BC635PCI-U

BC635PCI-U-OCXO

BC637PCI-U

BC637PCI-U-OCXO

Time and Frequency Processor

User Guide

Part #: 8500-0140

Revision A

Table of Contents

Chapter 1: Introduction

General

The Symmetricom model bc635PCI-U and bc637PCI-U Time and Frequency Processors are high performance, 32-bit PCI plug-in cards used for precise time synchronization of the host computer over the PCI bus. These timing cards operate at 33 MHz and are compliant with PCI Local Bus Specification Revision 2.3[1]. The products support *both the 3.3V and 5V signaling environments* defined by the PCI Local Bus Specification. They are considered Universal add-in cards that are capable of detecting the signaling environment and adapting themselves to that environment.

There are four separate products supported by this manual:

- BC635PCI-UStandard (with VCXO)
- BC637PCI-UOptional GPS receiver (with VCXO)
- BC635PCI-U-OCXOOptional OCXO
- BC637PCI-U-OCXOOptional GPS receiver and OCXO

These Time and Frequency Processors will be referred to as "TFP" or "TFPs" for the remainder of the document. All sections of this manual are applicable to all boards except where noted.

Key Features

The TFP has been designed with the following key features:

- Two independent sets of time capture registers. These registers latch and hold the current time on request. Time is provided in binary format (UNIX seconds through 100 nanoseconds).

- One set of time capture registers can also be used for event time capture. Time is captured on the rising or falling edge (user programmable) of the Event Input signal or on the rising edge of the Programmable Periodic Output signal.

- The TFP uses the reference source to discipline its internal 10 MHz VCXO (Voltage Controlled Crystal Oscillator). The VCXO output drives all timing functions on the card. The VCXO output and a 1 PPS signal are provided as outputs. The TFP is also capable of disciplining an external voltage controlled oscillator. As an option, the TFP board can be ordered with an OCXO (Oven Controlled Crystal Oscillator) installed.

- All modes of operation are supplemented by flywheel operation. If the synchronization source is lost, the TFP will continue to function at the last known reference rate.

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1.   The BC635/637PCI-U does not provide interrupts at system start-up and therefore does not support the PCI Local Bus Specification Revision 2.3 feature of software disable of interrupts at start-up.

The following operational modes are supported, and are distinguished by the reference source.

Mode	Source of Synchronization
0	Time Code - IRIG B, IRIG A, IEEE 1344 & NASA 36
1	Free Running - 10 MHz Selected Reference (Internal or External)
2	1 PPS - External One Pulse Per Second Input
3	RTC-Uses battery backed on-board real time clock I.C.
4-5	Reserved
6	GPS (bc637) - GPS Antenna/Receiver

- The TFP generates IRIG B time code synchronized to the reference source. Modulated and DC level shift formats are produced simultaneously.

- A Programmable Periodic output is provided. The output frequency is programmable and can be synchronized to the TFP 1 PPS signal.

- A Time Coincidence Strobe output is provided. It is programmable from hours through microseconds. This strobe also has an each second mode (referred to in this manual as Minor Time Mode) programmable to microseconds.

- Five maskable interrupt sources are supported. PCI bus levels one through seven are supported. All interrupt sources can be polled.

Definition of Terms

The following is a glossary of key terms used in the discussion of timing operations:

- **Discipline**: The word discipline, as used in this manual, means to adjust the frequency of the on-board oscillator to track the incoming reference signal. This reference signal can be in the form of a 1 pulse per second input, an input from IRIG, IEEE 1344, an external 10MHz signal, or the signal from a GPS receiver. Once the on-board oscillator has been disciplined to the reference signal, it can more accurately free run in the event that the reference signal is absent for a period of time.

- **Epoch**: A reference time or event. Epoch often refers to a one pulse per second event.

- **Event**: An event is defined here as a (rising or falling) transition of a digital signal which can be used to cause the current reference time to be captured and held thus providing an accurate time stamp of the event.

- **Flywheel**: To maintain time or frequency accuracy when a time or frequency reference has been lost or removed.

- **Jam-sync**: Is the process of *abruptly* synchronizing with a time reference, as opposed to gradually steering the on-card time to eventually match up with the time reference.

- **Major Time**: Units of time larger than or equal to seconds.

- **Minor Time**: Sub-second time to whatever resolution is supported.

- **Packet**: A group of bytes conforming to a defined structure. Packets are usually used in bit serial or byte serial data transmissions to allow framing of the transmitted data. The bc637PCI-U uses data packets to communicate with the optional GPS receiver.

- **Periodic**: A programmable frequency that is obtained by dividing the TFP reference frequency. Periodics are sometimes referred to as "heartbeats." Periodics may optionally be synchronous with the 1 PPS epoch.

- **Strobe**: The strobe is a programmable "alarm." It compares the reference time with a user-programmed time, and outputs a signal when the two values are the same. The signal is indicated by a transition from low to high voltage. The duration of the signal is equal to the resolution of the strobe comparators (i.e., the reference time and the programmed time).

- **TFP**: Time and Frequency Processor is the name given to the bc635PCI-U family of products.

Performance Specifications

Input Time Code Translator

Formats	IRIG A, IRIG B, IEEE 1344[1] and NASA 36 (Modulated or DCLS)
Carrier Range	+/- 50 PPM
Time Accuracy[2]	<5 µsec. (modulated) <1 µsec. (DCLS)
Flywheel Accuracy	Typical Drift < 2 Milliseconds Per Hour (Applies To Operational Modes other than RTC)
Modulation Ratio	3:1 to 6:1
Input Amplitude	0.5 to 5 Vp-p
Input Impedance	10 kΩ, AC Coupled

1.   IEEE 1344 compliance – The translator processes the 27 control function bits of IRIG B time code as set forth in IEEE 1344. The 27 control function bits provided by the input IRIG B input time code are output in the generated IRIG B time code one time frame after received. If the input IEEE 1344 bits are not present in the IRIG B time code, the last two digits of the year are placed in bits 1-9 of the control function field of the generated IRIG B time code.

2.   May require a calibration to attain this accuracy. See "Time Code Calibration" on page 21.

Output Time Code Generator

Format	IRIG B and IEEE 1344
Modulation Ratio	3:1
Output Amplitude	>3 Vp-p (fixed) into 50Ω
DC Level Shift	TTL / CMOS Compatible

PCI Bus Characteristics

Specifications	Designed Per PCI Local Bus Specification, Revision 2.3
Size	Single-Width 6.875" x 4.2"
Interrupts[1]	Auto Configurable IRQ Level 2 – 15

Power (bc635PCI-U)	+5V @ 350 mA
	+12V @ 400 mA
	-12V@ 70 mA
Power (bc637PCI-U)	+5V @ 470 mA
	+12V @ 400 mA
	-12V@ 70 mA
Power (bc635PCI-U-OCXO)	+5V @ 350 mA
	+12V @ 400 mA, 625 mA Maximum at start up
	-12V@ 70 mA
Power (bc637PCI-U-OCXO)	+5V @ 470 mA
	+12V @ 400 mA, 625 mA Maximum at start up
	-12V@ 70 mA

1.   Interrupts not supported on Windows 98/98SE

Digital Inputs

Event Capture	TTL / CMOS Rising or Falling Edge Triggered
	20 Nanoseconds Min. Width 250 Nanoseconds Min. Period
External 1 PPS	TTL / CMOS Positive Edge On Time
	20 nanoseconds minimum width

Digital Outputs

1 PPS	TTL Rising Edge On Time 63μS Positive pulse
Periodic	TTL Rising Edge On Time, variable frequency and pulse width
Strobe	TTL 1μS Positive pulse variable delay
1, 5, 10 MHz clock	TTL (see Chapter 4 for signal characteristics)

External 10 MHz Input

| Digital Input (or) | TTL / CMOS 40% to 60% Duty Cycle |
| Sine wave Input | 2 to 4 Vp-p |

Environmental Specifications

Temperature	Operating	0 °C to +50 °C (32 °F to +122 °F)
	Non-Operating	-30 °C to +85 °C (-22 °F to +185 °F)
Relative Humidity	Operating/Non-Operating	To 95% RH @ +45 °C (+113 °F), non-condensing

Chapter 2: Installation

General

Installation of PCI boards is quite a bit simpler than in most bus architectures due to two factors:

- Geographical addressing, which eliminates the need for DIP switches and jumpers normally required to select a "base address" or interrupt level for plug-in modules.

- Auto configuration, which allows the host computer to read the device ID and other configuration information directly from the Configuration Registers.

The only thing the user has to do is pick a vacant PCI slot and plug the Symmetricom bc635/7PCI-U Time and Frequency Processor (TFP) into it and install the device driver. Be sure to consult the user documentation that came with your particular workstation for any specific PCI card installation instructions.

Configuration

The TFP is available with a variety of software suitable for use with either Microsoft Windows 98/ 98SE/NT 4.0/2000/XP Professional. The kit includes drivers for low-level access as well as software programs for configuring and accessing the card.

Installation Under Windows NT 4.0/2000/XP

With the PC turned off, insert the Symmetricom bc635/7PCI-U Time and Frequency Processor (TFP) in an open PCI slot.

Boot the PC.

Once running, Windows may prompt you to install newly found hardware. Disregard/cancel this dialog box.

Insert the CD labeled "Bus Level Products" in your CD and follow the automated installation procedure. If Auto-Run is disabled, manually install the driver by running **setup.exe**, located on the CD-ROM. The driver can support up to four bc635/637PCI-U devices. If multiple cards are to be installed, device 0 should be installed first.

After the computer reboots, Windows will prompt to install the newly found hardware. Let windows install the utility and driver software automatically. If multiple setup files are detected, select the **W2kPci.inf** file.

Launch the bc635PCI Demonstration Software (bc635cpp.exe) to begin communication with the card.

Installation Under Windows 98, 98SE

With the PC turned off, insert the Symmetricom bc635/7PCI-U Time and Frequency Processor (TFP) in an open PCI slot and boot the PC.

The Plug & Play architecture supported by Microsoft Windows 98 will allow your system to automatically recognize and configure the bc635/637PCI-U. When the Plug & Play BIOS detects the presence of a new device, it will prompt the user for a driver if one does not already exist. When prompted, insert the CD labeled "Bus Level Products" into your CD-ROM drive and select the device you wish to load. **The Windows 98/98SE driver can only support one device (Device 0) per system.**

> *Note:* *If you are only installing a single card, simply select the First Device (Device 0). Windows will Prompt you to restart your computer. Click "No" and proceed to the next step.*

Once the OS is up, open and close the CD-ROM drive to start Auto-Run. Follow the installation procedure to install the driver. If Auto-Run is disabled, manually install the driver by running **setup.exe**, located on the CD-ROM.

Launch the bc635PCI Demonstration Software (bc635cpp.exe) to begin communication with the card.

Installation Under Other Operating Systems

Usage of the bc635/637PCI-U under other operating systems may require the customer to develop a PCI driver for the device. Symmetricom offers drivers for several versions of Linux, Solaris, VxWorks, and a generic UNIX driver. Please contact Symmetricom for the availability of a driver for a particular operating system. With the wide variety of machines and operating systems that support the PCI bus, it is not possible for Symmetricom to develop drivers for use in all of these environments. While the interface to the device is well defined in this manual, the instructions for enabling and accessing the device are beyond the scope of this manual. Refer to your system documentation for further details.

Note: *Contact factory for instructions when installing bc635/637PCI-U in a DEC Alpha machine.*

Chapter 3: Software Programs

General

A Configuration and Demo Program (BC635CPP.EXE), and a System Clock Utility (TRAY TIMECPP.EXE) are included with the bc635/637PCI-U module.

The System Clock Utility (described later in this chapter) is a system tray utility that queries the bc635PCI-U and periodically sets the PCI bus computer's system clock at a user-defined interval.

The BC635CPP.EXE program allows the user to access the bc635/637PCI-U card. This program is designed to operate under Microsoft Windows 98/NT 4.0/2000/XP. This utility can be used to query current settings, modify settings and retrieve or monitor data generated by the card. This program requires the runtime driver to be available in order to operate. The background window of the program provides current UTC time as well as information regarding the clock status, interrupt bit status, and clock reference source type. A full menu system (described in the following paragraphs) has been designed to provide access to the card. Each associated pull-down menu provides a logical grouping of commands. Most of the pull-down menus also include a Summary button that provides a review of the current settings associated with the logical group.

FILE Menu

This group provides a few common functions associated with Windows applications. However, the commands have been redefined to operate on the bc635/637PCI-U instead of files.

OPEN Device

The Open Device command allows the user open and operate up to three other installed bc635/637PCI-U devices. By default, the program opens and operates using the first device in the system (Device 0). By selecting a new device to Open, the program will close the currently selected device before opening the newly requested device. This command will also clear the interrupt mask.

INTERRUPT START

This command allows the user to start an interrupt service routine capable of handling the selected hardware interrupts used by the bc635/637PCI-U module. After starting the interrupt service routine, the user can initiate any interrupt source located under "Signals | Interrupts".

Note: Interrupts not supported on Windows 98/98SE

EXIT

This command allows the user to close the device and exit the program. This command will clear the interrupt mask.

TIME Menu

This group provides access to functions that control how the bc635/637PCI-U card maintains time data. These functions allow the user to select where to obtain time data, whether or not to manipulate the time data and how to present the time data to the user.

SET MODE

This menu selection can be used to change the operating mode of a card. Selecting this option reveals a secondary menu listing the available operating modes of the bc635/637PCI-U device. The available modes are Time Code, Free Running, External 1 PPS, RTC, and GPS. Note that bc635PCI-U cards do not support GPS mode.

GET BINARY TIME

This command exercises the time capture and time registers of the device. It makes 25 time requests, retrieves the 25 consecutive timestamps as fast as the system allows, and displays them in a box inside the program. This function is designed to display binary data. As the background window is constantly displaying time, this command is not typically used during normal operations. The device only provides binary time format.

GET EVENT TIME

This function exercises the event capture and event registers of the device. It makes 25 event requests, retrieves the 25 consecutive timestamps from the event registers as fast as the system allows, and displays them in a box inside the program. This function is designed to display binary data. The bc635/637PCI-U device should be set to use the binary time format when executing this function. The Demo program only supports the Event Time function in binary format. If the device is in decimal mode, the major time (in front of the decimal point) will be garbled but the minor time will still display correctly.

SET TIME

This function allows the user to set the time on the bc635/637PCI-U device. A box is displayed on the screen that contains the current time from years through seconds in a decimal format. The user

may change any or all of these values and select the OK button. This command will load the time properly regardless of the currently selected time format. This function is typically used when operating in either the Free Running or External 1 PPS modes. While the function may be used when operating in Time code or GPS modes, subsequent time data received from the selected reference source will overwrite the loaded time.

SET YEAR

This function allows the user to set the year data without affecting the other time data. Typically, this command is used when the board is operating in time code decoding mode. Many time code formats (including standard IRIG B) do not include year information in the data. Using this function will allow the bc635/637PCI-U device to extract the time of year data from the time code source while using year information provided by the user. The supported range is 1990 – 2037 (as shown in the demonstration program dialog box).

Caution: Setting the year value outside this range can cause unexpected results.

SET LOCAL OFFSET

This function allows the user to program a local offset into the bc635/637PCI-U device. If the local offset value is nonzero, the device will adjust any reference timing information in order to maintain a local time in bc635/637PCI-U clock. Use of this function only affects the time data in the TIME registers described in Chapter 5. Allowed values are –16 through +16, and can include half hour offsets.

SET PROPAGATION DELAY

This function allows the user to command the bc635/637PCI-U device to compensate for propagation delays introduced by the currently selected reference source. For example, when the unit is operating in Time code decoding mode, a long cable run could result in the input time code having a propagation delay. The delay value is programmable in units of 100ns and has an allowed range from –9999999 through +9999999.

SET LEAP EVENT

This function allows the user to program a future leap second event. The user must specify the Leap Event Time as the number of seconds elapsed since 0 hour Jan 1, 1970 UTC. Leap second insertion and deletion are allowed.

TIME SETTINGS

This function allows the user to modify other timing operations. The UTC Corrections may be enabled or disabled. Enabling UTC Corrections commands the device to include any leap second corrections provided by the reference source and act on any leap event data that is present. The default operation is to use UTC corrections. This function is also used to enable or disable the following options: IEEE Daylight Savings, Local Time Offset and Year Auto Increment. The board time format (Binary or Decimal) is also selected using this function.

TIME CURRENT SETTINGS

This function provides a summary of all the time data. In addition to the programmable values, the values of some of the device timing data are also presented as information points. These values include UTC Control, leap second count, leap second event data and leap second event time. All values are accessed via the "UTC Data" button.

TIME CODE Menu

This function group provides access to functions controlling bc635/637PCI-U card operation while decoding time code. These functions allow the user to control both the time code decoding and time code generating circuits of the device.

DECODE

This function allows the user to select the format and modulation types associated with an input timing signal. These values control how the device attempts to decode the input time code. These values may be set regardless of the mode but will only be used in time code decoding mode. The format defines the type of the time code data. The modulation defines the envelope for the signal and which input pin the signal will be extracted from. The default format is IRIG B and the default modulation envelope is AM (Amplitude Modulated). The boards also support IRIG A, IEEE 1344 and NASA36.

GENERATOR

This function allows the user to select the format of the time code that will be generated by the bc635/637PCI-U device. The time code generator supports IRIG B and IEEE 1344. See section 1.3 for detailed performance specifications.

GENERATOR OFFSET

The function allows the user to add an offset to the time code signal being produced by the bc635/637PCI-U device, and only affects the unit time code generation. This functionality is useful for driving time code display units so local time appears on them. Allowed values are –16 through +16, and can include half hour offsets.

Note: *IEEE 1344 is not affected by the generator offset value, since local time offset bits are defined by the specification.*

TIME CODE CURRENT SETTINGS

This function provides a summary of all the time code data. In addition to the programmable values, other values may be presented as information points.

SIGNALS Menu

This group provides access to functions that control various hardware timing signals either decoded or generated by the bc635/637PCI-U card.

HEARTBEAT

This function allows the user to command the bc635/637PCI-U to produce a clock signal at a specified frequency, with a specified duty cycle. The heartbeat signal, also referred to as a periodic pulse output (PPO), can be either synchronous or asynchronous to the internal 1 PPS epoch in the bc635/637PCI-U device. This functionality is implemented in hardware on the bc635/637PCI-U device by emulating an Intel 82C54 counter timer chip. The heartbeat circuit has two 16 bit divisors which are clocked by the internal counter of the bc635/637PCI. As the output of the first divisor provides the clock for the second divisor, manipulating the divisor values results in various duty cycles. The output of this circuitry is capable of creating a PCI bus interrupt. See Chapter 4 for a description of how to program the heartbeat output.

STROBE

This function allows the user to command the bc635/637PCI-U to produce a hardware signal at a particular time, or at a particular point during a 1 second interval. When major/minor mode is selected, a hardware signal will be produced when the internal time of the bc635/637PCI-U device matches the values entered for the major and minor strobe registers. Up to 22 bits of binary major time may be supplied in addition to the microseconds loaded in the minor strobe register. This allows strobe signals to be programmed up to 48 days in advance. This function is designed to operate with the timing format in binary mode. When minor mode is selected, a strobe signal is produced every second when the internal microsecond count in the bc635/637PCI-U device matches the value

entered in the minor strobe register. The input of the strobe register values may be done in either Binary of Decimal Time format. The output of this circuitry is capable of creating a PCI bus interrupt.

EVENTS

This function allows the user to command the bc635/637PCI-U device to monitor a hardware timing signal. The source for the signal can be either the External Event input on the device or the output of the Heartbeat (Periodic) mentioned earlier in this chapter. The External Event signal capture may be set to occur on either the rising or falling edge. The Heartbeat signal capture is always on the rising edge. When a signal occurs in the selected format, the time at which the signal occurred is loaded into the event time registers. The capture lockout checkbox can be used to control whether or not subsequent signals will overwrite the data in the event time registers. The output of this circuitry is capable of creating a PCI bus interrupt.

Note: *Though the hardware can capture events at up to a 250 kHz rate, the rate at which the event times can be extracted by software can be slower and is dependent on the operating system and on the speed of the host computer.*

FREQUENCY

This function allows the user to control the frequency signal output by the bc635/637PCI-U device. The available frequencies are 1, 5 and 10 MHz. The default state of this output is 10 MHz.

Note: *This feature is not supported with the OCXO option. The OCXO always outputs a 10 MHz sine wave.*

INTERRUPTS

This function allows the user to control the generation of PCI bus interrupts by the bc635/637PCI-U device. This program is capable of capturing PCI bus interrupts generated by the device. The detection of an interrupt will be displayed in the background of the main window. Five "LEDs" are displayed in the upper right corner of the window background. When an interrupt occurs, the program queries the interrupt source and the associated LED is displayed in red. In order to display consecutive interrupts, the LEDs are changed back to green once per second. This may result in LEDs only remaining red for a short period of time. If the latch event time box is checked, the program will latch the time in the event time registers when an interrupt is detected. The user may query the event time registers to see when a particular event occurred. The default state of the interrupt is OFF.

Note: *The latch event time box should not be checked when external events are selected as these already latch the time in the event registers.*

SIGNAL CURRENT SETTINGS

This function provides a summary of all the signal data. In addition to the programmable values, other values may be presented as information points.

HARDWARE Menu

When the Advanced menu is selected (see paragraph 3.6.4), this group provides additional access to functions that control the oscillator and its associated disciplining circuits. These functions modify the actual oscillator control function used to slave the internal oscillator to the selected reference signal. This function is not modified during standard operation.

SET OSC PARAMETERS

This group allows the user to select an external oscillator or the on board oscillator, in addition to enabling/disabling disciplining and jam-syncing.

HARDWARE CURRENT SETTINGS

This function provides a summary of all the oscillator data. In addition to the programmable values, other values may be presented as information points.

SPECIAL Menu

This group provides access to those functions which do not fit in any particular category. Most of these functions are not used during normal operation.

REGISTERS

This function allows the user to perform direct reads and writes to the bc635/637PCI-U device registers. While most of the functionality available through the registers can be controlled via other aspects of the demo/config program, this function may be useful for debugging purposes.

BOARD RESET

This function allows the user to reset the bc635/637PCI-U device. This command is useful when starting a test or in the case that unexpected behavior is observed from the card. This function is not used during normal operation.

Note: This command resets all DPRAM packet options, but does not reset any of the registers. After RESET, the registers retain their previous values. (See Command 0x1A).

AUTOTIME

This functions allows the user to control the data display in the background of the main program window. If this function is turned off, the display will stop updating, but will continue to show the reference source type.

MENU

This command allows the user to switch to an advanced version of the menu. If the advanced menu is selected, more options appear in and on the menu bar at the top of the program. Note that the advanced menu contains operations which may disable the function of the bc635/637PCI-U device and should only be used by customers familiar and comfortable with controlling the device at this level. It may also be used in response to requests during technical support sessions. This function is not necessary for normal operations. The additional functions revealed in the advanced menu are intended for Product Support use and are not described in this document.

SPECIAL CURRENT SETTINGS

This function provides information related to the PCI interface to the board. This command is useful for determining whether or not the driver has obtained access to the device. It may also be used to review the PCI mapping of the device onto the bus. The interrupt level selected during PCI configuration may also be reviewed.

System Clock Utility (Tray timecpp.exe)

This utility is designed to operate under Microsoft Windows 98/NT 4.0/2000/XP. This system tray utility will query the bc635PCI-U and set the system clock on a periodic basis.

Double click on the **"Tray TimeCPP.exe"** to install. Tray TimeCPP.exe is copied to the same folder as the other demonstration software.

A small world icon will show up on the lower right portion of the desktop (where the clock appears), click on that icon and it will display a window (Tray TimeCPP).

Click **Setup**

Under Selected Source on the Status tab, click on **Hardware** if it has not been selected as the source for time.

If the Current Status is: *"Waiting for the board to acquire time"* then the time on the host computer has not synchronized to the bc635PCI-U time yet. If the status is: *"Set Clock OK"* or "*Captured Board Time*," then the synchronizing process is taking effect.

Change the Update Interval to the desired value and press OK.

To allow the program to continue running in the background and synchronize the System Time, minimize the window or click OK. Pressing "Quit" will terminate the program.

Drag the program into your startup group to have it run automatically at boot time.

Chapter 4: Functional Description

General

This chapter provides a description of the bc635/637PCI-U Time and Frequency Processor (TFP) timing functions. This chapter should be read by everyone using the TFP. Several terms used in this chapter are defined in Chapter 1.

Timing Modes

The primary function of the TFP is to provide precise time to the user across the PCI bus. The TFP can derive time from any one of the sources listed in Chapter 1. In all but the Free Running mode of operation, the TFP synchronizes its on board 10 MHz oscillator to the timing source. The TFP achieves synchronization by extracting a 1 PPS (One Pulse Per Second) signal from the timing source and using this 1 PPS signal to discipline the oscillator such that the locally generated 1 PPS signal is matched in phase and frequency to the reference 1 PPS. Once synchronization is achieved, the TFP is able to maintain time even if the timing source is lost (though some timing drift will occur). This is referred to as *flywheeling*. The TFP must also obtain major time (days, hours, minutes, seconds) from the timing source if it's available. In Time Code Mode and the GPS mode this major time is readily available, but in the Free Running and External 1 PPS Modes, major time is not available and must be set manually by the user.

Mode 0 (Time Code Mode)

In Time Code Mode, the TFP derives time from the currently selected input time code. The TFP will accept time code in either a modulated or DCLS (DC Level Shift) form. Modulated time code is a sinusoidal analog signal that is amplitude modulated with the time data. DCLS is simply the envelope of the modulated time code and is a digital signal. All supported time codes provide both major time (days, hours, minutes, seconds) and minor time (subseconds) to the card, but only IEEE1344 provides the year information. For IRIG A, IRIG B, and NASA 36, the year is set by the RTC, but can be updated manually if needed.

Mode 1 (Free Running Mode)

In Free Running Mode, no external timing source is used. The TFP oscillator is allowed to free-run. The user must set major time manually. This mode allows the user to perform timing tests when an external timing source is unavailable.

Mode 2 (External 1 PPS Mode)

In External 1 PPS Mode, the TFP synchronizes its oscillator to a user supplied 1 PPS signal. The user must set major time manually.

Mode 3 (RTC)

In the Real Time Clock mode, the TFP synchronizes its oscillator to the 1 PPS signal from the on board real time clock circuit.

Mode 6 (GPS [bc637PCI-U only])

In GPS Mode, like Time Code Mode, both major and minor time are derived from the timing source. In addition to time, other information is available from the GPS system such as accurate position and velocity. This mode requires the use of a GPS antenna mounted with an unobstructed view to the sky. An unobstructed view to the sky is important because the GPS receiver must acquire and track at least four satellites initially to obtain accurate time. If, however, the user's position is accurately known, or has been previously determined by the GPS system, it can be sent to the GPS system and allow it to derive precise time from just one satellite.

More information on GPS is available in Appendix B.

Time Capture

The TFP supports two independent sets of time capture registers. Each set consists of two 32-bit wide registers that hold both the major and minor time. One set of registers, labeled TIME0 and TIME1, support time on demand across the PCI bus. Time is captured in these registers whenever the user accesses a special time request register (TIMEREQ). The captured time is held until a subsequent access of the TIMEREQ register. Valid time can be read from the TIMEx registers immediately following the access of the TIMEREQ register. Chapter 5 describes the available time formats used on the TFP.

The second set of time capture registers, labeled EVENT0 & EVENT1, are identical in format to the TIMEx registers. Time is captured in these registers whenever the user accesses the special time request register labeled EVENTREQ. Additionally, the EVENTx registers can be set up to capture time in response to either the Event Input (see below) or the Programmable Periodic Output (see next section).

Event Time Capture

The EVENTx registers can be configured to support event time capture. Four bits of the CONTROL register (see Chapter 5) are used to configure the event time capture function. An externally applied

digital signal (Event Input) can cause time to be captured in the same way as an access of the EVENTREQ register. The user can configure the EVENTx time capture to occur on a rising or falling edge of the Event Input signal, on the rising edge of the Programmable Periodic Output, or can be disabled. Note that EVENTREQ register accesses will continue to capture time even if event time capture is disabled. The EVENTx time capture function can also be set up in a capture lockout mode, where only the first Event Input or Periodic signal will store the event time.

Programmable Periodic Output (PPO)

The Programmable Periodic Output (PPO) or heartbeat allows the user to configure a redundant digital output synchronous with the timing source. The PPO can optionally be synchronized to the TFP 1 PPS signal, when the Periodic Output frequency is an integer value, otherwise, the 1 PPS signal will cut short the last Periodic Output cycle before the 1 PPS edge. For some low frequencies, this could mean the last and first cycles converge.

This signal is generated by dividing down a 1 MHz clock, synchronous to the on-board 10 MHz oscillator. The periodic output frequency can range from 250 kHz ($n_1 = n_2 = 2$) to less than 1Hz, and is determined by the relationship:

Frequency = $1,000,000 / (n_1 * n_2)$ Hz *Where $2 \leq n_1, n_2 \leq 65535$*

Duty Cycle = $(1 - (1 / n_2)) * 100\%$

Where:

- n_1 : Counter divider number 1

- n_2 : Counter divider number 2

- Duty Cycle:Percentage of High Pulse width to signal period

Setting the periodic output frequency to less than 1 Hz while in the synchronization mode will cause the periodic output to be held at a logic high level. In Synchronous mode, the falling edge of the heartbeat pulse after the on-time mark, is 1 μS late. All following edges are delayed by the same amount of time. For integer frequencies, the last pulse is shortened by 1 μS, and the output frequency is discontinuous by 1 μS at the PPS rising edge.

Time Coincidence Strobe Output

The TFP provides one Time Coincidence Strobe Output signal. The Strobe output is like an alarm that is activated at some preprogrammed time. The programmed strobe time is held in the STROBE1 - STROBE4 registers. The Strobe time can be set from hours through microseconds. The duration of the Strobe pulse is one microsecond. The rising edge of the Strobe occurs one microsecond after the programmed time. Two modes of operation are supported. In one mode (STRMODE=0), both the major and minor time are used to generate the Strobe. In the other mode (STRMODE=1), only the

minor time is used to generate the Strobe output that produces an output pulse once each second.

PCI Interrupts

The TFP supports the five sources of interrupts listed in Table 4-1. Each interrupt source can be individually masked off. Use the MASK register to mask on or off each interrupt source. Each interrupt source sets a bit in the INTSTAT register when it occurs. The TFP generates interrupts at an auto configured PCI IntReq level (LEVEL register.) When servicing a TFP interrupt, the user must read the INTSTAT register in order to determine the interrupt source(s) requesting service.

Table 4-1: TFP Interrupt Sources

Int	Source of Interrupt
0	Signal transition on Event Input has occurred (edge selected by EVSENSE)
1	PPO rising edge has occurred
2	Time Coincident Strobe output rising edge has occurred
3	One second epoch (1 PPS output) rising edge has occurred
4	GPS data packet is available (bc637PCI-U only)

Timing Outputs

In addition to the Programmable Periodic Output and Time Coincidence Strobe, the TFP provides other useful timing outputs that are synchronized to the timing source. The 1 PPS output is an approximately 63 µsec wide pulse with the rising edge occurring at each 1 second epoch. An IRIG B or IEEE 1344 time code output signal is available in both modulated and DCLS (DC Level Shift) forms. An output frequency of 1 MHz, 5 MHz, or 10 MHz TTL signal is provided from the standard 10 MHz VCXO. A 10 MHz sinusoidal output is available with the optional OCXO.

Time Code Calibration

This is a calibration procedure for the time code input accuracy of the Bc635/637PCI-U Time and Frequency Processor products. Modulation ratio, carrier frequency, impedance loading, and other effects can degrade time code performance accuracy. Some applications require very high synchronization accuracy while using a time code as a reference. The following calibration procedure helps assure the best time code synchronization accuracy. Because of the inherent differences in the types of input time code, a different calibration factor exists for each type of time code. The user should determine which time code to use in their system, and then perform the calibration for that code. The user can consult Symmetricom if unsure of which code type is best for their application.

Calibration Procedure

The following procedure uses the bc635cpp.exe program to perform all adjustments. This procedure will synchronize the On-Time mark of an incoming time code reference with the rising edge of an incoming 1 PPS signal. (The accuracy of this calibration is limited by the synchronization of the incoming 1 PPS and the on-time mark of the incoming time code).

Connect the Time code reference to the Time code Input on J1 of the bc635/637PCI-U card (pin 7 for AM or pin 10 for DCLS).

Select the Format and Modulation type for the reference Time code (using the Bc635cpp.exe pull down menu "Time code | Decode").

Connect the 1 PPS reference to the External Event Input on J1 of the bc635/637PCI-U card (pin 6).

Enable the External Event Input on the Rising Edge (using the Bc635cpp.exe pull down menu "Signals | Events", and select External Input and Rising Edge).

Force the card to Jam-Sync to the incoming time code (using the Bc635cpp.exe pull down menu "Special | Menu | Advanced", and then "Hardware | Force Jam-Sync" and click YES at the confirmation prompt).

Immediately read the minor event time (using the Bc635cpp.exe pull down menu "Time | Get Event Time").

Repeat the previous two steps until a consistent value is achieved. You may have to average two neighboring values (e.g., the average of X.000012 and X.000013 is X.0000125).

Convert the minor event time to a calibration factor. If the minor event time is close to rolling over (i.e., X.999950), subtract 1 from the minor event time to get the calibration factor in microseconds (e.g., –50us or 50E-6 sec); otherwise the minor event time is the calibration factor (e.g., X.000012 = 12us or 12E-6 sec).

Convert the units of the calibration factor measured in the previous step from microseconds to hundreds of nanoseconds by multiplying it by 10 (12us = 120 hundreds of ns). X hundreds of nanoseconds is equivalent to XE-7sec.

Set the Propagation delay on the card to the calibration factor in units of hundreds of nanoseconds as calculated in the previous step (using the Bc635cpp.exe pull down menu "Time | Set Prop Delay").

Force the card to Jam Sync to the incoming time code with the propagation delay inserted (using the Bc635cpp.exe pull down menu "Special | Menu | Advanced", and then "Hardware | Force Jam-Sync" and click YES at the confirmation prompt).

Allow the card to phase lock, frequency lock and stabilize (~15min) to the input Time code with the calibration factor inserted as a propagation delay.

Read the minor event time (using the Bc635cpp.exe pull down menu "Time | Get Event Time").

If the minor event time is greater than +/- 1us, adjust the old calibration factor by the amount of residual offset to create a new calibration factor, which should be inserted as a propagation delay as before.

Note this calibration factor and the associated time code type (i.e., IRIG B AM CAL = +120E-7) in a safe place. If another time code type is to be used as a reference, a new calibration factor must be determined for that code. If the user needs to use the propagation delay feature for the outgoing time code, the calibration factor must be added to the desired propagation delay to keep the time code accurate.

Note: If the card is ever reset, the propagation delay (and/or calibration factor) value is lost and thus must be reprogrammed.

Code Type: _____ Modulation: AM / DCCalibration Factor: _____E-7 sec.

Chapter 5: Device Registers

General

The bc635PCI-U Time & Frequency Processor (TFP) is controlled by a combination of hardware device registers and a dual-port RAM interface. This chapter describes the TFP device registers, and Chapter 6 describes the dual-port RAM interface.

The following TFP functional block diagram provides context for the subsequent description.

Time and Frequency Processor
PCI Architecture Block Diagram
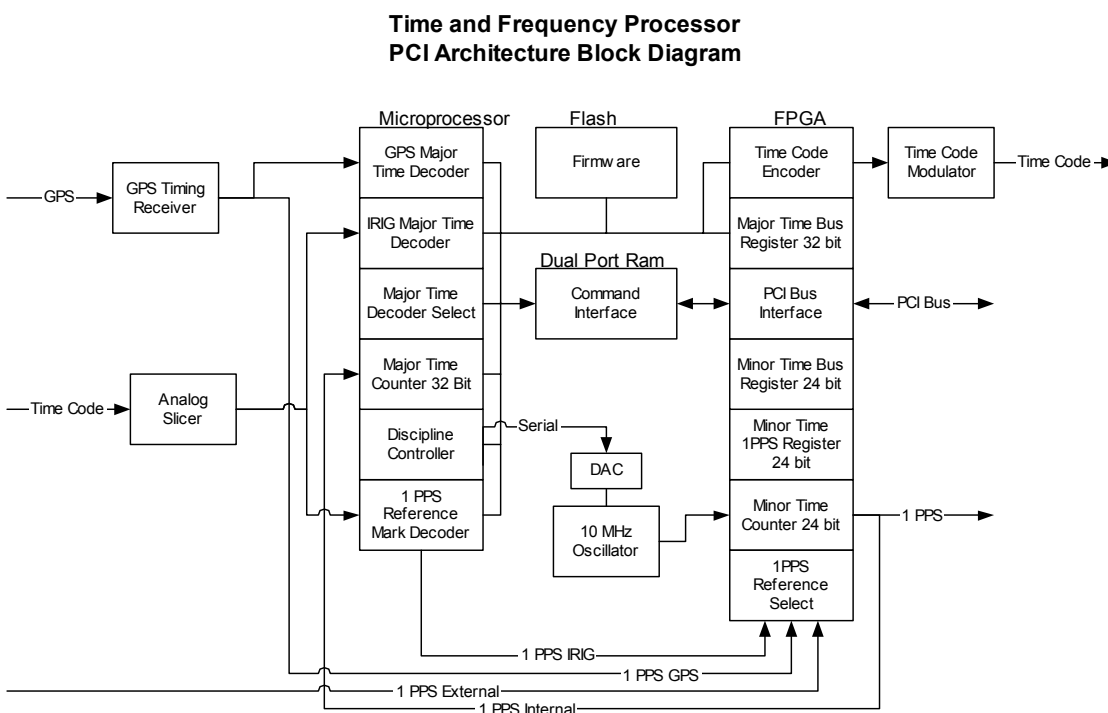
PCI Register Fields

The TFP is divided into three register fields: the Boot PROM field, the dual-port RAM field, and the device register field. The Boot PROM begins at address zero within the card's physical address space. The starting address and length of the two remaining spaces *should* be obtained from the 'reg' attribute in the Boot PROM since these attributes could conceivably change, (unlikely). The dual-port RAM field is listed first in the Boot PROM 'reg' attribute followed by the device register field. Table 5-1 lists the card's physical memory map for those users that don't have access to the Boot PROM information.

Note: The dual-port RAM is mapped in such a way that it contains the Boot PROM information and is also used for local RAM for the TFP micro-controller. Be sure to access the dual-port RAM

as described in Chapter 6. Do not access other areas within the dual-port RAM address space.

Table 5-1: TFP Physical Memory Map

Start	Type	Size	Register Field
0x0000	Read Only	Varies	Boot PROM
PCI Auto	R/W	0x1000	Dual-Port RAM
PCI Auto	R/W	0x40	Device Registers

Device Register Description

The TFP device registers are 32-bits wide (PCI word size). For many of the registers, only a few of the bits have any significance while the rest of the bits are ignored during writes and are meaningless during reads. Registers may be read only (R), write only (W), read/write (R/W), or access (A). Access type registers perform a function simply by being read or written without regard to the data contents. It's best to use a write operation with the access type registers because most optimizing compilers will remove statements that read a register but do nothing with the data returned. In some cases a read/write register is structured to support dissimilar data in the read and write directions. Table 5-2 summarizes the type of register located at each offset and provides a brief description of the register function. The offset of each register is relative to the start of the device register field starting address found in BAR0.

Table 5-2: TFP Device Register Summary

Offset	Type	Reset	Label	Description
0x00	A	See Note	TIMEREQ	Time Request (TIME0-1)
0x04	A	See Note	EVENTREQ	Event Request (EVENT0-1)
0x08	A	See Note	UNLOCK	Release Capture Lockout
0x0C	Reserved			
0x10	R/W	0	CONTROL	Control Register
0x14	R/W	See Note	ACK	Acknowledge Register
0x18	R/W	0	MASK	Interrupt Mask
0x1C	R/W	0	INTSTAT	Interrupt Status
0x20	W	See Note	MINSTRB	Minor Strobe Time
0x24	W	See Note	MAJSTRB	Major Strobe Time
0x28	Reserved			
0x2C	Reserved			
0x30	R	See Note	TIME0	Minor Time Holding Register
0x34	R	See Note	TIME1	Major Time Holding Register
0x38	R	See Note	EVENT0	Minor Event Holding Register
0x3C	R	See Note	EVENT1	Major Event Holding Register

Note: Register contents are undefined at reset.

TIMEREQ

Accessing this register (with a read or write operation) latches the current time and timing status in the TIME0 – TIME1 registers. The data value transferred is meaningless.

EVENTREQ

Accessing this register (with a read or write operation) latches the current time and timing status in the EVENT0 – EVENT1 registers. The data value transferred is meaningless. Accessing the EVENTREQ register does not generate an Event Input interrupt.

UNLOCK

Accessing this register (with a read or write operation) releases the EVENTx time capture lockout

function if it has been enabled, allowing the Event Input or Periodic Output to capture a new time.

CONTROL

This register controls a variety of TFP hardware functions. Table 5-3 lists the function of each bit in this register.

Table 5-3: CONTROL Register

Bit	Name	Function
0	LOCKEN	EVENTx Capture Lockout Enable 0 = Disable Lockout 1 = Enable Lockout
1	EVSOURCE	EVENTx Time Capture Register Source Select 0 = Event Input (Select Active Edge With EVSENSE) 1 = Programmable Periodic (Rising Edge Active Only)
2	Reserved	
3	EVENTEN	Event Capture Register Enable 0 = Disable 1 = Enable (Use EVSOURCE to Select Event Source)
4	STREN	Time Coincidence Strobe Output Enable 0 = Disable (Strobe Output is Held Low) 1 = Enable
5	STRMODE	Time Coincidence Strobe Mode 0 = Use Major and Minor Time for Strobe Function 1 = Use Minor Time Only for Strobe Function IN STRMODE = 1, an Output Strobe is Produced Each Second
6	FREQSEL0	Output Frequency Select 00 = 10MHz 01 = 5MHz 1X = 1MHz
7	FREQSEL1	Output Frequency Select 00 = 10MHz 01 = 5MHz 1X = 1MHz
8 - 31	Reserved	

Note: Register contents are undefined at reset.

The EVSOURCE bit selects one of two signal sources for capturing time in the EVENTx registers; either the Event Input signal from the Signal I/O connector or the Programmable Periodic Output. The EVSOURCE bit does not affect the Event Interrupt, as the Event Input signal is the only source for the Event Interrupt. This allows the Event Input to generate a PCI interrupt (without time capture) when the board is configured to use the Programmable Periodic Output (PPO) for EVENTx time capture (see Chapter 4).

The EVENTEN bit is used to enable signal capture of time into the EVENTx registers. This bit controls the PPO and Event Input for event time capture.

Enabling the Lockout function via the LOCKEN bit allows only the first instance of the selected signal source to latch time in the EVENTx registers. Use the UNLOCK register to re-arm the circuit.

Note that accessing the EVENTREQ register will continue to capture time in the EVENTx registers regardless of the value of LOCKEN.

ACK

The ACK register is used to prevent dual-port RAM data contention when the same address on both sides of a dual-port RAM are accessed simultaneously. See Chapter 6 for more information on the format and use of this register.

MASK

Bits 0-4 in the MASK register correspond to interrupt sources zero through four listed in Table 5-4. An interrupt source is enabled (to generate an PCI interrupt) by writing a value of one to the corresponding MASK bit. Writing a zero to the interrupt MASK bit disables that interrupt.

INTSTAT

The INTSTAT register has the same structure as the MASK register listed in Table 5-4. Each interrupt source sets its corresponding bit in this register when activated. The INTSTAT register bits get set regardless of the state of the MASK bits allowing the user to poll for the occurrence of the interrupt source(s). INTSTAT bits are cleared by writing to the INTSTAT register with the corresponding bit(s) set. For example, to clear INTSTAT bit zero, write 0x01 to the INTSTAT register. To clear all INTSTAT bits simultaneously, write 0x1F to the INTSTAT register. A PCI interrupt is generated anytime one or more INTSTAT bits are set *and* the corresponding bit(s) are set in the MASK register.

Table 5-4: INTSTAT Register

Bit	Function
0	Event Input Has Occurred
1	A Periodic Output Has Occurred
2	The Time Coincidence Strobe Has Occurred
3	A One Second Epoch (1 PPS Output) Has Occurred
4	A GPS Data Packet is Available (bc637PCI-U only)
5	Reserved
6	Reserved
7	Reserved
8-31	Reserved

Note: Register contents are undefined at reset.

MINSTRB - MAJSTRB

These registers hold the programmed Time Coincidence Strobe time. The contents of these registers depend on the time format selected. The Strobe time is programmable from hours through microseconds in the decimal time format. When the time format is set to binary, only the 22 least significant bits of the major time are used (in addition to microseconds), this allows the user to program the Strobe to become activated up to 48 days beyond the current time.

Note: Disable the Strobe output (see CONTROL register) while programming the Strobe time to prevent spurious Strobe output pulses.

TIME0 – TIME1

These registers hold time captured by an access of the TIMEREQ register. The contents of these registers depend on the time format selected.

EVENT0 – EVENT1

These registers hold time captured when the EVENTREQ register is accessed by an Event Input (if enabled), or a PPO is generated (if enabled). The contents of these registers depend on the time format selected.

TIME FORMAT

The TFP major time registers (TIME0, EVENT0, MAJSTRB) support binary time (Table 5-5 and decimal time (Table 5-6) formats. Sub-second time is always represented in binary format. The 32-bit binary format represents time as the number of seconds since midnight, January 1, 1970 UTC (Universal Time Coordinated,), which is the standard time format found on most UNIX systems. Note that the year field is stored in the dual-port RAM. The decimal time format is derived from the "struct-tm" format used on UNIX systems. The bottom numbers in each cell in tables 5-5 and 5-6 define the bit positions for each data field. All undefined bit positions in table 5-6 are N/A.

Table 5-5: TFP Binary Time Format

Register	Data Bits					
	31 - 28	27 - 24	23 - 20	19 - 16	15 - 8	7 - 0
TIME1 EVENT1	Major Time UNIX Seconds 31 - 0					
TIME0 EVENT0	N/A 31-28	Status 27 - 24	100ns 23 - 20	Binary μS 19 - 0		
MAJSTRB	N/A 31-22			Major Time UNIX Sec (22 bits LSB) 21 – 0		
MINSTRB	N/A 31-28	Status 27 - 24	N/A 23 - 20	Binary μS 19 - 0		

Table 5-6: TFP Decimal Time Format

Register	Data Bits					
	31 - 28	27 - 24	23 - 20	19 - 16	15 - 8	7 - 0
TIME1 EVENT1	Days (0–366) Bits 7-0 31-24		Hours (0 – 23) 20 - 16		Min(0–59) 12-8	Sec(0–59) 5-0
TIME0 EVENT0	Days Bit 8 28	Status 27 – 24	100ns 23 - 20	Binary μS 19 – 0		
MAJSTRB	N/A 31-24		Hours (0 – 23) 20-16		Min(0–59) 12-8	Sec(0–59) 5-0
MINSTRB	N/A 31-28	Status 27 - 24	N/A 23 - 20	Binary μS 19 - 0		

The format of the minor time registers (TIME0, EVENT0, MINSTRB) is always binary. 20 bits of binary microseconds (0 - 999,999) in the lower part of the registers with an additional four bit field of hundreds of nanoseconds (0 - 9) located in bits 20 - 23. Most UNIX time functions use microseconds, but the TFP maintains time to hundreds of nanoseconds.

STATUS BITS

The TFP Status bits found in the TIME0 and EVENT0 time registers are summarized in Table 5-7 and are described below. Bits 24, 25 and 26, in the PCI Windows demonstration program, are represented as LEDs labeled 'T', 'P' and 'F', respectively (0 = Green, 1 = Red).

Table 5-7: TIME0, EVENT0 Status Bits Summary

Bit	Description
24	Flywheeling 0: Locked To Selected Reference 1: Flywheeling (Not Locked)
25	Time Offset 0: < X Microseconds 1: > X Microseconds X = 5 (Mode 0) X = 2 (All Other Modes)
26	Frequency Offset 0: $<5 \times 10{-8}$ 1:$>5 \times 10{-8}$
27	Reserved

STATUS: Flywheeling (Bit 24)

When set, this bit indicates that the TFP is not tracking the reference time source, usually because the time source has been lost or has become unusable. While flywheeling, the TFP keeps time using its onboard oscillator. When a timing Mode change occurs, this bit is set until the TFP locks to the new timing source.

STATUS: Time Offset (Bit 25)

This bit indicates the synchronization accuracy of the TFP relative to the timing source. This bit is updated approximately once per second. When the TFP's oscillator is synchronized to less than 5 microseconds with time code mode as a reference and less than 2 microseconds in other modes, this bit is cleared.

STATUS: Frequency Offset (Bit 26)

This bit is an indication of the TFP on-board oscillator frequency offset relative to the timing source. This bit is updated approximately once per second and reflects the short-term stability of the TFP's oscillator.

Chapter 6: Dual-Port RAM Interface

General

The byte-wide dual-port RAM (DPRAM) interface provides a communications pathway between the user and the bc635PCI-U Time & Frequency Processor (TFP) micro-controller (MPU). The RAM size is 2Kx8. The ACK register is used in conjunction with the DPRAM to avoid data contention when a memory location is accessed simultaneously from both sides of the DPRAM. Four areas within the DPRAM are available to the user:

Input Area

This area is used for sending commands to the TFP to set the timing Mode, time code format, etc. This area is also used to send data packets to the optional bc637PCI-U GPS receiver.

Output Area

This area holds data that the user requests from the TFP.

GPS Packet Area

This area holds packets of data from the bc637PCI-U's GPS receiver such as position, velocity, GPS status, etc.

Year Area

This area holds the year number derived from the timing source (if available). The year value algorithm retains the current year throughout a power cycle.

Note: The DPRAM also holds the Boot PROM data and provides local RAM for the TFP MPU. Keep DPRAM accesses confined to the areas defined above, even reading other areas can cause DPRAM data contention.

The offset of each DPRAM area (relative to the DPRAM starting address) is stored at the top of the DPRAM as shown below, where "TOP" refers to the last DPRAM address. The offset values are subject to change as the TFP firmware is updated. Each offset is a two byte unsigned integer value.

Table 6-1: DPRAM Address and Contents

DPRAM Address	Contents
Top	Input Area Offset (LSB)
Top-1	Input Area Offset (MSB)
Top-2	Output Area Offset (LSB)
Top-3	Output Area Offset (MSB)
Top-4	GPS Packet Area Offset (LSB)
Top-5	GPS Packet Area Offset (MSB)
Top-6	Year Area Offset (LSB)
Top-7	Year Area Offset (MSB)

ACK Register

This register is used to prevent dual-port RAM data contention when the same address on both sides of a dual-port RAM is accessed simultaneously. Only three bits in this register are used, and each bit operates independently. The function of each bit in this register is described below.

ACK Bit 0

Set by the TFP to acknowledge the receipt of a user command from the DPRAM Input Area. The user can clear this bit by writing to the ACK register with bit 0 set, but cannot set this bit.

ACK Bit 2

Set by the TFP to indicate that a GPS packet is available in the DPRAM GPS Packet Area. The user can clear this bit by writing to the ACK register with bit two set, but cannot set this bit. The transition of this bit from zero to one activates interrupt source four.

ACK Bit 7

The user writes to the ACK register with bit seven set to cause the TFP to read a command from the DPRAM Input Area. This bit has no meaning when read.

TFP DPRAM Commands

This section describes the TFP commands available through the DPRAM Interface. Commands consist of a command ID byte followed by zero or more data bytes. The command ID byte is written to the first location in the DPRAM Input Area, followed by the command data byte(s). The following command data types are used. Command data is loaded into the DPRAM in the *Big-Endian* fashion; most significant byte first. Table 6-2 summarizes the DPRAM commands.

TABLE 6-2: DPRAM Commands

UINT8	Unsigned 8 Bit Integer (1 Byte)
INT8	Signed 8 Bit Integer (1 Byte)
UINT16	Unsigned 16-Bit Integer (2 Bytes)
INT16	Signed 16-Bit Integer (2 Bytes)
UINT32	Unsigned 32-Bit Integer (4 Bytes)
INT32	Signed 32-Bit Integer (4 Bytes)
FLOAT	ANSI / IEEE Std 754 Standard Floating-Point Format (4 Bytes)
DOUBLE	ANSI / IEEE Std 754 Standard Floating-Point Format (8 Bytes

The following steps should be followed when sending commands to the TFP.

Write the command ID and data bytes to the DPRAM starting at the first location in the Input Area.

Clear bit zero of the *ACK* register by writing 0x01 to the *ACK* register.

Inform the TFP that a command is waiting by writing 0x80 to the *ACK* register.

Wait for the TFP to set bit 0 of the *ACK* register. Do not begin writing another command to the Input Area until this bit becomes set.

Note: See the command summary on the following page. This summary is presented on one page for convenient viewing.

Table 6-3: DPRAM Command Summary

ID	Reset	Command
0x10	Note 1	Set TFP Timing Mode
0x11	0	Set Time Register Format
0x12	N/A	Set Major Time
0x13	0	Set Year
0x14	N/A	Set Periodic Output
0x15	0x42	Set Input Time Code Format (default: 'B')
0x16	0x4D	Set Input Time Code Modulation (default: 'M')
0x17	0	Set Propagation Delay Compensation
0x18	N/A	Request UTC Time Data (bc637 only)
0x19	N/A	Request TFP Data
0x1A	N/A	Software Reset
0x1B	0x42	Set Time Code Output Format (default: 'B')
0x1C	0	Set Generator Time Offset
0x1D	0	Set Local Time Offset
0x1E	0	Set Leap Second Event
0x20	0x49	Set Clock Source (default: 'I')
0x21	1	Control Jam-Sync
0x22	N/A	Force Jam-Sync
0x24	N/A	Load DAC
0x25	N/A	Set Disciplining Gain
0x30	N/A	Send Packet to GPS Receiver (bc637 only)
0x31	N/A	Request Packet from GPS Receiver (bc637 only)
0x32	N/A	Manual Request Packet from GPS Receiver (bc637 only)
0x33	0	Select GPS Time Format (bc637 only)
0x34	1	Set GPS Mode Flag (bc637 only)
0x40	1	Observe IEEE 1344 Local Time Flag
0x41	N/A	Request IEEE 1344 Daylight Saving and Local Time Flags
0x42	1	Year Auto Increment Flag
0x4F	N/A	Request PCI Firmware Part Number
0xF4	N/A	Request Assembly Part Number
0xF5	N/A	Request Hardware Fab Part Number
0xF6	N/A	Request TFP Model Identification
0xFE	N/A	Request TFP Serial Number (Request only)

Note:

- bc635PCI-U resets to Mode 0 (Time Code)
- bc637PCI-U resets to Mode 6 (GPS)

Command 0x10: Set TFP Timing Mode

This command selects the timing mode of the TFP. The default Timing Mode for the bc635PCI-U is time code Decoding Mode, for the bc637PCI-U is GPS Mode.

Byte	Type	Item	Value or Range
0	UINT8	ID	0x10
1	UINT8	Timing Mode	See Below

TFP Timing Mode:

- 0x00   Time Code Mode - IRIG A, IRIG B, IEEE 1344, NASA36 (bc635PCI-U default)
- 0x01   Free Running Mode - 10 MHz Selected Reference (Internal or External)
- 0x02   1 PPS Mode - External One Pulse Per Second
- 0x03   Real Time Clock Mode* - Battery backed on-board real time clock IC
- 0x06   GPS Mode (bc637PCI-U only) - GPS Antenna/Receiver (bc637PCI-U default)

Command 0x11: Set Time Register Format

This command allows the user to select the major time format. Available time formats are Binary Coded Decimal (BCD) and UNIX. The time format affects the TIMEx, and EVENTx registers and Command 0x12. See Tables 5-5 and 5-6 for the UNIX and BCD time register definitions, respectively.

Byte	Type	Item	Value or Range
0	UINT8	ID	0x11
1	UINT8	Data Format	See Below

Time Data Format:

- 0x00   BCD TIME FORMAT
- 0x01   UNIX TIME FORMAT (the default time data format)

Command 0x12: Set Major Time

This command allows the user to load the major time to the TFP Major Time Registers in binary (UNIX) or BCD format. The format is determined by Command 0x11 as referenced above. The default major time format is UNIX binary time. This command normally applies to the TFP while in time modes 1 or 2. The TFP derives its major time from the selected external timing reference signal in time modes 0 and 6, and from the RTC in mode 3. If the time mode 0, 3, or 6 is used, any major time written by this command will be overwritten when the selected source is providing a valid time to the TFP.

Byte	Type	Item	Value or Range
0	UINT8	ID	0x12

Case 1: UNIX Time Data Format = 0x01 (Command 0x11, format 0x01)*

Byte	Type	Item	Value or Range
1-4	UINT32	UNIX Time	0 to 0xffffffff

Case 2: BCD Time Data Format = 0x00 (Command 0x11, format 0x00)

Byte	Type	Item	Value or Range
0	UINT8	ID	0x12
1-2	UINT16	Year	1970 - 2050
3-4	UINT16	Days	0 to 0x16e (0 to 366)
5	UINT8	Hours	0 to 0x17 (0 to 23)
6	UINT8	Minutes	0 to 0x3b (0 to 59)
7	UINT8	Seconds	0 to 0x3b (0 to 59)

*default time data format

The time loaded by this command will not be readable until the one-second epoch following the load. There is a possibility the TFP will have incremented the time during the load. To prevent ambiguities in the time, the user must issue this command in advance of the 800-millisecond point within the one-second epoch, referencing the current epoch.

This command normally applies to the TFP modes 1 and 2. The TFP derives its major time from the timing reference signal in other modes. The format data of this command depends on the Command 0x11 time format selection.

Command 0x13: Set year

This command allows the user to set the year.

Byte	Type	Item	Value or Range
0	UINT8	ID	0x13
1	UINT16	Year	1970 - 2050

Command 0x14: Set Periodic Output

This command establishes the frequency of the TFP Programmable Periodic Output. Chapter 3 describes the relationship between the dividers n_1, n_2 and the Periodic Output frequency.

Byte	Type	Item	Value or Range
0	UINT8	ID	0x14
1	UINT8	Sync Flag	0 = Don't Sync To 1 PPS 1 = Sync To 1 PPS
2-3	UINT16	Divider n_1	2 - 65535
4-5	UINT16	Divider n_2	2 - 65535

Command 0x15: Set Input Time Code Format

This command selects the time code format for TFP Timing Mode "0" time code input. (See Command 0x10.) Use Command 0x16 to set the modulation type.

Byte	Type	Item	Value or Range
0	UINT8	ID	0x15
1	UINT8	format	See Below

Format Choices

- 0x41   IRIG A
- 0x42   IRIG B (the default time code input)
- 0x49   IEEE 1344 (1 kHz)
- 0x4E   NASA36

Command 0x16: Set Input Time Code Modulation Type

This command selects the time code modulation type format for TFP Timing Mode "0" time code input. (See Command 0x10.). Use Command 0x15 to select the time code format.

Byte	Type	Item	Value or Range
0	UINT8	ID	0x16
1	UINT8	modulation	See Below

Modulation Choices:

- 'M'   (0x4D) amplitude modulated sine wave
- 'D'   (0x44) pulse code modulation (DC level shift)

Command 0x17: Set Propagation Delay Compensation

It is sometimes desired to program an offset into the basic TFP time keeping functions relative to the reference input. For example, if the reference input is an IRIG B time code, there may be significant cable delay between the IRIG B generator and the TFP location. This command allows this time difference to be removed by inserting the known amount of offset between the IRIG B reference and TFP location. In the previous example, a positive offset should be used. The offset is programmable in units of 100 nanoseconds, and may be positive or negative.

Byte	Type	Item	Value or Range
0	UINT8	ID	0x17
1-4	INT32	offset	-9,999,999 to +9,999,999

Note: If offsets larger than +/- 990 microseconds are used, then the TFP jam-sync feature must be turned off using Command 0x21. Otherwise, a jam-sync will be performed when a difference between the reference time and the TFP time is greater than ±1 millisecond.

Command 0x18: Request UTC Time Data (bc637 only)

This command queries current GPS and UTC time information, and derived by the GPS receiver. This command must be used in conjunction with Command 0x19.

Byte	Type	Item	Value or Range
0	UINT8	ID	0x18
1	UINT8	GPS Time Format	See below

2	UINT8	Leap Second	0 to 0xff
3	INT8	Leap Second Flag	See below
4-7	UINT32	Leap Event UNIX Time	0 to 0xffffffff

GPS Time Format:

- 0x00   UTC Time (GPS time plus leap seconds)
- 0x01   GPS Time

Leap Second Flag:

- 0xff   Deletion Event
- 0x00   No Event
- 0x01   Addition Event

Command 0x19: Request TFP Data

This command requests data from the TFP that is not available via the device registers. The TFP transfers the requested data to the DPRAM Output Area. The data is available to the user as soon as the TFP sets ACK bit 0.

Byte	Type	Item	Value or Range
0	UINT8	ID	0x19
1	UINT8	Req. data type	(See DPRAM Command Summary List)

Command 0x1A: Software Reset

This command vectors the TFP MPU to its power-on reset point and contains no data.

Note: that the device registers are unaffected.

Command 0x1B: Set Time Code Output Format

This command allows the user to select the time code format that is generated by the TFP on J1.

Byte	Type	Item	Value or Range
0	UINT8	ID	0x1B
1	UINT8	Code Format	See below

Time Code Output Format:

- 0x42   IRIG B
- 0x49   IEEE 1344

Command 0x1C: Set Generator Time Offset

This command is used to add/subtract an offset to the time code generator output. This command affects the generator output only.

Byte	Type	Item	Value or Range
0	UINT8	ID	0x1C
1 - 2	UINT16	Local Offset	0xfff0 to 0x0010 (-16 to +16)
3	UINT8	Half Hour	0 or 1

HALF_HOUR:

- 0 = half hour not present (30 min)
- 1 = half hour present (30 min)

Command 0x1D: Set Local Time Offset

This command adds/subtracts local time offset to the TFP time. This command is typically used when the selected timing input is GPS (Command 0x10, Mode 6). This command affects the TFP time only. This offset does not affect the time code output. (See Command 0x1C.)

Byte	Type	Item	Value or Range
0	UINT8	ID	0x1D
1 - 2	UINT16	Local Offset	0xfff0 to 0x0010 (-16 to +16)
3	UINT8	Half Hour	0 or 1

HALF_HOUR:

- 0 = half hour not present (30 min)
- 1 = half hour present (30 min)

Command 0x1E: Program Leap Second Event

Byte	Type	Item	Value or Range
0	UINT8	ID	0x1E
1	INT8	LS_Flag	-1 to +1
2-5	UINT32	Leap Time	0xffffffff to 1

Leap Second Flag: LS_Flag:

- 1 = Insertion
- -1 = Deletion (0xff)
- 0 = Disable

Note: Leap insertion/deletion time is represented as UNIX time (seconds since 1970)

Command 0x20: Select Clock Source

This command selects the clock source for the TFP. The TFP uses a time base frequency of 10 MHz. The 10 MHz may be derived from the on-board oscillator or it may be supplied from an external oscillator via the J4 connector

Byte	Type	Item	Value or Range
0	UINT8	ID	0x20
1	UINT8	clock source	see below

Clock Source Choices

- 'I'   (0x49) Internal 10 MHz Oscillator *default setting*
- 'E'   (0x45) External 10 MHz Clock

Command 0x21: Control Jam-Sync

This command can be used to disable TFP jam-syncs that normally occur automatically. The default is jam-sync enabled.

It is sometimes desired to program an offset into the basic TFP time keeping functions relative to the reference input. For example, if the reference input is an IRIG B time code, there may be significant cable delay between the IRIG B generator and the TFP location. Command 0x17 allows this time difference to be removed by inserting the known amount of offset between the IRIG B reference and

TFP.

Byte	Type	Item	Value or Range
0	UINT8	ID	0x21
1	UINT8	jam-sync ctrl	0 = jam-syncs disabled 1 = jam-syncs enabled

Note: If offsets larger than +/- 990 microseconds are used, then the TFP jam-sync feature must be turned off using Command 0x21, otherwise, a jam-sync will be performed when the difference between the reference time and the TFP time greater than ±1 millisecond.

Command 0x22: Force Jam-Sync

This command forces the TFP to perform a single jam-sync operation and contains no data. The jam-sync will occur even if jam-syncs are disabled. (See Command 0x21.)

Command 0x24: Load DAC

The TFP on-board crystal oscillator frequency is voltage controlled using the output of a 16-bit DAC as the controlling voltage. This command allows the user to directly load a 16-bit value to the DAC. This feature allows the user to fine tune the TFP time base in the Free Running Mode. Since this voltage is routed out of the TFP via the J1 connector to allow external oscillators to be disciplined, it provides a means to devise a frequency control algorithm independent of the TFP. The DAC output voltage ranges from 0.5 V (value = 0x0000) to 4.5 V (value = 0xFFFF.) This value is oscillator dependent. The DAC value is defined at the factory based on the on-board oscillator and stored in the EEPROM. Use Command 0x19 to query the factory value.

Byte	Type	Item	Value or Range
0	UINT8	ID	0x24
1-2	UINT16	DAC value	0x0000 - 0xFFFF

Command 0x25: Set Disciplining Gain

This command allows the gain and sense of the disciplining process to be set by the user. A positive gain indicates that the voltage controlled clock source frequency increases with increasing control voltage. This feature is valuable to anyone using the TFP to discipline an external oscillator.

Byte	Type	Item	Value or Range
0	UINT8	ID	0x25
1-2	INT16	gain	-32768 to +32767

Note: Use this command with caution, as it will affect the TFP disciplining routine.

Gain Defaults:

- 0x02 = Crystek 600730-30 10.0 MHz
- 0x14 = MTI 210-xxxx 10.0 MHz

Command 0x27: Synchronize RTC to External Time Data

This command forces the TFP to synchronize the RTC time to the current time.

Command 0x31: Request Packet from GPS Receiver (bc637 only)

This command allows the user to request a GPS packet (i.e., position, velocity, status, etc.) from the GPS receiver. The format and use of this command is described in the GPS Appendix included in this manual only if you have the GPS option.

Command 0x32: Manually Request Packet from GPS Receiver (bc637 only)

This command is similar in function to Command 0x31. Refer to the GPS Appendix for details.

Command 0x33: Set GPS Time Format (bc637 only)

This command allows the user to select between GPS time and UTC when using Timing Mode 6 (GPS). The relationship between UTC and GPS time is shown below. The default setting is UTC. (UTC = GPS Time + Leap Seconds)

Byte	Type	Item	Value or Range
1	UINT8	ID	0x33
2	UINT8	GPS time format	flag

GPS time format flag:

- 0 = UTC (default)
- 1 = GPS Time

Command 0x34: Set GPS Mode Flag (bc637 only)

By default, the TFP directs the GPS receiver to static operational mode or station mode after the tracking bit resets to zero (0). This command allows the user to disable this feature. See GPS manual for packet 0x2c for details.

Byte	Type	Item	Value or Range
0	UINT8	ID	0x34
1	UINT8	Flag	0 or 1

GPS Mode Flag:

- 0 = disable
- 1 = enable (default)

Command 0x40: Observe Local Time Flag

This command programs the local time observed flag. If the local time flag is enabled, the TFP adjusts its time by the local time offset. See **Command 0x1d** for programming local time offset.

Byte	Type	Item	Value or Range
0	UINT8	ID	0x40
1	UINT8	Flag	0 or 1

Local Time Observe Flag:

- 0 = disable
- 1 = enable (default)

Command 0x41: Request Local Time Observe Flag

This command queries the daylight saving and local time observed flag. Use this command in conjunction with Command 0x19.

Byte	Type	Item	Value or Range
0	UINT8	ID	0x41
1	UINT8	flag	0x- 0xff

Flag:

- bit0 = reserve

- bit1 = reserve

- bit2 = reserve

- bit3 = local time observe flag

- bit4 – bit7 = don't care

Command 0x42: Year Auto Increment Flag

This command turns on the year auto increment flag. The year variable is stored into the EEPROM at the beginning of each year if the flag is enabled (default). This allows the card to keep track of the year for the time sources that do not provide it (IRIG A, IRIG B, NASA 36, PPS Sync, Free Running).

Byte	Type	Item	Value or Range
0	UINT8	ID	0x42
1	UINT8	Flag	0 or 1

Year Auto Increment Flag:

- 0 = disable

- 1 = enable (default)

Command 0x4F: PCI Firmware Part Number (request only)

This command allows the user to request the TFP firmware revision number.

Byte	Type	Item	Value or Range
0	UINT8	ID	0x4f
1	UINT8	'D'	
2	UINT8	'T'	
3	UINT8	'6'	
4	UINT8	'0'	
5	UINT8	'0'	
6	UINT8	'0'	
7	UINT8	Rev	
8	UINT8	Rev	
9	UINT8	Rev	
10	UINT8	Rev	
11	UINT8	Rev	

Rev = Revision of the Firmware Part Number

Command 0xF4: Assembly Part Number (request only)

This command queries the assembly part number of the TFP. The assembly number is an identification of the revision hardware. Use this command in conjunction with Command 0x19.

Byte	Type	Item	Value or Range
0	UINT8	ID	0xf4

Assembly: The assembly number is located on the left-hand side of the component side of the PCB.

Command 0xF5: Hardware Fab Part Number (read only)

This command queries the hardware fab part number of the TFP. The number is an identification of the fab being used for this hardware. Use this command in conjunction with Command 0x19.

Byte	Type	Item	Value or Range
0	UINT8	ID	0xf5
1-2	UINT16	ASSEMBLY	12083

Command 0xF6: TFP Model Identification (request only)

This command queries the PCI family TFP part number. Use this command in conjunction with Command 0x19.

Byte	Type	Item	Value or Range
0	UINT8	ID	0xf6
1	UINT8	Model	'B'
2	UINT8	Model	'C'
3	UINT8	Model	'6'
4	UINT8	Model	'3'
5	UINT8	Model	'5' or '7'
6	UINT8	Model	'P'
7	UINT8	Model	'C'
8	UINT8	Model	'I'

Model:

- "BC635PCI" = IRIG model only
- "BC637PCI" = GPS and IRIG model

Command 0xFE: TFP Serial Number (request only)

This command queries the TFP part number. Use this command in conjunction with Command 0x19.

Byte	Type	Item	Value or Range
0	UINT8	ID	0xf7
1-4	UINT32	SN	0x00 – 0xffffffff

Chapter 7: Inputs and Outputs

General

Table 7-1 shows the pin connections for J1.

Signal I/O Connector

This connector is used for most of the I/O signals as defined in table 7-1.

TABLE 7-1: J1 15 PIN

Pin	Direction	SIGNAL
1	input	External 10 MHz input
2	n/a	Ground
3	output	Strobe output
4	output	1 PPS output
5	output	Time Code output (AM)
6	input	External Event input
7	input	Time Code input (AM)
8	n/a	Ground (Recommended Time Code return)
9	output	Oscillator Control Voltage output
10	input	Time Code input (DCLS)
11	output	Time Code output (DCLS)
12	n/a	Ground
13	output	1,5,10 MHz output
14	input	External 1 PPS input
15	output	Periodic Pulse output

ACE III GPS Connector

This connector is used primarily for connecting the ACE III GPS. Data communications between the board and the GPS receiver are via serial signals. Additionally, the GPS receiver provides a 1 PPS signal to the board.

Appendix A: GPS Field Upgrade

Installation

Warning: The TFP is a static sensitive device. All modifications to this product should be in a static free workspace and performed by a qualified assembler or technician.

Parts Included

Part #	Description	Quantity
2310-4101	Standoff 4-40x5/16	4
55183	GPS Timing Module	1
91200	Antenna Kit	1
4001	4-40x3/16 Screw	8
4048	#4 Split Washer	8
8029	#10 Washer	2

Tools Needed

- Small Phillips screwdriver
- ¼ inch nut driver or open-end wrench

Installation Steps

Remove hole plug from front panel location GPS ANT.

Install standoffs part number 2310-4101 using four 4-40x3/16 screws (Part number 4001) and four split washers (Part number 4048) to the four mounting holes on the 55183 GPS Timing Module.

Remove nut and washer from 55183 SMB connector.

Install two #10 washers (Part number 8029) on 55183 SMB connector.

Install 55183 on bc635PCI-U module. Insert the 55183 SMB connector through front panel and secure the standoffs to the bc635PCI-U module using four 4001 screws and four 4048 washers. Note that some of the mounting holes on the bc635PCI-U module are oblong for mounting different size GPS Timing Modules. The mounting holes on the GPS timing will locate the standoffs in the correct location.

Install washer and nut to 55183 SMB connector.

Warning: do not over tighten SMB connector, which can be damaged if too much torque is applied to the nut.

Run cable to the roof and install antenna. Antenna needs clear view of the sky.

Hardware installation is complete.

Firmware Field Upgrade Kit Instructions

If you are running Microsoft Windows, follow the steps below. For all other Operating Systems, contact Symmetricom.

Upgrade Steps

Run the bc635cpp.exe program

Under Help click on Hardware Version. Write the board serial number in the line below. Contact Symmetricom Customer Service to obtain the password number for the board, and write the password number below.

> Serial Number:_____
> Password: _____

Under Special|Menu click on 'Advanced'

Select 'PCI' and click on 'Symmetricom Setting', a pop-up menu will appear.

Two upgrade options are available: upgrade the 'Crystal' from 'Standard' to 'MTI oven', and upgrade the model from 'bc635PCI-U' to 'bc637PCI-U' GPS.

To upgrade the model, select the 'Model' button and click on 'bc637PCI-U' button. Enter the password, listed above, in the password field. Select the OK button to change the model number.

Note that the password will only work with the board that has the serial number listed above.

Appendix B: GPS Receiver Interface

General

The bc637PCI-U GPS System consists of a bc637PCI-U Time and Frequency Processor equipped with special firmware, an ACE III GPS receiver/antenna module manufactured by Trimble Navigation Ltd., and an interconnecting cable. The bc637PCI-U module communicates with the ACE III via RS-422 serial (9600 bps) lines. The ACE III also provides a 1 PPS signal to the bc637PCI.

Note: The most common difficulty encountered using GPS equipment is antenna position. The GPS antenna must be located in an area which has a clear view of the sky. The GPS signals cannot penetrate foliage or structures. A good antenna position will provide optimal timing performance.

GPS Timing Mode (Mode 6) Characteristics

In order to function with the ACE III GPS Receiver the bc637PCI-U module must operate in Timing Mode 6 (GPS Timing Mode.) This is the default timing mode for the bc637PCI-U when equipped with the special GPS firmware which is a standard part of the bc637PCI-U GPS System. The GPS Timing Mode is characterized by the following:

The 1 PPS signal generated by the ACE III GPS Receiver provides the timing reference for all timing functions.

The on-board 10 MHz VCXO is disciplined to the GPS 1 PPS signal whenever the ACE III is tracking a sufficient number of satellites. If too few satellites are tracked then the bc637PCI-U will flywheel.

The bc637PCI-U extracts major time and satellite tracking status information from data packets sent from the ACE III. By default, the bc637PCI-U provides UTC time to the user. The user can select GPS time instead by issuing the DPRAM Command 0x33 (Select GPS Time Format) described in Chapter 5.

The bc637PCI-U provides a communications pathway between the user and the ACE III GPS Receiver. This pathway is most often used to receive GPS data packets for position, velocity, and GPS system status.

The bc637PCI-U ignores all other timing sources (i.e., the time code input and external 1 PPS input signals.)

Communicating With the GPS Receiver

The dual-port RAM (DPRAM) interface described in Chapter 5 provides the communications pathway between the user and the ACE III GPS Receiver. Using DPRAM commands and the

DPRAM GPS Packet Area, the user can send and receive GPS data packets. A GPS data packet consists of a packet length byte, a packet ID byte, and zero or more data bytes. A packet length of zero indicates that no valid packet ID and data bytes are present. The GPS data packet structure is summarized below:

Byte	Item
0	packet length = N = number of packet data bytes + 1 (for the packet ID byte)
1	packet ID
2 - N	packet data bytes

The GPS packet IDs and packet data formats are described later in this appendix and are taken from Trimble Navigation's ACE III manuals. The user can determine the packet length from the ACE III documentation. The ACE III documentation describes a packet structure that includes, in addition to the packet ID and packet data bytes, header and trailer bytes and byte-stuffing/unstuffing. The bc637PCI-U automatically adds (when sending packets) and removes (when receiving packets) the header and trailer bytes and handles all byte-stuffing/unstuffing operations. The bc637PCI-U user should be concerned with the packet length, packet ID, and packet data bytes only.

Sending GPS Data Packets to the GPS Receiver

To send a GPS data packet to the ACE III use the DPRAM command "Send Packet to GPS Receiver" (command ID 0x30.) The format of this command is shown below:

Byte	Type	Item	Value or Range
0	UINT8	command ID	0x30
1	UINT8	packet length	1 - 255
2	UINT8	packet ID	0x00 - 0xFF
3 - N	UINT8	packet data bytes	0 - 255

GPS packet data consists of various integer and floating-point data types. The user must convert these data types to an array of bytes.

Receiving GPS Data Packets from the GPS Receiver

The DPRAM GPS Packet Area holds packets received from the GPS receiver. The bc637PCI-U writes GPS packets to this area upon user request. The format of the packets in the GPS Packet

Area is shown below:

Byte	Type	Item	Value or Range
0	UINT8	packet length	1 - 255, 0 = no valid packet
1	UINT8	packet ID	0x00 - 0xFF
2 - N	UINT8	packet data bytes	0 - 255

There are two DPRAM commands that retrieve GPS Packets. These commands are described below. The bc637PCI-U sets ACK register bit two whenever it writes a GPS packet to the GPS Packet Area. The transition of ACK register bit two from zero to one is interrupt source four (GPS Packet Available.) The user must clear ACK register bit two.

Retrieve Packet from GPS Receiver (Command 0x31)

This command allows the user to retrieve a GPS packet (i.e., position, velocity, status, etc) from the GPS receiver by specifying the packet ID of the GPS packet of interest. Packets that can be retrieved with this command are listed below. Packets not found on this list must be retrieved with Command 0x32. The format of Command 0x31 is shown below:

Byte	Type	Item	Value or Range
0	UINT8	command ID	0x31
1	UINT8	packet ID	0x00 - 0xFF

Some of the more commonly requested GPS packets are sent from the GPS receiver to the bc637PCI-U either periodically (e.g., position fix) or whenever they change (e.g., satellite selection.) The bc637PCI-U monitors these packets and stores them in on-board RAM so that they can be transferred to the user immediately upon request. The rest of the GPS packets must be retrieved from the ACE III by the bc637PCI-U whenever the user requests them. Note that it can take 10's or 100's of milliseconds for the bc637PCI-U to retrieve a packet from the GPS receiver. GPS packets that are monitored by the bc637PCI-U are identified below.

Packet ID	Monitored	Packet Description
0x41	No	GPS Time
0x42	Yes	Single-Precision Position Fix, XYZ ECEF
0x43	Yes	Velocity Fix, XYZ ECEF
0x44	Yes	Satellite Selection
0x45	No	ACE III Firmware Version
0x46	Yes	Health of ACE III
0x47	No	Signal Level For All Satellites*
0x48	No	GPS System Message
0x49	No	Almanac Health Page For All Satellites
0x4A	Yes	Single-Precision Position Fix, Lat/Long/Alt

0x4B	Yes	Machine/Code ID And Additional Status
0x4D	No	Oscillator Offset
0x4F	No	UTC Parameters
0x55	No	I/O Options
0x56	Yes	Velocity fix, East-North-Up (ENU)
0x57	No	Information About Last Computed Fix
0x5E	No	Additional Fix Status
0x83	No	Double-Precision Position Fix, XYZ ECEF
0x84	No	Double-Precision Position Fix, Lat/Long/Alt

*Note: The first byte returned will be the length of the packet)

The retrieve packet command works as follows:

- If the requested packet is being monitored and a local copy exists, then the bc637PCI-U transfers its local copy of the packet to the DPRAM GPS Packet Area, sets ACK bit 2, then sets ACK bit 0 to acknowledge the retrieve packet command.

- If the requested packet is not being monitored or if the bc637PCI-U has not yet received a monitored packet, then the bc637PCI-U must request the packet from the ACE III by sending the appropriate request packet to the ACE III. Once the request has been sent to the ACE III the bc637PCI-U sets ACK bit 0 to acknowledge the retrieve packet command. Later, when the ACE III responds with the retrieved packet, the bc637PCI-U transfers the packet to the DPRAM GPS Packet Area and sets ACK bit 2. If the ACE III does not respond to the request within a timeout period (typically 3 seconds), then the bc637PCI-U sets the packet length byte in the DPRAM GPS Packet Area to zero and sets ACK bit 2.

- If the retrieved packet ID is not on the list above, the bc637PCI-U sets the packet length byte in the DPRAM GPS Packet Area to zero, sets ACK bit 2, then sets ACK bit 0.

Manually Request Packet from GPS Receiver (Command 0x32)

This command is a hybrid of commands 0x30 and 0x31. With this command the user specifies the packet length and ID of a packet sent by the ACE III (response packet) and specifies the packet length, ID, and data for the packet to be sent to the ACE III (request packet.) The bc637PCI-U sends the request packet to the ACE III and transfers the response packet to the DPRAM GPS Packet Area when it arrives. If the response packet ID is 0x00 then the bc637PCI-U will ignore the response, in which case, this command would be functionally identical to Command 0x30. The bc637PCI-U sets ACK bit 0 once the request packet is sent to the ACE III. Later, when the response packet has been transferred to the DPRAM GPS Packet Area, the bc637PCI-U sets ACK bit 2. As with Command 0x31, if the ACE III fails to respond within a timeout period, the bc637PCI-U sets the packet length in the DPRAM GPS Packet Area to zero and then sets ACK bit 2.

Note: A response packet length of 0 (ZERO) (Byte 1) will return any packet with the corresponding response packet ID (Byte 2). This is use full for packets like 0x47 that return variable length

responses.

Byte	Type	Item	Value or Range
0	UINT8	command ID	0x32
1	UINT8	response packet length	1 - 255
2	UINT8	response packet ID	0x00 - 0xFF
3	UINT8	request packet length	1 - 255
4	UINT8	request packet ID	0x00 - 0xFF
5 - N	UINT8	request packet data bytes	0 - 255

As an example of this command, let's suppose the user wants to retrieve packet 0x5B (satellite ephemeris status) for satellite number six. The ACE III sends packet 0x5B in response to packet 0x3B (request satellite ephemeris status.) Packet 0x3B specifies the PRN number for the satellite of interest, in this case, satellite number six. The appropriate command structure for this example is shown below.

Byte	Item	VALUE
0	command ID	0x32
1	response packet length	17
2	response packet ID	0x5B
3	request packet length	2
4	request packet ID	0x3B
5	satellite PRN number	6

Another example would be returning the SNR of the currently tracking satellites:

Byte	Item	VALUE
0	command ID	0x32
1	response packet length	0
2	response packet ID	0x47
3	request packet length	1
4	request packet ID	0x27

Position Fix Modes

One of the most confusing aspects of GPS operation is the selection of the position fix mode (GPS packet 0x22.) The GPS receiver supports the following four GPS position fix modes.

Position Fix Mode 0

This mode uses as many satellites as are available to perform both position fixes and timing functions. Confusion arises because this mode selection interacts with the dynamics code selection (GPS packet 0x2C.) If a non-static dynamics code is selected then only three or four satellites will be used because the GPS sensor assumes that it is moving. If only three satellites are usable then altitude will be held constant. If a static dynamics code is entered then mode zero will use three or four satellites for a navigation solution as previously, however, if only one or two satellites are available the sensor will use the satellite with highest elevation to continue calculating bias and bias rate (the timing functions will continue unimpaired). It is very advantageous, therefore, to enter a static dynamics code if the sensor is static.

Position Fix Mode 1

In this mode, a user specified satellite is used for timing functions. If mode 1 is selected, only a single satellite will be used for timing, and the current position will be assumed accurate and static.

GPS packet 0x34 allows the satellite associated with mode one to be selected. This packet has one data byte which specifies the PRN of the desired satellite. If a data byte value of 0 is entered, then the sensor will always track the single satellite which has the highest elevation within the constellation in view.

It is very advantageous to operate in a single satellite highest elevation mode for timing applications. The greatest contribution to timing error is the electron content variation in the path between the satellite and the receiver. This variation is minimized by selecting the highest elevation satellite.

Position Fix Mode 3 and 4

These modes are rarely used for timing applications unless the user operational platform is dynamic. Mode three is particularly useful in a marine environment where the sensor altitude is relatively constant.

bc637PCI-U GPS Default Parameters

The bc637PCI-U sends the following GPS packets to the ACE III on reset or whenever the Timing Mode is changed to GPS Timing Mode 6.

Set Operating Parameters (GPS packet 0x2C)

Packet Data Item	VALUE
Packet ID	0x2c
Dynamics Code	4 (Static)
Elevation Angle Mask	0.1745 Radians (10 Degrees)
Signal Level Mask	6.0
PDOP Mask	12.0
PDOP Switch	8.0

Set High-8 / High-6 Mode (GPS packet 0x75)

Packet Data Item	Value
packet ID	0x75
mode	0 (high-8)

Set I/O Options (GPS packet 0x35)

Packet Data Item	Value
Packet ID	0x35
Position	0x03
Velocity	0x03
Timing	0x00
Auxiliary	0x00

To change any of the packet 0x35 options, keep the following in mind: The bc637PCI-U monitors position and velocity packets so the "position" and "velocity" options should be sent with bits 0 and 1 set; the bc637PCI-U extracts major time from time packets broadcast by the ACE III so the "timing" option should be sent with bits zero, one, and two cleared.

GPS System Overview

The GPS system consists of three parts called segments:

- The space segment consists of 24 satellites and three spares broadcasting the radio navigation signals.

- The control segment tracks the satellites and uploads orbital information (ephemeris data) and clock corrections. There are five monitor stations, three uplink stations, and one master control station.

- The user segment tracks and receives the radio navigation signals and computes user position and time.

The signals transmitted from the satellites consist of two modulated carriers: L1 at 1.575 GHz and L2 at 1.227 GHz. The L1 signal is modulated with both a C/A code and a P code. T he L2 signal is modulated with a P code only. Civilian access to the system is provided through the C/A code. The P code is intended for authorized military users only. The ACE III operates on the C/A code.

The ACE III determines time and position by measuring the time of arrival of the satellite signals. If the user has no knowledge of either time or position, then four satellites are required to determine a solution for the four unknown quantities X,Y,Z and time. If position is known and static, then time can be determined by measuring the time of arrival of a single satellite signal. Each satellite broadcasts information which allows the user to calculate the position of the satellite. Knowledge of this position, the user position, and a model of the transmission path characteristics allows accurate time determination.

The structure and content of the satellite signals and the decoding and solution determination algorithms are beyond the scope of this manual. Further information may be obtained from the paperback overview Guide to GPS Positioning, prepared by David Wells and published by the Canadian GPS Associates.

Index

G

H

I

J

K

M