\_AddEthernetInterface() parameter list**

### Additional information

Refer to *Available network interface drivers* on page 149 for a list of available network interface drivers.

### Example

```
IP_AddEtherInterface(&IP_Driver_SAM7X); // Add Ethernet driver for your hardware
```

### 4.2.3 IP-AllowBackpressure()

#### Description

Allows back pressure if the driver supports this feature.

#### Prototype

```
void IP-AllowBackpressure ( int v );
```

#### Parameter

Parameter	Description
v	[IN] Zero to disable, 1 to enable back pressure.

**Table 4.4: IP-AllowBackPressure() parameter list**

#### Additional information

Back pressure is a window-based flow control mechanism for the half-duplex mode. It is a sort of feedback-based congestion control mechanism. The intent of this mechanism is to prevent loss by providing back pressure to the sending NIC on ports that are going too fast to avoid loss. Back pressure is enabled by default.

## 4.2.4 IP\_AssignMemory()

### Description

Assigns memory to the TCP/IP stack.

### Prototype

```
void IP_AssignMemory ( U32 * pMem,
                      U32  NumBytes );
```

### Parameter

Parameter	Description
<a href="#">pMem</a>	[IN] A pointer to the start of the memory region which should be assigned.
<a href="#">NumBytes</a>	[IN] Number of bytes which should be assigned.

**Table 4.5: IP\_AssignMemory() parameter list**

### Additional information

IP\_AssignMemory() should be the first function which is called in IP\_X\_Config(). The amount of RAM required depends on the configuration and the respective application purpose. The assigned memory pool is required for the socket buffers, memory buffers, etc.

### Example

```
#define ALLOC_SIZE      0x8000      // Size of memory dedicated to the stack in bytes
U32 _aPool[ALLOC_SIZE / 4];        // Memory area used by the stack.

IP_AssignMemory(_aPool, sizeof(_aPool));
```

## 4.2.5 IP\_ConfTCPSpace()

### Description

Configures the size of the TCP send and receive window size.

### Prototype

```
void IP_ConfTCPSpace ( unsigned SendSpace,  
                      unsigned RecvSpace );
```

### Parameter

Parameter	Description
<a href="#">SendSpace</a>	[IN] Size of the send window.
<a href="#">RecvSpace</a>	[IN] Size of the receive window.

**Table 4.6: IP\_ConfTCPSpace() parameter list**

### Additional information

The receive window size is the amount of unacknowledged data a sender can send to the receiver on a particular TCP connection before it gets an acknowledgment.

## 4.2.6 IP\_DNSC\_SetMaxTTL()

### Description

Sets the maximum Time To Live (TTL) of a DNS entry in seconds.

### Prototype

```
void IP_DNSC_SetMaxTTL( U32 TTL );
```

### Parameter

Parameter	Description
TTL	[IN] Maximum TTL of a DNS entry in seconds.

**Table 4.7: IP\_DNSC\_SetMaxTTL() parameter list**

### Additional information

The real TTL is the minimum of [TTL](#) and the TTL specified by the DNS server for the entry. The embOS/IP default for the maximum TTL of an DNS entry is 600 seconds.

## 4.2.7 IP\_DNS\_SetServer()

### Description

Sets the DNS server that should be used.

### Prototype

```
void IP_DNS_SetServer ( U32 DNSServerAddr );
```

### Parameter

Parameter	Description
<a href="#">DNSServerAddr</a>	[IN] Address of DNS server.

**Table 4.8: IP\_DNS\_SetServer() parameter list**

### Additional information

If a DHCP server is used for configuring your target, `IP_DNS_SetServer()` must not be called. The DNS server settings are part of the DHCP configuration setup. The DNS server has to be defined before calling `gethostbyname()` to resolve an internet address. Refer to *gethostbyname()* on page 88 for detailed information about resolving an internet address.

## 4.2.8 IP\_NI\_ConfigPHYAddr()

### Description

Configures the PHY address.

### Prototype

```
void IP_NI_ConfigPHYAddr ( unsigned Unit,
                          U8      Addr );
```

Parameter	Description
<a href="#">Unit</a>	[IN] Zero-based index of available network interfaces.
<a href="#">Addr</a>	[IN] 5-bit address.

**Table 4.9: IP\_NI\_ConfigPHYAddr() parameter list**

### Additional information

The PHY address is a 5-bit value. The available embOS/IP drivers try to detect the PHY address automatically, therefore this should not be called. If you use this function to set the address explicitly, the function must be called from within `IP_X_Config()`. Refer to *IP\_X\_Configure()* on page 174.

## 4.2.9 IP\_NI\_ConfigPHYMode()

### Description

Configures the PHY mode.

### Prototype

```
void IP_NI_ConfigPHYMode ( unsigned Unit,
                          U8      Mode );
```

Parameter	Description
Unit	[IN] Zero-based index of available network interfaces.
Mode	[IN] The operating mode of the PHY.

**Table 4.10: IP\_NI\_ConfigPHYMode() parameter list**

### Valid values for parameter Mode

Value	Description
IP_PHY_MODE_MII	Phy uses the Media Independent Interface (MII).
IP_PHY_MODE_RMII	Phy uses the Reduced Media Independent Interface (RMII).

### Additional information

The PHY can be connected to the MAC via two different modes, MII or RMII. Refer to section *MII / RMII: Interface between MAC and PHY* on page 21 for detailed information about the differences of the MII and RMII modes.

The selection which mode is used is normally done correctly by the hardware. The mode is typically sampled during power-on RESET. If you use this function to set the mode explicitly, the function must be called from within `IP_X_Config()`. Refer to *IP\_X\_Configure()* on page 174.

## 4.2.10 IP\_NI\_ConfigPoll()

### Description

Select polled mode for the network interface. This should be used only if the network interface can not activate an ISR itself.

### Prototype

```
void IP_NI_ConfigPoll( unsigned Unit );
```

Parameter	Description
Unit	[IN] Zero-based index of available network interfaces.

**Table 4.11: IP\_NI\_ConfigPoll() parameter list**

## 4.2.11 IP\_NI\_SetTxBufferSize()

### Description

Sets the size of the Tx buffer of the network interface.

### Prototype

```
int IP_NI_SetTxBufferSize ( unsigned Unit,
                           U8      NumBytes );
```

Parameter	Description
Unit	[IN] Zero-based index of available network interfaces.
NumBytes	[IN] Size of the Tx buffer (at least size of the MTU + 16 bytes for Ethernet.)

**Table 4.12: IP\_NI\_SetTxBufferSize() parameter list**

### Return value

-1: Not supported by the network interface driver.

0: OK

1: Error, called after driver initialization has been completed.

### Additional information

The default Tx buffer size is 1536 bytes. It can be useful to reduce the buffer size on systems with less RAM and an application that uses a small MTU. According to RFC 576 bytes is the smallest possible MTU. The size of the Tx buffer should be at least MTU + 16 bytes for Ethernet header and footer. The function should be called in IP\_X\_Config().

**Note:** This function is not implemented in all network interface drivers, since not all Media Access Controllers (MAC) support variable buffer sizes.

## 4.2.12 IP\_SetAddrMask()

### Description

Sets the IP address and subnet mask of an interface.

### Prototype

```
void IP_SetAddrMask ( U32 Addr,
                     U32 Mask );
```

### Parameter

Parameter	Description
<a href="#">Addr</a>	[IN] 4-byte IPv4 address.
<a href="#">Mask</a>	[IN] Subnet mask.

**Table 4.13: IP\_SetAddrMask() parameter list**

### Additional information

The address mask should only be set if no DHCP server is used to obtain IP address, subnet mask and default gateway. Refer to chapter *DHCP client* on page 139 for detailed information about the usage of the embOS/IP DHCP client.

### Example

```
IP_SetAddrMask(0xC0A80505, 0xFFFF0000);    // IP: 192.168.5.5
                                           // Subnet mask: 255.255.0.0
```

## 4.2.13 IP\_SetDefaultTTL()

### Description

Sets the default value for the Time-To-Live IP header field.

### Prototype

```
void IP_SetDefaultTTL ( int v );
```

### Parameter

Parameter	Description
v	[IN] Time-To-Live value.

**Table 4.14: IP\_SetDefaultTTL() parameter list**

### Additional information

By default the default TTL is 64. The TTL field length of the IP is 8 bits. The maximum value of the TTL field is therefore 255.

## 4.2.14 IP\_SetHWAddr()

### Description

Sets the media access control address (MAC) of an interface.

### Prototype

```
void IP_SetHWAddr( const U8 * pHWAddr );
```

### Parameter

Parameter	Description
<a href="#">pHWAddr</a>	[IN] 6-byte MAC address.

**Table 4.15: IP\_SetHWAddr() parameter list**

### Additional information

The MAC address needs to be unique for production units.

### Example

```
IP_SetHWAddr( "\x00\x22\x33\x44\x55\x66" );
```

## 4.2.15 IP\_SetMTU()

### Description

Allows to set the maximum transmission unit (MTU) of an interface.

### Prototype

```
void IP_SetMTU( U8  IFace,
               U32 Mtu );
```

### Parameter

Parameter	Description
<a href="#">IFace</a>	[IN] Zero-based index of available network interfaces.
<a href="#">Mtu</a>	[IN] Size of maximum transmission unit in bytes.

**Table 4.16: IP\_SetMTU() parameter list**

### Additional information

The MTU is the MTU from an IP standpoint, so the size of the IP-packet without local net header. A typical value for ethernet is 1500, since the maximum size of an Ethernet packet is 1518 bytes. Since Ethernet uses 12 bytes for MAC addresses, 2 bytes for type and 4 bytes for CRC, 1500 bytes "payload" remain. The minimum size of the MTU is 576 according to RFC 879. Refer to *[RFC 879] - TCP - The TCP Maximum Segment Size and Related Topics* for more information about the MTU.

A smaller MTU size is effective for TCP connections only, it does not affect UDP connections. All TCP connections are guaranteed to work with any MTU in the permitted range of 576 - 1500 bytes. The advantage of a smaller MTU is that smaller packets are sent in TCP communication, resulting in reduced RAM requirements especially if the window size is also reduced. The disadvantage is a loss of communication speed.

## 4.2.16 IP\_SetSupportedDuplexModes()

### Description

Allows to set the allowed Duplex modes.

### Prototype

```
int IP_SetSupportedDuplexModes( unsigned Unit,
                               unsigned DuplexMode);
```

### Parameter

Parameter	Description
Unit	[IN] Zero-based index of available network interfaces.
DuplexMode	[IN] OR-combination of one or more of the following valid values.

**Table 4.17: IP\_SetSupportedDuplexModes() parameter list**

### Valid values for parameter DuplexMode

Value	Description
IP_PHY_MODE_10_HALF	Support 10 Mbit half-duplex
IP_PHY_MODE_10_FULL	Support 10 Mbit full-duplex
IP_PHY_MODE_100_HALF	Support 100 Mbit half-duplex
IP_PHY_MODE_100_FULL	Support 100 Mbit full-duplex

## 4.2.17 IP\_SOCKET\_SetDefaultOptions()

### Description

Allows to set the maximum transmission unit (MTU) of an interface.

### Prototype

```
void IP_SOCKET_SetDefaultOptions ( U16 v );
```

### Parameter

Parameter	Description
v	[IN] Socket options which should be enabled. By default, keepalive (SO_KEEPAALIVE) socket option is enabled. Refer to <i>setsockopt()</i> on page 102 for a list of supported socket options.

**Table 4.18: IP\_SetDefaultOptions() parameter list**

## 4.2.18 IP\_SOCKET\_SetLimit()

### Description

Sets the maximum number of available sockets.

### Prototype

```
void IP_SOCKET_SetLimit ( unsigned Limit );
```

### Parameter

Parameter	Description
<code>Limit</code>	[IN] Sets a limit on number of sockets which can be created. The embOS/IP default is 0 which means that no limit is set.

**Table 4.19: IP\_SetLimit() parameter list**

## 4.2.19 IP\_TCP\_Set2MSLDelay()

### Description

Sets the maximum segment lifetime (MSL).

### Prototype

```
void IP_TCP_Set2MSLDelay( unsigned v );
```

### Parameter

Parameter	Description
v	[IN] Maximum segment lifetime. The embOS/IP default is 2 seconds.

**Table 4.20: IP\_Set2MSLDelay() parameter list**

### Additional information

The maximum segment lifetime is the amount of time any segment can exist in the network before being discarded. This time limit is constricted. When TCP performs an active close the connection must stay in TIME\_WAIT (2MSL) state for twice the MSL after sending the final ACK.

Refer to *[RFC 793] - TCP - Transmission Control Protocol* for more information about TCP states.

## 4.2.20 IP\_TCP\_SetConnKeepaliveOpt()

### Description

Sets the keepalive options.

### Prototype

```
void IP_TCP_SetConnKeepaliveOpt( U32 Init,
                                  U32 Idle,
                                  U32 Period,
                                  U32 MaxRep );
```

### Parameter

Parameter	Description
<a href="#">Init</a>	[IN] Maximum time for TCP-connection open (response to SYN) in ms. The embOS/IP default is 20 seconds.
<a href="#">Idle</a>	[IN] Time of TCP-inactivity before first keepalive probe is sent in ms. The embOS/IP default is 60 seconds.
<a href="#">Period</a>	[IN] Time of TCP-inactivity between keepalive probes in ms. The embOS/IP default is 10 seconds.
<a href="#">MaxRep</a>	[IN] Number of keepalive probes before we give up and close the connection. The embOS/IP default is 8 repetitions.

**Table 4.21: IP\_TCP\_SetConnKeepaliveOpt() parameter list**

### Additional information

Keepalives are not part of the TCP specification, since they can cause good connections to be dropped during transient failures. For example, if the keepalive probes are sent during the time that an intermediate router has crashed and is rebooting, TCP will think that the client's host has crashed, which is not what has happened. Nevertheless, the keepalive feature is very useful for embedded server applications that might tie up resources on behalf of a client, and want to know if the client host crashes.

## 4.2.21 IP\_TCP\_SetRetransDelayRange()

### Description

Sets the retransmission delay range.

### Prototype

```
void IP_TCP_SetRetransDelayRange( unsigned RetransDelayMin,
                                  unsigned RetransDelayMax );
```

### Parameter

Parameter	Description
<code>Init</code>	[IN] Minimum time before first retransmission. The embOS/IP default is 200 ms.
<code>Idle</code>	[IN] Maximum time to wait before a retransmission. The embOS/IP default is 5 seconds.

**Table 4.22: IP\_TCP\_SetRetransDelayRange() parameter list**

### Additional information

TCP is a reliable transport layer. One of the ways it provides reliability is for each end to acknowledge the data it receives from the communication partner. But data segments and acknowledgments can get lost. TCP handles this by setting a timeout when it sends data, and if the data is not acknowledged when the timeout expires, it retransmits the data. The timeout and retransmission is the measurement of the round-trip time (RTT) experienced on a given connection. The RTT can change over time, as routes might change and as network traffic changes, and TCP should track these changes and modify its timeout accordingly. `IP_TCP_SetRetransDelayRange()` should be called if the default limits are not sufficient for your application.

## 4.3 Management functions

### 4.3.1 IP\_Init()

#### Description

Initializes the TCP/IP stack.

#### Prototype

```
void IP_Init ( void );
```

#### Additional information

IP\_Init() initializes the IP stack and creates resources required for an OS integration. This function must be called before any other embOS/IP function is called.

#### Example

```
#include "IP.h"

void main(void) {
    IP_Init();
    /*
     * Use the stack
     */
}
```

## 4.3.2 IP\_Task()

### Description

Main task for starting the stack. After startup, it settles into a loop handling received packets. This loop sleeps until a packet has been queued in the receive queue; then it should be awakened by the driver which queued the packet.

### Prototype

```
void IP_Task ( void );
```

### Additional information

Implementing this task is the simplest way to include embOS/IP into your project. Typical stack usage is approximately 440 bytes. To be on the safe side set the size of the task stack to 1024 bytes.

**Note:** The priority of task `IP_Task` should be higher than the priority of an application task which uses the stack.

### Example

```
#include <stdio.h>

#include "RTOS.h"
#include "BSP.h"
#include "IP.h"
#include "IP_Int.h"

static OS_STACKPTR int _Stack0[512];    // Task stacks
static OS_TASK      _TCB0;              // Task-control-blocks
static OS_STACKPTR int _IPStack[1024]; // Task stacks
static OS_TASK      _IPTCB;            // Task-control-blocks

/*****
 *
 *      MainTask
 */
void MainTask(void);
void MainTask(void) {
    printf("*****\nProgram start\n");
    IP_Init();
    OS_SetPriority(OS_GetTaskID(), 255); // This task has highest prio!
    OS_CREATETASK(&_IPTCB, "IP_Task", IP_Task, 150, _IPStack);
    while (1) {
        BSP_ToggleLED(1);
        OS_Delay (200);
    }
}

/*****
 *
 *      main
 */
void main(void) {
    BSP_Init();
    BSP_SetLED(0);
    OS_IncDI();           /* Initially disable interrupts */
    OS_InitKern();        /* initialize OS */
    OS_InitHW();          /* initialize Hardware for OS */
    OS_CREATETASK(&_TCB0, "MainTask", MainTask, 100, _Stack0);
    OS_Start();
}
```

### 4.3.3 IP\_RxTask()

#### Description

The task reads all available packets from the network interface and sleeps until a new packet is received.

#### Prototype

```
void IP_RxTask ( void );
```

#### Additional information

This task is optional. Refer to *Tasks and interrupt usage* on page 17 for detailed information about the task and interrupt handling of embOS/IP. Typical stack usage is approximately 150 bytes. To be on the safe side set the size of the task stack to 1024 bytes.

**Note:** The priority of task `IP_RxTask()` should be higher than the priority of an application task which uses the stack.

## 4.3.4 IP\_Exec()

### Description

Checks if the driver has received a packet and handles timers.

### Prototype

```
void IP_Exec ( void );
```

### Additional information

This function is normally called from an endless loop in `IP_Task()`. If no particular IP task is implemented in your project, `IP_Exec()` should be called regularly.

## 4.4 Other IP stack functions

### 4.4.1 IP\_GetAddrMask()

#### Description

Returns the IP address and the subnet mask of the device in network byte order (for example, 192.168.1.1 is returned as 0xc0a80101).

#### Prototype

```
void IP_GetAddrMask ( U8 IFace, U32 * pAddr, U32 * pMask );
```

#### Parameter

Parameter	Description
<a href="#">IFace</a>	[IN] Interface.
<a href="#">pAddr</a>	[OUT] Address to store the IP address.
<a href="#">pMask</a>	[OUT] Address to store the subnet mask.

**Table 4.23: IP\_GetAddrMask() parameter list**

## 4.4.2 IP\_GetCurrentLinkSpeed()

### Description

Returns the current link speed.

### Prototype

```
int IP_GetCurrentLinkSpeed( void );
```

### Return value

0: link speed unknown  
1: link speed is 10 Mbit/s  
2: link speed is 100 Mbit/s  
3: link speed is 1000 Mbit/s

### Additional information

The application should check if the link is up before a packet will be sent. It can take 2-3 seconds till the link is up if the PHY has been reset.

### Example

```
//  
// Wait until link is up.  
//  
while (IP_GetCurrentLinkSpeed() == 0) {  
    OS_IP_Delay(100);  
}
```

### 4.4.3 IP\_GetGWAddr()

#### Description

Returns the gateway address of the interface in network byte order (for example, 192.168.1.1 is returned as 0xc0a80101).

#### Prototype

```
U32 IP_GetGWAddr ( U8 IFace );
```

#### Parameter

Parameter	Description
<a href="#">IFace</a>	[IN] Number of interface.

**Table 4.24: IP\_GetGWAddr() parameter list**

#### Return value

The gateway address of the interface.

## 4.4.4 IP\_GetHWAddr()

### Description

Returns the hardware address (Media Access Control address) of the interface.

### Prototype

```
void IP_GetHWAddr ( U8 IFace, U8 * pDest, unsigned Len );
```

### Parameter

Parameter	Description
<a href="#">IFace</a>	[IN] Number of interface.
<a href="#">pDest</a>	[OUT] Address of the buffer to store the 48-bit MAC address.
<a href="#">Len</a>	[IN] Size of the buffer. Should be at least 6-bytes.

**Table 4.25: IP\_GetHWAddr() parameter list**

## 4.4.5 IP\_GetIPAddr()

### Description

Returns the IP address of the interface.

### Prototype

```
U32 IP_GetIPAddr( U8 IFace );
```

### Parameter

Parameter	Description
IFace	[IN] Number of interface.

**Table 4.26: IP\_GetIPAddr() parameter list**

### Return value

The IP address of the interface in network byte order (for example, 192.168.1.1 is returned as 0xc0a80101).

### Example

```
void PrintIFaceIPAddr(void) {
    char ac[16];
    U32 IPAddr;

    IPAddr = IP_GetIPAddr(0);
    IP_PrintIPAddr(ac, IPAddr, sizeof(ac));
    printf("IP Addr: %s\n", ac);
}
```

## 4.4.6 IP\_GetIPPacketInfo()

### Description

Returns the start address of the data part of an IP packet.

### Prototype

```
const char * IP_GetIPPacketInfo( IP_PACKET * pPacket );
```

### Parameter

Parameter	Description
<code>pPacket</code>	[IN] Pointer to an IP_PACKET structure.

**Table 4.27: IP\_GetIPPacketInfo() parameter list**

### Return value

0 > Start address of the data part of the IP packet.

0 On failure.

### Example

```

/*****
*
*      _pfOnRxICMP
*/
static int _pfOnRxICMP(IP_PACKET * pPacket) {
    const char * pData;

    pData = IP_GetIPPacketInfo(pPacket);
    if(*pData == 0x08) {
        printf("ICMP echo request received!\n");
    }
    if(*pData == 0x00) {
        printf("ICMP echo reply received!\n");
    }
    return 0;
}

```

## 4.4.7 IP\_GetVersion()

### Description

Returns the version number of the stack.

### Prototype

```
int IP_GetVersion ( void );
```

### Additional information

The format of the version number: <Major><Minor><Minor><Revision><Revision>.  
For example, the return value 10201 means version 1.02a.

## 4.4.8 IP\_ICMP\_SetRxHook()

### Description

Sets a hook function which will be called if target receives a ping packet.

### Prototype

```
void IP_ICMP_SetRxHook(IP_RX_HOOK * pf);
```

### Parameter

Parameter	Description
<code>pf</code>	Pointer to the callback function of type <code>IP_RX_HOOK</code> .

**Table 4.28: IP\_ICMP\_SetRxHook() parameter list**

### Additional information

The return value of the callback function is relevant for the further processing of the ICMP packet. A return value of 0 indicates that the stack has to process the packet after the callback has returned. A return value of 1 indicates that the packet will be freed directly after the callback has returned.

The prototype for the callback function is defined as follows:

```
typedef int (IP_RX_HOOK)(IP_PACKET * pPacket);
```

### Example

```

/*****
 *
 *      Local defines, configurable
 *
 *****/
#define HOST_TO_PING      0xC0A80101

/*****
 *
 *      _pfOnRxICMP
 */
static int _pfOnRxICMP(IP_PACKET * pPacket) {
    const char * pData;

    pData = IP_GetIPPacketInfo(pPacket);
    if(*pData == 0x08) {
        printf("ICMP echo request received!\n");
    }
    if(*pData == 0x00) {
        printf("ICMP echo reply received!\n");
    }
    return 0; // Give packet back to the stack for further processing.
}

/*****
 *
 *      PingTask
 */
void PingTask(void) {
    int Seq;
    char * s = "This is a ICMP echo request!";

    while (IP_IFaceIsReady() == 0) {
        OS_Delay(50);
    }
    IP_ICMP_SetRxHook(_pfOnRxICMP);
    Seq = 1111;
    while (1) {
        BSP_ToggleLED(1);
        OS_Delay(200);
        IP_SendPing(htonl(HOST_TO_PING), s, strlen(s), Seq++);
    }
}

```

## 4.4.9 IP\_IFaceIsReady()

### Description

Checks if the interface is ready for usage.

### Prototype

```
int IP_IFaceIsReady ( void );
```

### Return value

1 network interface is ready.  
0 network interface is not ready.

### Additional information

The application has to check if the link is up before a packet will be sent and if the interface is configured. If a DHCP server is used for configuring your target, this function has to be called to assure that no application data will be sent before the target is ready.

### Example

```
//  
// Wait until interface is ready.  
//  
while (IP_IFaceIsReady() == 0) {  
    OS_Delay(100);  
}
```

## 4.4.10 IP\_PrintIPAddr()

### Description

Convert an 4-byte IP address to a dots-and-number string.

### Prototype

```
int IP_PrintIPAddr( char * pDest,
                   U32   IPAddr,
                   int   BufferSize );
```

### Parameter

Parameter	Description
<code>pDest</code>	[OUT] Buffer to store the IP address string.
<code>IPAddr</code>	[IN] IP address in network byte order.
<code>BufferSize</code>	[IN] Size of buffer <code>pDest</code> . Should be 16 byte to store an IPv4 address.

**Table 4.29: IP\_PrintIPAddr() parameter list**

### Return value

0 on error. Size of the buffer is too small.

>0 on success. Length of the IP address string.

### Example

```
void PrintIPAddr(void) {
    U32 IPAddr;
    char ac[16];

    IPAddr = 0xC0A80801; // IP address: 192.168.8.1
    IP_PrintIPAddr(ac, IPAddr, sizeof(ac));
    printf("IP address: %s\n", ac); // Output: IP address: 192.168.8.1
}
```

## 4.4.11 IP\_SendPacket()

### Description

Sends a user defined packet on the interface. The packet will not be modified by the stack. `IP_SendPacket()` allocates a packet control block (`IP_PACKET`) and adds it to the Out queue of the interface.

### Prototype

```
int IP_SendPacket( unsigned IFace,
                  void * pData,
                  int NumBytes );
```

### Parameter

Parameter	Description
<code>IFace</code>	[IN] Zero-based interface index.
<code>pData</code>	[IN] Data packet that should be sent.
<code>Numbytes</code>	[IN] Length of data which should be sent.

**Table 4.30: IP\_SendPacket() parameter list**

### Return value

- 0 O.K., packet in out queue
- 1 Error: Could not alloc packet control block
- 1 Error: Interface can not send

## 4.4.12 IP\_SendPing()

### Description

Sends a single “ping” (ICMP echo request) to the specified host.

### Prototype

```
int IP_SendPing ( ip_addr    host,
                  char      * data,
                  unsigned   datalen,
                  U16       pingseq );
```

### Parameter

Parameter	Description
<a href="#">host</a>	[IN] 4-byte IPv4 address in network endian byte order.
<a href="#">data</a>	[IN] Ping data, NULL if do not care.
<a href="#">datalen</a>	[IN] Length of data to attach to ping request.
<a href="#">pingseq</a>	[IN] Ping sequence number.

**Table 4.31: IP\_SendPing() parameter list**

### Return value

Returns 0 if ICMP echo request was successfully sent, else negative error message.

### Additional information

If you call this function with activated logging, the ICMP reply or (in case of an error) the error message will be sent to stdout. To enable the output of ICMP status messages, add the message type `IP_MTYPE_ICMP` to the log filter and the warn filter. Refer to *Debugging* on page 281 for detailed information about logging.

## 4.4.13 IP\_SetRxHook()

### Description

Sets a hook function which will be called if target receives a packet.

### Prototype

```
void IP_SetRxHook(IP_RX_HOOK * pf);
```

### Parameter

Parameter	Description
<a href="#">pf</a>	Pointer to the callback function of type <code>IP_RX_HOOK</code> .

**Table 4.32: IP\_SetRxHook() parameter list**

### Additional information

The return value of the callback function is relevant for the further processing of the packet. A return value of 0 indicates that the stack has to process the packet after the callback has returned. A return value of >0 indicates that the packet will be freed directly after the callback has returned.

The prototype for the callback function is defined as follows:

```
typedef int (IP_RX_HOOK)(IP_PACKET * pPacket);
```

### Example

Refer to *IP\_ICMP\_SetRxHook()* on page 74 for an example.

## 4.5 Stack internal functions, variables and data-structures

embOS/IP internal functions, variables and data-structures are not explained here as they are in no way required to use embOS/IP. Your application should not rely on any of the internal elements, as only the documented API functions are guaranteed to remain unchanged in future versions of embOS/IP.

# Chapter 5

## Socket interface

---

The embOS/IP socket API is almost compatible to the Berkeley socket interface. The Berkeley socket interface is the de facto standard for socket communication. All API functions are described in this chapter.

## 5.1 API functions

The table below lists the available socket API functions.

Function	Description
Socket interface	
<code>accept()</code>	Accepts an incoming attempt on a socket.
<code>bind()</code>	Assigns a name to an unnamed socket.
<code>closesocket()</code>	Closes an existing socket.
<code>connect()</code>	Establishes a connection to a socket.
<code>gethostbyname()</code>	Resolves a host name into an IP address.
<code>getpeername()</code>	Returns the IP addressing information of the connected host.
<code>getsockname()</code>	Returns the current name for the specified socket.
<code>getsockopt()</code>	Returns the socket options.
<code>listen()</code>	Marks a socket as accepting connections.
<code>recv()</code>	Receives data from a connected socket.
<code>recvfrom()</code>	Receives a datagram and stores the source address.
<code>select()</code>	Checks if socket is ready.
<code>send()</code>	Sends data on a connected socket.
<code>sendto()</code>	Sends data to a specified address.
<code>setsockopt()</code>	Sets a socket option.
<code>shutdown()</code>	Disables sends or receives on a socket.
<code>socket()</code>	Creates an unbound socket.
Helper macros	
<code>ntohl</code>	Converts a unsigned long value from network to host byte order.
<code>htonl</code>	Converts a unsigned long value from host byte order to network byte order.
<code>htons</code>	Converts a unsigned short value from host byte order to network byte order.
<code>ntohs</code>	Converts a unsigned short value from network to host byte order.

**Table 5.1: embOS/IP socket API function overview**

## 5.1.1 accept()

### Description

Accepts an incoming attempt on a socket.

### Prototype

```
long accept ( long          Socket,
             struct sockaddr * pAddr,
             int           * pAddrLen );
```

### Parameter

Parameter	Description
<code>Socket</code>	[IN] A descriptor identifying a socket.
<code>pAddr</code>	[OUT] An optional pointer to a buffer where the address of the connecting entity should be stored. The format of the address depends on the defined address family which was defined when the socket was created.
<code>pAddrLen</code>	[OUT] An optional pointer to an integer where the length of the received address should be stored. Just like the format of the address, the length of the address depends on the defined address family.

**Table 5.2: accept() parameter list**

### Return value

The returned value is a handle for the socket on which the actual connection will be made.

-1 in case of an error.

### Additional information

This call is used with connection-based socket types, currently with `SOCK_STREAM`. Refer to `socket()` on page 105 for more information about the different socket types.

Before calling `accept()`, the used socket `Socket` has to be bound to an address with `bind()` and should be listening for connections after calling `listen()`. `accept()` extracts the first connection on the queue of pending connections, creates a new socket with the same properties of `Socket` and allocates a new file descriptor for the socket. If no pending connections are present on the queue, and the socket is not marked as non-blocking, `accept()` blocks the caller until a connection is present. If the socket is marked non-blocking and no pending connections are present on the queue, `accept()` returns and reports an error. The accepted socket is used to read and write data to and from the socket which is connected to this one; it is not used to accept more connections. The original socket `Socket` remains open for accepting further connections.

The argument `pAddr` is a result parameter that is filled in with the address of the connecting entity as known to the communications layer. The exact format of the `pAddr` parameter is determined by the domain in which the communication is occurring. The `pAddrLen` is a value-result parameter. It should initially contain the amount of space pointed to by `pAddr`.

## 5.1.2 bind()

### Description

Assigns a name (port) to an unnamed socket.

### Prototype

```
int bind ( long          Socket,
          struct sockaddr * pAddr,
          int            AddrLen );
```

### Parameter

Parameter	Description
<code>Socket</code>	[IN] A descriptor identifying a socket.
<code>pAddr</code>	[IN] A pointer to a buffer where the address of the connecting entity is stored. The format of the address depends on the defined address family which was defined when the socket was created.
<code>AddrLen</code>	[IN] The length of the address.

**Table 5.3: bind() parameter list**

### Return value

0 on success.  
-1 on failure.

### Additional information

When a socket is created with `socket()` it exists in a name space (address family) but has no name assigned. `bind()` is used on an unconnected socket before subsequent calls to the `connect()` or `listen()` functions. `bind()` assigns the name pointed to by `pAddr` to the socket.

## 5.1.3 closesocket()

### Description

Closes an existing socket.

### Prototype

```
int closesocket ( long Socket );
```

### Parameter

Parameter	Description
Socket	[IN] Socket descriptor of the socket that should be closed.

Table 5.4: closesocket() parameter list

### Return value

0 on success.

-1 on failure.

### Additional information

closesocket() closes a connection on the socket associated with Socket and the socket descriptor associated with Socket will be returned to the free socket descriptor pool. Once a socket is closed, no further socket calls should be made with it.

If the socket promises reliable delivery of data and SO\_LINGER is set, the system will block the caller on the closesocket() attempt until it is able to transmit the data or until it decides it is unable to deliver the information (a timeout period, termed the linger interval, is specified in the setsockopt() call when SO\_LINGER is requested). If SO\_LINGER is disabled and a closesocket() is issued, the system will process the close in a manner that allows the caller to continue as quickly as possible. If SO\_LINGER is enabled with a timeout period of '0' and a closesocket() is issued, the system will perform a hard close.

### Example

```

/*****
*
*     _CloseSocketGracefully()
*
*   Function description
*   Wrapper for closesocket() with linger enabled to verify a gracefully
*   disconnect.
*/
static int _CloseSocketGracefully(long pConnectionInfo) {
    struct linger Linger;

    Linger.l_onoff = 1; // Enable linger for this socket.
    Linger.l_linger = 1; // Linger timeout in seconds
    setsockopt(hSocket, SOL_SOCKET, SO_LINGER, &Linger, sizeof(Linger));
    return closesocket(hSocket);
}

/*****
*
*     _CloseSocketHard()
*
*   Function description
*   Wrapper for closesocket() with linger option enabled to perform a hard close.
*/
static int _CloseSocketHard(long hSocket) {
    struct linger Linger;

    Linger.l_onoff = 1; // Enable linger for this socket.
    Linger.l_linger = 0; // Linger timeout in seconds
    setsockopt(hSocket, SOL_SOCKET, SO_LINGER, &Linger, sizeof(Linger));
    return closesocket(hSocket);
}

```

## 5.1.4 connect()

### Description

Establishes a connection to a socket.

### Prototype

```
int connect ( long          Socket,
             struct sockaddr * pAddr,
             int            AddrLen );
```

### Parameter

Parameter	Description
<code>Socket</code>	[IN] A descriptor identifying an unconnected socket.
<code>pAddr</code>	[IN] A pointer to a buffer where the address of the connecting entity is stored. The format of the address depends on the defined address family which was defined when the socket was created.
<code>AddrLen</code>	[IN] A pointer to an integer where the length of the received address is stored. Just like the format of the address, the length of the address depends on the defined address family.

**Table 5.5: connect() parameter list**

### Return value

0 on success.  
-1 on failure.

### Additional information

If `Socket` is of type `SOCK_DGRAM`, then this call specifies the peer with which the socket is to be associated. `pAddr` defines the address to which datagrams are sent and the only address from which datagrams are received.

If `Socket` is of type `SOCK_STREAM`, then this call attempts to make a connection to another socket. The other socket is specified by `pAddr` which is an address in the communications space of the socket. Each communications space interprets the `pAddr` parameter in its own way.

Generally, stream sockets may successfully `connect()` only once; datagram sockets may use `connect()` multiple times to change their association. Datagram sockets may dissolve the association by connecting to an invalid address, such as a NULL address.

### Example

```
#define SERVER_PORT          1234
#define SERVER_IP_ADDR      0xC0A80101    // 192.168.1.1

/*****
 *
 *      _TCPClientTask
 *
 * Function description
 *   Creates a connection to a given IP address, TCP port.
 */
static void _TCPClientTask(void) {
    int          TCPSockID;
    struct sockaddr_in ServerAddr;
    int          ConnectStatus;

    //
    // Wait until link is up. This can take 2-3 seconds if PHY has been reset.
    //
    while (IP_GetCurrentLinkSpeed() == 0) {
        OS_Delay(100);
    }
}
```

```

}

while(1) {
    TCPSockID = socket(AF_INET, SOCK_STREAM, 0); // Open socket
    if (TCPSockID < 0) { // Error, Could not get socket
        while (1) {
            OS_Delay(20);
        }
    } else {
        //
        // Connect to server
        //
        ServerAddr.sin_family      = AF_INET;
        ServerAddr.sin_port       = htons(SERVER_PORT);
        ServerAddr.sin_addr.s_addr = htonl(SERVER_IP_ADDR);
        ConnectStatus             = connect(TCPSockID,
                                           (struct sockaddr *)&ServerAddr,
                                           sizeof(struct sockaddr_in));

        if (ConnectStatus == 0) {
            //
            // Do something...
            //
        }
    }
    closesocket(TCPSockID);
    OS_Delay(50);
}
}

```

## 5.1.5 gethostbyname()

### Description

Resolve a host name into an IP address.

### Prototype

```
struct hostent * gethostbyname (char * name);
```

### Parameter

Parameter	Description
<a href="#">name</a>	[OUT] Host name.

**Table 5.6: gethostbyname() parameter list**

### Return value

On success, a pointer to a `hostent` structure is returned. Refer to *Structure hostent* on page 110 for detailed information about the `hostent` structure.

On failure, it returns NULL.

### Additional information

The function is called with a string containing the host name to be resolved as a fully-qualified domain name (for example, `myhost.mydomain.com`).

### Example

```
static void _DNSClient() {
    struct hostent *pHostEnt;
    char **ps;
    char **ppAddr;
    //
    // Wait until link is up.
    //
    while (IP_IFaceIsReady() == 0) {
        OS_Delay(100);
    }
    while(1) {
        pHostEnt = gethostbyname("www.segger.com");
        if (pHostEnt == NULL) {
            printf("Could not resolve host addr.\n");
            break;
        }
        printf("h_name: %s\n", pHostEnt->h_name);
        //
        // Show aliases
        //
        ps = pHostEnt->h_aliases;
        for (;;) {
            char * s;
            s = *ps++;
            if (s == NULL) {
                break;
            }
            printf("h_aliases: %s\n", s);
        }
        //
        // Show IP addresses
        //
        ppAddr = pHostEnt->h_addr_list;
        for (;;) {
            U32 IPAddr;
            char * pAddr;
            char ac[16];

            pAddr = *ppAddr++;
            if (pAddr == NULL) {
                break;
            }
        }
    }
}
```

```
IPAddr = *(U32*)pAddr;
IP_PrintIPAddr(ac, IPAddr, sizeof(ac));
printf("IP Addr: %s\n", ac);
}
}
}
```

## 5.1.6 getpeername()

### Description

Fills the passed structure `sockaddr` with the IP addressing information of the connected host.

### Prototype

```
int getpeername ( long          Socket,
                 struct sockaddr * pAddr,
                 struct int     * pAddrLen );
```

### Parameter

Parameter	Description
<a href="#">Socket</a>	[IN] A descriptor identifying a socket.
<a href="#">pAddr</a>	[OUT] A pointer to a structure of type <code>sockaddr</code> in which the IP address information of the connected host should be stored.
<a href="#">pAddrLen</a>	[OUT] A pointer to an integer to store the length of socket address.

**Table 5.7: getpeername() parameter list**

### Return value

0 on success.  
-1 on failure.

### Additional information

Refer to *Structure sockaddr* on page 107 for detailed information about the structure `sockaddr`.

## 5.1.7 getsockname()

### Description

Returns the current name for the specified socket.

### Prototype

```
int getsockname ( long          Socket,
                 struct sockaddr * pAddr );
```

### Parameter

Parameter	Description
Socket	[IN] A descriptor identifying a socket.
pAddr	[OUT] A pointer to a structure of type <code>sockaddr</code> in which the IP address information of the connected host should be stored.

**Table 5.8: getsockname() parameter list**

### Return value

0 on success.  
-1 on failure.

### Additional information

Refer to *Structure sockaddr* on page 107 for detailed information about the structure `sockaddr`.

## 5.1.8 getsockopt()

### Description

Returns the options associated with a socket.

### Prototype

```
int getsockopt ( long   Socket,
                int    Level,
                int    Option,
                void * pData,
                int    DataLen );
```

### Parameter

Parameter	Description
<a href="#">Socket</a>	[IN] A descriptor identifying a socket.
<a href="#">Level</a>	[IN] Compatibility parameter for <code>setsockopt()</code> and <code>getsockopt()</code> . Use symbol <code>SOL_SOCKET</code> .
<a href="#">Option</a>	[IN] The socket option which should be retrieved.
<a href="#">pData</a>	[OUT] A pointer to the buffer in which the value of the requested option should be stored.
<a href="#">DataLen</a>	[IN] The size of the data buffer.

**Table 5.9: getsockopt() parameter list**

### Valid values for parameter Option

Value	Description
<b>Standard option flags.</b>	
<code>SO_ACCEPTCONN</code>	Indicates that socket is in listen mode.
<code>SO_DONTROUTE</code>	Indicates that outgoing messages must bypass the standard routing facilities. Instead, messages are directed to the appropriate network interface according to the network portion of the destination address.
<code>SO_KEEPAIVE</code>	Indicates that the periodic transmission of messages on a connected socket is enabled. If the connected party fails to respond to these messages, the connection is considered broken.
<code>SO_LINGER</code>	Indicates that linger on close is enabled.
<code>SO_NOSLOWSTART</code>	Indicates that suppress slow start on this socket is enabled.
<code>SO_TIMESTAMP</code>	Indicates that the TCP timestamp option is enabled.
<b>embOS/IP socket options.</b>	
<code>SO_ERROR</code>	Stores the latest socket error in <code>pData</code> and clears the error in socket structure.
<code>SO_MYADDR</code>	Stores the IP address of the used interface in <code>pData</code> .
<code>SO_RCVTIMEO</code>	Returns the timeout for <code>recv()</code> . A return value of 0 indicates that no timeout is set.
<code>SO_NONBLOCK</code>	Gets sockets blocking status. Allows the caller to specify blocking or non-blocking IO that works the same as the other Boolean socket options. <code>pData</code> points to an integer value which will contain a non-zero value to set non-blocking IO or a 0 value to reset non-blocking IO.

## Return value

0 on success.  
-1 on failure.

## Additional information

`getsockopt()` retrieves the current value for a socket option associated with a socket of any type, in any state, and stores the result in `pData`. Options can exist at multiple protocol levels, but they are always present at the uppermost "socket" level. Options affect socket operations, such as the packet routing.

The value associated with the selected option is returned in the buffer `pData`. The integer pointed to by `DataLen` should originally contain the size of this buffer; on return, it will be set to the size of the value returned. For `SO_LINGER`, this will be the size of a `LINGER` structure. For most other options, it will be the size of an integer.

The application is responsible for allocating any memory space pointed to directly or indirectly by any of the parameters it specified. If the option was never set with `setsockopt()`, then `getsockopt()` returns the default value for the option.

The option `SO_ERROR` returns 0 or number of the socket error and clears the socket error. The following table lists the socket errors.

Symbolic name	Value	Description
<code>ENOBUFS</code>	1	No internal buffer was available.
<code>ETIMEDOUT</code>	2	Connection timed out.
<code>EISCONN</code>	3	Socket is already connected.
<code>EOPNOTSUPP</code>	4	Operation not supported.
<code>ECONNABORTED</code>	5	Connection aborted.
<code>EWouldBlock</code>	6	Operation on non-blocking socket could not be completed immediately.
<code>ECONNREFUSED</code>	7	Connection refused.
<code>ECONNRESET</code>	8	Peer resets connection.
<code>ENOTCONN</code>	9	Socket is not connected.
<code>EALREADY</code>	10	Operation was attempted on a non-blocking socket with an operation already in progress.
<code>EINVAL</code>	11	Invalid argument was supplied.
<code>EMSGSIZE</code>	12	The message which should be sent on a datagram socket was larger than the internal message buffer or some other network limit.
<code>EPIPE</code>	13	Connection error.
<code>EDESTADDRREQ</code>	14	A required address was omitted from an operation on a socket.
<code>ESHUTDOWN</code>	15	Cannot send after socket shutdown.
<code>ENOPROTOPT</code>	16	Bad protocol option.
<code>ENOMEM</code>	18	Not enough memory available.
<code>EADDRNOTAVAIL</code>	19	Cannot assign requested address.
<code>EADDRINUSE</code>	20	Address already in use.
<code>EAFNOSUPPORT</code>	21	Protocol family not supported.
<code>EINPROGRESS</code>	22	A blocking operation is currently executing.
<code>ELOWER</code>	23	Operation is in progress.
<code>ENOTSOCK</code>	24	Socket operation on non-socket.

**Table 5.10: embOS/IP socket error types**

Symbolic name	Value	Description
<a href="#">ETOOMANYREFS</a>	28	Multicast error.
<a href="#">EFAULT</a>	29	Bad address.
<a href="#">ENETUNREACH</a>	30	Network is unreachable.

**Table 5.10: embOS/IP socket error types**

## 5.1.9 listen()

### Description

Prepares the socket to accept connections.

### Prototype

```
int listen ( long Socket,
            int Backlog );
```

### Parameter

Parameter	Description
Socket	[IN] Socket descriptor of an unconnected socket.
Backlog	[IN] Backlog for incoming connections. Defines the maximum length of the queue of pending connections.

**Table 5.11: listen() parameter list**

### Return value

On success 0.

On failure, it returns -1.

### Additional information

The `listen()` call applies only to sockets of type `SOCK_STREAM`. If a connection request arrives when the queue is full, the client will receive an error with an indication of `ECONNREFUSED`.

### Example

```

/*****
*
*   _ListenAtTcpAddr
*
*   Function description
*   Starts listening at the given TCP port.
*/
static int _ListenAtTcpAddr(U16 Port) {
    int          Sock;
    struct sockaddr_in Addr;

    sock = socket(AF_INET, SOCK_STREAM, 0);
    memset(&Addr, 0, sizeof(Addr));
    addr.sin_family      = AF_INET;
    addr.sin_port        = htons(Port);
    addr.sin_addr.s_addr = INADDR_ANY;
    bind(sock, (struct sockaddr *)&Addr, sizeof(Addr));
    listen(Sock, 1);
    return Sock;
}

```

## 5.1.10 recv()

### Description

Receives data from a connected socket.

### Prototype

```
int recv ( long    Socket,
          char *  pRecv,
          int     Length,
          int     Flags );
```

### Parameter

Parameter	Description
<a href="#">Socket</a>	[IN] A descriptor identifying a socket.
<a href="#">pRecv</a>	[OUT] A pointer to a buffer for incoming data.
<a href="#">Length</a>	[IN] The length of buffer <a href="#">pRecv</a> in bytes.
<a href="#">Flags</a>	[IN] OR-combination of one or more of the following valid values.

**Table 5.12: recv() parameter list**

### Valid values for parameter Flag

Value	Description
MSG_PEEK	"Peek" at the data present on the socket; the data are returned, but not consumed, so that a subsequent receive operation will see the same data.

### Return value

If no error occurs, `recv()` returns the number of bytes received. If the connection has been gracefully closed, the return value is zero. Otherwise, -1 is returned, and a specific error code can be retrieved by calling `getsockopt()`. Refer to `getsockopt()` on page 92 for detailed information.

### Additional information

If a message is too long to fit in the supplied buffer, excess bytes may be discarded depending on the type of socket the message is received from. Refer to `connect()` on page 86 for more information about the different types of sockets.

You can only use the `recv()` function on a connected socket. To receive data on a socket, whether it is in a connected state or not refer to `recvfrom()` on page 97.

If no messages are available at the socket and the socket is blocking, the receive call waits for a message to arrive. If the socket is non-blocking (refer to `setsockopt()` on page 102 for more information), -1 is returned.

You can use the `select()` function to determine when more data arrives.

## 5.1.11 recvfrom()

### Description

Receives a datagram and stores the source address.

### Prototype

```
int recvfrom ( long          Socket,
              char          * pRecv,
              int           Length,
              int           Flags,
              struct sockaddr * pAddr,
              int           * pAddrLen );
```

### Parameter

Parameter	Description
<a href="#">Socket</a>	[IN] A socket descriptor of a socket.
<a href="#">pRecv</a>	[OUT] A pointer to a buffer for incoming data.
<a href="#">Length</a>	[IN] Specifies the size of the buffer <a href="#">pRecv</a> in bytes.
<a href="#">Flags</a>	[IN] OR-combination of one or more of the values listed in the table below.
<a href="#">pAddr</a>	[OUT] An optional pointer to a buffer where the address of the connecting entity is stored. The format of the address depends on the defined address family which was defined when the socket was created.
<a href="#">pAddrLen</a>	[IN/OUT] An optional pointer to an integer where the length of the received address is stored. Just like the format of the address, the length of the address depends on the defined address family.

**Table 5.13: recvfrom() parameter list**

### Valid values for parameter Flags

Value	Description
MSG_PEEK	"Peek" at the data present on the socket; the data are returned, but not consumed, so that a subsequent receive operation will see the same data.

### Return value

The number of bytes received or -1 if an error occurred.

### Additional information

If [pAddr](#) is not a NULL pointer, the source address of the message is filled in. [pAddrLen](#) is a value-result parameter, initialized to the size of the buffer associated with [pAddr](#), and modified on return to indicate the actual size of the address stored there.

If a message is too long to fit in the supplied buffer, excess bytes may be discarded depending on the type of socket the message is received from. Refer to *socket()* on page 105 for more information about the different types of sockets.

If no messages are available at the socket and the socket is blocking, the receive call waits for a message to arrive. If the socket is non-blocking (refer to *setsockopt()* on page 102 for more information), -1 is returned.

You can use the `select()` function to determine when more data arrives.

## 5.1.12 select()

### Description

Examines the socket descriptor sets whose addresses are passed in `readfds`, `writefds`, and `exceptfds` to see if some of their descriptors are ready for reading, ready for writing or have an exception condition pending.

### Prototype

```
int select ( IP_FD_set * readfds,
            IP_FD_set * writefds,
            IP_FD_set * exceptfds;
            long      tv );
```

### Parameter

Parameter	Description
<code>readfds</code>	See below.
<code>writefds</code>	
<code>exceptfds</code>	
<code>tv</code>	

**Table 5.14:** `select()` parameter list

### Return value

Returns a non-negative value on success. A positive value indicates the number of ready descriptors in the descriptor sets. 0 indicates that the time limit specified by `tv` expired. On failure, `select()` returns -1 and the descriptor sets are not changed.

### Additional information

On return, `select()` replaces the given descriptor sets with subsets consisting of those descriptors that are ready for the requested operation. The total number of ready descriptors in all the sets is returned. Any of `readfds`, `writefds`, and `exceptfds` may be given as NULL pointers if no descriptors are of interest. Selecting true for reading on a socket descriptor upon which a `listen()` call has been performed indicates that a subsequent `accept()` call on that descriptor will not block.

In the standard Berkeley UNIX Sockets API, the descriptor sets are stored as bit fields in arrays of integers. This works in the UNIX environment because under UNIX socket descriptors are file system descriptors which are guaranteed to be small integers that can be used as indexes into the bit fields. In embOS/IP, socket descriptors are pointers and thus a bit field representation of the descriptor sets is not feasible. Because of this, the embOS/IP API differs from the Berkeley standard in that the descriptor sets are represented as instances of the following structure:

```
typedef struct IP_FD_SET {           // The select socket array manager
    unsigned fd_count;              // how many are SET?
    long fd_array[FD_SETSIZE];     // an array of SOCKETS
} IP_fd_set;
```

Instead of a socket descriptor being represented in a descriptor set via an indexed bit, an embOS/IP socket descriptor is represented in a descriptor set by its presence in the `fd_array` field of the associated `IP_FD_SET` structure. Despite this non-standard representation of the descriptor sets themselves, the following standard entry points are provided for manipulating such descriptor sets: `IP_FD_ZERO(&fdset)` initializes a descriptor set `fdset` to the null set. `IP_FD_SET(fd, &fdset)` includes a particular descriptor, `fd`, in `fdset`. `IP_FD_CLR(fd, &fdset)` removes `fd` from `fdset`. `IP_FD_ISSET(fd, &fdset)` is nonzero if `fd` is a member of `fdset`, zero otherwise. These entry points behave according to the standard Berkeley semantics.

You should be aware that the value of `FD_SETSIZE` defines the maximum number of descriptors that can be represented in a single descriptor set. The default value of `FD_SETSIZE` is 2. This value can be increased in the source code version of embOS/IP to accommodate a larger maximum number of descriptors at the cost of increased processor stack usage.

Another difference between the Berkeley and embOS/IP `select()` calls is the representation of the timeout parameter. Under Berkeley Sockets, the timeout parameter is represented by a pointer to a structure. Under embOS/IP sockets, a timeout is specified by the `tv` parameter, which defines the maximum number of seconds that should elapse before the call to `select()` returns. A `tv` parameter equal to 0 implies that `select()` should return immediately (effectively a poll of the sockets in the descriptor sets). Note that there is no provision for no timeout, that is, there is no way to specify that `select()` block forever unless one of its descriptors become ready.

The final difference between the Berkeley and embOS/IP versions of `select()` is the absence in the embOS/IP version of the Berkeley width parameter. The width parameter is of use only when descriptor sets are represented as bit arrays and was thus deleted in the embOS/IP implementation.

**Note:** Under rare circumstances, `select()` may indicate that a descriptor is ready for writing when in fact an attempt to write would block. This can happen if system resources necessary for a write are exhausted or otherwise unavailable. If an application deems it critical that writes to a file descriptor not block, it should set the descriptor for non-blocking I/O. Refer to `setsockopt()` on page 102 for detailed information.

### Example

```
static void _Client() {
    int          so, AddrLen, r;
    struct sockaddr_in Addr;
    struct sockaddr soAddr;
    IP_fd_set    readfds;
    char         RecvBuffer[128];

    while (IP_IFaceIsReady() == 0) {
        OS_Delay(100);
    }
    so = socket(AF_INET, SOCK_DGRAM, 0);    // Open socket
    Addr.sin_family    = AF_INET;
    Addr.sin_port      = htons(2222);
    Addr.sin_addr.s_addr = INADDR_ANY;
    bind(so, (struct sockaddr *)&Addr, sizeof(Addr));
    AddrLen = sizeof(soAddr);
    while(1) {
        IP_FD_ZERO(&readfds);                // Clear the set
        IP_FD_SET(so, &readfds);            // Add descriptor to the set
        r = select(&readfds, NULL, NULL, 5000); // Check for activity.
        if (r <= 0) {
            continue;                        // No socket activity or error detected
        }
        if (IP_FD_ISSET(so, &readfds)) {
            r = recvfrom(so, RecvBuffer, sizeof(RecvBuffer), 0, &soAddr, &AddrLen);
            if (r == -1){
                continue;
            }
        }
        OS_Delay(100);
    }
}
```

## 5.1.13 send()

### Description

Sends data to a connected socket.

### Prototype

```
int send ( long    Socket,
          char *  pSend,
          int     Length,
          int     Flags );
```

### Parameter

Parameter	Description
Socket	[IN] A descriptor identifying a socket.
pSend	[IN] A pointer to a buffer of data which should be sent.
Length	[IN] The length of the message which should be sent.
Flags	[IN] OR-combination of one or more of the valid values listed in the table below.

**Table 5.15: send() parameter list**

### Valid values for parameter Flags

Value	Description
MSG_DONTROUTE	Specifies that the data should not be subject to routing.

### Return value

The total number of bytes which were sent or -1 if an error occurred.

### Additional information

`send()` may be used only when the socket is in a connected state. Refer to `sendto()` on page 101 for information about sending data to a non-connected socket.

If no messages space is available at the socket to hold the message to be transmitted, then `send()` normally blocks, unless the socket has been placed in non-blocking I/O mode.

`MSG_DONTROUTE` is usually used only by diagnostic or routing programs.

## 5.1.14 sendto()

### Description

Sends data to a specified address.

### Prototype

```
int sendto ( long          Socket,
            char          * pSend,
            int           Length,
            int           Flags,
            struct sockaddr * pAddr,
            int           ToLen );
```

### Parameter

Parameter	Description
<a href="#">Socket</a>	[IN] A descriptor identifying a socket.
<a href="#">pSend</a>	[IN] A pointer to a buffer of data which should be sent.
<a href="#">Length</a>	[IN] The length of the message which should be sent.
<a href="#">Flags</a>	[IN] OR-combination of one or more of the valid values listed in the table below.
<a href="#">pAddr</a>	[IN] An optional pointer to a buffer where the address of the connected entity is stored. The format of the address depends on the defined address family which was defined when the socket was created.
<a href="#">ToLen</a>	[IN] The size of the address in <a href="#">pAddr</a> .

**Table 5.16: sendto() parameter list**

### Valid values for parameter Flags

Value	Description
MSG_DONTROUTE	Specifies that the data should not be subject to routing.

### Return value

The total number of bytes which were sent or -1 if an error occurred.

### Additional information

In contrast to `send()`, `sendto()` can be used at any time. The connection state is in which case the address of the target is given by the [pAddr](#) parameter.

## 5.1.15 setsockopt()

### Description

Sets a socket option.

### Prototype

```
int setsockopt ( long   Socket,
                int    Level,
                int    Option,
                void * pData,
                int    DataLen );
```

### Parameter

Parameter	Description
<a href="#">Socket</a>	[IN] A descriptor identifying a socket.
<a href="#">Level</a>	[IN] Compatibility parameter for <code>setsockopt()</code> and <code>getsockopt()</code> . Use symbol <code>SOL_SOCKET</code> .
<a href="#">Option</a>	[IN] The socket option for which the value is to be set.
<a href="#">pData</a>	[IN] A pointer to the buffer in which the value for the requested option is supplied.
<a href="#">DataLen</a>	[IN] The size of the <code>pData</code> buffer.

**Table 5.17: setsockopt() parameter list**

### Valid values for parameter Option

Value	Description
<b>Standard option flags.</b>	
<code>SO_DONTROUTE</code>	Outgoing messages should bypass the standard routing facilities. Instead, messages are directed to the appropriate network interface according to the network portion of the destination address. By default, this socket option is disabled.
<code>SO_KEEPALIVE</code>	Enable periodic transmission of messages on a connected socket. If the connected party fails to respond to these messages, the connection is considered broken. By default, this socket option is enabled.
<code>SO_LINGER</code>	Controls the action taken when unsent messages are queued on a socket and a <code>closesocket()</code> is performed. Refer to <i>closesocket()</i> on page 85 for detailed information about the linger option. By default, this socket option is disabled.
<code>SO_TIMESTAMP</code>	Enable the TCP timestamp option. By default, this socket option is disabled.
<b>embOS/IP socket options.</b>	
<code>SO_CALLBACK</code>	Sets zero-copy callback routine. Refer to <i>TCP zero-copy interface</i> on page 113 for detailed information.
<code>SO_RCVTIMEO</code>	Sets a timeout for <code>recv()</code> . This changes the behavior of <code>recv()</code> . <code>recv()</code> is by default a blocking function which only returns if data has been received. If a timeout is set <code>recv()</code> will return in case of data reception or timeout. By default, this socket option is disabled.

Value	Description
SO_NONBLOCK	Sets socket blocking status. Allows the caller to specify blocking or non-blocking IO that works the same as the other Boolean socket options. <a href="#">pData</a> points to an integer value which will contain a non-zero value to set non-blocking IO or a 0 value to reset non-blocking IO. By default, this socket option is disabled.

### Return value

0 on success

### Example

```
void _EnableKeepAlive(long sock) {
    int v = 1;

    setsockopt(sock, SOL_SOCKET, SO_KEEPALIVE, &v, sizeof(v));
}
```

## 5.1.16 shutdown()

### Description

Disables sends or receives on a socket.

### Prototype

```
int shutdown( long Socket,
             int Mode );
```

### Parameter

Parameter	Description
Socket	[IN] A descriptor identifying a socket.
Mode	[IN] Indicator which part of communication should be disabled. Refer to additional information below.

**Table 5.18: shutdown() parameter list**

### Return value

Returns 0 on success.

On failure, it returns -1.

### Additional information

A `shutdown()` call causes all or part of a full-duplex connection on the socket associated with `Socket` to be shut down. If `Mode` is 0, then further receives will be disallowed. If `Mode` is 1, then further sends will be disallowed. If `Mode` is 2, then further sends and receives will be disallowed. The shutdown function does not block regardless of the `SO_LINGER` setting on the socket.

## 5.1.17 socket()

### Description

Creates a socket. A socket is an endpoint for communication.

### Prototype

```
long socket ( int Domain,
             int Type,
             int Proto );
```

### Parameter

Parameter	Description
Domain	[IN] Protocol family which should be used.
Type	[IN] Specifies the type of the socket.
Proto	[IN] Specifies the protocol which should be used with the socket. Must be set to zero.

**Table 5.19: socket() parameter list**

### Valid values for parameter Domain

Value	Description
AF_INET	IPv4 - Internet protocol version 4

### Valid values for parameter Type

Value	Description
SOCK_STREAM	Stream socket
SOCK_DGRAM	Datagram socket

### Return value

A non-negative descriptor on success.  
On failure, it returns -1.

### Additional information

The `Domain` parameter specifies a communication domain within which communication will take place; the communication domain selects the protocol family which should be used. The protocol family generally is the same as the address family for the addresses supplied in later operations on the socket.

A `SOCK_STREAM` socket provides sequenced, reliable, two-way connection based byte streams. A `SOCK_DGRAM` socket supports datagrams (connectionless, unreliable messages of a fixed - typically small - maximum length).

Sockets of type `SOCK_STREAM` are full-duplex byte streams, similar to UNIX pipes. A stream socket must be in a connected state before it can send or receive data.

A connection to another socket is created with a `connect()` call. Once connected, data can be transferred using `send()` and `recv()` calls. When a session has been completed, a `closesocket()` should be performed.

The communications protocols used to implement a `SOCK_STREAM` ensure that data is not lost or duplicated. If a piece of data (for which the peer protocol has buffer space) cannot be successfully transmitted within a reasonable length of time, then the connection is considered broken and calls will return -1 which indicates an error. The protocols optionally keep sockets "warm" by forcing transmissions roughly every minute in the absence of other activity. An error is then indicated if no response can be elicited on an otherwise idle connection for an extended period (such as five minutes).

`SOCK_DGRAM` sockets allow sending of datagrams to correspondents named in `sendto()` calls. Datagrams are generally received with `recvfrom()`, which returns the next datagram with its return address.

The operation of sockets is controlled by socket-level options. The `getsockopt()` and `setsockopt()` functions are used to get and set options. Refer to *getsockopt()* on page 92 and *setsockopt()* on page 102 for detailed information.

## 5.2 Socket data structures

### 5.2.1 Structure sockaddr

#### Description

This structure holds socket address information for many types of sockets.

#### Prototype

```
struct sockaddr {
    U16    sa_family;
    char   sa_data[14];
};
```

Member	Description
<code>sa_family</code>	Address family. Normally <code>AF_INET</code> .
<code>sa_data</code>	The character array <code>sa_data</code> contains the destination address and port number for the socket.

**Table 5.20: Structure `sockaddr` member list**

#### Additional information

The structure `sockaddr` is mostly used as function parameter. To deal with struct `sockaddr`, a parallel structure struct `sockaddr_in` is implemented. The structure `sockaddr_in` is the same size as structure `sockaddr`, so that a pointer can freely be casted from one type to the other. Refer to *Structure `sockaddr_in`* on page 108 for more information and an example.

## 5.2.2 Structure `sockaddr_in`

### Description

Structure for handling internet addresses.

### Prototype

```
struct sockaddr_in {
    short          sin_family;
    unsigned short sin_port;
    struct in_addr sin_addr;
    char          sin_zero[8];
};
```

Member	Description
<code>sin_family</code>	Address family. Normally <code>AF_INET</code> .
<code>sin_port</code>	Port number for the socket.
<code>sin_addr</code>	Structure of type <code>in_addr</code> . The structure represents a 4-byte number that represents one digit in an IP address per byte.
<code>sin_zero</code>	<code>sin_zero</code> member is unused.

**Table 5.21: Structure `sockaddr_in` member list**

### Example

Refer to `connect()` on page 86 for an example.

## 5.2.3 Structure in\_addr

### Description

4-byte number that represents one digit in an IP address per byte.

### Prototype

```
struct in_addr {  
    unsigned long  s_addr;  
};
```

Member	Description
<a href="#">s_addr</a>	Number that represents one digit in an IP address per byte.

**Table 5.22: Structure in\_addr member list**

## 5.2.4 Structure hostent

### Description

The hostent structure is used by functions to store information about a given host, such as host name, IPv4 address, and so on.

### Prototype

```
struct hostent {
    char *    h_name;
    char **   h_aliases;
    int      h_addrtype;
    int      h_length;
    char **   h_addr_list;
};
```

Member	Description
<a href="#">h_name</a>	Official name of the host.
<a href="#">h_aliases</a>	Alias list.
<a href="#">s_addrtype</a>	Host address type.
<a href="#">h_length</a>	Length of the address.
<a href="#">s_addr_list</a>	List of addresses from the name server.

**Table 5.23: Structure in\_addr member list**

## 5.3 Error codes

The following table contains a list of generic error codes, generally full success is 0. Definite errors are negative numbers, and indeterminate conditions are positive numbers.

Symbolic name	Value	Description
Programming errors		
<a href="#">IP_ERR_PARAM</a>	-10	Bad parameter.
<a href="#">IP_ERR_LOGIC</a>	-11	Sequence of events that shouldn't happen.
System errors		
<a href="#">IP_ERR_NOMEM</a>	-20	malloc() or calloc() failed.
<a href="#">IP_ERR_NOBUFFER</a>	-21	Run out of free packets.
<a href="#">IP_ERR_RESOURCE</a>	-22	Run out of other queue-able resource.
<a href="#">IP_ERR_BAD_STATE</a>	-23	TCP layer error.
<a href="#">IP_ERR_TIMEOUT</a>	-24	Timeout error on TCP layer.
Networking errors		
<a href="#">IP_ERR_BAD_HEADER</a>	-32	Bad header at upper layer (for upcalls).
<a href="#">IP_ERR_NO_ROUTE</a>	-33	Can not find a reasonable next IP hop.
Networking errors		
<a href="#">IP_ERR_SEND_PENDING</a>	1	Packet queued pending an ARP reply.
<a href="#">IP_ERR_NOT_MINE</a>	2	Packet was not of interest (upcall reply).

**Table 5.24: embOS/IP error types**



# Chapter 6

## TCP zero-copy interface

---

The TCP protocol can be used via socket functions or the TCP zero-copy interface which is described in this chapter.

## 6.1 TCP zero-copy

This section documents an optional extension to the Sockets layer, the TCP zero-copy API. The TCP zero-copy API is intended to assist the development of higher-performance embedded network applications by allowing the application direct access to the TCP/IP stack packet buffers. This feature can be used to avoid the overhead of having the stack copy data between application-owned buffers and stack-owned buffers in `send()` and `recv()`, but the application has to fit its data into, and accept its data from, the stack buffers.

The TCP zero-copy API is small because it is simply an extension to the existing Sockets API that provides an alternate mechanism for sending and receiving data on a socket. The Sockets API is used for all other operations on the socket.

### 6.1.1 Allocating, freeing and sending packet buffers

The two functions for allocating and freeing packet buffers are straightforward requests:

`IP_TCP_Alloc()` allocates a packet buffer from the pool of packet buffers on the stack and `IP_TCP_Free()` frees a packet buffer. Applications using the TCP zero-copy API are responsible for allocating packet buffers for use in sending data, as well as for freeing buffers that have been used to receive data and those that the application has allocated but decided not to use for sending data. As these packet buffers are a limited resource, it is important that applications free them promptly when they are no longer of use.

The functions for sending data, `IP_TCP_Send()` and `IP_TCP_SendAndFree()`, send a packet buffer of data using a socket. The TCP zero-copy interface supports two different approaches to send and free a packet. One approach is that the stack frees the packet independent from the success of sending the packet. Therefore, `IP_TCP_SendAndFree()` is called to send and free the packet. It frees the packet independent from the success of the send operation. The other approach is that `IP_TCP_Send()` is called. In this case it is the responsibility of the application to free the packet. Depending on the return value the application can decide if `IP_TCP_Free()` should be called to free the packet.

### 6.1.2 Callback function

Applications that use the TCP Zero-copy API for receiving data must include a callback function for acceptance of received packets, and must register the callback function with the socket using the `setsockopt()` sockets function with the `SO_CALLBACK` option name. The callback function, once registered, receives not only received data packets, but also connection events that result in socket errors.

## 6.2 Sending data with the TCP zero-copy API

To send data with the TCP zero-copy API, you should proceed as follow:

1. Allocating a packet buffer
2. Filling the allocated buffer
3. Sending the packet

The following section describes the procedure for allocating a packet buffer, sending data, and freeing the packet buffer step by step.

### 6.2.1 Allocating a packet buffer

The first step in using the TCP zero-copy API to send data is to allocate a packet buffer from the stack using the `IP_TCP_Alloc()` function. This function takes the maximum length of the data you intend to send in the buffer as argument and returns a pointer to an `IP_PACKET` structure.

```
IP_PACKET * pPacket;
U32      DataLen;           // Amount of data to send

DataLen = 512;              // Should indicate amount of data to send
pPacket = IP_TCP_Alloc(DataLen);
if (pPacket == NULL) {
    // Error, could not allocate packet buffer
}
```

This limits how much data you can send in one call using the TCP zero-copy API, as the data sent in one call to `IP_TCP_Send()` must fit in a single packet buffer. The actual limit is determined by the big packet buffer size, less 68 bytes for protocol headers. If you try to request a larger buffer than this, `IP_TCP_Alloc()` returns `NULL` to indicate that it cannot allocate a sufficiently large buffer.

### 6.2.2 Filling the allocated buffer with data

Having allocated the packet buffer, you now fill it with the data to send. The function `IP_TCP_Alloc()` has initialized the returned `IP_PACKET` `pPacket` and so `pPacket->pData` points to where you can start depositing data.

### 6.2.3 Sending the packet

Finally, you send the packet by giving it back to the stack using the function `IP_TCP_Send()`.

```
e = IP_TCP_Send(socket, pPacket);
if (e < 0) {
    IP_TCP_Free(pPacket);
}
```

This function sends the packet over TCP, or returns an error. If its return value is less than zero, it has not accepted the packet and the application has to decide either to free the packet or to retain it for sending later. Use `IP_TCP_SendAndFree()` if the packet should be freed automatically in any case.

## 6.3 Receiving data with the TCP zero-copy API

To receive data with the TCP zero-copy API, you should proceed as follow:

1. Writing a callback function
2. Registering the callback function

### 6.3.1 Writing a callback function

Using the TCP zero-copy API for receiving data requires the application developer to write a callback function that the stack can use to inform the application of received data packets and other socket events. This function is expected to conform to the following prototype:

```
int rx_callback(long Socket, IP_PACKET * pPacket, int code);
```

The stack calls this function when it has received a data packet or other event to report for a socket. The parameter `Socket` identifies the socket. The parameter `pPacket` passes a pointer to the packet buffer (if there is a packet buffer). If `pPacket` is not NULL, it is a pointer to a packet buffer containing received data for the socket. `pPacket->pData` points to the start of the received data, and `pPacket->NumBytes` indicates the number of bytes of received data in this buffer.

The parameter `code` passes an error event (if there is an error to report). If `code` is not 0, it is a socket error indicating that an error or other event has occurred on the socket. Typical nonzero values are `ESHUTDOWN` and `ECONNRESET`. `ESHUTDOWN` defines that the connected peer has closed its end of the connection and sends no more data. `ECONNRESET` defines that the connected peer has abruptly closed its end of the connection and neither sends nor receives more data.

#### Returned values

The callback function may return one of the following values:

Symbolic	Numerical	Description
<code>IP_OK</code>	0	Data handled, packet can be freed.
<code>IP_OK_KEEP_PACKET</code>	1	Data will be handled by application later, the stack should NOT free the packet. This will be done by the application at a later time when the data has been handled and the packet is no longer needed.

**Table 6.1: embOS/IP TCP zero-copy - Valid return values for the receive callback function**

**Note:** The callback function is called from the stack and is expected to return promptly. Some of the places where the stack calls the callback function require that the data structures on the stack remain consistent through the callback, so the callback function must not call back into the stack except to call `IP_TCP_Free()`.

### 6.3.2 Registering the callback function

The application must also inform the stack of the callback function. `setsockopt()` function provides an additional socket option, `SO_CALLBACK`, which should be used for this purpose once the socket has been created. The following code fragment illustrates the use of this option to register a callback function named `RxUpcall()` on the socket `Socket`:

```
setsockopt(Socket, SOL_SOCKET, SO_CALLBACK, (void *)RxUpcall, 0);
```

The function `setsockopt()` is described in `setsockopt()` on page 102.

## 6.4 API functions

Function	Description
<a href="#">IP_TCP_Alloc()</a>	Allocates a packet buffer.
<a href="#">IP_TCP_Free()</a>	Frees a packet buffer.
<a href="#">IP_TCP_Send()</a>	Sends a packet.
<a href="#">IP_TCP_SendAndFree()</a>	Sends and frees a packet.

**Table 6.2: embOS/IP TCP zero-copy API function overview**

## 6.4.1 IP\_TCP\_Alloc()

### Description

Allocates a packet buffer large enough to hold datalen bytes of TCP data, plus TCP, IP and MAC headers.

### Prototype

```
IP_PACKET * IP_TCP_Alloc (int datasize);
```

### Parameter

Parameter	Description
<code>datasize</code>	[IN] Length of the data which should be received.

**Table 6.3: IP\_TCP\_Alloc() parameter list**

### Return value

Success: Returns a pointer to the allocated buffer.

Error: NULL

### Additional information

This function must be called to allocate a buffer for sending data via `IP_TCP_Send()`. It returns the allocated packet buffer with its `pPacket->pData` field set to where the application must deposit the data to be sent.

This `datasize` limits how much data that you can send in one call using the TCP zero-copy API, as the data sent in one call to `IP_TCP_Send()` must fit in a single packet buffer, with the TCP, IP, and lower-layer headers that the stack needs to add in order to send the packet.

The actual limit is determined by the big packet buffer size (normally 1536 bytes). Refer to `IP_AddBuffers()` on page 42 for more information about defining buffer sizes. If you try to request a larger buffer than this, `IP_TCP_Alloc()` returns NULL to indicate that it cannot allocate a sufficiently-large buffer.

### Example

```
IP_PACKET * pPacket;
U32 DataLen; // Amount of data to send

DataLen = 1024; // Should indicate amount of data to send
pPacket = IP_TCP_Alloc(DataLen);
if (pPacket == NULL) {
    // Error, could not allocate packet buffer
}
```

## 6.4.2 IP\_TCP\_Free()

### Description

Frees a packet buffer allocated by `IP_TCP_Alloc()`.

### Prototype

```
void IP_TCP_Free ( IP_PACKET * pPacket );
```

### Parameter

Parameter	Description
<code>pPacket</code>	[IN] Pointer to the <code>IP_Packet</code> structure.

**Table 6.4: IP\_TCP\_Free() parameter list**

### 6.4.3 IP\_TCP\_Send()

#### Description

Sends a packet buffer on a socket.

#### Prototype

```
int IP_TCP_Send ( U32          s,
                 IP_PACKET * pPacket );
```

#### Parameter

Parameter	Description
<code>s</code>	[IN] Socket descriptor.
<code>pPacket</code>	[IN] Pointer to a packet buffer.

**Table 6.5: IP\_TCP\_Send() parameter list**

#### Return value

0 The packet was sent successfully.

<0 The packet was not accepted by the stack. The application must re-send the packet using a call to `IP_TCP_Send()`, or free the packet using `IP_TCP_Free()`.

>0 The packet has been accepted and queued on the socket but has not yet been transmitted.

#### Additional information

Applications using the TCP zero-copy API are responsible for allocating packet buffers for use in sending data, as well as for freeing buffers that have been used to receive data and those that the application has allocated but decided not to use for sending data. As these packet buffers are a limited resource, it is important that applications free them promptly when they are no longer of use.

Packets have to be freed after processing. The TCP zero-copy interface supports two different approaches to free a packet. One approach is that the stack frees the packet independent from the success of sending the packet. Therefore, `IP_TCP_SendAndFree()` is called to send the packet and free the packet. It frees the packet independent from the success of the send operation. The other approach is that `IP_TCP_Send()` is called. In this case it is the responsibility application programmer to free the packet. Depending on the return value the application programmer can decide if `IP_TCP_Free()` should be called to free the packet.

## 6.4.4 IP\_TCP\_SendAndFree()

### Description

Sends a packet buffer on a socket.

### Prototype

```
int IP_TCP_SendAndFree ( U32          s,
                        IP_PACKET * pPacket );
```

### Parameter

Parameter	Description
<a href="#">s</a>	[IN] Socket descriptor.
<a href="#">pPacket</a>	[IN] Pointer to the <code>IP_Packet</code> structure.

**Table 6.6: IP\_TCP\_Send() parameter list**

### Return value

0 The packet was sent successfully.

<0 The packet was not accepted by the stack.

>0 The packet has been accepted and queued on the socket but has not yet been transmitted.

### Additional information

Applications using the TCP zero-copy API are responsible for allocating packet buffers for use in sending data, as well as for freeing buffers that have been used to receive data and those that the application has allocated but decided not to use for sending data. As these packet buffers are a limited resource, it is important that applications free them promptly when they are no longer of use.

`IP_TCP_SendAndFree()` frees packet [pPacket](#) after processing. It frees the packet independent from the success of the send operation.



# Chapter 7

## UDP zero-copy interface

---

The UDP transfer protocol can be used via socket functions or the zero-copy interface which is described in this chapter.

## 7.1 UDP zero-copy

The UDP zero-copy API functions are provided for systems that do not need the overhead of sockets. These routines impose a lower demand on CPU and system memory requirements than sockets. However, they do not offer the portability of sockets.

UDP zero-copy API functions are intended to assist the development of higher-performance embedded network applications by allowing the application direct access to the TCP/IP stack packet buffers. This feature can be used to avoid the overhead of having the stack copy data between application-owned buffers and stack-owned buffers in `sendto()` and `recvfrom()`, but the application has to fit its data into, and accept its data from, the stack buffers. Refer to *embOS/IP UDP discover (OS\_IP\_UDPDiscover.c / OS\_IP\_UDPDiscoverZeroCopy.c)* on page 37 for detailed information about the UDP zero-copy example application.

### 7.1.1 Allocating, freeing and sending packet buffers

The two functions for allocating and freeing packet buffers are straightforward requests:

`IP_UDP_Alloc()` allocates a packet buffer from the pool of packet buffers on the stack and `IP_UDP_Free()` frees a packet buffer. Applications using the UDP zero-copy API are responsible for allocating packet buffers for use in sending data, as well as for freeing buffers that have been used to receive data and those that the application has allocated but decided not to use for sending data. As these packet buffers are a limited resource, it is important that applications free them promptly when they are no longer of use.

The functions for sending data, `IP_UDP_Send()` and `IP_UDP_SendAndFree()`, send a packet buffer of data using a port. The UDP zero-copy interface supports two different approaches to send and free a packet. One approach is that the stack frees the packet independent from the success of sending the packet. Therefore, `IP_UDP_SendAndFree()` is called to send and free the packet. It frees the packet independent from the success of the send operation. The other approach is that `IP_UDP_Send()` is called. In this case it is the responsibility of the application to free the packet. Depending on the return value the application can decide if `IP_UDP_Free()` should be called to free the packet.

### 7.1.2 Callback function

Applications that use the UDP zero-copy API for receiving data must include a callback function for acceptance of received packets, and must register the callback function with a port using the `IP_UDP_Open()` function. The callback function, once registered, receives all matching data packets.

## 7.2 Sending data with the UDP zero-copy API

To send data with the UDP zero-copy API, you should proceed as follow:

1. Allocating a packet buffer
2. Filling the allocated buffer
3. Sending the packet

The following section describes the procedure for allocating a packet buffer, sending data, and freeing the packet buffer step by step.

### 7.2.1 Allocating a packet buffer

The first step in using the UDP zero-copy API to send data is to allocate a packet buffer from the stack using the `IP_UDP_Alloc()` function. This function takes the maximum length of the data you intend to send in the buffer as argument and returns a pointer to an `IP_PACKET` structure.

```
IP_PACKET * pPacket;
U32      DataLen;           // Amount of data to send

DataLen = 512;              // Should indicate amount of data to send
pPacket = IP_UDP_Alloc(DataLen);
if (pPacket == NULL) {
    // Error, could not allocate packet buffer
}
```

This limits how much data you can send in one call using the UDP zero-copy API, as the data sent in one call to `IP_UDP_Send()` must fit in a single packet buffer. The actual limit is determined by the big packet buffer size, less typically 42 bytes for protocol headers (14 bytes for Ethernet header, 20 bytes IP header, 8 bytes UDP header). If you try to request a larger buffer than this, `IP_UDP_Alloc()` returns `NULL` to indicate that it cannot allocate a sufficiently large buffer.

### 7.2.2 Filling the allocated buffer with data

Having allocated the packet buffer, you now fill it with the data to send. The function `IP_UDP_Alloc()` has initialized the returned `IP_PACKET` `pPacket` and so `pPacket->pData` points to where you can start depositing data.

### 7.2.3 Sending the packet

Finally, you send the packet by giving it back to the stack using the function `IP_UDP_Send()`.

```
#define SRC_PORT 50020
#define DEST_PORT 50020
#define DEST_ADDR 0xC0A80101

e = IP_UDP_Send(0, DEST_ADDR, SRC_PORT, DEST_PORT, pPacket);
if (e < 0) {
    IP_UDP_Free(pPacket);
}
```

This function sends the packet over UDP, or returns an error. If its return value is less than zero, it has not accepted the packet and the application has to decide either to free the packet or to retain it for sending later. Use `IP_UDP_SendAndFree()` if the packet should be freed automatically in any case.

## 7.3 Receiving data with the UDP zero-copy API

To receive data with the UDP zero-copy API, you should proceed as follow:

1. Writing a callback function
2. Registering the callback function

### 7.3.1 Writing a callback function

Using the UDP zero-copy API for receiving data requires the application developer to write a callback function that the stack can use to inform the application of received data packets. This function is expected to conform to the following prototype:

```
int rx_callback(IP_PACKET * pPacket, void * pContext)
```

The stack calls this function when it has received a data packet for a port. The parameter `pPacket` points to the packet buffer. The packet buffer contains the received data for the socket. `pPacket->pData` points to the start of the received data, and `pPacket->NumBytes` indicates the number of bytes of received data in this buffer.

#### Returned values

The callback function may return one of the following values:

Symbolic	Numerical	Description
<code>IP_OK</code>	0	Data handled. embOS/IP will free the packet.
<code>IP_OK_KEEP_PACKET</code>	1	Data will be handled by application later, the stack should NOT free the packet. This will be done by the application at a later time when the data has been handled and the packet is no longer needed.

**Table 7.1: embOS/IP UDP zero-copy - Valid return values for the receive callback function**

**Note:** The callback function is called from the stack and is expected to return promptly. Some of the places where the stack calls the callback function require that the data structures on the stack remain consistent through the callback, so the callback function must not call back into the stack except to call `IP_UDP_Free()`.

### 7.3.2 Registering the callback function

The application must also inform the stack of the callback function. This is done by calling the `IP_UDP_Open()` function. The following code fragment illustrates the use of this option to register a callback function named `RxUpCall()` on the port 50020:

```
#define SRC_PORT 50020
#define DEST_PORT 50020
```

```
IP_UDP_Open(0L /* any foreign host */, SRC_PORT, DEST_PORT, RxUpCall, 0L /* any tag */);
```

The function `IP_UDP_Open()` is described in *IP\_UDP\_Open()* on page 135.

## 7.4 API functions

Function	Description
<code>IP_UDP_Alloc()</code>	Returns a pointer to a packet buffer big enough for the specified sizes.
<code>IP_UDP_Close()</code>	Closes a UDP connection handle.
<code>IP_UDP_FindFreePort()</code>	Returns a free local port number.
<code>IP_UDP_Free()</code>	Frees the buffer which was used for a packet.
<code>IP_UDP_GetDataPtr()</code>	Returns pointer to data contained in the received UDP packet.
<code>IP_UDP_GetLPort()</code>	Extracts local port information from a UDP packet.
<code>IP_UDP_GetSrcAddr()</code>	Retrieves the IP address of the sender of the given UDP packet.
<code>IP_UDP_Open()</code>	Creates a UDP connection handle.
<code>IP_UDP_Send()</code>	Sends an UDP packet to a specified host.
<code>IP_UDP_SendAndFree()</code>	Sends an UDP packet to a specified host and frees the packet.

**Table 7.2: embOS/IP UDP zero-copy API function overview**

## 7.4.1 IP\_UDP\_Alloc()

### Description

Returns a pointer to a packet buffer big enough for the specified sizes.

### Prototype

```
IP_PACKET * IP_UDP_Alloc( int NumBytes );
```

### Parameter

Parameter	Description
<a href="#">NumBytes</a>	[IN] Length of the data which should be received.

**Table 7.3: IP\_UDP\_Alloc() parameter list**

### Return value

Success: Returns a pointer to the allocated buffer.

Error: NULL

### Additional information

Applications using the UDP zero-copy API are responsible for allocating packet buffers for use in sending data, as well as for freeing buffers that have been used to receive data and those that the application has allocated but decided not to use for sending data. As these packet buffers are a limited resource, it is important that applications free them promptly when they are no longer of use.

The UDP zero-copy interface supports two different approaches to free a packet. One approach is that the stack frees the packet independent from the success of sending the packet. Therefore, `IP_UDP_SendAndFree()` is called to send the packet and free the packet. It frees the packet independent from the success of the send operation. The other approach is that `IP_UDP_Send()` is called. In this case it is the responsibility application programmer to free the packet. Depending on the return value the application programmer can decide if `IP_UDP_Free()` should be called to free the packet.

## 7.4.2 IP\_UDP\_Close()

### Description

Closes a UDP connection handle and removes the connection from demux table list of connections and deallocates it.

### Prototype

```
void IP_UDP_Close( IP_UDP_CONN Con );
```

### Parameter

Parameter	Description
<a href="#">Con</a>	[IN] UDP connection handle.

**Table 7.4: IP\_UDP\_Close() parameter list**

### 7.4.3 IP\_UDP\_FindFreePort()

#### Description

Obtains a random port number, that is suitable for use as the `lport` parameter in a call to `IP_UDP_Open()`.

#### Prototype

```
U16 IP_UDP_FindFreePort( void );
```

#### Return value

A usable port number in local endianness.

#### Additional information

The returned port number is suitable for use as the `lport` parameter in a call to `IP_UDP_Open()`. Refer to `IP_UDP_Open()` on page 135 for more information. `IP_UDP_FindFreePort()` avoids picking port numbers in the reserved range 0-1024, or in the range 1025-1199, which may be used for server applications.

## 7.4.4 IP\_UDP\_Free()

### Description

Frees the buffer which was used for a packet.

### Prototype

```
void IP_UDP_Free( IP_PACKET * pPacket );
```

### Parameter

Parameter	Description
<a href="#">pPacket</a>	[IN] Pointer to a packet structure.

**Table 7.5: IP\_UDP\_Free() parameter list**

## 7.4.5 IP\_UDP\_GetDataPtr()

### Description

Returns pointer to data contained in the received UDP packet.

### Prototype

```
void * IP_UDP_GetDataPtr(const IP_PACKET *pPacket);
```

### Parameter

Parameter	Description
<a href="#">pPacket</a>	[IN] Pointer to a packet structure.

**Table 7.6: IP\_UDP\_GetDataPtr() parameter list**

## 7.4.6 IP\_UDP\_GetLPort()

### Description

Extracts local port information from a UDP packet.

### Prototype

```
U16 IP_UDP_GetLPort ( const IP_PACKET * pPacket );
```

### Parameter

Parameter	Description
<a href="#">pPacket</a>	[IN] Pointer to a packet structure.

**Table 7.7: IP\_UDP\_GetLPort() parameter list**

## 7.4.7 IP\_UDP\_GetSrcAddr()

### Description

Returns pointer to data contained in the received UDP packet.

### Prototype

```
void IP_UDP_GetSrcAddr( const IP_PACKET * pPacket,  
                       void          * pSrcAddr,  
                       int           AddrLen );
```

### Parameter

Parameter	Description
<a href="#">pPacket</a>	[IN] Pointer to a packet structure.
<a href="#">pSrcAddr</a>	[IN] Pointer to a buffer to store the source address.
<a href="#">AddrLen</a>	[IN] Size of the buffer used to store the source address.

**Table 7.8: IP\_UDP\_GetSrcAddr() parameter list**

## 7.4.8 IP\_UDP\_Open()

### Description

Creates a UDP connection handle to receive, and pass upwards, UDP packets that match the parameters passed.

### Prototype

```
IP_UDP_CONN IP_UDP_Open( IP_ADDR      IPAddr,
                          U16         fport,
                          U16         lport,
                          int(*routine) (IP_PACKET *, void * pContext),
                          void *      pContext );
```

### Parameter

Parameter	Description
<a href="#">IPAddr</a>	[IN] IP address.
<a href="#">fport</a>	[IN] Foreign port.
<a href="#">lport</a>	[IN] Local port.
<a href="#">(*routine)</a>	[IN] Callback function which is called when a UDP packet is received.
<a href="#">pContext</a>	[IN/OUT] Application defined context pointer.

**Table 7.9: IP\_UDP\_Open() parameter list**

### Return value

Success: Returns a pointer to the UDP connection handle.

Error: NULL

### Additional information

The parameters [IPAddr](#), [fport](#), and [lport](#), can be set to 0 as a wild card, which enables the reception of broadcast datagrams. The callback handler function is called with a pointer to a received datagram and a copy of the data pointer which is passed to [IP\\_UDP\\_Open\(\)](#). This can be any data the programmer requires, such as a pointer to another function, or a control structure to aid in demultiplexing the received UDP packet.

The returned handle is used as parameter for [IP\\_UDP\\_Close\(\)](#) only. If [IP\\_UDP\\_Close\(\)](#) is not called, there is no need to save the return value.

## 7.4.9 IP\_UDP\_Send()

### Description

Send an UDP packet to a specified host.

### Prototype

```
int IP_UDP_Send( int          IFace,
                IP_ADDR     FHost,
                U16         fport,
                U16         lport,
                IP_PACKET * pPacket );
```

### Parameter

Parameter	Description
<a href="#">IFace</a>	[IN] Zero-based index of available interfaces.
<a href="#">IPAddr</a>	[IN] IP address of the target host in network endianness.
<a href="#">fport</a>	[IN] Foreign port.
<a href="#">lport</a>	[IN] Local port.
<a href="#">pPacket</a>	[IN] Data which should be sent to the target host.

**Table 7.10: IP\_UDP\_Send() parameter list**

### Return value

On success: 0

On error: Non-zero error code

### Additional information

The packet [pPacket](#) has to be allocated by calling [IP\\_UDP\\_Alloc\(\)](#). Refer to [IP\\_UDP\\_Alloc\(\)](#) on page 128 for detailed information.

If you expect to get any response to this packet you should have opened a UDP connection prior to calling [IP\\_UDP\\_Send\(\)](#). Refer to [IP\\_UDP\\_Open\(\)](#) on page 135 for more information about creating an UDP connection.

[IP\\_UDP\\_Send\(\)](#) does not free the packet after sending. It is the responsibility of the application programmer to free the packet. Depending on the return value the application programmer can decide if [IP\\_UDP\\_Free\(\)](#) should be called to free the packet.

## 7.4.10 IP\_UDP\_SendAndFree()

### Description

Send an UDP packet to a specified host and frees the packet.

### Prototype

```
int IP_UDP_SendAndFree( int      IFace,
                       IP_ADDR  FHost,
                       U16      fport,
                       U16      lport,
                       IP_PACKET * pPacket );
```

### Parameter

Parameter	Description
<a href="#">IFace</a>	[IN] Zero-based index of available interfaces.
<a href="#">IPAddr</a>	[IN] IP address of the target host in network endianness.
<a href="#">fport</a>	[IN] Foreign port.
<a href="#">lport</a>	[IN] Local port.
<a href="#">pPacket</a>	[IN] Data which should be sent to the target host.

**Table 7.11: IP\_UDP\_SendAndFree() parameter list**

### Return value

On success: 0

On error: Non-zero error code

### Additional information

The packet [pPacket](#) has to be allocated by calling [IP\\_UDP\\_Alloc\(\)](#). Refer to [IP\\_UDP\\_Alloc\(\)](#) on page 72 for detailed information.

If you expect to get any response to this packet you should have opened a UDP connection prior to calling this. Refer to [IP\\_UDP\\_Open\(\)](#) on page 135 for more information about creating an UDP connection.

Packets are freed by calling [IP\\_UDP\\_SendAndFree\(\)](#). Therefore, no call of [IP\\_UDP\\_Free\(\)](#) is required.



# Chapter 8

## DHCP client

---

This chapter explains the usage of the Dynamic Host Control Protocol (DHCP) with embOS/IP. All API functions are described in this chapter.

## 8.1 DHCP backgrounds

DHCP stands for Dynamic Host Configuration Protocol. It is designed to ease configuration management of large networks by allowing the network administrator to collect all the IP hosts "soft" configuration information into a single computer. This includes IP address, name, gateway, and default servers. Refer to *[RFC 2131] - DHCP - Dynamic Host Configuration Protocol* for detailed information about all settings which can be assigned with DHCP.

DHCP is a "client/server" protocol, meaning that machine with the DHCP database "serves" requests from DHCP clients. The clients typically initiate the transaction by requesting an IP address and perhaps other information from the server. The server looks up the client in its database, usually by the client's media address, and assigns the requested fields. Clients do not always need to be in the server's database. If an unknown client submits a request, the server may optionally assign the client a free IP address from a "pool" of free addresses kept for this purpose. The server may also assign the client default information of the local network, such as the default gateway, the DNS server, and routing information.

When the IP addresses is assigned, it is "leased" to the client for a finite amount of time. The DHCP client needs to keep track of this lease time, and obtain a lease extension from the server before the lease time runs out. Once the lease has elapsed, the client should not send any more IP packets (except DHCP requests) until he get another address. This approach allows computers (such as laptops or factory floor monitors) which will not be permanently attached to the network to share IP addresses and not hog them when they are not using the net.

DHCP is just a superset of the Bootstrap Protocol (BOOTP). The main differences between the two are the lease concept, which was created for DHCP, and the ability to assigned addresses from a pool. Refer to *[RFC 951] - Bootstrap Protocol* for detailed information about the Bootstrap Protocol.

## 8.2 API functions

Function	Description
<a href="#">IP_DHCPC_Activate()</a>	Activates the DHCP client.
<a href="#">IP_DHCPC_GetState()</a>	Returns the state of the DHCP client.
<a href="#">IP_DHCPC_Halt()</a>	Stops all DHCP client activity.
<a href="#">IP_DHCPC_SetCallback()</a>	Sets a callback for an interface.

**Table 8.1: embOS/IP DHCP client interface function overview**

## 8.2.1 IP\_DHCP\_Activate()

### Description

Activates the DHCP client.

### Prototype

```
void IP_DHCP_Activate ( int          IFIndex,
                      const char * sHost,
                      const char * sDomain,
                      const char * sVendor );
```

### Parameter

Parameter	Description
<code>IFIndex</code>	[IN] Zero-based index number specifying the interface which should request configuration information from a DHCP server.
<code>sHost</code>	[IN] Pointer to host name to use in negotiation. Can be NULL.
<code>sDomain</code>	[IN] Pointer to domain name to use in negotiation. Can be NULL.
<code>sVendor</code>	[IN] Pointer to vendor to use in negotiation. Can be NULL.

**Table 8.2: IP\_DHCP\_Activate() parameter list**

### Additional information

This function is typically called from within `IP_X_Config()`. This function initializes the DHCP client. It attempts to open a UDP connection to listen for incoming replies and begins the process of configuring a network interface using DHCP. The process may take several seconds, and the DHCP client will keep retrying if the service does not respond.

The parameters `sHost`, `sDomain`, `sVendor` are optional (can be NULL). If not NULL, must point to a memory area which remains valid after the call since the string is not copied.

### Example

```
// Correct function call
IP_DHCP_Activate(0, "Target", NULL, NULL);
// Illegal function call
char ac;
sprintf(ac, "Target%d", Index);
IP_DHCP_Activate(0, ac, NULL, NULL);
// Correct function call
static char ac;
sprintf(ac, "Target%d", Index);
IP_DHCP_Activate(0, ac, NULL, NULL);
```

If you start the DHCP client with activated logging the output on the terminal I/O should be similar to the listing below:

```
DHCP: Sending discover!
DHCP: Received packet from 192.168.1.1
DHCP: Packet type is OFFER.
DHCP: Renewal time: 2160 min.
DHCP: Rebinding time: 3780 min.
DHCP: Lease time: 4320 min.
DHCP: Host name received.
DHCP: Sending Request.
DHCP: Received packet from 192.168.1.1
DHCP: Packet type is ACK.
DHCP: Renewal time: 2160 min.
DHCP: Rebinding time: 3780 min.
DHCP: Lease time: 4320 min.
DHCP: Host name received.
DHCP: IFace 0: IP: 192.168.199.20, Mask: 255.255.0.0, GW: 192.168.1.1.
```

## 8.2.2 IP\_DHCP\_GetState()

### Description

Returns the state of the DHCP client.

### Prototype

```
int IP_DHCP_GetState( int IFIndex );
```

### Parameter

Parameter	Description
IFIndex	[IN] Zero-based index number specifying the interface which should be halted.

**Table 8.3: IP\_DHCP\_GetState() parameter list**

### Return value

0 DHCP client not used.  
 >0 DHCP client in use.

## 8.2.3 IP\_DHCP\_Halt()

### Description

Stops all DHCP activity on a network interface.

### Prototype

```
void IP_DHCP_Halt( int IFIndex );
```

### Parameter

Parameter	Description
<code>IFIndex</code>	[IN] Zero-based index number specifying the interface which should be halted.

**Table 8.4: IP\_DHCP\_Halt() parameter list**

## 8.2.4 IP\_DHCP\_SetCallback()

### Description

This function allows the caller to set a callback for an interface.

### Prototype

```
void IP_DHCP_SetCallback( int IFIndex, int (*routine)(int,int) );
```

### Parameter

Parameter	Description
IFIndex	[IN] Zero-based index number of available network interfaces.
(*routine)	[IN] Callback functions which should be called with every status change.

**Table 8.5: IP\_DHCP\_SetCallback() parameter list**

### Additional information

The callback is called with every status change. This mechanism is provided so that the caller can do some processing when the interface is up (like doing initialization or blinking LEDs, etc.). Refer to *[RFC 2331] DHCP - Dynamic Host Configuration Protocol* for detailed information about DHCP states.



# Chapter 9

## Network interface drivers

---

embOS/IP has been designed to cooperate with any kind of hardware. To use specific hardware with embOS/IP, a so-called network interface driver for that hardware is required. The network interface driver consists of basic functions for accessing the hardware and a global table that holds pointers to these functions.

## 9.1 General information

To use embOS/IP, a network interface driver matching the target hardware is required. The code size of a network interface driver depends on the hardware and is typically between 1 and 3 Kbytes. The driver handles both the MAC (media access control) unit as well as the PHY (Physical interface). We recommend using drivers written and tested by SEGGER. However, it is possible to write your own driver. This is explained in section *Writing your own driver* on page 165.

The driver interface has been designed to allow support of internal and external Ethernet controllers (EMACs). It also allows to take full advantage of hardware features such as MAC address filtering and checksum computation in hardware.

### 9.1.1 MAC address filtering

The stack passes a list of MAC addresses to the driver. The driver is responsible for making sure that all packets from all MAC addresses specified are passed to the stack. It can do so with "precise filtering" if the hardware has sufficient filters for the given number of MAC addresses. If more MAC addresses are passed to the driver than hardware filters are available, the driver can use a hash filter if available in hardware or switch to promiscuous mode.

This is a very flexible solution which allows making best use of the hardware filtering capabilities on all known Ethernet controllers. It also allows simple implementations to simply switch to promiscuous mode.

### 9.1.2 Checksum computation in hardware

When the interface is initialized, the stack queries the capabilities of the driver. If the hardware can compute IP, TCP, UDP, ICMP checksums, it can indicate this to the stack. In this case, the stack does not compute these checksums, improving throughput and reducing CPU load.

### 9.1.3 Ethernet CRC computation

Every Ethernet packet includes a 32-bit trailing CRC. In most cases, the Ethernet controller is capable of computing the CRC. The drivers take advantage of this. The CRC is computed in the driver only if the hardware does not support CRC computation.

## 9.2 Available network interface drivers

Network interface drivers are optional components to embOS/IP. The following network interface drivers are available:

Driver (Device)	Identifier
ATMEL AT91CAP9	IP_Driver_CAP9
ATMEL AT91RM9200	IP_Driver_AT91RM9200
ATMEL AT91SAM7X	IP_Driver_SAM7X
ATMEL AT91SAM9260	IP_Driver_SAM9260
ATMEL AT91SAM9263	IP_Driver_SAM9263
ATMEL AT91SAM9XE	IP_Driver_SAM9XE
DAVICOM DM9000	IP_Driver_DM9000
RENESAS H8S2472	IP_Driver_H8S2472
RENESAS SH7670	IP_Driver_SH7670
FREESCALE ColdFire MCF5223x	IP_Driver_MCF5223x
FREESCALE ColdFire MCF5329	IP_Driver_MCF5329
LUMINARY LM3S6965	IP_Driver_LM3S6965
NXP LPC17xx	IP_Driver_LPC17xx
NXP LPC2378 / LPC2478	IP_Driver_LPC24xx
NXP LPC32xx	IP_Driver_LPC32xx
SMSC LAN9115 / LAN9215	IP_Driver_LAN9115
SMSC LAN9118	IP_Driver_LAN9118
SMSC LAN91C111	IP_Driver_LAN91C111
ST STR912	IP_Driver_STR912
ST STM32F107 (Connectivity Line)	IP_Driver_STM32F107
NIOSII IFI GMACII EMAC	IP_Driver_GMACII
NIOSII MaCo-Engineering EMAC	IP_Driver_NIOSII_MaCo
NIOSII More than IP A2A bridge	IP_Driver_NIOSII_More10IP_A2A

**Table 9.1: List of default network interface driver labels**

To add a driver to embOS/IP, `IP_AddEtherInterface()` should be called with the proper identifier before the TCP/IP stack starts any transmission. Refer to `IP_AddEtherInterface()` on page 43 for detailed information.

## 9.2.1 ATMEL AT91SAM7X

The ATMEL AT91SAM7X's are flash microcontrollers with integrated Ethernet, USB and CAN interfaces, based on the 32-bit ARM7TDMI RISC processor.

### 9.2.1.1 Supported hardware

The network interface driver for the AT91SAM7X can be used with every ATMEL AT91SAM7X target board. The driver has been tested on the following eval boards:

Tested evaluation boards
ATMEL AT91SAM7X-EK
Olimex SAM7-EX256

**Table 9.2:** List of tested eval boards

### 9.2.1.2 Configuring the driver

#### Adding the driver to embOS/IP

To add the driver, use `IP_AddEtherInterface()` with the driver identifier `IP_Driver_SAM7X`. This function has to be called from `IP_X_Config()`. Refer to `IP_AddEtherInterface()` on page 43 and `IP_X_Configure()` on page 174 for more information.

#### Example

```
void IP_X_Config(void) {
    IP_AssignMemory(_aPool, sizeof(_aPool)); // Assigning memory
    IP_AddEtherInterface(&IP_Driver_SAM7X); // Add Ethernet driver
    IP_SetHWAddr("\x00\x22\x33\x44\x55\x66"); // MAC addr: Needs to be unique
                                              // for production units

    IP_DHCP_Activate(0, "TARGET", NULL, NULL);
    //
    // Run-time configure buffers.
    // The default setup will do for most cases.
    //
    IP_AddBuffers(12, 256); // Small buffers.
    IP_AddBuffers(6, 1536); // Big buffers. Size should be 1536 to
                            // allow a full ether packet to fit.

    IP_ConfTCPSpace(6 * 1024, 4 * 1024);
    IP_SetWarnFilter(0xFFFFFFFF); // 0xFFFFFFFF: Do not filter:
                                  // Output all warnings.

    IP_SetLogFilter(IP_MTYPE_INIT
                   | IP_MTYPE_LINK_CHANGE
                   | IP_MTYPE_DHCP);
}
```

### 9.2.1.3 Driver specific configuration functions

Function	Description
<code>IP_NI_SAM7X_ConfigNumRxBuffers()</code>	Sets the number of Rx buffers.

**Table 9.3:** embOS/IP SAM7X driver specific function overview

#### 9.2.1.3.1 IP\_NI\_SAM7X\_ConfigNumRxBuffers()

##### Description

Sets the number of Rx buffers of the driver. This function has to be called in the configuration phase.

##### Prototype

```
void IP_NI_SAM7X_ConfigNumRxBuffers( U16 NumRxBuffers );
```

## Parameter

Parameter	Description
<a href="#">NumRxBuffers</a>	[IN] The number of Rx buffers.

Table 9.4: IP\_NI\_SAM7X\_ConfigNumRxBuffers() parameter list

## 9.2.1.4 Required BSP functions

Function	Description
<a href="#">BSP_ETH_Init()</a>	Initializes the network interface.

Table 9.5: embOS/IP driver specific function overview

### 9.2.1.4.1 BSP\_ETH\_Init()

#### Description

This function is called from the network interface driver. It initializes the network interface. This function should be used to enable the ports which are connected to the network hardware. It is called from the driver during the initialization process.

#### Prototype

```
void BSP_ETH_Init( unsigned Unit );
```

#### Parameter

Parameter	Description
<a href="#">Unit</a>	[IN] Zero-based index of available network interfaces.

Table 9.6: BSP\_ETH\_Init() parameter list

#### Example

```
/* Excerpt from implementation for ATMEL AT91SAM7X-EK */

#define AT91C_PMC_PCER      (*(volatile unsigned*) 0xFFFFFC10)
#define AT91C_PIOB_PPUDR  (*(volatile unsigned*) 0xFFFFF660)
#define AT91C_PIOB_PER     (*(volatile unsigned*) 0xFFFFF600)
#define AT91C_PIOB_OER    (*(volatile unsigned*) 0xFFFFF610)
#define AT91C_PIOB_CODR   (*(volatile unsigned*) 0xFFFFF634)
#define AT91C_PIOB_SODR   (*(volatile unsigned*) 0xFFFFF630)
#define AT91C_PIOB_ODR    (*(volatile unsigned*) 0xFFFFF614)
#define AT91C_PIOB_PDR    (*(volatile unsigned*) 0xFFFFF604)
#define AT91C_RSTC_RMR    (*(volatile unsigned*) 0xFFFFFD08)
#define AT91C_PIOB_ASR    (*(volatile unsigned*) 0xFFFFF670)
#define AT91C_RSTC_RCR    (*(volatile unsigned*) 0xFFFFFD00)
#define AT91C_RSTC_ERSTL          (0xF << 8)
#define AT91C_RSTC_EXTRST         (0x1 << 3)
#define AT91C_RSTC_NRSTL          (1UL << 16)

void BSP_ETH_Init(unsigned Unit) {
    unsigned v;

    AT91C_PMC_PCER      = (1 << _PIOB_ID); // Enable clock for PIOB
    AT91C_PIOB_PPUDR    = 1UL << 15;      // Disable RXDV pullup,
                                           // enter PHY normal mode

    AT91C_PIOB_PPUDR    = 1UL << 16;
    //
    // Init PIO and perform a RESET of PHY since PHY
    //
    v                    = 0
                        | (1 << 0)
                        | (1 << 15)
                        | (1 << 16)
                        | (1 << 18)
```

```

;

AT91C_PIOB_PER      = v; // Entire lower 19 bits enabled
AT91C_PIOB_OER      = v;
AT91C_PIOB_CODR     = 0
                    | (1 << 7)      // 0: node mode, 1: repeater mode
                    | (1 << 15)     // 0: Normal mode, 1: test mode
                    | (1 << 16)     // 0: MII
                    | (1 << 18)     // 0: Power down
;

AT91C_PIOB_SODR     = 0
                    | (1 << 0)      // Isolate
;

//
// Perform hardware reset using RESET pin of MCU
//
AT91C_RSTC_RMR = 0xA5000000 | AT91C_RSTC_ERSTL & (1 << 8);
AT91C_RSTC_RCR = 0xA5000000 | AT91C_RSTC_EXTRST;
while ((AT91C_RSTC_RSR & AT91C_RSTC_NRSTL) == 0); // Wait until RESET timer has
                                                    // expired

//
// Switch to peripheral functions
//
v = 0x3FFFF; // Lower 18 bits are used for the peripheral
AT91C_PIOB_ODR = v; // Entire lower 18 bits disabled
AT91C_PIOB_ASR = v; // Select peripheral A use
AT91C_PIOB_PDR = v; // Disable GPIO mode, select peripheral
}

```

### 9.2.1.5 Addition information

None.

## 9.2.2 ATMEL AT91SAM9260

The ATMEL AT91SAM9260 is based on the ARM926EJ-S™ processor. Its peripheral set includes USB Full Speed Host and Device interfaces, a 10/100 Base T Ethernet MAC, Image Sensor Interface, Multimedia Card Interface (MCI), Synchronous Serial Controllers (SSC), USARTs, Master/Slave Serial Peripheral Interfaces (SPI), a three-channel 16-bit Timer Counter (TC), a Two Wire Interface (TWI) and four-channel 10-bit ADC.

### 9.2.2.1 Supported hardware

The network interface driver for the AT91SAM9260 can be used with every ATMEL AT91SAM9260 target board. The driver has been tested on the following eval boards:

Tested evaluation boards
ATMEL AT91SAM9260

Table 9.7: List of tested eval boards

### 9.2.2.2 Configuring the driver

#### Adding the driver to embOS/IP

To add the driver, use `IP_AddEtherInterface()` with the driver identifier `IP_Driver_SAM9260`. This function must be called from `IP_X_Config()`. Refer to `IP_AddEtherInterface()` on page 43 and `IP_X_Configure()` on page 174 for more information.

#### Example

```
void IP_X_Config(void) {
    IP_AssignMemory(_aPool, sizeof(_aPool)); // Assigning memory
    IP_AddEtherInterface(&IP_Driver_SAM9260); // Add Ethernet driver
    IP_SetHWAddr("\x00\x22\xC7\xff\xff\xff"); // MAC addr: Needs to be unique
                                                // for production units

    IP_DHCP_Activate(0, "TARGET", NULL, NULL);
    //
    // Run-time configure buffers.
    // The default setup will do for most cases.
    //
    IP_AddBuffers(50, 256); // Small buffers.
    IP_AddBuffers(50, 1536); // Big buffers. Size should be 1536 to
                              // allow a full ether packet to fit.

    IP_ConfTCPSpace(16 * 1024, 16 * 1024);
    IP_SetWarnFilter(0xFFFFFFFF); // 0xFFFFFFFF: Do not filter:
                                    // Output all warnings.

    IP_SetLogFilter(IP_MTYPE_INIT
                   | IP_MTYPE_LINK_CHANGE
                   | IP_MTYPE_DHCP);
}

```

### 9.2.2.3 Driver specific configuration functions

Function	Description
<a href="#">IP_NI_SAM9260_ConfigNumRxBuffers()</a>	Sets the number of Rx buffers.

Table 9.8: embOS/IP SAM9260 driver specific function overview

#### 9.2.2.3.1 IP\_NI\_SAM9260\_ConfigNumRxBuffers

##### Description

Sets the number of Rx buffers of the driver. This function has to be called in the configuration phase.

##### Prototype

```
void IP_NI_SAM9260_ConfigNumRxBuffers( U16 NumRxBuffers );
```

## Parameter

Parameter	Description
<a href="#">NumRxBuffers</a>	[IN] The number of Rx buffers.

**Table 9.9: IP\_NI\_SAM9260\_ConfigNumRxBuffers() parameter list**

## 9.2.2.4 Required BSP functions

Function	Description
<a href="#">BSP_ETH_Init()</a>	Initializes the network interface.

**Table 9.10: embOS/IP driver specific function overview**

### 9.2.2.4.1 BSP\_ETH\_Init()

#### Description

This function is called from the network interface driver. It initializes the network interface. This function should be used to enable the ports which are connected to the network hardware. It is called from the driver during the initialization process.

#### Prototype

```
void BSP_ETH_Init( unsigned Unit );
```

#### Parameter

Parameter	Description
<a href="#">Unit</a>	[IN] Zero-based index of available network interfaces.

**Table 9.11: BSP\_ETH\_Init() parameter list**

#### Example

```

/*****
 *
 *      BSP_ETH_Init()
 *
 *      Function description
 *      This function is called from the network interface driver.
 *      It initializes the network interface. This function should be used
 *      to enable the ports which are connected to the network hardware.
 *      It is called from the driver during the initialization process.
 *
 *      Note:
 *      (1) If your MAC is connected to the PHY via Media Independent
 *          Interface (MII) change the macro _USE_RMII and call
 *          IP_NI_ConfigPHYMode() from within IP_X_Config()
 *          to change the default of driver.
 *
 */
void BSP_ETH_Init(unsigned Unit) {
    unsigned PinsA;
    unsigned PinsB;

    PMC_PCER          = (1 << ID_EMAC_PORT);           // Enable clock for PIO
    EMAC_PORT_PPUDR   = (1 << EMAC_PORT_RXDV_BIT);     // Disable RXDV pullup,
                                                    // enter PHY normal mode

#ifdef _USE_RMII
    EMAC_PORT_PPUER   = (1 << EMAC_PORT_RMII_BIT);     // Enable Pullup => Switch to RMII.
#else
    EMAC_PORT_PPUDR   = (1 << EMAC_PORT_RMII_BIT);     // Disable Pullup => Switch to MII.
#endif
    //
    // Power up PHY, may not be required, if set as hardwired option on target
    //
#ifdef EMAC_PORT_PWR_PHY_BIT
    EMAC_PORT_PER     = (1 << EMAC_PORT_PWR_PHY_BIT);
    EMAC_PORT_OER     = (1 << EMAC_PORT_PWR_PHY_BIT);
    EMAC_PORT_CODR    = (1 << EMAC_PORT_PWR_PHY_BIT);
#endif
    //
    // Init PIO Pins: EMAC is connected to specific lines of PIO

```

```

//
PinsA          = (1uL << 12)
                | (1uL << 13)
                | (1uL << 14)
                | (1uL << 15)
                | (1uL << 16)
                | (1uL << 17)
                | (1uL << 18)
                | (1uL << 19)
                | (1uL << 20)
                | (1uL << 21)
                ;
PinsB          = (1uL << 10)
                | (1uL << 11)
                | (1uL << 22)
                | (1uL << 25)
                | (1uL << 26)
                | (1uL << 27)
                | (1uL << 28)
                | (1uL << 29)
                ;
EMAC_PORT_ASR = PinsA;          // Select peripheral A use
EMAC_PORT_BSR = PinsB;          // Select peripheral B use
EMAC_PORT_PDR = PinsA | PinsB; // Disable GPIO mode, select peripheral function
//
// Initialize priority of BUS MATRIX. EMAC needs highest priority for SDRAM access
//
MATRIX_SCFG3 = 0x01160030;      // Assign EMAC as default master, activate priority
arbitration, increase cycles
MATRIX_PRAS3 = 0x00320000;      // Set Priority of EMAC to 3 (highest value)
}

```

### 9.2.2.5 Addition information

None.

## 9.2.3 DAVICOM DM9000/DM9000A

The Davicom DM9000 is a fully integrated single chip Fast Ethernet MAC controller with a generic processor interface, a 10/100M PHY and SRAM.

### 9.2.3.1 Supported hardware

The network interface driver for the Davicom DM9000 can be used with every target board which complies with the following:

- Davicom DM9000 is presented
- DM 9000 is connected to the data/address bus; data bus is 16-bits wide
- INT pin connected to CPU in a way which allows generating interrupts

The driver has been tested on the following eval boards:

Tested evaluation boards
ATMEL AT91SAM9261-EK

**Table 9.12:** List of tested eval boards

### 9.2.3.2 Configuring the driver

#### Adding the driver to embOS/IP

To add the driver, use `IP_AddEtherInterface()` with the driver identifier `IP_Driver_DM9000`. This function must be called from within `IP_X_Config()`. Refer to `IP_AddEtherInterface()` on page 43 and `IP_X_Configure()` on page 174 for more information.

#### Example

```
void IP_X_Config(void) {
    IP_AssignMemory(_aPool, sizeof(_aPool));    // Assigning memory
    IP_AddEtherInterface(&IP_Driver_DM9000);    // Add Ethernet driver
    IP_NI_DM9000_ConfigAddr(0, (void*) (0x30000000), (void*) (0x30000000 + 0x04));
    IP_NI_ConfigPoll(0);                        // No ISR routine
    IP_SetHWAddr("\x00\x22\x33\x44\x55\x66");    // MAC addr: Needs to be unique
    IP_DHCP_Activate(0, "TARGET", NULL, NULL);
    //
    // Run-time configure buffers. The default setup will do for most cases.
    //
    IP_AddBuffers(12, 256);                      // Small buffers.
    IP_AddBuffers(12, 1536);                      // Big buffers. Size should be 1536 to
                                                // allow a full ether packet to fit.

    IP_ConfTCPSpace(6 * 1024, 4 * 1024);
    IP_SetWarnFilter(0xFFFFFFFF);                // 0xFFFFFFFF: Do not filter:
                                                // Output all warnings.

    IP_SetLogFilter(IP_MTYPE_INIT
                    | IP_MTYPE_LINK_CHANGE
                    | IP_MTYPE_DHCP );
}
```

### 9.2.3.3 Driver-specific configuration functions

Function	Description
<code>IP_NI_DM9000_ConfigAddr()</code>	Sets the base address for commands and data register.
<code>IP_NI_DM9000_ISR_Handler()</code>	Interrupt service routine for the network interface.

**Table 9.13: embOS/IP DM9000 driver-specific function overview**

#### 9.2.3.3.1 IP\_NI\_DM9000\_ConfigAddr()

##### Description

Sets the base address (for command) and data address.

##### Prototype

```
void IP_NI_DM9000_ConfigAddr( unsigned Unit,
                             void * pBase,
                             void * pValue );
```

##### Parameter

Parameter	Description
<code>Unit</code>	[IN] Zero-based index of available network interfaces.
<code>pBase</code>	[IN] Pointer to the control register of the MAC.
<code>pValue</code>	[IN] Pointer to the data register of the MAC.

**Table 9.14: IP\_NI\_DM9000\_ConfigAddr() parameter list**

##### Additional information

This function must be called from within `IP_X_Config`. Refer to `IP_X_Configure()` on page 174 for detailed information.

#### 9.2.3.3.2 IP\_NI\_DM9000\_ISR\_Handler()

##### Description

This is the interrupt service routine for the network interface (EMAC). It handles all interrupts (Rx, Tx, Error).

##### Prototype

```
void IP_NI_DM9000_ISR_Handler( unsigned Unit );
```

##### Parameter

Parameter	Description
<code>Unit</code>	[IN] Zero-based index of available network interfaces.

**Table 9.15: IP\_NI\_DM9000\_ISR\_Handler() parameter list**

### 9.2.3.4 Required BSP functions

Function	Description
<a href="#">BSP_ETH_Init()</a>	Initializes the network interface.

**Table 9.16: embOS/IP driver specific function overview**

#### 9.2.3.4.1 BSP\_ETH\_Init()

##### Description

This function is called from the network interface driver. It initializes the network interface. This function should be used to enable the ports which are connected to the network hardware. It is called from the driver during the initialization process.

##### Prototype

```
void BSP_ETH_Init( unsigned Unit );
```

## 9.2.4 FREESCALE ColdFire MCF5329

### 9.2.4.1 Supported hardware

The network interface driver for the ColdFire MCF5329 MCU can be used with every target board. The driver has been tested on the following eval boards:

Tested evaluation boards
LOGICPD ZOOM COLDFIRE SDK with MCF5329 Fire Engine

Table 9.17: List of tested eval boards

### 9.2.4.2 Configuring the driver

#### Adding the driver to embOS/IP

To add the driver, use `IP_AddEtherInterface()` with the driver identifier `IP_Driver_MCF5329`. This function must be called from `IP_X_Config()`. Refer to `IP_AddEtherInterface()` on page 43 and `IP_X_Configure()` on page 174 for more information.

#### Example

```

/* Sample implementation taken from the configuration for the ColdFire MCF5329 */

#define ALLOC_SIZE                0xA000           // Size of memory dedicated
                                                // to the stack in bytes
U32 _aPool[ALLOC_SIZE / 4];           // This is the memory area used
                                                // by the stack.

/*****
 *
 *      IP_X_Config
 */
void IP_X_Config(void) {
    IP_AssignMemory(_aPool, sizeof(_aPool));    // Assigning memory
    IP_AddEtherInterface(&IP_Driver_MCF5329);  // Add ethernet driver
    IP_SetHWAddr((const unsigned char *)"\x00\x22\xC7\xFF\xFF\xFF");
    //
    // Use DHCP client or define IP address, subnet mask,
    // gateway address and DNS server according to the
    // requirements of your application.
    //
    IP_DHCP_Activate(0, "TARGET", NULL, NULL);
    // IP_SetAddrMask(0xC0A805E6, 0xFFFF0000);    // Assign IP addr. and subnet mask
    // IP_SetGWAddr(0, 0xC0A80201);              // Set gateway address
    // IP_DNS_SetServer(0xCC98B84C);             // Set DNS server address,
                                                // for example 204.152.184.76

    //
    // Run-time configure buffers.
    // The default setup will do for most cases.
    //
    IP_AddBuffers(12, 256);                  // Small buffers.
    IP_AddBuffers(10, 1536);                 // Big buffers.
    IP_ConfTCPSpace(4 * 1024, 4 * 1024);     // Define the TCP Tx and Rx window size
    //
    // Define log and warn filter
    //
    IP_SetWarnFilter(0xFFFFFFFF);
    IP_SetLogFilter(IP_MTYPE_INIT
                    | IP_MTYPE_LINK_CHANGE
                    | IP_MTYPE_DHCP
                    );
}

```

### **9.2.4.3 Driver-specific configuration functions**

None.

### **9.2.4.4 Required BSP functions**

None.

### **9.2.4.5 Addition information**

None.

## Parameter

Parameter	Description
Unit	[IN] Zero-based index of available network interfaces.

**Table 9.18: BSP\_ETH\_Init() parameter list**

### Example

```

/* Excerpt from implementation for the ATMEL AT91SAM9261-EK */

#define _PIOC_ID      (4)
#define _PMC_PCER    (*(volatile unsigned int*) 0xFFFFF810)
#define _PIOC_PER    (*(volatile unsigned int*) 0xFFFFFC00)
#define _PIOC_ODR    (*(volatile unsigned int*) 0xFFFFFC14)
#define _PIOC_OER    (*(volatile unsigned int*) 0xFFFFFC10)
#define _PIOC_SODR   (*(volatile unsigned int*) 0xFFFFFC30)
#define _PIOC_CODR   (*(volatile unsigned int*) 0xFFFFFC34)

/*****
 *
 *      BSP_ETH_Init()
 */
void BSP_ETH_Init(unsigned Unit) {
    int i;
    _PMC_PCER  |= (1 << _PIOC_ID);           // Enable peripheral clock
    _PIOC_PER   = (1 << 10) | (1 << 11);     // Enable Ports for RESET and Interrupt
    _PIOC_OER   = (1 << 10);                 // Switch RESET to output mode
    _PIOC_ODR   = (1 << 11);                 // Switch Interrupt to output mode
    //
    // Activate & deactivate RESET of Ethernet controller.
    // We do this in a loop to allow sufficient time for Controller to get out of RESET
    //
    for (i = 0; i < 1000; i++) {
        _PIOC_SODR = (1 << 10);              // Activate RESET
    }
    for (i = 0; i < 1000; i++) {
        _PIOC_CODR = (1 << 10);              // Deactivate RESET
    }
}

```

### 9.2.4.6 Addition information

None.

## 9.2.5 NXP LPC23xx / 24xx

The NXP LPC23xx and LPC24xx MCU families are flash microcontrollers with integrated Ethernet, USB and CAN interfaces, based on the 32-bit ARM7TDMI-S RISC processor.

### 9.2.5.1 Supported hardware

The network interface driver for the NXP LPC23xx and LPC24xx MCUs can be used with every NXP LPC23xx/LPC24xx target board. The driver has been tested on the following eval boards:

Tested evaluation boards
KEIL MCB2300
IAR LPC2468 V1.0
EmbeddedArtists LPC2468

**Table 9.19:** List of tested eval boards

### 9.2.5.2 Configuring the driver

#### Adding the driver to embOS/IP

To add the driver, use `IP_AddEtherInterface()` with the driver identifier `IP_Driver_LPC24xx`. This function must be called from `IP_X_Config()`. Refer to `IP_AddEtherInterface()` on page 43 and `IP_X_Configure()` on page 174 for more information.

#### Example

```

/* Sample implementation taken from the configuration for the NXP LPC2468 */

/*****
 *
 *      IP_X_Config
 *
 * Function description
 * This function is called by the IP stack during IP_Init().
 */
void IP_X_Config(void) {
    IP_AssignMemory(_aPool, sizeof(_aPool));    // Assigning memory
    IP_AddEtherInterface(&IP_Driver_LPC24xx);  // Add ethernet driver
    IP_SetHWAddr("\x00\x22\x33\x44\x55\x66");  // MAC addr: Needs to be unique
                                              // for production units

    IP_DHCP_Activate(0, "TARGET", NULL, NULL);
    //
    // Run-time configure buffers.
    // The default setup will do for most cases.
    //
    IP_AddBuffers(6, 256);                      // Small buffers.
    IP_AddBuffers(8, 1536);                     // Big buffers. Size should be 1536
                                              // to allow a full ether packet to fit.

    IP_ConfTCPSpace(6 * 1024, 6 * 1024);
    IP_SetWarnFilter(0xFFFFFFFF);              // Do not filter: Output all warnings.
    IP_SetLogFilter(IP_MTYPE_INIT
                    | IP_MTYPE_LINK_CHANGE
                    );
}

```

### 9.2.5.3 Driver-specific configuration functions

None.

## 9.2.5.4 Required BSP functions

Function	Description
<code>BSP_ETH_Init()</code>	Initializes the network interface.

Table 9.20: embOS/IP driver specific function overview

### 9.2.5.4.1 BSP\_ETH\_Init()

#### Description

This function is called from the network interface driver. It initializes the network interface. This function should be used to enable the ports which are connected to the network hardware. It is called from the driver during the initialization process.

#### Prototype

```
void BSP_ETH_Init( unsigned Unit );
```

#### Parameter

Parameter	Description
<code>Unit</code>	[IN] Zero-based index of available network interfaces.

Table 9.21: BSP\_ETH\_Init() parameter list

#### Example

```
/* Sample implementation for NXP LPC2468 */

#define PINSEL2      *(volatile unsigned long *) (0xE002C008)
#define PINSEL3      *(volatile unsigned long *) (0xE002C00C)

/*****
 *
 *      ETH_Init
 */
void BSP_ETH_Init(unsigned Unit) {
    /*-----
     * write to PINSEL2/3 to select the PHY functions on P1[17:0]
     *-----*/
    /* P1.6, ENET-TX_CLK, has to be set for EMAC to address a BUG in
     the rev"xx-X" or "xx-Y" silicon(see errata). On the new rev.(xxAY, released
     on 06/22/2007), P1.6 should NOT be set. */
    if (MAC_MODULEID == 0x39022000) { // Older chip ?
        PINSEL2 = 0x50151105; /* Selects P1[0,1,4,6,8,9,10,14,15] */
    } else {
        PINSEL2 = 0x50150105; /* Selects P1[0,1,4,8,9,10,14,15] */
    }
    PINSEL3 = (PINSEL3 & ~0x0000000f) | 0x5;
}
```

## 9.2.5.5 Addition information

None.

## 9.2.6 ST STR912

The ST STR912 is based on the ARM966E-S™ processor. It is a flash microcontroller with integrated Ethernet, USB and CAN interfaces, AC Motor Control, 4 Timers, ADC, RTC, and DMA.

### 9.2.6.1 Supported hardware

The network interface driver for the STR912 can be used with every target ST STR912 target board. The driver has been tested on the following eval boards:

Tested evaluation boards
IAR STR912FA development board

**Table 9.22: List of tested eval boards**

### 9.2.6.2 Configuring the driver

#### Adding the driver to embOS/IP

To add the driver, use `IP_AddEtherInterface()` with the driver identifier `IP_Driver_STR912`. This function must be called from `IP_X_Config()`. Refer to `IP_AddEtherInterface()` on page 43 and `IP_X_Configure()` on page 174 for more information.

#### Example

```
/* Sample implementation taken from the configuration for the ST STR912 */

void IP_X_Config(void) {
    IP_AssignMemory(_aPool, sizeof(_aPool)); // Assigning memory
    IP_AddEtherInterface(&IP_Driver_STR912); // Add Ethernet driver
    IP_SetHWAddr("\x00\x22\x33\x44\x55\x66"); // MAC addr: Needs to be unique
                                           // for production units

    IP_DHCP_Activate(0, "TARGET", NULL, NULL);
    //
    // Run-time configure buffers.
    // The default setup will do for most cases.
    //
    IP_AddBuffers(20, 256); // Small buffers.
    IP_AddBuffers(12, 1536); // Big buffers. Size should be 1536
                             // to allow a full ether packet to fit.

    IP_ConfTCPSpace(8 * 1024, 8 * 1024);
    IP_SetWarnFilter(0xFFFFFFFF); // 0xFFFFFFFF: Do not filter:
    IP_SetLogFilter(IP_MTYPE_INIT // Output all warnings.
                   | IP_MTYPE_LINK_CHANGE
                   | IP_MTYPE_DHCP);
}
```

### 9.2.6.3 Driver-specific configuration functions

None.

### 9.2.6.4 Required BSP functions

None.

### 9.2.6.5 Addition information

None.

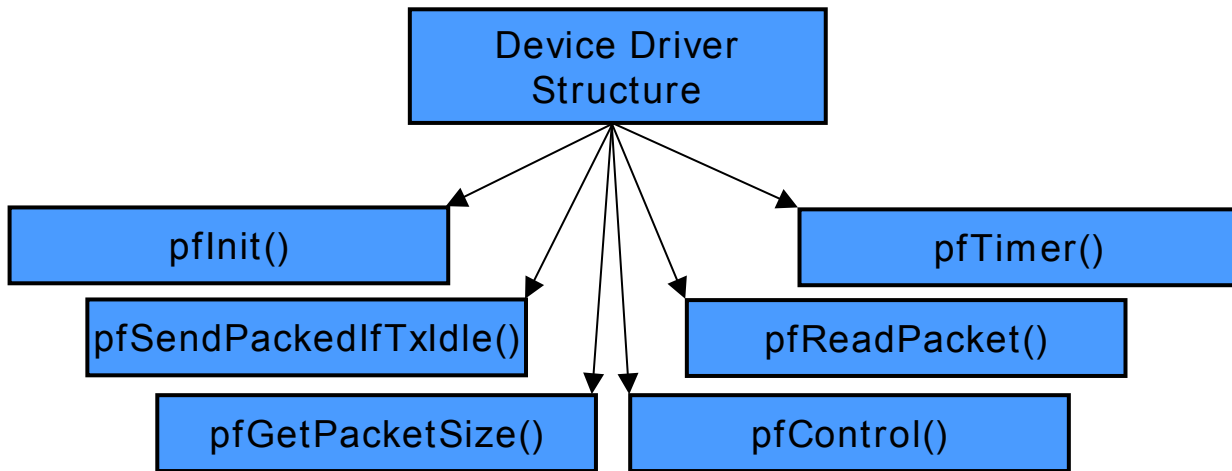
## 9.3 Writing your own driver

If you are going to use embOS/IP with your own hardware, you may have to write your own network interface driver. This section describes which functions are required and how to integrate your own network interface driver into embOS/IP.

**Note:** We strongly recommend contacting SEGGER if you need to have a driver for a particular piece of hardware which is not yet supported. Writing a driver is a difficult task which requires a thorough understanding of Ethernet, MAC, and PHY.

### 9.3.1 Network interface driver structure

embOS/IP uses a simple structure with function pointers to call the appropriate driver function for a device. Use the supplied template `IP_NI_Template.c` for the implementation.



#### Data structure

```

typedef struct IP_HW_DRIVER {
    int (*pfInit) ( unsigned Unit );
    int (*pfSendPacket) ( unsigned Unit );
    int (*pfGetPacketSize) ( unsigned Unit );
    int (*pfReadPacket) ( unsigned Unit, U8 * pDest, unsigned NumBytes );
    void (*pfTimer) ( unsigned Unit );
    int (*pfControl) ( unsigned Unit, int Cmd, void * p );
} IP_HW_DRIVER;
  
```

#### Elements of IP\_HW\_DRIVER

Element	Meaning
<code>pfInit</code>	Pointer to the initialization function.
<code>pfSendPacket</code>	Pointer to the send packet function.
<code>pfGetPacketSize</code>	Pointer to the get packet size function.
<code>pfReadPacket</code>	Pointer to the read packet function.
<code>pfTimer</code>	Optional: Pointer to the timer function. The routine is called from the stack periodically.
<code>pfControl</code>	Pointer to the control function.

**Table 9.23: IP\_HW\_DRIVER - List of structure member variables**

#### Example

```

/* Sample implementation taken from the driver for the ATMEL AT91SAM7X */
/*****
 *
 * Driver API Table
 *
 *****/
const IP_HW_DRIVER IP_Driver_SAM7X = {
    _Init,
    _SendPacketIfTxIdle,
    _GetPacketSize,
    _ReadPacket,
    _Timer,
    _Control
};
  
```

## 9.3.2 Device driver functions

This section provides descriptions of the network interface driver functions required by embOS/IP. Note that the names used for these functions are not really relevant for embOS/IP because the stack accesses them through a structure of function pointers.

Function	Description
<code>pfControl()</code>	This function is used to implement additional driver specific control functions. It can be empty.
<code>pfInit()</code>	General initialization function of the driver.
<code>pfGetPacketSize()</code>	Reads buffer descriptors to find out if a packet has been received.
<code>pfReadPacket()</code>	Reads the first packet in the buffer.
<code>pfSendPacketIfTxIdle()</code>	Send the next packet in the send queue if transmitter is idle.
<code>pfTimer()</code>	Timer function called by the networking task, <code>IP_Task()</code> , once per second.

**Table 9.24: embOS/IP network interface driver functions**

### 9.3.3 Driver template

The driver template `IP_NI_Template.c` is supplied in the folder `Sample\Driver\Template\`.

#### Example

```

/*****
 *          SEGGER MICROCONTROLLER SYSTEME GmbH
 *          Solutions for real time microcontroller applications
 *****/
 *
 *          (C) 2007 - 2008  SEGGER Microcontroller Systeme GmbH
 *
 *          www.segger.com    Support: support@segger.com
 *****/
 *
 *          TCP/IP stack for embedded applications
 *
 *****/
-----
File      : IP_NI_Template.c
Purpose   : Network interface driver template
-----
END-OF-HEADER -----
*/

#include "IP_Int.h"

/*****
 *
 *          _SetFilter
 *
 *          Function description
 *          Sets the MAC filter(s)
 *          The stack tells the driver which addresses should go thru the filter.
 *          The number of addresses can generally be unlimited.
 *          In most cases, only one address is set.
 *          However, if the NI is in multiple nets at the same time or if multicast is used,
 *          multiple addresses can be set.
 *
 *          Notes
 *          (1) Procedure
 *          In general, precise filtering is used as far as supported by the hardware.
 *          If the more addresses need to be filtered than precise address filters are
 *          available, then the hash filter is used.
 *          Alternatively, the MAC can be switched to promiscuous mode for simple
 *          implementations.
 */
static int _SetFilter(IP_NI_CMD_SET_FILTER_DATA * pFilter) {
    U32 v;
    U32 w;
    unsigned i;
    unsigned NumAddr;
    const U8 * pAddrData;

    NumAddr = pFilter->NumAddr;
    for (i = 0; i < NumAddr; i++) {
        pAddrData = (&pFilter->pHWAddr + i);
    }
    return 0;    // O.K.
}

/*****
 *
 *          _SendPacket
 *
 *          Function description
 *          Send the next packet in the send queue.
 *          Function is called from 2 places:
 *          - from a task via pfSendPacketIfTxIdle() in Driver structure
 *          - from ISR when Tx is completed (TxInterrupt)
 */
static int _SendPacket(void) {
    U32 v;
    void * pPacket;
    unsigned NumBytes;

```

```

IP_GetNextOutPacket(&pPacket, &NumBytes);           // Get information about next
                                                    // packet in the Queue. 0
                                                    // means no packet in queue

if (NumBytes == 0) {
    return 0;
}
IP_LOG((IP_MTYPE_DRIVER, "DRIVER: Sending packet: %d bytes", NumBytes));

//
// Start send
//

return 0;
}

/*****
*
*     _ISR_Handler
*
* Function description
* This is the interrupt service routine for the NI (EMAC).
* It handles all interrupts (Rx, Tx, Error).
*/
static void _ISR_Handler(void) {
}

/*****
*
*     _Init
*
* Function description
* General init function of the driver.
* Called by the stack in the init phase before any other driver function.
*/
static int _Init(unsigned Unit) {
    int r;

    r = _PHY_Init(Unit);                          // Configure the PHY
    if (r) {
        return 1;
    }
    //
    // TBD
    //
    return 0;
}

/*****
*
*     _SendPacketIfTxIdle
*
* Function description
* Send the next packet in the send queue if transmitter is idle.
* If transmitter is busy, nothing is done since the next packet is sent
* automatically with Tx-interrupt.
* Function is called from a task via function pointer in in driver structure.
*/
static int _SendPacketIfTxIdle(unsigned Unit) {
    //
    // TBD
    //
    return 0;
}

/*****
*
*     _GetPacketSize()
*
* Function description
* Reads buffer descriptors in order to find out if a packet has been received.
* Different error conditions are checked and handled.
* Function is called from a task via function pointer in driver structure.
*
* Return value
* Number of buffers used for the next packet.
*/

```

```

*    0 if no complete packet is available.
*/
static int _GetPacketSize(unsigned Unit) {
    //
    // TBD
    //
    return 0;
}

/*****
*
*    _ReadPacket
*
* Function description
* Reads the first packet into the buffer.
* NumBytes must be the correct number of bytes as retrieved by _GetPacketSize();
* Function is called from a task via function pointer in driver structure.
*/
static int _ReadPacket(unsigned Unit, U8 *pDest, unsigned NumBytes) {
    //
    // TBD
    //
    return 0;
}

/*****
*
*    _Timer
*
* Function description
* Timer function called by the Net task once per second.
* Function is called from a task via function pointer in driver structure.
*/
static void _Timer(unsigned Unit) {
    // _UpdateLinkState();
}

/*****
*
*    _Control
*
* Function description
* Control function for various purposes.
* Function is called from a task via function pointer in driver structure.
*
* Return value
* -1: Command is not supported
* !=-1: Command supported. Typically 0 means success,
* but can also be a return value.
*/
static int _Control(unsigned Unit, int Cmd, void * p) {
    switch (Cmd) {
        case IP_NI_CMD_SET_FILTER:
            return _SetFilter((IP_NI_CMD_SET_FILTER_DATA*)p);
        case IP_NI_CMD_SET_BPRESSURE:
            //
            // TBD: Enable back pressure (if supported) and change return value to 0
            //
            break;
        case IP_NI_CMD_CLR_BPRESSURE:
            //
            // TBD: Disable back pressure (if supported) and change return value to 0
            //
            break;
        case IP_NI_CMD_GET_MAC_ADDR:
            break;
        case IP_NI_CMD_GET_CAPS:
            //
            // TBD: Retrieves the capabilities, which are a logical-or combination of
            // the IP_NI_CAPS (if any)
            //
            // {
            // int v;
            //
            // v = 0
            // | IP_NI_CAPS_WRITE_IP_CHKSUM // Driver capable of inserting the
            // |                               // IP-checksum into an outgoing packet?
    }
}

```

```

// | IP_NI_CAPS_WRITE_UDP_CHKSUM // Driver capable of inserting the
// | IP_NI_CAPS_WRITE_TCP_CHKSUM // UDP-checksum into an outgoing packet?
// | IP_NI_CAPS_WRITE_ICMP_CHKSUM // Driver capable of inserting the
// | IP_NI_CAPS_CHECK_IP_CHKSUM // TCP-checksum into an outgoing packet?
// | IP_NI_CAPS_CHECK_UDP_CHKSUM // Driver capable of inserting the
// | IP_NI_CAPS_CHECK_TCP_CHKSUM // ICMP-checksum into an outgoing packet?
// | IP_NI_CAPS_CHECK_ICMP_CHKSUM // Driver capable of computing and
// comparing the IP-checksum of
// incoming packets?
// Driver capable of computing and
// comparing the UDP-checksum of an
// incoming packet?
// Driver capable of computing
// and comparing the TCP-checksum of
// an incoming packet?
// Driver capable of computing
// and comparing the ICMP-checksum of
// an incoming packet?

// }
// return v;
break;
case IP_NI_CMD_POLL:
//
// Poll MAC (typically once per ms) in cases where MAC does not
// trigger an interrupt.
//
break;
default:
;
}
return -1;
}

/*****
*
* Public API struct
*
* This is the only public part of the driver.
* All driver functions are called indirectly via this structure
*
*/
const IP_HW_DRIVER IP_Driver_Template = {
    _Init,
    _SendPacketIfTxIdle,
    _GetPacketSize,
    _ReadPacket,
    _Timer,
    _Control
};

/***** End of file *****/

```



# Chapter 10

## Configuring embOS/IP

---

embOS/IP can be used without changing any of the compile-time flags. All compile-time configuration flags are preconfigured with valid values, which match the requirements of most applications. Network interface drivers can be added at runtime.

The default configuration of embOS/IP can be changed via compile-time flags which can be added to `IP_Conf.h`. `IP_Conf.h` is the main configuration file for the TCP/IP stack.

## 10.1 Runtime configuration

Every driver folder includes a configuration file with implementations of runtime configuration functions explained in this chapter. These functions can be customized.

### 10.1.1 IP\_X\_Configure()

#### Description

Helper function to prepare and configure the TCP/IP stack.

#### Prototype

```
void IP_X_Config (void);
```

#### Additional information

This function is called by the startup code of the TCP/IP stack from `IP_Init()`. Refer to `IP_Init()` on page 63 for more information.

#### Example

```

/*****
*
*   IP_X_Config
*
*   Function description
*   This function is called by the IP stack during IP_Init().
*
*   Typical memory/buffer configurations:
*   Microcontroller system, size optimized
*   #define ALLOC_SIZE 0x3000           // 12 KBytes RAM
*   mtu = 576;                         // 576 is minimum acc.
*                                       // to RFC, 1500 is max. for Ethernet
*   IP_SetMTU(0, mtu);                 // Maximum Transmission Unit is 1500
*                                       // for ethernet by default
*   IP_AddBuffers(8, 256);             // Small buffers.
*   IP_AddBuffers(4, mtu + 16);        // Big buffers. Size should be mtu
*                                       // + 16 byte for ethernet header
*                                       // (2 bytes type, 2*6 bytes MAC,
*                                       // 2 bytes padding)
*   IP_ConfTCPSpace(1 * 1024, 1 * 1024); // Define TCP Tx and Rx window size
*
*   Microcontroller system, speed optimized or multiple connections
*   #define ALLOC_SIZE 0x6000           // 24 KBytes RAM
*   mtu = 1500;                        // 576 is minimum acc. to RFC,
*                                       // 500 is max. for Ethernet
*   IP_SetMTU(0, mtu);                 // Maximum Transmission Unit is 1500
*                                       // for ethernet by default
*   IP_AddBuffers(12, 256);            // Small buffers.
*   IP_AddBuffers(6, mtu + 16);        // Big buffers. Size should be mtu
*                                       // + 16 byte for ethernet header
*                                       // (2 bytes type, 2*6 bytes MAC,
*                                       // 2 bytes padding)
*   IP_ConfTCPSpace(4 * 1024, 4 * 1024); // Define TCP Tx and Rx window size
*                                       // System with lots of RAM
*   #define ALLOC_SIZE 0x20000         // 128 KBytes RAM
*   mtu = 1500;                        // 576 is minimum acc. to RFC,
*                                       // 1500 is max. for Ethernet
*   IP_SetMTU(0, mtu);                 // Maximum Transmission Unit is 1500
*                                       // for ethernet by default
*   IP_AddBuffers(50, 256);            // Small buffers.
*   IP_AddBuffers(50, mtu + 16);       // Big buffers. Size should be mtu
*                                       // + 16 byte for ethernet header
*                                       // (2 bytes type, 2*6 bytes MAC,
*                                       // 2 bytes padding)
*   IP_ConfTCPSpace(8 * 1024, 8 * 1024); // Define TCP Tx and Rx window size
*/
void IP_X_Config(void) {
    IP_AssignMemory(_aPool, sizeof(_aPool)); // Assigning memory
    IP_AddEtherInterface(&IP_Driver_STR912); // Add ethernet driver
    IP_SetHWAddr("\x00\x22\x33\x44\x55\x66"); // MAC addr: Needs to be unique
                                              // for production units

    //
    // Use DHCP client or define IP address, subnet mask,
    // gateway address and DNS server according to the
    // requirements of your application.

```

```

//
IP_DHCP_Activate(0, "TARGET", NULL, NULL);
// IP_SetAddrMask(0xC0A805E6, 0xFFFF0000); // Assign IP addr. and subnet mask
// IP_SetGWAddr(0, 0xC0A80201); // Set gateway address
// IP_DNS_SetServer(0xCC98B84C); // Set DNS server address,
// for example 204.152.184.76

//
// Run-time configure buffers.
// The default setup will do for most cases.
//
IP_AddBuffers(20, 256); // Small buffers.
IP_AddBuffers(8, 1536); // Big buffers. Size should be 1536 to
// allow a full ether packet to fit.

IP_ConfTCPSpace(6 * 1024, 4 * 1024); // Define the TCP Tx and Rx window size
//
// Define log and warn filter
// Note: The terminal I/O emulation affects the timing
// of your communication, since the debugger stops the target
// for every terminal I/O output unless you use DCC!
//
IP_SetWarnFilter(0xFFFFFFFF); // 0xFFFFFFFF: Output all warnings.
IP_SetLogFilter(IP_MTYPE_INIT // Output all messages from init
                | IP_MTYPE_LINK_CHANGE // Output a msg if link status changes
                | IP_MTYPE_DHCP // Output general DHCP status messages
);
}

```

## 10.1.2 Driver handling

IP\_X\_Config() is called at initialization of the TCP/IP stack. It is called by the IP stack during IP\_Init(). IP\_X\_Config() should help to bundle the process of adding and configuring the driver.

## 10.1.3 Memory and buffer assignment

The total memory requirements of the TCP/IP stack can basically be computed as the sum of the following components:

Description	ROM
IP-Stack core	app. 200 bytes
Sockets	n * app. 200 bytes
UDP connection	n * app. 100 bytes
TCP/ connection	n * app. 200 bytes + RAM for TCP Window

### 10.1.3.1 RAM for TCP window

The data for the TCP window is typically stored in large buffers. The number of large buffers required is typically:

RxWindowSize / BigBufferSize

This amount of buffers (and RAM for these buffers) is needed for every simultaneously active TCP connection, where "active" means sending & receiving data.

### 10.1.3.2 Required buffers

Most of the RAM used by the stack is used for packet buffers. Packet buffers are used to hold incoming and outgoing packets and data in receive and transmit windows of TCP connections.

### Example configuration - Extremely small (4 Kbytes)

```
#define ALLOC_SIZE 0x1000 // 6 Kbytes RAM
mtu = 576; // 576 is minimum acc.
// to RFC, 1500 is max. for Ethernet
IP_SetMTU(0, mtu); // Maximum Transmission Unit is 1500
// for ethernet by default
IP_AddBuffers(4, 256); // Small buffers.
IP_AddBuffers(2, mtu + 16); // Big buffers. Size should be mtu
// + 16 byte for ethernet header
// (2 bytes type, 2*6 bytes MAC,
// 2 bytes padding)
IP_ConfTCPSpace(1 * (mtu-40), 1 * (mtu-40)); // Define TCP Tx and Rx window size
```

### Example configuration - Small (12 Kbytes)

```
#define ALLOC_SIZE 0x3000 // 12 Kbytes RAM
mtu = 576; // 576 is minimum acc.
// to RFC, 1500 is max. for Ethernet
IP_SetMTU(0, mtu); // Maximum Transmission Unit is 1500
// for ethernet by default
IP_AddBuffers(8, 256); // Small buffers.
IP_AddBuffers(4, mtu + 16); // Big buffers. Size should be mtu
// + 16 byte for ethernet header
// (2 bytes type, 2*6 bytes MAC,
// 2 bytes padding)
IP_ConfTCPSpace(2 * (mtu-40), 2 * (mtu-40)); // Define TCP Tx and Rx window size
```

### Example configuration - Normal (24 Kbytes)

```
#define ALLOC_SIZE 0x6000 // 24 Kbytes RAM
mtu = 1500; // 576 is minimum acc. to RFC,
// 500 is max. for Ethernet
IP_SetMTU(0, mtu); // Maximum Transmission Unit is 1500
// for ethernet by default
IP_AddBuffers(12, 256); // Small buffers.
IP_AddBuffers(6, mtu + 16); // Big buffers. Size should be mtu
// + 16 byte for ethernet header
// (2 bytes type, 2*6 bytes MAC,
// 2 bytes padding)
IP_ConfTCPSpace(3 * (mtu-40), 3 * (mtu-40)); // Define TCP Tx and Rx window size
// System with lots of RAM
```

### Example configuration - Large (128KB byte)

```
#define ALLOC_SIZE 0x20000 // 128 Kbytes RAM
mtu = 1500; // 576 is minimum acc. to RFC,
// 1500 is max. for Ethernet
IP_SetMTU(0, mtu); // Maximum Transmission Unit is 1500
// for ethernet by default
IP_AddBuffers(50, 256); // Small buffers.
IP_AddBuffers(50, mtu + 16); // Big buffers. Size should be mtu
// + 16 byte for ethernet header
// (2 bytes type, 2*6 bytes MAC,
// 2 bytes padding)
IP_ConfTCPSpace(6 * (mtu-40), 6 * (mtu-40)); // Define TCP Tx and Rx window size
```

## 10.2 Compile-time configuration

The following types of configuration macros exist:

### Binary switches "B"

Switches can have a value of either 0 or 1, for deactivated and activated respectively. Actually, anything other than 0 works, but 1 makes it easier to read a configuration file. These switches can enable or disable a certain functionality or behavior. Switches are the simplest form of configuration macros.

### Numerical values "N"

Numerical values are used somewhere in the code in place of a numerical constant. A typical example is the configuration of the sector size of a storage medium.

### Function replacements "F"

Macros can basically be treated like regular functions although certain limitations apply, as a macro is still put into the code as simple text replacement. Function replacements are mainly used to add specific functionality to a module which is highly hardware-dependent. This type of macro is always declared using brackets (and optional parameters).

### 10.2.1 Compile-time configuration switches

Type	Symbolic name	Default	Description
System configuration macros			
N	<code>IP_IS_BIGENDIAN</code>	--	Macro to define if a big endian target is used.
Debug macros			
N	<code>IP_DEBUG</code>	0	Macro to define the debug level of the embOS/IP build. Refer to <i>Debug level</i> on page 178 for a description of the different debug level.
Optimization macros			
F	<code>IP_CKSUM</code>	IP_cksum (C-routine in IP stack)	Macro to define an optimized checksum routine to speed up the stack. An optimized checksum routine is typically implemented in assembly language. Optimized versions for the GNU, IAR and ADS compilers are supplied.
F	<code>IP_MEMCPY</code>	memcpy (C-routine in standard C-library)	Macro to define an optimized memcpy routine to speed up the stack. An optimized memcpy routine is typically implemented in assembly language. Optimized version for the IAR compiler is supplied.
F	<code>IP_MEMSET</code>	memset (C-routine in standard C-library)	Macro to define an optimized memset routine to speed up the stack. An optimized memset routine is typically implemented in assembly language.

Type	Symbolic name	Default	Description
F	<a href="#">IP_MEMMOVE</a>	memmove (C-routine in standard C-library)	Macro to define an optimized memmove routine to speed up the stack. An optimized memmove routine is typically implemented in assembly language.
F	<a href="#">IP_MEMCMP</a>	memcmp (C-routine in standard C-library)	Macro to define an optimized memcmp routine to speed up the stack. An optimized memcmp routine is typically implemented in assembly language.
Other macros			
B	<a href="#">IP_TCP_ACCEPT_CHECKSUM_FFFF</a>	0	Configured the stack to accept 0xFFFF as TCP checksum. Some wrong TCP implementations generate the invalid TCP checksum 0xFFFF. Normally, embOS/IP does not accept packets with 0xFFFF as TCP checksum. Note: This is not compliant with RFC1071 and RFC1624.

## 10.2.2 Debug level

embOS/IP can be configured to display debug information at higher debug levels to locate a problem (Error) or potential problem. To display information, embOS/IP uses the logging routines (see chapter *Debugging* on page 281). These routines can be blank, they are not required for the functionality of embOS/IP. In a target system, they are typically not required in a release (production) build, since a production build typically uses a lower debug level.

If (`IP_DEBUG == 0`): used for release builds. Includes no debug options.

If (`IP_DEBUG == 1`): `IP_PANIC()` is mapped to `IP_Panic()`.

If (`IP_DEBUG >= 2`): `IP_PANIC()` is mapped to `IP_Panic()` and logging support is activated.

# Chapter 11

## Web server (Add-on)

---

The embOS/IP web server is an optional extension to embOS/IP. The web server can be used with embOS/IP or with a different TCP/IP stack. All functions that are required to add a web server task to your application are described in this chapter.

## 11.1 embOS/IP web server

The embOS/IP web server is an optional extension which adds the HTTP protocol to the stack. It combines a maximum of performance with a small memory footprint. The web server allows an embedded system to present web pages with dynamically generated content. It comes with all features typically required by embedded systems: multiple connections, authentication, forms and low RAM usage. RAM usage has been kept to a minimum by smart buffer handling.

The web server implements the relevant parts of the following Request For Comments (RFC).

RFC#	Description
[RFC 1945]	HTTP - Hypertext Transfer Protocol -- HTTP/1.0 Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc1945.txt">ftp://ftp.rfc-editor.org/in-notes/rfc1945.txt</a>
[RFC 2616]	HTTP - Hypertext Transfer Protocol -- HTTP/1.1 Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc2616.txt">ftp://ftp.rfc-editor.org/in-notes/rfc2616.txt</a>

The following table shows the contents of the embOS/IP web server root directory:

Directory	Content
Application\	Contains the example application to run the web server with embOS/IP.
Config	Contains the web server configuration file. Refer to <i>Configuration</i> on page 198 for detailed information.
Inc	Contains the required include files.
IP	Contains the web server sources, <code>IP_Webserver.c</code> , <code>IP_Webserver.h</code> and <code>IP_UTIL_BASE64.c</code> , <code>IP_UTIL_BASE64.h</code> .
IP\FS\	Contains the sources for the file system abstraction layer and the read-only file system. Refer to <i>File system abstraction layer</i> on page 302 for detailed information.
Windows\Webserver\	Contains the source, the project files and an executable to run embOS/IP web server on a Microsoft Windows host. Refer to <i>Using the web server sample</i> on page 185 for detailed information.

**Supplied directory structure of embOS/IP web server package**

## 11.2 Feature list

- Low memory footprint.
- Dynamic web pages (Server Side Includes).
- Authentication supported.
- Forms: POST and GET support.
- Multiple connections supported.
- r/o file system included.
- HTML to C converter included.
- Independent of the file system: any file system can be used.
- Independent of the TCP/IP stack: any stack with sockets can be used.
- Demo with authentication, various forms, dynamic pages included.
- Project for executable on PC for Microsoft Visual Studio included.

## 11.3 Requirements

### **TCP/IP stack**

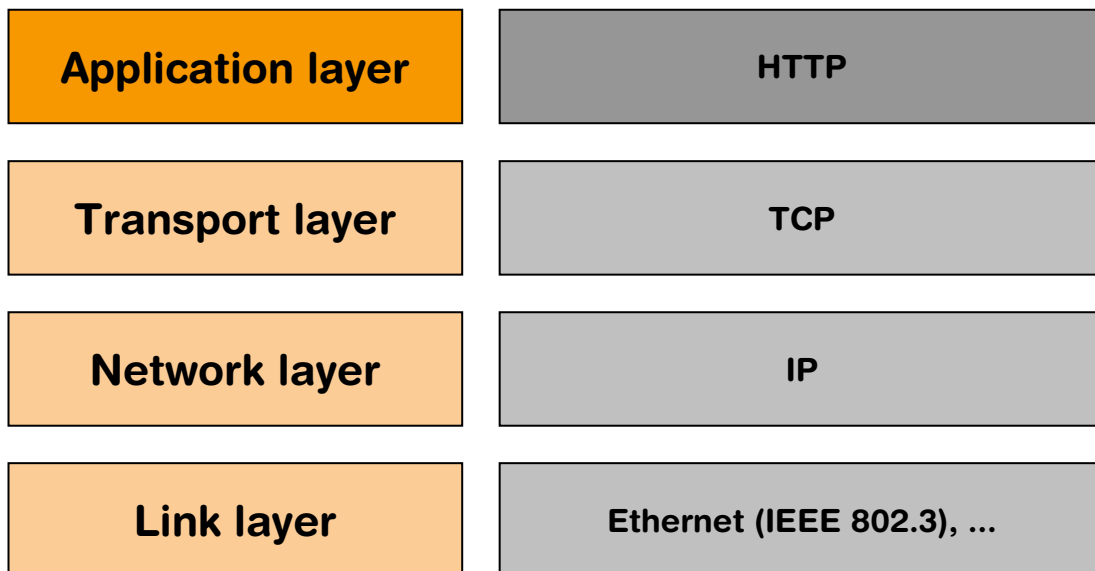
The embOS/IP web server requires a TCP/IP stack. It is optimized for embOS/IP, but any RFC-compliant TCP/IP stack can be used. The shipment includes a Win32 simulation, which uses the standard Winsock API and an implementation which uses the socket API of embOS/IP.

### **Multi tasking**

The web server needs to run as a separate thread. Therefore, a multi tasking system is required to use the embOS/IP web server.

## 11.4 HTTP backgrounds

It is a communication protocol originally designed to transfer information via hypertext pages. The development of HTTP is coordinated by the IETF (Internet Engineering Task Force) and the W3C (World Wide Web Consortium). The current protocol version is 1.1.



### 11.4.1 HTTP communication basics

HTTP is a challenge and response protocol. A client initiates a TCP connection to the web server and sends a HTTP request. A HTTP request starts with a method token. [RFC 2616] defines 8 method tokens. The method token indicates the method to be performed on the requested resource. embOS/IP web server supports all methods which are typically required by an embedded web server.

HTTP method	Description
GET	The GET method means that it retrieves whatever information is identified by the Request-URI.
HEAD	The HEAD method means that it retrieves the header of the content which is identified by the Request-URI.
POST	The POST method submits data to be processed to the identified resource. The data is included in the body of the request.

**Table 11.1: Supported HTTP methods**

The following example shows parts of a HTTP session, where a client (for example, 192.168.1.75) asks the embOS/IP web server for the hypertext page `example.html`. The request is followed by a blank line, so that the request ends with a double new-line, each in the form of a carriage return followed by a line feed.

```
GET /example.html HTTP/1.1
Host: 192.168.1.75
```

The first line of every response message is the Status-Line, consisting of the protocol version followed by a numeric status code. The Status-Line is followed by the content-type, the server, expiration and the transfer-encoding. The server response ends with an empty line, followed by length of content that should be transferred. The length indicates the length of the web page in bytes.

```

HTTP/1.1 200 OK
Content-Type: text/html
Server: embOS/IP
Expires: THU, 26 OCT 1995 00:00:00 GMT
Transfer-Encoding: chunked

```

A3

Thereafter, the web server sends the requested hypertext page to the client. The zero at the end of the web page followed by an empty line signals that the transmission of the requested web page is complete.

```

<HTML>
  <HEAD>
    <TITLE>embOS/IP examples</TITLE>
  </HEAD>
  <BODY>
    <CENTER>
      <H1>Website: example.htm</H1>
    </CENTER>
  </BODY>
</HTML>
0

```

## 11.4.2 HTTP status codes

The first line of a HTTP response is the Status-Line. It consists of the used protocol version, a status code and a short textual description of the Status-Code. The Status-Code element is a 3-digit integer result code of the attempt to understand and satisfy the request.

The first digit of the Status-Code defines the class of response. The last two digits do not have any categorization role. There are 5 values for the first digit:

- 1xx: Informational - Request received, continuing process.
- 2xx: Success - The action was successfully received, understood, and accepted.
- 3xx: Redirection - Further action must be taken in order to complete the request.
- 4xx: Client Error - The request contains bad syntax or cannot be fulfilled.
- 5xx: Server Error - The server failed to fulfill an apparently valid request.

Refer to *[RFC 2616]* for a complete list of defined status-codes. embOS/IP web server supports a subset of the defined HTTP status codes. The following status codes are implemented:

Status code	Description
200	OK. The request has succeeded.
401	Unauthorized. The request requires user authentication.
404	Not found. The server has not found anything matching the Request-URI.
501	Not implemented. The server does not support the HTTP method.
503	Service unavailable. The server is currently unable to handle the request due to a temporary overloading of the server.

**Table 11.2: embOS/IP status codes**

## 11.5 Using the web server sample

Ready to use examples for Microsoft Windows and embOS/IP are supplied. If you use another TCP/IP stack, the sample `OS_IP_Webserver.c` has to be adapted. The sample application opens a port which listens on port 80 until an incoming connection is detected. If a connection has been established, `IP_WEBS_Process()` handles the client request in an extra task, so that the server is further listening on port 80. The example application uses a read-only file system to make web pages available. Refer to *File system abstraction layer* on page 302 and *File system abstraction layer* on page 302 for detailed information about the read-only file system.

### 11.5.1 Using the Windows sample

If you have MS Visual C++ 6.00 or any later version available, you will be able to work with a Windows sample project using embOS/IP web server. If you do not have the Microsoft compiler, an precompiled executable of the web server is also supplied.

#### Building the sample program

Open the workspace `Start_Webserver.dsw` with MS Visual Studio (for example, double-clicking it). There is no further configuration necessary. You should be able to build the application without any error or warning message.

The server uses the IP address of the host PC on which it runs. Open a web browser and connect by entering the IP address of the host (`127.0.0.1`) to connect to the web server.

### 11.5.2 Running the web server example on target hardware

The embOS/IP web server sample application should always be the first step to check the proper function of the web server with your target hardware.

Add all source files located in the following directories (and their subdirectories) to your project and update the include path:

- Application
- Config
- Inc
- IP
- IP\IP\_FS\FS\_RO\
- IP\IP\_FS\FS\_RO\Generated\

It is recommended that you keep the provided folder structure.

The sample application can be used on the most targets without the need for changing any of the configuration flags. The server processes up to three connections using the default configuration.

**Note:** Three connections mean that the target can handle up to three targets in parallel, if every target uses only one connection. Because a single web browser often attempts to open more than one connection to a web server to request the files (`.gif`, `.jpeg`, etc.) which are included in the requested web page, the number of possible parallel connected targets is less than the number of possible connections.

Every connection is handled in an separate task. Therefore, the web server uses up to four tasks in the default configuration, one task which listens on port 80 and accepts connections and three tasks to process the accepted connections. To modify the number of connections, only the macro `MAX_CONNECTIONS` has to be modified.

The supplied sample web pages `index.htm`, `embos.htm` and `stats.htm` include dynamic content, refer to *Common Gateway Interface (CGI)* on page 187 for detailed information about the implementation of dynamic content.

### 11.5.3 Changing the file system type

By default, the web server uses the supplied read-only file system. If a real file system like emFile should be used to store the web pages, you have to modify the function `_WebServerChildTask()` of the example `OS_IP_Webserver.c`.

```

/*****
*
*      _WebServerChildTask
*
*/
static void _WebServerChildTask(void * Context) {
    long Sock;
    int Opt;

    _pFS_API = &IP_FS_ReadOnly;
    Sock = (long)Context;
    Opt = 1;
    setsockopt(Sock, SOL_SOCKET, SO_KEEPALIVE, &Opt, sizeof(Opt));
    if (_ConnectCnt < MAX_CONNECTIONS) {
        IP_WEBS_Process(_Send, _Recv, Context, _pFS_API, &_Application);
    } else {
        IP_WEBS_ProcessLast(_Send, _Recv, Context, _pFS_API, &_Application);
    }
    _closesocket(Sock);
    _AddToConnectCnt(-1);
    OS_Terminate(0);
}

```

The usage of the read-only file system is configured with the following line:

```
_pFS_API = &IP_FS_ReadOnly;
```

To use emFile as file system for your web server application, add the emFile abstraction layer `IP_FS_FS.c` to your project and change the line to:

```
_pFS_API = &IP_FS_FS;
```

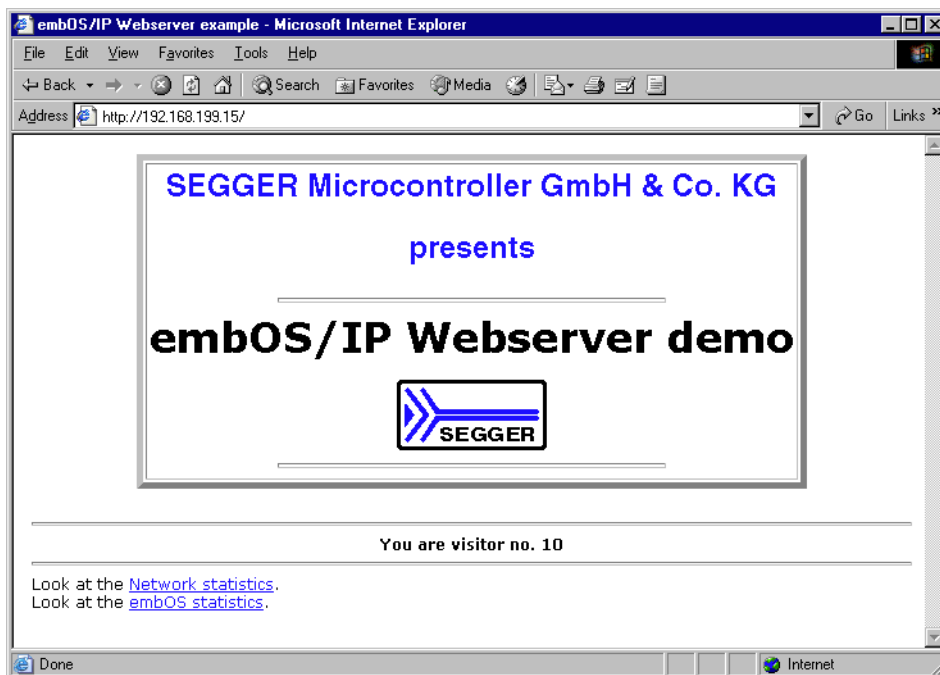
Refer to *File system abstraction layer* on page 302 and *File system abstraction layer* on page 302 for detailed information about the emFile and read-only file system abstraction layer.

## 11.6 Dynamic content

embOS/IP supports two different approaches to implement dynamic content in your web server application. A Common Gateway Interface (CGI) like interface for static HTML pages with dynamic elements and virtual files which are completely generated from the application.

### 11.6.1 Common Gateway Interface (CGI)

A Common Gateway Interface (CGI) like interface is used to implement dynamic content in web pages. Every web page will be parsed by the server each time a request is received. The server searches the web page for a special tag. In the default configuration, the searched tag starts `<!--#exec cgi="` and ends with `-->`. The tag will be analyzed and the parameter will be extracted. This parameter specifies a server-side command and will be given to the user application, which can handle the command. The following screenshot shows the example page `index.htm`.



The HTML source for the page includes the following line:

```
<!--#exec cgi="Counter"-->
```

When the web page is requested, the server parses the tag and the parameter `Counter` is searched for in an array of structures of type `WEBS_CGI`. The structure includes a string to identify the command and a pointer to the function which should be called if the parameter is found.

```
typedef struct {
    const char * sName;    // e.g. "Counter"
    void (*pf)(WEBS_OUTPUT * pOutput, const char * sParameters, const char * sValue);
} WEBS_CGI;
```

In the example, `Counter` is a valid parameter and the function `_callback_ExecCounter` will be called. You need to implement the `WEBS_CGI` array and the callback functions in your application.

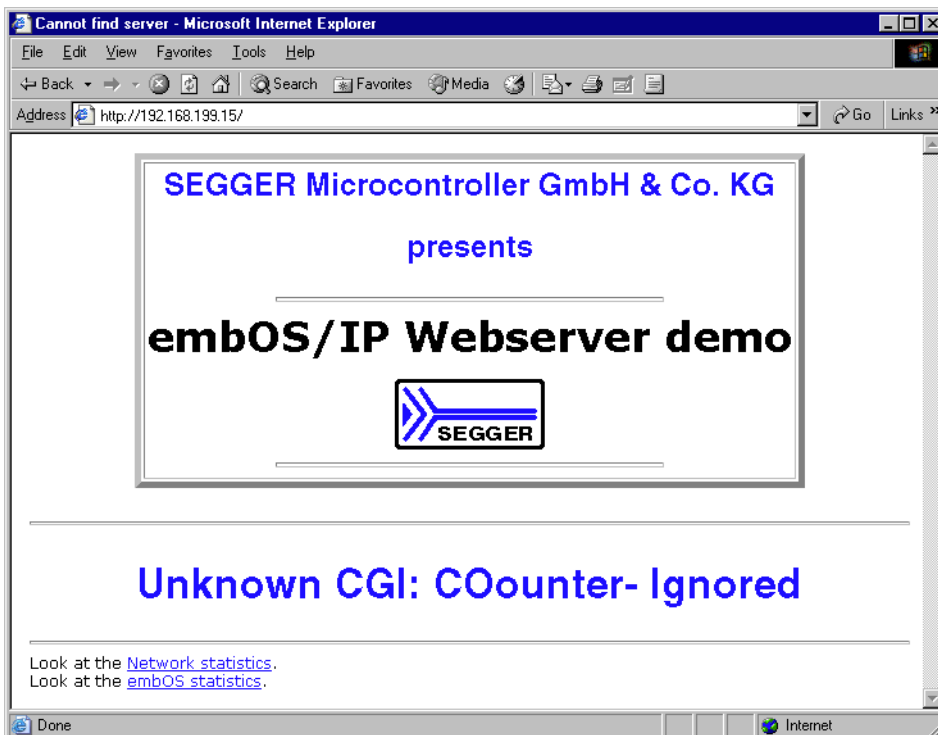
```
static const WEBS_CGI _aCGI[] = {
    {"Counter" , _callback_ExecCounter },
    {"GetOSInfo" , _callback_ExecGetOSInfo},
    {"GetIPAddr" , _callback_ExecGetIPAddr},
    {NULL}
};
```

`ExecCounter()` is a simple example of how to use the CGI feature. It returns a string that includes the value of a variable which is incremented with every call to `ExecCounter()`.

```
void ExecCounter(      WEBS_OUTPUT * pOutput,
                      const char   * sParameters,
                      const char   * sValue ) {
    char ac[40];
    static char Cnt = 1;

    sprintf(ac, "You are visitor no.: %d", Cnt);
    IP_WEBS_SendString(pOutput, ac);
    Cnt++;
}
```

If the web page includes the CGI tag followed by an unknown command (for example, a typo like `COounter` instead of `Counter` in the source code of the web page) an error message will be sent to the client.



### 11.6.1.1 Add new CGI functions to your web server application

To define new CGI functions, three things have to be done.

1. Add a new command name which should be used as tag to the `WEBS_CGI` structure.  
For example: `UserCGI`

```
static const WEBS_CGI _aCGI[] = {
    {"Counter"   , _callback_ExecCounter  },
    {"GetOSInfo" , _callback_ExecGetOSInfo},
    {"GetIPAddr" , _callback_ExecGetIPAddr},
    {"UserCGI"   , _callback_ExecUserCGI  },
    {NULL}
};
```

2. Implement the new function in your application source code.

```
void _callback_ExecUserCGI(      WEBS_OUTPUT * pOutput,
                                const char   * sParameters
                                const char   * sValue ) {
    /* Add application code here */
}
```

3. Add the new tag to the source code of your web page:

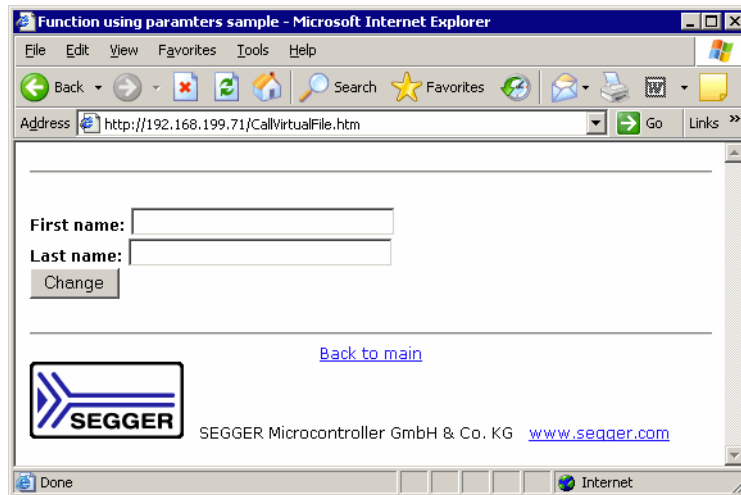
```
<!--#exec cgi="UserCGI"-->
```

## 11.6.2 Virtual files

embOS/IP supports virtual files. A virtual file is not a real file which is stored in the used file system. It is a function which is called instead. The function generates the content of a file and sends it to the client.

The web server checks the extension of all requested files, the extension `.cgi` is by default used for virtual files. To change the extension that is used to detect a virtual file, refer to `IP_WEBS_SetFileInfoCallback()` on page 208 for detailed information.

The embOS/IP web server comes with an example (`CallVirtualFile.htm`) that requests a virtual file. The sample web page contains a form with two input test fields, named `FirstName` and `LastName`, and a button to transmit the data to the server.



When the button on the web page is pressed, the file `Send.cgi` is requested. The embOS/IP Web server recognizes the extension `.cgi`, checks if a virtual file with the name `Send.cgi` is defined and calls the defined function. The function in the example is `_callback_SendCGI` and gets the string `FirstName=Foo&LastName=Bar` as parameter.

```
typedef struct {
    const char * sName;
    void (*pf)(WEBS_OUTPUT * pOutput, const char * sParameters);
} WEBS_VFILES;
```

In the example, `Send.cgi` is a valid URI and the function `_callback_SendCGI` will be called.

```
static const WEBS_VFILES _aVFiles[] = {
    {"Send.cgi", _callback_SendCGI },
    NULL
};
```

The virtual file `Send.cgi` gets two parameters. The strings entered in the input fields `Firstname` and `LastName` are transmitted with the URI. For example, you enter `Foo` in the first name field and `Bar` for last name and push the button. The browser will transmit the following string to our web server:

```
Send.cgi?FirstName=Foo&LastName=Bar
```

You can parse the string and use it in the way you want to. In the example we parse the string and output the values on a web page which is build from the function `_callback_SendCGI()`.

```
static void _callback_SendCGI(WEBS_OUTPUT * pOutput, const char * sParameters) {
    char aPara0[32];
    char aValue0[32];
    char aPara1[32];
    char aValue1[32];
    int r;
```



## 11.7 Authentication

"HTTP/1.0", includes the specification for a Basic Access Authentication scheme. The basic authentication scheme is a non-secure method of filtering unauthorized access to resources on an HTTP server, because the user name and password are passed over the network as clear text. It is based on the assumption that the connection between the client and the server can be regarded as a trusted carrier. As this is not generally true on an open network, the basic authentication scheme should be used accordingly.

The basic access authentication scheme is described in:

RFC#	Description
[RFC 2617]	HTTP Authentication: Basic and Digest Access Authentication Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc2617.txt">ftp://ftp.rfc-editor.org/in-notes/rfc2617.txt</a>

The "basic" authentication scheme is based on the model that the client must authenticate itself with a user-ID and a password for each realm. The realm value should be considered an opaque string which can only be compared for equality with other realms on that server. The server will service the request only if it can validate the user-ID and password for the protection space of the Request-URI. There are no optional authentication parameters.

Upon receipt of an unauthorized request for a URI within the protection space, the server should respond with a challenge like the following:

```
WWW-Authenticate: Basic realm="Embedded web server"
```

where "embOS/IP embedded web server" is the string assigned by the server to identify the protection space of the Request-URI. To receive authorization, the client sends the user-ID and password, separated by a single colon (":") character, within a base64 encoded string in the credentials.

If the user agent wishes to send the user-ID "user" and password "pass", it would use the following header field:

```
Authorization: Basic dXNlcjpwYXNz
```

## 11.7.1 Authentication example

The client requests a resource for which authentication is required:

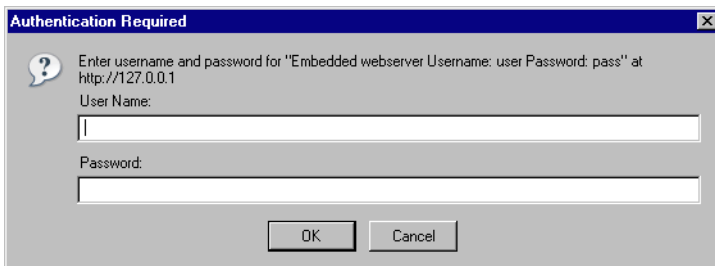
```
GET /conf/Authen.htm HTTP/1.1
Host: 192.168.1.75
```

The server answers the request with a "401 Unauthorized" status page. The header of the 401 error page includes an additional line WWW-Authenticate. It includes the realm for which the proper user name and password should be transmitted from the client (for example, a web browser).

```
HTTP/1.1 401 Unauthorized
Date: Mon, 04 Feb 2008 17:00:44 GMT
Server: embOS/IP
Accept-Ranges: bytes
Content-Length: 695
Connection: close
Content-Type: text/html
X-Pad: avoid browser bug
WWW-Authenticate: Basic realm="embOS/IP embedded web server"
```

```
<HTML>
<HEAD><TITLE>401 Unauthorized</TITLE></HEAD>
<BODY>
<H1>401 Unauthorized</H1>
Browser not authentication-capable or authentication failed.<P>
</BODY>
</HTML>
```

The client interprets the header and opens a dialog box to enter the user name and password combination for the realm of the resource.



**Note:** The embOS/IP web server example always uses the following user name and the password combination: User Name: user - Password: pass

Enter the proper user name/password combination for the requested realm and confirm with the **OK** button. The client encodes the user name/password combination to a base64 encoded string and requests the resource again. The request header is enhanced by the following line: Authorization: Basic dXNlcjpwYXNz

```
GET /conf/Authen.htm HTTP/1.1
Host: 192.168.1.75
Authorization: Basic dXNlcjpwYXNz
```

The server decodes the user name/password combination and checks if the decoded string matches to the defined user name/password combination of the realm. If the strings are identical, the server delivers the page. If the strings are not identical, the server answers again with a "401 Unauthorized" status page.

```

HTTP/1.1 200 OK
Content-Type: text/html
Server: embOS/IP
Expires: THU, 26 OCT 1995 00:00:00 GMT
Transfer-Encoding: chunked

```

```

200
<HTML>
  <HEAD>
    <TITLE>web server configuration</TITLE>
  </HEAD>
  <BODY>
    <!-- Content of the page -->
  </BODY>
</HTML>

0

```

## 11.7.2 Configuration of the authentication

The embOS/IP web server checks the access rights of every resource before returning it. The user can define different realms to separate different parts of the web server resources. An array of `WEBS_ACCESS_CONTROL` structures has to be implemented in the user application. Refer to *Structure WEBS\_ACCESS\_CONTROL* on page 217 for detailed information about the elements of the `WEBS_ACCESS_CONTROL` structure. If no authentication should be used, the array includes only one entry for the root path.

```

WEBS_ACCESS_CONTROL _aAccessControl[] = {
  { "/", NULL, NULL },
  0
};

```

To define a realm "conf", an additional `WEBS_ACCESS_CONTROL` entry has to be implemented.

```

WEBS_ACCESS_CONTROL _aAccessControl[] = {
  { "/conf/", "Login for configuration", "user:pass" },
  { "/", NULL, NULL },
  0
};

```

The string "Login for configuration" defines the realm. "user:pass" is the user name/password combination stored in one string.

## 11.8 Form handling

The embOS/IP web server supports both `POST` and `GET` actions to receive form data from a client. `POST` submits data to be processed to the identified resource. The data is included in the body of the request. `GET` is normally only used to requests a resource, but it is also possible to use `GET` for actions in web applications. Data processing on server side might create a new resource or update existing resources or both.

Every HTML form consists of input items like textfields, buttons, checkboxes, etc. Each of these input items has a `name` tag. When the user places data in these items in the form, that information is encoded into the form data. Form data is a stream of `<name>=<value>` pairs separated by the "&" character. The value each of the input item is given by the user is called the value. The `<name>=<value>` pairs are URL encoded, which means that spaces are changed into "+" and special characters are encoded into hexadecimal values. Refer to *[RFC 1738]* for detailed information about URL encoding. The parsing and decoding of form data is handled by the embOS/IP web server. Thereafter, the server calls a callback function with the decoded and parsed strings as parameters. The responsibility to implement the callback function is on the user side.

Valid characters for CGI function names:

- A-Z
- a-z
- 0-9
- . \_ -

Valid characters for CGI parameter values:

- A-Z
- a-z
- 0-9
- All URL encoded characters
- . \_ - \*()!\$\\

## 11.8.1 Simple form processing sample

The following example shows the handling of the output of HTML forms with your web server application. The example web page `ExampleGET.htm` implements a form with three inputs, two text fields and one button.

First name:

Last name:

The HTML code of the web page as it is added to the server is listed below:

```
<html>
  <head><title>embOS/IP web server form example</title></head>
  <body>
    <form action="" method="GET">
      <p>
        First name:
        <input name="FirstName"
              type="text" size="30"
              maxlength="30"
              value="<!--#exec cgi="FirstName"-->"
        >
        <br>
        Last name:
        <input name="LastName"
              type="text"
              size="30"
              maxlength="30"
              value="<!--#exec cgi="LastName"-->"
        >
        <br>
        <input type="submit" value="Send">
      </p>
    </form>
  </body>
</html>
```

The action field of the form can specify a resource that the browser should reference when it sends back filled-in form data. If the action field defines no resource, the current resource will be requested again.

If you request the web page from the embOS/IP web server and check the source of the page in your web browser, the CGI parts "`<!--#exec cgi="FirstName"-->`" and "`<!--#exec cgi="LastName"-->`" will be executed before the page will be transmitted to the server, so that in the example the values of the `value=` fields will be empty strings.

The HTML code of the web page as seen by the web browser is listed below:

```
<html>
  <head><title>embOS/IP web server form example</title></head>
  <body>
    <form action="" method="GET">
      <p>
        First name:
        <input name="FirstName"
              type="text" size="30"
              maxlength="30"
              value=""
        >
        <br>
        Last name:
        <input name="LastName"
              type="text"
              size="30"
              maxlength="30"
              value=""
        >
      </p>
    </form>
  </body>
</html>
```

```

        >
        <br>
        <input type="submit" value="Send">
    </p>
</form>
</body>
</html>

```

To start form processing, you have to fill in the `FirstName` and the `LastName` field and click the `Send` button. In the example, the browser sends a `GET` request for the resource referenced in the form and appends the form data to the resource name as an URL encoded string. The form data is separated from the resource name by `"?"`. Every `<name>=<value>` pair is separated by `"&"`.

First name:

Last name:

For example, if you type in the `FirstName` field `John` and `Doe` in the `LastName` field and confirm the input by clicking the `Send` button, the following string will be transmitted to the server and shown in the address bar of the browser.

```
http://192.168.1.230/ExampleGET.htm?FirstName=John&LastName=Doe
```

**Note:** If you use `POST` as HTTP method, the `name=<value>` pairs are not shown in the address bar of the browser. The `<name>=<value>` pairs are in this case included in the entity body.

The embOS/IP web server parses the form data. The `<name>` field specifies the name of a CGI function which should be called to process the `<value>` field. The server checks therefore if an entry is available in the `WEBS_CGI` array.

```

static const WEBS_CGI_aCGI[] = {
    {"FirstName",  _callback_ExecFirstName},
    {"LastName",  _callback_ExecLastName },
    {NULL}
};

```

If an entry can be found, the specified callback function will be called.

The callback function for the parameter `FirstName` is defined as follow:

```

/*****
*
*      Static data
*
*****/
static char _acFirstName[12];

/*****
*
*      _callback_FirstName
*/
static void _callback_ExecFirstName(          WEBS_OUTPUT * pOutput,
                                             const char   * sParameters,
                                             const char   * sValue ) {

    if (sValue == NULL) {
        IP_WEBS_SendString(pOutput, _acFirstName);
    } else {
        _CopyString(_acFirstName, sValue, sizeof(_acFirstName));
    }
}

```

The function returns a string if `sValue` is `NULL`. If `sValue` is defined, it will be written into a character array. Because HTTP transmission methods `GET` and `POST` only transmit the value of filled input fields, the same function can be used to output a stored value of an input field or to set a new value. The example web page shows after entering and transmitting the input the new values of `FirstName` and `LastName` as value in the input fields.

First name:

Last name:

The source of the web page as seen by the web browser is listed below:

```

<html>
<head><title>embOS/IP web server form example</title></head>
<body>
  <form action="" method="GET">
    <p>
      First name:
      <input name="FirstName"
             type="text" size="30"
             maxlength="30"
             value="John"
            >
    <br>
      Last name:
      <input name="LastName"
             type="text"
             size="30"
             maxlength="30"
             value="Doe"
            >
    <br>
    <input type="submit" value="Send">
  </p>
</form>
</body>
</html>

```

## 11.9 Configuration

The embOS/IP web server can be used without changing any of the compile time flags. All compile time configuration flags are preconfigured with valid values, which match the requirements of most applications.

The following types of configuration macros exist:

### Binary switches "B"

Switches can have a value of either 0 or 1, for deactivated and activated respectively. Actually, anything other than 0 works, but 1 makes it easier to read a configuration file. These switches can enable or disable a certain functionality or behavior. Switches are the simplest form of configuration macros.

### Numerical values "N"

Numerical values are used somewhere in the source code in place of a numerical constant. A typical example is the configuration of the sector size of a storage medium.

### Alias "A"

A macro which operates like a simple text substitute. An example would be the define `U8`, which the preprocessor would replace with `unsigned char`.

### Function replacements "F"

Macros can basically be treated like regular functions although certain limitations apply, as a macro is still put into the source code as simple text replacement. Function replacements are mainly used to add specific functionality to a module which is highly hardware-dependent. This type of macro is always declared using brackets (and optional parameters).

### 11.9.1 Compile time configuration switches

Type	Symbolic name	Default	Description
F	<code>WEBS_WARN</code>	--	Defines a function to output warnings. In debug configurations ( <code>DEBUG == 1</code> ) <code>WEBS_WARN</code> maps to <code>IP_Warnf_Application()</code> .
F	<code>WEBS_LOG</code>	--	Defines a function to output logging messages. In debug configurations ( <code>DEBUG == 1</code> ) <code>WEBS_LOG</code> maps to <code>IP_Logf_Application()</code> .
N	<code>WEBS_IN_BUFFER_SIZE</code>	512	Defines the size of the input buffer. The input buffer is used to store the HTTP client requests.
N	<code>WEBS_OUT_BUFFER_SIZE</code>	512	Defines the size of the output buffer. The output buffer is used to store the HTTP response.
N	<code>WEBS_PARA_BUFFER_SIZE</code>	256	Defines the size of the buffer used to store the parameter/value string that is given to a virtual file. If virtual files are not used in your application, remove the definition from <code>WEBS_Conf.h</code> to save RAM.

Type	Symbolic name	Default	Description
N	<a href="#">WEBS_TEMP_BUFFER_SIZE</a>	256	Defines the size of the TEMP buffer used internally by the web server.
N	<a href="#">WEBS_AUTH_BUFFER_SIZE</a>	32	Defines the size of the buffer used to store the authentication string. Refer to <i>Authentication</i> on page 191 for detailed information about authentication.
N	<a href="#">WEBS_FILENAME_BUFFER_SIZE</a>	32	Defines the size of the buffer used to store the filename strings.

### Status message web pages

The status message web pages are visualizations of the information transmitted to the client in the header of the web server response. Because these visualizations are not required for the functionality of the web server, the macros can be empty.

Type	Symbolic name	Default
A	<a href="#">WEBS_401_PAGE</a>	"<HTML>\n" \ "<HEAD>\n" \ "<TITLE>401 Unauthorized</TITLE>\n" \ "</HEAD>\n" \ "<BODY>\n" \ "<H1>401 Unauthorized</H1>\n" \ "Browser not authentication-capable" \ "or authentication failed.\n" \ "</BODY>\n" \ "</HTML>\n"
A	<a href="#">WEBS_404_PAGE</a>	"<HTML>\n" \ "<HEAD>\n" \ "<TITLE>404 Not Found</TITLE>\n" \ "</HEAD>\n" \ "<BODY>\n" \ "<H1>404 Not Found</H1>\n" \ "The requested document was not " \ "found on this server.\n" \ "</BODY>\n" \ "</HTML>\n"
A	<a href="#">WEBS_501_PAGE</a>	"<HTML>\n" \ "<HEAD>\n" \ "<TITLE>501 Not implemented</TITLE>\n" \ "</HEAD>\n" \ "<BODY>\n" \ "<H1>Command is not implemented</H1>\n" \ "</BODY>\n" \ "</HTML>\n"
A	<a href="#">WEBS_503_PAGE</a>	"<HTML>\n" \ "<HEAD>\n" \ "<TITLE>503 Connection limit reached</TITLE>\n" \ "</HEAD>\n" \ "<BODY>\n" \ "<H1>503 Connection limit reached</H1>\n" \ "The max. number of simultaneous connections to " \ "this server reached.<P>\n" \ "Please try again later.\n" \ "</BODY>\n" \ "</HTML>\n"

## 11.10 API functions

Function	Description
<code>IP_WEBS_Process()</code>	Processes a HTTP request of a client.
<code>IP_WEBS_ProcessLast()</code>	Processes a HTTP request of a client and closes the connection thereafter.
<code>IP_WEBS_OnConnectionLimit()</code>	Outputs an error message to the connected client.
<code>IP_WEBS_SendMem()</code>	Sends data to a connected target.
<code>IP_WEBS_SendString()</code>	Sends a string to a connected target.
<code>IP_WEBS_SendStringEnc()</code>	Encodes and sends a string to a connected target.
<code>IP_WEBS_SendUnsigned()</code>	Sends an unsigned value to a connected target.
<code>IP_WEBS_SetFileInfoCallback()</code>	Sets a callback function to handle file information used by the web server.
CGI/virtual file related functions	
<code>IP_WEBS_CompareFileNameExt()</code>	Checks the file name extension.
<code>IP_WEBS_GetNumParas()</code>	Returns the number of parameter/value pairs.
<code>IP_WEBS_ParaValue()</code>	Gets a parameter value pair.
<code>IP_WEBS_DecodeAndCopyString()</code>	Decodes an HTML encoded string and copy it into a buffer.
<code>IP_WEBS_DecodeString()</code>	Decodes an HTML encoded string.
Utility functions	
<code>IP_UTIL_BASE64_Decode()</code>	Decodes a Base64 encoded string.
<code>IP_UTIL_BASE64_Encode()</code>	Encodes a string as a Base64 string.

**Table 11.3: embOS/IP web server interface function overview**

## 11.10.1 IP\_WEBS\_Process()

### Description

Processes a HTTP request of a client.

### Prototype

```
int IP_WEBS_Process (
    IP_WEBS_tSend      pfSend,
    IP_WEBS_tReceive   pfReceive,
    void               * pConnectInfo,
    const IP_WEBS_FS_API * pFS_API
    const WEBS_APPLICATION * pApplication);
```

### Parameter

Parameter	Description
<a href="#">pfSend</a>	[IN] Pointer to the function to be used by the server to send data to the client.
<a href="#">pfReceive</a>	[IN] Pointer to the function to be used by the server to receive data from the client.
<a href="#">pConnectInfo</a>	[IN] Pointer to the connection information.
<a href="#">pFS_API</a>	[IN] Pointer to the used file system API.
<a href="#">pApplication</a>	[IN] Pointer to a structure of type WEBS_APPLICATION.

**Table 11.4: IP\_WEBS\_Process() parameter list**

### Return value

0 OK.

### Additional Information

This function is part of the thread functionality of the web server. The following types are used as function pointers to the routines used to send and receive bytes from/to the client:

```
typedef int (*IP_WEBS_tSend) (const unsigned char * pData,
                              int len,
                              void * pConnectInfo);
```

```
typedef int (*IP_WEBS_tReceive) (const unsigned char * pData,
                                  int len,
                                  void * pConnectInfo);
```

The send and receive functions should return the number of bytes successfully sent/received to/from the client. The pointer [pConnectInfo](#) is passed to the send and receive routines. It can be used to pass a pointer to a structure containing connection information or to pass a socket number. For details about the parameter [pFS\\_API](#) and the `IP_WEBS_FS_API` structure, refer to *File system abstraction layer* on page 302. For details about the parameter [pApplication](#) and the `WEBS_APPLICATION` structure, refer to *Structure WEBS\_APPLICATION* on page 218.

Refer to [IP\\_WEBS\\_ProcessLast\(\)](#) on page 202 and [IP\\_WEBS\\_OnConnectionLimit\(\)](#) on page 203 for further information.

## 11.10.2 IP\_WEBS\_ProcessLast()

### Description

Processes a HTTP request of a client and closes the connection thereafter.

### Prototype

```
int IP_WEBS_Process (
    IP_WEBS_tSend      pfSend,
    IP_WEBS_tReceive   pfReceive,
    void               * pConnectInfo,
    const IP_WEBS_FS_API * pFS_API
    const WEBS_APPLICATION * pApplication);
```

### Parameter

Parameter	Description
<a href="#">pfSend</a>	[IN] Pointer to the function to be used by the server to send data to the client.
<a href="#">pfReceive</a>	[IN] Pointer to the function to be used by the server to receive data from the client.
<a href="#">pConnectInfo</a>	[IN] Pointer to the connection information.
<a href="#">pFS_API</a>	[IN] Pointer to the used file system API.
<a href="#">pApplication</a>	[IN] Pointer to a structure of type WEBS_APPLICATION.

**Table 11.5: IP\_WEBS\_Process() parameter list**

### Return value

0 OK.

### Additional Information

This function is part of the thread functionality of the web server. This is typically called for the last available connection. In contrast to `IP_WEBS_Process()`, this function closes the connection as soon as the command is completed in order to not block the last connection longer than necessary and avoid connection-limit errors.

The following types are used as function pointers to the routines used to send and receive bytes from/to the client:

```
typedef int (*IP_WEBS_tSend) (const unsigned char * pData,
                             int len,
                             void * pConnectInfo);
```

```
typedef int (*IP_WEBS_tReceive) (const unsigned char * pData,
                                 int len,
                                 void * pConnectInfo);
```

The send and receive functions should return the number of bytes successfully sent/received to/from the client. The pointer `pConnectInfo` is passed to the send and receive routines. It can be used to pass a pointer to a structure containing connection information or to pass a socket number. For details about the parameter `pFS_API` and the `IP_WEBS_FS_API` structure, refer to *File system abstraction layer* on page 302. For details about the parameter `pApplication` and the `WEBS_APPLICATION` structure, refer to *Structure WEBS\_APPLICATION* on page 218.

Refer to `IP_WEBS_Process()` on page 201 and `IP_WEBS_OnConnectionLimit()` on page 203 for further information.

## 11.10.3 IP\_WEBS\_OnConnectionLimit()

### Description

Outputs an error message to the connected client.

### Prototype

```
void IP_WEBS_OnConnectionLimit( const IP_WEBS_API * pIP_API,
                               void           * CtrlSock );
```

### Parameter

Parameter	Description
<code>pIP_API</code>	[IN] Pointer to a structure of type <code>IP_FTPTS_API</code> .
<code>CtrlSock</code>	[IN] Pointer to the socket which is related to the command connection.

**Table 11.6: IP\_WEBS\_OnConnectionLimit() parameter list**

### Additional information

This function is typically called by the application if the connection limit is reached. The structure type `IP_WEBS_API` contains mappings of the required socket functions to the actual IP stack. This is required because the socket functions are slightly different on different systems. Refer to `IP_WEBS_Process()` on page 201 and `IP_WEBS_ProcessLast()` on page 202 for further information.

### Example

Pseudo code:

```
//
// Call IP_WEBS_Process() or IP_WEBS_ProcessLast() if multiple or just
// one more connection is available
//
do {
    if (NumAvailableConnections > 1) {
        IP_WEBS_Process();
        return;
    } else if (NumAvailableConnections == 1) {
        IP_WEBS_ProcessLast();
        return;
    }
    Delay();
} while (!Timeout)
//
// No connection available even after waiting => Output error message
//
IP_WEBS_OnConnectionLimit();
```

## 11.10.4 IP\_WEBS\_SendMem()

### Description

Sends data to a connected target.

### Prototype

```
int IP_WEBS_SendMem ( WEBS_OUTPUT * pOutput,
                      const char * s,
                      unsigned NumBytes);
```

### Parameter

Parameter	Description
<code>pOutput</code>	[IN] Pointer to the WEBS_OUTPUT structure.
<code>s</code>	[IN] Pointer to a memory location that should be transmitted.
<code>NumBytes</code>	[IN] Number of bytes that should be sent.

**Table 11.7: IP\_WEBS\_SendMem() parameter list**

### Return value

0 OK.

## 11.10.5 IP\_WEBS\_SendString()

### Description

Sends a zero-terminated string to a connected target.

### Prototype

```
int IP_WEBS_SendString(          WEBS_OUTPUT * pOutput,
                               const char    * s);
```

### Parameter

Parameter	Description
<code>pOutput</code>	[IN] Pointer to the WEBS_OUTPUT structure.
<code>s</code>	[IN] Pointer to a string that should be transmitted.

**Table 11.8: IP\_WEBS\_SendString() parameter list**

### Return value

0 OK.

## 11.10.6 IP\_WEBS\_SendStringEnc()

### Description

Encodes and sends a zero-terminated string to a connected target.

### Prototype

```
int IP_WEBS_SendString(          WEBS_OUTPUT * pOutput,  
                           const char      * s);
```

### Parameter

Parameter	Description
<code>pOutput</code>	[IN] Pointer to the WEBS_OUTPUT structure.
<code>s</code>	[IN] Pointer to a string that should be transmitted.

**Table 11.9: IP\_WEBS\_SendStringEnc() parameter list**

### Return value

0 OK.

### Additional information

This function encodes the string `s` with URL encoding, which means that spaces are changed into "+" and special characters are encoded to hexadecimal values. Refer to *[RFC 1738]* for detailed information about URL encoding.

## 11.10.7 IP\_WEBS\_SendUnsigned()

### Description

Sends an unsigned value to the client.

### Prototype

```
int IP_WEBS_SendUnsigned ( WEBS_OUTPUT * pOutput,
                           unsigned      v,
                           unsigned      Base,
                           int           NumDigits );
```

### Parameter

Parameter	Description
<code>pOutput</code>	[IN] Pointer to the <code>WEBS_OUTPUT</code> structure.
<code>s</code>	[IN] Value that should be sent.
<code>Base</code>	[IN] Numerical base.
<code>NumDigits</code>	[IN] Number of digits that should be sent. 0 can be used as a wild-card.

**Table 11.10: IP\_WEBS\_SendUnsigned() parameter list**

### Return value

0 OK.

## 11.10.8 IP\_WEBS\_SetFileInfoCallback()

### Description

Sets a callback function to receive the file information which are used by the stack.

### Prototype

```
void IP_WEBS_SetFileInfoCallback ( IP_WEBS_pfGetFileInfo pf );
```

### Parameter

Parameter	Description
pf	[IN] Pointer to a callback function.

**Table 11.11: IP\_WEBS\_SetFileInfoCallback() parameter list**

### Additional information

The function can be used to change the default behavior of the web server. If the file info callback function is set, the web server calls it to retrieve the file information. The file information are used to decide how to handle the file and to build the HTML header. By default (no file info callback function is set), the web server parses every file with the extension `.htm` to check if dynamic content is included; all requested files with the extension `.cgi` are recognized as virtual files. Beside of that, the web server sends by default the expiration date of a web site in the HTML header. The default expiration date (THU, 01 JAN 1995 00:00:00 GMT) is in the past, so that the requested website will never be cached. This is a reasonable default for web pages with dynamic content. If the callback function returns 0 for `DateExp`, the expiration date will not be included in the header. For static websites, it is possible to add the optional "Last-Modified" header field. The "Last-Modified" header field is not part of the header by default. Refer to *Structure IP\_WEBS\_FILE\_INFO* on page 219 for detailed information about the structure `IP_WEBS_FILE_INFO`.

### Example

```
static void _GetFileInfo(const char * sFilename, IP_WEBS_FILE_INFO * pFileInfo){
    int v;

    //
    // .cgi files are virtual, everything else is not
    //
    v = IP_WEBS_CompareFilenameExt(sFilename, ".cgi");
    pFileInfo->IsVirtual = v ? 0 : 1;
    //
    // .htm files contain dynamic content, everything else is not
    //
    v = IP_WEBS_CompareFilenameExt(sFilename, ".htm");
    pFileInfo->AllowDynContent = v ? 0 : 1;
    //
    // If file is a virtual file or includes dynamic content,
    // get current time and date stamp as file time
    //
    pFileInfo->DateLastMod = _GetTimeDate();
    if (pFileInfo->IsVirtual || pFileInfo->AllowDynContent) {
        //
        // Set last-modified and expiration time and date
        //
        pFileInfo->DateExp      = _GetTimeDate(); // If "Expires" HTTP header field should
                                                // be transmitted, set expiration date.
    } else {
        pFileInfo->DateExp      = 0xEE210000; // Expiration far away (01 Jan 2099)
                                                // if content is static
    }
}
```

## 11.10.9 IP\_WEBS\_CompareFileNameExt()

### Description

Checks if the given filename has the given extension.

### Prototype

```
char IP_WEBS_CompareFilenameExt( const char * sFilename,
                                const char * sExt );
```

### Parameter

Parameter	Description
<code>sFilename</code>	[IN] Name of the file.
<code>sExt</code>	[IN] Extension which should be checked.

**Table 11.12: IP\_WEBS\_CompareFilenameExt() parameter list**

### Return value

0 Match

!= 0 Mismatch

### Additional information

The test is case-sensitive, meaning:

```
IP_WEBS_CompareFilenameExt("Index.html", ".html")    ---> Match
IP_WEBS_CompareFilenameExt("Index.htm", ".html")     ---> Mismatch
IP_WEBS_CompareFilenameExt("Index.HTML", ".html")    ---> Mismatch
IP_WEBS_CompareFilenameExt("Index.html", ".HTML")    ---> Mismatch
```

## 11.10.10 IP\_WEBS\_GetNumParas()

### Description

Returns the number of parameter/value pairs.

### Prototype

```
int IP_WEBS_GetNumParas ( const char * sParameters );
```

### Parameter

Parameter	Description
<code>sParameters</code>	[IN] Zero-terminated string with parameter/value pairs.

**Table 11.13: IP\_WEBS\_GetNumParas() parameter list**

### Return value

Number of parameters/value pairs.

-1 if the string does not include parameter value pairs.

### Additional information

Parameters are separated from values by a '='. If a string includes more as one parameter/value pair, the parameter/value pairs are separated by a '&'. For example, if the virtual file Send.cgi gets two parameters, the string should be similar to the following: Send.cgi?FirstName=Foo&LastName=Bar

`sParameter` is in this case `FirstName=Foo&LastName=Bar`. If you call `IP_WEBS_GetNumParas()` with this string, the return value will be 2.

## 11.10.11 IP\_WEBS\_GetParaValue()

### Description

Parses a string for valid parameter/value pairs and writes the results in the respective buffers.

### Prototype

```
int IP_WEBS_GetParaValue( const char * sBuffer,
                          int      ParaNum,
                          char * sPara,
                          int      ParaLen,
                          char * sValue,
                          int      ValueLen );
```

### Parameter

Parameter	Description
<code>sBuffer</code>	[IN] Zero-terminated parameter/value string that should be parsed.
<code>ParaNum</code>	[IN] Zero-based index of the parameter/value pairs.
<code>sPara</code>	[Out] Buffer to store the the parameter name. (Optional, can be NULL.)
<code>ParaLen</code>	[IN] Size of the buffer to store the parameter. (0 if <code>sPara</code> is NULL.)
<code>sValue</code>	[Out] Buffer to store the the value. (Optional, can be NULL.)
<code>ValueLen</code>	[IN] Size of the buffer to store the value. (0 if <code>sValue</code> is NULL.)

**Table 11.14: IP\_WEBS\_GetParaValue() parameter list**

### Return value

0: O.K.  
>0: Error

### Additional information

A valid string is in the following format:

<Param0>=<Value0>&<Param1>=<Value1>& ... <Paramn>=<Valuen>

If the parameter value string is `FirstName=John&LastName=Doo` and parameter 0 should be copied, `sPara` will be `FirstName` and `sValue` `John`. If parameter 1 should be copied, `sPara` will be `LastName` and `sValue` `Doo`.

## 11.10.12 IP\_WEBS\_DecodeAndCopyStr()

### Description

Checks if a string includes url encoded characters, decodes the characters and copies them into destination buffer.

### Prototype

```
void IP_WEBS_DecodeAndCopyStr (      char * pDest,
                                     int    DestLen,
                                     const char * pSrc,
                                     int    SrcLen );
```

### Parameter

Parameter	Description
<code>pDest</code>	[OUT] Buffer to store the decoded string.
<code>DestLen</code>	[IN] Size of the destination buffer.
<code>pSrc</code>	[IN] Source string that should be decoded.
<code>SrcLen</code>	[IN] Size of the source string.

**Table 11.15: IP\_WEBS\_DecodeAndCopyStr() parameter list**

### Additional information

Destination string is 0-terminated. Source and destination buffer can be identical.

<code>pSrc</code>	<code>SrcLen</code>	<code>pDest</code>	<code>DestLen</code>
"FirstName=J%F6rg"	16	"FirstName=Jörg\0"	15
"FirstName=John"	14	"FirstName=John\0"	15

**Table 11.16: Example**

## 11.10.13 IP\_WEBS\_DecodeString()

### Description

Checks if a string includes url encoded characters, decodes the characters.

### Prototype

```
int IP_WEBS_DecodeString( const char * s );
```

### Parameter

Parameter	Description
s	[IN/OUT] Zero-terminated string that should be decoded.

**Table 11.17: IP\_WEBS\_DecodeString() parameter list**

### Return value

0 String does not include url encoded characters. No change.

>0 Length of the decoded string, including the terminating null character.

### Additional information

## 11.10.14 IP\_UTIL\_BASE64\_Decode()

### Description

Performs BASE-64 decoding according to RFC3548.

### Prototype

```
int IP_UTIL_BASE64_Decode( const U8 * pSrc,
                          int SrcLen,
                          U8 * pDest,
                          int * pDestLen );
```

### Parameter

Parameter	Description
<code>pSrc</code>	[IN] Pointer to data to encode.
<code>SrcLen</code>	Number of bytes to encode.
<code>pDest</code>	[IN] Pointer to the destination buffer.
<code>pDestLen</code>	[IN] Pointer to the destination buffer size. [OUT] Pointer to the number of bytes used in the destination buffer.

**Table 11.18: IP\_UTIL\_BASE64\_Decode() parameter list**

### Return value

< 0 Error  
 > 0 Number of source bytes encoded, further call required  
 0 All bytes encoded

### Additional information

For more information, refer to <http://tools.ietf.org/html/rfc3548>.

## 11.10.15 IP\_UTIL\_BASE64\_Encode()

### Description

Performs BASE-64 encoding according to RFC3548.

### Prototype

```
int IP_UTIL_BASE64_Encode( const U8 * pSrc,
                          int SrcLen,
                          U8 * pDest,
                          int * pDestLen );
```

### Parameter

Parameter	Description
<code>pSrc</code>	[IN] Pointer to data to encode.
<code>SrcLen</code>	Number of bytes to encode.
<code>pDest</code>	[IN] Pointer to the destination buffer.
<code>pDestLen</code>	[IN] Pointer to the destination buffer size. [OUT] Pointer to the number of bytes used in the destination buffer.

**Table 11.19: IP\_UTIL\_BASE64\_Decode() parameter list**

### Return value

< 0    Error  
> 0    Number of source bytes encoded, further call required  
0      All bytes encoded

### Additional information

For more information, refer to <http://tools.ietf.org/html/rfc3548>.

## 11.11 Web server data structures

### 11.11.1 Structure WEBS\_CGI

#### Description

Used to store the CGI command names and the pointer to the proper callback functions.

#### Prototype

```
typedef struct {  
    const char * sName;  
    void (*pf)(WEBS_OUTPUT * pOutput, const char * sParameters);  
} WEBS_CGI;
```

Member	Description
<a href="#">sName</a>	Name of the CGI command.
<a href="#">pf</a>	Pointer to a callback function.

**Table 11.20:** Structure WEBS\_CGI member list

#### Additional information

Refer to *Common Gateway Interface (CGI)* on page 187 for detailed information about the use of this structure.

## 11.11.2 Structure WEBS\_ACCESS\_CONTROL

### Description

Used to store information for the HTTP Basic Authentication scheme.

### Prototype

```
typedef struct {
    const char * sPath;
    const char * sRealm;
    const char * sUserPass;
} WEBS_ACCESS_CONTROL;
```

Member	Description
<code>sPath</code>	A string which defines the path of the resources.
<code>sRealm</code>	A string which defines the realm which requires authentication. Optional, can be NULL.
<code>sUserPass</code>	A string containing the user name/password combination. Optional, can be NULL.

**Table 11.21: Structure WEBS\_ACCESS\_CONTROL member list**

### Additional information

If `sRealm` is initialized with `NULL`, `sUserPass` is not interpreted by the web server. Refer to *Authentication* on page 191 for detailed information about the HTTP Basic Authentication scheme.

## 11.11.3 Structure WEBS\_APPLICATION

### Description

Used to store application-specific parameters.

### Prototype

```
typedef struct {
    const WEBS_CGI * paCGI;
    WEBS_ACCESS_CONTROL * paAccess;
    void (*pfHandleParameter)(          WEBS_OUTPUT * pOutput,
                                         const char      sPara,
                                         const char      * sValue );
} WEBS_APPLICATION;
```

Member	Description
<a href="#">paCGI</a>	Pointer to an array of structures of type WEBS_CGI.
<a href="#">paAccess</a>	Pointer to an array of structures of type WEBS_ACCESS_CONTROL.
<a href="#">pfHandleParameter</a>	Pointer to an array of structures of type WEBS_CGI.

**Table 11.22: Structure WEBS\_APPLICATION member list**

## 11.11.4 Structure IP\_WEBS\_FILE\_INFO

### Description

Used to store application-specific parameters.

### Prototype

```
typedef struct {
    U32 DateLastMod;           // Used for "Last modified" header field
    U32 DateExp;              // Used for "Expires" header field
    U8  IsVirtual;
    U8  AllowDynContent;
} IP_WEBS_FILE_INFO;
```

Member	Description
<a href="#">DateLastModified</a>	The date when the file has been last modified.
<a href="#">DateExp</a>	The date of the expiration of the validity.
<a href="#">IsVirtual</a>	Flag to indicate if a file is virtual or not. Valid values are 0 for non-virtual, 1 for virtual files.
<a href="#">AllowDynContent</a>	Flag to indicate if a file should be parsed for dynamic content or not. 0 means that the file should not be parsed for dynamic content, 1 means that the file should be parsed for dynamic content.

**Table 11.23: Structure IP\_WEBS\_FILE\_INFO member list**

## 11.12 Resource usage

The ROM usage depends on the compiler options, the compiler version and the used CPU. The memory requirements of the web server presented in the tables below have been measured on a system as follows: ARM7, IAR Embedded Workbench V5.11, Thumb mode, Size optimization.

### Configuration used

```
#define WEBS_IN_BUFFER_SIZE      128
#define WEBS_OUT_BUFFER_SIZE     128
#define WEBS_TEMP_BUFFER_SIZE   128
#define WEBS_PARA_BUFFER_SIZE    0
#define WEBS_ERR_BUFFER_SIZE     (WEBS_OUT_BUFFER_SIZE / 2)
#define WEBS_AUTH_BUFFER_SIZE   32
#define WEBS_FILENAME_BUFFER_SIZE 32
```

### 11.12.1 ROM usage

Add-on	ROM [Kbytes]
embOS/IP web server	5.4

### 11.12.2 RAM usage:

Almost all of the RAM used by the web server is taken from task stacks. The amount of RAM required for every child task depends on the configuration of your server.

Task	Description	RAM [bytes]
ParentTask	Listens for incoming connections.	500
ChildTask	Handles a request.	1800

**Note:** The web server requires at least 1 child task.

The approximately RAM usage for the web server can be calculated as follows:

RAM usage = 0.1 Kbytes + ParentTask + (NumberOfChildTasks \* 1.8 Kbytes)

#### Example: Web server accepting only 1 connection

RAM usage = 0.1 Kbytes + 500 +(1 \* 1.8 Kbytes)

RAM usage = 2.4 Kbytes

#### Example: Web server accepting up to 3 connections in parallel

RAM usage = 0.1 Kbytes + 500 + (3 \* 1.8 Kbytes)

RAM usage = 6.0 Kbytes

# Chapter 12

## SMTP client (Add-on)

---

The embOS/IP SMTP client is an optional extension to embOS/IP. The SMTP client can be used with embOS/IP or with a different TCP/IP stack. All functions that are required to add the SMTP client task to your application are described in this chapter.

## 12.1 embOS/IP SMTP client

The embOS/IP SMTP client is an optional extension which can be seamlessly integrated into your TCP/IP application. It combines a maximum of performance with a small memory footprint. The SMTP client allows an embedded system to send emails with dynamically generated content. The RAM usage of the SMTP client module has been kept to a minimum by smart buffer handling.

The SMTP client implements the relevant parts of the following Request For Comments (RFC).

RFC#	Description
[RFC 821]	Simple Mail Transfer Protocol Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc821.txt">ftp://ftp.rfc-editor.org/in-notes/rfc821.txt</a>
[RFC 974]	Mail routing and the domain system Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc974.txt">ftp://ftp.rfc-editor.org/in-notes/rfc974.txt</a>
[RFC 2554]	<i>SMTP Service Extension for Authentication</i> Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc2554.txt">ftp://ftp.rfc-editor.org/in-notes/rfc2554.txt</a>
[RFC 5321]	Simple Mail Transfer Protocol Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc5321.txt">ftp://ftp.rfc-editor.org/in-notes/rfc5321.txt</a>

The following table shows the contents of the embOS/IP SMTP client root directory:

Directory	Content
Application\	Contains the example application to run the SMTP client with embOS/IP.
Config	Contains the SMTP client configuration file. Refer to <i>Configuration</i> on page 227 for detailed information.
Inc	Contains the required include files.
IP	Contains the SMTP client sources, <code>IP_SMTPC.c</code> and <code>IP_SMTPC.h</code> .
Windows\SMTPC\	Contains the source, the project files and an executable to run embOS/IP SMTP client on a Microsoft Windows host.

**Supplied directory structure of embOS/IPSMTP client package**

## 12.2 Feature list

- Low memory footprint.
- Independent of the TCP/IP stack: any stack with sockets can be used.
- Example applications included.
- Project for executable on PC for Microsoft Visual Studio included.

## 12.3 Requirements

### **TCP/IP stack**

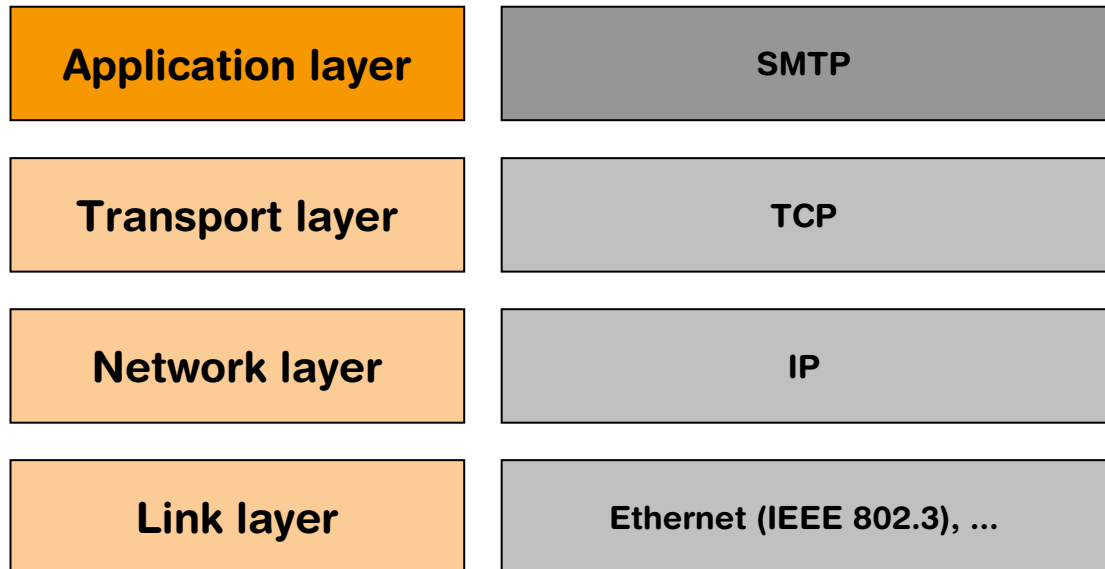
The embOS/IP SMTP client requires a TCP/IP stack. It is optimized for embOS/IP, but any RFC-compliant TCP/IP stack can be used. The shipment includes a Win32 simulation, which uses the standard Winsock API and an implementation which uses the socket API of embOS/IP.

### **Multi tasking**

The SMTP client needs to run as a separate thread. Therefore, a multi tasking system is required to use the embOS/IP SMTP client.

## 12.4 SMTP backgrounds

The Simple Mail Transfer Protocol is a text based communication protocol for electronic mail transmission across IP networks.



Using SMTP, an embOS/IP application can transfer mail to an SMTP servers on the same network or to SMTP servers in other networks via a relay or gateway server accessible to both networks. When the embOS/IP SMTP client has a message to transmit, it establishes a TCP connection to an SMTP server and transmits after the handshaking the message content.

The handshaking mechanism includes normally an authentication process. The RFC's define the following four different authentication schemes:

- PLAIN
- LOGIN
- CRAM-MD5
- NTLM

In the current version, the embOS/IP SMTP client supports only PLAIN authentication. The following listing shows a typical SMTP session:

```
S: 220 srv.sample.com ESMTP
C: HELO
S: 250 srv.sample.com
C: AUTH LOGIN
S: 334 VXNlcm5hbWU6
C: c3BzZXk29IulbkY29tZcZlZlZQ==
S: 334 UGFzc3dvcmQ6
C: UlblhFz7ZlblsZlZQ==
S: 235 go ahead
C: Mail from:<user0@sample.com>
S: 250 ok
C: Rcpt to:<user1@sample.com>
S: 250 ok
C: Rcpt to:<user2@sample.com>
S: 250 ok
C: Rcpt to:<user3@sample.com>
S: 250 ok
C: DATA
S: 354 go ahead
C: Message-ID: <1000.2234@sample.com>
C: From: "User0" <User0@sample.com>
C: TO: "User1" <User1@sample.com>
C: CC: "User2" <User2@sample.com>, "User3" <User3@sample.com>
```

```
C: Subject: Testmail
C: Date: 1 Jan 2008 00:00 +0100
C:
C: This is a test!
C:
C: .
S: 250 ok 1231221612 qp 3364
C: quit
S: 221 srv.sample.com
```

## 12.5 Configuration

The embOS/IP SMTP client can be used without changing any of the compile time flags. All compile time configuration flags are preconfigured with valid values, which match the requirements of most applications.

The following types of configuration macros exist:

### Binary switches "B"

Switches can have a value of either 0 or 1, for deactivated and activated respectively. Actually, anything other than 0 works, but 1 makes it easier to read a configuration file. These switches can enable or disable a certain functionality or behavior. Switches are the simplest form of configuration macros.

### Numerical values "N"

Numerical values are used somewhere in the source code in place of a numerical constant. A typical example is the configuration of the sector size of a storage medium.

### Alias "A"

A macro which operates like a simple text substitute. An example would be the define `U8`, which the preprocessor would replace with `unsigned char`.

### Function replacements "F"

Macros can basically be treated like regular functions although certain limitations apply, as a macro is still put into the source code as simple text replacement. Function replacements are mainly used to add specific functionality to a module which is highly hardware-dependent. This type of macro is always declared using brackets (and optional parameters).

### 12.5.1 Compile time configuration switches

Type	Symbolic name	Default	Description
F	<code>SMTPC_WARN</code>	--	Defines a function to output warnings. In debug configurations ( <code>DEBUG == 1</code> ) <code>SMTPC_WARN</code> maps to <code>IP_Warnf_Application()</code> .
F	<code>SMTPC_LOG</code>	--	Defines a function to output logging messages. In debug configurations ( <code>DEBUG == 1</code> ) <code>SMTPC_LOG</code> maps to <code>IP_Logf_Application()</code> .
N	<code>SMTPC_SERVER_PORT</code>	25	Defines the port where the SMTP server is listening.
N	<code>SMTPC_IN_BUFFER_SIZE</code>	256	Defines the size of the input buffer. The input buffer is used to store the SMTP replies of the SMTP server.
N	<code>SMTPC_AUTH_USER_BUFFER_SIZE</code>	48	Defines the size of the buffer used for the Base-64 encoded user name.
N	<code>SMTPC_AUTH_PASS_BUFFER_SIZE</code>	48	Defines the size of the buffer used for the Base-64 encoded password.

## 12.6 API functions

Function	Description
SMTP client functions	
<a href="#">IP_SMTPC_Send()</a>	Sends an email to a mail transfer agent.

**Table 12.1: embOS/IP SMTP client interface function overview**

## 12.6.1 IP\_SMTPC\_Send()

### Description

Sends an email to one or multiple recipients.

### Prototype

```
int IP_SMTPC_Send( const IP_SMTPC_API          * pIP_API,
                  IP_SMTPC_MAIL_ADDR         * paMailAddr,
                  int                          NumMailAddr,
                  IP_SMTPC_MESSAGE           * pMessage,
                  const IP_SMTPC_MTA         * pMTA,
                  const IP_SMTPC_APPLICATION * pApplication );
```

### Parameter

Parameter	Description
<code>pIP_API</code>	[IN] Pointer to an <code>IP_SMTPC_API</code> structure. Refer to <i>Structure IP_SMTPC_API</i> on page 231 for detailed information about the elements of the <code>IP_SMTPC_API</code> structure.
<code>paMailAddr</code>	[IN] Pointer to an array of <code>IP_SMTPC_MAIL_ADDR</code> structures. Refer to <i>Structure IP_SMTPC_MAIL_ADDR</i> on page 234 for detailed information about the elements of the <code>IP_SMTPC_MAIL_ADDR</code> structure. The first element of the array has to be filled with the data of the sender (FROM). The order of the following data sets for recipients (TO), carbon copies (CC) and blind carbon copies (BCC) is not relevant.
<code>NumMailAddr</code>	[IN] Number of email addresses.
<code>pMessage</code>	[IN] Pointer to an array of <code>IP_SMTPC_MESSAGE</code> structures. Refer to <i>Structure IP_SMTPC_MESSAGE</i> on page 236 for detailed information about the elements of the <code>IP_SMTPC_MESSAGE</code> structure.
<code>pMTA</code>	[IN] Pointer to an array of <code>IP_SMTPC_MTA</code> structures. Refer to <i>Structure IP_SMTPC_MTA</i> on page 237 for detailed information about the elements of the <code>IP_SMTPC_MTA</code> structure.
<code>pApplication</code>	[IN] Pointer to an array of <code>IP_SMTPC_APPLICATION</code> structures. Refer to <i>Structure IP_SMTPC_APPLICATION</i> on page 233 for detailed information about the elements of the <code>IP_SMTPC_APPLICATION</code> structure.

**Table 12.2:** IP\_SMTPC\_Send() parameter list

### Return value

- 0 OK.
- 1 Error.

## 12.7 SMTP client data structures

Function	Description
<a href="#">IP_SMTPC_API</a>	Structure with pointers to the required socket interface functions.
<a href="#">IP_SMTPC_APPLICATION</a>	Structure with application related elements.
<a href="#">IP_SMTPC_MAIL_ADDR</a>	Structure to store the mail addresses.
<a href="#">IP_SMTPC_MESSAGE</a>	Structure defining the message format.
<a href="#">IP_SMTPC_MTA</a>	Structure to store the login information for the mail transfer agent.

**Table 12.3: embOS/IP SMTP client interface function overview**

## 12.7.1 Structure IP\_SMTPC\_API

### Description

Structure with pointers to the required socket interface functions.

### Prototype

```
typedef struct {
    SMTPC_SOCKET (*pfConnect)    (char * SrvAddr);
    void          (*pfDisconnect) (SMTPC_SOCKET Socket);
    int           (*pfSend)       (const char *      pData,
                                   int              Len,
                                   SMTPC_SOCKET Socket);

    int           (*pfReceive)    (char *          pData,
                                   int              Len,
                                   SMTPC_SOCKET Socket);
} IP_SMTPC_API;
```

Member	Description
<a href="#">pfConnect</a>	Pointer to the function (for example, <code>connect()</code> ).
<a href="#">pfDisconnect</a>	Pointer to the disconnect function (for example, <code>closesocket()</code> ).
<a href="#">pfSend</a>	Pointer to a callback function (for example, <code>send()</code> ).
<a href="#">pfReceive</a>	Pointer to a callback function (for example, <code>recv()</code> ).

**Table 12.4:** Structure IP\_SMTPC\_API member list

### Example

```
/******
 *
 *      _Connect
 *
 *  Function description
 *  Creates a socket and opens a TCP connection to the mail host.
 */
static SMTPC_SOCKET _Connect(char * SrvAddr) {
    long IP;
    long Sock;
    struct hostent * pHostEntry;
    struct sockaddr_in sin;
    int r;
    //
    // Convert host into mail host
    //
    pHostEntry = gethostbyname(SrvAddr);
    if (pHostEntry == NULL) {
        SMTPC_LOG(("gethostbyname failed: %s\r\n", SrvAddr));
        return NULL;
    }
    IP = *(unsigned*)(*pHostEntry->h_addr_list);
    //
    // Create socket and connect to mail server
    //
    Sock = socket(AF_INET, SOCK_STREAM, 0);
    if(Sock == -1) {
        SMTPC_LOG(("Could not create socket!"));
        return NULL;
    }
    IP_MEMSET(&sin, 0, sizeof(sin));
    sin.sin_family = AF_INET;
    sin.sin_port = htons(SERVER_PORT);
    sin.sin_addr.s_addr = IP;
    r = connect(Sock, (struct sockaddr*)&sin, sizeof(sin));
    if(r == SOCKET_ERROR) {
```

```

    SMTPC_LOG(("Socket error :"));
    return NULL;
}
SMTPC_LOG(("APP: Connected.\r\n"));
return (SMTPC_SOCKET)Sock;
}

/*****
 *
 *    _Disconnect
 *
 * Function description
 * Closes a socket.
 */
static void _Disconnect(SMTPC_SOCKET Socket) {
    closesocket((long)Socket);
}

/*****
 *
 *    _Send
 *
 * Function description
 * Sends data via socket interface.
 */
static int _Send(const char * buf, int len, void * pConnectionInfo) {
    return send((long)pConnectionInfo, buf, len, 0);
}

/*****
 *
 *    _Recv
 *
 * Function description
 * Receives data via socket interface.
 */
static int _Recv(char * buf, int len, void * pConnectionInfo) {
    return recv((long)pConnectionInfo, buf, len, 0);
}

static const IP_SMTPC_API _IP_Api = {
    _Connect,
    _Disconnect,
    _Send,
    _Recv
};
};

```

## 12.7.2 Structure IP\_SMTPC\_APPLICATION

### Description

Structure with pointers to application related functions.

### Prototype

```
typedef struct {
    U32 (*pfGetTimeDate) (void);
    int (*pfCallback)(int Stat, void *p);
    const char * sDomain;    // email domain
} IP_SMTPC_APPLICATION;
```

Member	Description
<a href="#">pfGetTimeDate</a>	Pointer to the function which returns the current system time. Used to set the correct date and time of the email.
<a href="#">pfCallback</a>	Pointer to status callback function. Can be NULL.
<a href="#">sDomain</a>	Domain name. For example, <i>sample.com</i> . According to RFC 821 the maximum total length of a domain name or number is 64 characters.

**Table 12.5: Structure IP\_SMTPC\_APPLICATION member list**

### Example

```
*****
*
*     _GetTimeDate
*/
static U32 _GetTimeDate(void) {
    U32 r;
    U16 Sec, Min, Hour;
    U16 Day, Month, Year;

    Sec   = 0;           // 0 based. Valid range: 0..59
    Min   = 0;           // 0 based. Valid range: 0..59
    Hour  = 0;           // 0 based. Valid range: 0..23
    Day   = 1;           // 1 based. Means that 1 is 1.
                        // Valid range is 1..31 (depending on month)
    Month = 1;           // 1 based. Means that January is 1. Valid range is 1..12.
    Year  = 28;           // 1980 based. Means that 2008 would be 28.
    r     = Sec / 2 + (Min << 5) + (Hour << 11);
    r    |= (U32)(Day + (Month << 5) + (Year << 9)) << 16;
    return r;
}

*****
*
*     _Application
*/
static const SMTPC_APPLICATION _Application = {
    _GetTimeDate,
    NULL,
    "sample.com"    // Your domain.
};
```

## 12.7.3 Structure IP\_SMTPC\_MAIL\_ADDR

### Description

Structure to store an email address.

### Prototype

```
typedef struct {
    const char * sName;
    const char * sAddr;
    int Type;
} IP_SMTPC_MAIL_ADDR;
```

Member	Description
sName	Name of the recipient (for example, "Foo Bar"). Can be NULL.
sAddr	email address of the recipient (for example, "foo@bar.com").
Type	Type of the email address.

**Table 12.6:** Structure IP\_SMTPC\_MAIL\_ADDR member list

### Valid values for parameter Type

Value	Description
SMTPC_REC_TYPE_FROM	email address of the sender (FROM).
SMTPC_REC_TYPE_TO	email address of the recipient (TO).
SMTPC_REC_TYPE_CC	email address of a recipient which should get a carbon copy (CC) of the email.
SMTPC_REC_TYPE_BC	email address of a recipient which should get a blind carbon copy (BCC) of the email.

### Additional information

The structure is used to store the data sets of the sender and all recipients. IP\_SMTPC\_Send() gets a pointer to an array of IP\_SMTPC\_MAIL\_ADDR structures as parameter. The first element of these array has to be filled with the data of the sender (FROM). The order of the following data sets for Recipients (TO), Carbon Copies (CC) and Blind Carbon Copies (BCC) is not relevant. For detailed information about IP\_SMTPC\_Send() refer to *IP\_SMTPC\_Send()* on page 229.

### Example

```
/******
 *
 *      Mailer
 */
static void _Mailer(void) {
    SMTPC_MAIL_ADDR MailAddr[4];
    SMTPC_MTA Mta;
    SMTPC_MESSAGE Message;

    IP_MEMSET(&MailAddr, 0, sizeof(MailAddr));
    //
    // Sender
    //
    MailAddr[0].sName = 0; // for example, "Your name";
    MailAddr[0].sAddr = 0; // for example, "user@foobar.com";
    MailAddr[0].Type = SMTPC_REC_TYPE_FROM;
    //
    // Recipient(s)
    //
    MailAddr[1].sName = 0; // "Recipient";
    MailAddr[1].sAddr = 0; // "recipient@foobar.com";
    MailAddr[1].Type = SMTPC_REC_TYPE_TO;
```

```

MailAddr[2].sName = 0; // "CC Recp 1";
MailAddr[2].sAddr = 0; // "cc1@foobar.com";
MailAddr[2].Type = SMTPC_REC_TYPE_CC;
MailAddr[3].sName = 0; // "BCC Recp 1"
MailAddr[3].sAddr = 0; // "bcc1@foobar.com";;
MailAddr[3].Type = SMTPC_REC_TYPE_BCC;
//
// Message
//
Message.sSubject = "SMTP message sent via embOS/IP SMTP client";
Message.sBody = "embOS/IP SMTP client - www.segger.com";
//
// Fill mail transfer agent structure
//
Mta.sServer = 0; // for example, "mail.foobar.com";
Mta.sUser = 0; // for example, "user@foobar.com";
Mta.sPass = 0; // for example, "password";
//
// Check if sample is configured!
//
if(Mta.sServer == 0) {
    SMTPC_WARN(("You have to enter valid SMTP server, sender and recipi-
ent(s).\r\n"));
    while(1);
}
//
// Wait until link is up. This can take 2-3 seconds if PHY has been reset.
//
while (IP_IFaceIsReady() == 0) {
    OS_Delay(100);
}
SMTPC_Send(&_IP_Api, &MailAddr[0], 4, &Message, &Mta, &Application);
while(1);
}

```

## 12.7.4 Structure IP\_SMTPC\_MESSAGE

### Description

Structure to store the subject and the text of the email.

### Prototype

```
typedef struct {  
    const char    * sSubject;  
    const char    * sBody;  
    int           MessageSize;  
} IP_SMTPC_MESSAGE;
```

Member	Description
<a href="#">sSubject</a>	Pointer to the string used as subject of the email.
<a href="#">sBody</a>	Pointer to the string used as message of the email.
<a href="#">MessageSize</a>	Size of the message.

**Table 12.7: Structure IP\_SMTPC\_MESSAGE member list**

## 12.7.5 Structure IP\_SMTPC\_MTA

### Description

Structure to store the server address and the login information.

### Prototype

```
typedef struct {
    const char * sServer;
    const char * sUser;
    const char * sPass;
} IP_SMTPC_MTA;
```

Member	Description
<code>sServer</code>	Server address (for example, "mail.foobar.com").
<code>sUser</code>	Account user name (for example, "foo@bar.com"). Can be <code>NULL</code> .
<code>sPass</code>	Account password (for example, "password"). Can be <code>NULL</code> .

**Table 12.8: Structure IP\_SMTPC\_MTA member list**

### Additional information

The parameters `sUser` and `sPass` have to be `NULL` if no authentication is used by the server. If `sUser` is set in the application code, the client tries to use authentication. This means that the client sends the `AUTH LOGIN` command to the server. If the server does not support authentication, he will return an error code and the client closes the session.

## 12.8 Resource usage

The ROM usage depends on the compiler options, the compiler version and the used CPU. The memory requirements of the SMTP client presented in the tables below have been measured on a system as follows: ARM7, IAR Embedded Workbench V5.11, Thumb mode, Size optimization.

### Configuration used

```
#define SMTPC_OUT_BUFFER_SIZE 256
```

### 12.8.1 ROM usage

Add-on	ROM [Kbytes]
embOS/IP SMTP client	TBD

### 12.8.2 RAM usage:

Almost all of the RAM used by the SMTP client is taken from task stacks.

Task	Description	RAM [bytes]
		TBD

# Chapter 13

## FTP server (Add-on)

---

The embOS/IP FTP server is an optional extension to the TCP/IP stack. The FTP server can be used with embOS/IP or with a different TCP/IP stack. All functions which are required to add a FTP server task to your application are described in this chapter.

## 13.1 embOS/IP FTP server

The embOS/IP FTP server is an optional extension which adds the FTP protocol to the stack. FTP stands for File Transfer Protocol. It is the basic mechanism for moving files between machines over TCP/IP based networks such as the Internet. FTP is a client/server protocol, meaning that one machine, the client, initiates a file transfer by contacting another machine, the server and making requests. The server must be operating before the client initiates his requests. Generally a client communicates with one server at a time, while most servers are designed to work with multiple simultaneous clients.

The FTP server implements the relevant parts of the following RFCs.

RFC#	Description
[RFC 959]	FTP - File Transfer Protocol Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc959.txt">ftp://ftp.rfc-editor.org/in-notes/rfc959.txt</a>

The following table shows the contents of the embOS/IP FTP server root directory:

Directory	Contents
Application\	Contains the example application to run the FTP server with embOS/IP.
Config	Contains the FTP server configuration file.
Inc	Contains the required include files.
IP	Contains the FTP server sources.
IP\FS\	Contains the sources for the file system abstraction layer and the read-only file system. Refer to <i>File system abstraction layer function table</i> on page 303 for detailed information.
Windows\FTPserver\	Contains the source, the project files and an executable to run embOS/IP FTP server on a Microsoft Windows host.

**Supplied directory structure of embOS/IP FTP server package**

## 13.2 Feature list

- Low memory footprint.
- Multiple connections supported.
- Independent of the file system: Any file system can be used.
- Independent of the TCP/IP stack: Any stack with sockets can be used.
- Demo application included.
- Project for executable on PC for Microsoft Visual Studio included.

## 13.3 Requirements

### **TCP/IP stack**

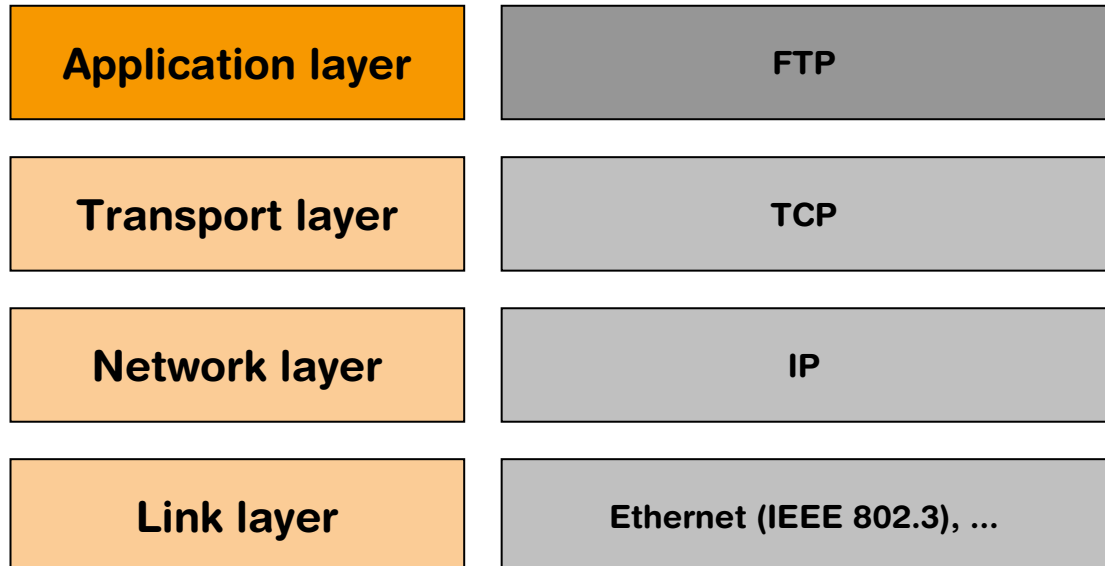
The embOS/IP FTP server requires a TCP/IP stack. It is optimized for embOS/IP, but any RFC-compliant TCP/IP stack can be used. The shipment includes a Win32 simulation, which uses the standard Winsock API and an implementation which uses the socket API of embOS/IP.

### **Multi tasking**

The FTP server needs to run as a separate thread. Therefore, a multi tasking system is required to use the embOS/IP FTP server.

## 13.4 FTP basics

The File Transfer Protocol (FTP) is an application layer protocol. FTP is an unusual service in that it utilizes two ports, a 'Data' port and a 'CMD' (command) port. Traditionally these are port 21 for the command port and port 20 for the data port. FTP can be used in two modes, active and passive. Depending on the mode, the data port is not always on port 20.



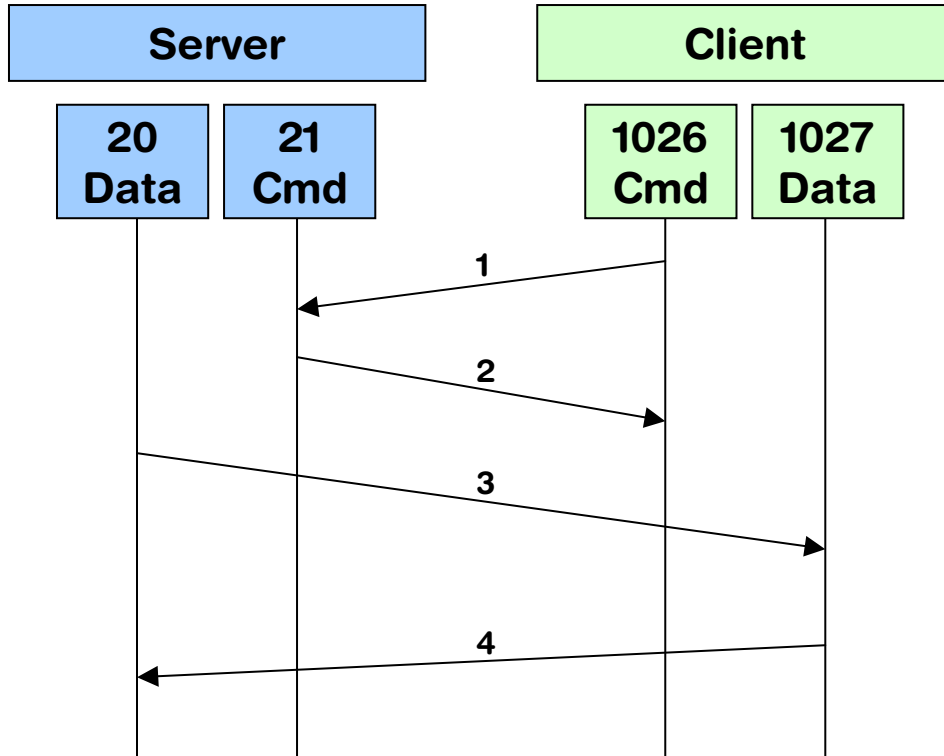
When an FTP client contacts a server, a TCP connection is established between the two machines. The server does a passive open (a socket is listen) when it begins operation; thereafter clients can connect with the server via active opens. This TCP connection persists for as long as the client maintains a session with the server, (usually determined by a human user) and is used to convey commands from the client to the server, and the server replies back to the client. This connection is referred to as the FTP command connection.

The FTP commands from the client to the server consist of short sets of ASCII characters, followed by optional command parameters. For example, the FTP command to display the current working directory is `PWD` (Print Working Directory). All commands are terminated by a carriage return-linefeed sequence (CRLF) (ASCII 10,13; or Ctrl-J, Ctrl-M). The servers replies consist of a 3 digit code (in ASCII) followed by some explanatory text. Generally codes in the 200s are success and 500s are failures. See the RFC for a complete guide to reply codes. Most FTP clients support a verbose mode which will allow the user to see these codes as commands progress.

If the FTP command requires the server to move a large piece of data (like a file), a second TCP connection is required to do this. This is referred to as the FTP data connection (as opposed to the aforementioned command connection). In active mode the data connection is opened by the server back to a listening client. In passive mode the client opens also the data connection. The data connection persists only for transporting the required data. It is closed as soon as all the data has been sent.

### 13.4.1 Active mode FTP

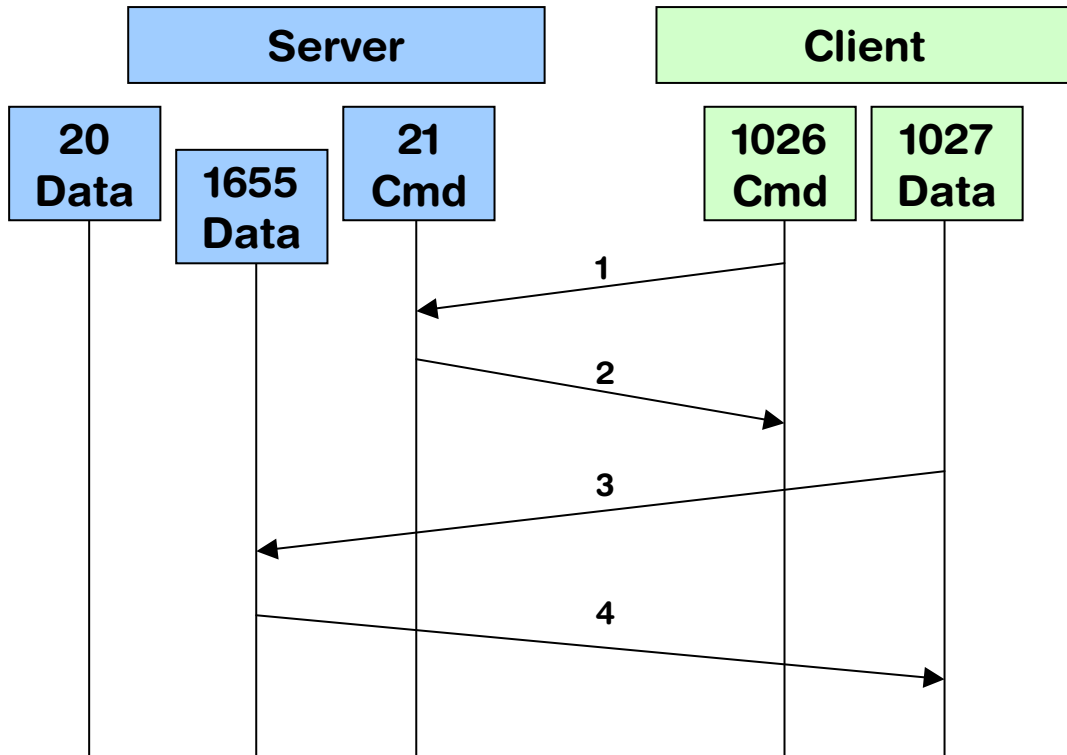
In active mode FTP the client connects from a random unprivileged port  $P$  ( $P > 1023$ ) to the FTP server's command port, port 21. Then, the client starts listening to port  $P+1$  and sends the FTP command `PORT P+1` to the FTP server. The server will then connect back to the client's specified data port from its local data port, which is port 20.



## 13.4.2 Passive mode FTP

In passive mode FTP the client connects from a random unprivileged port P ( $P > 1023$ ) to the FTP server's command port, port 21. In opposite to an active mode FTP connection where the client opens a passive port for data transmission and waits for the connection from server-side, the client sends in passive mode the "PASV" command to the server and expects an answer with the information on which port the server is listening for the data connection.

After receiving this information, the client connects to the specified data port of the server from its local data port.



### 13.4.3 FTP reply codes

Every FTP command is answered by one or more reply codes defined in [RFC 959]. A reply is an acknowledgment (positive or negative) sent from server to user via the control connection in response to FTP commands. The general form of a reply is a 3-digit completion code (including error codes) followed by Space <SP>, followed by one line of text and terminated by carriage return line feed <CRLF>. The codes are for use by programs and the text is usually intended for human users.

The first digit of the reply code defines the class of response. There are 5 values for the first digit:

- 1yz: Positive preliminary reply
- 2yz: Positive completion reply
- 3yz: Positive intermediate reply
- 4yz: Transient negative Completion reply
- 5yz: Permanent negative Completion reply

The second digit of the reply code defines the group of the response.

- x0z: Syntax - Syntax errors, syntactically correct commands that don't fit any functional category, unimplemented or superfluous commands.
- x1z: Information - These are replies to requests for information, such as status or help.
- x2z: Connections - Replies referring to the control and data connections.
- x3z: Authentication and accounting - Replies for the login process and accounting procedures.
- x4z: Unspecified as yet.
- x5z: File system - These replies indicate the status of the Server file system vis-a-vis the requested transfer or other file system action.

The third digit gives a finer gradation of meaning in each of the function categories, specified by the second digit.

## 13.4.4 Supported FTP commands

embOS/IP FTP server supports a subset of the defined FTP commands. Refer to [RFC 959] for a complete detailed description of the FTP commands. The following FTP commands are implemented:

FTP commands	Description
CDUP	Change to parent directory
CWD	Change working directory
DELE	Delete
LIST	List
MKD	Make directory
NLST	Name list
NOOP	No operation
PASS	Password
PASV	Passive
PORT	Data port
PWD	Print the current working directory
RETR	Retrieve
RMD	Remove directory
SIZE	Size of file
STOR	Store
SYST	System
TYPE	Representation type
USER	User name
XCUP	Change to parent directory
XMKD	Make directory
XPWD	Print the current working directory
XRMD	Remove directory

**Table 13.1: embOS/IP FTP commands**

## 13.5 Using the FTP server sample

Ready to use examples for Microsoft Windows and embOS/IP are supplied. If you use another TCP/IP stack the sample `OS_IP_FTPServer.c` has to be adapted. The sample application opens a port which listens on port 21 until an incoming connection is detected. If a connection has been established `IP_FTPTS_Process()` handles the client request in an extra task, so that the server is further listening on port 21. The example application requires a file system to make data files available. Refer to *File system abstraction layer* on page 302 and *File system abstraction layer* on page 302 for detailed information.

### 13.5.1 Using the Windows sample

If you have MS Visual C++ 6.00 or any later version available, you will be able to work with a Windows sample project using embOS/IP FTP server. If you do not have the Microsoft compiler, a precompiled executable of the FTP server is also supplied. The base directory of the Windows sample application is `C:\FTP\`.

#### Building the sample program

Open the workspace `Start_FTPServer.dsw` with MS Visual Studio (for example, double-clicking it). There is no further configuration necessary. You should be able to build the application without any error or warning message.

The server uses the IP address of the host PC on which it runs. Open a FTP client and connect by entering the IP address of the host (`127.0.0.1`) to connect to the FTP server. The server accepts anonymous logins. You can also login with the user name "Admin" and the password "Secret".

### 13.5.2 Running the FTP server example on target hardware

The embOS/IP FTP server sample application should always be the first step to check the proper function of the FTP server with your target hardware.

Add all source files located in the following directories (and their subdirectories) to your project and update the include path:

- Application
- Config
- Inc
- IP
- IP\IP\_FS\[NameOfUsedFileSystem]

It is recommended that you keep the provided folder structure.

The sample application can be used on the most targets without the need for changing any of the configuration flags. The server processes two connections using the default configuration.

**Note:** Two connections mean that the target can handle up one target. A target requires always two connection, one for the command transfer and one for the data transfers. Every connection is handled in an separate task. Therefore, the FTP server uses up to three tasks in the default configuration. One task which listens on port 21 and accepts connections and two tasks to process the accepted connection. To modify the number of connections only the macro `MAX_CONNECTIONS` has to be modified.

## 13.6 Access control

The embOS/IP FTP server supports a fine-grained access permission scheme. Access permissions can be defined on user-basis for every directory. The access permission of a directory is a combination of the following attributes: visible, readable and writable. To control the access permission three callback functions have to be implemented in the user application. The callback functions are defined in the structure `FTPS_ACCESS_CONTROL`. For detailed information about this structure, refer to *Structure FTPS\_ACCESS\_CONTROL* on page 259.

### 13.6.1 pfFindUser()

#### Description

Callback function which checks if the user is valid.

#### Prototype

```
int (*pfFindUser) ( const char * sUser );
```

#### Return value

0 - UserID invalid or unknown  
 0 < - UserID, no password required  
 0 > - UserID, password required

#### Parameter

Parameter	Description
<code>sUser</code>	[IN] User name.

**Table 13.2: pfFindUser() parameter list**

#### Example

```
enum {
    USER_ID_ANONYMOUS = 1,
    USER_ID_ADMIN
};

/*****
 *
 *      _FindUser
 *
 * Function description
 *   Callback function for user management.
 *   Checks if user name is valid.
 *
 * Return value
 *   0   UserID invalid or unknown
 *   > 0   UserID, no password required
 *   < 0   - UserID, password required
 */
static int _FindUser (const char * sUser) {
    if (strcmp(sUser, "Admin") == 0) {
        return - USER_ID_ADMIN;
    }
    if (strcmp(sUser, "anonymous") == 0) {
        return USER_ID_ANONYMOUS;
    }
    return 0;
}
```

## 13.6.2 pfCheckPass()

### Description

Callback function which checks if the password is valid.

### Prototype

```
int (*pfCheckPass) (      int    UserId,
                    const char * sPass );
```

### Parameter

Parameter	Description
UserId	[IN] Id number
Pass	[IN] Password string.

**Table 13.3: pfCheckPass() parameter list**

### Example

```
enum {
    USER_ID_ANONYMOUS = 1,
    USER_ID_ADMIN
};

/*****
 *
 *      _CheckPass
 *
 * Function description
 * Callback function for user management.
 * Checks user password.
 *
 * Return value
 * 0   UserID know, password valid
 * 1   UserID unknown or password invalid
 */
static int _CheckPass (int UserId, const char * sPass) {
    if ((UserId == USER_ID_ADMIN) && (strcmp(sPass, "Secret") == 0)) {
        return 0;
    } else {
        return 1;
    }
}
```

## 13.6.3 pfGetDirInfo()

### Description

Callback function which checks the permissions of the connected user for every directory.

### Prototype

```
int (*pfGetDirInfo) (      int    UserId,
                        const char * sDirIn,
                        char * pDirOut,
                        int    SizeOfDirOut );
```

### Parameter

Parameter	Description
UserId	[IN]
sDirIn	[IN]
pDirOut	[OUT]
SizeOfDirOut	[IN] Size of

**Table 13.4: pfGetDirInfo() parameter list**

### Additional information

### Example

```
/* Excerpt from IP_FTPServer.h */
#define IP_FTPS_PERM_VISIBLE (1 << 0)
#define IP_FTPS_PERM_READ (1 << 1)
#define IP_FTPS_PERM_WRITE (1 << 2)

/* Excerpt from OS_IP_FTPServer.c */
/*****
 *
 *      _GetDirInfo
 *
 *      Function description
 *      Callback function for user management.
 *      Checks user authorizations.
 *
 *      Return value
 *      Returns a combination of the following:
 *      IP_FTPS_PERM_LIST
 *      IP_FTPS_PERM_READ
 *      IP_FTPS_PERM_WRITE
 */
static int _GetDirInfo (int UserId, const char * sDirIn, char * sDirOut, int DirOut-
Size) {
    int Perm;

    Perm = IP_FTPS_PERM_VISIBLE | IP_FTPS_PERM_READ | IP_FTPS_PERM_WRITE;
    if (strcmp(sDirIn, "ReadOnly") == 0) {
        Perm = IP_FTPS_PERM_VISIBLE | IP_FTPS_PERM_READ;
    }
    if (strcmp(sDirIn, "NotReadable") == 0) {
        Perm = IP_FTPS_PERM_VISIBLE;
    }
    if (strcmp(sDirIn, "Admin") == 0) {
        if (UserId != USER_ID_ADMIN) {
            return 0;    // Only Admin is allowed for this directory
        }
    }
    if (sDirOut == NULL) {
```

```
    return Perm;
}
if ((int)strlen(sDirIn) >= DirOutSize) {
    return 0;    // Does not fit
}
strcpy(sDirOut, sDirIn);
return Perm;
}
```

## 13.7 Configuration

The embOS/IP FTP server can be used without changing any of the compile time flags. All compile time configuration flags are preconfigured with valid values, which match the requirements of most applications.

The following types of configuration macros exist:

### Binary switches "B"

Switches can have a value of either 0 or 1, for deactivated and activated respectively. Actually, anything other than 0 works, but 1 makes it easier to read a configuration file. These switches can enable or disable a certain functionality or behavior. Switches are the simplest form of configuration macros.

### Numerical values "N"

Numerical values are used somewhere in the source code in place of a numerical constant. A typical example is the configuration of the sector size of a storage medium.

### Alias "A"

A macro which operates like a simple text substitute. An example would be the define `U8`, which the preprocessor would replace with `unsigned char`.

### Function replacements "F"

Macros can basically be treated like regular functions although certain limitations apply, as a macro is still put into the source code as simple text replacement. Function replacements are mainly used to add specific functionality to a module which is highly hardware-dependent. This type of macro is always declared using brackets (and optional parameters).

### 13.7.1 Compile time configuration switches

Type	Symbolic name	Default	Description
F	<code>FTPS_WARN</code>	--	Defines a function to output warnings. In debug configurations ( <code>DEBUG == 1</code> ) <code>FTPS_WARN</code> maps to <code>IP_Warnf_Application()</code>
F	<code>FTPS_LOG</code>	--	Defines a function to output logging messages. In debug configurations ( <code>DEBUG == 1</code> ) <code>FTPS_LOG</code> maps to <code>IP_Logf_Application()</code> .
N	<code>FTPS_AUTH_BUFFER_SIZE</code>	32	Defines the size of the buffer used for the authentication string.
N	<code>FTPS_BUFFER_SIZE</code>	512	Defines the size of the send and receive buffer of the FTP server.
N	<code>FTPS_MAX_PATH</code>	128	Defines the maximum length of the buffer used for the path string.
N	<code>FTPS_MAX_PATH_DIR</code>	64	Defines the maximum length of the buffer used for the directory string.
N	<code>FTPS_ERR_BUFFER_SIZE</code>	256	Defines the size of the buffer used for the authentication string.

## 13.7.2 FTP server system time

The FTP server requires a system time for the transmission of a complete file timestamp. FTP servers send only a piece of the timestamp of a file, either month, day and year or month, day and time. For the decision which pieces of the timestamp has to be transmitted, it compares the year of the current system time with the year which is stored in the timestamp of the file. Depending on the result of this comparison either the year or the time will be sent. The following two examples show the output for both cases.

### Example

1. If the value for year in the timestamp of the file is smaller then the value for year in the current system time, year will be sent:

```
-rw-r--r-- 1 root 2000 Jan 1 2007 PAKET00.TXT
```

In this case, the FTP client leaves this column empty or fills the missing time with 00:00. The following screenshot shows the output of the Microsoft Windows command line FTP client:

```
-rw-r--r-- 1 root 5072 Jan 1 1980 PAKET00.TXT
```

2. If the value for year in the timestamp of the file is identical to the value for year in the current system time, the time (HH:MM) will be sent:

```
-rw-r--r-- 1 root 1000 Jul 29 11:04 PAKET01.TXT
```

In this case, the FTP client leaves this column empty or fills the missing year with the current year. The following screenshot shows the output of the Microsoft Windows command line FTP client:

```
-rw-r--r-- 1 root 5070 Jul 29 11:04 PAKET01.TXT
```

In the example, the value for the current time and date is defined to 1980-01-01 00:00. Therefore, the output will be similar to example 1., since no real time clock (RTC) has been implemented. Refer to *pfGetTimeDate()* on page 255 for detailed information.

### 13.7.2.1 pfGetTimeDate()

#### Description

Returns the current system time.

#### Prototype

```
int (*pfGetTimeDate) ( void );
```

#### Return value

Current system time. If no real time clock is implemented, it should return 0x00210000 (1980-01-01 00:00)

#### Additional information

The format of the time is arranged as follows:

Bit 0-4: 2-second count (0-29)

Bit 5-10: Minutes (0-59)

Bit 11-15: Hours (0-23)

Bit 16-20: Day of month (1-31)

Bit 21-24: Month of year (1-12)

Bit 25-31: Number of years since 1980 (0-127)

This function pointer is used in the `FTPS_APPLICATION` structure. Refer to *Structure FTPS\_APPLICATION* on page 260 for further information.

#### Example

```
static U32 _GetTimeDate(void) {
    U32 r;
    U16 Sec, Min, Hour;
    U16 Day, Month, Year;

    Sec   = 0;           // 0 based. Valid range: 0..59
    Min   = 0;           // 0 based. Valid range: 0..59
    Hour  = 0;           // 0 based. Valid range: 0..23
    Day   = 1;           // 1 based. Means that 1 is 1.
                        // Valid range is 1..31 (depending on month)
    Month = 1;           // 1 based. Means that January is 1. Valid range is 1..12.
    Year  = 28;           // 1980 based. Means that 2008 would be 28.
    r     = Sec / 2 + (Min << 5) + (Hour << 11);
    r    |= (U32)(Day + (Month << 5) + (Year << 9)) << 16;
    return r;
}
```

## 13.8 API functions

Function	Description
<code>IP_FTPS_Process()</code>	Initializes and starts the embOS/IP FTP server.
<code>IP_FTPS_OnConnectionLimit()</code>	Returns when the connection is closed or a fatal error occurs.

**Table 13.5: embOS/IP FTP server interface function overview**

## 13.8.1 IP\_FTPS\_Process()

### Description

Initializes and starts the FTP server.

### Prototype

```
int IP_FTPS_Process ( const IP_FTPS_API      * pIP_API,
                    void                    * pConnectInfo,
                    const IP_FS_API         * pFS_API,
                    const FTPS_APPLICATION * pApplication );
```

### Parameter

Parameter	Description
<a href="#">pIP_API</a>	[IN] Pointer to a structure of type IP_FTPS_API.
<a href="#">pConnectInfo</a>	[IN] Pointer to the connection info.
<a href="#">pFS_API</a>	[IN] Pointer to the used file system API.
<a href="#">pApplication</a>	[IN] Pointer to a structure of type FTPS_APPLICATION.

**Table 13.6: IP\_FTPS\_Process() parameter list**

### Additional information

The structure type IP\_FTPS\_API contains mappings of the required socket functions to the actual IP stack. This is required because the socket functions are slightly different on different systems. The connection info is the socket which was created when the client has been connected to the command port (usually port 21). For detailed information about the structure type IP\_FS\_API refer to *Appendix A - File system abstraction layer* on page 301. For detailed information about the structure type FTPS\_APPLICATION refer to *Structure FTPS\_APPLICATION* on page 260.

## 13.8.2 IP\_FTPS\_OnConnectionLimit()

### Description

Returns when the connection is closed or a fatal error occurs.

### Prototype

```
void IP_FTPS_OnConnectionLimit( const IP_FTPS_API * pIP_API,  
                               void             * CtrlSock );
```

### Parameter

Parameter	Description
<code>pIP_API</code>	[IN] Pointer to a structure of type <code>IP_FTPS_API</code> .
<code>CtrlSock</code>	[IN] Pointer to the socket which is related to the command connection.

**Table 13.7: IP\_FTPS\_OnConnectionLimit() parameter list**

### Additional information

The structure type `IP_FTPS_API` contains mappings of the required socket functions to the actual IP stack. This is required because the socket functions are slightly different on different systems.

## 13.9 FTP server data structures

### 13.9.1 Structure FTPS\_ACCESS\_CONTROL

#### Description

This structure contains the pointer to the access control callback functions.

#### Prototype

```
typedef struct {
    int (*pfFindUser) ( const char * sUser );
    int (*pfCheckPass) (      int      UserId,
                          const char * sPass );
    int (*pfGetDirInfo) (      int      UserId,
                             const char * sDirIn,
                             char * sDirOut,
                             int      SizeOfDirOut );
} FTPS_ACCESS_CONTROL;
```

Member	Description
<a href="#">pfFindUser</a>	Callback function that checks if the user is valid.
<a href="#">pfCheckPass</a>	Callback function that checks if the password is valid.
<a href="#">pfGetDirInfo</a>	Callback function that checks the permissions of the connected user for every directory.

**Table 13.8: Structure FTPS\_ACCESS\_CONTROL member list**

#### Example

Refer to *Access control* on page 249 for an example.

## 13.9.2 Structure FTPS\_APPLICATION

### Description

Used to store application specific parameters.

### Prototype

```
typedef struct {
    FTPS_ACCESS_CONTROL * pAccess;
    U32 (*pfGetTimeDate) (void);
} FTPS_APPLICATION;
```

Member	Description
<a href="#">pAccess</a>	Pointer to the FTPS_ACCESS_APPLICATION structure.
<a href="#">pfGetTimeDate</a>	Pointer to the function which returns the current system time.

**Table 13.9: Structure FTPS\_APPLICATION member list**

### Example

For additional information to structure FTPS\_ACCESS\_APPLICATION refer to *Structure FTPS\_ACCESS\_CONTROL* on page 259. For additional information to function pointer `pfGetTimeDate()` refer to *FTP server system time* on page 254.

### Example

```
/* Excerpt from OS_IP_FTPServer.c */

/*****
 *
 *      FTPS_ACCESS_CONTROL
 *
 * Description
 * User/pass data table
 */
static FTPS_ACCESS_CONTROL _Access_Control = {
    _FindUser,
    _CheckPass,
    _GetDirInfo
};

/*****
 *
 *      _GetTimeDate
 */
static U32 _GetTimeDate(void) {
    U32 r;
    U16 Sec, Min, Hour;
    U16 Day, Month, Year;

    Sec = 0;          // 0 based. Valid range: 0..59
    Min = 0;          // 0 based. Valid range: 0..59
    Hour = 0;         // 0 based. Valid range: 0..23
    Day = 1;          // 1 based. Means that 1 is 1.
                        // Valid range is 1..31 (depending on month)
    Month = 1;        // 1 based. Means that January is 1. Valid range is 1..12.
    Year = 28;        // 1980 based. Means that 2008 would be 28.
    r = Sec / 2 + (Min << 5) + (Hour << 11);
    r |= (U32)(Day + (Month << 5) + (Year << 9)) << 16;
    return r;
}

/*****
 *
 *      FTPS_APPLICATION
 *
 * Description
 * Application data table, defines all application specifics
 * used by the FTP server
 */
static const FTPS_APPLICATION _Application = {
    &_Access_Control,
    _GetTimeDate
};
```

## 13.10 Resource usage

The ROM usage depends on the compiler options, the compiler version and the used CPU. The memory requirements of the FTP server presented in the tables below have been measured on a system as follows: ARM7, IAR Embedded Workbench V5.11, Thumb mode, Size optimization.

### Configuration used

```
#define FTPTS_AUTH_BUFFER_SIZE    32
#define FTPTS_BUFFER_SIZE        128
#define FTPTS_MAX_PATH            128
#define FTPTS_MAX_PATH_DIR       64
#define FTPTS_ERR_BUFFER_SIZE    (FTPTS_BUFFER_SIZE / 2)
```

### 13.10.1 ROM usage

Add-on	ROM [Kbytes]
embOS/IP FTP server	6.8

### 13.10.2 RAM usage:

Almost all of the RAM used by the FTP server is taken from task stacks. The amount of RAM required for every child task depends on the configuration of your server.

Task	Description	RAM [bytes]
ParentTask	Listens for incoming connections.	500
ChildTask	Handles a request.	1800

**Note:** The FTP server requires at least 1 child task.

The approximately RAM usage for the FTP server can be calculated as follows:

RAM usage = 0.2 Kbytes + ParentTask + (NumberOfChildTasks \* 1.8 Kbytes)

#### Example: FTP server accepting up only 1 connection

RAM usage = 0.2 Kbytes + 0.5 Kbytes + (1 \* 1.8 Kbytes)

RAM usage = 2.5 Kbytes



# Chapter 14

## FTP client (Add-on)

---

The embOS/IP FTP client is an optional extension to the TCP/IP stack. The FTP client can be used with embOS/IP or with a different TCP/IP stack. All functions which are required to add a FTP client to your application are described in this chapter.

## 14.1 embOS/IP FTP client

The embOS/IP FTP client is an optional extension which adds the client part of FTP protocol to the stack. FTP stands for File Transfer Protocol. It is the basic mechanism for moving files between machines over TCP/IP based networks such as the Internet. FTP is a client/server protocol, meaning that one machine, the client, initiates a file transfer by contacting another machine, the server and making requests.

The FTP client implements the relevant parts of the following RFCs.

RFC#	Description
[RFC 959]	FTP - File Transfer Protocol Direct download: <a href="ftp://ftp.rfc-editor.org/in-notes/rfc959.txt">ftp://ftp.rfc-editor.org/in-notes/rfc959.txt</a>

The following table shows the contents of the embOS/IP FTP client root directory:

Directory	Contents
Application\	Contains the example application to run the FTP client with embOS/IP.
Config	Contains the FTP client configuration file.
Inc	Contains the required include files.
IP	Contains the FTP client sources.
IP\FS\	Contains the sources for the file system abstraction layer and the read-only file system. Refer to <i>File system abstraction layer function table</i> on page 303 for detailed information.
Windows\FTPclient\	Contains the source, the project files and an executable to run embOS/IP FTP client on a Microsoft Windows host.

**Supplied directory structure of embOS/IP FTP client package**

## 14.2 Feature list

- Low memory footprint.
- Multiple connections supported.
- Independent of the file system: Any file system can be used.
- Independent of the TCP/IP stack: Any stack with sockets can be used.
- Demo application included.
- Project for executable on PC for Microsoft Visual Studio included.

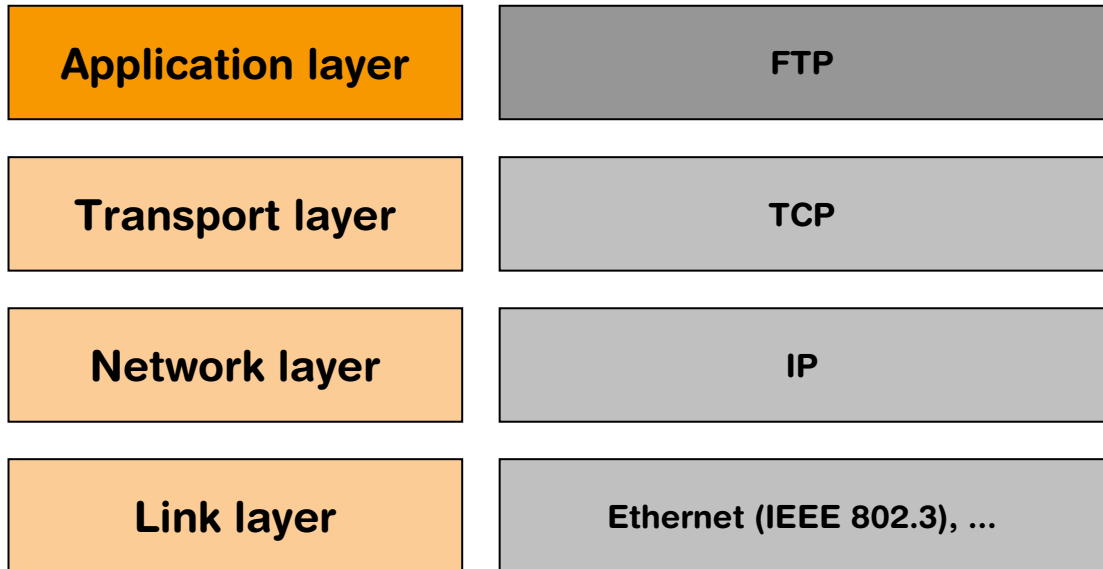
## 14.3 Requirements

### TCP/IP stack

The embOS/IP FTP client requires a TCP/IP stack. It is optimized for embOS/IP, but any RFC-compliant TCP/IP stack can be used. The shipment includes a Win32 simulation, which uses the standard Winsock API and an implementation which uses the socket API of embOS/IP.

## 14.4 FTP basics

The File Transfer Protocol (FTP) is an application layer protocol. FTP is an unusual service in that it utilizes two ports, a 'Data' port and a 'CMD' (command) port. Traditionally these are port 21 for the command port and port 20 for the data port. FTP can be used in two modes, active and passive. Depending on the mode, the data port is not always on port 20.



When an FTP client contacts a server, a TCP connection is established between the two machines. The server does a passive open (a socket is listen) when it begins operation; thereafter clients can connect with the server via active opens. This TCP connection persists for as long as the client maintains a session with the server, (usually determined by a human user) and is used to convey commands from the client to the server, and the server replies back to the client. This connection is referred to as the FTP command connection.

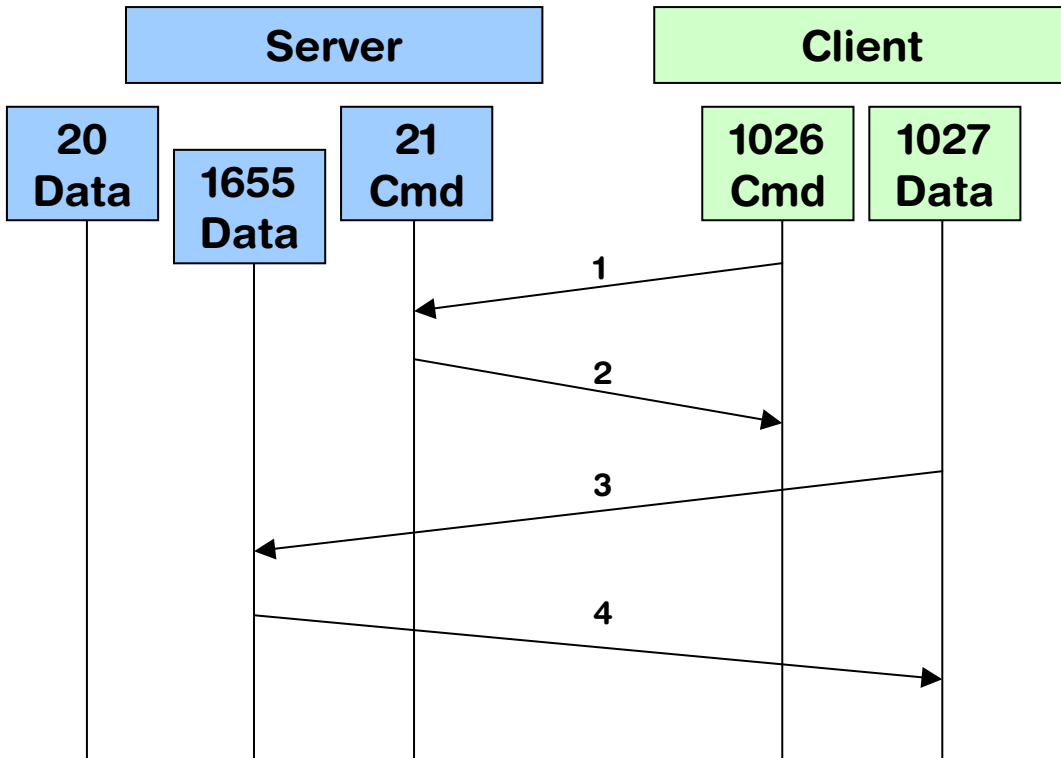
The FTP commands from the client to the server consist of short sets of ASCII characters, followed by optional command parameters. For example, the FTP command to display the current working directory is `PWD` (Print Working Directory). All commands are terminated by a carriage return-linefeed sequence (CRLF) (ASCII 10,13; or Ctrl-J, Ctrl-M). The servers replies consist of a 3 digit code (in ASCII) followed by some explanatory text. Generally codes in the 200s are success and 500s are failures. See the RFC for a complete guide to reply codes. Most FTP clients support a verbose mode which will allow the user to see these codes as commands progress.

If the FTP command requires the server to move a large piece of data (like a file), a second TCP connection is required to do this. This is referred to as the FTP data connection (as opposed to the aforementioned command connection). In active mode the data connection is opened by the server back to a listening client. In passive mode the client opens also the data connection. The data connection persists only for transporting the required data. It is closed as soon as all the data has been sent.

## 14.4.1 Passive mode FTP

In passive mode FTP the client connects from a random unprivileged port  $P$  ( $P > 1023$ ) to the FTP server's command port, port 21. In opposite to an active mode FTP connection where the client opens a passive port for data transmission and waits for the connection from server-side, the client sends in passive mode the "PASV" command to the server and expects an answer with the information on which port the server is listening for the data connection.

After receiving this information, the client connects to the specified data port of the server from its local data port.



**Note:** In the current version of embOS/IP, the FTP client supports only passive mode FTP. Active mode FTP will be added in one of the coming versions.

## 14.4.2 Supported FTP client commands

embOS/IP FTP client supports a subset of the defined FTP commands. Refer to [RFC 959] for a complete detailed description of the FTP commands. The following FTP commands are implemented:

FTP commands	Description
CDUP	Change to parent directory
CWD	Change working directory
PASS	Password
PASV	Passive
PWD	Print the current working directory
RETR	Retrieve
STOR	Store
SYST	System
TYPE	Representation type
USER	User name

**Table 14.1: embOS/IP FTP client commands**

## 14.5 Configuration

The embOS/IP FTP client can be used without changing any of the compile time flags. All compile time configuration flags are preconfigured with valid values, which match the requirements of most applications.

The following types of configuration macros exist:

### Binary switches "B"

Switches can have a value of either 0 or 1, for deactivated and activated respectively. Actually, anything other than 0 works, but 1 makes it easier to read a configuration file. These switches can enable or disable a certain functionality or behavior. Switches are the simplest form of configuration macros.

### Numerical values "N"

Numerical values are used somewhere in the source code in place of a numerical constant. A typical example is the configuration of the sector size of a storage medium.

### Alias "A"

A macro which operates like a simple text substitute. An example would be the define `U8`, which the preprocessor would replace with `unsigned char`.

### Function replacements "F"

Macros can basically be treated like regular functions although certain limitations apply, as a macro is still put into the source code as simple text replacement. Function replacements are mainly used to add specific functionality to a module which is highly hardware-dependent. This type of macro is always declared using brackets (and optional parameters).

### 14.5.1 Compile time configuration switches

Type	Symbolic name	Default	Description
F	<code>FTPS_WARN</code>	--	Defines a function to output warnings. In debug configurations ( <code>DEBUG == 1</code> ) <code>FTPS_WARN</code> should be mapped to <code>IP_Warnf_Application()</code>
F	<code>FTPS_LOG</code>	--	Defines a function to output logging messages. In debug configurations ( <code>DEBUG == 1</code> ) <code>FTPS_LOG</code> should be mapped to <code>IP_Logf_Application()</code> .
N	<code>FTPC_BUFFER_SIZE</code>	512	Defines the size of the in and the out buffer of the FTP client. This means that the client requires the defined number of bytes for each buffer. For example, <code>FTPC_BUFFER_SIZE == 512</code> means 1024 bytes RAM requirement.
N	<code>FTPC_CTRL_BUFFER_SIZE</code>	256	Defines the maximum length of the buffer used for the control channel.
N	<code>FTPC_SERVER_REPLY_BUFFER_SIZE</code>	128	Defines the maximum length of the buffer used for the server reply strings. This buffer is only required and used in debug builds. In release builds the memory will not be allocated.

## 14.6 API functions

Function	Description
<code>IP_FTFC_Connect()</code>	Establishes a connection to a FTP server.
<code>IP_FTFC_Disconnect()</code>	Closes an established connection to a FTP server.
<code>IP_FTFC_ExecCmd()</code>	Sends a command to a FTP server.
<code>IP_FTFC_Init()</code>	Initializes the embOS/IP FTP client.

**Table 14.2: embOS/IP FTP client interface function overview**

## 14.6.1 IP\_FTFC\_Connect()

### Description

Establishes a connection to a FTP server.

### Prototype

```
int IP_FTFC_Connect ( IP_FTFC_CONTEXT * pContext,
                    const char *      sServer,
                    const char *      sUser,
                    const char *      sPass,
                    unsigned           PortCmd,
                    unsigned           Mode );
```

### Parameter

Parameter	Description
<code>pContext</code>	[IN] Pointer to a structure of type <code>IP_FTFC_CONTEXT</code> .
<code>sServer</code>	[IN] Dot-decimal IP address of a FTP server, for example "192.168.1.55".
<code>sUser</code>	[IN] User name if required for the authentication. Can be <code>NULL</code> .
<code>sPass</code>	[IN] Password if required for the authentication. Can be <code>NULL</code> .
<code>PortCmd</code>	[IN] Port number of the port which is in listening mode on the FTP server. The well-known port for an FTP server that is waiting for connections is 21.
<code>Mode</code>	[IN] FTP transfer mode.

**Table 14.3: IP\_FTFC\_Connect() parameter list**

Valid values for parameter Mode	Description
<code>FTFC_MODE_PASSIVE</code>	Use passive mode FTP.

### Return value

0 on success.

1 on error. Illegal parameter (`pContext == NULL`).

-1 on error during the process of establishing a connection.

### Additional information

The function `IP_FTFC_Init()` must be called before a call `IP_FTFC_Connect()`. For detailed information about `IP_FTFC_Init()` refer to *IP\_FTFC\_Init()* on page 277.

**Note:** In the current version of embOS/IP, the FTP client supports only passive mode FTP.

### Example

Refer to *IP\_FTFC\_ExecCmd()* on page 274 for an example application which uses `IP_FTFC_Connect()`.

## 14.6.2 IP\_FTFC\_Disconnect()

### Description

Closes an established connection to a FTP server.

### Prototype

```
int IP_FTFC_Disconnect ( IP_FTFC_CONTEXT * pContext );
```

### Parameter

Parameter	Description
<code>pContext</code>	[IN] Pointer to a structure of type <code>IP_FTFC_CONTEXT</code> .

**Table 14.4: IP\_FTFC\_Disconnect() parameter list**

### Return value

0 on success.

1 on error. Illegal parameter (`pContext == NULL`).

### Example

Refer to *IP\_FTFC\_ExecCmd()* on page 274 for an example application which uses `IP_FTFC_Disconnect()`.

## 14.6.3 IP\_FTPC\_ExecCmd()

### Description

Executes a command on the FTP server.

### Prototype

```
int IP_FTPC_ExecCmd ( IP_FTPC_CONTEXT * pContext,
                    unsigned Cmd,
                    const char * sPara );
```

### Parameter

Parameter	Description
<code>pContext</code>	[IN] Pointer to a structure of type <code>IP_FTPC_CONTEXT</code> .
<code>Cmd</code>	[IN] See table below.
<code>sPara</code>	[IN] String with the required parameters for the command. Depending on the command, the parameter can be <code>NULL</code> .

**Table 14.5: IP\_FTPC\_ExecCmd() parameter list**

Valid values for parameter Cmd	Description
<code>FTPC_CMD_CWD</code>	The command CWD (Change Working Directory). <code>sPara</code> is the path to the directory that should be accessed.
<code>FTPC_CMD_CDUP</code>	The command CDUP (Change to Parent Directory). <code>sPara</code> is <code>NULL</code> .
<code>FTPC_CMD_STOR</code>	The command STOR (Store). <code>sPara</code> is the name of the file that should be stored on the server. The FTP client opens the file and transmits it to the FTP server.
<code>FTPC_CMD_RETR</code>	The command RETR (Retrieve). <code>sPara</code> is the name of the file that should be received from the server. The FTP client creates a file on the used storage medium and stores the retrieved file.
<code>FTPC_CMD_PWD</code>	The command PWD (Print Working Directory). <code>sPara</code> is <code>NULL</code> .

### Return value

0 on success.

1 on error. Illegal parameter (`pContext == NULL`).

-1 on error during command execution.

### Additional information

`IP_FTPC_Init()` and `IP_FTPC_Connect()` have to be called before `IP_FTPC_ExecCmd()`. Refer to *IP\_FTPC\_Init()* on page 277 for detailed information about how to initialize the FTP client and refer to *IP\_FTPC\_Connect()* on page 272 for detailed information about how to establish a connection to a FTP server.

`IP_FTPC_ExecCmd()` sends a command to the server and handles everything what is required on FTP client side. The commands which are listed in section *Supported FTP client commands* on page 269, but not explained here, are normally not directly called from the user application. There is no need to call `IP_ExecCmd()` with these commands. The FTP client uses these commands internally and sends them to the server if required. For example, the call of `IP_FTPC_Connect()` sends the the com-

mands USER, PASS and SYST to the server and process the server replies for each of the commands, an explicit call of IP\_FTPC\_Exec() with one of these commands is not required.

## Example

```

/* Excerpt from the example application OS_IP_FTPClient.c */

/*****
 *
 *      MainTask
 *
 * Note:
 * The size of the stack of this task should be at least
 * 1200 bytes + FTPC_CTRL_BUFFER_SIZE + 2 * FTPC_BUFFER_SIZE.
 */
void MainTask(void);
void MainTask(void) {
    IP_FTPC_CONTEXT FTPConnection;
    U8 acCtrlIn[FTPC_CTRL_BUFFER_SIZE];
    U8 acDataIn[FTPC_BUFFER_SIZE];
    U8 acDataOut[FTPC_BUFFER_SIZE];
    int r;

    //
    // Initialize the IP stack
    //
    IP_Init();
    OS_CREATETASK(&TCB, "IP_Task", IP_Task , 150, _IPStack); // Start the IP_Task
    //
    // Check if target is configured
    //
    while (IP_IFaceIsReady() == 0) {
        BSP_ToggleLED(1);
        OS_Delay(50);
    }
    //
    // FTP client task
    //
    while (1) {
        BSP_SetLED(0);
        //
        // Initialize FTP client context
        //
        memset(&FTPConnection, 0, sizeof(FTPConnection));
        //
        // Initialize the FTP client
        //
        IP_FTPC_Init(&FTPConnection, &IP_Api, &IP_FS_FS, acCtrlIn, sizeof(acCtrlIn),
                    acDataIn, sizeof(acDataIn), acDataOut, sizeof(acDataOut));
        //
        // Connect to the FTP server
        //
        r = IP_FTPC_Connect(&FTPConnection, "192.168.199.164", "Admin", "Secret",
                           21, FTPC_MODE_PASSIVE);
        if (r == FTPC_ERROR) {
            FTPC_LOG(("APP: Could not connect to FTP server.\r\n"));
            goto Disconnect;
        }
        //
        // Change from root directory into directory "Test"
        //
        r = IP_FTPC_ExecCmd(&FTPConnection, FTPC_CMD_CWD, "/Test/");
        if (r == FTPC_ERROR) {
            FTPC_LOG(("APP: Could not change working directory.\r\n"));
            goto Disconnect;
        }
    }
}

```

```
//
// Upload the file "Readme.txt"
//
r = IP_FTPC_ExecCmd(&FTPConnection, FTPC_CMD_STOR, "Readme.txt");
if (r == FTPC_ERROR) {
    FTPC_LOG(("APP: Could not upload data file.\r\n"));
    goto Disconnect;
}
//
// Change back to root directory.
//
r = IP_FTPC_ExecCmd(&FTPConnection, FTPC_CMD_CDUP, NULL);
if (r == FTPC_ERROR) {
    FTPC_LOG(("APP: Change to parent directory failed.\r\n"));
    goto Disconnect;
}
//
// Disconnect.
//
Disconnect:
    IP_FTPC_Disconnect(&FTPConnection);
    FTPC_LOG(("APP: Done.\r\n"));
    BSP_ClrLED(0);
    OS_Delay (10000);
}
}
```

## 14.6.4 IP\_FTPC\_Init()

### Description

Initializes the FTP client context.

### Prototype

```
int IP_FTPC_Init ( IP_FTPC_CONTEXT *   pContext,
                  const IP_FTPC_API *  pIP_API,
                  const IP_FS_API *    pFS_API,
                  U8 *                  pCtrlBuffer,
                  unsigned               NumBytesCtrl,
                  U8 *                  pDataInBuffer,
                  unsigned               NumBytesDataIn,
                  U8 *                  pDataOutBuffer,
                  unsigned               NumBytesDataOut );
```

### Parameter

Parameter	Description
<a href="#">pContext</a>	[IN] Pointer to a structure of type <code>IP_FTPC_CONTEXT</code> .
<a href="#">pIP_API</a>	[IN] Pointer to a structure of type <code>IP_FTPC_API</code> .
<a href="#">pFS_API</a>	[IN] Pointer to the file system API.
<a href="#">pControlBuffer</a>	[IN] Pointer to the buffer used for the control channel information.
<a href="#">NumBytesCtrl</a>	[IN] Size of the control buffer in bytes.
<a href="#">pDataInBuffer</a>	[IN] Pointer to the buffer used to receive data from the server.
<a href="#">NumBytesDataIn</a>	[IN] Size of the receive buffer in bytes.
<a href="#">pDataOutBuffer</a>	[IN] Pointer to the buffer used to transmit data to the server.
<a href="#">NumBytesDataOut</a>	[IN] Size of the transmit buffer in bytes.

**Table 14.6: IP\_FTPC\_Init() parameter list**

### Return value

0 on success.

1 on error. Invalid parameters.

### Additional information

`IP_FTPC_Init()` must be called before any other FTP client function will be called. For detailed information about the structure type `IP_FS_API` refer to *Appendix A - File system abstraction layer* on page 301. For detailed information about the structure type `IP_FTPC_API` refer to *Appendix A - File system abstraction layer* on page 301.

### Example

Refer to `IP_FTPC_ExecCmd()` on page 274 for an example application which uses `IP_FTPC_Init()`.

## 14.7 FTP client data structures

### 14.7.1 Structure IP\_FTPEC\_API

#### Description

This structure contains the pointer to the socket functions which are required to use the FTP client.

#### Prototype

```
typedef struct {
    FTPEC_SOCKET (*pfConnect)    (const char * SrvAddr, unsigned SrvPort);
    void         (*pfDisconnect) (FTPEC_SOCKET Socket);
    int          (*pfSend)       (const char * pData, int Len,
                                FTPEC_SOCKET Socket);
    int          (*pfReceive)    (char * pData, int Len, FTPEC_SOCKET Socket);
} IP_FTPEC_API;
```

Member	Description
<a href="#">pfConnect</a>	Callback function that handles the connect to a FTP server on socket level.
<a href="#">pfDisconnect</a>	Callback function that disconnects a connection to the FTP server on socket level.
<a href="#">pfSend</a>	Callback function that sends data to the FTP server on socket level.
<a href="#">pfReceive</a>	Callback function that receives data from the FTP server on socket level.

**Table 14.7: Structure IP\_FTPEC\_API member list**

## 14.8 Resource usage

The ROM usage depends on the compiler options, the compiler version and the used CPU. The memory requirements of the FTP client presented in the tables below have been measured on a system as follows: ARM7, IAR Embedded Workbench V5.41b, Thumb mode, Size optimization.

### Configuration used

```
#define FTPC_BUFFER_SIZE          512
#define FTPC_CTRL_BUFFER_SIZE    256
#define FTPC_SERVER_REPLY_BUFFER_SIZE 128 // Only required in debug builds
                                         // with enabled logging.
```

### 14.8.1 ROM usage

Add-on	ROM [Kbytes]
embOS/IP FTP client	

### 14.8.2 RAM usage:

Almost all of the RAM used by the FTP server is taken from task stacks. The amount of RAM required depends on the configuration of your client.

Build	Description	RAM [bytes]
Release	A task used for the FTP client without debugging features and disabled debug outputs.	app. 1400

The approximately task stack size required for the FTP client can be calculated as follows:

$$\text{TaskStackSize} = 2 * \text{FTPC\_BUFFER\_SIZE} + \text{FTPC\_CTRL\_BUFFER\_SIZE}$$

Build	Description	RAM [bytes]
Debug	A task used for the FTP client with debugging features and enabled debug outputs.	app. 1550

The approximately task stack size required for the FTP client can be calculated as follows:

$$\text{TaskStackSize} = 2 * \text{FTPC\_BUFFER\_SIZE} + \text{FTPC\_CTRL\_BUFFER\_SIZE} + \text{FTPC\_SERVER\_REPLY\_BUFFER\_SIZE}$$



# Chapter 15

## Debugging

---

embOS/IP comes with various debugging options. These includes optional warning and log outputs, as well as other run-time options which perform checks at run time as well as options to drop incoming or outgoing packets to test stability of the implementation on the target system.

## 15.1 Message output

The debug builds of embOS/IP include a fine grained debug system which helps to analyze the correct implementation of the stack in your application. All modules of the TCP/IP stack can output logging and warning messages via terminal I/O, if the specific message type identifier is added to the log and/or warn filter mask. This approach provides the opportunity to get and interpret only the logging and warning messages which are relevant for the part of the stack that you want to debug.

By default, all warning messages are activated in all embOS/IP sample configuration files. All logging messages are disabled except for the messages from the initialization and the DHCP setup phase.

## 15.2 Testing stability

embOS/IP allows to define drop-rates for both receiver and transmitter. This feature can be used to simulate packet loss. Packet loss means that one or more packets fail to reach their destination. Packet loss can be caused by a number of factors (for example, signal degradation over the network medium, faulty networking hardware, error in network applications, etc.).

Two variables, `IP_TxDropRate` and `IP_RxDropRate`, are implemented to define the drop-rate while the target is running. There is no need to recompile the stack. The default value of these variables is 0, which means that no packets should be dropped from the stack. Any other value of `n` (for example, `n = 2,3, ...`) will drop every `n`-th packet. This allows testing the reliability of communication and performance drop. A good value to test the stability is typically around 50.

To change the value of `IP_TxDropRate` and/or `IP_RxDropRate` the following steps are required:

1. Download your embOS/IP application into the target.
2. Start your debugger.
3. Open the **Watch** window and add one or both drop-rate variables.
4. Assign the transmit and/or receive drop-rate and start your application.

## 15.3 API functions

Function	Description
Filter functions	
<code>IP_Log()</code>	This function is called by the stack in debug builds with log & warn output (debug level > 1). In a release build, this function may not be linked in.
<code>IP_Warn()</code>	This function is called by the stack in debug builds with log & warn output (debug level > 1). In a release build, this function may not be linked in.
<code>IP_AddLogFilter()</code>	Adds an additional filter condition to the mask which specifies the logging messages that should be displayed.
<code>IP_AddWarnFilter()</code>	Adds an additional filter condition to the mask which specifies the warning messages that should be displayed.
<code>IP_SetLogFilter()</code>	Sets the mask that defines which logging message should be displayed.
<code>IP_SetWarnFilter()</code>	Sets the mask that defines which warning message should be displayed.
General debug functions/macros	
<code>IP_PANIC()</code>	Called if the stack encounters a critical situation.

**Table 15.1: embOS/IP debugging API function overview**

## 15.3.1 IP\_AddLogFilter()

### Description

Adds an additional filter condition to the mask which specifies the logging messages that should be displayed.

### Prototype

```
void IP_AddLogFilter(U32 FilterMask);
```

### Parameter

Parameter	Description
<code>FilterMask</code>	Specifies which logging messages should be added to the filter mask. Refer to <i>Message types</i> on page 290 for a list of valid values for parameter <code>FilterMask</code> .

**Table 15.2: IP\_AddLogFilter() parameter list**

### Additional information

`IP_AddLogFilter()` can also be used to remove a filter condition which was set before. It adds/removes the specified filter to/from the filter mask via a disjunction.

### Example

```
IP_AddLogFilter(IP_MTYPE_DRIVER); // Activate driver logging messages
/*
 * Do something
 */
IP_AddLogFilter(IP_MTYPE_DRIVER); // Deactivate all driver logging messages
```

## 15.3.2 IP\_AddWarnFilter()

### Description

Adds an additional filter condition to the mask which specifies the warning messages that should be displayed.

### Prototype

```
void IP_AddWarnFilter(U32 FilterMask);
```

### Parameter

Parameter	Description
<code>FilterMask</code>	Specifies which warning messages should be added to the filter mask. Refer to <i>Message types</i> on page 290 for a list of valid values for parameter <code>FilterMask</code> .

**Table 15.3: IP\_AddWarnFilter() parameter list**

### Additional information

`IP_AddWarnFilter()` can also be used to remove a filter condition which was set before. It adds/removes the specified filter to/from the filter mask via a disjunction.

### Example

```
IP_AddWarnFilter(IP_MTYPE_DRIVER); // Activate driver warning messages
/*
 * Do something
 */
IP_AddWarnFilter(IP_MTYPE_DRIVER); // Deactivate all driver warning messages
```

### 15.3.3 IP\_SetLogFilter()

#### Description

Sets a mask that defines which logging message that should be logged. Logging messages are only available in debug builds of embOS/IP.

#### Prototype

```
void IP_SetLogFilter( U32 FilterMask );
```

#### Parameter

Parameter	Description
<code>FilterMask</code>	Specifies which logging messages should be displayed. Refer to <i>Message types</i> on page 290 for a list of valid values for parameter <code>FilterMask</code> .

**Table 15.4:** IP\_SetLogFilter() parameter list

#### Additional information

This function should be called from `IP_X_Config()`. By default, the filter condition `IP_MTYPE_INIT` is set. Refer to *IP\_X\_Configure()* on page 174 for more information.

## 15.3.4 IP\_SetWarnFilter()

### Description

Sets a mask that defines which warning messages that should be logged. Warning messages are only available in debug builds of embOS/IP.

### Prototype

```
void IP_SetWarnFilter( U32 FilterMask );
```

### Parameter

Parameter	Description
<code>FilterMask</code>	Specifies which warning messages should be displayed. Refer to <i>Message types</i> on page 290 for a list of valid values for parameter <code>FilterMask</code> .

**Table 15.5: IP\_SetWarnFilter() parameter list**

### Additional information

This function should be called from `IP_X_Config()`. By default, all filter conditions are set. Refer to *IP\_X\_Configure()* on page 174 for more information.

## 15.3.5 IP\_PANIC()

### Description

This macro is called by the stack code when it detects a situation that should not be occurring and the stack can not continue. The intention for the `IP_PANIC()` macro is to invoke whatever debugger may be in use by the programmer. In this way, it acts like an embedded breakpoint.

### Prototype

```
IP_PANIC ( const char * sError );
```

### Additional information

This macro maps to a function in debug builds only. If `IP_DEBUG > 0`, the macro maps to the stack internal function `void IP_Panic ( const char * sError )`. `IP_Panic()` disables all interrupts to avoid further task switches, outputs `sError` via terminal I/O and loops forever. When using an emulator, you should set a breakpoint at the beginning of this routine or simply stop the program after a failure. The error code is passed to the function as parameter.

In a release build, this macro is defined empty, so that no additional code will be included by the linker.

## 15.4 Message types

The same message types are used for log and warning messages. Separate filters can be used for both log and warnings. For details, refer to *IP\_SetLogFilter()* on page 287 and *IP\_SetWarnFilter()* on page 288 as well as *IP\_AddLogFilter()* on page 285 and *IP\_AddWarnFilter()* on page 285 for more information about using the message types.

Symbolic name	Description
<code>IP_MTYPE_INIT</code>	Activates output of messages from the initialization of the stack that should be logged.
<code>IP_MTYPE_CORE</code>	Activates output of messages from the core of the stack that should be logged.
<code>IP_MTYPE_ALLOC</code>	Activates output of messages from the memory allocating module of the stack that should be logged.
<code>IP_MTYPE_DRIVER</code>	Activates output of messages from the driver that should be logged.
<code>IP_MTYPE_ARP</code>	Activates output of messages from ARP module that should be logged.
<code>IP_MTYPE_IP</code>	Activates output of messages from IP module that should be logged.
<code>IP_MTYPE_TCP_CLOSE</code>	Activates output of messages from TCP module that should be logged when a TCP connection gets closed.
<code>IP_MTYPE_TCP_OPEN</code>	Activates output of messages from TCP module that should be logged when a TCP connection gets opened.
<code>IP_MTYPE_TCP_IN</code>	Activates output of messages from TCP module that should be logged if a TCP packet is received.
<code>IP_MTYPE_TCP_OUT</code>	Activates output of messages from TCP module that should be logged if a TCP packet is sent.
<code>IP_MTYPE_TCP_RTT</code>	Activates output of messages from TCP module regarding TCP roundtrip time.
<code>IP_MTYPE_TCP</code>	Activates output of messages from TCP that module should be logged.
<code>IP_MTYPE_UDP_IN</code>	Activates output of messages from UDP module that should be logged when a UDP packet is received.
<code>IP_MTYPE_UDP_OUT</code>	Activates output of messages from UDP module that should be logged if a UDP packet is sent.
<code>IP_MTYPE_UDP</code>	Activates output of messages from UDP module that should be logged if a UDP packet is sent or received.
<code>IP_MTYPE_LINK_CHANGE</code>	Activates output of messages regarding to the link change process.
<code>IP_MTYPE_DHCP</code>	Activates output of messages from DHCP client module that should be logged.
<code>IP_MTYPE_DHCP_EXT</code>	Activates output of optional messages from DHCP client module that should be logged.
<code>IP_MTYPE_ICMP</code>	Activates output of messages from the ICMP module that should be logged.
<code>IP_MTYPE_NET_IN</code>	Activates output of messages from NET_IN module that should be logged.

**Table 15.6: embOS/IP message types**

Symbolic name	Description
IP_MTYPE_NET_OUT	Activates output of messages from NET_OUT module that should be logged.
IP_MTYPE_DNS	Activates output of messages from DNS module that should be logged.
IP_MTYPE_SOCKET_STATE	Activates output of messages from socket module that should be logged when state has been changed.
IP_MTYPE_SOCKET_READ	Activates output of messages from socket module that should be logged if a socket is used to read data.
IP_MTYPE_SOCKET_WRITE	Activates output of messages from socket module that should be logged if a socket is used to write data
IP_MTYPE_SOCKET	Activates all socket related output messages.

**Table 15.6: embOS/IP message types**



# Chapter 16

## OS integration

---

embOS/IP is designed to be used in a multitasking environment. The interface to the operating system is encapsulated in a single file, the IP/OS interface. For embOS, all functions required for this IP/OS interface are implemented in a single file which comes with embOS/IP.

This chapter provides descriptions of the functions required to fully support embOS/IP in multitasking environments.

## 16.1 General information

The complexity of the IP/OS Interface depends on the task model selected. Refer to *Tasks and interrupt usage* on page 17 for detailed informations about the different task models. All OS interface functions for embOS are implemented in `IP_OS_embOS.c` which is located in the root folder of the IP stack.

## 16.2 OS layer API functions

Function	Description
General macros	
<code>IP_OS_Delay()</code>	Blocks the calling task for a given time.
<code>IP_OS_DisableInterrupt()</code>	Disables interrupts.
<code>IP_OS_EnableInterrupt()</code>	Enables interrupts.
<code>IP_OS_GetTime32()</code>	Returns the current system time in ticks. Return the current system time in ms. On 32-bit systems, the value will wrap around after approximately 49.7 days. This is taken into account by the stack.
<code>IP_OS_Init()</code>	Creates and initializes all objects required for task synchronization. These are 2 events (for <code>IP_Task</code> and <code>IP_RxTask</code> ) and one semaphore for protection of critical code which may not be executed from multiple task at the same time.
<code>IP_OS_Lock()</code>	The stack requires a single lock, typically a resource semaphore or mutex. This function locks this object, guarding sections of the stack code against other tasks. If the entire stack executes from a single task, no functionality is required here.
<code>IP_OS_Unlock()</code>	Unlocks the single lock used locked by a previous call to <code>IP_OS_Lock()</code> .
IP_Task synchronization	
<code>IP_OS_SignalNetEvent()</code>	Wakes the <code>IP_Task</code> if it is waiting for a NET-event or timeout in the function <code>IP_OS_WaitNetEvent()</code> .
<code>IP_OS_WaitNetEvent()</code>	Called from <code>IP_Task</code> only. Blocks until the timeout expires or a NET-event occurs, meaning <code>IP_OS_SignalNetEvent()</code> is called from an other task or ISR.
IP_RxTask synchronization	
<code>IP_OS_SignalRxEvent()</code>	Wakes the <code>IP_RxTask</code> if it is waiting for a NET-event or timeout in the function <code>IP_OS_WaitRxEvent()</code> .
<code>IP_OS_WaitRxEvent()</code>	Optional. Called from <code>IP_RxTask</code> , if it is used to receive data. Blocks until the timeout expires or a NET-event occurs, meaning <code>IP_OS_SignalRxEvent()</code> is called from the ISR.
Application task synchronization	
<code>IP_OS_WaitItem()</code>	Suspend a task which needs to wait for a object. This object is identified by a pointer to it and can be of any type, for example a socket.
<code>IP_OS_WaitItemTimed()</code>	Suspend a task which needs to wait for a object. This object is identified by a pointer to it and can be of any type, for example a socket. The second parameter defines the maximum time in timer ticks until the event have to be signaled.
<code>IP_OS_SignalItem()</code>	Sets an event object to signaled state, or resumes tasks which are waiting at the event object. Function is called from a task, not an ISR.

**Table 16.1: Target OS interface function list**

### 16.2.1 Examples

#### OS interface routine for embOS

All OS interface routines are implemented in `IP_OS_embOS.c` which is located in the root folder of the IP stack.



# Chapter 17

## Performance & resource usage

---

This chapter covers the performance and resource usage of embOS/IP. It contains information about the memory requirements in typical systems which can be used to obtain sufficient estimates for most target systems.

## 17.1 Memory footprint

embOS/IP is designed to fit many kinds of embedded design requirements. Several features can be excluded from a build to get a minimal system. Note that the values are only valid for the given configuration.

### System

The following table shows the hardware and the toolchain details of the project:

Detail	Description
CPU	ARM7
Tool chain	IAR Embedded Workbench for ARM V4.41A
Model	ARM7, Thumb instructions; no interwork;
Compiler options	Highest size optimization;

**Table 17.1: ARM7 sample configuration**

The following table shows the ROM requirement of embOS/IP:

Description	ROM
embOS/IP - complete stack	approximately 18 Kbytes

The memory requirements of a interface driver is about 1.5 - 2.0 Kbytes.

## 17.2 Performance

### System

Detail	Description
CPU	ARM7 with integrated MAC running with 48Mhz
Tool chain	IAR Embedded Workbench for ARM V4.41A
Model	ARM7, Thumb instructions; no interwork;
Compiler options	Highest speed optimization;

**Table 17.2: ARM7 sample configuration**

The following table shows the send and receive speed of embOS/IP:

Description	Speed [Mbytes per second]
TCP - socket interface	
Send speed	approximately 4.0
Receive speed	approximately 4.0
TCP - zero-copy interface	
Send speed	approximately 4.8
Receive speed	approximately 4.8

The performance of any network will depend on several considerations, including the length of the cabling, the size of packets, and the amount of traffic.



# Chapter 18

## Appendix A - File system abstraction layer

---

## 18.1 File system abstraction layer

This section provides a description of the file system abstraction layer used by embOS/IP applications which require access to a data storage medium. The file system abstraction layer is supplied with the embOS/IP web server and the embOS/IP FTP server.

Three file system abstraction layer implementations are available:

File name	Description
IP_FS_FS.c	Mapping of the embOS/IP file system abstraction layer functions to the emFile functions.
IP_FS_RO.c	Implementation of a read-only file system. Typically used in a web server application.
IP_FS_WIN32.c	Mapping of the embOS/IP file system abstraction layer functions to the Windows file I/O functions.

### Supplied implementations of the file system abstraction layer

## 18.2 File system abstraction layer function table

embOS/IP uses a function table to call the appropriate file system function.

### Data structure

```
typedef struct {
    //
    // Read only file operations. These have to be present on ANY file system,
    // even the simplest one.
    //
    void * (*pfOpenFile)    ( const char * sFilename,
                             const char * sOpenFlags );

    int    (*pfCloseFile)  ( void * hFile );
    int    (*pfReadAt)     ( void * hFile,
                             void * pBuffer,
                             U32    Pos,
                             U32    NumBytes );

    long   (*pfGetLen)     ( void * hFile );
    //
    // Directory query operations.
    //
    void    (*pfForEachDirEntry) ( void * pContext,
                                   const char * sDir,
                                   void (*pf) (void * pContext,
                                               void * pFileEntry));

    void    (*pfGetDirEntryFileName) ( void * pFileEntry,
                                       char * sFileName,
                                       U32    SizeOfBuffer );

    U32     (*pfGetDirEntryFileSize) ( void * pFileEntry,
                                       U32 * pFileSizeHigh );

    int     (*pfGetDirEntryFileTime) ( void * pFileEntry );
    U32     (*pfGetDirEntryAttributes) ( void * pFileEntry );
    //
    // Write file operations.
    //
    void * (*pfCreate)      ( const char * sFileName );
    void * (*pfDeleteFile) ( const char * sFilename );
    int    (*pfRenameFile) ( const char * sOldFilename,
                             const char * sNewFilename );

    int    (*pfWriteAt)    ( void * hFile,
                             void * pBuffer,
                             U32    Pos,
                             U32    NumBytes );

    //
    // Additional directory operations
    //
    int     (*pfMKDir)      ( const char * sDirName);
    int     (*pfRMDir)     ( const char * sDirName);
} IP_FS_API;
```

## Elements of IP\_FS\_API

Function	Description
Read only file system functions (required)	
<a href="#">pfOpenFile</a>	Pointer to a function that creates/opens a file and returns the handle of these file.
<a href="#">pfCloseFile</a>	Pointer to a function that closes a file.
<a href="#">pfReadAt</a>	Pointer to a function that reads a file.
<b>Table 18.1: embOS/IP file system API function overview</b>	
<a href="#">pfGetLen</a>	Pointer to a function that returns the length of a file.
Directory query operations	
<a href="#">pfForEachDirEntry</a>	Pointer to a function which is called for each directory entry.
<a href="#">pfGetDirEntryFileName</a>	Pointer to a function that returns the name of a file entry.
<a href="#">pfGetDirEntryFileSize</a>	Pointer to a function that returns the size of a file.
<a href="#">pfGetDirEntryFileTime</a>	Pointer to a function that returns the time-stamp of a file.
<a href="#">pfGetDirEntryAttributes</a>	Pointer to a function that returns the attributes of a directory entry.
Write file operations	
<a href="#">pfCreate</a>	Pointer to a function that creates a file.
<a href="#">pfDeleteFile</a>	Pointer to a function that deletes a file.
<a href="#">pfRenameFile</a>	Pointer to a function that renames a file.
<a href="#">pfWriteAt</a>	Pointer to a function that writes a file.
Simple write type file system functions (optional)	
<a href="#">pfCreate</a>	Pointer to a function that creates a file.
<a href="#">pfDeleteFile</a>	Pointer to a function that deletes a file.

## 18.2.1 emFile interface

The embOS/IP web server and FTP server are shipped with an interface to emFile, SEGGER's file system for embedded applications. It is a good example how to use a real file system with the embOS/IP web server / FTP server.

```
/* Excerpt from IP_FS_FS.c */  
  
const IP_FS_API IP_FS_FS = {  
    _FS_Open,  
    _Close,  
    _ReadAt,  
    _GetLen,  
    _ForEachDirEntry,  
    _GetDirEntryFileName,  
    _GetDirEntryFileSize,  
    _GetDirEntryFileTime,  
    _GetDirEntryAttributes,  
    _Create,  
    _DeleteFile,  
    _RenameFile,  
    _WriteAt  
};
```

The emFile interface is used in all SEGGER Eval Packages.

## 18.2.2 Read-only file system

The embOS/IP web server and FTP server are shipped with a very basic implementation of a read-only file system. It is a good solution if you use embOS/IP without a real file system like emFile.

```
/* Excerpt from FS_RO.c */

const IP_WEBS_FS_API IP_FS_ReadOnly = {
    _FS_RO_FS_Open,
    _FS_RO_Close,
    _FS_RO_ReadAt,
    _FS_RO_GetLen,
    NULL,
    NULL,
    NULL,
    NULL,
    NULL,
    NULL,
    NULL,
    NULL,
};
```

The read-only file system can be used in the example applications. It is sufficient, if the server should only deliver predefined files which are hardcoded in the sources of your application. It is used by default with the embOS/IP Web server example application.

## 18.2.3 Using the read-only file system

The read-only file system relies on an array of directory entries. A directory entry consists of a file name, a pointer to the data and an entry for the file size in bytes. This array of directory entries will be searched if a client requests a page.

```
/* Excerpt from FS_RO.c */
typedef struct {
    const char * sFilename;
    const unsigned char * pData;
    unsigned int FileSize;
} DIR_ENTRY;

#include "webdata\generated\embos.h" /* HTML page */
#include "webdata\generated\index.h" /* HTML page */
#include "webdata\generated\segger.h" /* segger.gif */
#include "webdata\generated\stats.h" /* HTML page */

DIR_ENTRY _aFile[] = {
    /* file name      file array      current size */
    /* -----      -----      ----- */
    { "/embos.htm",   embos_file,     EMBOS_SIZE },
    { "/index.htm",  index_file,     INDEX_SIZE },
    { "/segger.gif", segger_file,    SEGGER_SIZE },
    { "/stats.htm",  stats_file,     STATS_SIZE },
    { 0 }
};
```

The example source files can easily be replaced. To build new contents for the read-only file system the following steps are required:

1. Copy the file which should be included in the read-only file system into the folder: IP\IP\_FS\F\_S\_RO\webdata\html\
2. Use a text editor (for example, Notepad) to edit the batch file m.bat. The batch file is located under: IP\IP\_FS\F\_S\_RO\webdata\. Add the file which should be built. For example: If your file is called example.htm, you have to add the following line to m.bat:  
call cc example htm
3. m.bat calls cc.bat. cc.bat uses bin2C.exe an utility which converts any file to a standard C array. The new files are created in the folder:  
IP\IP\_FS\F\_S\_RO\webdata\generated\

4. Add the new source code file (for example, `example.c`) into your project. To add the new file to your read-only file system, you have to add the new file to the `DIR_ENTRY` array `_aFile[]` and include the generated header file (for example, `example.h`) in `FS_RO.c`.

The expanded definition of `_aFile[]` should look like:

```
#include "webdata\generated\embos.h"           /* HTML page */
#include "webdata\generated\index.h"          /* HTML page */
#include "webdata\generated\segger.h"         /* segger.gif */
#include "webdata\generated\stats.h"         /* HTML page */
#include "webdata\generated\example.h"       /* NEW HTML page */

DIR_ENTRY _aFile[] = {
  /* file name      file array      current size */
  /* -----      -----      ----- */
  { "/embos.htm",   embos_file,     EMBOS_SIZE   },
  { "/index.htm",  index_file,     INDEX_SIZE   },
  { "/segger.gif", segger_file,    SEGGER_SIZE  },
  { "/stats.htm",  stats_file,    STATS_SIZE   },
  { "/example.htm", example_file,  EXAMPLE_SIZE },
  { 0 }
};
```

5. Recompile your application.

## 18.2.4 Windows file system interface

The embOS/IP web server and FTP server is shipped with an implementation.

```
const IP_FS_API IP_FS_Win32 = {
    //
    // Read only file operations.
    //
    _IP_FS_WIN32_Open,
    _IP_FS_WIN32_Close,
    _IP_FS_WIN32_ReadAt,
    _IP_FS_WIN32_GetLen,
    //
    // Simple directory operations.
    //
    _IP_FS_WIN32_ForEachDirEntry,
    _IP_FS_WIN32_GetDirEntryFileName,
    _IP_FS_WIN32_GetDirEntryFileSize,
    _IP_FS_WIN32_GetDirEntryFileTime,
    _IP_FS_WIN32_GetDirEntryAttributes,
    //
    // Simple write type file operations.
    //
    _IP_FS_WIN32_Create,
    _IP_FS_WIN32_DeleteFile,
    _IP_FS_WIN32_RenameFile,
    _IP_FS_WIN32_WriteAt,
    //
    // Additional directory operations
    //
    _IP_FS_WIN32_MakeDir,
    _IP_FS_WIN32_RemoveDir
};
```

The Windows file system interface is supplied with the FTP and the Web server add-on packages. It is used by default with the embOS/IP FTP server application.

# Chapter 19

## Glossary

---

ARP	Address Resolution Protocol.
CPU	Central Processing Unit. The “brain” of a microcontroller; the part of a processor that carries out instructions.
DHCP	Dynamic Host Configuration Protocol.
DNS	Domain Name System.
EOT	End Of Transmission.
FIFO	First-In, First-Out.
FTP	File Transfer Protocol.
HTML	Hypertext Markup Language.
HTTP	Hypertext Transfer Protocol.
ICMP	Internet Control Message Protocol.
IP	Internet Protocol.
ISR	Interrupt Service Routine. The routine is called automatically by the processor when an interrupt is acknowledged. ISRs must preserve the entire context of a task (all registers).
LAN	Local Area Network.
MAC	Media Access Control.
NIC	Network Interface Card.
PPP	Point-to-Point Protocol.
RFC	Request For Comments.
RIP	Routing Information Protocol.
RTOS	Real-time Operating System.
Scheduler	The program section of an RTOS that selects the active task, based on which tasks are ready to run, their relative priorities, and the scheduling system being used.
SLIP	Serial Line Internet Protocol.
SMTP	Simple Mail Transfer Protocol.

Stack	An area of memory with LIFO storage of parameters, automatic variables, return addresses, and other information that needs to be maintained across function calls. In multitasking systems, each task normally has its own stack.
Superloop	A program that runs in an infinite loop and uses no real-time kernel. ISRs are used for real-time parts of the software.
Task	A program running on a processor. A multitasking system allows multiple tasks to execute independently from one another.
TCP	Transmission Control Protocol.
TFTP	Trivial File Transfer Protocol.
Tick	The OS timer interrupt. Usually equals 1 ms.
UDP	User Datagram Protocol.



# Index

<b>C</b>		<b>L</b>	
Compile-time configuration .....	177	Logging functions	
<b>D</b>		IP_AddLogFilter() .....	285
Debugging		IP_AddWarnFilter() .....	286
IP_Panic() .....	289	IP_SetLogFilter() .....	287
DHCP client		IP_SetWarnFilter() .....	288
IP_DHCP_Activate() .....	142	<b>M</b>	
IP_DHCP_Halt() .....	144–145	Management functions	
<b>E</b>		IP_Exec() .....	66
embOS/IP		IP_Init() .....	63
Features .....	14	IP_RxTask() .....	65
Integrating into your system .....	28	IP_Task() .....	64
layers .....	15	<b>N</b>	
<b>F</b>		Network interface drivers	
FS abstraction layer		ATMEL AT91SAM7X .....	150
emFile interface .....	305	ATMEL AT91SAM9260 .....	153
<b>I</b>		DAVICOM DM9000 .....	156
IP stack function		FREESCALE ColdFire MCF5329 .....	159
IP_AddBuffers() .....	42	NXP LPC23xx/24xx .....	162
IP_AddEthernetInterface() .....	43	ST STR912 .....	164
IP_AllowBackpressure() .....	44	<b>O</b>	
IP_AssignMemory() .....	45	OS integration .....	293
IP_ConfTCPSpace() .....	46	API functions .....	295
IP_GetCurrentLinkSpeed() .....	68	Other IP stack functions	
IP_GetIPAddr() .....	69–71	IP_DNS_SetServer() .....	47–48
IP_IFaceIsReady() .....	75	IP_GetVersion() .....	73
IP_NI_ConfigPHYAddr() .....	49	IP_PrintIPAddr() .....	76
IP_NI_ConfigPHYMode() .....	50	<b>S</b>	
IP_NI_ConfigPoll() .....	51	Socket functions	
IP_SendPacket() .....	77	accept() .....	83
IP_SendPing() .....	78	bind() .....	84
IP_SetAddrMask() .....	53	closesocket() .....	85
IP_SetHWAddr() .....	55	connect() .....	86
IP_SetSupportedDuplexModes() .....	57	gethostbyname() .....	88
IP_TCP_Set2MSLDelay() .....	60	getpeername() .....	90
IP_TCP_SetConnKeepaliveOpt() .....	61	getsockname() .....	91
IP_TCP_SetRetransDelayRange() .....	62	listen() .....	95

recv()	96
recvfrom()	97
select()	98
send()	100
sendto()	101
setsockopt()	102
socket()	105
Structure hostent	110
Structure in_addr	109
Structure sockaddr	107
Structure sockaddr_in	108
Syntax, conventions used	7

## T

### TCP zero-copy

IP_TCP_Alloc()	118
IP_TCP_Free()	119
IP_TCP_Send()	120
IP_TCP_SendAndFree()	121

## U

### UDP zero-copy

IP_UDP_Alloc()	128
IP_UDP_Close()	129
IP_UDP_FindFreePort()	130
IP_UDP_Free()	131
IP_UDP_Open()	135
IP_UDP_Send()	136–137

### Utility functions

IP_UTIL_BASE64_Decode()	214
IP_UTIL_BASE64_Encode()	215