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Connecting an M68HC08 Family Microcontroller to an Internet Service Provider (ISP) Using the Point-to-Point Protocol (PPP)

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Introduction

This application note is based on an M68HC08 Family microcontroller (MCU) and implements one of the most popular and accepted Internet protocols: the point-to-point protocol (PPP) to exchange UDP/IP (user datagram protocol/Internet protocol) data with other hosts on the Internet. The source code is written entirely in C, showing much of the benefits of the M68HC08 CPU features to support this high-level language (HLL) programming and enables it to be easily ported to other MCUs. The program code occupies less than 6K of memory.

Today the Internet is an integral part of our daily lives. Millions of people all over the world are familiar with the mediums to obtain and manage information over the World Wide Web. Those same people feed the exponential growth of the Internet, enabling new consumer products in the electronic industry.

The Internet is entering a new era where it impacts our lives at work and at home, regardless of distance. It is clear that this tendency will effect the next evolution of the information super highway.

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The benefits are endless. Imagine the ability to add new product features remotely, perform device management and remote diagnostics, integrate an interactive and intuitive browser interface to the electronic device, and using that interface all over the world. As these consumer requirements evolve, the integration of the Internet-enabling technology into new and existing electronic devices will become more of a reality.

Unfortunately, for most electronic devices, implementing the technology to achieve this networking connectivity based on open Internet standards isn't easy. For instance, most household appliances are based on very low-cost 8-bit microcontroller technology, and chances are that the host MCU includes neither a network port nor the hardware resources to support TCP/IP (transmission control protocol/Internet protocol) and other Internet protocols without disrupting their primary function.

Implementing an entire Internet communications stack requires significant memory and processing resources from the microcontroller-based system. In most cases, adding those resources to the system surpasses the cost and viability of the main reason why the system was conceived.

However, different techniques to Web-enable devices have come to life recently: from implementations of limited TCP/IP functionality in resource constrained systems, to single-chip stacks, to device object servers. Each method has its own advantages and disadvantages.

The intention of this application note is to show that a small, resource-constrained microcontroller can be connected to the Internet when the appropriate resources and well-suited CPU (central processor unit) architecture, such as the one of the M68HC08 Family of MCUs, are put in place.

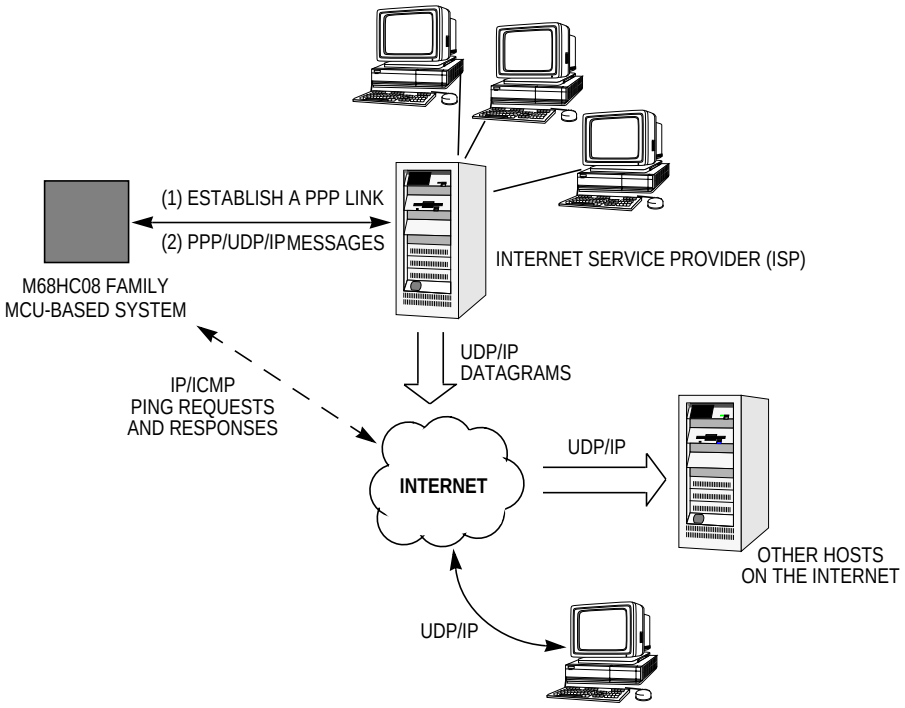


Figure 1. Application Note Framework

Internet Primer

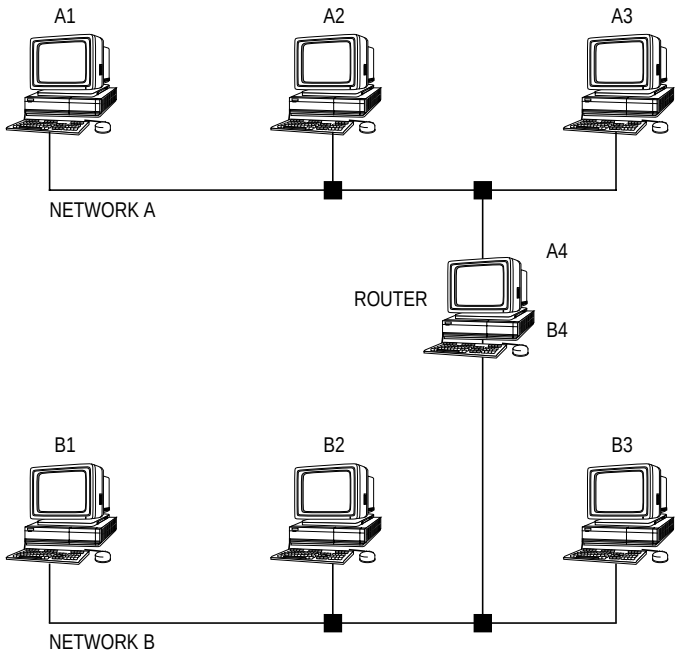
The Internet can be seen as a network of several internetworks (or networks of networks) operating over a mechanism used to connect them together. This mechanism relies on the Internet protocol, often referred as the IP protocol.

To understand how this Internet platform operates, first consider how a local area network or LAN works. A LAN is basically a group of electronic devices (or hosts) in relative physical proximity connected to each other over a shared medium. A host is essentially anything on the network that is capable of receiving and transmitting information packets on the network. Regardless of the technology used for networking, all hosts share a common physical medium. On top of this medium, a commonly accepted protocol allows all hosts in the LAN to send and receive information to each other.

A LAN works well in practice, especially when a relatively small number of hosts conforms to it. The larger the number of hosts connected to the LAN the larger the traffic of data the shared conduit will experience.

Consider this scenario. A company runs a common LAN for its departments. Human resources (HR) is working on the weekly payroll while production is programming the manufacturing plan of the day and engineering is testing the next fancy product the company will launch to market. It does not make sense for HR to experience the high latency on the network caused by the manufacturing process or even engineering testing using the same channel of communication. At the end of the day, nobody will get paid because HR did not finish the payroll processing.

One solution to this scenario would be to split the company LAN in different sections, one for each department. Then instead of having just one network, the company would have three, and data traffic would be reduced to a specific department only. Although the problem is now solved, all three LANs still need to be connected together so they can share specific information. To interconnect two or more networks, we need a computer or host that is attached to both networks and that can forward packets from one network to the other; such a machine is called a router. **Figure 2** shows how a router interconnects two networks.



NOTE:
In a LAN, a router is a member of two networks at the same time.

Figure 2. LAN Router is a Member of Two Networks Simultaneously

A router listens to data traffic in network A and network B at the same time. It will detect any transmissions intended for one network to the other and will forward such data over the appropriate network. According to the figure, it is assumed that the router is a machine connected to both networks at the same time. This approach works well in an office environment where hosts are physically close to each other. However, when the physical distance becomes an issue, this scheme changes a bit to define a wide area network or WAN.

In a WAN, connections are typically point-to-point. This means that only a single computer is connected to another in a remote location. In this scheme, a conduit is shared between two hosts rather than being shared by many computers. Consider the diagram in **Figure 3**.

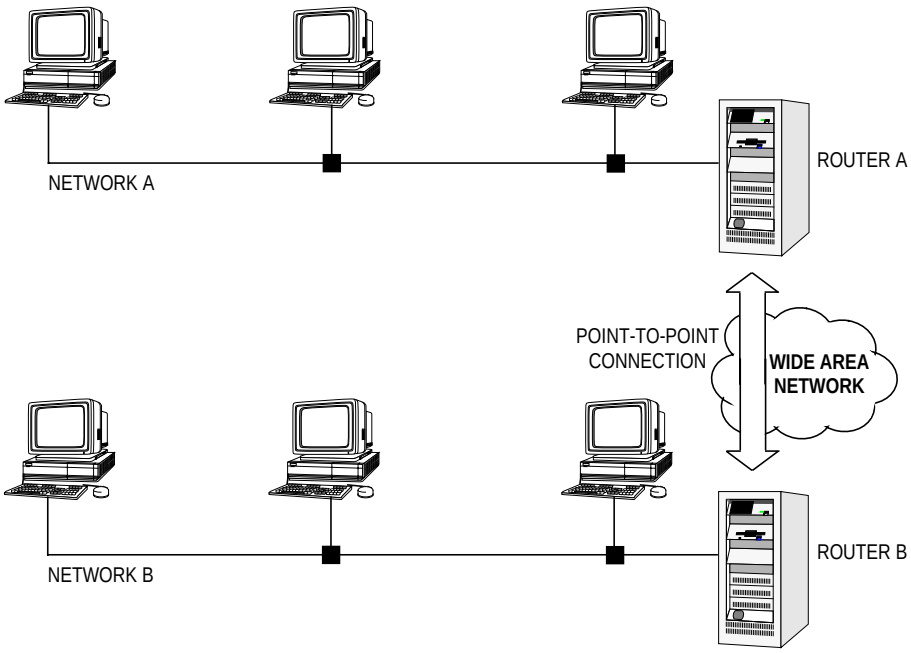


Figure 3. Connecting Two Remote Networks

The Internet is not very different from this scenario. As a matter of fact, the Internet is a collection of LANs or WANs connected to each other by routers operating on a worldwide basis. It is mainly composed of two different kinds of machines: hosts and routers running standard protocols.

According to **Figure 2**, assume the fact that network B can be connected to a network C and in turn be connected to another network in Asia called network D and so on. Such networks interconnected by routers form an internet. When different internets are connected together on a worldwide basis, they form the Internet.

What makes it possible for different computer systems (and in turn different network platforms) to operate together is a complete suite of standards and networking protocols commonly referred as Internet protocols.

Like most networking software, Internet protocols are modeled in layers. A layered model of a software is often referred to as a stack. The Internet protocols can be modeled in five layers as shown in **Figure 4**.

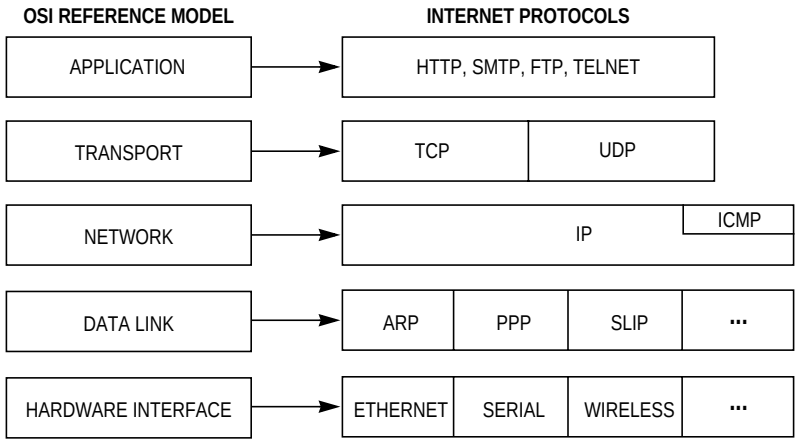


Figure 4. OSI Reference Model and Internet Networking Stack

In the Internet protocol stack, every layer adds a header and/or a trailer to data moving down the stack. For instance, if an application using the HyperText Transfer Protocol (HTTP), such as a Web browser, wants to send an HTTP command to a remote host on the Internet, the TCP layer will add a header intended for its peer TCP at the remote location. The TCP will move the HTTP command down the stack to the IP layer. In turn, this layer will add another header to the TCP encapsulated HTTP packet with information intended to the peer IP layer and so on, as shown in **Figure 5**.

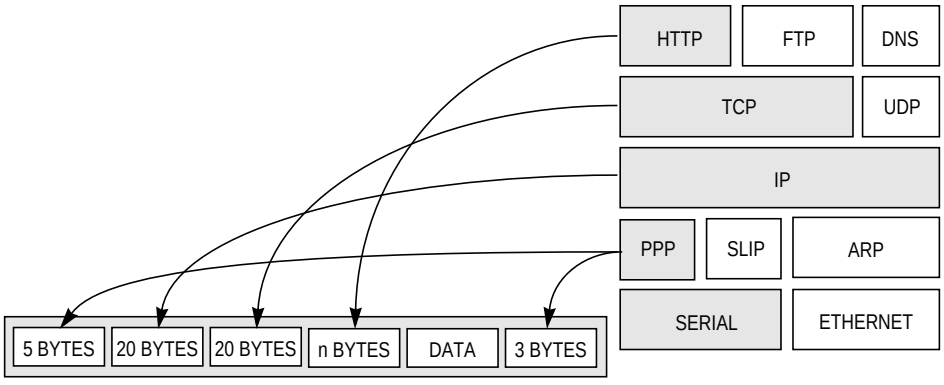


Figure 5. Header and Trailer Data Added to an HTTP Message Traveling Down the TCP/IP Stack

Of all the internet family of protocols, the most fundamental is the Internet protocol (IP). Being the best place to start in the quest of understanding the Internet, a brief description of the Internet protocol is included in the next section.

Internet Protocol (IP)

The Internet protocol (IP) is the protocol that makes possible the transmission of blocks of data, called datagrams, from one host to another over the Internet.

The primary functions of the IP are:

1. Finding a route for each datagram and getting it to its destination in an internetwork
2. Fragmenting and reassembling of IP packets
3. Removing old IP packets from the network

The IP protocol defines datagrams or blocks of data plus a header added that conforms the fundamental units of internet communication. The header contains the numerical address of both the source and destination devices connected to the Internet. These types of addresses are often referred to as IP addresses. IP addresses uniquely identify each host on the Internet and are used by routers to direct the datagrams to their destinations. Often, routers do not care about the payload inside the datagram, since their job is to route the datagram to its destination as fast as possible.

Routers are machines that are primarily concerned with the Internet protocol. From the network standpoint, a router is just another host; from the user standpoint, routers are invisible. The user and the upper layer of the stack only see one large internetwork. These are the benefits of the IP protocol.

Fragmentation is another task performed by the IP. Fragmentation is needed when a packet is too large to fit the network interface below the IP layer. If a large datagram arrives at the IP layer, IP divides the datagram into smaller fragments before sending them. When a datagram fragment arrives, IP must reassemble the entire packet before passing it to the next upper layer.

A complete IP implementation should include features to support fragmentation and reassembly. Implementation of such features requires more CPU bandwidth and more memory resources in RAM and ROM, not to mention the complexity it adds to the software implementation. For this reason, this application note does not implement fragmentation or reassembly. If for any reason the remote computer sends a fragmented packet to the M68HC08, the PPP implementation will reject it and ignore it.

The IP protocol implements a mechanism to remove old datagrams from the network. On each header of an IP packet, an 8-bit long time-to-live field indicates the maximum number of routers that this packet must travel on to reach its destination before it is discarded. This is due to the fact that unroutable packets could be bouncing all over the Internet, forever eating valuable bandwidth.

The best way to get a better understanding of the IP protocol is to take a look at the format of an IP packet. See **Figure 6**.

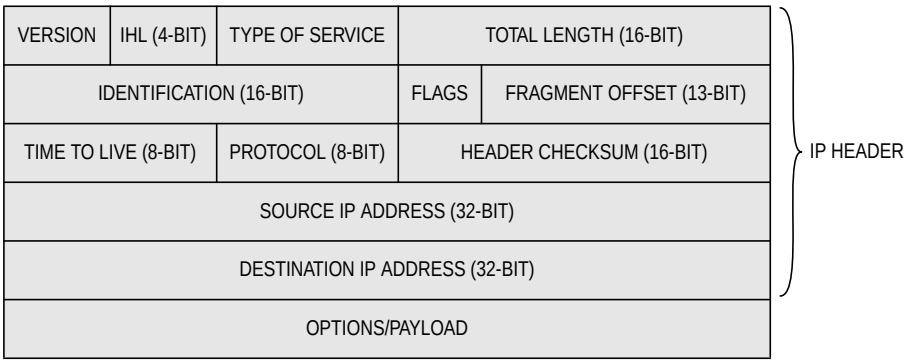


Figure 6. Internet Protocol Datagram Layout

A brief description of each of the fields found in an IP packet is given in **Table 1**.

Table 1. Fields in an IP Packet

Field	Description
Version	Indicates the format of the Internet header. Two values are valid for this field: Four (current IP standard) and six for the future IPv6.
IHL (IP header length)	The length of the Internet header measured in 32-bit words, usually 5
Type of service	Specify reliability, precedence, delay and throughput parameters
Total Length	Total length of the datagram (header and data) measured in bytes
Identification	An ID assigned by the sender to aid in assembling fragmented datagrams
Flags (3 bits)	One bit indicates fragmentation; another is the "Don't fragment" bit, specifying whether the fragment may be fragmented. The last bit is reserved.
Fragment offset	Indicates a fragment portion
Time to live	Indicates the maximum time the datagram is allowed to remain in the Internet
Protocol	Indicates the next layer protocol which is to receive the payload of the datagram
Header checksum	A checksum of the header only
Source address	The sender IP address
Destination address	The destination IP address
Options	The option field is variable in length and is optional. There may be zero or more options. This application note does not support options.
Padding	If options are present, padding ensures the IP header ends on a 32-bit boundary.
Data	Payload of the datagram

An example of an IP datagram is shown in **Figure 7**. Notice how the IP packet carries ICMP data of a ping request from 192.168.55.2 to 192.168.55.1.

```
45 00 00 1C 00 F4 00 00 80 01
A4 99 C0 A8 37 02 C0 A8 37 01
08 00 F6 51 01 00 00 AE
```

Figure 7. Example of an IP Datagram with ICMP Payload

The IP implementation used by this application note does not use most of the fields in the IP header. For every incoming datagram, the implementation checks the version and header length to avoid IP headers longer than 20 bytes. IP checksums are not checked since a more robust frame check sequence (FCS) over the entire IP datagram are computed at the PPP level.

The IP protocol does not provide a mechanism to detect if a datagram has successfully reached its destination. It does not care if a packet sent is lost, duplicated, or corrupted. It relies on higher level protocols to ensure a reliable transmission. That's precisely the job of the next layer up the stack, the transport layer, which in the case of TCP/IP includes UDP and TCP.

UDP Protocol

UDP stands for user datagram protocol, a standard protocol with assigned number 17 as described by RFC 790 (request for comments). Its status is recommended, but almost every TCP/IP stack implementation that is in use in commercial products includes UDP. Think of UDP as an application interface to IP since applications never use IP directly. The UDP layer can be regarded as extremely thin with eight bytes of header, and, consequently, it has low overhead. But it requires the application layer to take full responsibility for error recovery, packet retransmissions, and so on.

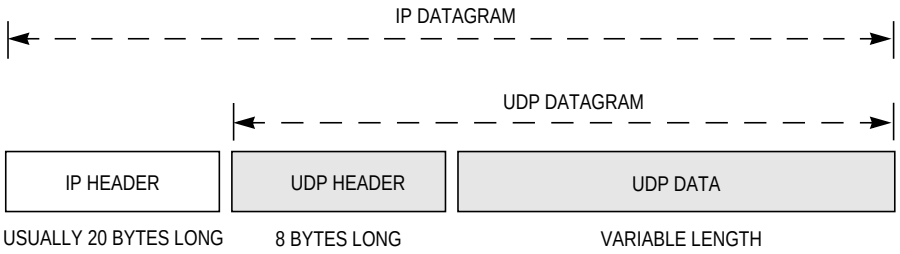


Figure 8. UDP as an Application Interface to IP

UDP provides no means for flow control or error recovery like his peer TCP, thus making it an unreliable protocol. Unreliable means that UDP does not use acknowledgments when a datagram arrives at its destination, it does not order incoming messages arriving out of sequence, and it does not provide feedback to control the rate at which incoming information flows between hosts. Thus UDP messages can be lost, duplicated, or arrive out of order. This means that it is up to the application using UDP to make the transfer reliable.

UDP is mainly used for transmitting live audio and video, for which some lost or out of sequence data is not a big issue and the advantage of having a transport protocol with low overhead is evident.

The UDP header reflects the simplicity of the protocol in **Figure 9**.

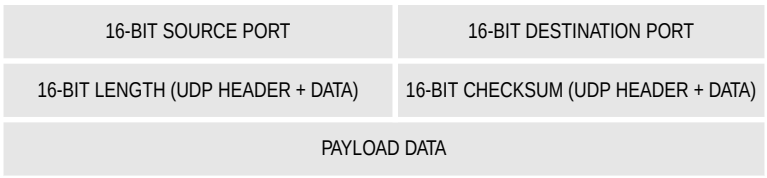


Figure 9. UDP Packet Format

UDP simply serves as a multiplexer/demultiplexer for sending and receiving datagrams using ports to direct them to different services at both ends of the Internet conversation. Notice how the UDP format specifies two ports; one is the source port and the other is the destination port.

A port is a 16-bit number, used by the host-to-host protocol to identify to which higher level protocol or application program it must deliver incoming messages. In a TCP connection, for instance, a well-known port is port 80. HTTP servers expect an incoming request from clients through this port.

Standard applications using UDP include Trivial File Transfer Protocol (TFTP), Domain Name System (DNS) name server, Remote Procedure Call (RPC) used by the Network File System (NFS), Simple Network Management Protocol (SNMP), and Lightweight Directory Access Protocol (LDAP).

A UDP/IP packet containing a "Hello World!" message is shown in **Figure 10**. The packet is being sent from a host with IP address 192.168.55.2 to 192.168.55.1. The source port is 1020 while the destination port is 11222.

```
45 00 00 28 00 F0 00 00 80 11 97 34 C0 A8 37 02
C0 A8 37 01 03 FC 2B D6 00 14 DB 63 48 65 6C 6C
6F 20 57 6F 72 6C 64 21
```

Figure 10. UDP Packet Carrying "Hello World!" Message

Internet Control Message Protocol (ICMP)

The Internet control message protocol or ICMP is used to provide feedback about problems in the communication environment used by the IP as stated in RFC 792 which describes this protocol. ICMP provides mechanisms to tell whether the part of the Internet we are sending datagrams to or want to access is active.

ICMP is always carried by the IP or encapsulated within the IP data packets. ICMP datagrams will always have a protocol number of 1 inside the IP header, indicating ICMP. The IP Data field will contain the actual ICMP message in the layout shown next in **Figure 11**.

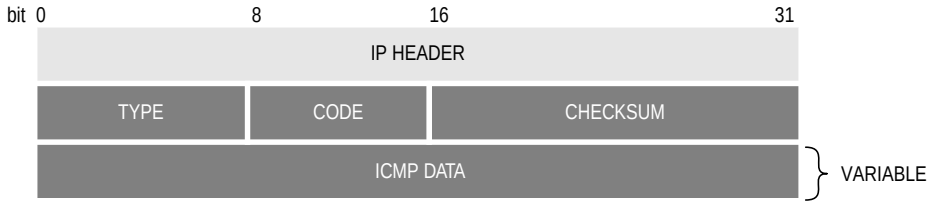
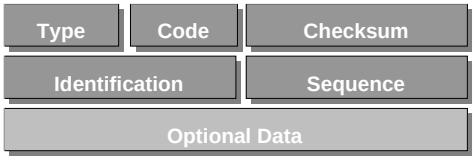


Figure 11. ICMP Message Layout

The ICMP message layout is very simple. Implementations of this protocol should check the type and code fields to determine the nature of the message. For instance, a type field set to 8 requires an *echo* reply from the destination IP. The originator of this ICMP message can then determine if the host is reachable or not. This is perhaps the most popular ICMP application used today and is called ping (described next). After the Code field, the checksum follows and is calculated over the entire ICMP packet without taking the IP header into account.

This application note implements ICMP support to send and receive ping messages. The format of a ping message (officially called echo request) is shown in **Figure 12**.



Type

8 - ECHO REQUEST

0 - ECHO REPLY

Code

Always 0 for ECHO messages

Identification and Sequence

Two 16-bit fields to aid in matching echoes and replies

Data

This data is optional for the originator; however, for an upcoming ping request, the data must be returned in the reply message.

Figure 12. Ping Message Format or Echo/Echo Reply Message Format

Once the sender sets the type field to 8 (echo request) and the code to 0, it must initialize the identifier and sequence number prior to a ping execution. Those fields are used when multiple echo requests are sent. If desired, the ping originator can add optional data to the ICMP packet. The maximum amount of data should be no more than 64 Kbytes long. Since this amount also applies to incoming requests, this application note silently discards such big packets.

Dialing an Internet Service Provider (ISP)

Once connected to the Internet, a system can send packets of information to other hosts who are on-line regardless of the physical location of the destination host. That's the main job of the IP protocol and the internetwork infrastructure of routers and gateways that form the Internet. Each time a system wants to be connected to the Internet it must have the physical interface to do so. One of the most popular ways to establish an Internet connection is by using a modem attached to a phone line with the help of an Internet service provider or ISP. An ISP is a company that provides access to the Internet and other related services such as Web site building and hosting. An ISP has the equipment and the telecommunication line access required to have an access point to the Internet with a unique IP address.

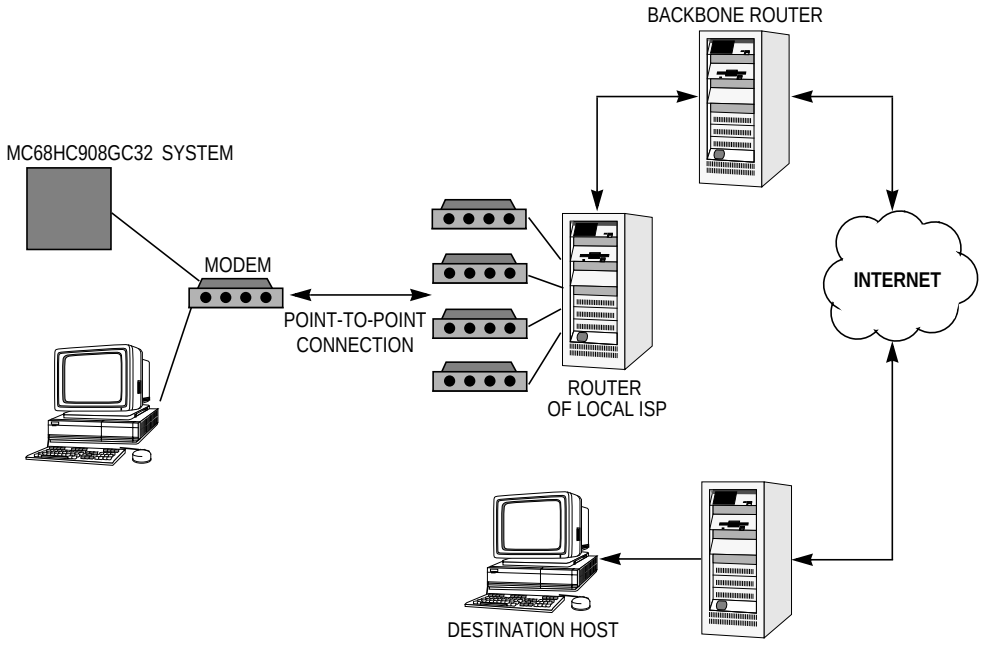


Figure 13. Modem Connection to an Internet Service Provider (ISP)

A host first dials to the phone number of the ISP. After the user is logged in and the password authentication process is done, the ISP assigns a unique IP address to the dialing host. This unique IP address is often referred to as point of presence or POP. Since the dialing host now owns a POP, it is part of the ISP network by means of the ISP router. At that time, the dialing host is now connected to the Internet.

When the host sends an IP packet to the Internet, the host does not know where the destination device is; it simply knows its IP address. When the IP packet reaches the ISP router, the router will try to resolve the IP address on the ISP local network. This step will be executed by each router the IP packet travels on.

Point-to-Point Protocol (PPP)

The point-to-point protocol or PPP is the predominant connection type used today for serial links. PPP is a complete suite of standard protocols widely adopted by the industry that allows two hosts to interoperate in a multi-vendor network using a serial link such as RS232.

Accordingly to RFC 1662, PPP uses a HDLC-like framing providing address and control fields; for PPP these fields are constants 0xFF and 0x03. For RS232 interfaces, PPP can be seen as a byte-oriented asynchronous link with one stop bit, no parity, and with no special requirements for the transmission rate.

The only absolute requirement imposed by PPP is the provision of a full-duplex circuit not requiring the use of control signals such as RTS or CTS. Because signaling is not required, the physical layer can be decoupled from the data link layer hiding much of the details of the physical transport.

The format of a PPP packet is shown in **Figure 14.**

Start Flag 0x7F	Address 0xFF	Control 0x03	Protocol (2 Bytes)	Code (1 Byte)	ID (1 Byte)	Length (2 Bytes)	Payload (Variable)	Checksum (2 Bytes)	End Flag 0x7F

Protocol	Description
0xC021	Link control protocol (LCP)
0xC023	Password authentication protocol (PAP)
0xC223	Challenge handshake authentication protocol (CHAP)
0x8021	Internet protocol control protocol (IPCP)
0x0021	Internet protocol

Figure 14. PPP Packet Format and Protocol Identifiers

PPP Framing

Every frame starts and ends with the 0x7F flag. Since this is a special flag, no other instances should be placed inside the packet. To avoid confusion with the link status, this character and other control characters of the ASCII set inside the frame must be escaped. The control escape sequence is defined as 0x7D followed by the result of an XOR operation of the control character with 0x20. This also applies to the 0x7D escape indicator. The escape sequence must be applied to all bytes in a PPP frame but the start and stop indicators. After the start flag, two HDLC constants follow: 0xFF and 0x03. The protocol field is always two bytes long, indicating what type of protocol is contained in the payload and how it should be treated. For practical purposes, this application note will treat the code, ID, and length fields as separate fields from the payload, but, officially, they are part of it.

The code is the type of negotiation packet for LCP, PAP, IPCP, and CHAP frames. For IP datagrams it is usually 0x45 (when the header does not include options which is true most of the time). The ID should be unique for each frame to be negotiated and responses should use that same ID to tie them up together. An exception to this rule is when a PPP frame encapsulates an IP datagram. In such a case and for practical purposes, the ID usually will be the type of service. The payload is variable and depends on the negotiation options of a request or a response. In the case of a IP datagram, the size is compatible with the size field of the PPP frame.

The payload contains the negotiation options or the rest of the IP packet. Finally, a 2-byte checksum or frame check sequence (FCS) which is computed over the entire unescaped packet with the help of a lookup table defined in RFC 1662.

In a PPP session, both peers have no distinction of who is the server and who is the client. Both end-points can carry up a negotiation equally. However, for practical purposes, this application note defines a PPP server as the end-point located and handled by the ISP and a PPP client as the end-point that initiates the connection. Another way to define a PPP server is the end of the link that requires password authentication, that is the authenticator.

Usually, PPP sessions are started by a client dialing up an ISP. To start a session, the PPP client must establish, maintain, and terminate a physical connection with the ISP.

The overall process is illustrated in **Figure 15**.

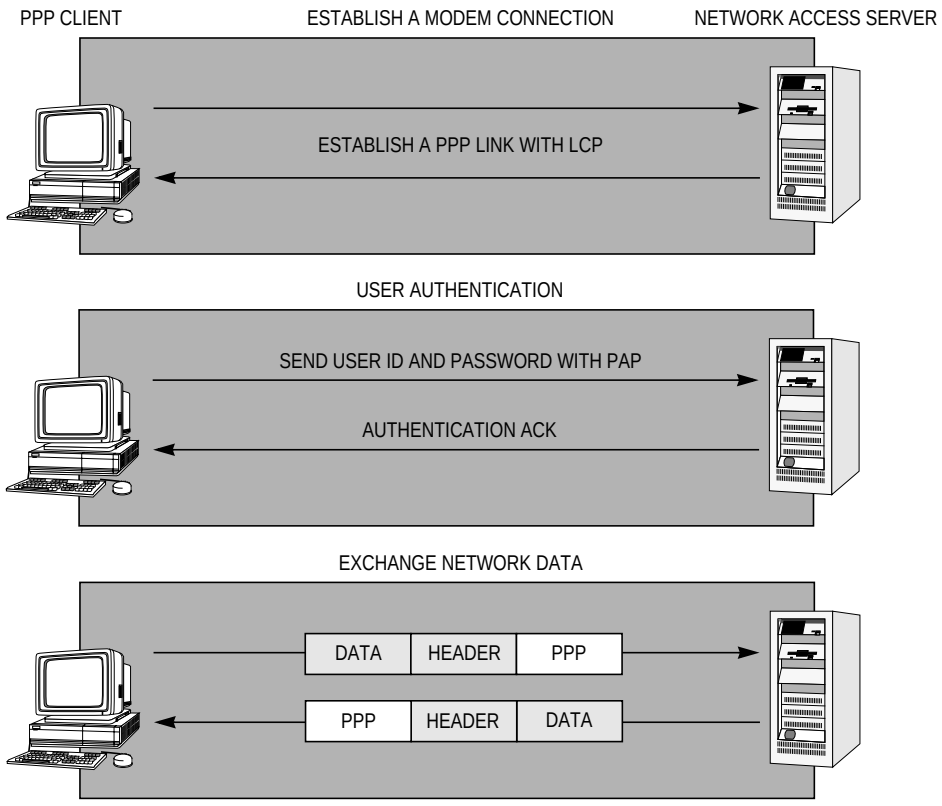


Figure 15. Creating a PPP Link with an ISP

A more in-depth look of the dial up sequence for PPP will show that the sequence involves the following three steps:

1. LCP negotiations — Establish and configure link and framing parameters such as maximum frame size
2. Negotiate authentication protocols — The authentication protocols defined for PPP are the challenge authentication protocol (CHAP) and the password authentication protocol (PAP). The security level of these protocols ranges from encrypted authentication (CHAP) to clear text password authentication (PAP). This application note only supports PAP.
3. Negotiate network control protocols (NCP) — NCPs are used to establish and configure different network protocol parameters, such as IP. This includes negotiating protocol header compression or IP address assignation.

Before a link is considered ready for use by network-layer protocols, a specific sequence of events must happen. The LCP provides a method of establishing, configuring, maintaining, and terminating the connection.

LCP goes through four phases:

1. Link establishment and configuration negotiation (LCP phase) — In this phase, link control packets are exchanged and link configuration options are negotiated. Once options are agreed upon, the link is open, but not necessarily ready for network-layer protocols to be started.
2. Authentication (PAP or CHAP phase) — This phase is optional. Each end of the link authenticates itself with the remote end using authentication methods agreed to during phase 1.
3. Network-layer protocol configuration negotiation (IPCP phase) — Once LCP has finished the previous phase, network-layer protocols may be separately configured by the appropriate NCP.
4. Link termination — LCP may terminate the link at any time. This usually will be done at the request of a human user, but may happen because of a physical event.

LCP Negotiations

The link control protocol (LCP) is used to establish the connection through an exchange of configure packets. LCP negotiations are the first to take place during the PPP session.

The mechanism for PPP negotiations relies on the packet codes described in **Table 2**.

Table 2. Packet Codes

Type	Packet Type	Defined In	Description
0	Vendor specific	RFC2153	Proprietary vendor extensions
1	Configure-request	RFC1661	Configuration options the sender desires to negotiate
2	Configure-ack	RFC1661	Configuration options the sender is acknowledging
3	Configure-nak	RFC1661	Unacceptable configuration options from the configure-request packet; acceptable values are included
4	Configure-reject	RFC1661	Configuration options are not recognizable or are not acceptable for negotiations
5	Terminate-request	RFC1661	Terminate this link
6	Terminate-ack	RFC1661	Terminate acknowledge
7	Code-reject	RFC1661	Reception of an LCP packet with an unknown code
8	Protocol-reject	RFC1661	Reception of a PPP packet with an unknown protocol field
9	Echo-request	RFC1661	Initiation of a loopback mechanism
10	Echo-reply	RFC1661	Response to an echo-request
11	Discard-request	RFC1661	Discard this packet for testing and debugging purposes

Figure 16 shows an example of the first LCP packet transmitted by an ISP.

```
LCP Packet
0000: 7F FF 03 C0 21 01 71 00 2B 01 04 06 40 05 06 3A 5D 8B B4 02 06 00
0016: 00 00 00 11 04 06 40 17 04 00 64 00 02 03 04 C0 23 13 09 03 08 00
002C: 03 0A 2C 2C 95 7F 7F
```

NOTE: The figure shows a packet without applying the escape sequence.

Figure 16. First LCP Packet Transmitted by an ISP

A description of the LCP data is given in **Table 3**.

Table 3. LCP Data Description

Field Type	Hexadecimal Value(s)	Meaning
Framing	7F	Start of packet
	FF 03	Framing
Protocol	C0 21	LCP protocol
Negotiation code	01	REQ - Request options
ID	71	ID for this packet
Size of packet	00 2B	Size of payload starting from negotiation code
Options	01	**Option 1, Maximum-Receive-Unit**
	04	Size of option 1, 4 Bytes
	06 40	Option value requested, MRU = 1600
	05	**Option 5, Magic number**
	06	Size of option 5, 6 Bytes
	3A 5D 8B B4	Value of magic number
	02	**Option 2, Async-Control-Character-Map**
	06	Size of option 2
	00 00 00 00	Escape no characters
	11	**Option 17, Multilink-MRRU**
	04	Size of option 11
	06 40	Value
	17	**Option 23, Link Discriminator for BACP**
	04	Size of option 17
	00 64	Value
	00	**Option 0, Vendor Specific**
	02	Size of option 0
	03	**Option 3, Authentication-Protocol**
	04	Size of option 3
	C0 23	Value set to PAP
	13	**Option 19, Multilink-Endpoint-Discriminator**
	09	Size of option 13
	03 08 00 03 0A 2C 2C	Value of option 13
Checksum	95 7F	Checksum of this packet
Framing	7F	End of packet

The most common LCP negotiations happening during initial connection are maximum-receive-unit, protocol-field-compression, magic-number, authentication-protocol and async-control-character-map, all described in RFC1661 and RFC1662. This application note tries to force negotiations to go our way. It first tries to use the default settings provided by the ISP and goes from there. However, different implementations should modify the state machine inside *HandleLCPOptions ()* routine to handle LCP options differently.

Password Authentication Protocol (PAP)

The password authentication protocol is defined in RFC 1334. PAP is intended primarily for use by hosts and routers that connect to a PPP network server commonly via dial-up lines, but it might be applied to dedicated point-to-point links as well. The server can use the identification of the connecting host or router in the selection of options for network layer negotiations. The authenticate-request packet format is shown in **Figure 17**.

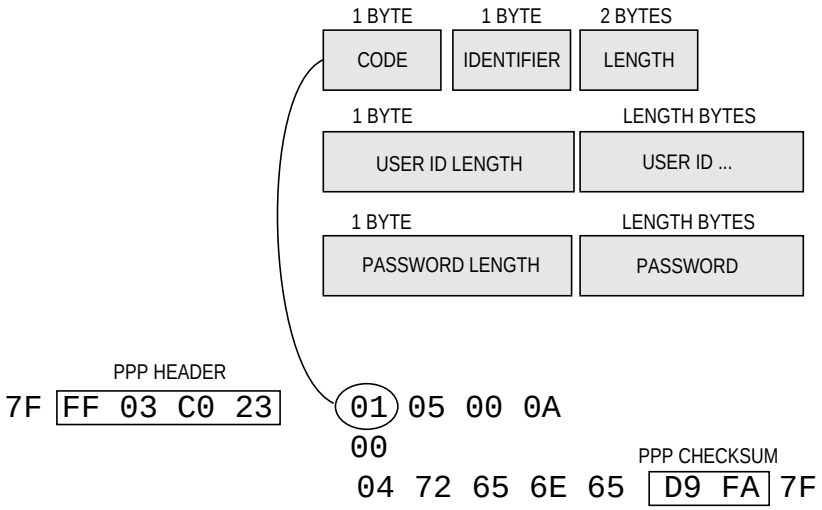


Figure 17. PAP Packet Layout and Sample — User ID = "", Password = "rene"

Internet Protocol Control Protocol

After the PPP host has been authenticated, the next phase is the network-layer protocol. The Internet protocol control protocol (IPCP) is used to configure the Internet protocol environment to be used in a PPP link. Options such as IP address, IP compression, primary DNS server, etc., are negotiated using IPCP.

The format of an IPCP frame is similar to that of LCP: a 1 byte negotiation code followed by ID, length, and options. Once the IP protocol has been configured, datagrams from each network can be sent in both direction over the link. Further details of IPCP are covered in RFC 1332.

PPP Negotiations

All LCP negotiations are performed in a state machine implemented inside the PPP.C module. When the first LCP packet arrives from the ISP, the state machine responds with a NAK packet with the same options the ISP sent us before. This will force the ISP to reply with a request for the authentication protocol to be used. The negotiation flow is shown in **Figure 18**.

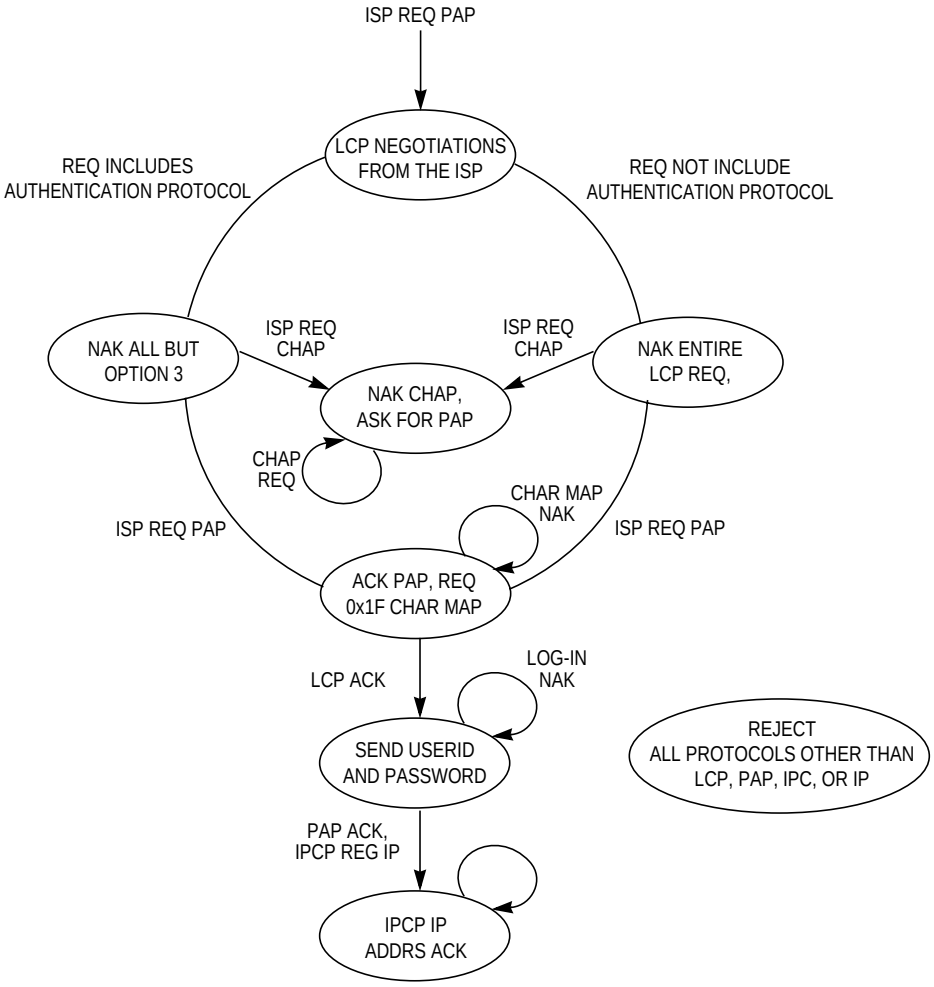


Figure 18. PPP Normal Negotiation Flow

A hexadecimal dump of the LCP, PAP, and IPCP negotiation sequence is shown in **Figure 19**. This dump is a recorded PPP session between a real ISP and the M68HC08-based application. First, LCP negotiations are shown in **Figure 19**.

```
(1) First LCP packet sent by the ISP
FF 03 C0 21 01 01 00 30 02 06 00 0A 00 00 03 05 C2 23 80 05 06 00 77 BB 67 07
02 08 02 11 04 05 DC 13 13 01 20 B6 60 C1 67 BB 77 00 C0 DC 5E C1
F5 10 00 00 67 40

(2) PPP response from the HC08 (NAK all but option 3 – Password Authentication)
FF 03 C0 21 04 01 00 2B 02 06 00 0A 00 00 05 06 00 77 BB 67 07 02 08 02
11 04 05 DC 13 13 01 20 B6 60 C1 67 BB 77 00 C0 DC 5E C1 F5 10 00 00 00
00

(3) ISP is forced to negotiate authentication protocol (either CHAP or PAP from
previous NAK frame sent )
FF 03 C0 21 01 02 00 09 03 05 C2 23 80 2A CA

(4) HC08 respond with NAK to CHAP, we want to use PAP instead
FF 03 C0 21 01 02 00 09 03 05 C0 23 80 2A CA

(5) ISP agrees and reply with a new REQ, this time requesting PAP
FF 03 C0 21 01 03 00 08 03 04 C0 23 F6 74

(6) HC-9 ACK PAP
FF 03 C0 21 02 03 00 08 03 04 C0 23 F6 74

(7) HC08 wants to negotiate the character map to escape
FF 03 C0 21 01 04 00 0A 02 06 FF FF FF FF E4 06

(8) ISP agrees on escape all control characters
FF 03 C0 21 02 04 00 0A 02 06 FF FF FF FF B0 8E
```

Figure 19. LCP Negotiations with an ISP

After ISP agrees to use PAP during the LCP negotiation phase, the M68HC08 must send the user ID and password to log into the ISP network. This process is illustrated in **Figure 20**.

```
(9) HC08 sends PAP Packet to login ISP network
FF 03 C0 23 01 05 00 0A 00 04 72 65 6E 65 D9 FA

(10) ISP Acknowledge User ID and Password
FF 03 C0 23 02 05 00 05 00 67 49
```

Figure 20. PAP Sequence

Now that the M68HC08 has been authenticated, the next step is to configure the network protocols to be used inside the ISP network. Since we are negotiating with an Internet service provider, IPCP will be used for sure to negotiate IP. IPCP negotiations follow PAP authentication as illustrated in **Figure 21**.

```
(11) ISP send REQ for IPCP negotiations
FF 03 80 21 01 01 00 10 02 06 00 2D 0F 01 03 06 C0 A8 37 01 C2 81

(12) HC08 reply with a NAK for all options but option 3 - IP address
FF 03 80 21 04 01 00 0A 02 06 00 2D 0F 01 6C 65

(13) ISP sends a reply because of the previous NAK sent, this time
with IP address only
FF 03 80 21 01 02 00 0A 03 06 C8 26 16 02 A4 17

(14) HC08 now as an IP address assigned by the ISP
FF 03 80 21 02 02 00 0A 03 06 C8 26 16 02 A4 17

(15) HC08 REQ an IP address to complete three way hand shake
FF 03 80 21 01 03 00 0A 03 06 00 00 00 00 CD 63

(16) ISP reply with a NAK containing the pre-assigned IP address
FF 03 80 21 03 03 00 0A 03 06 C8 38 6F 42 41 F2

(17) HC08 is now On-Line with IP Address: 200.56.111.66
FF 03 80 21 02 03 00 0A 03 06 C8 38 6F 42 66 DE
```

Figure 21. IPCP Negotiations between an ISP and the MC68HC08GP32

Serial Line Internet Protocol (SLIP)

This application note also implements the serial line Internet protocol (SLIP) to communicate directly with hosts acting as routers or gateways. The SLIP specifies a way to encapsulate raw IP datagrams over a regular serial communication line. It is a de facto standard not an Internet standard. However, given its popularity, SLIP is described in RFC 1055. Because of its simplicity, SLIP is very easy to implement in comparison with other point-to-point protocols. However, since SLIP specifies only a way to frame an IP packet, it is far less reliable than PPP since it does not provide mechanisms for IP addressing or support for multiple protocols running on top of it. Addressing is a big issue since both ends of the point-to-point link need to know each other's IP addresses for routing purposes.

SLIP defines the following escape codes to signal frame boundaries: END (hexadecimal 0xC0) and ESC (hexadecimal 0xDB).

To send an IP datagram packet, the SLIP host commonly sends an END character, signaling the start of a frame. If any instance of the END code exists within the IP datagram, a 2-byte sequence of ESC and 0xDC are sent instead. After the last byte of the datagram has been sent, an END character is then transmitted as shown in **Figure 22**.

Since the ESC code is also a special character, a SLIP implementation should escape this code as well but with this 2-byte sequence: ESC and 0xDD.

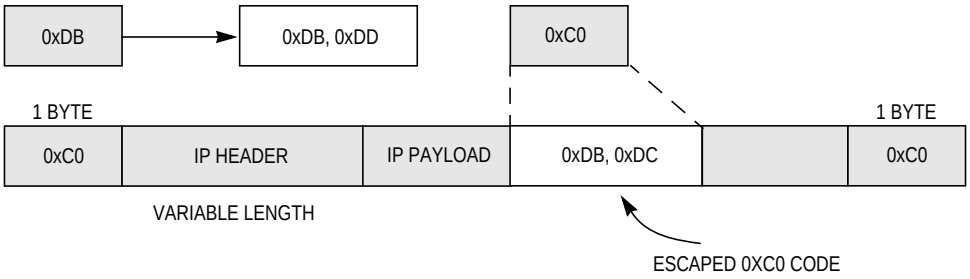


Figure 22. SLIP Frame Layout

One major disadvantage of SLIP is that it requires a dial-up script to negotiate the user ID and authentication with an Internet service provider. Different ISPs would require different scripts, and any changes on the script in the ISP side would require appropriate changes on the client side, thus making it more difficult to implement in a small MCU. Because of the limitations and lack of features, the SLIP protocol is expected to be replaced by the point-to-point protocol (PPP).

UDP/IP Application

This application note shows how a small and inexpensive microcontroller such as the MC68HC908GP32 can be connected to the Internet and still save resources on chip to perform basic operations like remote monitoring and/or control.

The application is very simple: a small system based on the MC68HC908GP32 that monitors an external variable by using the 8-bit analog-to-digital (A/D) builds on chip via a module channel.

In case the A/D reading or some other event is triggered (a pre-fixed A/D threshold has been reached for example), the MC68HC908GP32-based system will send a UDP/IP asynchronous notification to a pre-compiled IP address. This destination IP could be a proxy gateway on the Web, or a custom UDP/IP terminal working as a standalone application, or in the form of a Java applet, or an ActiveX control embedded in a Web page.

Application Framework Block Diagram

The application framework is shown in **Figure 23**. The MC68HC908GP32 acts as a message initiator. It waits until program-defined conditions are meet. A predefine condition could be a security system signaling that it has been triggered, air conditioner has reached a pre-defined threshold, door bell, etc. The system will first dial an ISP to establish a PPP link (1). The ISP will authenticate the system and will assign a unique IP address. After that, the MC68HC908GP32 will now be ready to send a notification to the Internet via PPP/UDP/IP (2).

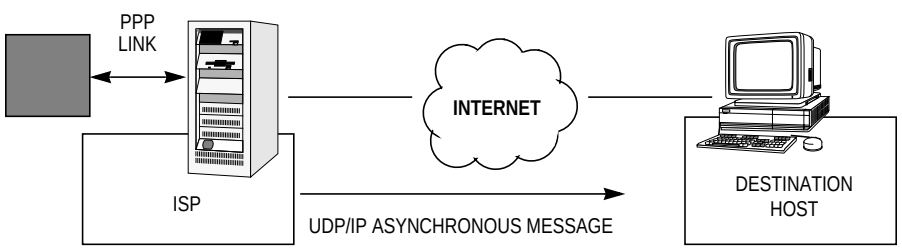


Figure 23. Application Framework

Once on the Internet, a message could travel to virtually everywhere in the planet. With little effort, the UDP datagram could be publicized by a program running at the destination host.

Software Operation

The software implementation has been divided in a series of C modules. Code reuse/borrowing and expandability are the main intention for such modularity, so M68HC08 programmers can borrow and/or modify the source code to meet specific application needs for other members of the M68HC08 Family of MCUs. Or they can build a set of libraries and/or features to be integrated in future applications in the form of object code to be linked together during the development process.

These modules are defined by this application note:

- Main C modules
  - Main.C
  - CommDrv.C
  - ModemDrv.C
  - PPP.C
  - SLIP.C
  - IP.C
  - UDP.C
  - ICMP.C
- Miscellaneous C module
  - Delay.C

The software consists of a main routine (the standard C main() function) that is divided in two in-line portions of code. The first portion initializes the communications port and all the other software modules of the system. The second portion is an infinite loop which calls *ModemEntry ()* and *PPPEntry()* functions. This is needed to perform modem handshake and PPP negotiations, respectively. (SLIP could be used instead of PPP by calling *SLIPEntry()* from the main loop.)

The first module we need to inspect is the CommDrv.C. This module is responsible for the appropriate operation of the serial communications of the system. It implements a pseudo-standard method of accessing the serial port hardware. To the application, the serial port can be seen as a set of "API like" routines that perform straight and logical operations (*OpenComm(), CloseComm(), WriteComm()* etc).

The intention of such implementation is to pursue a fixed level of abstraction to the application code. Abstraction can bring us a lot of benefits. For instance, code reuse and code maintainability are, among others some of the strongest justifications of using it. When hardware changes, the abstraction changes in one portion of the code; changes are almost transparent to the application or portions of the source code. For example, changing the baud rate of the serial port or more often changing the address of the registers (and even the registers) in the initialization sequence of the serial port would require a change in the definitions in the header file of the module and/or the source code of the *OpenComm()* routine. The benefit, if not obvious, will become evident after linking. Different methods for abstracting hardware exists today, but the implementation is well beyond the scope of this application note.

NOTE: *The MC68HC908GP32 defines the interrupt vector table in the upper section of the FLASH ROM at address 0xFFDC to 0xFFFF as illustrated in* ***Table 4****. In that space, we need to store each of the FLASH ROM locations of every interrupt service routines (ISRs) used by the microcontroller.*

Table 4. MC68HC908GP32 Interrupt Vector Table

Vector	Address	Vector Description
17	0xFFDC	Timebase module vector
16	0xFFDE	Analog-to-digital conversion complete
15	0xFFE0	Keyboard scan vector
14	0xFFE2	Serial communications transmit vector
13	0xFFE4	Serial communications receive vector
12	0xFFE6	Serial communications error vector
11	0xFFE8	SPI transmit vector
10	0xFFEA	SPI receive vector
9	0xFFEC	Timer interface module 2 overflow vector
8	0xFFEE	Timer interface module 2 channel 1 vector
7	0xFFF0	Timer interface module 2 channel 0 vector
6	0xFFF2	Timer interface module 1 overflow vector
5	0xFFF4	Timer interface module 1 channel 1 vector
4	0xFFF6	Timer interface module 1 channel 0 vector
3	0xFFF8	PLL vector
2	0xFFFA	IRQ vector
1	0xFFFC	Software interrupt vector
-	0xFFFE	Reset

The CommDrv.C module defines the ISR code for the interrupt generated each time the SCI receives a byte character. However, this ISR is compiled by the compiler to generate the object code that the linker will realize and place it in FLASH ROM. That means that the source code of the ISR is installed at link time (or design time, if you will) not at run time. Since the serial port of the MCU in this specific implementation will be shared between different modules to perform different tasks at run time, a way must be found to share that ISR with different modules. For instance, the MCU must dial to an ISP by using a modem; after the ISP answers, SLIP scripts or PPP negotiations need to be executed. Modem.C and PPP.C must rely on the CommDrv.C ISR.

One way to achieve the flexibility needed is to forward the ISR to a location in RAM that points to the ultimate interrupt service handler: in other words, a pointer to an ISR that turns out to be a pointer to a function. By using this approach, the programmer has total control of the incoming flow of characters through the serial port.

Actually, the body of the ISR of the CommDrv.C is simple and is shown **Figure 24**.

```
static void CommDrvDefaultProc (register BYTE value) { (void) value; };
static void (* EvtProcedure) (register BYTE value) = CommDrvDefaultProc;

/////////////// Interrupt Service Routine /////////////////
void @interrupt UartRxISR (void) {
       SCS1;                        // Clear Interrupt flag
       EvtProcedure (SCDR);         // Forward ISR to EventProc
}
```

Figure 24. Body of the SCI ISR

Listing 1

The M68HC08 CPU has very powerful addressing modes in comparison with other 8-bit MCUs' architectures in the market. The ISR definition in CommDrv uses a powerful indexed addressing mode provided by the M68HC08 CPU. The JSR instruction can jump to a subroutine pointed to by the index register H:X, which allows the program counter to jump to an effective address with 16-bit resolution.

But for every value-added feature, we must pay a price, and, in this case, we lose valuable CPU bandwidth. The minimum assembly code needed to represent the code in **Listing 1** is represented in **Figure 25**.

```
PSH     H
LDA     SCS1     ;Read contents of SCS1 register
LDA     SCDR     ;Store Serial port character on Acc
LDHX    0x45     ;Load Effective 16-bit address of pseudo-ISR
JSR     ,X       ;Jump to Event Handler
PUL     H
RTI              ;Return from Interrupt
```

Figure 25. Minimum Assembly Code

If we can force the compiler to place **EvtProcedure* (register BYTE value) pointer in the zero page section of RAM, we can get similar results from a compiler, but this will depend mainly on the compiler itself and the context of the development environment used at design time.

The **EvtProcedure* pointer becomes initialized at design time by this construct.

```
static void (* EvtProcedure) (register BYTE value) = CommDrvDefaultProc;
```

CommDrvDefaultProc() is a private function defined in CommDrv which does nothing but initialize **EvtProcedure* pointer and is defined as follows.

```
static void CommDrvDefaultProc (register BYTE value) { (void) value; };
```

By using the *CommEventProc()* function, an application can "mutate" the behavior of the SCI ISR, as shown in this application note.

Overview of the Modem Interface

This application note was built around a “Hayes-compatible” external modem. In the past, when a high-speed modem was considered to be a 9600-baud unit, a company called Hayes Microcomputer Products Inc. made a modem that was widely accepted by microcomputer users. The implementation features and the serial commands used by these modems became a de facto standard in the industry. Given its popularity and for compatibility reasons, nowadays most modems are “Hayes-compatible.”

Operation of a Hayes-Compatible Model

A Hayes modem is always in two states:

- Command mode
- On-line state

When in command mode, instructions can be given to it from the serial port. For example, we can instruct the modem to dial a number or to ignore incoming calls by means of simple commands. These commands are diverted to the modem and are never transmitted.

In the on-line state, once a connection has been established with a modem of a remote system (for instance, an ISP), the local modem enters the on-line state and no longer attempts to interpret the data being sent to it. In other words, every data sent while on-line state is transmitted to the remote modem regardless of its nature. If the remote system hangs up or for any other reason the carrier signal is lost while in on-line state, the modem will revert to local command mode.

When the modem receives a command (in command mode), it returns a result code. This code can be in the form of either a text string or a numeric code. A numeric code is more appropriate for embedded systems, but if we want to control the modem by using a terminal and a keyboard, a verbose mode or text messages are more preferable. We can set the type of result code by using a command message.

Table 5 shows the result codes of a Hayes-compatible modem.

Table 5. Result Codes Summary

No.	Verbose Equivalent	Description
0	OK	Command executed
1	CONNECT	Connection established
2	RING	Ring signal detected
3	NO CARRIER	Carrier signal lost or not detected
4	ERROR	Invalid command, checksum, error in command line, or command line too long
5	CONNECT 1200	Connection established at 1200 bps
6	NO DIALTONE	No dial tone detected
7	BUSY	Busy signal detected
8	NO ANSWER	No response when dialing a system
9	CONNECT 2400	Connection established at 2400 bps

All command messages start with AT, unless otherwise specified. Several commands can be given in one command line. The Hayes command set provides comprehensive messages to configure the modem, dial phone numbers, and answer incoming calls. This application note implements a way to initiate calls only, but making the software answer incoming calls should not be that difficult if the appropriate commands are listened to and issued to the modem.

Although the term “Hayes compatible” is often used in this document, there is no absolute standard defined. Not all Hayes modems work the same way. Always refer to the modem documentation provided by the modem manufacturer.

The software in this application note assumes the configuration and behavior from the modem listed in **Table 6**.

Table 6. Default Configuration of Modem Used in This Application Note

Requirements	Hayes Command Required
Character echo in command state disabled	ATE0
Modem returns result codes	ATQ0
Display result codes in verbose form	ATV1
Long space disconnect disabled	ATY0
Track the presence of data carrier	AT&C1
Hang up and assume command state when an on-to-off transition of DTR occurs	AT&D2

As far as the M68HC08-based system is concerned, the external Hayes-compatible modem is just a serial device connected to the SCI. From a software standpoint, the modem implementation runs on top of the serial port driver; in other words, it relies on services provided by the CommDrv module. The wire connections made from the modem to the M68HC08 system include signal ground, transmitter, and receiver pins.

The modem provides several standard hardware signals for modem handshaking. Only two have been hardwired to the system, carrier detect (CD) and data terminal ready (DTR), making a total of five pins to drive the modem as shown in **Table 7**.

Table 7. DB9 Connector Interface to the MC68HC908GP32

DB9 Pin No.	Pin Name	Description	M68HC08 Pin
1	CD	Carrier detect	PORTD 1
2	RxD	Receiver data	SCI receiver
3	TxD	Transmitter data	SCI transmitter
4	DTR	Data terminal ready	PORTD 0
5	GND	Signal ground	System ground

Notice that the SCI on chip drives the transmitter and receiver signals "directly" from the modem (after an RS232 to CMOS converter) while two extra GPIO (general-purpose input/output) pins provide the DTR (data terminal ready) and CD (carrier detect) signals for modem handshaking. DTR is required to hang up the phone while in on-line state and return to command mode when an on-to-off transition occurs. A CD signal can be pooled from the application to know if the modem is in command mode (CD = 1) or in the on-line state (CD = 0).

The modem driver runs on top of the serial communications routines and relies on them. Because of this, the modem implementation provides its own service routine for incoming characters through the serial port, thus avoiding problems while decoding modem response messages. Once the modem goes on line, the modem service routine is removed from the SCI ISR. This allows installation of the appropriate handler for the point-to-point link (SLIP or PPP) at run time.

The modem service routine simply enqueues (puts into queue) incoming characters from the serial port. By default the maximum number of characters that can be stored in the modem queue is 32. This queue performs as a FIFO (first in, first out) buffer and most of the modem functions rely on it. A common FIFO like the one used in this application note has two pointers; one is used to add data to the FIFO while the other removes queue data. This operation is described in **Figure 26**.

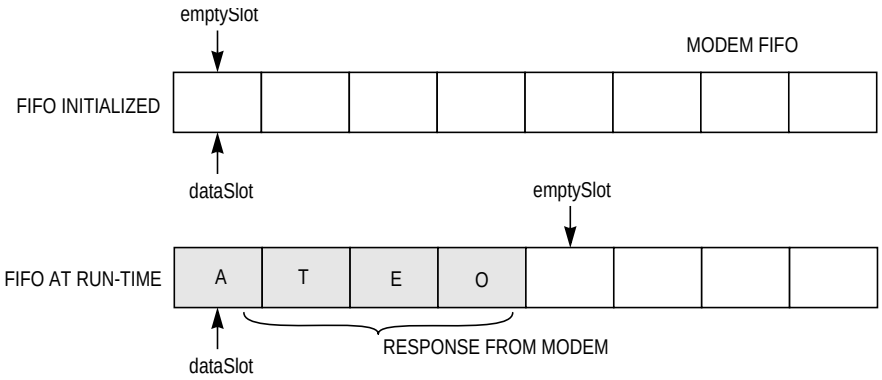


Figure 26. Implementation of a FIFO for the Modem Interface

Figure 26 shows the two internal pointers that make up a FIFO. At initialization time, both pointers are equal to zero, thus indicating that the FIFO is empty. Once a character is received from the SCI, it is stored at the location pointed to by *emptySlot* before it becomes incremented by one. The figure also shows an ATE0 reply from the modem stored in the FIFO following the process just described. Notice how *emptySlot* now points to the next free location of the FIFO. The *dataSlot* pointer has a similar behavior. To read a character from the FIFO, the application calls the *ModemGetch()* function to retrieve the letter A pointed to by *dataSlot*, then it is incremented by one. At this point, *dataSlot* now points to the letter T. This process is repeated for every character added to the FIFO by the modem input routine.

The code to enqueue character in the FIFO is simple and is illustrated in the next piece of code in **Figure 27**.

```
#define MODEM_BUFFER_SIZE 32     // Default size of modem buffer

volatile BYTE mDataSlot = 0;     // Points to the next available character
volatile BYTE mEmptySlot = 0;    // Points to next available slot of the FIFO

static BYTE *ModemBuffer;                // Pointer to Modem buffer

void ProcModemReceive (BYTE c) {
      ModemBuffer [mEmptySlot++] = c;           // enqueue the character
      if (mEmptySlot > MODEM_BUFFER_SIZE) {     // Check for FIFO overflow
            mEmptySlot = 0;                    // the FIFO is circular
   }
}
```

Figure 27. Code to Enqueue a Character in the Modem FIFO

Listing 2

The listing shows the modem service routine that must be called from the ISR of the SCI driver.

The method just described allows great flexibility while handling the FIFO. For instance, to retrieve the number of characters stored in the FIFO, the software only needs to subtract *dataSlot* from *emptySlot*. Another example is the operation to flush the contents of the FIFO will simply require the statement *dataSlot = emptySlot*.

The code to dequeue (pull out of queue) a character from the FIFO is shown in **Figure 28**.

```
BYTE ModemGetch (void) {
BYTE c = 0;
    if (mDataSlot != mEmptySlot) {
         c = ModemBuffer [mDataSlot];
         mDataSlot++;
         if (mDataSlot > MODEM_BUFFER_SIZE) mDataSlot = 0;
                   return(c);
    }
    else {
       return (BYTE)0x00;
       }
}
```

Figure 28. Code to Dequeue a Character from the Modem FIFO

Listing 3

Two important functions are also defined inside the modem module: the *Transmit()* and *Waitfor()* functions. The first transmits data to the modem while the second waits for any particular character or a string of characters before it times out. When used together, both functions provide support for complex scripts required for SLIP sessions. Obviously, those scripts will be built in the ROM code, making it difficult to maintain in some applications.

PPP Module

The PPP implementation runs on top of the hardware interface software. It provides the appropriate mechanism required for LCP, PAP, and IPCP negotiations. These negotiations are performed in a fixed state machine called by the *PPPEntry()* function. This machine is responsive; it builds response packets based on the contents of the received ones. This helps the user to force negotiations to go the desired way.

The PPP module defines two buffers in RAM: the *InBuffer[]* and *OutBuffer[].* By default, each buffer is 88 bytes long. The *InBuffer* stores all incoming packets either from the PPP or SLIP while the *OutBuffer* stores the packets for output.

These buffers are defined inside the PPP module because of the exhaustive use they are exposed to at the PPP level. The buffers are global since they are used by all the other modules of the stack. Each module must define a structure describing the data arrangement they expect. Consider the situation in **Figure 29**.

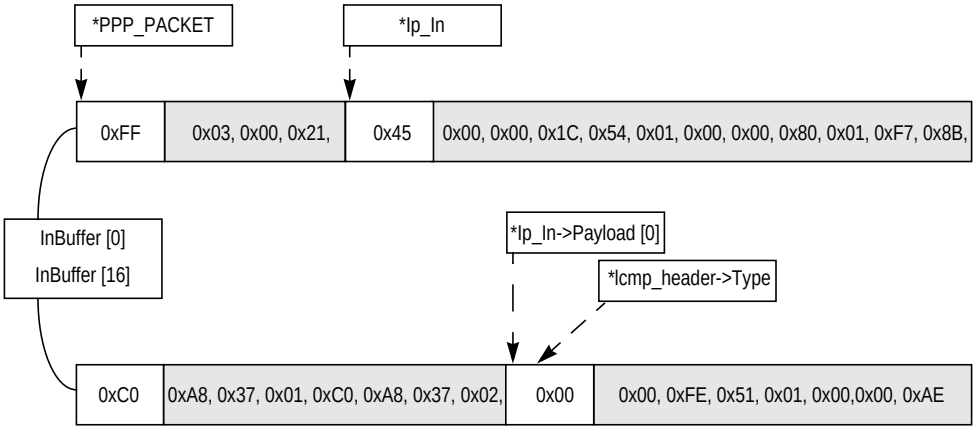


Figure 29. How InBuffer is Shared Between Different Protocol Modules — A Ping Response Using PPP, IP, and ICMP

Figure 29 shows an ECHO reply message type as received by the *PPPEntry()* function. This function then executes the IP handler which in turn passes the *ip_in* pointer to the ICMP handler. Inside this handler the ICMP data can be accessed using the *Payload* field by casting a *ICMPDatagram* struct defined in Icmp.h.

To fill the *InBuffer*, each time a character arrives through the serial port, the SCI ISR should pass the character to the *ProcPPPReceive ()* in the case of PPP or *ProcSLIPReceive()* for SLIP. Both functions decode an entire frame once completed and validated.

The diagram in **Figure 30** illustrates this procedure.

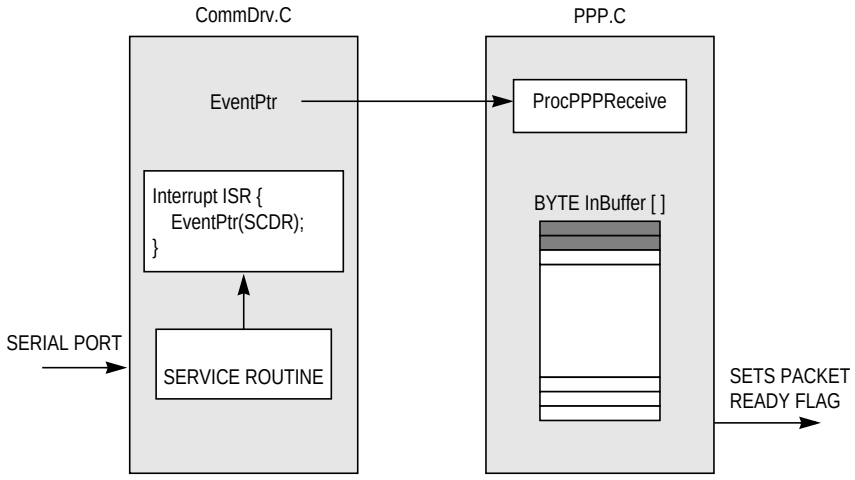


Figure 30. PPP Module Frames Incoming Packet and Stores It in InBuffer

ProcPPPReceive() acts as the ISR for each incoming character. Since the only way for an ISR to communicate with the main thread of execution is by means of a global variable, the PPP module defines a global status byte called *PPPStatus*. When a complete PPP frame is ready for processing, *ProcPPPReceive* sets the *IsFrame* flag. This flag is pooled by *PPPEntry()* in the application main loop.

Listing 4. Body of PPPEntry Function shows the body of the *PPPEntry* function. Note that this also applies to the SLIP interface module.

```
void PPPEntry (void) {

   if (PPPStatus & IsFrame) {    /* Is a PPP packet available for processing? */

        witch (*(WORD *)(&InBuffer [2])) {   /* Process specific protocol */

        case 0xC021:/* LCP Handler */
               HandleLCPOptions ();
        break;

        case 0xC023:/* PAP Handler */
               HanldePAPPackets ();
        break;

        case 0x8021:  /* IPCP Handler */
               HandleIPCPOptions ();
        break;

        case 0x0021:/* IP Data Handler */
             IPHandler ((IPDatagram *)&InBuffer [4]);
        break;

        default:
        break;
     };
     PPPStatus &= ~IsFrame;/* Reset IsFrame Flag */
     PPPStatus |= ReSync;/* Resynchronize PPP framer */
  }
}
```

Figure 31. Body of PPPEntry Function

Listing 4. Body of PPPEntry Function

After a PPP packet is detected, *PPPEntry()* retrieves the protocol field from the packet and then calls the appropriate handler. If new protocols are to be implemented, handlers should be placed inside the switch statement.

Notice how the *IsFrame* flag is cleared at the end of the packet processing. This is needed to avoid frame overlapping (when a new frame is being received before the processing of the previous one occurs). Clearing the *IsFrame* flag tells the *ProcPPPReceive* routine that it can wait for another PPP packet. To do so, it must check the first occurrence of a 0x7F character (the start of a PPP packet). That is why the *ReSync* flag must be set to True. The *ReSync* flag commands the PPP framer to wait for the start of the next incoming packet.

Internet Protocol Implementation

IP datagrams are handled by a switch statement inside the interface entry function *PPPEntry()* or *SLIPEntry().* Not much happens at the IP level: Only the destination IP address is checked to see if the datagram has been intended to the M68HC08 IP address.

```
void IPHandler (IPDatagram *ip) {

       /* Compare IP address with datagram received */
       if (!IPCompare ((BYTE *)&ip->SourceAddress[0]) {
                     /* Misrouted datagram or broadcast message received  */
       }
       else
              switch (ip->Protocol) {

                     case UDP:     /* Call UDP Handler */
                          UDP_Handler ((UDPDatagram *)&ip->SourceAddress [0]);
                     break;

                     case TCP:     /* Handle TCP segment */
                     break;

                     case ICMP:    /* Handle ICMP commands */
                            IcmpHandler ((IPDatagram *)ip);
                     break;

                     default:      /* Transport protocol unsupported */
                     break;
        }
}
```

Figure 32. Handler of IP Packets

At reset the *IPInit ()* function must be called to initialize the IP datagram pointers to the input and output buffers, respectively. The *ip_in* and *ip_out* pointers are global, so other modules can rely on them to build and send datagrams from scratch. For instance, some ICMP messages would require access to the TTL field in an IP datagram or, in the case of UDP and TCP, calculating the pseudo-header involves the source and destination addresses from the IP header. This is why the UDP implementation defines a *UDPDatagram* structure containing the source and destination IP addresses from the IP header.

The IP implementation checks the protocol field located in the IP header to call the appropriate protocol handler. Since this application note describes UDP and some ICMP functionality, only those protocols are presented with a handler.

In case an ICMP message is received, this code is executed.

```
    switch (ip->Payload [0]) {

          case ECHO:
       Move ((BYTE *)ip, (BYTE *)ip_out, ip->Length);  /* Move ping datagram
to output buffer */

          /* Swap source and destination IP addresses on Output Buffer */
          ip_out->DestAddress [0] = ip->SourceAddress [0];
          ip_out->DestAddress [1] = ip->SourceAddress [1];
          ip_out->DestAddress [2] = ip->SourceAddress [2];
          ip_out->DestAddress [3] = ip->SourceAddress [3];

          ip_out->SourceAddress [0] = ip->DestAddress [0];
          ip_out->SourceAddress [1] = ip->DestAddress [1];
          ip_out->SourceAddress [2] = ip->DestAddress [2];
          ip_out->SourceAddress [3] = ip->DestAddress [3];

          ip_out->Payload [0] = ECHO_REPLY;  /* This will be the echo reply */
          ip_out->Payload [1] = 0;           /* Set ICMP Code to 0 */
          ip_out->Payload [2] = 0;          /* Set ICMP checksum field to 0 */
          ip_out->Payload [3] = 0;           /* during checksum generation */

          /* Calculate ICMP checksum */
       Value = IPCheckSum ((BYTE *)&ip_out->Payload[0], (ip->Length - 20) >> 1);

          ip_out->Payload [2] = (Value >> 8); /* Set ICMP checksum */
          ip_out->Payload [3] = (Value & 0xFF);
          IPNetSend (ip_out);                 /* Send ICMP packet over IP */
    break;

    case ECHO_REPLY:
          // Code to handle ping responses
          // goes here
    break;

    case TRACEROUTE:
    break;

    default:
    break;
}
```

Figure 33. Handler of ICMP Packets

An ECHO type message is commonly referred to as a ping request from a remote host. The handler simply swaps the source and destination IP addresses and changes the message type to ECHO_REPLY. Before the packet is sent back through the IP interface (using the *IPNetSend* function), a new checksum for the ICMP message must be recalculated.

The UDP implementation is not that different from the ICMP. However, since almost all UDP processing is done at the application level, the UDP module supports the use of a CALLBACK for processing incoming UDP data.

Each time an incoming IP packet containing UDP data is received by the PPP or SLIP interface, the CALLBACK function specified by *UDPSetCallbackProc ()* is called from within the UDP handler. The UDP implementation specifies a default callback procedure in case it is not specified outside this module. The callback function has this format.

```
void UDPReceive (BYTE *udp_data, BYTE size_of_data, WORD udp_port) {
       // Do something
}
```

Because no buffered mechanism is used in the software, the data pointer passed to the callback function points to the UDP data physically located inside the section of RAM allocated for *InBuffer[]*. For this reason, this data must be processed on the fly. Also there is no risk of recursivity while executing the callback function because the *InBuffer* and the PPP framer have been blocked by the *PPPEntry()* function.

Summary

The M68HC08 has a powerful instruction set and addressing modes. With some effort, the source code presented in this application note can be highly optimized in both speed and size using the M68HC08 CPU features for the C language (not to mention the optimizations that can be achieved using assembly language).

Imagine the possibilities, and keep in mind that the MC68HC908GP32 has plenty of hardware resources to use in an Internet-enabled application: an SPI, two 2-channel timers, A/D channels, a timebase module, a keyboard interface module, and more than half the RAM and FLASH ROM of the total available.

Internet programming can be difficult sometimes, especially when the programmer has little or no experience with the inner aspects of the TCP/IP protocol suite. This document serves as a good introduction to such exciting technology. Remember that when the appropriate tools and utilities are in place, getting the knowledge to create Internet applications can be achieved easily through experimentation.

The software presented in this document can be used as a reference for more professional and serious applications. Improving the software should be easy. Here is a hint: Because buffering is used, adding more hardware interfaces should be easy. Just code the appropriate framer for input and output, define a global flag to signal events to the application main loop, share the *InBuffer* with the *ip_in* pointer, and you are finished.

Perhaps the reader can argue that the buffer approach is slow and inappropriate for a small MCU, but it has been proven that the M68HC08 supports it easily. Besides, there is no reason to avoid a byte-by-byte processing technique. The CPU can process and validate incoming packets on the fly without storing headers or trailers reducing the amount of RAM required to store a packet.

The same applies to outgoing packets when there is enough information on memory to reproduce them. Perhaps this would be the job of a SOCKET structure running on top of the PPP implementation. It is just a matter of sitting down, coding, and experimenting with the M68HC08. A creative programmer with an Internet-ready M68HC08 can be a powerful combination.

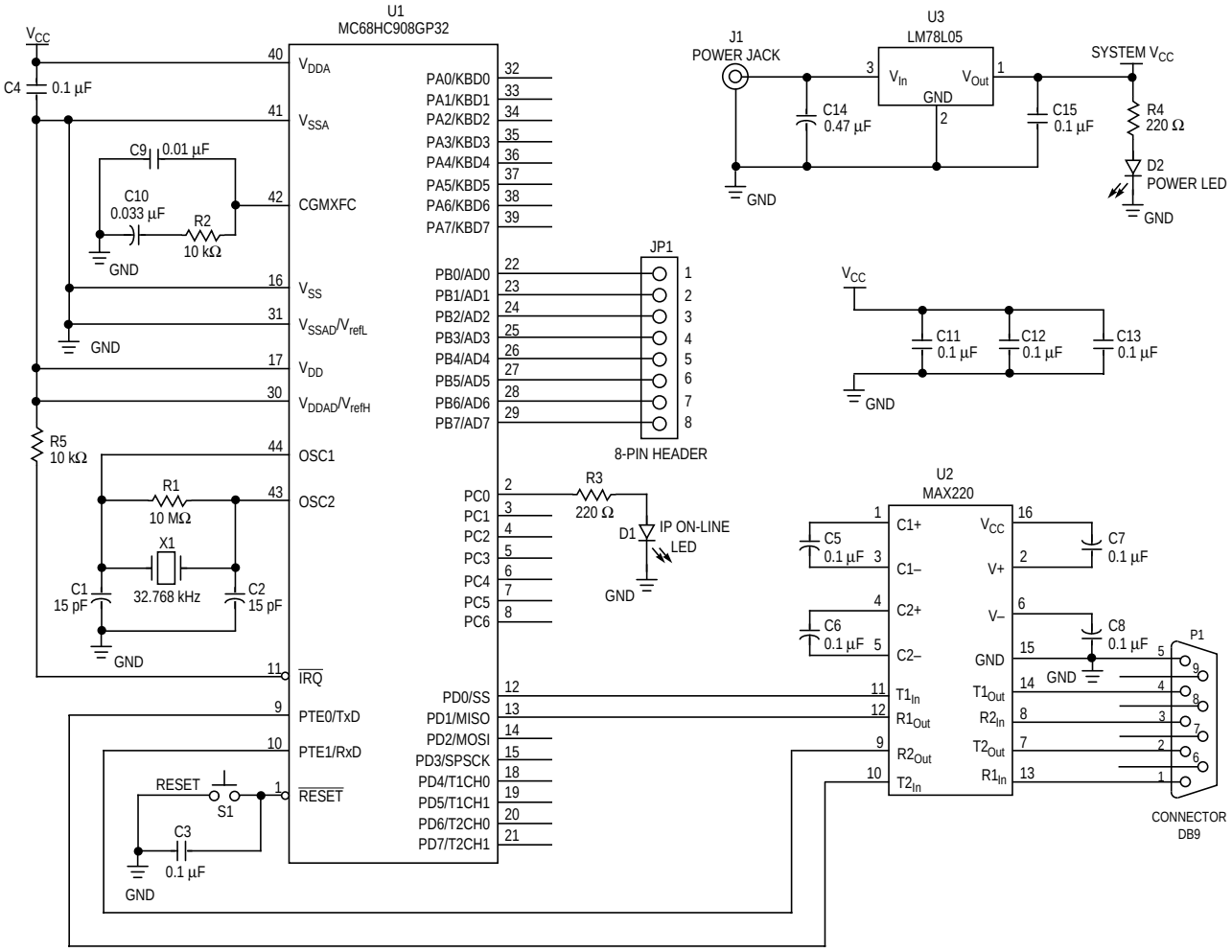


Figure 34. MC68HC908GP32 UDP/IP Implementation

Code Implementation

The source code of this application note is described in **Table 8**.

Table 8. Code Statistics

Segment	Location Org	Location End	Size in Bytes
Non-initialized data in zero page RAM	0x0040	0x0044	4
Non-initialized data in RAM	0x0067	0x0128	193
Program code	0xB000	0xC513	5395
Program initialized RAM	0x0045	0x0066	33
Text string and constants	0xC53E	0xC7C8	650
Vector table	0xFFDC	0xFFFF	35
Total RAM		230	
Total ROM		6080	

Main.C
Application Main Function

```
#include <iogp20.h>
#include "CommDrv.h"
#include "ModemDrv.h"
#include "ppp.h"
#include "UDP.h"
#include "IP.h"
#include "SLIP.h"

//#define USE_SLIP                                  // Uncomment this line if SLIP is to be used

BYTE RemoteServer [4] = {200, 168, 3, 11};        // Remote Server to send notifications

const char * ModemCommand [] = {                  // Array of modem initialization commands
        "ATZ\r",                                  // Reset Command
        "ATE0\r",                                 // Disable Echo
        "AT&C1\r",                                // Track presence of data carrier
        "AT&D3\r"                                 // Reset modem when an on-to-off transition
of DTR ocurres
};



/*********************************************************************
Function :      ModemHandler

Parameters :    Code - Numeric response code from a Modem dial command

Date :          January 2001

Desc :          This function handles the numeric responses from a dial command
                issued to the modem

*********************************************************************/
void ModemHandler (BYTE Code) {

        switch (Code) {
                case '0':                         // OK
                break;

                case '1':                         // CONNECT
#ifdef USE_SLIP
                        CommEventProc (ProcSLIPReceive);// Install SLIP Serive
                                                        //routine
#else

                ModemBuffFlush ();                // Flush contents of Modem Buffer
                if (ModemGetch () != 0x7F) {      // Test for PPP packets
                        Waitfor (":", 100);       // Wait for "Username:" of ISP script
                        PPPSendVoidLCP ();        // ForcePPPtransactionsinsteadof
                                                  // scripts
}
```

```
CommEventProc   (ProcPPPReceive);               // Install PPP service routine
#endif
                break;

                case '2':                       // RING
                break;

                case '3':                       // NO CARRIER
                break;

                case '4':                       // ERROR
                break;

                case '6':                       // NO DIAL TONE
                break;

                case '7':                       // BUSY
                break;

                case '8':                       // NO ANSWER
                break;

                case '9':                       // CONNECT 2400
                break;

                default:                        // TIME OUT, NO RESPONSE FROM MODEM RECEIVED!
                break;
        }
}


/*********************************************************************
Function :      UDPReceive

Parameters :    Data of UDP packet,
                size - size of data in bytes
                RemoteIP - sender IP address
                port - UDP port number

Date :          January 2001

Desc :          This function is executed each time a UDP packet is received
                and validated.

*********************************************************************/
void UDPReceive (BYTE *data, BYTE size, DWORD RemoteIP, WORD port) {

        switch (port) {                         // Select the port number of the UDP packet
               case 1080:                       // If port number equals 1080 then reply
                                                // with ADC channel 0
                        ADSCR &= 0x00;          // Get an A/D lecture
                        while (!(0x80 & ADSCR));
                        udp_out->Payload [0] = ADR;             // Format UDP payload
                        UDPSendData ((BYTE *)&RemoteIP, 11222, 0, 1);// Send UDP reply
                break;
```

```
                case 1081:                          // Port = 1081, reply with ADC ch1
                        ADSCR &= 0x01;
                        while (!(0x80 & ADSCR));
                        udp_out->Payload [0] = ADR;
                        UDPSendData ((BYTE *)&RemoteIP, 11222, 0, 1);
                break;

                case 1082:                          // Data through UDP port 1082
                                                    // Do something here
                break;

                case 1083:                          // Data through UDP port 1083
                break;
        }
}


/*********************************************************************
Function :      LinkTask

Parameters :    None

Date :          January 2001

Desc :          This function synchronize the phone line with the PPP
                link.

*********************************************************************/
void LinkTask (void) {
        if ((PPPStatus & LinkOn) && (!ModemOnLine())) {// PPP Link ON while Phone is
                                                        // on-hook!
                PPPStatus &= ~LinkOn;                   // Clear PPP link flag
                PORTC = 0x00;
                CommEventProc (ProcModemReceive);      // Install Modem handler
        }
}


/*********************************************************************
Function :      ApplicationTask

Parameters :    None

Date :          January 2001

Desc :          This function checks channel 2 of the A/D and sends a warning
                message to a remote server using UDP if a conversion is higher than
                hexadecimal 0x35.
*********************************************************************/
void ApplicationTask (void) {
        ADSCR &= 0x02;                          // Test A/D channel 2
        while (!(0x80 & ADSCR));                // Wait for A/D conversion
        if (ADR > 0x35) {                       // If sample is above 0x35
                                                // Send a potification
```

```
                if (!ModemOnLine ()) {          // Test if Modem on-line
NoOperation;                                    // Modem Not on-line,
                                                // we can re-dial here
                }
                UDPSendData ((BYTE *)&RemoteServer, 8010, "Warning from HC08!" , 18);
        }
}


////////////////////////////////////////////////////////////////////////////
// M A I N
////////////////////////////////////////////////////////////////////////////
void main(void) {

  InitPLL ();                                           // Init PLL to 4.9152MHz

  CONFIG1 = (BYTE)0x0B;                         // LVI operates in 5-V mode,
                                                // STOP instruction enabled
                                                // COP Module Dissabled

  CONFIG2 = (BYTE)0x03;                        // Oscillator enabled to operate during stop mode
                                              // Use internal data bus clock as source for the SCI
  PORTC = 0;                    // Set PortC to 0
  DDRC = 0xFF;                  // Set PortC direction to output

        IPInit ();                              // Initialize IP

#ifdef USE_SLIP
        SLIPInit ();                            // Initialize SLIP implementation
        IPBindAdapter (SLIP);                   // Send IP packets using SLIP format
#else
        PPPInit ();                             // Initialize PPP interface
        IPBindAdapter (PPP);                    // Send IP packets using PPP format
#endif
        UDPSetCALLBACK (UDPReceive);            // Set Callback for incoming UDP data

        ModemInit ();                           // Modem Init
        ModemBindBuff (PPPGetInputBuffer());    // Set Modem Buffer for command reception
        CommEventProc (ProcModemReceive);       // re-direct incoming SCI characters to the
                                                // modem interface
        OpenComm (BAUDS_2400,                   // Open the serial port
                ENABLE_RX |                     // Enable SCI Rx and Tx modules
                ENABLE_TX |
                ENABLE_RX_EVENTS);              // Enable Rx IRQs
        {                                       // Create some stack variables
        BYTE Res = 0;                           // Create two temp vars in the stack
        BYTE index;

        for (index = 0; index <= 3; index++) {  // Loop through Modem initiazation
                                                // commands
                transmit (ModemCommand [index]); // Transmit modem command
                Res = Waitfor ("OK", 30);       // Wait for OK

                if (!Res) {                     // Invalid response received
                                                // Do something here
```

```
                        ModemReset ();          // Reset modem
                        index = 0;              // Loop again
                }
        }
        Res = ModemDial ("6842626");            // Dial ISP
        ModemHandler (Res);                     // Handle Modem response
        }

        EnableInterrupts;
        for (;;) {                              // Application Loop

#ifdef USE_SLIP
        SLIPEntry();                            // Poll SLIP packets
#else
LinkTask ();                                    // Synchronize PPP link with Modem
        PPPEntry ();                            // Poll for PPP packets
#endif
                ApplicationTask ();                             // Call application
    }
}
```

CommDrv.C
Serial Communications Interface Driver

```
/*****************************************************************************
File Name : CommDrv.c

Author : Rene Trenado

Location : Motorola Applications Lab, Baja California

Date Created : July 2000

Current Revision : 0.0

Notes : This file contains the code to drive the serial port
*****************************************************************************/

#include "CommDrv.h"

static void CommDrvDefaultProc (register BYTE value);
static void (* EvtProcedure) (register BYTE value) = CommDrvDefaultProc;

/*****************************************************************
Function :      CommDrvDefaultProc

Parameters :

Date :          July 2000

Desc :
```

```
*********************************************************************/
static void CommDrvDefaultProc (BYTE value) {
  (void)value;
}


/*********************************************************************
Function :      UseDefaultCommProc

Parameters :

Date :          July 2000

Desc :

*********************************************************************/
void UseDefaultCommProc (void) {
        DisableInterrupts;
        EvtProcedure = CommDrvDefaultProc;
        EnableInterrupts;
}



/*********************************************************************
Function :      OpenComm

Parameters :

Date :          July 2000

Desc :

*********************************************************************/
void OpenComm (register BYTE BaudRate, register CommOptions Options) {
  SCBR = BaudRate;              // Set the baud rate
  SCC1 = 0x40;                  // Enable baud rate generator //
  SCC2 = Options;
}


/*********************************************************************
Function :      CloseComm

Parameters :

Date :          July 2000

Desc :

*********************************************************************/
void CloseComm (void) {
}
```

```
/*********************************************************************
Function :      AssignCommEventProc

Parameters :

Date :          July 2000

Desc :

*********************************************************************/
void CommEventProc (EventProc Proc) {
  DisableInterrupts;                // Disable Interrupts
  EvtProcedure = Proc;              // Install service handler
  EnableInterrupts;                 // Enable interrupts
}



/*********************************************************************
Function :      WriteComm

Parameters :

Date :          July 2000

Desc :

*********************************************************************/
void WriteComm (BYTE c) {
  SCDR = c;                                     // Write char to SCI data register
  while (!(SCS1 & 0x80));                       // Wait until character gets transmited
}



/*********************************************************************
Function :      ReadComm

Parameters :

Date :          July 2000

Desc :

*********************************************************************/
BYTE ReadComm (void) {
  while (!(SCS1 & 0x20));
  return SCDR;
}


/*********************************************************************
Function :      WriteCommStr
```

```
Parameters :

Date :          July 2000

Desc :

*********************************************************************/
void WriteCommStr (char* string) {
  while (*string) {
    SCDR = *string++;
    while (!(SCS1 & 0x80));
  }
}



/*********************************************************************
Function :      CommRx

Parameters :

Date :          July 2000

Desc :

*********************************************************************/
void @interrupt UartRxISR (void) {
        SCS1;                                    // acknowledge this IRQ
        EvtProcedure (SCDR);                    // Fordward the character to a service routine
}
```

SLIP.C
Serial Line Internet Protocol Implementation Module

```
/*////////////////////////////////////////////////////////////////////////

File Name : SLIP.C

Author : Rene Trenado

Location : Motorola Applications Lab, Baja California

Date Created : September 2000

Current Revision : 0.0

Notes : This file contains the code for the SLIP module
////////////////////////////////////////////////////////////////////////*/
```

```
#include "CommdRV.h"
#include "slip.h"
#include "IP.h"
#include "Icmp.h"
#include "udp.h"

static BYTE              *SLIP_Packet;          // local pointer to the SLIP buffer */
BYTE                     SLIPStatus = 0;               // status and control byte of the
SLIP module */
static volatile BYTE     FrameSize = 0;         // provides internal control for SLIP buffer
management  */



/*********************************************************************
Function :      ProcSLIPReceive

Parameters :    A Byte character to stream in a SLIP Packet

Date :          August 2000

Desc :          This function process a BYTE following SLIP popular
                specification. The Async event on input driver should
                call this function (usually the COMM ISR).
*********************************************************************/
void ProcSLIPReceive (BYTE c) {

        if (SLIPStatus & IsFrame) return;

        if (SLIPStatus & ReSync) {// Ignore incoming data until a start of
                                  // packet is found
                if (c != 0xC0) {
                        return;
                }
                SLIPStatus &= ~ReSync;          // Clear the synchronization flag to stream
                                                // incoming packet in SLIP buffer
                FrameSize = 0;                  // FrameSize records size of incoming
                                                // packets
        }

        if (SLIPStatus & IsESC) {               // Is the byte received a control char?
                switch (c) {                    // if so decode it
                         case ESC_END:
                                                // Store Special char on Input Buffer
                               SLIP_Packet [FrameSize++] = SLIP_END;
                        break;

                        case ESC_ESC:
                                                // Store Special char on Input Buffer
                               SLIP_Packet [FrameSize++] = SLIP_ESC;
                        break;

                        default:                // SLIP Protocol violation
                        break;
                }
```

```
                SLIPStatus &= ~IsESC;            // Clear the special control character flag
        }
        else {
                switch (c) {
                        case SLIP_ESC:           // Special ESC Character received
                                SLIPStatus |= IsESC;
                        break;

                        case SLIP_END:           // Special END Character received
                        if (FrameSize > 0) {     // Avoid zero length packets
                                SLIP_Packet [FrameSize] = 0;// Append a NULL character
                                SLIPStatus |= IsFrame;       // Signal Frame availability
                                        // Extra control processing can be done here
                                        /* ..... */
                                }
                        break;

                        default:                 // Data of Packet received
                                SLIP_Packet [FrameSize++] = c;// Store Byte
                                        // Avoid & discard large SLIP packets
                                if (FrameSize > (SLIP_MAX_SIZE)) {
                                        FrameSize = 0;
                                        // Resynchronize SLIP packet reception
                                        SLIPStatus |= ReSync;
                                }
                        break;
                }
        }
}


/*********************************************************************
Function :      SLIPInit

Parameters :    None

Date :          September 2000

Desc :          Initialize the SLIP Module
*********************************************************************/
void SLIPInit (void) {
        SLIPStatus |= ReSync;
        SLIP_Packet = (BYTE *)ip_in;
}


/*********************************************************************
Function :      ProcSLIPSend

Parameters :    Buffer:  a pointer to a buffer containing the IP packet to send
                len:     the size of the SLIP packet

Date :          September 2000
```

```
Desc :          Sends a BYTE array of len length following the popular SLIP format

*********************************************************************/
void ProcSLIPSend (BYTE *ptr, BYTE len) {

        WriteComm (SLIP_END);                   // Write start of SLIP frame

        while (len--) {                         // Send all buffer in SLIP format
                switch (*ptr) {                 // check to see if is a special character
                        case SLIP_END:
                               WriteComm (SLIP_ESC);       // escape special character
                               WriteComm (ESC_END);
                        break;

                        case SLIP_ESC:
                               WriteComm (SLIP_ESC);       // escape special character
                               WriteComm (ESC_ESC);
                        break;

                        default:
                               WriteComm (*ptr);          // send raw character
                }
                ptr++;                          // continue with next character send
        }
        WriteComm (SLIP_END);                   // Write END of SLIP frame
}


/*********************************************************************
Function :      SLIPEntry

Parameters :    None

Date :          August 2000

Desc :          SLIP Module Entry, Applications should call SLIPEntry
                frequently in the main loop or in portions of the app
                code.
*********************************************************************/
void SLIPEntry (void) {
        if (SLIPStatus & IsFrame) {
                if (!IPCompare (&ip_in->DestAddress[0])) {

                        /* Misrouted datagram or broadcast message received */
                        /* Do extra processing here */
                }
                else {

                switch    (ip_in->Protocol) {    /* Select protocol handler */
                        case UDP:
                               UDP_Handler ((UDPDatagram *)&ip_in->SourceAddress[0]);
                        break;

                        case TCP:
                        break;
```

```
                        case ICMP:
                               IcmpHandler ((IPDatagram *)ip_in);
                        break;

                        default:
                        break;
                }
                }
                SLIPStatus &= ~IsFrame;          /* Acknowledge datagram processing */
                SLIPStatus |= ReSync;            /* Synchronize packet reception */
        }
}
```

PPP.C
Point-to-Point Protocol Implementation

```
/*////////////////////////////////////////////////////////////////////////
File Name : PPP.C

Author : Rene Trenado

Location : Motorola Applications Lab, Baja California

Date Created : September 2000

Current Revision : 0.0

Notes : This file contains the code for the PPP module
////////////////////////////////////////////////////////////////////////*/
#include <iogp20.h>
#include <string.h>
#include "CommDrv.h"
#include "ppp.h"
#include "IP.h"
#include "Udp.h"
#include "ICMP.h"


const char * User =      "MyName";               // Username of ISP account
const char * Password = "MyPassword";            // Password of username


/************************ Private Functions ************************/
static void HandleLCPOptions (void);
static void HandleIPCPOptions (void);
static WORD PPPfcs16 (WORD fcs, BYTE *cp, int len);
static void RejectProtocol (BYTE *InBuffer);
```

```
//////////////////// Protected ROM Data ////////////////////////
static const BYTE PPPData [] = {
        0xff,0x03,0xc0,0x21,0x02,0x01,0x00,0x04,0x00,0x00
};

static const BYTE LCPTerminate[] = {
        0xff,0x03,0xc0,0x21,0x05,0x04,0x00,0x04,0x80,0xfe
};

static const unsigned short fcstab[256] = {
        0x0000, 0x1189, 0x2312, 0x329b, 0x4624, 0x57ad, 0x6536, 0x74bf,
        0x8c48, 0x9dc1, 0xaf5a, 0xbed3, 0xca6c, 0xdbe5, 0xe97e, 0xf8f7,
        0x1081, 0x0108, 0x3393, 0x221a, 0x56a5, 0x472c, 0x75b7, 0x643e,
        0x9cc9, 0x8d40, 0xbfdb, 0xae52, 0xdaed, 0xcb64, 0xf9ff, 0xe876,
        0x2102, 0x308b, 0x0210, 0x1399, 0x6726, 0x76af, 0x4434, 0x55bd,
        0xad4a, 0xbcc3, 0x8e58, 0x9fd1, 0xeb6e, 0xfae7, 0xc87c, 0xd9f5,
        0x3183, 0x200a, 0x1291, 0x0318, 0x77a7, 0x662e, 0x54b5, 0x453c,
        0xbdcb, 0xac42, 0x9ed9, 0x8f50, 0xfbef, 0xea66, 0xd8fd, 0xc974,
        0x4204, 0x538d, 0x6116, 0x709f, 0x0420, 0x15a9, 0x2732, 0x36bb,
        0xce4c, 0xdfc5, 0xed5e, 0xfcd7, 0x8868, 0x99e1, 0xab7a, 0xbaf3,
        0x5285, 0x430c, 0x7197, 0x601e, 0x14a1, 0x0528, 0x37b3, 0x263a,
        0xdecd, 0xcf44, 0xfddf, 0xec56, 0x98e9, 0x8960, 0xbbfb, 0xaa72,
        0x6306, 0x728f, 0x4014, 0x519d, 0x2522, 0x34ab, 0x0630, 0x17b9,
        0xef4e, 0xfec7, 0xcc5c, 0xddd5, 0xa96a, 0xb8e3, 0x8a78, 0x9bf1,
        0x7387, 0x620e, 0x5095, 0x411c, 0x35a3, 0x242a, 0x16b1, 0x0738,
        0xffcf, 0xee46, 0xdcdd, 0xcd54, 0xb9eb, 0xa862, 0x9af9, 0x8b70,
        0x8408, 0x9581, 0xa71a, 0xb693, 0xc22c, 0xd3a5, 0xe13e, 0xf0b7,
        0x0840, 0x19c9, 0x2b52, 0x3adb, 0x4e64, 0x5fed, 0x6d76, 0x7cff,
        0x9489, 0x8500, 0xb79b, 0xa612, 0xd2ad, 0xc324, 0xf1bf, 0xe036,
        0x18c1, 0x0948, 0x3bd3, 0x2a5a, 0x5ee5, 0x4f6c, 0x7df7, 0x6c7e,
        0xa50a, 0xb483, 0x8618, 0x9791, 0xe32e, 0xf2a7, 0xc03c, 0xd1b5,
        0x2942, 0x38cb, 0x0a50, 0x1bd9, 0x6f66, 0x7eef, 0x4c74, 0x5dfd,
        0xb58b, 0xa402, 0x9699, 0x8710, 0xf3af, 0xe226, 0xd0bd, 0xc134,
        0x39c3, 0x284a, 0x1ad1, 0x0b58, 0x7fe7, 0x6e6e, 0x5cf5, 0x4d7c,
        0xc60c, 0xd785, 0xe51e, 0xf497, 0x8028, 0x91a1, 0xa33a, 0xb2b3,
        0x4a44, 0x5bcd, 0x6956, 0x78df, 0x0c60, 0x1de9, 0x2f72, 0x3efb,
        0xd68d, 0xc704, 0xf59f, 0xe416, 0x90a9, 0x8120, 0xb3bb, 0xa232,
        0x5ac5, 0x4b4c, 0x79d7, 0x685e, 0x1ce1, 0x0d68, 0x3ff3, 0x2e7a,
        0xe70e, 0xf687, 0xc41c, 0xd595, 0xa12a, 0xb0a3, 0x8238, 0x93b1,
        0x6b46, 0x7acf, 0x4854, 0x59dd, 0x2d62, 0x3ceb, 0x0e70, 0x1ff9,
        0xf78f, 0xe606, 0xd49d, 0xc514, 0xb1ab, 0xa022, 0x92b9, 0x8330,
        0x7bc7, 0x6a4e, 0x58d5, 0x495c, 0x3de3, 0x2c6a, 0x1ef1, 0x0f78
};

//////////////////// Public  R A M  Data ////////////////////////////
volatile BYTE            PPPStatus = 0;
BYTE                     InBuffer [PPP_BUFFER_SIZE + 1];/// Input Buffer for PPP data
BYTE                     OutBuffer[PPP_BUFFER_SIZE + 1];/// Output Buffer for PPP
data


//////////////////// Protected  R A M   Data ////////////////////////
static BYTE           *PPP_Packet = InBuffer;
static volatile BYTE  FrameSize = 0;
static EventProc      PPPEntryProc;
```

```
/*********************************************************************
Function :      PPPInit

Parameters :    None

Date :          September 2000

Desc :          Initialize the PPP Module
*********************************************************************/
void PPPInit (void) {
        PPPStatus |= ReSync;
}



/*********************************************************************
Function :      PPPGetInputBuffer

Parameters :    None

Date :          September 2000

Desc :          Returns a PPP Input Buffer pointer to caller

*********************************************************************/
BYTE *PPPGetInputBuffer (void) {
        return &InBuffer[0];
}



/*********************************************************************
Function :      PPPGetOutputBuffer

Parameters :    None

Date :          September 2000

Desc :          Returns a pointer to PPP Output Buffer to caller

*********************************************************************/
BYTE *PPPGetOutputBuffer (void) {
        return &OutBuffer[0];
}



/*********************************************************************
Function :      PPPfcs16

Parameters :    fcs: current fcs
                cp: pointer to PPP data
```

```
                len: size of PPP data

Date :          September 2000

Desc :          Calculate a new fcs given the current fcs and the new data.

*****************************************************************/
static WORD PPPfcs16 (WORD fcs, BYTE *cp, int len) {
           while (len--)
                   fcs = (fcs >> 8) ^ fcstab[(fcs ^ *cp++) & 0xff];
       return (fcs);
}


/*****************************************************************
Function :      public PPPGetChecksum

Parameters :    cp:             A pinter to the PPP Packet
                len:            Size of PPP Packet

Date :          September 2000

Desc :          Returns the Checksum of the PPP Packet pointed by cp
*****************************************************************/
WORD PPPGetChecksum (register unsigned char *cp, register int len) {
           return ~PPPfcs16( PPPINITFCS16, cp, len );
}



/*****************************************************************
Function :      ProcPPPReceive

Parameters :    A Byte character to stream in a PPP Packet

Date :          August 2000

Desc :          This function process a BYTE following HDLC - PPP
                specifications. The Async event on input driver should
                call this function (usually the COMM ISR).
*****************************************************************/
void ProcPPPReceive (register BYTE c) {

        PPPStatus |= ByteRx;

        if (PPPStatus & IsFrame) return;

        if (PPPStatus & ReSync) {
                if (c != 0x7E) return;
                PPPStatus &= ~ReSync;
                FrameSize = 0;
        }

        if (PPPStatus & IsESC) {
                PPP_Packet [FrameSize++] = 0x20 ^ c;
```

```
                PPPStatus &= ~IsESC;
        }
        else {
                switch    (c) {
                        case ESC:               // Special ESC (0x7D) Character received
                               PPPStatus |= IsESC;
                        break;

                        case END:               // Special END (0x7E) Character received
                                                // Avoid cero length packets (0x7F - 0x7F
                                                // conditions);

                               if (FrameSize > 0) {
                                       PPP_Packet [FrameSize] = 0;
                                       PPPStatus |= IsFrame;// Signal Frame availability
                               }
                        break;

                        default:
                               PPP_Packet [FrameSize++] = c;
                               if (FrameSize > (PPP_BUFFER_SIZE - 6)) {
                                        FrameSize = 0;
                                        PPPStatus |= ReSync;
                               }
                        break;
                }
        }
}


/*********************************************************************
Function :      PPPSend

Parameters :    Buffer:  A pointer to a buffer containing the PPP packet to send
                len:     the size of the PPP packet

Date :          September 2000

Desc :          Sends a BYTE array of len length following HDLC - PPP specifications

*********************************************************************/
void ProcPPPSend (BYTE *Buffer, BYTE len) {
WORD Checksum = 0;

        Checksum = PPPGetChecksum (Buffer, Buffer[7] + 4);
        Buffer [Buffer[7]+4] = Checksum & 0xFF;
        Buffer [Buffer[7]+5] = (Checksum >> 8) & 0xFF;

        WriteComm (0x7E);

        while (len--) {
                if ((signed char)*Buffer < (signed char)0x20) {
                        WriteComm (0x7D);
                        WriteComm (*Buffer ^ 0x20);
                } else {
```

```
                        switch (*Buffer) {
                                case 0x7E:
                                                WriteComm (0x7D);
                                                WriteComm (0x5E);
                                break;

                                case 0x7D:
                                                WriteComm (0x7D);
                                                WriteComm (0x5D);
                                break;

                                default:
                                                WriteComm (*Buffer);
                                break;
                        }
                }
                Buffer++;
        }
        WriteComm (0x7E);
}


/*********************************************************************
Function :      public PPPFrameSize

Parameters :    None

Date :          August 2000

Desc :          Returns the size of the current available PPP packet
                stored in InBuffer. Caller should call this function
                if needed only when the IsFram flag has been signaled.

*********************************************************************/
BYTE PPPFrameSize (void) {
        return FrameSize;
}




/*********************************************************************
Function :      protected HandleLCPOptions

Parameters :    None

Date :          August 2000

Desc :          State Machine that implements LCP packet negotiation

*********************************************************************/
static void HandleLCPOptions (void) {
BYTE *dest = OutBuffer;                         // A pointer to the options of output buffer
BYTE *ptr = (BYTE *)&InBuffer[8];               // A pointer to the options of input buffer
```

```
        switch (InBuffer [4] ) {

                //+++++++++++++++++++++++++++++++++++++++++++++++++++
                case TERMINATE:                  //Server Terminate-Request received
                         Move (InBuffer, OutBuffer, InBuffer[7]+6);
                         OutBuffer [4] = TERMINATE_ACK;
                         ProcPPPSend ((BYTE *)OutBuffer, OutBuffer[7] + 6);
                         PPPStatus &= ~LinkOn;
                break;


//+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
                case REQ:

//////////////////////////////////////////////////////////////////
        /////// Server requesting option 2 ///////

//////////////////////////////////////////////////////////////////
                if ((InBuffer [8] == 0x02) && (InBuffer [7] <= 0x0A))  {

                                if ((InBuffer [10] == 0xFF) &&
                                                (InBuffer [11] == 0xFF) &&
                                                (InBuffer [12] == 0xFF) &&
                                                (InBuffer [13] == 0xFF)) {

                                                InBuffer [4] = ACK;
                                                ProcPPPSend (InBuffer, InBuffer [7] + 6);
                                                return;
                                }
                } else

        ////////////////////////////////////////////////////////////////////
        /////// Server requesting first options, reject all but 3 ///////
        ////////////////////////////////////////////////////////////////////
                if ((InBuffer [8] != 0x03) && (InBuffer [7] > 9)) {
                BYTE OptionsSize;
                BYTE Option;
                BYTE Size;
                         Move (InBuffer, OutBuffer, 8)// Move LCP header to output buffer
                         OutBuffer [4] = REJ;         // Output will be a reject packet
                                dest += 8;            // Offset output pointer to
                                                      // LCP options
                                OptionsSize = InBuffer[7] - 4; // Get size of LCP
                                                               // options
                                while (OptionsSize > 0) {      // Is there options to
                                                               // process?
                                       Option = *ptr;          // Get option number
                                       Size = *(ptr + 1);      // Get size of this option
                                        OptionsSize -= Size;   // Reduce the amount of
                                                               // OptionsSize

                                       if (Option == 3) {     // Is this option 3?
                                                              // (authentication protocol)
```

```
                                                ptr += Size; // Remove this option in
                                                             // output packet
                                                // Set New Packet size
                                                OutBuffer [7] = OutBuffer [7] - Size;
                                        }
                                        else {

                                          // Copy this option to the output buffer
                                          while (Size-- ) {
                                                *dest++ = *ptr++;
                                          }
                                    }
                                }
                        } else

////////////////////////////////////////////////////////////////////
        /////// Server Request CHAP protocol, We reply with
        /////// a suggestion of the PAP protocol instead
        ////////////////////////////////////////////////////////////////////
                if ((InBuffer [8] == 0x03) && (InBuffer [10] == 0xC2)) {
                        InBuffer [4] = NAK;             // NAK CHAP protocol
                                InBuffer [10] = 0xC0;    // We suggest PAP instead
                                                         // Send the NAK reply
                                ProcPPPSend (InBuffer, InBuffer[7]+6);
                                return;
                        } else


////////////////////////////////////////////////////////////////////
        /////// Server Request PAP protocol //////////
        /////// We Acknowledge this reply and then we start negotiating
        /////// the Async-Control-Char..., Here we send both packets!!!
        ////////////////////////////////////////////////////////////////////
                        if ((InBuffer [8] == 0x03) && (InBuffer [10] == 0xC0)) {
                                Move (InBuffer, OutBuffer, InBuffer[7]+6);
                                OutBuffer[4] = ACK;
                                ProcPPPSend ((BYTE *)OutBuffer, OutBuffer[7] + 6);

                                OutBuffer[4] = REQ;
                                OutBuffer[5] = OutBuffer [5] + 1;
                                OutBuffer[7] = 0x0A;
                                OutBuffer[8] = 0x02;
                                OutBuffer[9] = 0x06;
                                OutBuffer[10] = 0xFF;
                                OutBuffer[11] = 0xFF;
                                OutBuffer[12] = 0xFF;
                                OutBuffer[13] = 0xFF;
                        }
                ProcPPPSend ((BYTE *)OutBuffer, OutBuffer[7] + 6);
break;


//+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
case ACK:
```

```
        ////////////////////////////////////////////////////////////////////
        /////// Server Acknowledge Async Control //////////
        ////////////////////////////////////////////////////////////////////
                if (InBuffer [8] == 0x02) {
                        SendPAPPacket (REQ, InBuffer[5] + 1, User, Password);
                }
        break;

        //++++++++++++++++++++++++++++++++++++++++++++++++++++
        case NAK:
        break;

        //++++++++++++++++++++++++++++++++++++++++++++++++++++
        case REJ:
        break;

        //++++++++++++++++++++++++++++++++++++++++++++++++++++
        case TERMINATE_ACK:                     // Terminate ACK!
                PPPStatus &= ~LinkOn;
        break;
        }
        return;
}


/*********************************************************************
Function :      protected HandleIPCPOptions

Parameters :    None

Date :          August 2000

Desc :          State Machine that implement IPCP packet negotiation

*********************************************************************/
static void HandleIPCPOptions (void) {
BYTE *dest = (BYTE *)&OutBuffer[8];
BYTE *ptr = (BYTE *)&InBuffer[8];
BYTE FrameSize;
BYTE Option;
BYTE Size;


        switch (InBuffer [4] ) {
               case REQ:
                        if ((InBuffer [8] != 0x03) && (InBuffer [7] > 0x0A)) {
                                OutBuffer [0] = 0xFF;  // Build a IPCP header
                                OutBuffer [1] = 0x03;
                                OutBuffer [2] = 0x80;  // Set IPCP protocol
                                OutBuffer [3] = 0x21;
                                OutBuffer [4] = REJ;   // This will be a
                                                        // REJ packet for now
                                OutBuffer [5] = InBuffer [5];
                                FrameSize = InBuffer[7] - 4;
                                ///////// Ignore all but option #3 ///////
```

```
                                        while (FrameSize > 0) {
                                               Option = *ptr;
                                               Size = *(ptr + 1);

                                               FrameSize -= Size;

                                               if (Option == 3) {
                                                    ptr += Size;
                                                    //Set New Packet size
                                                  OutBuffer [7] = InBuffer [7] - Size;
                                        }
                                        else {
                                        while (Size-- ) {
                                                    *dest++ = *ptr++;
                                        }
                                    }
                              }
                        }
                  else {
                        // Acknowledge IP Address //
                        Move (InBuffer, OutBuffer, InBuffer[7]+6);
                        OutBuffer [4] = ACK;

                        ProcPPPSend ((BYTE *)OutBuffer, OutBuffer[7] + 6);

                        // Now Request IP address to complete 3-way handshake
                        OutBuffer [4] = REQ;                // Request command
                        OutBuffer [5] = OutBuffer [5] + 1; // Packet ID = ID + 1
                        OutBuffer [10] = 0;                // IP address is set
                                                           // to 0 so ISP server
                        OutBuffer [11] = 0;                // can assing us one
                        OutBuffer [12] = 0;
                        OutBuffer [13] = 0;
                  }
                  ProcPPPSend ((BYTE *)OutBuffer, OutBuffer[7] + 6);
      break;

      case ACK:
             if (InBuffer [8] == 3) {                    // Reply of the only IPCP
                                                         // Request we can send
                        IPAddress [0] = InBuffer [10];   // ISP assigned IP
                        IPAddress [1] = InBuffer [11];
                        IPAddress [2] = InBuffer [12];
                        IPAddress [3] = InBuffer [13];

                        PORTC = 0xFF;
                        PPPStatus |= LinkOn;               // PPP Link is now up
                  }
      break;

      case NAK:
                  if ((InBuffer [8] == 0x03) && (InBuffer [7] <= 0x0A)) {
                              /// Request IP Address ////
                              Move (InBuffer, OutBuffer, InBuffer[7]+6);
                              OutBuffer [4] = 0x01;
```

```
                                        ProcPPPSend ((BYTE *)OutBuffer, OutBuffer[7] + 6);
                        }
                break;

                case REJ:
                break;
        }

}


/*********************************************************************
Function :      public PPPSendPAPPacket

Parameters :    Action:  REQ, REJ, NAK
                ID:             Sequence number of PPP packet
                user:           User name for login
                password:       Password in plain text

Date :          September 2000

Desc :          Formats a PAP packet on Output Buffer. This function
                supports the type field for future implementation of
                the PPP module in server mode.
*********************************************************************/
void SendPAPPacket (BYTE Action, BYTE ID, char* user, char* password) {
        OutBuffer [0] = 0xFF;
        OutBuffer [1] = 0x03;
        OutBuffer [2] = 0xC0;                   // Format PAP packet header
        OutBuffer [3] = 0x23;
        OutBuffer [4] = Action;
        OutBuffer [5] = InBuffer [5] + 1;       // Increment ID
        OutBuffer [6] = 0;
        OutBuffer [7] = strlen (user) + strlen (password) + 6;// Set length of PAP
        OutBuffer [8] = strlen (user);                         // Set length of
                                                               // Username
        Move (user, &OutBuffer [9], strlen (user));           // Store Username
        OutBuffer [9 + strlen (user)] = strlen (password);    // Set length of
                                                              // password
        Move (password, &OutBuffer [10 + strlen (user)], strlen (password));
        ProcPPPSend ((BYTE *)OutBuffer, OutBuffer[7] + 6);   // Send PAP packet
}


/*********************************************************************
Function :      Move

Parameters :    src:            A pointer to the data to copy
                dest:           A pointer to the destination location
                numBYTEs:       Number of bytes to copy

Date :          September 2000

Desc :          Copies a block of numBYTEs bytes from src pointer
```

```
                to dest pointer
*********************************************************************/
void Move (BYTE *src, BYTE *dest, register numBYTEs) {
        if ( numBYTEs <= 0 ) return;
        if ( src < dest ) {
                src += numBYTEs;
                dest += numBYTEs;
                do {
                *--dest = *--src;
                } while ( --numBYTEs > 0 );
        } else
                do {
                     *dest++ = *src++;
                } while ( --numBYTEs > 0 );
}



/*********************************************************************
Function :      protected RejectProtocol

Parameters :    InBuffer -> A pointer to the buffer that has the PPP
                Packet to reject

Date :          August 2000

Desc :          Rejects the a PPP packet based on its Protocol field
                Stored on InBuffer

*********************************************************************/
static void RejectProtocol (BYTE *InBuffer) {

        OutBuffer [0] = 0xFF;
        OutBuffer [1] = 0x03;
        OutBuffer [2] = 0xC0;
        OutBuffer [3] = 0x21;
        OutBuffer [4] = 0x08;
        OutBuffer [5] = 20;
        OutBuffer [6] = 0;
        OutBuffer [7] = InBuffer[7] + 6;
        Move (&InBuffer[2], &OutBuffer[8], InBuffer [7] + 2);
        ProcPPPSend ((BYTE *)OutBuffer, OutBuffer[7] + 6);
}



/*********************************************************************
Function :      protected PPPSendVoidLcp

Parameters :    None

Date :          September 2000

Desc :          Sends a void LCP packet with no options to the PPP Server.
```

```
                This will force the server to reply with his options to
                negotiate. Some ISPs require scripts to stablish a connection thus
                a void LCP packet will try to force the server to negotiate PPP.
*********************************************************************/
void PPPSendVoidLCP (void) {
WORD Checksum;

        Move (PPPData, OutBuffer, PPPData[7] + 6);
        ProcPPPSend ((BYTE *)OutBuffer, OutBuffer[7] + 6);
}


/*********************************************************************
Function :      PPPTerminate

Parameters :    None

Date :          September 2000

Desc :          Terminates a PPP link by sending a terminate LCP packet
*********************************************************************/
void PPPTerminate (void) {
   Move ((BYTE *)LCPTerminate, OutBuffer, 10);
   ProcPPPSend (OutBuffer, 10);
}


/*********************************************************************
Function :      PPPEntry

Parameters :    None

Date :          August 2000

Desc :          PPP Module Entry, Applications should call PPPEntry
                frequently in the main loop or in portions of the app
                code.
*********************************************************************/
void PPPEntry (void) {
        if (PPPStatus & IsFrame) {
        switch (*(WORD *)(&InBuffer [2])) {

                case LCP_PACKET:
                         HandleLCPOptions ();
                break;

                case PAP_PACKET:
                         if (InBuffer [4] == 0x02) {// Authentication OK
                               NoOperation;
                         }
                break;

                case IPCP_PACKET:                // IPCP Handler
                         HandleIPCPOptions ();
                break;
```

```
                case IP_DATAGRAM:                // IP Data Handler
                        if (!IPCompare ((BYTE *)&InBuffer [20])) {
                                // Misrouted datagram or broadcast
                                // message received
                        }
                        else
                               switch (InBuffer [13]) {

                                      case UDP:
                                                UDP_Handler ((UDPDatagram *)&InBuffer[16]);
                                      break;

                                      case TCP:
                                      break;

                                      case ICMP:
                                                IcmpHandler ((IPDatagram *)&InBuffer[4]);
                                      break;

                                      default:
                                      break;
                               }
                break;

                default:
                        RejectProtocol (InBuffer);// Cannot handle this type of packet
                break;
        }                       // End of switch statement
        PPPStatus &= ~IsFrame;
        PPPStatus |= ReSync;
        }                       // End of if IsFrame

}
```

ModemDrv.C
Modem Support Routines

```
/*////////////////////////////////////////////////////////////////////////
File Name : ModemDrv.C

Author : Rene Trenado

Location : Motorola Applications Lab, Baja California

Date Created : December 2000

Current Revision : 0.0

Notes : This file contains the functions required to handle an external modem
////////////////////////////////////////////////////////////////////////*/
#include <iogp20.h>
```

```
#include "CommDrv.h"
#include "ModemDrv.h"

#define MODEM_BUFFER_SIZE       32              // Size of Modem Buffer

#define DTR_ON           PORTD &= 0xFE;         // DTR Pin is PORTD0, Macro to set it ON
#define DTR_OFF PORTD |= 0x01;                  // Macro to set DTR OFF
#define DTR_PIN (PORTD & 0x01)                  // DTR Pin = Pin 0 of PORT D

// Byte pointers of the ring buffer (FIFO)
volatile BYTE   mDataSlot = 0;                  // Points to the next available character
volatile BYTE   mEmptySlot = 0;                 // Points to next available slot of the FIFO

static BYTE *ModemBuffer;                       // Pointer to Modem buffer


/*********************************************************************
Function :      ModemInit

Parameters :    None

Date :          December 2000

Desc :          Initializes the ring buffer & clears the DTR pin

*********************************************************************/
void ModemInit (void) {
        mDataSlot = 0;                          // Initialize FIFO Modem pointers
        mEmptySlot = 0;
        DDRD |= 0x01;                           // DTR pin set to output
        DTR_OFF;                                // DTR Off
}


/*********************************************************************
Function :      ModemBuffFlush

Parameters :    None

Date :          January 2001

Desc :          Flushes the receiving FIFO (ring buffer)

*********************************************************************/
void ModemBuffFlush (void) {
        mDataSlot = mEmptySlot;
}


/*********************************************************************
Function :      ModemDial

Parameters :    A string containing the phone number to dial

Date :          December 2000
```

```
Desc :          It sets the modem response mode to numeric (instead of verbose),
                then it dials a phone number & sets the DTR pin. This function
                returns a numeric code describing a response from the modem or
                a timeout. Applications should handle this reaponse code.
*********************************************************************/
BYTE ModemDial (char * Number) {
signed char delayCount = 80;
        transmit ("ATV0\r");                    // Force a numeric response from modem
        if (!Waitfor ("0", 30)) {               // Wait for an OK response
                return -1;
        }

        DTR_ON;                                 // Set DTR to ON
        transmit ("ATDT");                      // Dial the ISP number
        transmit (Number);
        transmit ("\r");
        ModemBuffFlush ();                      //  Flush contents of buffer
                                                // Wait for a reply
        while ((!ModemBuffNotEmpty()) && (--delayCount > 0)) {
                Delay (250);
        }
        if (delayCount) {
                return ModemGetch ();           // Return the numeric response to caller
        }
        return -1;                              // No response received from modem
}



/*********************************************************************
Function :      ModemHangUp

Parameters :    None

Date :          December 2000

Desc :          This function clears DTR to force the modem to hang up if
                it was on line and/or make the modem to go to command mode.
*********************************************************************/
void ModemHangUp (void) {
        DTR_ON;                                 // Make a DTR transition to hang-up
        Delay (40);                             // Wait a couple of miliSeconds
        DTR_OFF;                                // Finish the DTR transition
}
```

```
/*********************************************************************
Function :      ModemOnLine

Parameters :    None

Date :          January 2001

Desc :          Returns the status of the CD (carrier detect) signal.
*********************************************************************/
BYTE ModemOnLine (void) {
        return (PORTD & 0x02) ^ 0x02;            // Return the status of the CD line
}



/*********************************************************************
Function :      ModemBindBuff

Parameters :    A pointer to a buffer in RAM

Date :          January 2001

Desc :          Binds the FIFO capabilities of this module to a buffer
                in RAM.
*********************************************************************/
void ModemBindBuff (BYTE *lpInBuffer) {
        ModemBuffer = lpInBuffer;
        ModemBuffer [0] = 0;
}

/*********************************************************************
Function :      ModemReset

Parameters :    None

Date :          January 2001

Desc :          Resets the Modem
*********************************************************************/
void ModemReset (void) {
        ModemInit ();
}

/*********************************************************************
Function :      ModemBuffNotEmpty

Parameters :    None

Date :          January 2001

Desc :          Returns True if modem buffer NOT empty, false otherwise.
```

```
*********************************************************************/
BYTE ModemBuffNotEmpty (void) {
        return !(mDataSlot == mEmptySlot);

}

/*********************************************************************
Function :      ModemInBufferCount

Parameters :    None

Date :          January 2001

Desc :          Returns the number of characters available in the Modem
                Queue.
*********************************************************************/
BYTE ModemInBufferCount (void) {
        if ((mEmptySlot - mDataSlot) >= 0)
                return (BYTE)(mEmptySlot - mDataSlot);
        else {
                return (BYTE)((mEmptySlot + MODEM_BUFFER_SIZE) - mDataSlot);
        }
}



/*********************************************************************
Function :      Waitfor

Parameters :    A string to wait for
                A Time out value

Date :          January 2001

Desc :          Returns True if Modem response matches the String argument,
                False otherwise. Time is the number of times the Delay funtion
                will be called from within the waiting loop.
*********************************************************************/
BYTE Waitfor (char *String, BYTE Time) {
BYTE c = 0;
BYTE Offset = 0;

   while (Time-- > 0) {
                Delay (100);                                // Wait =~ 150 mSec
                while (ModemBuffNotEmpty()) {               // Wait for characters
                         c = ModemGetch ();                 // Extract a character from FIFO
                         if (c == String [Offset]) {     // Is C a part of the string?
                                Offset++;                   // Compare with next character
                                if (String [Offset] == 0) {  // is this the end of string?
                                       return True;           // match = True
                                }
                         }
                         else                       // c does not belong to String
                Offset = 0;                         // Reset String pointer
                }
```

```
        }
        return False;
}


/*********************************************************************
Function :      ProcModemReceive

Parameters :    A character received from the SCI

Date :          November 2000

Desc :          Stores incoming characters in the Modem Queue
*********************************************************************/
void ProcModemReceive (BYTE c) {
        ModemBuffer [mEmptySlot++] = c;
        if (mEmptySlot > MODEM_BUFFER_SIZE) {
                mEmptySlot = 0;
     }
}


/*********************************************************************
Function :      ModemGetch

Parameters :    None

Date :          November 2000

Desc :          Dequeue a previously stored character in the Modem Queue.
                Returns a null character if the Queue is empty
*********************************************************************/
BYTE ModemGetch (void) {
BYTE c = 0;
    if (mDataSlot != mEmptySlot) {
         c = ModemBuffer [mDataSlot];
         mDataSlot++;
         if (mDataSlot > MODEM_BUFFER_SIZE) mDataSlot = 0;
                return(c);
    }
    else {
       return (BYTE)0x00;
       }
}


/*********************************************************************
Function :      transmit

Parameters :    A string to transmit to the Modem

Date :          November 2000

Desc :          Any data passed to this function will be sended to the Modem.
                Applications can build complex scripts by calling transmit and
```

```
                Waifor functions however, its up to the application to control
                the appropriate flow of data when the Modem is on command mode
                and on-line mode.
*********************************************************************/
void transmit (char *data) {
        Delay (250);
        while (*data) {
                WriteComm (*data++);
        }
}
```

IP.C
Internet Protocol Implementation

```
/*////////////////////////////////////////////////////////////////////////

File Name : IP.C

Author : Rene Trenado

Location : Motorola Applications Lab, Baja California

Date Created : September 2000

Current Revision : 0.0

Notes : This file contains the Internet Protocol variables & support routines

////////////////////////////////////////////////////////////////////////*/
#include "IP.h"
#include "PPP.h"
#include "SLIP.h"

extern BYTE     InBuffer [PPP_BUFFER_SIZE + 1];  // Input Buffer for PPP data
extern BYTE     OutBuffer[PPP_BUFFER_SIZE + 1];

BYTE IPAddress[4] = {220, 1, 141, 149};          // Default IP Address

static volatile char IPAdapter = PPP;            // Default interface for IP output

IPDatagram *ip_in;                               // A pointer to received IP datagrams
IPDatagram *ip_out;                              // Global buffer for IP packet output



/*********************************************************************
Function :      IPInit

Parameters :    None

Date :          September 2000

Desc :          Initializes the IP module pointers
```

```
*********************************************************************/
void IPInit (void) {
        ip_in = (IPDatagram *)&InBuffer [4];
        ip_out = (IPDatagram *)&OutBuffer [4];
}



/*********************************************************************
Function :      Bind adapter

Parameters :    Interface: A Byte ID

Date :          September 2000

Desc :          Selects the output format of an IP packet

*********************************************************************/
void IPBindAdapter (INTERFACE Interface) {
        IPAdapter = Interface;                  // switch to different output interface
}


/*********************************************************************
Function :      IPNetSend

Parameters :    ip: A pointer to a IP datagram to transmit

Date :          November 2000

Desc :          Sends a IP datagram over the interface specified

*********************************************************************/
void IPNetSend (IPDatagram* ip) {
static WORD Id = 0xF0;                          // ID to be used in IP datagrams

        ip_out->Version_HLen    = 0x45;         // Header Forma=IPv4, Length = 5
        ip_out->Service         = 0;            // Always zero
        ip_out->LengthUpper     = 0;            // High byte of datagram Length
        ip_out->ID              = htons(Id++);  // Merge IP ID
        ip_out->Frag            = 0;            // No flags nor enable fragmentation
        ip_out->TTL             = 0x80;         // Time to live set to default
        ip_out->Checksum        = 0;            // Clear checksum to avoid
                                                // miscalculations
                                                // Get checksum of entire datagram
        ip_out->Checksum        = htons(IPCheckSum ((BYTE *)ip_out, 10));

        switch (IPAdapter) {                   // Select the adapter to output the IP datagram
               case PPP:                        // Output through PPP adapter
                        OutBuffer [0] = 0xff;   // Frame PPP packet
                        OutBuffer [1] = 0x03;
                        OutBuffer [2] = 0x00;   // This is a IP datagram, set
                                                // protocol type
                        OutBuffer [3] = 0x21;
```

```
                        ProcPPPSend (OutBuffer, OutBuffer [7] + 6);
                break;

                case SLIP:                          // Output through SLIP interface
                        ProcSLIPSend ((BYTE *)ip_out, ip_out->Length);
                break;


                case ETHERNET:                      // Send datagram over ethernet
                break;

                default:
                break;
        }
}


/*********************************************************************
Function :      IPCompare

Parameters :    Ip: A pointer to a IP address to compare

Date :          November 2000

Desc :          Compares an IP address to the default IP address defined
                in this module

*********************************************************************/
BYTE IPCompare (BYTE *IPOne) {
        if (IPOne [0] != IPAddress[0]) return (BYTE)0x00;
        if (IPOne [1] != IPAddress[1]) return (BYTE)0x00;
        if (IPOne [2] != IPAddress[2]) return (BYTE)0x00;
        if (IPOne [3] != IPAddress[3]) return (BYTE)0x00;

        return (BYTE) 0x01;
}



/*********************************************************************
Function :      IPChecksum

Parameters :    Data: A pointer to an array of Words
                Size: Size of the array

Date :          August 2000

Desc :          Obtains the IP checksum of an array of 16-bit words of size "Size"

*********************************************************************/
DWORD IPCheckSum (BYTE* Data, WORD Size) {
unsigned long   Sum = 0;

        while (Size-->0) {
                Sum += ((unsigned long)((*Data << 8) + *(Data+1)) & 0xFFFF);
```

```
                Data+=2;
        }

        Sum = (Sum >> 16) + (Sum & 0xFFFF);
        Sum += (Sum >> 16);

        return (WORD) ~Sum;
}
```

UDP.C
User Datagram Protocol Implementation

```
/*////////////////////////////////////////////////////////////////////////////

File Name : UDP.c

Author : Rene Trenado

Location : Motorola Applications Lab, Baja California

Date Created : December 2001

Current Revision : 0.0

Notes : This file contains the code to handle and create UDP transport
        packets.

////////////////////////////////////////////////////////////////////////////*/
#include "IP.h"
#include "UDP.h"
#include "Ppp.h"

#define UDP_HEADER_LENGTH       8

static WORD UDPLocalPort = 1080;                // Default UDP port (can be set to anything)
static void UDPDefaultCallBack (BYTE *data, BYTE size, DWORD RemoteIP, WORD Port);
static UDPCALLBACK UDPCallback = UDPDefaultCallBack;

UDPDatagram *udp_in;                            // Pointer to incoming UDP packet
UDPDatagram *udp_out;                           // Pointer for output UDP packet


/*********************************************************************
Function :      UDPSetCallbackProc

Parameters :     Proc: A pointer to a function to callback each time a UDP/IP
                packet is received from the Internet

Date :          December 2000

Desc :          Sets the callback function to call each time a UDP packet is received
                over the physical interface
```

```
*********************************************************************/
void UDPSetCALLBACK (UDPCALLBACK Proc) {
        DisableInterrupts;
        UDPCallback = Proc;
        EnableInterrupts;
}


/*********************************************************************
Function :      UDPDefaultCallBack

Parameters :     None

Date :          December 2000

Desc :          The default callback available after RESET not accesible
                from outside this module

*********************************************************************/
static void UDPDefaultCallBack (BYTE *data, BYTE size, DWORD RemoteIP, WORD Port) {

}


/*********************************************************************
Function :      UDPBind

Parameters :    Port: local port to use in UDP packets to transmit

Date :          November 2000

Desc :          Specifies the local port to use for sending UDP
                packets over IP

*********************************************************************/
void UDPBind (WORD Port) {
        UDPLocalPort = Port;                    // Set source UDP port
}



/*********************************************************************
Function :      UDP_Checksum

Parameters :     udp: A pointer to the start of a udp/ip packet (0x45)

Date :          November 2000

Desc :          Calculates the pseudo-header checksum of a UDP packet

*********************************************************************/
WORD UDP_Checksum (BYTE* udp) {
DWORD Checksum = 0;
```

```
        Checksum = IPCheckSum (&udp[12], (8 + udp[25]) >> 1);

        Checksum = ~Checksum +  0x11;
        Checksum += udp [25];
        Checksum = (Checksum >> 16) + (Checksum & 0xFFFF);
        Checksum += (Checksum >> 16);

        return (WORD)~Checksum;
}


/*********************************************************************
Function :      UDPHandler

Parameters :     udp: a pointer to the udp (struct UDPDatagram) packet received

Date :          November 2000

Desc :          Invokes the callback proc so the application can handle the
                UDP data received

*********************************************************************/
void UDP_Handler (UDPDatagram *udp) {
        udp_in = udp;
        udp_in->Payload [udp_in->Length - UDP_HEADER_LENGTH] = 0x00;
        UDPCallback (                           // Invoque the CALLBACK function
                (BYTE *)udp_in->Payload,
                udp_in->Length - UDP_HEADER_LENGTH,
                *((DWORD *)&udp_in->SourceIP),
                udp_in->DestPort);
}



/*********************************************************************
Function :      UDPSendData

Parameters :     BYTE Ip[]:     The IP address of the remote host
                Port:          UDP port of the remote host
                Payload:  Data to send
                Size:          Number of bytes to send to remote host

Date :          November 2000

Desc :          Sends data (payload) over UDP to a remote host specified by IP [] using
                Port as the destination UDP port.

*********************************************************************/
void UDPSendData (BYTE Ip[], WORD Port, BYTE* Payload, BYTE size) {
WORD Checksum = 0;

        ip_out->DestAddress [0] = Ip [0];       // Store source and destination
        ip_out->DestAddress [1] = Ip [1];       // IP addresses
        ip_out->DestAddress [2] = Ip [2];
        ip_out->DestAddress [3] = Ip [3];
```

```
        ip_out->SourceAddress [0] = IPAddress [0];
        ip_out->SourceAddress [1] = IPAddress [1];
        ip_out->SourceAddress [2] = IPAddress [2];
        ip_out->SourceAddress [3] = IPAddress [3];

        udp_out = (UDPDatagram *) &ip_out->SourceAddress;

        // Insert Data Payload if available as an argument
        if (Payload)
                Move (Payload, &udp_out->Payload[0], size);

        // Format payload as a null terminated string
        udp_out->Payload[size] = 0x00;
        if (size % 2) {                         // Pad the payload
                size++;
        }

        udp_out->Length = size + UDP_HEADER_LENGTH;     // Calculate the UDP length
        ip_out->Length = size + UDP_HEADER_LENGTH + 20;// get IP packet length
        ip_out->Protocol = UDP;                         // Protocol set to UDP

        udp_out->SourcePort = htons(UDPLocalPort);// Set source and destination ports
        udp_out->DestPort = htons(Port);
        udp_out->LengthUpper = 0;               // Packet cannot be longer than 256
                                                // bytes

                                                // (in this implementation)
        udp_out->Checksum = 0;                  // Set checksum to 0
        Checksum = UDP_Checksum ((BYTE *)ip_out);// Obtain the packet checksum
        udp_out->Checksum = htons (Checksum);

        IPNetSend (ip_out);                     // Send the packet to the IP layer
}
```

ICMP.C
Internet Control Message Protocol Module Implementation

```
/*////////////////////////////////////////////////////////////////////////

File Name : ICMP.c

Author : Rene Trenado

Location : Motorola Applications Lab, Baja California

Date Created : January 2001

Current Revision : 0.0

Notes : This file contains the code to handle and create ICMP messages
```

```
////////////////////////////////////////////////////////////////////////////*/
#include "IP.h"
#include "ICMP.h"


/*********************************************************************
Function :      ICMPPing

Parameters :    IP Address to ping

Date :          September 2000

Desc :          Sends a ICMP ECHO message to a remote host

*********************************************************************/
void IcmpPing (BYTE Ip[]) {
WORD Value;
static BYTE Seq = 0xAB;

        ip_out->SourceAddress [0] = IPAddress [0];// Ping will have our source address
        ip_out->SourceAddress [1] = IPAddress [1];
        ip_out->SourceAddress [2] = IPAddress [2];
        ip_out->SourceAddress [3] = IPAddress [3];

        ip_out->DestAddress [0] = Ip[0];         // Set destination IP address
        ip_out->DestAddress [1] = Ip[1];
        ip_out->DestAddress [2] = Ip[2];
        ip_out->DestAddress [3] = Ip[3];

        ip_out->Payload [0] = ECHO;              // ICMP message type set to ECHO
        ip_out->Payload [1] = 0;                 // ICMP code must by set to zero
        ip_out->Payload [2] = 0;                 // reset checksum
        ip_out->Payload [3] = 0;

        ip_out->Payload [4] = 1;                 // set ID of ICMP message
        ip_out->Payload [5] = 0;
        Seq++;
        ip_out->Payload [6] = (Seq >> 8) & 0xFF; // set sequence number of ICMP Msg
        ip_out->Payload [7] = Seq & 0xFF;

        ip_out->Protocol = ICMP;                 // IP datagram will carry ICMP data
        ip_out->Length = 28;                     // ECHO message doesn't include data

        Value = IPCheckSum ((BYTE *)&ip_out->Payload[0], (ip_out->Length - 20) >> 1);
        ip_out->Payload [2] = (Value >> 8);      // obtain ICMP checksum
        ip_out->Payload [3] = (Value & 0xFF);

        IPNetSend (ip_out);                      // Net send to IP layer
}
```

```
/*********************************************************************
Function :      ICMP_Handler

Parameters :    IP Datagram containing ICMP data

Date :          September 2000

Desc :          Handles incoming IP datagrams according to the TYPE field
                of the ICMP message contained in the input IP datagram

*********************************************************************/
void IcmpHandler (IPDatagram* ip) {
WORD Value;

        switch (ip->Payload [0]) {

                case ECHO:
                        /* Move ping datagram to output buffer */
                        Move ((BYTE *)ip, (BYTE *)ip_out, ip->Length);

                        /* Swap source and destination IP addresses on Output Buffer */
                        ip_out->DestAddress [0] = ip->SourceAddress [0];
                        ip_out->DestAddress [1] = ip->SourceAddress [1];
                        ip_out->DestAddress [2] = ip->SourceAddress [2];
                        ip_out->DestAddress [3] = ip->SourceAddress [3];

                        ip_out->SourceAddress [0] = ip->DestAddress [0];
                        ip_out->SourceAddress [1] = ip->DestAddress [1];
                        ip_out->SourceAddress [2] = ip->DestAddress [2];
                        ip_out->SourceAddress [3] = ip->DestAddress [3];

                        ip_out->Payload [0] = ECHO_REPLY;/* Echo reply */
                        ip_out->Payload [1] = 0;         /* Set ICMP Code to 0 */
                        ip_out->Payload [2] = 0;         /* Set ICMP checksum to 0
                                                            during checksum generation */
                        ip_out->Payload [3] = 0;
                        Value = IPCheckSum ((BYTE *)&ip_out->Payload[0], (ip->Length - 20)
>> 1);  /* Calculate ICMP checksum */

                        ip_out->Payload [2] = (Value >> 8);/* Set ICMP checksum */
                        ip_out->Payload [3] = (Value & 0xFF);
                        IPNetSend (ip_out);     /* Send ICMP packet over IP */
                break;

                case ECHO_REPLY:                // Code to handle ping responses
                                                // goes here
                        NoOperation;
                break;

                case TRACEROUTE:
                break;

                default:
                break;
        }
}
```

PLL.C
Code of InitPLL Function

```
/*////////////////////////////////////////////////////////////////////////////

File Name : Pll.c

Author : Rene Trenado

Location : Motorola Applications Lab, Baja California

Date Created : September 2000

Current Revision : 0.0

Notes : This file contains the code of the InitPll function

////////////////////////////////////////////////////////////////////////////*/

#include "pll.h"


/*********************************************************************
Function :      InitPll

Parameters :    None

Date :          September 2000

Desc :          Initializes the PLL to operate at 4.91520 MHz

*********************************************************************/
#asm
        xdef    _InitPLL

_InitPLL:
        BCLR    5,0x36                          ;turn off PLL so it can be initialized
        MOV      #0x00,0x38                     ;Set multiplier for 4.9152MHz
        MOV      #0x96,0x39                     ;see manual for calculations
        MOV      #0x80,0x3A                     ;Set range select
        BSET    7,0x37                          ;Allow automatic acquisition & tracking
        BSET    5,0x36                          ;turn PLL back on
HERE:
        BRCLR     6,0x37,HERE                   ;Wait for PLL to lock
        BSET      4,0x36                        ;Select PLL as Source

#endasm
```

Delay.C
Source Code of Variable Delay() Function

```
/*************************************************************************
File Name : Delay.c

Author : Rene Trenado

Location : Motorola Applications Lab, Baja California

Date Created : July 2000

Current Revision : 0.0

Notes : This file contains the code for a variable Delay function
*************************************************************************/

#include "delay.h"

BYTE delayCounter;


/*********************************************************************
Function :      Delay

Parameters :    A Byte containing the number of times __Delay will be
                called

Date :          July 2000

Desc :          This function blocks the CPU in multiples of _Delay times

*********************************************************************/
void Delay (register BYTE times) {
        _Delay();
}


/*********************************************************************
Assembly Function :      __1msDelay

Parameters :    None

Date :          July 2000

Desc :          This function blocks the CPU in multiples of 1.3mSecs
                delayCount specifies the time base
                __1msDelay = delayCounter x 1.3 mSec

*********************************************************************/
#asm

        xref.b  _delayCounter
        xdef    __Delay
```

```
BUSFREQ:        EQU             2

_1msDelay:
                PSHA                                ;2 cycles
                LDA             #BUSFREQ            ;2
DLLoop:         DBNZA           DLSub               ;3
                BRA             DLDone              ;3
DLSub:
                MOV             #$FF,_delayCounter  ;4
Here:
                DBNZ             _delayCounter,Here ;5
                BRA             DLLoop              ;3
DLDone:         PULA                                ;2
                RTS                                 ;4


/*********************************************************************
Function :      _Delay

Parameters :    A Byte containing the number of times a base delay will be
                called

Date :          July 2000

Desc :          This function blocks the CPU in multiples (Acc value) of
                delay times

*********************************************************************/

__Delay:
                JSR             _1msDelay
                DBNZA           __Delay
                RTS

#endasm
```

CommDrv.H
Header File for SCI Driver

```
/*////////////////////////////////////////////////////////////////////////

File Name : CommDrv.h

Author : Rene Trenado

Location : Motorola Applications Lab, Baja California

Date Created : July 2000

Current Revision : 0.0
```

```
Notes : This file contains comm port specific definitions

//////////////////////////////////////////////////////////////////////////*/
#ifndef _H_COMMDRV_
#define _H_COMMDRV_

#include "Notation.h"

#define BAUDS_2400    3   // 8 Divisor
#define BAUDS_4800    2   // 4 Divisor
#define BAUDS_9600    1   // 2 Divisor
#define BAUDS_19200   0   // 1 Divisor

typedef enum  {
  ENABLE_RX = 0x04,             // enable receiver
  ENABLE_TX = 0x08,             // enable transmitter
  ENABLE_RX_EVENTS = 0x20,      // enable receiver interrupts
  ENABLE_TX_EVENTS = 0x80       // enable transmitter interrupts
} CommOptions;

#define SCC1  *((BYTE *)0x13)                    // Status and contro registers
#define SCC2  *((BYTE *)0x14)
#define SCS1  *((volatile BYTE *)0x16)
#define SCDR  *((volatile BYTE *)0x18)
#define SCBR  *((BYTE *)0x19)

extern void @interrupt UartRxISR (void);                 // export ISR

/////////////// API Functions to Export ////////////////////
void OpenComm (register BYTE BaudRate, register CommOptions Options);
void CloseComm (void);
void CommEventProc (EventProc Proc);
void WriteComm (BYTE c);
void WriteCommStr (char* string);
BYTE ReadComm (void);
void UseDefaultCommProc (void);

#endif
```

PPP.H
Header File for PPP Implementation

```
/*//////////////////////////////////////////////////////////////////////////

File Name : PPP.h

Author : Rene Trenado

Location : Motorola Applications Lab, Baja California

Date Created : September 2000
```

```
Current Revision : 0.0

Notes : Definitions for the PPP implementation

////////////////////////////////////////////////////////////////////////////*/
#ifndef __PPP_H
#define __PPP_H 1

#include "Notation.h"

#ifndef NULL
#define NULL    0
#endif

#define ESC     0x7D
#define END     0x7E

#define REQ             1
#define ACK             2
#define NAK             3
#define REJ             4
#define TERMINATE       5
#define TERMINATE_ACK   6

typedef struct {
        WORD Framing;
        WORD Protocol;
        BYTE Request;
        BYTE Id;
        BYTE LengthHigh;
        BYTE Length;
        BYTE FirstOption;
        BYTE FirstOptionLength;
        BYTE Param;
        BYTE Data;
} PPPFrame;


#define PPPINITFCS16    0xffff  /* Initial FCS value */
#define PPPGOODFCS16    0xf0b8  /* Good final FCS value */

////////////// Functions to Export ///////
void PPPInit (void);
BYTE *PPPGetInputBuffer (void);
BYTE *PPPGetOutputBuffer (void);
void ProcPPPReceive (register BYTE c);
void ProcPPPSend (BYTE *Buffer, BYTE len);
WORD PPPGetChecksum (register unsigned char *cp, register int len);
void SendPAPPacket (BYTE Action, BYTE ID, char* user, char* password);
void Move (BYTE *src, BYTE *dest, register numBYTEs);
void PPPEntry (void);
void PPPTerminate (void);
void PPPSendVoidLCP (void);

extern volatile BYTE PPPStatus;
```

```
#define IsESC   0x01            // Previous character received was a ESC char
#define ReSync  0x04            // Re Synchronize to avoid inconplete IP frame reception
#define IsFrame 0x08            // A full packet
#define ByteRx  0x10            // Receive a Byte
#define         LinkOn    0x20  // PPP Link is On

extern BYTE IPAddress[4];

#define PPP_BUFFER_SIZE  88

#define LCP_PACKET       0xC021
#define PAP_PACKET       0xC023
#define CHAP_PACKET      0xC223
#define IPCP_PACKET      0x8021
#define IP_DATAGRAM      0x0021

#endif
```

SLIP.H
Header File for SLIP Implementation

```
/*////////////////////////////////////////////////////////////////////////////

File Name : SLIP.h

Author : Rene Trenado

Location : Motorola Applications Lab, Baja California

Date Created : June 2000

Current Revision : 0.0

Notes : Definitions for the SLIP implementation

////////////////////////////////////////////////////////////////////////////*/

#ifndef __SLIP_H
#define __SLIP_H1

#include "Notation.h"

#ifndef NULL
#define NULL    0
#endif

#define SLIP_MAX_SIZE    88

#define SLIP_END         0xC0   //300 octal
#define SLIP_ESC         0xDB   //333 octal
#define ESC_END          0xDC   //334 octal
```

```
#define ESC_ESC          0xDD   //335 octal

extern BYTE SLIPStatus;

void SLIPInit (void);
void ProcSLIPSend (BYTE *ptr, BYTE len);
void SLIPEntry (void);
void ProcSLIPReceive (BYTE c);

#define IsESC   0x01            // Previous character received was a ESC char
#define ReSync  0x04            // Re Synchronize to avoid inconplete IP frame reception
#define IsFrame 0x08            // A full packet
#define ByteRx  0x10            // Receive a Byte


#endif
```

ModemDrv.H
Header file for Modem driver

```
#ifndef __MODEMDRV_H
#define __MODEMDRV_H     1

#include "Notation.h"

void ProcModemReceive (BYTE c);
void ModemBindBuff (BYTE *lpInBuffer);
void ModemInit (void);
BYTE ModemDial (char * Number);
void transmit (char *data);
void ModemHangUp (void);
BYTE ModemOnLine (void);
BYTE ModemBuffNotEmpty (void);
void ModemBuffFlush (void);
BYTE ModemInBufferCount (void);
BYTE Waitfor (char *String, BYTE Time);
BYTE ModemGetch (void);
BYTE ModemInBufferCount (void);
void ModemReset (void);

#endif
```

IP.H
Internet Protocol Implementation definitions

```
/*////////////////////////////////////////////////////////////////////////

File Name : IP.h

Author : Rene Trenado

Location : Motorola Applications Lab, Baja California

Date Created : September 2000

Current Revision : 0.0

Notes : Definitions for the IP implementation

////////////////////////////////////////////////////////////////////////*/
#ifndef __IP_H
#define __IP_H

#include "Notation.h"

typedef struct {
        BYTE    Version_HLen;
        BYTE    Service;
        BYTE    LengthUpper;
        BYTE    Length;
        WORD    ID;
        WORD    Frag;
        BYTE    TTL;
        BYTE    Protocol;
        WORD    Checksum;
        BYTE    SourceAddress [4];
        BYTE    DestAddress [4];
        BYTE    Payload [64];
} IPDatagram;

extern IPDatagram *ip_in;
extern IPDatagram *ip_out;

typedef enum { RAW_SERIAL = 1, SLIP, PPP, PARALLEL, ETHERNET } INTERFACE;

#define TCP     0x06
#define UDP     0x11
#define ICMP    0x01

extern BYTE IPAddress[4];


/*////////////////////////////////////////////////////
IP Exported Functions
////////////////////////////////////////////////////*/
BYTE    IPCompare        (BYTE *IPOne);
DWORD   IPCheckSum       (BYTE *Data, WORD Size);
```

```
void    IPBindAdapter    (INTERFACE Interface);
void    IPInit (void);
#endif
```

UDP.H
UDP Header Definitions

```
/*////////////////////////////////////////////////////////////////////////////

File Name : UDP.h

Author : Rene Trenado

Location : Motorola Applications Lab, Baja California

Date Created : December 2001

Current Revision : 0.0

Notes : This file contains definitions needed by the UDP module.

////////////////////////////////////////////////////////////////////////////*/
#ifndef __UDP_H
#define __UDP_H

#include "Notation.h"

typedef struct {
        BYTE    SourceIP [4];
        BYTE    DestinationIP [4];
        WORD    SourcePort;
        WORD    DestPort;
        BYTE    LengthUpper;
        BYTE    Length;
        WORD    Checksum;
        BYTE    Payload[54];
} UDPDatagram;

extern UDPDatagram *udp_out;

typedef void (* UDPCALLBACK)(BYTE *data, BYTE size, DWORD RemoteIP, WORD Port);
void UDPSetCALLBACK (UDPCALLBACK Proc);
void UDP_Handler (UDPDatagram *udp);
WORD UDP_Checksum (BYTE* udp);
void UDPBind (WORD Port);
void UDPSendData (BYTE Ip[], WORD Port, BYTE* Payload, BYTE size);


#endif
```

ICMP.H
ICMP Header Definitions

```
/*////////////////////////////////////////////////////////////////////////////

File Name : Icmp.h

Author : Rene Trenado

Location : Motorola Applications Lab, Baja California

Date Created : January 2001

Current Revision : 0.0

Notes : This file contains Icmp module specific definitions

////////////////////////////////////////////////////////////////////////////*/
#ifndef __ICMP_H
#define __ICMP_H

#include "Notation.h"

typedef struct {
        BYTE    Type;
        BYTE    Code;
        WORD    Checksum;
        WORD    Identifier;
        WORD    SeqNumber;
} ICMPDatagram;

#define ECHO             8
#define ECHO_REPLY       0
#define TRACEROUTE       30

void IcmpHandler (IPDatagram *ip);
void IcmpPing (BYTE Ip[]);

#endif
```

PLL.h
Header Definitions for the PLL.c Module

```
#ifndef __PLL_H
#define __PLL_H

extern void InitPLL (void);

#endif
```

Delay.h
Header Definitions for Delay() Function Support

```
#ifndef __Delay_H
#define __Delay_H

#include "Notation.h"

extern void Delay (register BYTE Time);

#endif
```

Notation.h
Notation Used in the Source Code

```
#ifndef __NOTATION_H
#define __NOTATION_H     1

#define BIG_ENDIAN

#if defined(BIG_ENDIAN)

#define htons(A)         (A)
#define htonl(A)         (A)
#define ntohs(A)         (A)
#define ntohl(A)         (A)

#elif defined(LITTLE_ENDIAN)

#define htons(A)         ((((A) & 0xFF00) >> 8) | \
                          (((A) & 0x00FF) << 8))

#define htonl(A)         ((((A) & 0xFF000000) >> 24) | \
                          (((A) & 0x00FF0000) >> 8) | \
                          (((A) & 0x0000FF00) << 8) | \
                          (((A) & 0x000000FF) << 24))

#define ntohs   htons
#define ntohl   htohl

#else

#error "User Must define LITTLE_ENDIAN or BIG_ENDIAN!!!"

#endif


#define DWORD unsigned long
#define BYTE unsigned char
#define WORD unsigned int
```

```
#define False 0
#define True  1

typedef void (*EventProc)(BYTE c);

typedef struct {
        unsigned char    b0;
        unsigned char    b1;
        unsigned char    b2;
        unsigned char    b3;
        unsigned char    b4;
        unsigned char    b5;
        unsigned char    b6;
        unsigned char    b7;
} TByteBits;

typedef union {
        unsigned char    Value;
        TByteBits        Bits;
} TByte;

#define AppLoop          while(1)

#define EnableInterrupts        _asm("CLI\n");  //Enable interrupts
#define DisableInterrupts       _asm("SEI\n");  //Enable interrupts
#define NoOperation             _asm("NOP\n"); // No operation
#endif
```

CommDrv.C
Serial Communications Interface Driver for the PC

```
#include <dos.h>
#include "CommDrv.h"

static void CommDrvDefaultProc (BYTE value);

static void (* EvtProcedure) (BYTE value) = CommDrvDefaultProc;

static void interrupt UartISR (void);
static void interrupt (*IsrOriginal)();

static Word Port = COM1;
static  Byte IRQMask;

////////////////////////////////////////////////
// Assigns an Event Handler for Comm Driver
////////////////////////////////////////////////
void InitCommDriver (void) {
        EvtProcedure = CommDrvDefaultProc;
}
```

```
WORD CommPort (void) {
        return Port;
}

////////////////////////////////////////////////
// Assigns an Event Handler for Comm Driver
////////////////////////////////////////////////
void CommEventProc (EventProc Proc) {
        disable ();
        EvtProcedure = Proc;
        enable ();
}


////////////////////////////////////////////////
// Default Event Handler for Comm Driver
////////////////////////////////////////////////
static void CommDrvDefaultProc (BYTE value) {
        (void) value;
}

////////////////////////////////////////////////
void OpenComm (Word CommPort, BYTE Bauds) {

        disable ();

        Port = CommPort;

        // Configura el puerto "CommPort" a 9600,n,8,1
        outportb (Port + LCR, LATCH_DIVISOR);
        outportb (Port + DIVISOR_BAJO, Bauds);
        outportb (Port + DIVISOR_ALTO, 0x0);
        outportb (Port + LCR, 0x03);

        outportb (Port + MCR, HABILITA_INT);
        outportb (Port + IER, RX_ENABLE | MODEM_STATUS);

        if (Port == COM1) {
                IsrOriginal = getvect (COM1_ISR);
                setvect (COM1_ISR, UartISR);     }
        else    {
                IsrOriginal = getvect (COM2_ISR);
                setvect (COM2_ISR, UartISR);     }


        IRQMask = inportb (PIC_IMR);

        outportb (PIC_IMR, (Port == COM1) ? (IRQMask & 0xEF):(IRQMask & 0xF7));

        enable ();
}

void CloseComm (void) {

        if (!Port) return;
```

```
        outportb (Port + MCR, 0);
        outportb (Port + IER, 0);
        outportb (PIC_IMR, IRQMask);

        if (Port == COM1) {
                setvect (COM1_ISR, IsrOriginal); }
        else {
                setvect (COM2_ISR, IsrOriginal); }
}

void WriteComm (Byte c) {
        while (!(inportb(Port + LSR) & 0x20));
        outportb (Port + THR, c);
}


void WriteCommStr (char * string) {
        while (*string) {
                WriteComm (*string++);
    }
}


void interrupt UartISR (void) {

        switch (inportb (Port + IIR) & 0xFE) {
                case 0x00:      //Modem Status
                        // if a change in CD line
                        if (inportb (Port + MSR) & 0x08) {
                                outportb (Port + MCR, inportb (Port + MCR) | 0x02); // Set
RTS line to high
                        }
                        else {
                                outportb (Port + MCR, inportb (Port + MCR) & ~0x02); //
Clear RTS line to high
                        }
                break;

                case 0x04:      //Rx Char
                        EvtProcedure (inportb (Port + RBR));
                break;
        }

        outport (PIC_ICR, 0x20);//Ack this IRQ
}
```

CommDrv.H
Serial Communications Interface Definitions for the PC

```
#ifndef __COMM_H
#define __COMM_H1

#include "Notation.h"

#define COM1    0x3F8
#define COM2    0x2F8
#define COM4    0x2E8

#define RBR             0      // Receive Buffer
#define THR             0      // Transmitter Buffer
#define DIVISOR_BAJO    0      // Latch divisor low
#define DIVISOR_ALTO    1      // Latch divisor high
#define IER             1      // Interrupt Enable Register
#define IIR             2      // Interrupt ID Register
#define LCR             3      // Line Control Register
#define MCR             4      // Modem Control Register
#define LSR             5      // Line Status Register
#define MSR             6      // Modem Status Register


#define LATCH_DIVISOR    128
#define HABILITA_INT     8

#define RX_ENABLE        1      //RxRDY Enable IRQ
#define TX_ENABLE        2      //Tx Biuffer Empty IRQ
#define MODEM_STATUS     8      //Modem handshake lines have changed

#define PIC_ICR          0x20   // PIC address
#define PIC_IMR          0x21   // PIC IRQ Mask Register
#define COM1_ISR0x0C     // COM1 Vector Table Index
#define COM2_ISR0x0B     // COM2 Vector Table index
#define COM4_ISR0x08 + 9 // COM2 Vector Table index


#define ASCII   0
#define BINARY  1

/////////////// Functions to Export ////////////////////
void InitCommDriver (void);
void OpenComm (Word CommPort, BYTE Bauds);
void OpenComm (Word CommPort, BYTE Bauds);
void CloseComm (void);
void CommEventProc (EventProc Proc);
void WriteComm (Byte c);
void WriteCommStr (char * string);
WORD CommPort (void);

#define BAUDS_2400       0x30
#define BAUDS_4800       0x18
#define BAUDS_9600  0x0C
#define BAUDS_19200 0x06
```

```
#define BAUDS_38400 0x03

#endif
```

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