Technical Note

TN_157

Ethernet Explained

Version 1.0

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The FTDI FT900 32 bit MCU series, provides for high data rate, computationally intensive data transfers. One of the interfaces used for this high speed communication is Ethernet. This application note discusses some of the key features of an Ethernet link and how the FT900 assists in establishing the link.

Table of Contents

1 Introduction

The FTDI FT900, 32 bit MCU series, provides for high data rate, computationally intensive data transfers. The devices contain a variety of high speed interfaces including Ethernet, CAN BUS, Camera I/F, DACs and ADCs. This document will explore the details of an Ethernet link.

1.1 Scope

This application note discusses some of the key features of an Ethernet link and how the FT900 assists in establishing the link.

2   What is Ethernet?

Ethernet is a full duplex serial data protocol over twisted pair wires (or wireless). The data may be transmitted to many devices over a network or peer to peer.

FTDI FT900 MCU supports full-duplex and half-duplex modes.

- CSMA/CD protocol for half-duplex operation.
- IEEE 802.3x flow control for full-duplex operation.

2.1 Speeds

Currently there are 3 main speed variants for Ethernet traffic:

- 10Base-T: 10 Mbit/s
- 100Base-TX: 100 Mbit/s also referred to as fast Ethernet.
- 1000Base-T: 1GBit/s also referred to as gigabit Ethernet

FTDI FT900 MCU supports 10/100 Mbit/s transfer speeds.

2.2 Connections

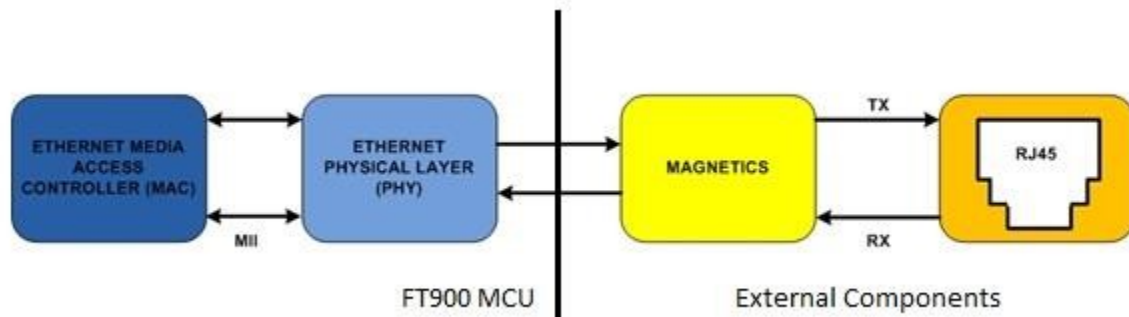The MAC and PHY blocks are onchip on the FT900.

Figure 2.1 Ethernet Link

2.2.1   The Ethernet Media Access Controller (MAC)

The Ethernet media access controller is responsible for managing all data packets that are to be sent and received over a network. The controller is driven by the system software and handles all the addressing and data packetizing. The controller connects directly with the PHY.

With the FT900, the link is established via a Media Independent Interface (MII), which is an internal 4-bit wide bi-directional bus (4 transmit data bits, 4 receive data bits)

2.2.2   The Ethernet Physical Layer (PHY)

The Ethernet Physical Layer (PHY) is responsible for the physical link between the Ethernet controller and the network.

This layer is onchip on the FT900 so only the differential signals are available at pin level.

2.2.3   Magnetics

The magnetics allow different nodes on the Ethernet network to connect over long distances. It removes any connection issues created by different ground offsets at different nodes.
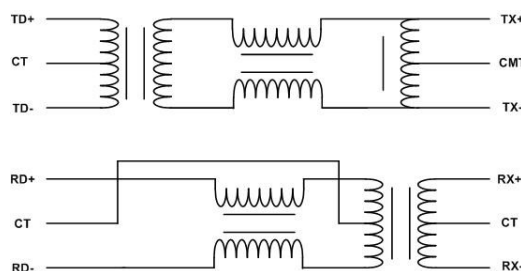

Figure 2.2 Magnetics

The turns ratio on the coils is typically 1:1.

2.2.4   RJ45 connector

The RJ45 connector is a standard connector format for Ethernet link. It allows for a similar approach to cabling up USB, whereby standard connectors, with a standard pinout are used at each node.

PIN	10Base-T Signal	100Base-T Signal
1	TX+	TX+
2	TX-	TX-
3	RX+	RX+
4	nc	nc
5	nc	nc
6	RX-	RX-
7	nc	nc
8	nc	nc

Table 2-1 RJ45 Female Connector Pinout

2.2.5   FTDI FT900 Ethernet Connections

2.2.5.1 RXIP

Ethernet receive data input positive. Differential received signal pair.

2.2.5.2 RXIN

Ethernet receive data input negative. Differential received signal pair.

2.2.5.3 TXOP

Ethernet transmit data output positive. Differential transmitted signal pair.

2.2.5.4 TXON

Ethernet transmit data output negative. Differential transmitted signal pair.

2.2.5.5 RREFSET

Ethernet reference voltage input. Connect 12.3Kohm +/- 1% resistor to GND.

2.2.5.6 ENET_LED0

Ethernet activity indicator LED 0. The source can be configured via the Ethernet PHY Miscellaneous Configuration Register.

2.2.5.7 ENET_LED1

Ethernet activity indicator LED 1. The source can be configured via the Ethernet PHY Miscellaneous Configuration Register.

2.3 Addressing

2.3.1 MAC Address

Every Ethernet controller has a unique MAC address to ensure it can be independently identified. The MAC address is 6 bytes in length with the first 3 bytes identifying the Ethernet controller manufacturer. These 3 bytes are controlled and issued by the IEEE Registration Authority.

The format of the MAC address is: MM::MM::MM::SS::SS::SS

MM identifies the manufacturer. For example, A0-48-1C is Hewlett Packard.

SS identifies a device serial number and is a unique number. There are 2^{24} combinations.

The MAC address on FTDI FT900 MCU is programmable.

2.3.2 IP Address

The IP address assigned to a device is used to identify it on a TCP/IP network. As with the MAC address different elements have specific meaning. The basic format is for a 32 bit number split into 4 octets (1 octet = 1 byte) and typically displayed as a series of decimal numbers from 0-255, e.g. 192.168.0.1 is commonly used for accessing Wi-Fi router configuration pages.

The first 8 bits define a network class, while the remaining elements define the host within the network.

Class	Description	Leading Bit values	Start address
A	Usually reserved for government agencies and large companies	0	0.0.0.0 (00000000.x.x.x)
Loopback	Loopback address. The host computer can send a message back to itself	0111 1111	127.0.0.1 (01111111.0.0.1)
B	Used for medium-sized networks	10	128.0.0.0 (10000000.x.x.x)
C	Commonly used for small to mid-size networks	110	192.0.0.0 (11000000.x.x.x)
D	Used for multicasts	1110	224.0.0.0 (11100000.x.x.x)
E	Used for experimental purposes only	1111	240.0.0.0
Broadcast	Messages that are intended for all computers on a network	11111111	255.255.255.255

Table 2-2 IP Classes

2.4 Network Control

2.4.1   CSMA/CD

Ethernet protocol regulates communication among nodes via Carrier Sense Multiple Access / Collision Detect (CSMA / CD) which is required as multiple devices can be connected on the same wires. To allow for successful communication, each node 'listens' to determine if the network is busy before establishing a link. It also listens to its own message while transmitting and can detect if another node started transmitting at the same time since the message would not match what was sent.

When nodes detect a collision, they stop transmission, wait for a random amount of time and attempt to retransmit when the network is ready ie no other transmissions.

2.4.2   Hub

An Ethernet hub is a device for connecting multiple Ethernet devices together and making them act as a single network segment.

2.4.3   Bridges and Switches

To avoid congestion problems as networks increase in size, network switches and bridges can be added which can filter or repeat messages from multiple segments with the goal of reducing unnecessary traffic in a particular segment. It does this by examining the destination address of the frame before deciding how to handle it.

In the figure below, if A transmits to B, the bridge receives the message and blocks or filters it from segment 2. If A transmits to C, the bridge will transmit or forward the frame to segment 2.

2.4.4   Collision and Broadcast Domains

A collision domain is a part of a network where packet collisions can occur. A collision occurs when two devices send a packet at the same time on the shared network segment. The packets collide and both devices must send the packets again, which reduces network efficiency. Collisions are often in a hub environment, because each port on a hub is in the same collision domain. By contrast, each port on a bridge, a switch or a router is in a separate collision domain.

A broadcast domain is a domain in which a broadcast is forwarded. A broadcast domain contains all devices that can reach each other at the data link layer by using broadcast. All ports on a hub or a switch are by default in the same broadcast domain. All ports on a router are in the different broadcast domains and routers don't forward broadcasts from one broadcast domain to another.

The table below shows what effect a collision and broadcast domain on each device has.

	Collision Domain	**Broadcast Domain**
Ethernet Hub	Continues	Continues
Ethernet Switch / Bridge	Ends	Continues
Router	Ends	Ends
Firewall	Ends	Ends

Table 2-3 Collision and Broadcast Domains

The figure below shows an example network. Note that Segment 1 and Segment 2 are on two separate collision domains because of the Bridge / Switch.
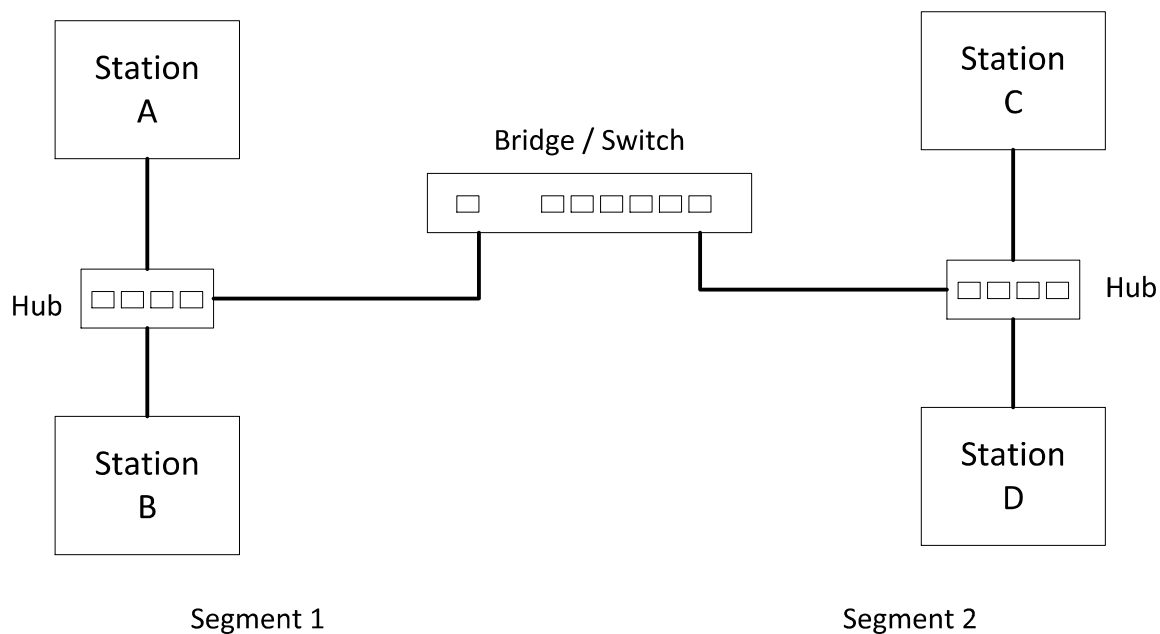
Figure 2.3 Ethernet Network Example

2.5 Ethernet Frame

A data packet on an Ethernet link transports an Ethernet frame.

The internal structure of an Ethernet frame is specified in IEEE 802.3-2012.

Layer	Preamble	Start of Frame Delimiter	MAC Dest.	MAC Source	802.1Q Tag (optional)	Length	Payload	Frame Check (32 bit CRC)	Interpacket Gap
	7 octets	1 octet	6 octets	6 octets	4 octets	2 octets	1500 octets max	4 octets	12 octets
Layer 2 Frame									
Layer 1 Packet									

Table 2-4 Ethernet Frame Structure

The table below describes the frame entries.

Field	Description
Preamble	Consists of a pattern of alternating 1 and 0 bits, which allows devices on the network to easily detect a new incoming frame
Start of Frame Delimiter	Marks the end of the preamble
MAC Destination	Destination MAC address
MAC Source	Source MAC address
Length	Indicates the size of the payload
Payload	The minimum payload is 42 octets when an 802.1Q tag is present and 46 octets when absent. The maximum payload is 1500 octets.
Frame Check	32 bit CRC which allows detection of corrupted data within the entire frame.
Interpacket gap	Idle state time between packets.

Table 2-5 Ethernet Frame Field Description

3 Protocols

The Ethernet protocol specifies a set of rules for constructing frames, as discussed in the previous section.

The transport layer is responsible for delivering data and establishes the concept of the port which is associated with an IP address of the host, as well as the type of protocol used for communication. The protocols that primarily use ports are discussed in this section. The table below gives an idea of port number and associated functionality.

Port Range	Port Functionality
0-1023	Common, well-known services
1024-49151	Registered ports used for Internet Assigned Numbers Authority (IANA)-registered services
49152-65535	Can be used for any purpose

Table 3-1 Ethernet Port Functionality

3.1 Transmission Control Protocol / Internet Protocol (TCP/IP)

TCP is a connection-oriented protocol like a datastream and is used for many application layer protocols, including HTTP web browsing and email transfer.

TCP is the more complex Internet Protocol incorporating reliable transmission and data stream services with flow and congestion control. It can detect network problems such as lost or duplicated and request re-transmission, and re-arrange out-of-order packets. Handshaking and acknowledgement is performed between nodes.

The TCP header consists of:

- Source / Destination Port numbers
- Sequence Number
- Acknowledgement Number
- Header Size
- Control Flags
- Window Size
- Checksum for data integrity

Applications include web browsers, email, FTP and peer-to-peer file sharing.

3.2 User Datagram Protocol (UDP)

UDP is known as a connection-less protocol, where no prior communications is required to set up transmission channels or data paths.

The delivery, arrival time, and order of arrival are not guaranteed by the network.

UDP is generally used for simpler messaging transmissions with less reliability and typically gives higher throughput and shorter latency.

The UDP header consists of

- Source / Destination Port numbers
- Data Length
- Checksum for data integrity

Applications include Voice Over IP, streaming media applications and online games

4 FT900 Ethernet Controller

The FT900 contains an Ethernet media access controller and PHY capable of supporting Ethernet protocols upto and including 10/100Base-TX. The controller is compatible with the IEEE 802.3-2002 specification and connects directly to the magnetics and RJ45. Using the FT900 solution will provide users with access to fast Ethernet data channels and bridge to other fast interfaces supplied in the device such as the parallel camera interface or CAN bus controllers to enable a wide variety of peripherals to be accessed via Ethernet.

Additionally the FT900 Ethernet Controller supports double buffering for 2kB TX and 2kB RX memory, and promiscuous mode support to allow network activity to be monitored.

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Appendix A – References

Document References

FT900 Datasheet

Acronyms and Abbreviations

Terms	Description
MAC	Media Access Controller
PHY	Physical Layer
MCU	Micro Controller Unit
IP	Internet Protocol
CSMA	Carrier Sense Multiple Access
CD	Collision Detection
TCP/IP	Transmission Control Protocol/Internet Protocol
UDP	User Datagram Protocol
Mbit/s	Network transfer speed Mega bits per second
MII	Media Independent Interface
USB	Universal Serial Bus
TX	Transmit
RX	Receive
GND	Ground
LED	Light Emitting Diode
Wi-Fi	Wireless Fidelity
CRC	Cyclic Redundancy Check
IANA	Internet Assigned Numbers Authority
HTTP	Hypertext Transfer Protocol
FTP	File Transfer Protocol
IEEE	Institute of Electrical and Electronics Engineers

Appendix B – List of Tables & Figures

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Appendix C – Revision History

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