Freescale Semiconductor
Application Note

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Implementing an IEEE 1588 V2 Node on the Kinetis K60 Using the Freescale MQX IEEE 1588 Communication Library

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1 Introduction

This application note describes implementation of the IEEE® 1588 V2 Precision Time Protocol (PTP) on the Kinetis® K60 processor running the MQX™ Operating System. The solution is targeting the TWR-K60N512 KIT and Freescale’s Kinetis K60 microprocessor. The demo software runs under the Freescale MQX Real Time Operation System and uses the Freescale MQX IEEE 1588 Communication Library. The library is based on the IEEE 1588 V2 protocol software by IXXAT Automation GmbH.

Contents

This document discusses the following topics:

- IEEE 1588 protocol basics
- IEEE 1588 protocol implementation for Kinetis K60 based on MQX1588 library
- Description of the IEEE 1588 demo application targeting the TWR-K60N512 KIT

2 IEEE 1588 basic overview

The IEEE 1588 standard is known as Precision Clock Synchronization Protocol for Networked Measurement Control Systems, also known as Precision Time Protocol (PTP). The IEEE 1588 PTP allows clocks distributed across an Ethernet network to be accurately synchronized using a process whereby the distributed nodes exchange timestamped messages.

The technology behind the standard was originally developed by Agilent Technologies® and was used for distributed measuring and control tasks. The challenge is to synchronize networked measuring devices with each other in terms of time, making them able to record measured values and providing them with a precise system timestamp. Based on this timestamp, the measured values can then be correlated with each other.

Typical applications of the IEEE 1588 time synchronization include:

- Time-sensitive telecommunication services that require precise time synchronization between communicating nodes
- Industrial network switches that synchronize sensors and actuators over a single wire distributed control network to control an automated assembly process
- Powerline networks that synchronize across large-scale distributed power grid switches to enable smooth transfer of power
- Test/measurement devices that must maintain accurate time synchronization with the device under test in many different operating environments
- Printing machines, cooperative robotic systems, and residential Ethernet

These applications require precise clock synchronization between devices with accuracy in the sub-microsecond range. It is a remarkable feature of the IEEE 1588 that this synchronization precision is achieved through regular Ethernet connectivity with standard Ethernet frames.

This solution allows nearly any device of any performance to participate in high-precision synchronized networks that are simple to operate and configure.

Other key benefits of the IEEE 1588 protocol include:

- Convergence times of less than a minute for sub-microsecond synchronization between heterogeneous distributed devices with different clocks, resolution, and stability.
- Automatic configuration and segmentation. Each node uses the best master clock algorithm (BMC) to determine the best clock in the segment. Every PTP node stores its features within a specified dataset. These features are transmitted to other nodes within its sync telegrams. Based on this, other nodes are able to synchronize their datasets with the features of the actual master and can adjust their clocks. The cyclic running of the BMC also allows hot swapping; that is, nodes can be connected or removed during propagation time.

- Simple configuration and operation with low compute resource and network bandwidth consumption

2.1 Synchronization principle

Network clocks are organized in a master-slave hierarchy. IEEE 1588 identifies the master clock and then establishes two-way timing exchange by which the master sends messages to its slaves to initiate synchronization. Each slave then responds to synchronize itself to its master. This sequence is repeated throughout the specified network to achieve and maintain clock synchronization.

The process starts with one node (master clock) transmitting a sync telegram that contains the estimated transmission time. The exact transmission time of the sync telegram is captured by a clock and transmitted in a second follow-up message. By comparing the timestamp information contained within the first and second telegrams against its own clock, the receiver can calculate the time difference between its own clock and the master clock (see Figure 1). Sync and follow-up messages are sent as multicast. Some IEEE 1588 systems enable hardware timestamping and the insertion of actual timestamps into the sync message. In this case, follow up messages are not needed (so called one-step mode of operation).

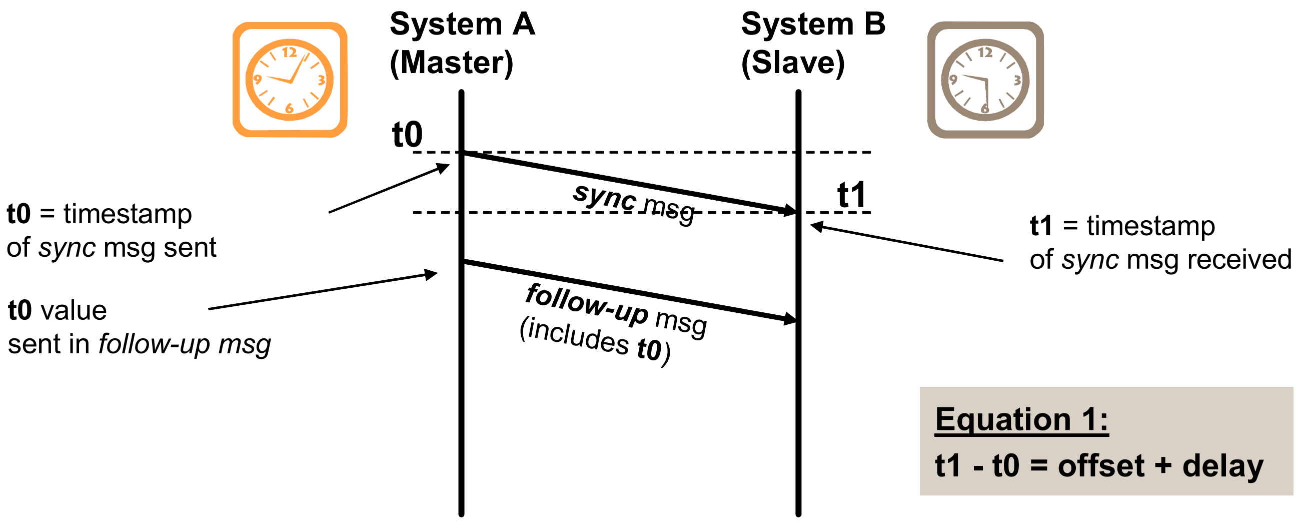


Figure 1. Offset and delay measurement—sync message, follow-up message

The telegram propagation time is determined cyclically in a second transmission process between the slave and the master (delay telegrams). The slave can then correct its clock and adapt it to the current bus propagation time (see Figure 2). Delay_req and delay_resp messages are point-to-point but sent with a multicast address for simplicity.

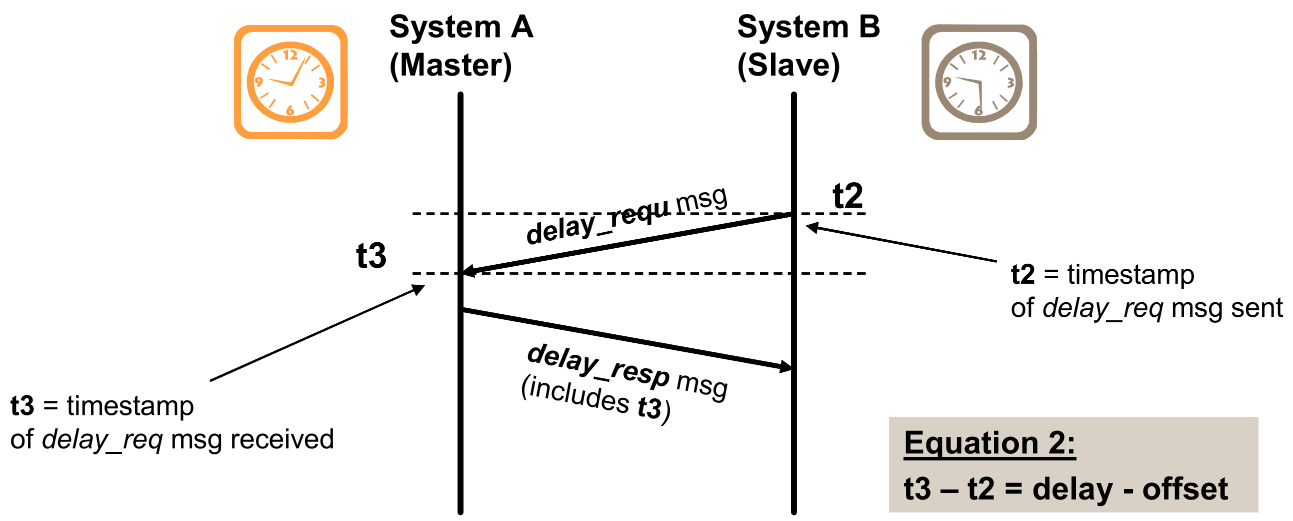


Figure 2. offset and delay measurement—delay messages

Figure 3 serves as an example of the IEEE 1588 synchronization sequence (one cycle) and calculation of the actual offset and the actual delay between master and slave node.

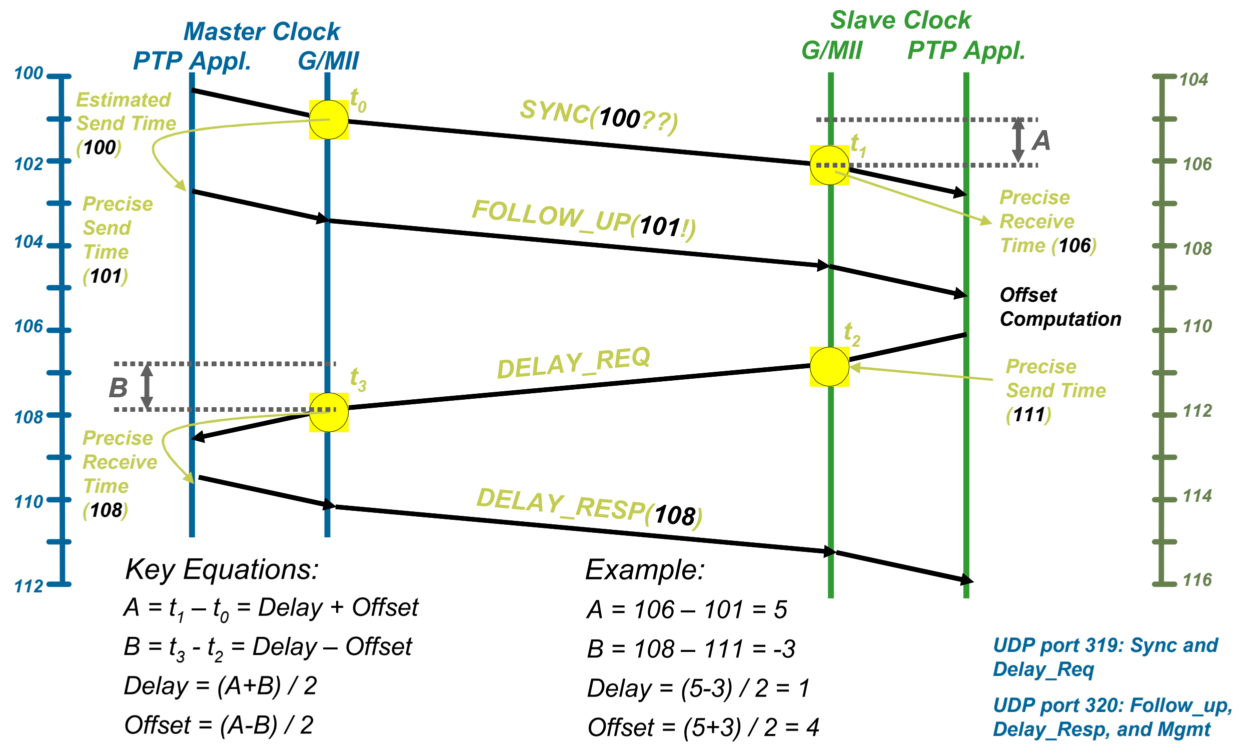


Figure 3. IEEE 1588 synchronization message sequence

For more information about the IEEE 1588 standard, visit the web page for the National Institute of Standards and Technology.

2.2 Timestamping

The PTP protocol can be implemented completely in software using a standard Ethernet module. However, because the timestamp information is applied at the application level, the delay fluctuation introduced by the software stack running on both master and slave devices mean that only a limited precision can be achieved (see Figure 4).

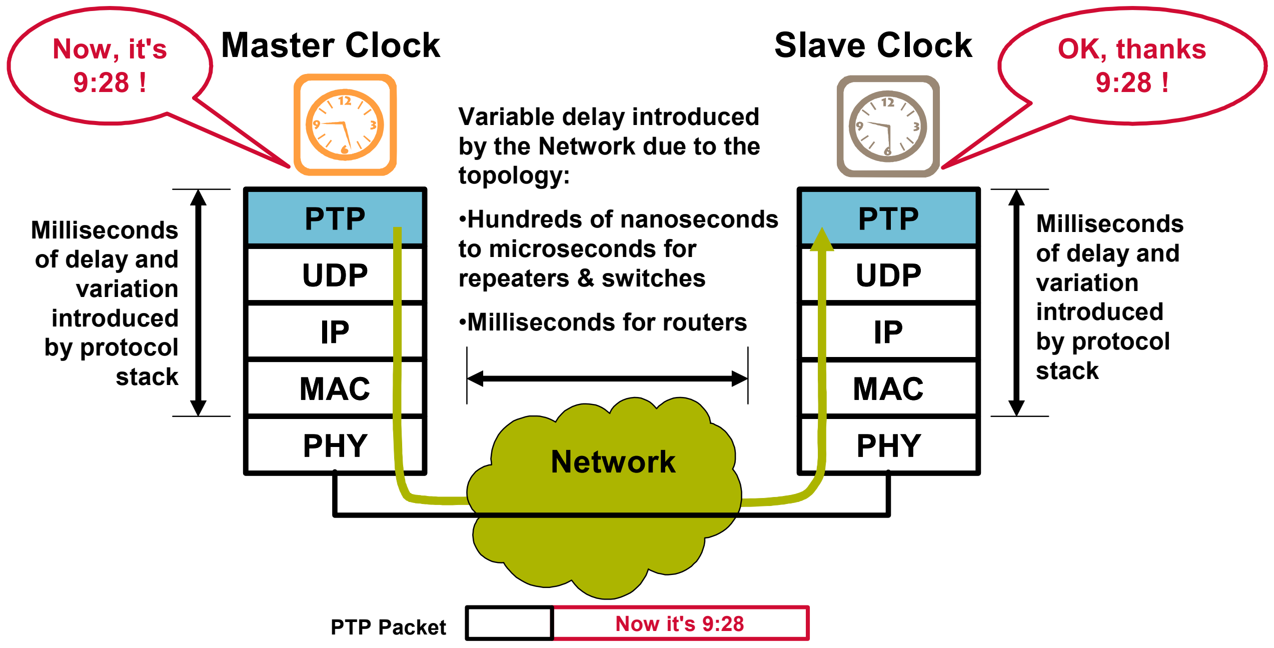

Now, it's 9:28 !
Master Clock
Slave Clock
OK, thanks 9:28 !
Variable delay introduced by the Network due to the topology:
•Hundreds of nanoseconds to microseconds for repeaters & switches
•Milliseconds for routers
Milliseconds of delay and variation introduced by protocol stack
PTP
UDP
IP
MAC
PHY
Milliseconds of delay and variation introduced by protocol stack
Network
PTP Packet
Now it's 9:28

Figure 4. Software timestamp implementation

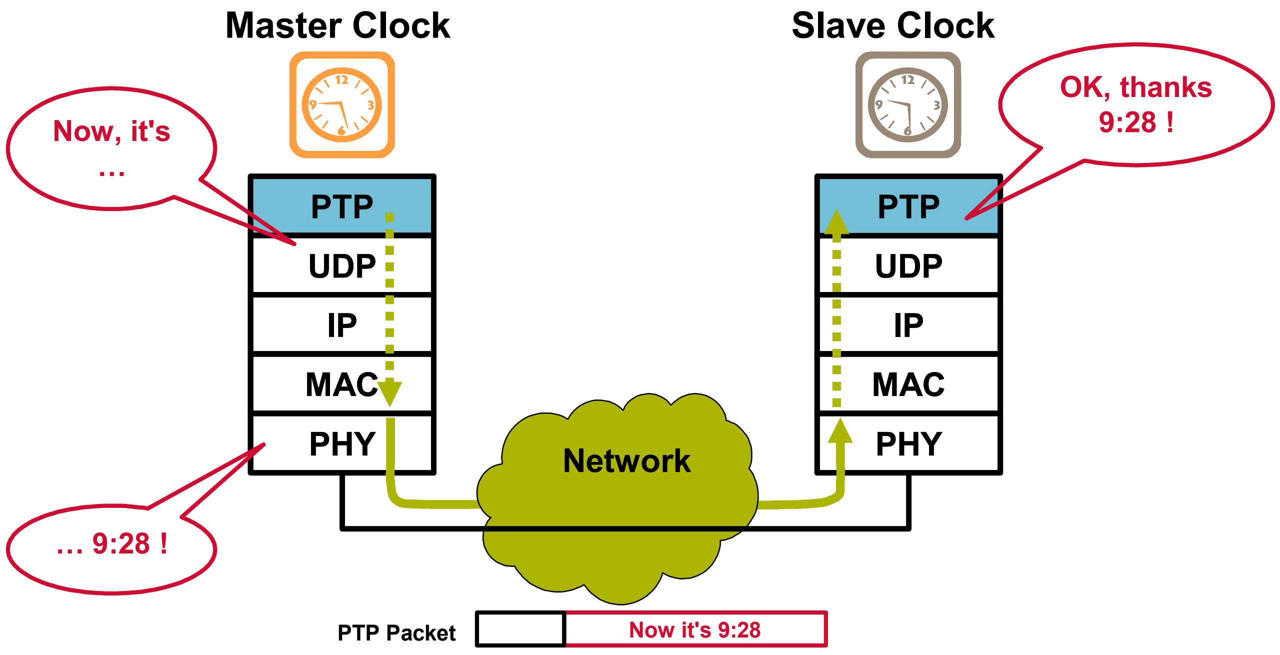


Figure 5. Hardware timestamp implementation

It is possible to minimize the impact of the protocol stack delay by taking timestamps closer to the physical interface, that is, at the MAC or PHY layers (see Figure 5). Dedicated hardware with timestamping capabilities, such as MAC-NET peripheral module of the Freescale Kinetis K60, allows synchronization with significantly improved accuracy.

3 IEEE 1588 implementation for Kinetis K60 based on MQX1588 library

Freescale Semiconductor's Kinetis TWR-K60N512 KIT serves as a hardware platform for hardware timestamping-based IEEE 1588 solutions. When combined with the Freescale MQX1588 library, which uses the MQX TCP/IP stack, and the IEEE 1588 V2 protocol software by IXXAT Automation GmbH, customers can develop highly accurate IEEE 1588 systems. Figure 6 illustrates the hardware and software components of this solution.

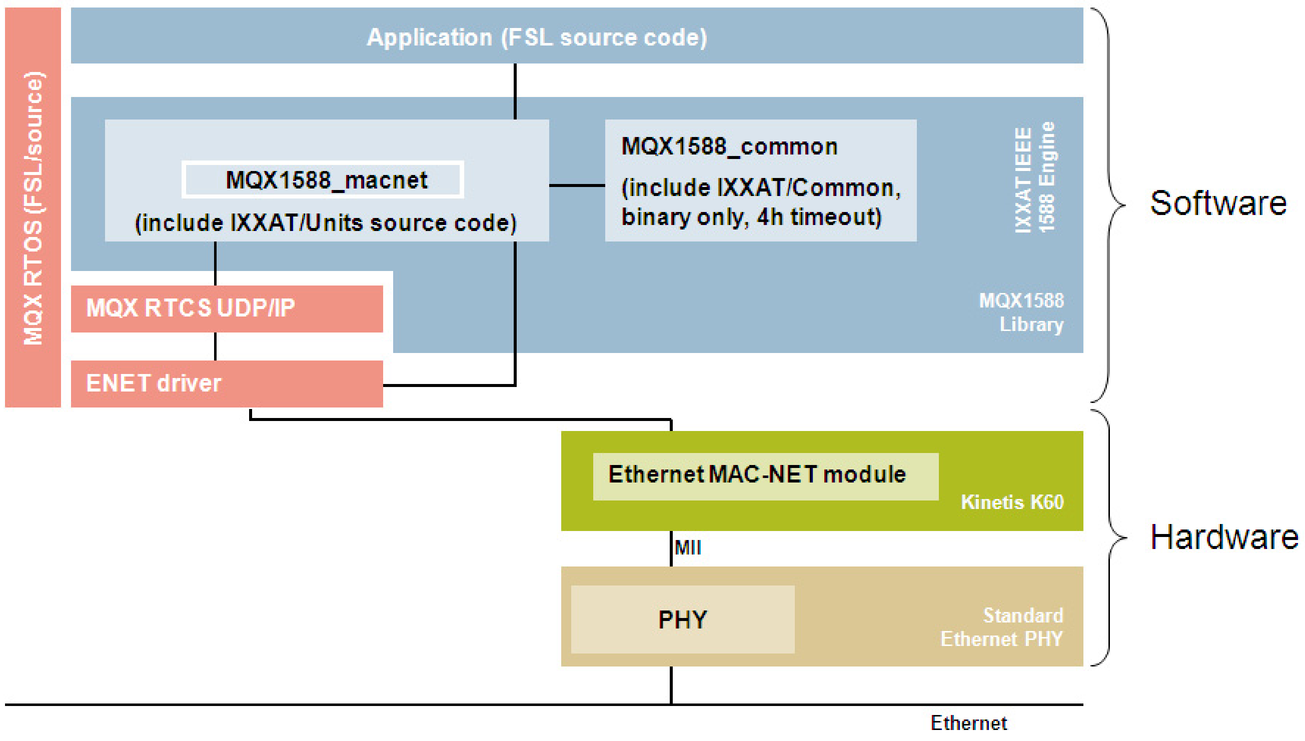


Figure 6. IEEE 1588 solution for Kinetis K60

3.1 Hardware components

3.1.1 TWR-K60N512 tower module kit

The K60N512 tower module kit (TWR-K60N512-KIT) is part of the Freescale Tower System, a modular development platform that enables rapid prototyping and tool re-use through the implementation of reconfigurable hardware. It can function as a stand-alone, low-cost platform for the evaluation of the Kinetis K10, K20 and K60 family of microcontroller (MCU) devices. The TWR-K60N512 features the

Kinetis K60 low-power microcontroller based on the ARM® Cortex™-M4 architecture with USB 2.0 full-speed OTG controller and 10/100 Mbps Ethernet MAC.

The TWR-K60N512-KIT includes:

- TWR-K60N512 MCU module
- TWR-SER, a serial module including USB host/device/OTG, Ethernet, CAN, RS232, and RS485
- TWR-ELEV, the primary and secondary elevator modules

The TWR-K60N512 MPU module features include:

- K60N512 in 144 MAPBGA, K60N512VMD100
- Capacitive touch pads
- Integrated, open source JTAG
- SD card slot
- MMA7660 3-axis accelerometer
- Tower Plug-In (TWRPI) socket for expansion (sensors, etc.)
- Tower connectivity for access to USB, Ethernet, RS232/RS485, CAN, SPI, I²C, Flexbus, etc.
- Potentiometer, four LEDs, two pushbuttons, and an infrared port

For more information about the TWR-K60N512-KIT, refer to the *TWR-K60N512 Tower Module User's Manual*, *TWR-K60N512-UM,* or visit www.freescale.com/tower.

3.1.2 Kinetis K60 32-bit microprocessor

Kinetis is the most scalable portfolio of low power, mixed signal ARM®Cortex™-M4 MCUs in the industry. Phase 1 of the portfolio consists of five MCU families with over 200 pin-, peripheral- and software-compatible devices. Each family offers excellent performance, memory, and feature scalability with common peripherals, memory maps, and packages, providing easy migration both within and between families.

Kinetis MCUs are built from Freescale's innovative 90nm Thin Film Storage (TFS) flash technology with unique FlexMemory. Kinetis MCU families combine the latest low power innovations and high performance, high precision mixed-signal capability with a broad range of connectivity, human-machine interface, and safety & security peripherals. Kinetis MCUs are supported by a market-leading enablement bundle from Freescale and numerous ARM 3rd party ecosystem partners.

The K60 MCU family includes IEEE 1588 Ethernet, full- and high-speed USB 2.0 On-The-Go with device charge detect capability, hardware encryption and tamper detection capabilities. Devices start from 256 KB of flash in 100LQFP packages extending up to 1 MB in a 256 MAPBGA package with a rich suite of analog, communication, timing, and control peripherals. High memory density K60 family devices include an optional single precision floating point unit, NAND flash controller and DRAM controller.

Figure 7 is a block diagram for the K60 family of microprocessors. For more information, refer to the *K60 Sub-Family Reference Manual*, *K60P104M100SF2RM*.

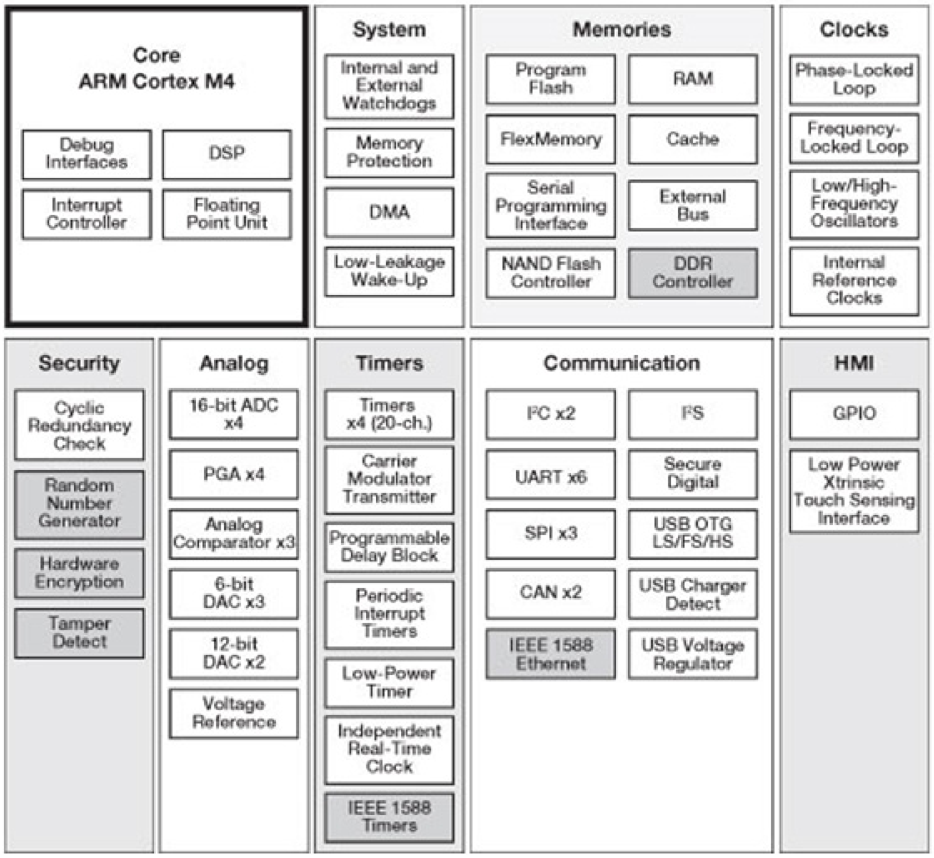


Figure 7. Kinetis K60 block diagram

3.2 Software components

3.2.1 Freescale MQX real time operation system

The MQX is a real-time operating system (RTOS) from MQX Embedded™ and ARC International®. It has been designed for uniprocessor, multiprocessor, and distributed-processor embedded real-time systems.

To leverage the success of the MQX RTOS, Freescale Semiconductor adopted this software platform for its ColdFire™, Kinetis and Power Architecture™ families of microprocessors. Compared to the original MQX distributions, the Freescale MQX distribution is simpler to configure and use. One single release now contains the MQX operating system plus all the other software components supported for a given microprocessor part (TCP/IP Stack, USB Host and Device Stack, Filesystem, and more).

The MQX RTOS is a runtime library of functions that programs use to become real-time multitasking applications. The main features are its scalable size, component-oriented architecture, and ease of use. It supports multiprocessor applications and can be used with flexible embedded I/O products for networking, data communications, and file management.

The Freescale MQX RTOS offers leading-edge software technology for embedded designs based on Freescale microprocessors and microcontroller. The Freescale MQX RTOS offers a straightforward application programming interface (API) with a modular, component-based architecture that makes it simple to fine-tune custom applications. It also allows developers to add web servers, e-mail, network management, security, and routing to their designs. Components are linked in only if needed, preventing unused functions from bloating the memory footprint. By leveraging Freescale's strong network of partners, Freescale MQX software solutions easily scale across third-party software and tools such as security, industrial protocols, and graphical plug-ins.

For more information, refer to *Freescale MQX Real-Time Operating System User's Guide*, *MQXUG*, or *Freescale MQX Real-Time Operating System Reference Manual, MQXRM*, or visit www.freescale.com/mqx.

3.2.2 Freescale MQX1588 library

The Freescale MQX1588 library was created to support IEEE1588 V2 standard in the MQX RTOS and to provide users with an easy way to develop IEEE1588 applications in MQX-based systems. The MQX1588 library is based on the IEEE 1588 V2 protocol software by IXXAT Automation GmbH, adapted for usage in the MQX environment.

The IXXAT IEEE 1588 V2 stack is a full implementation of the IEEE 1588-2008 standard with the following features:

- Ordinary/boundary clock
- Transparent clock
- Unicast messaging
- Best master algorithm
- One step/two step support
- Peer-to-peer and end-to-end delay mechanism
- Management protocol/interface
- Simple API for interfacing the application
- Runs with and without OS
- Easily adaptable to target hardware, UDP/IP stack and OS
- Optimized filter algorithms for the usage in standard Ethernet networks with high bus loads

For more information, refer to *Freescale MQX IEEE1588 Communication Library User's Guide, MQX1588UG*.

3.2.3 MQX RTCS full-featured TCP/IP stack

Freescale MQX Real-Time TCP/IP Communication Suite (RTCS) is a fast and low-footprint embedded internet stack that supports a rich set of standard protocols that span from data link to application layer such as FTP, Telnet, DHCP, DNS servers and clients, and SNMP clients. It provides great flexibility ranging from simple application such as Ethernet-serial to complex gateway systems. It also allows developers to add Web servers, e-mail, network management, security, and routing to their designs.

For more information, refer to *Freescale MQX RTCS User's Guide, MQXRTCSUG*.

4 Detailed description of the IEEE1588 demo software

A demonstration application has been created to show the functionality and usage of the MQX1588 library. This demo application provides an example of how to:

- Set up all parts of the application including the RTCS
- Use the MQX1588 library
- Implement user-overridable MQX1588API functions
- Realize nonvolatile storage using the standard MQX NAND Flash driver
- Implement the user interface for the application (Shell, Telnet, and HTTP Web Server)

The demo software goes with the installation of the MQX1588 library and can be found in the *demo* folder of the mqx1588lib software package. The application projects can be found in the following subdirectories:

- *cw10*: dedicated for CodeWarrior Development Studio for Microcontrollers Version 10 projects
- *iar*: dedicated for IAR Embedded Workbench for ARM projects

Start by opening the *iar\demo1588_two_step_twrk60n512.ewp* project file in IAR Embedded Workbench for ARM 6.10 or the *cw10\demo1588_two_step_twrk60n512\.project* file in the CodeWarrior 10. Both projects contain basic three build targets:

- Int. Flash Release—this target is suitable for final application deployment. When programmed to Flash, the application starts immediately after reset. Variables are allocated in internal SRAM memory.
- Int. Flash Debug—same as above, only the Debug-compiled libraries are used. This target is suitable for debugging before deployment. On boards without external memory, this is the only target suitable for debugging larger applications.
- Int. Ram Release—solely for debugging purposes with code located in the internal RAM memory. Both code and variables are located in this internal memory. Application executable is loaded to RAM automatically by the debugger.
- Int. Ram Debug—same as above, only the Debug-compiled libraries are used. This target is suitable for debugging before deployment.

The application requires Freescale MQX 3.7 to be installed and rebuilt with compile-time configuration options as stated in Chapter 3 of the *Freescale MQX IEEE1588 Communication Library User's Guide.*

4.1 MQX1588 library usage

The following binary libraries from the MQX1588 library are used in the demo software. Debug versions of binary images (postfix _d) are used in Debug targets and release version of binary images are used in release targets.

Table 1. List of binary libraries used from the MQX1588 library suite

mqx1588_common_two_step_d.a	Debug version of the MQX1588_common library for two-step mode implementations
mqx1588_common_two_step.a	Release version of the MQX1588_common library for two-step mode implementations
mqx1588_macnet_d.a	Debug version of the MQX1588_macnet library
mqx1588_macnet.a	Release version of the MQX1588_macnet library

The user-overridable API functions for the MQX1588 library are implemented in the *MQX1588user.c* file. This file implements two functions for reading and writing the MQX1588 configuration data to/from the nonvolatile storage (external NAND flash memory) and one error callback function.

4.2 MQX tasks list

This section describes all application tasks created with the help of the MQX RTOS. See Figure 8 for the overview of application tasks and assigned priorities (the higher number, the lower the task priority).

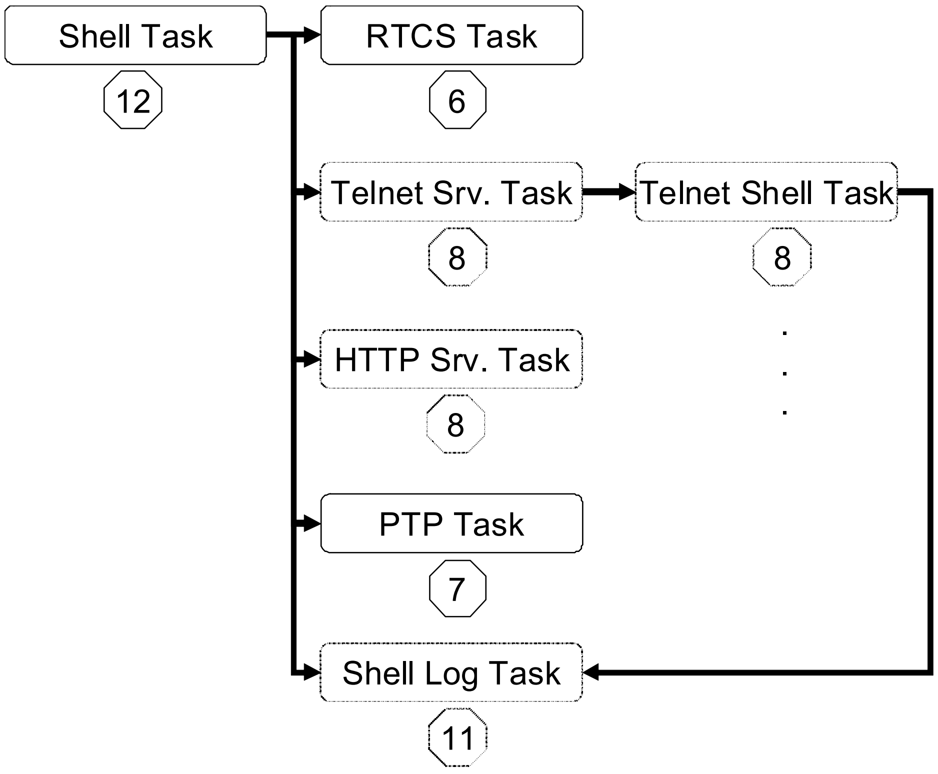


Figure 8. Overview of all tasks

- *Shell* task—the only task with assigned autostart attribute; that is, it is started when MQX starts. This task runs the serial port shell and starts another application tasks, as shown in Figure 8.
- *RTCS* task—started by the Shell task and runs the TCP/IP stack.

- *Telnet Server* task—once enabled (see Section 4.5.2, “Telnet console“), this task listens on a stream socket. Any time a client initiates a connection, the server creates a new Telnet Shell task and redirects the new task’s I/O to the connected socket. Command processing is done by the specified shell.
- *HTTP Server* task—once enabled (see Section 4.5.2, “Telnet console“), this task handles, evaluates, and responds to HTTP requests.
- *PTPMain* task—created by the Shell task and runs the PTP engine. As the evaluation version of the IXXAT IEEE 1588 stack is provided, the PTP engine is automatically stopped 4 hours after the MQX start time.
- *Telnet Shell* task—created by the Telnet Server task and runs the Telnet shell, similar to the shell on the serial port.
- *Shell Log* task—created either by the Shell task when the serial line shell command “show on” is applied, or by the Telnet Server task when the Telnet shell command “show on” is applied. The Shell Log task prints log data (actual IEEE1588 time, offset to master, master-to-slave delay, slave-to-master delay, one-way delay, drift) once per second, to either the serial console or the Telnet console.

4.3 Nonvolatile storage

With the exception of the MQX1588 configuration data, which relates to the MQX1588 library, the user can specify other application data to be stored in the external NAND flash memory. The following application-specific structure is defined in the *MQX1588DEMO.h* file:

```
typedef struct
{
  MQX1588_CONFIG lib1588_cfg;
  boolean        autorun;
  uint_32        checksum;
} MQX1588DEMO_CONFIG, _PTR_ MQX1588DEMO_CONFIG_PTR;
```

lib1588_cfg

This is the configuration structure of the MQX1588 library and its content is vital for proper IEEE 1588 stack functionality. It includes the PTP low-level library-specific parameters, network configuration parameters, and MQX1588 library-specific parameters. See the MQX1588 library documentation for more details about this structure. The MQX1588_ReadConfig() and MQX1588_WriteConfig() user-overridable functions are dedicated for reading out and writing into this structure.

autorun

This enables the automatic resumption of the PTPMain task after its creation and thus starts the clock synchronization process after the board reset without any user intervention.

checksum

This 32-bit checksum field is required to maintain and verify MQX1588DEMO_CONFIG structure integrity in the flash memory.

The *default_MQX1588DEMOCfg* structure of the `MQX1588DEMO_CONFIG` type is defined in the *ptp_cfg.h* file. This structure is saved in the external NAND flash memory once the application is started for the first time or once the checksum of the configuration structure saved in the NAND Flash memory is invalid. The user can modify this default configuration structure before project compilation.

Application-specific functions MQX1588DEMO_ReadConfig() and MQX1588DEMO_WriteConfig() that access the MQX1588DEMO_CONFIG structure saved in the NAND flash memory are implemented in the *MQX1588DEMO.c* file. These functions are used by the MQX1588 library API functions MQX1588_ReadConfig() and MQX1588_WriteConfig() each time the MQX1588 configuration data reading or writing is requested.

4.4 Timestamping

The timestamping capability of the Kinetis K60 10/100Mbps Ethernet MAC-NET module allows the precise timestamping of incoming and outgoing frames. This module incorporates an adjustable timer module which implements a free running 32-bit counter. Through dedicated correction logic, the timer can be adjusted to allow synchronization to a remote master and provide a synchronized timing reference for the local system. The timer can be configured to cause an interrupt after a fixed time period to allow the synchronization of software timers or to perform other synchronized system functions.

When a PTP frame is received, the MAC latches the value of the timer when the frame's Start Frame Delimiter (SFD) field is detected and provides the captured timestamp on the Rx buffer descriptor. This is done for all received frames.

When transmitting, the client driver (MAC-NET driver) should detect 1588 event frames and indicate in the Tx buffer descriptor that the frame has to be timestamped. Afterwards, the MAC module records the timestamp for the frame in the dedicated register and generates an interrupt to indicate that the new Tx timestamp is available.

Detailed description of the timestamping capabilities of the MAC-NET peripheral module can be found in the *K60 Sub-Family Reference Manual*, *K60P104M100SF2RM.*

4.5 User interface

The Freescale MQX1588 library-based IEEE 1588 demo application for Kinetis K60 can be interfaced by:

- Serial line console
- Telnet console
- HTTP web server
- IXXAT PTPManager

The following compile-time configuration options must be set in the *MQX1588DEMO.h* in order to enable the Telnet server and HTTP web server in the application.

Table 2. Compile time configuration options of the MQX1588 demo

Option	Value
MQX1588DEMOCFG_ENABLE_WEBSERVER	1
MQX1588DEMOCFG_ENABLE_TELNET_SERVER	1

4.5.1 Serial line console

The MQX shell library is a part of MQX and allows you to execute commands on the target system either through the serial line or the Telnet client. In addition to the standard shell utilities, the user can add other commands to the shell. These can be useful for setting up application parameters, monitoring and control of the PTP engine. The list of embedded shell commands defined for the IEEE1588 demo application is summarized in Table 3.

Table 3. Embedded shell commands overview

Command	Functionality
exit	Usage — exit Exits the shell.
ptp	Usage — ptp [on|off] on – starts the IXXAT IEEE1588 engine off – stops the IXXAT IEEE1588 engine
ptpdisplay	Usage — ptpdisplay <option> <on|off> Selects what IEEE1588 specific runtime data will be printed out when show command executed. Options: • offs – actual offset to master (unfiltered/filtered) • mtsd – actual master-to-slave delay (unfiltered/filtered) • stmd – actual slave-to-master delay (unfiltered/filtered) • owd – actual one-way delay (unfiltered/filtered) • meanDrft – actual drift [psec/sec] between Slave and Master • gmstraddr – actual grand master address • mstraddr – actual master address

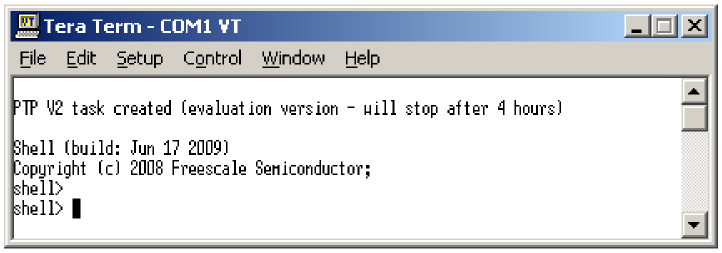
Table 3. Embedded shell commands overview (continued)

Command	Functionality
cfgparam	Usage — cfgparam [<option> <value>] Enables to change PTP engine configuration parameters and network configuration parameters. Changed values are saved in the nonvolatile storage and applies after the reset. Options: • clkClass – clock class of local clock • scldVar – log2 of scaled variance of local clock • prio1 – clock priority 1 of local clock • prio2 – clock priority 2 of local clock • domNmb – domain number attribute of local clock • slaveOnly – 0 = slave only, 1 = slave or master • dlrqIntv – log2 of delay request interval • AnncIntv – log2 of announce interval • anncRcptTmo – announce receipt timeout • syncIntv – log2 of sync interval • pdelReqIntv – log2 of pdelay request interval • ip_addrX – IP address of the interface X • ip_netmaskX – IP netmask of the interface X • ip_gatewayX – IP gateway of the interface X • mac_addrX – MAC address of the interface X • autorun – on|off
netstat	Usage — netstat Displays the TCP/IP statistics.
show	Usage — show <on|off> Displays actual IEEE1588 time and other IEEE1588 specific runtime data as selected by the ptpdisplay shell command. Options: • on – starts regular display of current time & actual offset (once per second) • off – stops regular display of current time & actual offset
help	Usage — help [<command>] • <command> = command to get help on

To set up the serial line shell, which serves as a default user interface, connect your PC and the UART socket of the TWR-SER2 serial board with the RS232 cable. The following parameters of the serial port must be set in order to establish the connection:

- Baud rate: 115200
- Data bits: 8
- Parity: none
- Stop bit: 1
- Flow control: none

The Shell task is started automatically after the reset. Figure 9 shows the welcome message of the shell and the command prompt that displays after reset.



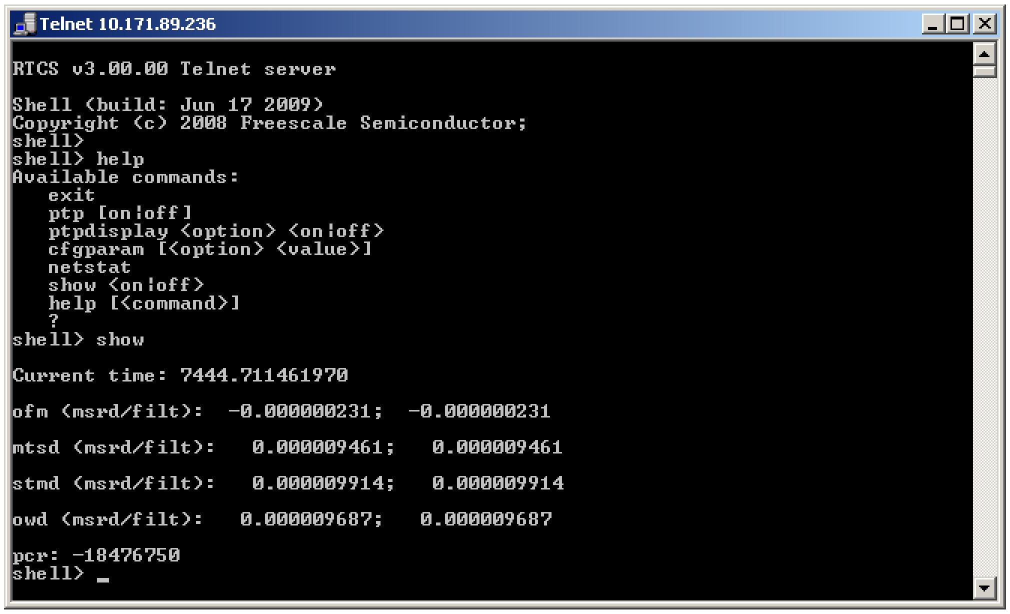
```
PTP V2 task created (evaluation version - will stop after 4 hours)

Shell (build: Jun 17 2009)
Copyright (c) 2008 Freescale Semiconductor;
shell>
shell>
```

Figure 9. Serial line shell

4.5.2 Telnet console

The MQX1588DEMOCFG_ENABLE_TELNET_SERVER compile-time configuration options must be set in the *MQX1588DEMO.h* in order to enable the Telnet server in the application (see Table 2).

While using the Telnet console, the embedded command shell is accessible after the communication with the TWR-K60N512-KIT is established. This is done by entering the command *open <defined IP address>* into the user preferred Telnet Client. A set of Telnet shell commands is the same as for the serial line shell, see Table 3.



```
RTCS v3.00.00 Telnet server

Shell (build: Jun 17 2009)
Copyright (c) 2008 Freescale Semiconductor;
shell>
shell> help
Available commands:
   exit
   ptp [on|off]
   ptpdisplay <option> <on|off>
   cfgparam [<option> <value>]
   netstat
   show <on|off>
   help [<command>]
   ?
shell> show

Current time: 7444.711461970

ofm (msrd/filt):  -0.000000231;  -0.000000231

mtsd (msrd/filt):   0.000009461;   0.000009461

stmd (msrd/filt):   0.000009914;   0.000009914

owd (msrd/filt):   0.000009687;   0.000009687

pcr: -18476750
shell> _
```

Figure 10. Telnet console

4.5.3 HTTP web server

The Hypertext Transfer Protocol (HTTP) server is one of the MQX RTCS components. It is comprised of a simple web server that handles, evaluates, and responds to HTTP requests and can be used as a GUI for the IEEE1588 demo application. Once enabled by the compile time configuration option (see Table 2), it allows the implementation of a web server with support for dynamically generated web pages. Common Gateway Interface (CGI) callback functions are registered with the HTTP server by the application. These functions are called back from the HTTP server when the client requests that the assigned CGI file be retrieved (for example http://169.254.3.3/data1588.cgi).

The content of all application web pages is stored in the flash memory and can be accessible from any web browser by applying the target Ethernet port IP address. The default IP addresses of the board are169.254.3.3. for port0 and 169.254.3.4. for port1.

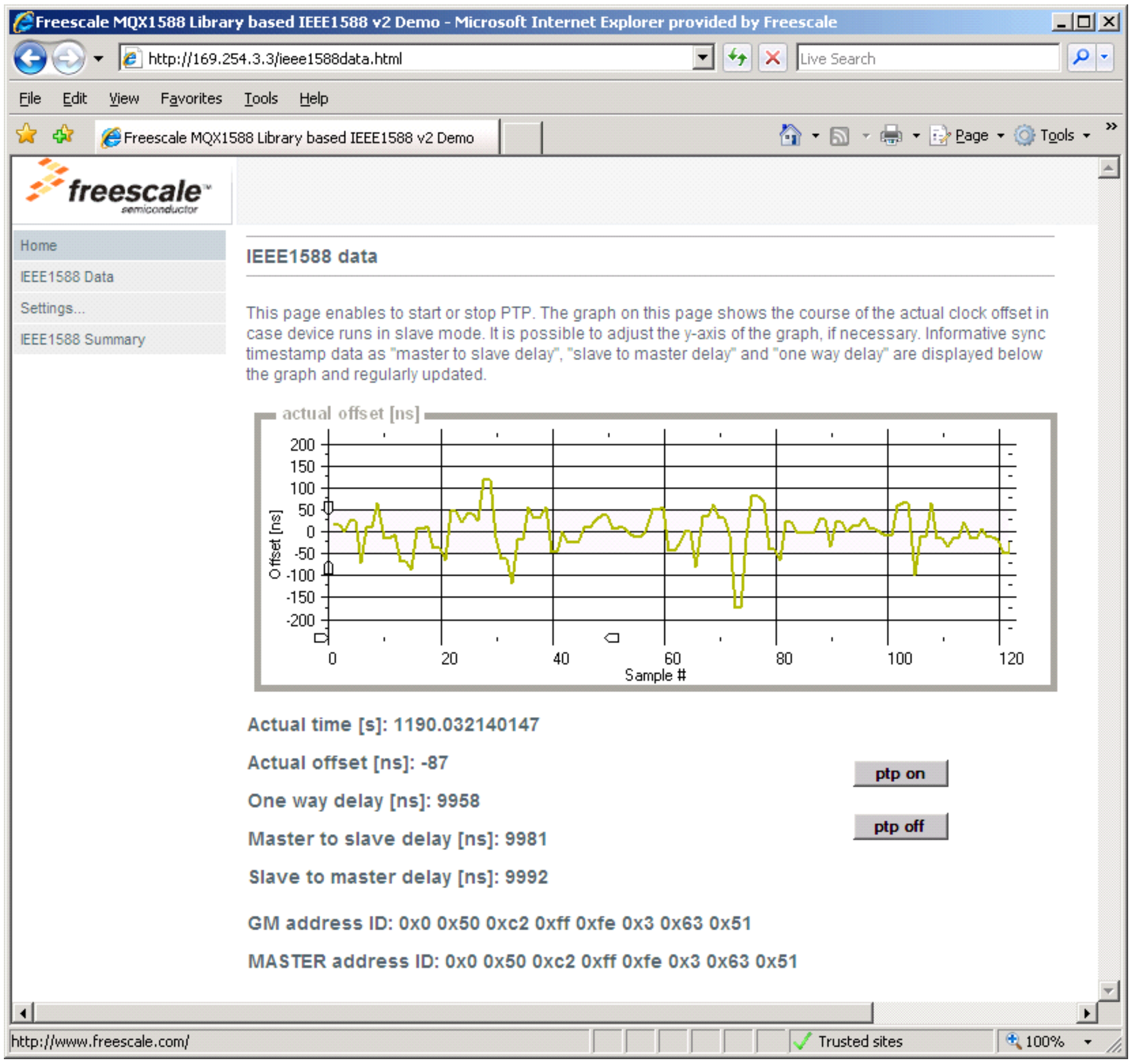
After navigating to the device IP address, the browser window displays a web server welcome page with a user menu on the left side. You can click on the *IEEE1588 Data* menu item to see the course of the actual clock offset, as in Figure 11. The following selected PTP stack variables are displayed on this page:

- Actual time (s)
- Actual offset (ns)
- One-way delay (ns)
- Master-to-slave delay (ns)
- Slave-to-master delay (ns)
- GrandMaster address
- Master address

This page also allows the start or stop of the PTP engine by clicking on the respective button.

NOTE

The pages contain binary ActiveX graph component to visualize time differences. You may need to add the device IP address to your list of trusted sites to enable automatic installation of this component.


Freescale MQX1588 Library based IEEE1588 v2 Demo - Microsoft Internet Explorer provided by Freescale
http://169.254.3.3/ieee1588data.html
Live Search
File Edit View Favorites Tools Help
Freescale MQX1588 Library based IEEE1588 v2 Demo
Page Tools
freescale semiconductor
Home
IEEE1588 Data
Settings...
IEEE1588 Summary
actual offset [ns]
Offset [ns]
Sample #
ptp on
ptp off
http://www.freescale.com/
Trusted sites
100%

IEEE1588 data

This page enables to start or stop PTP. The graph on this page shows the course of the actual clock offset in case device runs in slave mode. It is possible to adjust the y-axis of the graph, if necessary. Informative sync timestamp data as "master to slave delay", "slave to master delay" and "one way delay" are displayed below the graph and regularly updated.

Actual time [s]: 1190.032140147

Actual offset [ns]: -87

One way delay [ns]: 9958

Master to slave delay [ns]: 9981

Slave to master delay [ns]: 9992

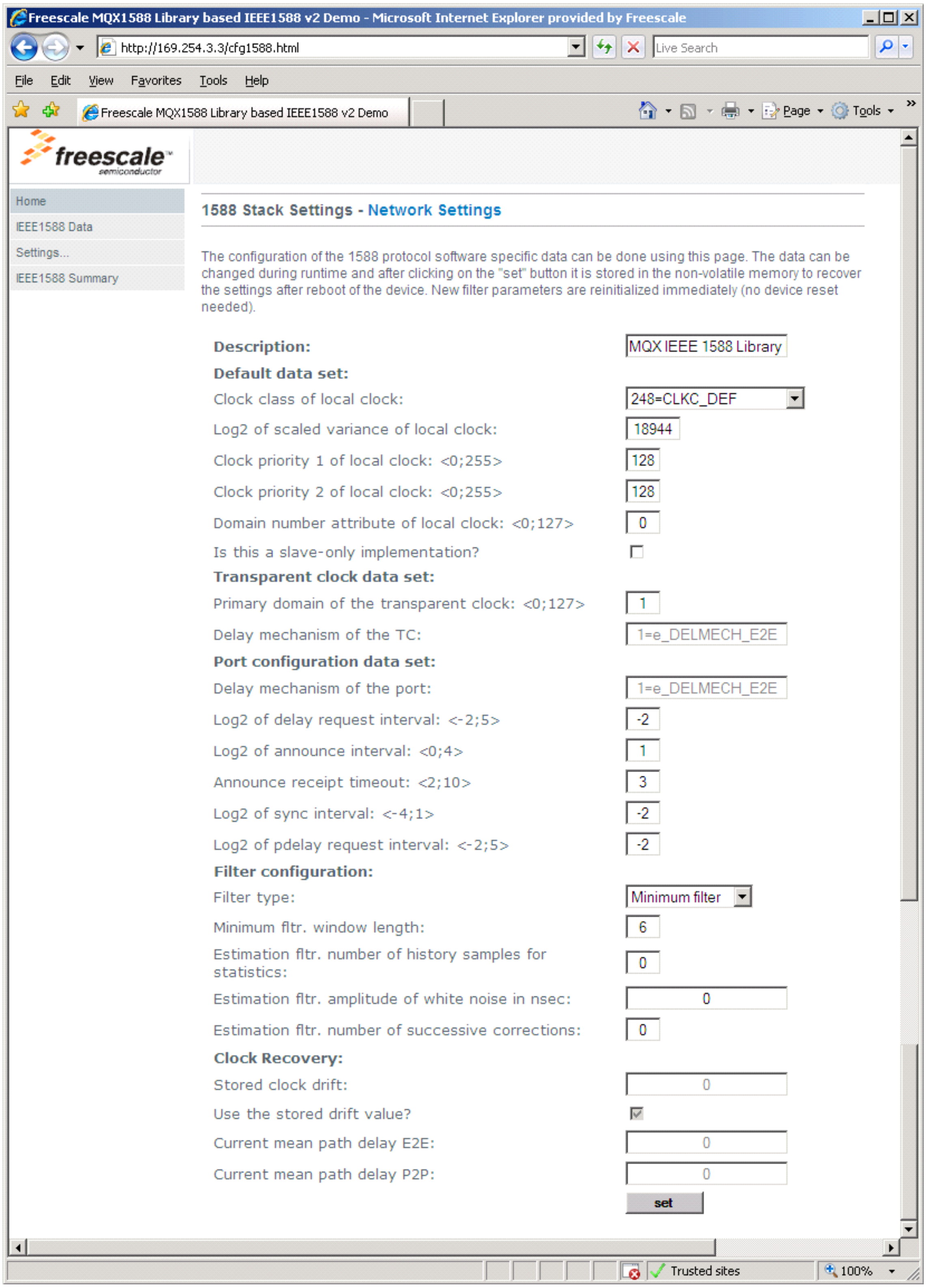
GM address ID: 0x0 0x50 0xc2 0xff 0xfe 0x3 0x63 0x51

MASTER address ID: 0x0 0x50 0xc2 0xff 0xfe 0x3 0x63 0x51

Figure 11. “IEEE1588 Data” page of the demo application

Another important menu item is the *Settings* attribute, which has several submenus:

- *1588 Stack Settings*—enables a change of the configuration of the 1588 protocol software specific data (see Figure 12). The data can be changed during runtime and is stored in the nonvolatile memory to be restored after device reset.
- *Network Settings*—enables a change of the basic network parameters, such as the MAC address, IP address, Gateway, and Netmask (see Figure 13). These parameters are saved in the nonvolatile memory and applied after the device reset.



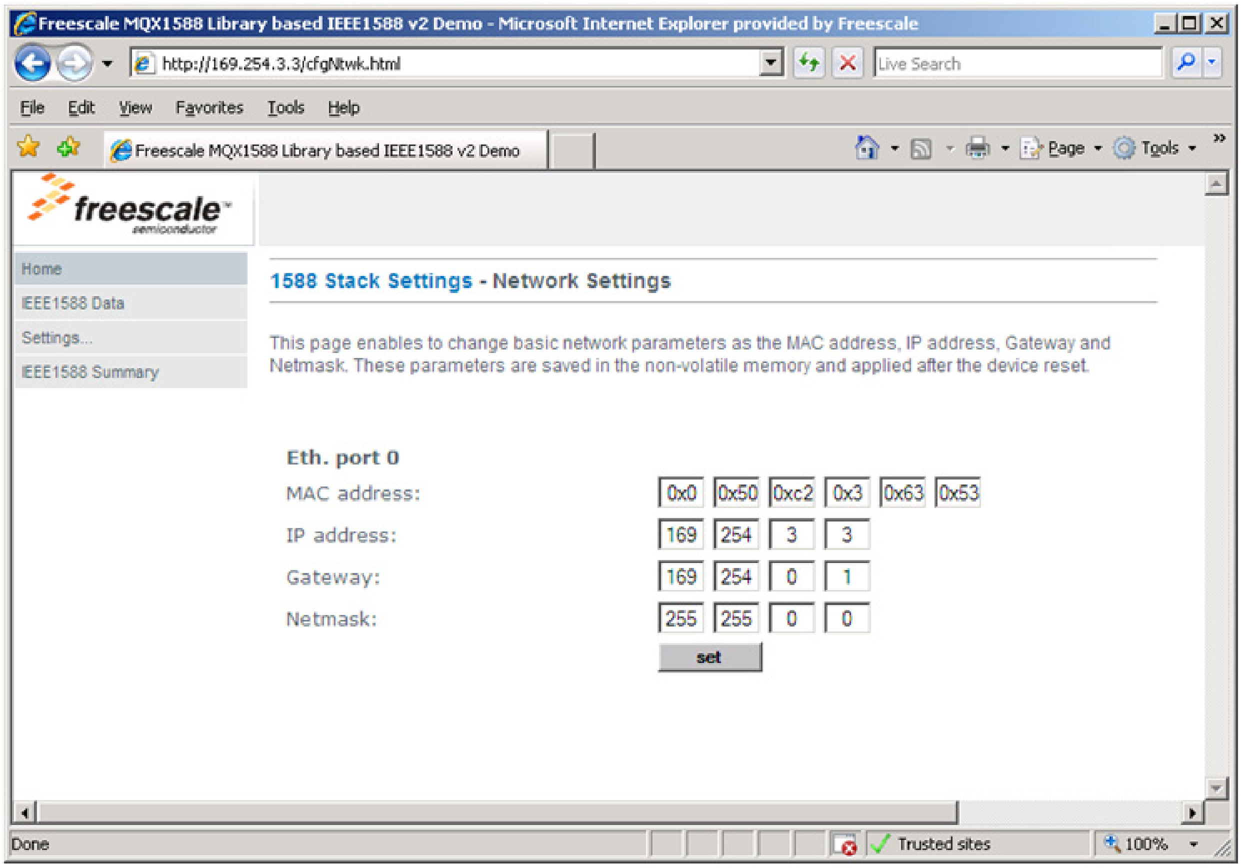
Freescale MQX1588 Library based IEEE1588 v2 Demo - Microsoft Internet Explorer provided by Freescale
http://169.254.3.3/cfg1588.html
Live Search
File Edit View Favorites Tools Help
Freescale MQX1588 Library based IEEE1588 v2 Demo
Page Tools
freescale semiconductor
Home
IEEE1588 Data
Settings...
IEEE1588 Summary
Trusted sites
100%

1588 Stack Settings - Network Settings

The configuration of the 1588 protocol software specific data can be done using this page. The data can be changed during runtime and after clicking on the "set" button it is stored in the non-volatile memory to recover the settings after reboot of the device. New filter parameters are reinitialized immediately (no device reset needed).

Description:	MQX IEEE 1588 Library
Default data set:	
Clock class of local clock:	248=CLKC_DEF
Log2 of scaled variance of local clock:	18944
Clock priority 1 of local clock: <0;255>	128
Clock priority 2 of local clock: <0;255>	128
Domain number attribute of local clock: <0;127>	0
Is this a slave-only implementation?	☐
Transparent clock data set:	
Primary domain of the transparent clock: <0;127>	1
Delay mechanism of the TC:	1=e_DELMECH_E2E
Port configuration data set:	
Delay mechanism of the port:	1=e_DELMECH_E2E
Log2 of delay request interval: <-2;5>	-2
Log2 of announce interval: <0;4>	1
Announce receipt timeout: <2;10>	3
Log2 of sync interval: <-4;1>	-2
Log2 of pdelay request interval: <-2;5>	-2
Filter configuration:	
Filter type:	Minimum filter
Minimum fltr. window length:	6
Estimation fltr. number of history samples for statistics:	0
Estimation fltr. amplitude of white noise in nsec:	0
Estimation fltr. number of successive corrections:	0
Clock Recovery:	
Stored clock drift:	0
Use the stored drift value?	✓
Current mean path delay E2E:	0
Current mean path delay P2P:	0
	set

Figure 12. “1588 Stack Settings” page of the demo application


Freescale MQX1588 Library based IEEE1588 v2 Demo - Microsoft Internet Explorer provided by Freescale
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Freescale MQX1588 Library based IEEE1588 v2 Demo
Page Tools
freescale semiconductor
Home
IEEE1588 Data
Settings...
IEEE1588 Summary
set
Done
Trusted sites
100%

1588 Stack Settings - Network Settings

This page enables to change basic network parameters as the MAC address, IP address, Gateway and Netmask. These parameters are saved in the non-volatile memory and applied after the device reset.

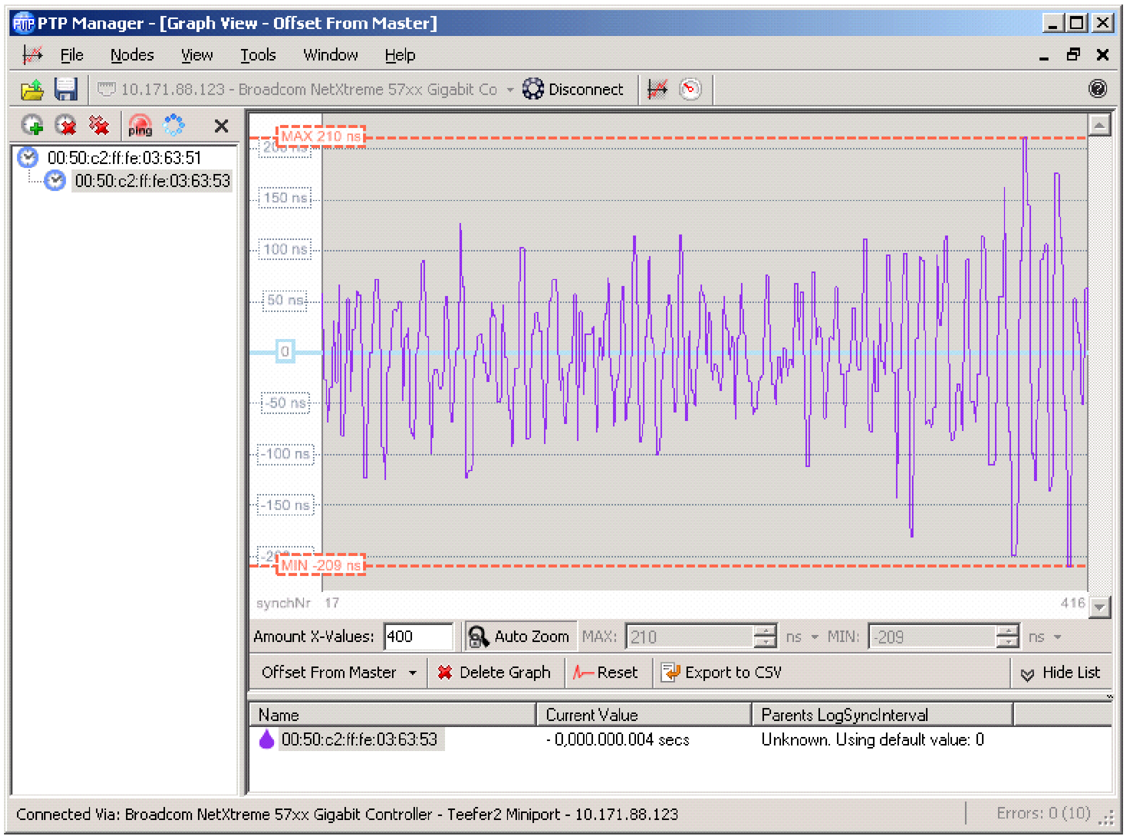
Eth. port 0

MAC address:	0x0	0x50	0xc2	0x3	0x63	0x53
IP address:	169	254	3	3		
Gateway:	169	254	0	1		
Netmask:	255	255	0	0		

Figure 13. “Network Settings” page of the demo application

4.5.4 IXXAT PTPManager

Another possibility for accessing the running 1588 demo application and monitoring the 1588 communication between each node in the network is the IXXAT PTPManager. It allows you to monitor all 1588 nodes within the network and to use the PTP management messages to get/set different 1588node parameters. This way, the offset between the master node and the slave node can be captured and displayed graphically. This PC application can be downloaded from the IXXAT webpages.



Name	Current Value	Parents LogSyncInterval
00:50:c2:ff:fe:03:63:53	- 0,000.000.004 secs	Unknown. Using default value: 0

Connected Via: Broadcom NetXtreme 57xx Gigabit Controller - Teefer2 Miniport - 10.171.88.123 Errors: 0 (10)

Figure 14. IXXAT PTPManager

5 IEEE1588 demo

This section describes how to build an IEEE1588 demo using the TWR-K60N512-KIT and the demo software of the MQX1588 library.

5.1 Hardware setup and jumper settings

The following parts of the TWR-K60N512-KIT must be used and connected each other to build a correct hardware setup.

- TWR-K60N512 Rev. C processor board
- TWR-SER serial board
- TWR-ELEV primary and secondary—four-story elevator boards

As described in *Getting Started with Freescale MQX RTOS*, the following jumper settings have to be checked to ensure correct functionality of the demo:

Table 4. TWR-K60N512 Rev. C board jumper settings

J6 on position 2-3	processor clock taken from the TWR-SER board

Table 5. TWR-SER board jumper setting

CLK_SEL 3-4	
CLKIN-SEL 2-3	processor clock is taken from PHY
ETH-CONFIG J12 9-10	select RMII communication mode

The demo can be configured in a back-to-back (point-to-point) configuration where two boards are connected directly using the crossover Ethernet cable. It deals with a simple type of connection often used for evaluating the system accuracy and the overall performance. The back-to-back configuration using two TWR-K60N512-KITs is illustrated in Figure 15. The application can be interfaced by the serial console only.

Figure 16 shows another demo concept which consists of two or more TWR-K60N512-KITs. An Ethernet switch/hub provides the connection between all boards. The slave node can be interfaced by the serial console or by the Telnet console or by the Internet Explorer web browser or by the IXXAT PTPManager. The user can also monitor the 1588 communication between these 1588 nodes using any network protocol analyzer (WireShark).

Another Freescale evaluation boards with the IEEE1588 support can be involved in the demo to enlarge the IEEE1588 network. The following ColdFire and PowerQUICC boards can be incorporated:

- ColdFire M5234BCC
- ColdFire M52259EVB
- ColdFire TWR-MCF54418 KIT
- PowerQUICC MPC8360MDS
- PowerQUICC MPC8313E-RDB
- i.MX28 Evaluation Kit

Visit www.freescale.com. for updated information about Freescale platforms with the IEEE1588 support.

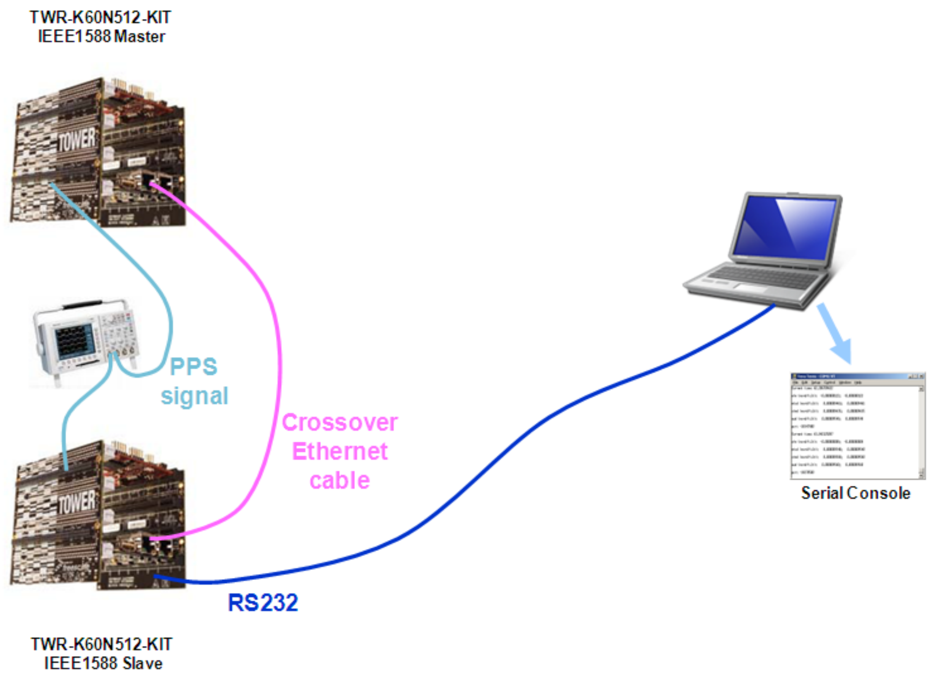


Figure 15. Back-to-back configuration of the demo

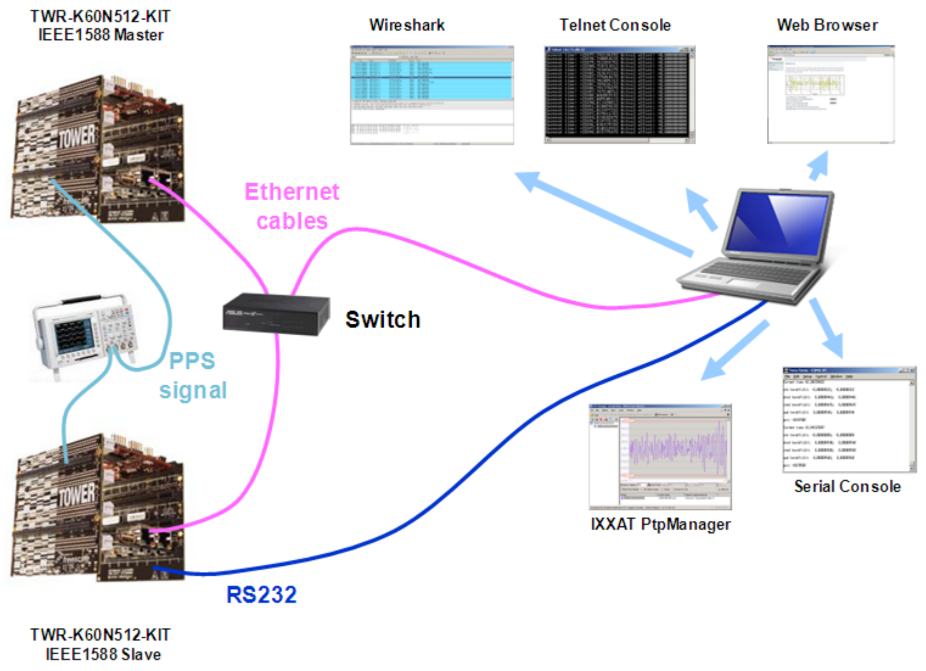


Figure 16. Demo extended to include multiple IEEE1588 nodes

5.2 Measuring the clock synchronicity

To measure the synchronicity of the clocks, the K60 provides an option to generate a pulse-per-second (PPS) signal. This signal is generated directly from the 1588 timer (ENET0_TMR2 by default) and is routed to the GPIO PTC18. This GPIO pin is routed to the J9-21 pin on the primary TWR-ELEV board of the tower system.

To measure and compare PPS signals from different boards, attach the oscilloscope probe to the J9-21 pin of the primary TWR-ELEV board. Figure 17 illustrates clock synchronicity measurement using the oscilloscope.

To measure the clock synchronization accuracy, a test was performed between two TWR-K60N512-KITs connected back-to-back. Table 6 summarizes the configuration of the IXXAT 1588 V2 stack used for testing:

Table 6. 1588 stack configuration for clock synchronization accuracy Testing

1588 configuration	Assigned value
Clock basic type	Ordinary Clock
Delay request mechanism	End-to-End
One-step mode	False
Announce message interval	2 seconds
Sync message interval	0.25 seconds
Delay request interval	0.25 seconds
Used filter	Minimum filter
Filter window length	6
Measurement period	0.5 hours

The results of the clock synchronization accuracy test are provided below, see Table 7.

Table 7. Clock synchronization accuracy test results

Average clock offset	–0.44 ns
Standard deviation	16.16 ns
Peak-to-peak range	–51 ns to +57 ns

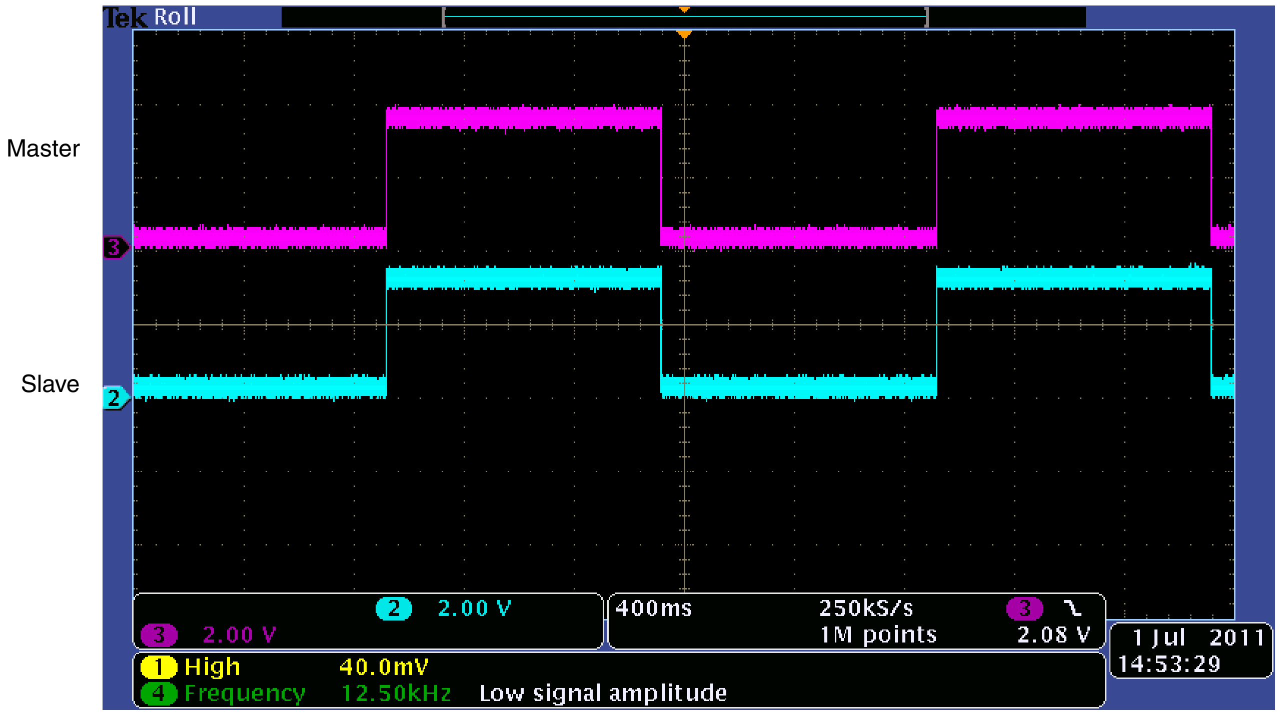


Figure 17. Oscilloscope screen shot—measuring the clock synchronicity (PPS)

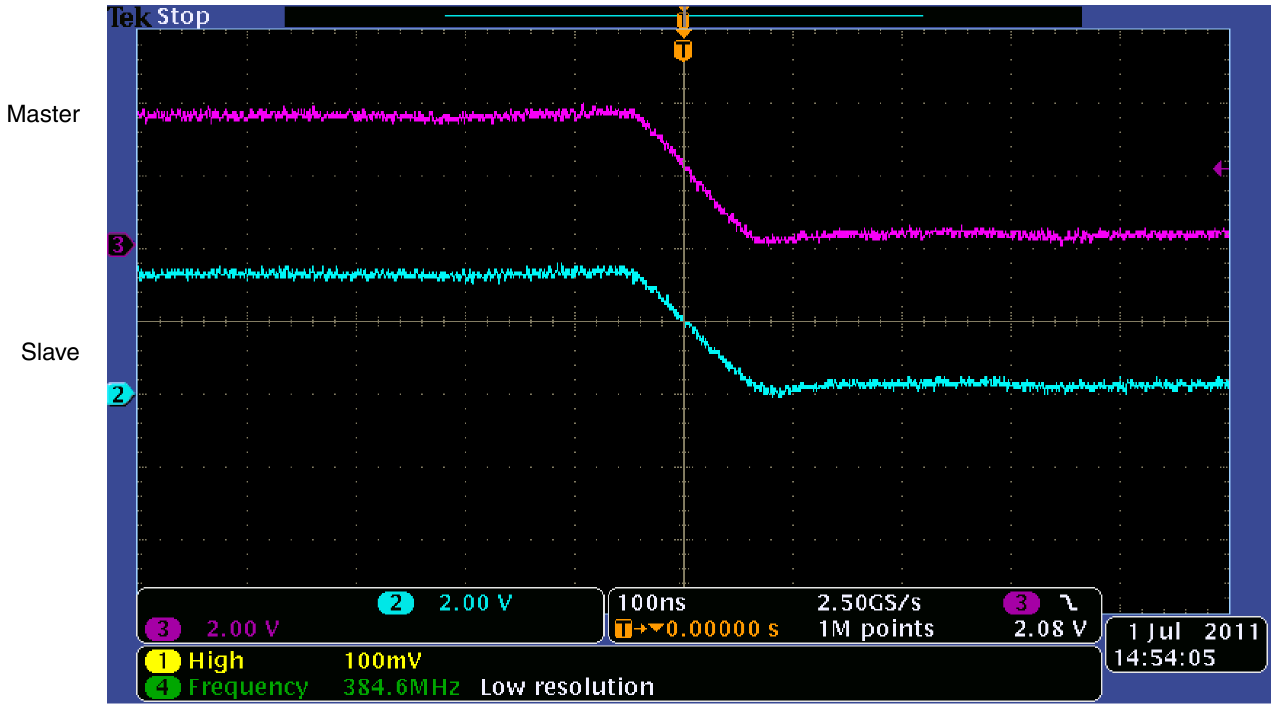


Figure 18. Oscilloscope screen shot—detail of the PPS signal edges

6 Conclusion

This application note describes an IEEE 1588 Precision Time Protocol demo application that targets the Kinetis K60 processor and the TWR- K60N512-KIT. The application software runs under the Freescale MQX RTOS and uses the MQX RTCS TCP/IP stack and the Freescale MQX1588 Library for quick IEEE1588 application development. This solution can be easily ported to other processors from the Kinetis family with the MQX and RTCS support.

The demo system can be targeted to applications that require precise clock synchronization between devices with accuracy in the sub-microsecond range. Typical applications include industrial network switches, time-sensitive telecommunication services, powerline networks, and test/measurement devices. For more information and updates go to www.freescale.com.

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