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# TTM635/637VME
# TTM350/357VXI
# Time and Frequency Processor

Revision B

User's Guide

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**TTM635/637VME-TTM350/357VXI**
**TIME AND FREQUENCY PROCESSOR**

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# CHAPTER ONE
# INTRODUCTION

## 1.0 GENERAL

The TTM635VME / TTM350VXI Time and Frequency Processor User's Guide provides the following information:

- Introduction and theory of operation description.
- Installation and setup.
- Detailed operation and programming interfaces.
- Input and output signals.
- Programming examples.

## 1.1 KEY FEATURES

The Time and Frequency Processor (TFP) has been designed with the following key features:

- Time on demand (days through 0.1 microseconds) with zero latency. This feature is implemented with hardware registers which latch the current time upon host request.
- Event logging (days through 0.1 microseconds). This feature is implemented with a second set of hardware registers. Time is captured on a positive or negative input edge.
- Five operational modes are supported. Modes are distinguished by the reference source.

| Mode | Source of Synchronization |
|---|---|
| **0** | Timecode - IRIGA IRIGB XR3 2137 NASA36 |
| **1** | Free running - on board VCXO used as reference. |
| **2** | 1 pps - accepts input one pulse per second. |
| **3** | RTC - uses battery backed on board real time clock IC. |
| **6** | GPS (optional) - uses GPS receiver/antenna |



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- Provides an output clock synchronized to the selected reference; programmable 1, 5, or 10 MHz TTL.

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

- Generates synchronized IRIG B timecode. Modulated and DC level shift formats are produced simultaneously. Also generates IRIG H DC level shift.

- Programmable frequency output (periodics) is provided. The periodic output operates in the synchronous or asynchronous mode.

- A time coincidence strobe output is provided. Programmable from hours through milliseconds. This strobe also has an each second mode programmable to milliseconds.

- Five maskable interrupt sources are supported. IRQ levels one through seven are programmable.

| Int. # | Source of Interrupt |
|---|---|
| **0** | External event input has occurred. |
| **1** | Periodic output has occurred. |
| **2** | Time coincidence strobe has occurred. |
| **3** | One second epoch (1pps output) has occurred. |
| **4** | Output data packet is available. |

- Time-of-day, hours, minutes, and seconds are displayed on front panel LED's. Status information is provided by the decimal points on the LEDs.

- Most inputs and outputs are accessible via the P2 connector.

## 1.2 PHYSICAL OVERVIEW

The TFP is a B size module (6U X 160 mm). Operation is controlled by a block of thirty-two D16 registers written and read by the host via the VMEbus (A16 : D16). The TFP is available in two versions. The TTM635VME is intended for use in a VMEbus system with most I/O signals available on rows A and C of the P2 connector. The TTM350VXI is intended for use in a VXIbus system, and is shipped without a P2 connector. A dip switch is used to select VME or VXI register compatibility. In VMEbus systems the register block can be located on any 64 byte boundary. In VXIbus systems the register block can be located at any of the 256 logical addresses (A15 and A14 must be high). The logical address is returned during an interrupt acknowledge cycle.



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## 1.3 SPECIFICATIONS

### 1.3.1 TIMECODE READER

| | |
|---|---|
| **Format – AM** | IRIG-A IRIG-B XR3 2137 NASA 36. |
| **Carrier Range** | +/- 50 ppm. |
| **Modulation Ratio** | 3:1 to 6:1. |
| **Input Amplitude** | 1 to 5 volts peak to peak. |
| **Input Impedance** | 10KΩ AC coupled. |

| | |
|---|---|
| **Format - DCLS** | IRIG-A IRIG-B NASA 36. |
| **Carrier Range** | +/- 50 ppm. |
| **Input Amplitude** | TTL/CMOS Compatible |
| **Input Impedance** | 10K Ω DC coupled. |

### 1.3.2 TIMECODE GENERATOR

| | |
|---|---|
| **Format - AM** | IRIG-B. |
| **Modulation Ratio** | 3:1. |
| **Output Amplitude** | 0 to 10 Vp-p, adjusted by VR1, into 50 Ω. |

| | |
|---|---|
| **Format - DCLS** | IRIG-B IRIG-H |
| **DC Level Shift** | TTL/CMOS compatible, into 50Ω. |

### 1.3.3 BUS CHARACTERISTICS

| | |
|---|---|
| **Address Space** | A16, AM codes $29 and $2D, 64 bytes. |
| **Data Transfer** | D16. |
| **Interrupter** | D08(0), I(1-7), ROAK. |
| **Power** | +5 @ 750 millamps<br>+12 @ 100 milliamps (VCXO) +12 @ 350milliamp (OCXO continuous) +12 @ 600 milliamps (OCXO warmup)<br>-12 @ 30 milliamps |



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### 1.3.4 DIGITAL INPUTS

| | |
|---|---|
| **Event Capture** | TTL/CMOS positive or negative edge triggered. |
| | 20 nanoseconds minimum width 250 nanoseconds minimum period. |
| | Input impedance 10K Ω |

| | |
|---|---|
| **External 1 PPS** | TTL/CMOS positive edge on time. |
| | Twenty nanoseconds minimum width. |
| | Input impedance 10K Ω |

### 1.3.5 EXTERNAL 10MHz INPUT/OUTPUT

| | |
|---|---|
| **10 MHz Input** | TTL/CMOS 45% To 55% Duty Cycle. |
| | 1.5 to 4 Vp-p, AC coupled 2.5 KHz impedance. |

***Note***: When an ovenized or rubidium onboard oscillator is used, the external 10 MHz input feature is disabled. Instead the output of the ovenized or rubidium oscillator appears on this pin. It can only drive a single high impedance load.

### 1.3.6 DIGITAL OUTPUTS

| | |
|---|---|
| **1pps** | TTL/CMOS positive edge on time, 200mS positive pulse, into 50 Ω. |
| **Periodics** | TTL/CMOS positive edge on time, into 50Ω. (See section 4.1.5) |
| **Strobe** | TTL/CMOS positive edge on time, 1mS positive pulse, into 50 Ω. |
| **1, 5, 10 MHz Clock** | TTL/CMOS positive edge on time, 5 & 10 MHz square wave, 1 MHz 80/20 duty cycle, into 50 Ω. |

### 1.3.7 OSCILLATOR CONTROL OUTPUT

| | |
|---|---|
| **Control Range** | 0 – 5V |
| **Transfer Coefficient** | Positive |

## 1.4 ENVIRONMENTAL SPECIFICATIONS

| | | |
|---|---|---|
| **Temperature** | Operating | 0 to 70$^{o}$ centigrade. |
| | Non-Operating | -30 to +85$^{o}$ centigrade. |
| **Relative Humidity** | Operating | 85% @ +85 $^{o}$ C, 1000 hours. |
| **Altitude** | Operating | -400 to 18,000 meters MSL. |



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## 1.5 THEORY OF OPERATION

This section describes the functions provided by the TTM635VME/TTM350VXI Time and Frequency Processor (TFP).

### 1.5.1 TIME

This function controls how the TFP card acquires and 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 system.

#### 1.5.1.1 TIME SYNC MODE

This allows the user to select the operating mode (time source) of the TFP device. Available modes are Time Code Decoding, Freerunning, External 1 PPS, RTC & GPS (Optional).

#### 1.5.1.2 TIME FORMAT

The event time capture and time registers of the TFP default to the decimal time format. The major time registers are divided into 4 bit fields for each decimal digit of days, hours minutes and seconds. For the GPS mode only, the time registers can operate in the binary format where major time is represented as seconds since the GPS epoch.

#### 1.5.1.3 SET TIME

This function allows the user to set the time on the TFP device. Decimal time values can be entered into the time registers. This function is typically used when operating in either the Freerunning 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.

#### 1.5.1.4 SET YEAR

This function allows the user to set the year data. Typically, this function 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 TFP device to extract the time of year data from the time code source while using year information provided by the user. The board will decode the year and roll over the days for a leap year (365-366-001) or a non-leap year (365-001). The supported range is 1990 – 2037. The board will follow the input time source (after a 1 second delay) if the input rollover day sequence does not match the board rollover day sequence as defined by the programmed year.

#### 1.5.1.5 SET LOCAL OFFSET

This function allows the user to program a local offset of 1-hour increments into the TFP device. If the local offset value is nonzero, the device will adjust any reference timing information in order to maintain a local time in TFP clock. Use of this function only affects the time data in the



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TIME and EVENT registers described in paragraph 3.1.

### 1.5.1.6 SET PROPAGATION DELAY

This function allows the user to command the TFP 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.

### 1.5.1.7 DAYS

When a time source signal is not present at board power up, the board will begin counting at day 000. The following two tables show the results of the midnight end of year rollover cases. The TFP can be operated to count days in two modes.

For the default Day 000 Invalid Mode, the TFP will not accept an input day of 000. Table 1.1 shows the possible combinations of current board state and input source data on the left side, and the result of the midnight rollover on the right side. Note that the table includes combinations such as where the board is set to a non-leap year, but the source is in a leap year. For the Freerun cases the board is loaded with a day and time just before the midnight rollover. In the Timecode cases the board is set to the year shown, and the board tracks the time source through the midnight rollover.

**Table 1.1 Day 000 Invalid Mode**

| Combination number | Board year-day | Input mode | Source Year | Source day | Board year | Board day | Notes |
|---|---|---|---|---|---|---|---|
| 1.1.1 | 99 | Timecode | N/A | 000 – 001 | 99 | Freerun – 001 | 1 |
| 1.1.2 | 99 | Timecode | 99 | 365 – 001 | 99 – 00 | 365 – 001 | |
| 1.1.3 | 99 | Timecode | 00 | 365 – 366 | 99 – 00 | 365 – 366 | 2 |
| 1.1.4 | 99 | Timecode | 00 | 366 – 001 | 99 – 00 | 366 – 001 | 3 |
| 1.2.1 | 99-365 | Freerun | N/A | N/A | 99 – 00 | 365 – 001 | |
| 1.2.2 | 99-366 | Freerun | N/A | N/A | 99 – 00 | 366 – 001 | |
| 2.1.1 | 00 | Timecode | 00 | 365 – 366 | 00 | 365 – 366 | |
| 2.1.2 | 00 | Timecode | 99 | 365 – 001 | 00 | 365 – 001 | 4 |
| 2.1.3 | 00 | Timecode | 00 | 366 – 001 | 00 – 01 | 366 – 001 | |
| 2.2.1 | 00-365 | Freerun | N/A | N/A | 00 | 365 – 366 | |
| 2.2.2 | 00-366 | Freerun | N/A | N/A | 00 – 01 | 366 – 001 | |

Note 1: The board goes to flywheel mode when the input timcode day is 000. After the source timecode transitions to day 001 the board will begin tracking the input timecode.
Note 2: The board will go to day 001 for about one second, then to day 366
Note 3: The board will go to year 00 at the day rollover 366 - 001.
Note 4: Day will go to 366 for about one second, then go to day 001



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For the optional Accept Day 000 Mode, the TFP will accept an input source with an input day of 000. Table 1.2 shows the possible combinations for this mode.

**Table 1.2 Accept Day 000 Mode**

| Combination number | Board year-day | Input mode | Input Year | Input day | Board year | Board day | Notes |
|---|---|---|---|---|---|---|---|
| 3.1.1 | 99 | Timecode | N/A | 000 | 99 | 000 – 001 | |
| 3.1.2 | 99 | Timecode | 99 | 364 – 365 | 99 | 364 – 365 | |
| 3.1.3 | 99 | Timecode | 99 | 365 – 001 | 99 – 00 | 365 – 001 | 5 |
| 3.1.4 | 99 | Timecode | 00 | 365 – 366 | 99 – 00 | 365 – 366 | 6 |
| 3.1.5 | 99 | Timecode | 00 | 366 – 001 | 99 – 00 | 366 – 001 | 5 |
| 3.2.1 | 99-000 | Freerun | N/A | 000 | 99 | 000 – 001 | |
| 3.2.2 | 99-364 | Freerun | N/A | 364 | 99 | 364 – 365 | |
| 3.2.3 | 99-365 | Freerun | N/A | 365 | 99 – 00 | 365 – 000 | |
| 3.2.4 | 99-366 | Freerun | N/A | 366 | 99 – 00 | 366 – 000 | |
| 4.1.1 | 00 | Timecode | N/A | 000 – 001 | 00 | 000 – 001 | |
| 4.1.2 | 00 | Timecode | 00 | 365 – 366 | 00 | 365 – 366 | |
| 4.1.3 | 00 | Timecode | 00 | 366 – 001 | 00 – 01 | 366 – 001 | 5 |
| 4.1.4 | 00 | Timecode | 99 | 365 – 001 | 00 | 365 – 001 | 7 |
| 4.2.1 | 00-000 | Freerun | N/A | N/A | 00 | 000 – 001 | |
| 4.2.2 | 00-365 | Freerun | N/A | N/A | 00 | 365 – 366 | |
| 4.2.3 | 00-366 | Freerun | N/A | N/A | 00 - 01 | 366 – 000 | |

Note 5: Day went to 000 for about one second, then went to day 001
Note 6: Day went to 000 for about one second, then went to day 366
Note 7: Day went to 366 for about one second, then went to day 001

### 1.5.2 TIME CODE

This function group provides access to functions controlling TFP 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.

#### 1.5.2.1 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. The default format is IRIG-B and the default modulation envelope is AM (amplitude modulated).

#### 1.5.2.2 GENERATE

This function allows the user to select the format of the time code that will be generated by the TFP device. The time code generator supports IRIG-B and IRIG-H DCLS.



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### 1.5.3 SIGNALS

This group provides access to functions that control various hardware timing signals either decoded or generated by the TFP card.

#### 1.5.3.1 HEARTBEAT (PERIODIC) OUTPUT

This function allows the user to command the TFP to produce a clock signal at a specified frequency. The heartbeat signal, also referred to as a periodic, can be either synchronous or asynchronous to the internal 1 PPS epoch in the TFP device. This functionality is implemented in hardware on the TFP device by an Intel 82C54 counter timer chip. The heartbeat circuit has two 16 bit divisors, which are clocked by the counter. As the output of the first divisor provides the clock for the second divisor, manipulating the divisor values results in various frequencies and duty cycles. The output of this circuitry is capable of creating a VME bus interrupt. See Section 4.1.5 for a description of how to program the heartbeat output.

#### 1.5.3.2 STROBE OUTPUT

This function allows the user to command the TFP to produce a hardware signal at a particular time, or at a particular point during each 1 second interval. When major/minor mode is selected, a hardware signal will be produced when the internal time of the TFP device matches the values entered for the major and minor strobe registers. The major time in hours, minutes and seconds may be supplied in addition to the milliseconds loaded in the minor strobe register. When minor mode is selected, a strobe signal is produced every second when the internal millisecond count in the TFP device matches the value entered in the minor strobe register. The output of this circuitry is capable of creating a VME bus interrupt.

#### 1.5.3.3 EVENT INPUT

This function allows the user to command the TFP 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 function can be used to control whether or not subsequent events will overwrite the data in the event time registers. The output of this circuitry is capable of creating a VME bus interrupt.

#### 1.5.3.4 FREQUENCY OUTPUT

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



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### 1.5.4 INTERRUPTS

This function allows the user to control the generation of VME bus interrupts by the TFP device. Three control registers are provided to control the VME interrupts.

### 1.5.5 OSCILLATOR PARAMETERS

This group allows the user to select an external oscillator or the on board oscillator, in addition to enabling/disabling disciplining and jamsyncing. If disciplining and jamsyncing are disabled, the oscillator control DAC can be programmed to hold the oscillator control voltage to a specific value. When the TFP is synchronized to an input time source, the oscillator will be disciplined to the input source signal. The external oscillator control mode only works if a VCXO is on the board.

The oscillator has a control range of ±30 PPM for the standard VCXO version, and ±2 PPM for the optional oven version. If the input time source is outside these limits, the TPF will exhibit periodic slips (if the TFP reference deviates from the input source by more than ± 1 millisecond, a forced jamsync is performed). If the input time source is lost or removed, the TFP will continue to "flywheel" at the last known code rate. Typical accuracy is five parts in $10^7$ (two milliseconds of drift per hour).

### 1.5.6 RTC FUNCTIONS

A *FIFO Packet command* allows the user to force the Real Time Clock (RTC) time to the board time. The RTC mode is used to synchronize the TFP to the RTC Time. This mode is not recommended when using the oven oscillator because the accuracy of the RTC is not high enough to ensure that the oven will be able to track it without exceeding the control range of the OCXO.

A *Battery Manager* is used to enable the battery to power the RTC when the board power is removed. The battery voltage status is monitored by the Battery Manager, and the battery status can be accessed by a FIFO Packet Command. The Battery Manager can be commanded to disconnect the battery so that it does not power the RTC during storage. The battery is automatically re-enabled the next time the board is powered up.

### 1.5.7 BOARD RESET

This function allows the user to reset the TFP 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.



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# CHAPTER TWO
# INSTALLATION AND SETUP

## 2.0 VME/VXI COMPATIBILITY SWITCHES

The TFP is designed for both VMEbus and VXIbus compatibility. Switches SW2-3 and SW2-4 are used to select the bus protocol. To select VXIbus compatibility set SW2-3 and SW2-4 to the OPEN or OFF position. To select VMEbus compatibility set SW2-3 and SW2-4 to the CLOSED or ON position.

**SW1 and SW2 Location**

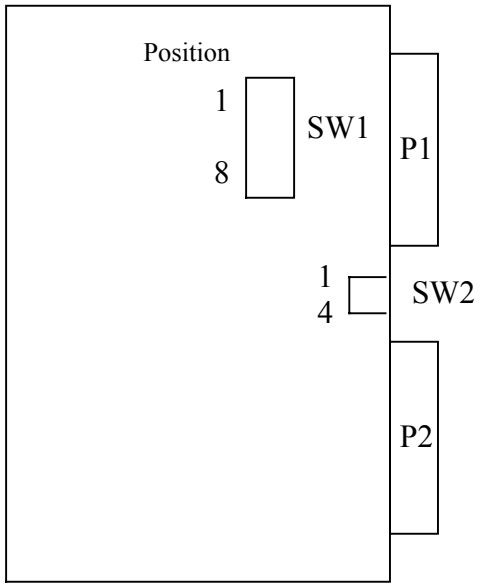



**Figure 2-1 Address Switches**

Switch SW2-3 controls the register block addressing within the A16 address space. With this switch in the VXI position, address bits A14 and A15 must be one for A16 selection. Switch SW1 is then used to select the logical address for the module. With SW2-3 in the VME position, the module can be mapped to any 64 byte block in the A16 address space. SW2-1 and SW2-2 set the A14 and A15 address bits, and SW1 is used to set the A13 through A6 address bits.

Switch SW2-4 controls the status/ID byte returned during interrupt acknowledge cycles. With SW2-4 in the VXI position, the Status/ID byte returned during interrupt acknowledge cycles is the logical address set with SW1. When SW2-4 is in the VME position, the Status/ID byte returned during interrupt acknowledge cycles is the user programmable vector loaded into the VECTOR register (discussed in Chapter Three).



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## 2.1 VMEbus BASE ADDRESS SELECTION

Base address selection for the VMEbus requires the setting of switch SW1 (A6 through A13) and SW2 (A14 and A15). The TTM635VME occupies 64 bytes in the A16 address space and can be freely located on any 64 byte boundary. The correspondence of the switch positions to the address bits is illustrated in Table 2-1.

**Table 2-1**
**Address Bits Switch Positions**

| | SW2 | | SW1 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Address Bit | A15 | A14 | A13 | A12 | A11 | A10 | A09 | A08 | A07 | A06 | |
| Switch Number | 2 | 1 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | A16 address range used. (The BASE address is on the left side.) |
| Example switch settings for SW1 and SW2. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0x0000 - 0x003F |
| 1 = OPEN or OFF | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0x0040 - 0x007F |
| 0 = CLOSED or ON | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0x0080 - 0x00BF |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0x00C0 - 0x00FF |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0x0100 - 0x013F |
| | … | … | … | … | … | … | … | … | … | … | … |
| | … | … | … | … | … | … | … | … | … | … | … |
| | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0xEFC0 - 0xFEFF |
| | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0xFF00 - 0xFF3F |
| | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0xFF40 - 0xFF74 |

To select a base address, set each of the switches to the logical zero (CLOSED or ON) or the logical one (OPEN or OFF) state.

## 2.2 TTM350VXI LOGICAL ADDRESS SELECTION

Logical address selection for the VXIbus requires the setting of switch SW1 (A6 through A13). The TTM350VXI occupies 64 bytes in the A16 address space and can be located at any of the 256 logical addresses within the VXIbus. The correspondence between the switch positions and the address bits, and the logical state corresponding to a switch setting follows the description provided in Section 2.1



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## 2.3 JUMPER BLOCKS

The jumper block locations are shown in Figure 2-2. The jumper blocks are not drawn to scale in order to make the numbers more visible. It may be helpful to refer to the schematic diagrams to obtain a clearer idea of the function of each jumper block option. The board silkscreen has labels for the jumper block pin numbers. The ACE III module and Acutime 2000 Smart Antennas are GPS sensor options that are available from Symmetricom, Inc. Provisions for using the board with the now obsolete Acutime Smart Antenna is also provided.

**JP1**
With the shunt in the 1-2 position the TFP is configured to use DC level shift input timecode. In the 3-4 or open position the TFP is configured to use modulated timecode. Do not install a jumper on JP1 pins 1-2 if a shunt is installed on JP2A pins 3-4.

**JP2**
In the 1-2 position the TFP is configured to use a single ended 1 PPS GPS input from the Acutime Smart Antenna. In the 3-4 position the TFP is configured to use a differential 1 PPS input.

**JP2A**
A shunt on pins 1-2 enables the differential 1 PPS input from the Acutime 2000 Smart Antenna. Do not install a shunt on JP2 pins 1-2 if the ACE III GPS module is installed. With a shunt in the 3-4 position a differential DCLS input can be used. Do not install a jumper on JP1 pins 1-2 if a shunt is installed on JP2A pins 3-4.

**JP3**
This jumper block selects the source for the differential output on J4 pins 3 and 4. In the 1-2 position the TFP is configured to use the Acutime or Acutime 2000 Smart Antenna as the GPS sensor. In the 2-3 position the TFP is configured to output differential DCLS.

**JP4**
This jumper block is not present on these boards.

**JP5**
In the 1-2 position this shunt places a “100 Ω” load between the RS-422 input lines. In the 3-4 position the “100 Ω” load is bypassed. When the TFP is the terminal device on an RS-422 daisy chain the load should be used. When the TFP is not at the end of the chain the load should be omitted.

**JP6**
In the 1-2 position this shunt places GROUND on P2 pin C12. In the 2-3 position the 1, 5, 10MHz clock is driven out of P2 pin C12. Note that the shunt is rotated in the two positions, and that pin 4 is not used in either position.

**JP7**



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This jumper block is for factory use only, and a shunt must not be installed.

**JP8**
In the 1-2 position this shunt enables the serial input from the ACE III GPS module. In the 2-3 position it enables the serial input from the Acutime or Acutime 2000 Smart Antenna.

**JP9**
This jumper block selects the oscillator type. Install a shunt on the jumper block pins as defined by an X below:

| 1-2 OSCSEL1 | 3-4 OSCSEL0 | Oscillator Type |
|---|---|---|
| | | VCXO |
| X | | Future Use |
| | X | OCXO |
| X | X | External |

**JP10**
This jumper block is for factory use only, and shunts must not be installed.

**JP11**
This jumper block is configured at the factory to select the X72 voltage input.



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**Jumper Location**

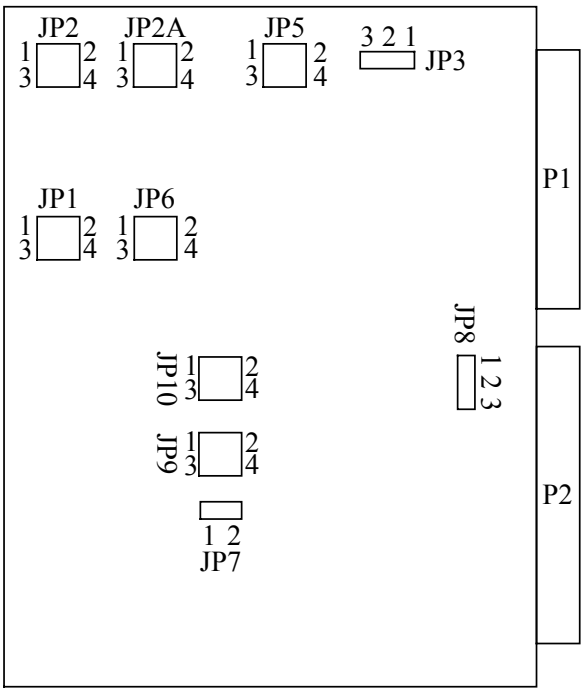



**Figure 2-2 Jumper Locations**



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## 2.4 INSTALLATION

To install the TFP into a computer chassis follow the steps below.

- Remove the IACKIN*/IACKOUT* back plane shunt for the TFP slot. This step should be performed even if TFP interrupts are not used.

- TTM635VME users must verify that signals on rows A and C of the P2 connector are not used for VSB or other purposes. The TFP provides signal I/O on rows A and C that may produce a conflict. If a conflict does exist, a solution is to obtain a TTM350VXI with the P2 connector removed.

- Verify that power is off and insert the TFP into the chassis, securing it in the slot by tightening the two front panel screws.



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# CHAPTER THREE
# INTERFACES

## 3.0 GENERAL

The TFP occupies 64 bytes in the VMEbus/VXIbus, A16 address space. Refer to Section 2.1 for details on VMEbus Base Address selection, and to Section 2.2 for VXIbus logical address selection. TFP data transfers are D16 with the exception of packet I/O which allows D08(0) transfers. A glossary of key terms commonly used in the discussion of timing operation is provided below.

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

**Flywheel**
Maintain time or frequency accuracy as well as local resources when a time or frequency reference has been lost or removed.

**Periodic**
A programmable frequency which is obtained by dividing the TFP reference frequency. Periodics are sometimes referred to as "heartbeats." Periodics may optionally be synchronous with the 1pps epoch if the period is expressible as a ratio of integers.

**Major Time**
Units of time larger than or equal to seconds. A *day hr:min:sec* format is usually implied.

**Minor Time**
Subsecond 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 transmission to allow framing of the transmitted data.

## 3.1 DATA INPUT AND OUTPUT

Communication with the TFP is performed using a set of memory mapped registers. These registers may be read only (R), write only (W), or read/write (R/W). In some cases a read/write register is structured to support dissimilar data in the read and write directions. Table 3-1 summarizes the type of register located at each hexadecimal offset, and provides a brief description of the register function. The data format and detailed descriptions of each register are provided in the next section.



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**Table 3-1**

| TFP Register Map Summary | | | |
|---|---|---|---|
| **HEX Offset** | **Type** | **Label** | **Function Read/Write** |
| 0 | R | ID Register. | VXIbus ID Register |
| 2 | R | Device. | VXIbus Device Type Register |
| 4 | R/W | Status/Control. | VXIbus Status / Control Registers |
| 6-08 | Reserved | | |
| 0A | R | TIMEREQ | Time Request (Time Latching Strobe) |
| 0C | R | TIME0 | Requested Time (includes status byte) |
| 0E | R | TIME1 | Requested Time |
| 10 | R | TIME2 | Requested Time |
| 12 | R | TIME3 | Requested Time |
| 14 | R | TIME4 | Requested Time |
| 16 | R | EVENT0 | Event Time |
| 18 | R/W | EVENT1 / STROBE1 | Event Time/Strobe Time |
| 1A | R/W | EVENT2 / STROBE2 | Event Time/Strobe Time |
| 1C | R/W | EVENT3 / STROBE3 | Event Time/Strobe Time |
| 1E | R | EVENT4 | Event Time |
| 20 | R/W | UNLOCK | Release Lockout/Capture Time |
| 22 | R/W | ACK | Acknowledge Register |
| 24 | R/W | CMD | Command Register |
| 26 | R/W | FIFO | FIFO Input/Output (D16 or D08[O]) |
| 28 | R/W | MASK | Interrupt Mask |
| 2A | R/W | INTSTAT | Interrupt Status |
| 2C | R/W | VECTOR | Interrupt Vector |
| 2E | R/W | LEVEL | Interrupt Level |
| 30-3E | Reserved | | |

**Offset 0x00 ID REGISTER Reset Value 0xFEF4**

This register was implemented to satisfy the VXIbus Specification. Bit assignments are as follows:

**Table 3-2**

| **Bit #** | **15-14** | **13-12** | **11-0** |
|---|---|---|---|
| Use Of Field | Device Class | Addressing Modes | Manufacturer's ID |
| TFP Meaning | Register Based | A16 Only | 0xef4 |



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**Offset 0x02 DEVICE Reset Value 0xF350**
This register simply contains (in the case of an A16 only device) a manufacturer's card ID.

**Offset 0x04 STATUS Reset Value 0xFFFF**
The TFP does not support VXIbus initialization and diagnostic features. The reset value is always returned.

**Offset 0x04 CONTROL Reset Value 0xFFFE**
Writing to this register with bit 0 set will deassert any pending interrupts and will clear all used bits in offsets 0x20 through 0x2E (except FIFO at offset 0x28). Writing to this register with bit zero cleared has no effect. All other bits are ignored during a write.

**Offset 0x0A TIMEREQ Reset Value NA**
Reading this register latches the current time and status into offsets 0x0C through 0x14. The value read is indeterminate.

*** * * WARNING * * ***

Many compilers will optimize out of existence an assignment made to a local variable if that variable is not used. For example, the following code snippet may not read offset 0x0A.

```
timeptr = (short *)(BASE + 0x0A) ;          /* initialize pointer */
local_dummy = *timeptr++ ;                  /* latch the time ?? */
read_time(timeptr) ;                        /* read the time */
```

The following form is recommended. Use of the global prevents optimizing out.

```
timeptr = (short *) (BASE + 0x0A) ;         /* initialize pointer */
global_dummy = *timeptr++ ;                 /* latch the time */
read_time(timeptr) ;                        /* read the time */
```



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**Offset 0X0C** **TIME0** **Reset Value NA**
**Offset 0X0E** **TIME1** **Reset Value NA**
**Offset 0X10** **TIME2** **Reset Value NA**
**Offset 0X12** **TIME3** **Reset Value NA**
**Offset 0X14** **TIME4** **Reset Value NA**

For clarity the above offsets have been grouped.

**Table 3-3**

| Bit # | 15-12 | 11-8 | 7-4 | 3-0 |
|---|---|---|---|---|
| **TIME0 Field** | Not Defined | Not Defined | Status (Note 1) | Days Hundreds |
| **TIME1 Field** | Days Tens | Days Units | Hours Tens | Hours Units |
| **TIME2 Field** | Minutes Tens | Minutes Units | Seconds Tens | Seconds Units |
| **TIME3 Field** | 10E-1 Seconds | 10E-2 Seconds | 10E-3 Seconds | 10E-4 Seconds |
| **TIME4 Field** | 10E-5 Seconds | 10E-6 Seconds | 10E-7 Seconds | Not Defined |

**Offset 0x16** **EVENT0** **Reset Value NA**
**Offset 0x18** **EVENT1** **Reset Value NA**
**Offset 0x1A** **EVENT2** **Reset Value NA**
**Offset 0x1C** **EVENT3** **Reset Value NA**
**Offset 0x1E** **EVENT4** **Reset Value NA**

For clarity the above offsets have been grouped.

**Table 3-4**

| Bit # | 15-12 | 11-8 | 7-4 | 3-0 |
|---|---|---|---|---|
| **EVENT0 Field** | Not Defined | Not Defined | Status (Note 1) | Days Hundreds |
| **EVENT1 Field** | Days Tens | Days Units | Hours Tens | Hours Units |
| **EVENT2 Field** | Minutes Tens | Minutes Units | Seconds Tens | Seconds Units |
| **EVENT3 Field** | 10E-1 Seconds | 10E-2 Seconds | 10E-3 Seconds | 10E-4 Seconds |
| **EVENT4 Field** | 10E-5 Seconds | 10E-6 Seconds | 10E-7 Seconds | Not Defined |

*Note 1*:

bit 7 1 = RTC Battery failure 0 = RTC Battery OK
bit 6 1 = frequency offset > 5E7 in Mode 0 0 = frequency offset < 5E7 in Mode 0
1 = frequency offset > 5E8 0 = frequency offset < 5E8
bit 5 1 = time offset > X microseconds 0 = time offset < X microseconds
(X = 5 for mode 0, X = 2 more all other modes)
bit 4 1 = flywheeling (not locked) 0 = locked to selected reference



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**Offset 0x18 STROBE1 Reset Value 0xXX00**
**Offset 0x1A STROBE2 Reset Value 0x0000**
**Offset 0x1C STROBE3 Reset Value 0x0000**

For clarity the above offsets have been grouped.

**Table 3-5**

| Bit # | 15-12 | 11-8 | 7-4 | 3-0 |
|---|---|---|---|---|
| **STROBE1 Field** | Not Defined | Not Defined | Hours Tens | Hours Units |
| **STROBE2 Field** | Minutes Tens | Minutes Units | Seconds Tens | Seconds Units |
| **STROBE3 Field** | 10E-1 Seconds | 10E-2 Seconds | 10E-3 Seconds | Not Defined |

**Offset 0x20 UNLOCK Reset Value NA**
A read of this register releases the time capture lockout function if it has been enabled. See "CMD OFFSET 0x24" for additional details. The data read from this offset is meaningless. A write to the UNLOCK register acts as a secondary time latching strobe. Time is latched in EVENT0 - EVENT4. This feature allows the host to capture two times independently.

**Offset 0x22 ACK Reset Value 0xXX00**

**Table 3-6**

| Bit # | Control | Function (SET = "1" = High Voltage, CLEAR = "0" = Low Voltage) |
|---|---|---|
| **0** | TFP<br>HOST | SETS bit to acknowledge the receipt of a valid input packet from host<br>CLEARS bit by writing to this register with bit 0 SET. |
| **1** | Reserved | |
| **2** | TFP<br>HOST | SETS bit when output FIFO contains a data packet.<br>CLEARS bit by writing to this register with bit 2 SET.<br>This bit can generate a VMEbus interrupt. (see OFFSET 0x2A INTSTAT). |
| **3** | Reserved | |
| **4** | TFP<br>HOST | SETS bit if output FIFO contains data. CLEARS bit if output FIFO empty.<br>CLEARS output FIFO by writing to this register with bit four SET. |
| **5** | Reserved | |
| **6** | Reserved | |
| **7** | HOST | *Must* write to this register with bit seven SET to cause TFP to take action on the data packet previously written to the input FIFO. This will generate an interrupt to the TFP microcontroller. |
| **8-15** | Reserved | |



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**Offset 0x24 CMD Reset Value 0xXX00**

This register is used to command the TFP to perform specific functions.

**Table 3-7**

| Bit # | Name | Function | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **0** | LOCKEN | Event capture lockout (0 = disable lockout 1 = enable lockout). Prevents a new event from overwriting a previous event until an *UNLOCK* is performed (see OFFSET 0x20 UNLOCK). | | | | | | | |
| **1** | HBEN | Enable periodic time capture (0 = disable 1 = enable). When enabled the periodic output is logically OR'ED with the event input, and the time of the periodic may be read in EVENT0 - EVENT4. | | | | | | | |
| **2** | EVSENSE | Event capture sense select (0 = rising edge 1= falling edge). | | | | | | | |
| **3** | EVENTEN | Event capture enable (0 = disable 1 = enable). | | | | | | | |
| **4** | STREN | Time coincidence output strobe enable (0 = disable 1 = enable). | | | | | | | |
| **5** | STRMODE | Strobe mode (0 = use major and minor time 1 = use minor time only). In mode (1) an output strobe is produced each second. | | | | | | | |
| **6** | FREQSEL0 | 0 | 10 MHz | 1 | 5 MHz | 0 | 1 MHz | 1 | 1 MHz |
| **7** | FREQSEL1 | 0 | | 0 | | 1 | | 1 | |
| **8-15** | Reserved | | | | | | | | |

**Offset 0x26 FIFO Reset Value NA**

Reads take data from the output FIFO. Writes place data into the input FIFO. Both the input FIFO and the output FIFO may also be accessed via D08(O) at offset 0x27. Each FIFO has a depth of 512 bytes.

Data must be written to and read from the FIFO in the following data packet format.

| | | |
|---|---|---|
| byte 1 | 0x01 | header byte (ASCII SOH) |
| byte 2 | "A" through "Z" | idbyte (defined in Chapter Four) |
| byte 3 | data | always ASCII i.e. 0 = 0x30 |
| byte 4 | data | |
| . | . | the number of data bytes varies |
| byte N | data | |
| byte N+1 | 0x17 | tail byte (ASCII ETB) |



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**Offset 0x28 MASK Reset Value 0xXX00**

**Table 3-8**

| Bit # | INT # | Source Of Interrupt |
|---|---|---|
| **0** | 0 | External event input has occurred. |
| **1** | 1 | Periodic pulse output has occurred. |
| **2** | 2 | Time coincidence strobe has occurred. |
| **3** | 3 | The one pulse per second (1pps) output has occurred. |
| **4** | 4 | A data packet is available in the output *FIFO*. |
| **5-15** | Reserved | |

An interrupt source is enabled by writing a one to the mask bit corresponding to that source. An interrupt source is disabled by writing a zero to the mask bit corresponding to that source.

**Offset 0x2A INTSTAT Reset Value 0xXX00**

The INTSTAT register has the same basic structure as the MASK register. The TFP sets bits zero through four of this register depending upon which interrupt source generated the interrupt. The INTSTAT register bits are set regardless of the state of the mask bits. This feature allows the host to poll for the occurrence of the interrupt sources. INTSTAT bits are cleared by writing to the INTSTAT register with the corresponding bit(s) set.

*** * * WARNING * * ***

It is the transition of an INTSTAT bit from a zero to a one that causes an interrupt to be generated (assuming that the corresponding MASK bit was set). If the bit in the INTSTAT register is not cleared by the host it is not possible to generate a second interrupt. It is good programming practice to clear the INTSTAT register immediately after interrupts have been enabled.

**Offset 0x2C VECTOR Reset Value 0xXX00**

The VECTOR register holds the eight bit Status/ID byte that the TFP will return during interrupt acknowledge cycles for VMEbus applications.



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**Offset 0x2E LEVEL Reset Value 0xXX00**

The LEVEL register selects the level at which an interrupt will be generated. Only bits zero through two are used. These bits are encoded as follows:

| Bit | | | IRQ Level |
|---|---|---|---|
| 0 | 0 | 0 | Disabled |
| 0 | 0 | 1 | IRQ1 |
| 0 | 1 | 0 | IRQ2 |
| 0 | 1 | 1 | IRQ3 |
| 1 | 0 | 0 | IRQ4 |
| 1 | 0 | 1 | IRQ5 |
| 1 | 1 | 0 | IRQ6 |
| 1 | 1 | 1 | IRQ7 |



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# CHAPTER FOUR
# FIFO DATA PACKETS

## 4.0 GENERAL

Communication with the TFP is performed using a byte serial data packet protocol. The packet bytes are read from, and written to the TFP, using D08(O) transfers at offset 0x27 or D16 transfers at offset 0x26. In the case of a D16 transfer, only the low order byte is used. The packet structure is defined in Chapter Three, "OFFSET 0x26". Table 4-1 shows a summary of the Data Packet commands. Some of the parameters that are programmed by packets are stored in the CPU non-volatile memory (NVM). (See Table 4-2)

## 4.1 WRITING DATA PACKETS

The following steps should be followed when loading data packets to the TFP. Failure to perform one or more of these steps correctly is a common reason for customer support calls.

- Write the packet to the input FIFO.
- Clear bit 0 of the ACK register by writing 0x01 to the ACK register.
- Inform the TFP that an input packet is available by writing 0x80 to the ACK register.
- The TFP will set bit 0 of the ACK register when the packet is processed.

When the host sets bit seven of the ACK register, an interrupt to the TFP CPU is generated. The TFP service routine performs minimalist packet integrity checking. The TFP checks that the first packet byte is 0x01 (ASCII SOH). If the SOH is found, the TFP loads FIFO data into an input buffer until a byte value of 0x17 (ASCII ETB) is found. The packet is then processed in accordance with the idbyte value. When processing is complete, the TFP sets bit zero of the ACK register, clears the input FIFO, and resumes its previous task. If an SOH is not the first packet byte, if more than 40 bytes are read before encountering an ETB, or if the idbyte value is invalid, then TFP clears the FIFO, clears bit zero of the ACK register, and resumes its previous task.



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**Table 4-1**
**Data Packet Command Summary**

| ID | Reset | Command |
|---|---|---|
| A | Note 1 | Set TFP Timing Mode |
| B | N/A | Set Major Time |
| C | N/A | Command Input |
| D | 0 | Load D/A Converter |
| F | N/A | Set Heartbeat (Periodic) Control |
| G | 0 | Set Propagation Delay Offset Control |
| H | B | Set Time Code Format for Mode 0 |
| I | I | Clock Source Select |
| J | N/A | Send Data to GPS Receiver (TTM637VME/TTM357VXI only) |
| K | B | Select Generator Code |
| L | N/A | Set Real Time Clock |
| M | 0 | Local Time Offset Select |
| O | N/A | Request Data from the TFP |
| P | 01 | Path Selection |
| Q | N/A | Set Disciplining Gain |
| S | 00 | Set Year |
| U | 0 | User LED Decimal Point |

**Data Packet Response Summary**

| ID | Reset | Command |
|---|---|---|
| o-0 | N/A | Request RTC Time |
| o-1 | 0 | Request Current D to A Value |
| o-2 | N/A | Request Leap Seconds (Currently GPS Specific) |
| o-3 | N/A | Request RTC Year |
| o-4 | 00 | Request Year |
| o-a | Note 1 | Request Selected Mode (mode number is binary, not ASCII) |
| o-b | N/A | Request Firmware Version |
| o-c | N/A | Request Battery Status |
| o-f | N/A | Request Periodic Control |
| o-g | 0 | Request Propagation Delay Offset |
| o-h | B | Request Time Code Format |
| o-i | I | RequestClock Source |
| o-k | B | Request Generator Code |
| o-m | 0 | Request Local Time Offset |
| o-p | 01 | Request  Path |
| o-q | N/A | Request Disciplining Gain |
| o-t | N/A | Request Oscillator Jumper Settings J9 |

***Note One*:** TTM635VME/TTM350VXI resets to Mode 0 (Time Code)
TTM637VME/TTM357VXI resets to Mode 6 (GPS)



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### 4.1.1 PACKET "A" SELECT TFP OPERATIONAL MODE

This packet contains a single data byte (zero through seven) which defines the TFP operational mode. The mode is saved in the CPU NVM. The modes are enumerated below.

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "A" |
| byte | 3 | mode (binary byte, not ASCII number) |
| byte | 4 | ETB |

**Mode 0 (Zero) Time Code Decoding Mode**
The TFP uses an input timecode as the timing reference. See packet "H" for time codes supported. Both modulated carrier and DC level shift formats are supported (DC level shift is not supported for 2137 or XR3 codes). The TFP locks its crystal oscillator to the input code rate.

**Mode 1 Free Running Mode**
This mode is virtually the same as Mode 2. Without a 1pps input the TFP runs at the last known oscillator frequency. Major time can be set with the "B" packet. The TFP timebase can be adjusted with packet "D."

**Mode 2 External 1 pps Mode**
The TFP synchronizes to the signal on the 1pps input. Major time can be loaded with the "B" packet. The acquisition range is the same as described in mode zero.

**Mode 3 Real Time Clock Mode**
The TFP synchronizes to the onboard real time clock (RTC) IC, and the major time is also derived from the clock IC. The RTC is battery backed.

**Mode 6 GPS Mode**
This is an optional mode available with the TTM637VME/TTM357VXI configuration. It is described in a separate User's Guide.



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### Mode 7 Diagnostic and Default Setting Mode

Initially this mode was provided to allow the TFP to be photographed. The LED display is loaded with static time 12:34:56. As more NVM parameters were added it became useful to use this mode as a means of setting all NVM data to standard defaults. This data and the default values established by mode seven are as follows, see Table 4-2.

**Table 4-2**
**Mode 7 Default Values**

| Variable | Default | Description |
|---|---|---|
| **Mode** | See Note | TFP Operational Mode |
| **Time Code** | IRIG B | Reference Time Code Expected |
| **Format** | Modulated | Modulated Time Code Expected |
| **Gencode** | IRIG B | TFP Generates IRIG B |
| **Path** | 1 | Path Selection Variable (See "P" Packet) |
| **Local** | 0 | Local Time Offset (GPS Modes Only) |
| **Accum** | 0 | VCXO DAC Value (Nominally Centered) |
| **Leapsec** | 0 | GPS To UTC Leap Second Correction (Only Used In GPS Modes) |

The diagnostic utility of this mode resides in the fact that the operator can immediately determine if the host program is communicating properly with the TFP by simply observing the display. To borrow from the classic K&R, to make 12:34:56 appear "you have to be able to create the program text, compile it, run it, and find out where your output went. With these mechanical details mastered, everything else is comparatively easy."

***Note***: The TTM635VME and TTM350VXI default to Mode 0 (zero). The TTM637VME and TTM350VXI default to Mode 6.



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### 4.1.2 PACKET "B" SET MAJOR TIME

In Mode 1 and Mode 2 the only way to set major time is using this packet. It is not likely that this packet would be used in any other mode since all other modes derive major time from the timing reference signal. The packet format is as follows:

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "B" |
| byte | 3 | days hundreds |
| byte | 4 | days tens |
| byte | 5 | *days units (Jan 1 is defined as day 001) |
| byte | 6 | hours tens |
| byte | 7 | hours units |
| byte | 8 | minutes tens |
| byte | 9 | minutes units |
| byte | 10 | seconds tens |
| byte | 11 | seconds units |
| byte | 12 | ETB |

***Note:*** All data fields must be in ASCII format.

*Day 000 is an invalid time code in IRIG time codes. If Day 000 is desired, see "Packet 'P' Path Selection."

The time loaded by packet "B" will not be used until the one second epoch following the load. The TFP increments the time before loading it to output buffer registers. The time is incremented at approximately 918 milliseconds into the current frame, and the buffer registers are loaded 950 milliseconds into the current frame. The buffer registers are transferred to a set of holding registers synchronously with the 1pps output. The time loaded by packet "B" should be input well in advance of the 918 millisecond point in the frame, and should reference the current frame.



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### 4.1.3 PACKET "C" COMMAND INPUT

This packet has a single data byte and is used to direct the TPF to take the specific actions below.

| | | | |
|---|---|---|---|
| byte | 1 | SOH | |
| byte | 2 | "C" | |
| byte | 3 | "1" - "7" | (Definitions Below) |
| byte | 7 | ETB | |

| | | |
|---|---|---|
| "1" | Not Used | (Warm Start on Early Software Versions) |
| "2" | Software Reset | vectors TFP CPU to Power on Reset Point |
| "3" | Jamsynch | Force TFP Minor Time To Zero on the Next 1pps Input |
| "4" | Not Used | (Jamsynch Lockout On Early Software Versions) |
| "5" | Buf to RTC | Load Current Time to the Real Time Clock IC |
| "6" | Variables | Dumps Battery Backed RAM to FIFO (Factory Use Only) |
| "7" | Battery Manager | Disables RTC battery during storage. The battery is automatically enabled at the next board powerup. |

### 4.1.4 PACKET "D" LOAD D/A CONVERTER

The TFP reference crystal oscillator is voltage controlled using the buffered output of a 16-bit D/A converter as the controlling voltage. Packet "D" allows the user to directly load a 16-bit value to the D/A converter. This feature would allow a user to fine tune the TFP time base in the external oscillator mode. Upon receipt by the timing engine, the input value is converted to two's complement format by subtracting 32768 from the value programmed. Users who are disciplining an external source using a read-modify-write paradigm based on this packet in conjunction with the read packet "O1" MUST take this into account. The value read back by the query command can be converted back to an unsigned value by adding 32768 modulo 65536. We are not aware of any other use for this packet in normal operation. Since this voltage is routed out of the TFP via pin 9 on the J1 connector to allow external oscillators to be disciplined, it would provide a means to devise a frequency control algorithm independent of the TFP. The format is shown below. (See also bit 3 of the path byte loaded by the "P" packet.)

| | | | |
|---|---|---|---|
| byte | 1 | SOH | |
| byte | 2 | "D" | |
| byte | 3 | "0" - "F" | bits 12-15 |
| byte | 4 | "0" - "F" | bits 08-11 |
| byte | 5 | "0" - "F" | bits 04-07 |
| byte | 6 | "0" - "F" | bits 01-03 |
| byte | 7 | ETB | |

***Note:*** All data fields must be in ASCII format.



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While the board is disciplining the oscillator and the TFP is locked to the input time source, the current value of the D/A converter is written to NVM 4 times a day. When the board is powered up or reset, the last D/A converter value is used as the startup value until disciplining begins.

**Examples** (see Packet 'O', response format '1', section 4.1.13 )

Setting the DAC to its midpoint:

0x8000 is half of 0xFFFF. The input byte stream is "D","8","0","0","0".

*Reading back the value:*
The output is "0","0","0","0". Add 0x8000 to get 0x8000.
If value is greater than 0x10000, subtract 0x10000 => 0x8000 < 0x10000 => 0x8000.

Setting the DAC to 25% output:

0x4000 is 25% of 0xFFFF. The input byte stream is "D","4","0","0","0".

*Reading back the value:*
The output is "C","0","0","0". Add 0x8000 to get 0x14000,
If value is greater than 0x10000, subtract 0x10000 => 0x14000 > 0x10000 => 0x4000.

Setting the DAC to 75% output:

0xC000 is 75% of 0xFFFF. The input byte stream is "D","C","0","0","0".

*Reading back the value:*
The output is "4","0","0","0". Add 0x8000 to get 0xC000.
If value is greater than 0x10000, subtract 0x10000 => 0xC000 < 0x10000 => 0xC000.

Setting the DAC to current value + 1% of tuning range:

*Read back the current value:*
The output is "F","F","E","0". Add 0x8000 to get 0x17FE0.
If value is greater than 0x10000, subtract 0x10000 => 0x17FE0 > 0x10000 => 0x7FE0.
Add 1% of 0xFFFF which is 0x28F. 0x28F + 0x7FE0 = 0x826F.
The input byte stream is "D","8","2","6","F".

*Reading back the value:*
The output is "0","2","6","F". Add 0x8000 to get 0x826F.
If value is greater than 0x10000, subtract 0x10000 => 0x826F < 0x10000 => 0x826F.

### 4.1.5 PACKET "F" HEARTBEAT (PERIODIC) CONTROL

This packet establishes the frequency of the TFP output periodics. The number of output pulses is defined by the following equation.



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N = 10,000,000 / (n1 * n2)

where N = output pulses per second
n1 = a programmable number in the range of 2 to 65535
n2 = a programmable number in the range of 2 to 65535

The “F” packet establishes the value of n1 and n2. There is a one byte qualifier associated with the “F” packet. This qualifier allows the periodics to be asynchronous or synchronous with respect to the 1pps epoch. If the synchronous format is chosen n1 and n2 must be selected such that N is an integer.

The duty cycle of the output waveform is dependent on the particular values of n1 and n2 selected. Divider n2 physically follows divider n1. The following example serves as an illustration. If n1 * n2 = 20, the output frequency is 500kHz. If n1 is selected as ten and n2 is selected as two a square wave is output since the last divider is a divide by two. If n1 is selected as two and n2 is selected as ten the output waveform is a pulse train with a one tenth duty cycle.

The packet “F” format is as follows:

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | “F” |
| byte | 3 | “2” for asynchronous “5” for synchronous |
| byte | 4 | “0” - “F” m1 bits 12-15 |
| byte | 5 | “0” - “F” m1 bits 08-11 |
| byte | 6 | “0” - “F” m1 bits 04-07 |
| byte | 7 | “0” - “F” m1 bits 00-03 |
| byte | 8 | “0” - “F” m2 bits 12-15 |
| byte | 9 | “0” - “F” m2 bits 08-11 |
| byte | 10 | “0” - “F” m2 bits 04-07 |
| byte | 11 | “0” - “F” m2 bits 00-03 |
| byte | 12 | ETB |

If a two (asynchronous) qualifier is used then the values of n1 and n2 are the same as the packet values m1 and m2. If the five (synchronous) qualifier is used, then the values of n1 and n2 are equal of packet values m1+1 and m2+1 respectively. For example, if a synchronous 500KHz square wave is desired then the qualifier byte is five, m1 = 9, and m2 = 1. Additional insight into the operation of the counter can be gained by reading the Intel documentation for the 82C54 integrated circuit. The two and five qualifiers correspond to the Intel defined Modes 2 and 5.

The periodic engine of the TTM635/637VME consists of two sections of an INTEL 82C54 programmable interval timer connected in a serial configuration and driven by the TFP 10 MHz reference. Glue logic in one of the logic cell arrays supports both synchronous (with the 1pps epoch) and asynchronous operation. It is helpful (although not essential) to read the INTEL data sheet on the 82C54. Packet "F" allows the user complete access to the serial counters using standard INTEL loading protocols.



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Two counter modes are supported; 1pps synchronous and asynchronous. It is the responsibility of the user to select the appropriate mode. No error checking is performed by the TTM635/637VME firmware. The synchronous mode should only be selected if the number of output counts per second is an integer. If the number of counts per second is not an integer then the asynchronous mode should be used. The number of counts per second is always of the following form:

N = (10,000,000) / (n1 * n2)

where: N = counts per second
n1 = Counter #1 divide
n2 = Counter #2 divide

The range of values for Counter #1 and #2 is mode dependent as follows.

Asynchronous Mode: 2 to 65535
Synchronous Mode: 3 to 65535

* * * WARNING * * *

Periodic heartbeat pulse/interrupt generation can not be guaranteed in synchronous mode when counter divide values of two are used.

The two modes of operation are accessed using standard INTEL mode identifiers. For synchronous operation the mode byte must be an ASCII "5." For asynchronous operation the mode byte must be an ASCII "2." The packet format is as follows:

| | | |
|---|---|---|
| byte | 1 | SOH. |
| byte | 2 | "F." |
| byte | 3 | ASCII "2" (asynch) or "5" (synch). |
| byte | 4 | ASCII "0" - "F" (n1 bits 2-15). |
| byte | 5 | ASCII "0" - "F" (n1 bits 8-11). |
| byte | 6 | ASCII "0" - "F" (n1 bits 4-7). |
| byte | 7 | ASCII "0" - "F" (n1 bits 0-3). |
| byte | 8 | ASCII "0" - "F" (n2 bits 12-15). |
| byte | 9 | ASCII "0" - "F" (n2 bits 8-11). |
| byte | 10 | ASCII "0" - "F" (n2 bits 4-7). |
| byte | 11 | ASCII "0" - "F" (n2 bits 0-3). |
| byte | 12 | ETB. |

* * * IMPORTANT * * *

When Mode 5 is used, the value of n1 and n2 produced by the 82C54 hardware is n1+1 and n2+1. This is a result of the way INTEL designed the 82C54, and is unrelated to our design.



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Example: It is desired to implement 10000 counts per second synchronous with the 1pps.

```
 mode  =  "5"  (synchronous)
 n1+1  =  10
 n2+1  =  100  (10,000,000) / (10 * 100) = 10000
```

```
byte    1       SOH.
byte    2       "F."
byte    3       "5" (mode).
byte    4       "0."
byte    5       "0."
byte    6       "0."
byte    7       "9" (n1 = 9).
byte    8       "0."
byte    9       "0."
byte    10      "6."
byte    11      "3" (n2 = 99 = 0x63).
byte    12      ETB.
```

Other values of (n1+1) and (n2+1) could have been used. For example, (n1+1) = 25 and (n2+1) = 40.



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### 4.1.6 PACKET "G" PROPOGATION DELAY OFFSET CONTROL

It is frequently desired to program an offset into the basic TFP timekeeping functions relative to the reference input. For example, if the reference input is an IRIG B timecode, there may be significant cable delay between the IRIG B generator and the TFP location. Packet "G" allows this time difference to be removed by inserting the known amount of offset between the IRIG B reference and TFP locations. The offset is programmable in units of one hundred nanoseconds, and may be positive or negative. The format is shown below.

| | | | |
|---|---|---|---|
| byte | 1 | SOH | |
| byte | 2 | "G" | |
| byte | 3 | "+" or "-" | advance or retard |
| byte | 4 | "0" - "9" | BCD millisecond hundreds |
| byte | 5 | "0" - "9" | BCD millisecond tens |
| byte | 6 | "0" - "9" | BCD millisecond units |
| byte | 7 | "0" - "9" | BCD microsecond hundreds |
| byte | 8 | "0" - "9" | BCD microsecond tens |
| byte | 9 | "0" - "9" | BCD microsecond units |
| byte | 10 | "0" - "9" | BCD nanosecond hundreds |
| byte | 11 | ETB | |

For the IRIG B scenario described above, a positive offset should be used.

*** * * WARNING * * ***

If offsets larger than ± 990 microseconds are used, then the TFP jamsynch feature must be turned off using packet "P." The reason for this requirement is that under normal operation if a difference between the reference time and the TFP time is detected to be greater than ±1 millisecond the TFP timbers is "jammed" to the reference time so that a lengthy steering process is avoided.



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### 4.1.7 PACKET "H" SET TIMECODE FORMAT FOR MODE 0

Packet "H" allows the host to select the timecode format and modulation type. The packet format is as follows. The timecode format and modulation values are maintained in NVM.

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "H" |
| byte | 3 | format |
| byte | 4 | modulation |
| byte | 5 | ETB |

**Format Choices**

| | |
|---|---|
| "A" | IRIG A |
| "B" | IRIG B |
| "C" | 2137 (XR3 with 100Hz symbol rate) |
| "N" | NASA 36 |
| "X" | XR3 (25Hz symbol rate) |

**Modulation Choices**

| | |
|---|---|
| "M" | amplitude modulated sine wave |
| "D" | pulse code modulation (DC level shift)<br>DC level shift not is supported for 2137 and XR3 codes. |

### 4.1.8 PACKET "I" CLOCK SOURCE SELECT

Packet "I" is used to select the clock source for the TFP. The TFP uses a frequency of 10MHz for all timing functions. The 10 MHz be may derived from the TFP VCXO or it may be supplied from an external oscillator via J1 pin #1 or P2 pin #C22. The packet format is as follows.

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "I" |
| byte | 3 | "E" or "I" External or Internal |
| byte | 4 | ETB |

On power on the TFP always defaults to the internal oscillator selection. This packet has no effect on boards with Oven Oscillators

### 4.1.9 PACKET "J" SEND DATA TO GPS RECEIVER

The format and content variations are discussed in a separate User's Guide.



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### 4.1.10 PACKET "K" SELECT GENERATOR CODE

The timecode generated by the TFP is selected by packet "K." Only two options are available as described below. The generator code type is maintained in NVM.

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "K" |
| byte | 3 | code |
| byte | 4 | ETB |

**Code Options**

"B" generate IRIG B amplitude modulated and DC level shift
"H" generate IRIG H DC level shift only

### 4.1.11 PACKET "L" SET REAL TIME CLOCK

This packet loads the battery backed real time clock IC which is used as the source of major time and 1pps epoch when mode three is selected. The format is shown below.

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "L" |
| byte | 3 | years tens |
| byte | 4 | years units |
| byte | 5 | months tens |
| byte | 6 | months units (January = month 1) |
| byte | 7 | day-of-month tens |
| byte | 8 | day-of-month units |
| byte | 9 | hours tens |
| byte | 10 | hours units |
| byte | 11 | minutes tens |
| byte | 12 | minutes units |
| byte | 13 | seconds tens |
| byte | 14 | seconds units |
| byte | 15 | ETB |

All data fields must be in ASCII format. The TFP need not be in mode three when packet "L" is downloaded.



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### 4.1.12 PACKET "M" LOCAL TIME OFFSET SELECT (GPS MODES ONLY)

This packet allows time to be displayed with a hour offset. This situation usually arises when the source of time is in an UTC (Universal Time Coordinated) format and the local time is desired to be displayed. The offset only applies to the hour's digits. This offset is maintained in NVM. The format is as follows.

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "M" |
| byte | 3 | sign "+" or "-" |
| byte | 4 | hours tens |
| byte | 5 | hours units |
| byte | 6 | ETB |

The hours are in range, from -12 to +12. A positive sign is used from the prime meridian heading East, and a negative sign is used from the prime meridian heading West. For example, Eastern Standard Time would be -05 relative to UTC.



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### 4.1.13 PACKET "O" REQUEST DATA FROM THE TFP

This packet is used to request data from the TFP which is not available via the register interfaces. It was added as a "catch all" packet for universal data transfer. This packet has been created with a very extensive format, and additional data will be made available as customer needs and suggestions are addressed. The primary purpose of this packet is to allow the user to verify the integrity of the programmed setup data.

***Note:*** The user is advised that repetitively issuing Packet "O" can cause excessive CPU overhead and may disrupt time keeping.

The TFP signals a packet ready condition by setting bit 2 in the ACK register. It is the responsibility of the host to clear this bit by writing to the ACK register with bit 2 set.

Currently seventeen different data packets may be requested using the "O" packet. The formats are as follows:

**Request Format**

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "O" |
| byte | 3 | "0", "1", "2", "3", "4", "a", "b", "c", "f", "g", "h", "i", "k", "m", "p", "q" or "t" |
| byte | 4 | ETB |

**Response Format "0" Request RTC Time (See Packet "L")**

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "o" (lower case letter) |
| byte | 3 | "0" (zero) |
| byte | 4 | years tens |
| byte | 5 | years units |
| byte | 6 | months tens |
| byte | 7 | months units |
| byte | 8 | day-of-month tens |
| byte | 9 | day-of-month units |
| byte | 10 | hours tens |
| byte | 11 | hours units |
| byte | 12 | minutes tens |
| byte | 13 | minutes units |
| byte | 14 | seconds tens |
| byte | 15 | seconds units |
| byte | 16 | ETB |



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**Response Format "1" Request Current D To A Value**

| | | | |
|---|---|---|---|
| byte | 1 | SOH | |
| byte | 2 | "o" | (lower case letter) |
| byte | 3 | "1" | |
| byte | 4 | "0" - "F" | bits 12-15 |
| byte | 5 | "0" - "F" | bits 08-11 |
| byte | 6 | "0" - "F" | bits 04-07 |
| byte | 7 | "0" - "F" | bits 00-03 |
| byte | 8 | ETB | |

**Response Format "2" Request Leap Seconds (Currently GPS Specific)**

| | | | |
|---|---|---|---|
| byte | 1 | SOH | |
| byte | 2 | "o" | (lower case letter) |
| byte | 3 | "2" | |
| byte | 4 | leap second tens | |
| byte | 5 | leap second units | |
| byte | 6 | ETB | |

**Response Format "3" Request RTC Year**

| | | | |
|---|---|---|---|
| byte | 1 | SOH | |
| byte | 2 | "o" (lower case letter) | |
| byte | 3 | "3" | |
| byte | 4 | RTC years tens | |
| byte | 5 | RTC year units | |
| byte | 6 | ETB | |

**Response Format "4" Request Year**

| | | | |
|---|---|---|---|
| byte | 1 | SOH | |
| byte | 2 | "o" (lower case letter) | |
| byte | 3 | "4" | |
| byte | 4 | years tens | |
| byte | 5 | year units | |
| byte | 6 | ETB | |

**Response Format "a" Request Selected Mode**

| | | | |
|---|---|---|---|
| byte | 1 | SOH | |
| byte | 2 | "o" (lower case letter) | |
| byte | 3 | "a" | |
| byte | 4 | mode binary byte | 0 = Time Code<br>1 = Freerunning<br>2 = External 1PPS<br>3 = Real Time Clock<br>6 = GPS<br>7 = Diagnostic |
| byte | 5 | ETB | |



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**Response Format "b" Request Firmware Version – bytes 4 through 10 define the firmware version, bytes 11 through 13 define the firmware revision.**

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "o" (lower case letter) |
| byte | 3 | "b" |
| byte | 4 | "D" |
| byte | 5 | "T" |
| byte | 6 | "0" – "9" |
| byte | 7 | "0" – "9" |
| byte | 8 | "0" – "9" |
| byte | 9 | "0" – "9" |
| byte | 10 | "0" – "9" |
| byte | 11 | "0" – "9", "A" – "Z" |
| byte | 12 | "0" – "9", "A" – "Z" |
| byte | 13 | "0" – "9", "A" – "Z" |
| byte | 14 | ETB |

**Response Format "c" Request Battery Status**

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "o" (lower case letter) |
| byte | 3 | "c" |
| byte | 4 | status |
| byte | 5 | ETB |

**Status Responses**

| | |
|---|---|
| "1" | Battery Failed |
| "0" | Battery OK |

**Response Format "f" Request Periodic Control**

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "o" (lower case letter) |
| byte | 3 | "f" |
| byte | 4 | "2" for asynchronous "5" for synchronous |
| byte | 5 | "0" - "F" m1 bits 12-15 |
| byte | 6 | "0" - "F" m1 bits 08-11 |
| byte | 7 | "0" - "F" m1 bits 04-07 |
| byte | 8 | "0" - "F" m1 bits 00-03 |
| byte | 9 | "0" - "F" m2 bits 12-15 |
| byte | 10 | "0" - "F" m2 bits 08-11 |
| byte | 11 | "0" - "F" m2 bits 04-07 |
| byte | 12 | "0" - "F" m2 bits 00-03 |
| byte | 13 | ETB |

**Response Format "g" Request Propogation Delay Offset**

| | | |
|---|---|---|
| byte | 1 | SOH |



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| | | |
|---|---|---|
| byte | 2 | "o" (lower case letter) |
| byte | 3 | "g" |
| byte | 4 | "+" or "-" advance or retard |
| byte | 5 | "0" - "9" BCD millisecond hundreds |
| byte | 6 | "0" - "9" BCD millisecond tens |
| byte | 7 | "0" - "9" BCD millisecond units |
| byte | 8 | "0" - "9" BCD microsecond hundreds |
| byte | 9 | "0" - "9" BCD microsecond tens |
| byte | 10 | "0" - "9" BCD microsecond units |
| byte | 11 | "0" - "9" BCD nanosecond hundreds |
| byte | 12 | ETB |

**Response Format "h" Request Timecode Format**

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "o" (lower case letter) |
| byte | 3 | "h" |
| byte | 4 | format |
| byte | 5 | modulation |
| byte | 6 | ETB |

**Format Responses**

| | |
|---|---|
| "A" | IRIG A |
| "B" | IRIG B |
| "C" | 2137 (XR3 with 100Hz symbol rate) |
| "N" | NASA 36 |
| "X" | XR3 (25Hz symbol rate) |

**Modulation Responses**

| | |
|---|---|
| "M" | amplitude modulated sine wave |
| "D" | pulse code modulation (DC level shift) |

**Response Format "i" Request Clock Source**

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "o" (lower case letter) |
| byte | 3 | "i" |
| byte | 4 | "E" or "I" External or Internal |
| byte | 5 | ETB |



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**Response Format "k" Request Generator Code**

byte 1 SOH
byte 2 "o" (lower case letter)
byte 3 "k"
byte 4 code
byte 5 ETB

**Code Responses**

"B" generating IRIG B amplitude modulated and DC level shift
"H" generating IRIG H DC level shift only

**Response Format "m" Request Local Time Offset**

byte 1 SOH
byte 2 "o" (lower case letter)
byte 3 "m"
byte 4 sign "+" or "-"
byte 5 hours tens
byte 6 hours units
byte 7 ETB

**Response Format "p" Request Path (See Packet "P")**

byte 1 SOH
byte 2 "o" (lower case letter)
byte 3 "p"
byte 4 "0" - "F" path upper nibble
byte 5 "0" - "F" path lower nibble
byte 6 ETB

**Upper Nibble Bit Definitions**

| | | |
|---|---|---|
| bit 3 | 0 = normal time format (default) | 1 = long second format (See Note.) |
| bit 2 | 0 = no broadcast of RTC (default) | 1 = send packet "o" "0" each sec. |
| bit 1 | 0 = use GPS leap seconds (default) | 1 = ignore GPS leap seconds |
| bit 0 | 0 = FIFO echo off (default) | 1 = FIFO echo on |

**Lower Nibble Definitions**

| | | |
|---|---|---|
| bit 3 | 0 = enable TFP disciplining (default) | 1 = disable TFP discipline |
| bit 2 | 0 = enable jamsynch (default) | 1 = disable jamsynch |
| bit 1 | Not used. Return value not defined. | |
| bit 0 | 0 = Accept Day 000 | 1 = Day 000 invalid (default) |



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**Response Format "q" Request Disciplining Gain**

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "o" (lower case letter) |
| byte | 3 | "q" |
| byte | 4 | "0" - "F" least significant nibble |
| byte | 5 | "0" – "F" second nibble |
| byte | 6 | "0" – "F" third nibble |
| byte | 7 | "0" - "F" most significant nibble |
| byte | 8 | sense: "1" = positive, "0" = negative |
| byte | 9 | ETB |

**Response Format "t" Request Oscillator Jumper Settings – this packet reports the state of the shunts on the J9 jumper block.**

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "o" (lower case letter) |
| byte | 3 | "t" |
| byte | 4 | "0" |
| byte | 5 | code |
| byte | 6 | ETB |

**Code Responses**

| | |
|---|---|
| "0" | External Oscillator |
| "1" | X72 Oscillator |
| "2" | OCXO |
| "3" | VCXO |



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### 4.1.14 PACKET "P" PATH SELECTION

The path selection might better be called a switch or branch selector. The purpose of this packet is to allow the user to exercise control over certain TFP processes. The path packet is used to download a single byte. Each bit in the byte has a toggling action relative to a TFP function. The format is described below.

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "P" |
| byte | 3 | "0" - "F" path upper nibble |
| byte | 4 | "0" - "F" path lower nibble |
| byte | 5 | ETB |

**Upper Nibble Bit Definitions**

| | | |
|---|---|---|
| bit 3 | 0 = normal time format (default) | 1 = long second format (See Note.) |
| bit 2 | 0 = no broadcast of RTC (default) | 1 = broadcast packet "o" "0" each second |
| bit 1 | 0 = use GPS leap seconds (default) | 1 = ignore GPS leap seconds |
| bit 0 | 0 = FIFO echo off (default) | 1 = FIFO echo on |

**Lower Nibble Definitions**

| | | |
|---|---|---|
| bit 3 | 0 = enable TFP disciplining (default) | 1 = disable TFP discipline |
| bit 2 | 0 = enable jamsynch (default) | 1 = disable jamsynch |
| bit 1 | Not used, write 0 | |
| bit 0 | 0 = Accept Day 000 | 1 = Day 000 invalid (default) |

***Note***: TIME0 through TIME4 contain atomic seconds since January 6, 1980. Use only in GPS Mode. (See Table 4-2.)

#### 4.1.14.1 LOWER NIBBLE BIT DESCRIPTIONS

**Bit 0**

In Time Code mode (Mode 0) it is sometimes desired to use day 000. This is an invalid code in IRIG time codes and clearing this bit overrides the normal checking and allows a board lock on this otherwise invalid code. See Chapter Three for a description of the TIME fields (offset 0x0C).

***Note***: Day 001 is always January 1 as per IRIG specifications. We allow day 000 only for those people that want this capability, say for testing purposes (many time-code generators start with Day 000), and are not bothered by an extra day in the year roll over.



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**Bit 1**
This bit is not used. Write a value of 0 to this bit when the packet is used.

**Bit 2**
Jamsynch is a method employed to match the output 1pps signal to the input time mark. If you change modes of operation on a warmed up unit and want to rush the re-synchronizing you can enable jamsynch, then use Packet "C" to force a jamsynch of the unit, which will cause the 1pps signal to be reset to the time-mark time. There are disadvantages to using this method. If a strobe was scheduled for a time between the flywheeling time and the jamsynch it will be missed in the jump to the new time. There is also a break in the lock for a couple of seconds. Jamsynchs are ineffective on a cold unit that has the oscillator changing frequency at a high rate during warm up.

**Bit 3**
Oscillator disciplining might be disabled if you were using an external clock source that requires a different disciplining routine and you are using the on-board DAC and disciplining through a Packet "D."

### 4.1.14.2 UPPER NIBBLE BIT DESCRIPTIONS

**Bit 0**
When enabled, packets written to the INPUT FIFO will be automatically echoed to the OUTPUT FIFO.

**Bit 1**
This bit is used when you want to report UTC time instead of GPS time. The change is that leap seconds are added to the time to derive UTC.

**Bit 2**
When enabled, the RTC data is automatically inserted into the OUT-FIFO every second. This could be useful if you have a system that is maintaining two different times such as UTC and local time.

**Bit 3**
In GPS mode (Mode 5 or 6) you may want to report the time in seconds from the start of the GPS epoch (seconds from start of January 6, 1980). Some systems may find it easier to deal with time strictly in seconds. The table below reflects that fields TIME1 and TIME2 contain a 32 bit contiguous binary number representing GPS Epoch seconds. The minor time remains in decimal sub-seconds as reflected by Table 4-2.



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**Table 4-2**
**Time0 through Time4 Fields**

| Bit # | 15-12 | 11-8 | 7-4 | 3-0 |
|---|---|---|---|---|
| **TIME0 Field** | Not Defined. | Not Defined. | Status. | Unused. |
| **TIME1 Field** | $2^{28}$ Seconds. | $2^{24}$ Seconds. | $2^{20}$ Seconds. | $2^{16}$ Seconds. |
| **TIME2 Field** | $2^{12}$ Seconds. | $2^{8}$ Seconds. | $2^{4}$ Seconds. | Seconds. |
| **TIME3 Field** | 10E-1 Seconds. | 10E-2 Seconds. | 10E-3 Seconds. | 10E-4 Seconds. |
| **TIME4 Field** | 10E-5 Seconds. | 10E-6 Seconds. | 10E-7 Seconds. | Not Defined. |

### 4.1.15 PACKET "Q" SET DISCIPLINING GAIN

This packet allows the gain and sense of the disciplining process to be set via the host bus. Originally this feature was used for Symmetricom developmental purposes, but it would also be indispensable to anyone attempting to discipline an external oscillator using the TFP. The format is as follows. The gain can be set as an eight bit value (for backwards compatibility) using:

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "Q" |
| byte | 3 | "0" - "F" least significant nibble |
| byte | 4 | "0" - "F" most significant nibble |
| byte | 5 | sense: "1" = positive, "0" = negative |
| byte | 6 | ETB |

Or as a 16 bit value (to support oscillators that require high gain, for example X72) using:

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "Q" |
| byte | 3 | "0" - "F" least significant nibble |
| byte | 4 | "0" – "F" second nibble |
| byte | 5 | "0" – "F" third nibble |
| byte | 6 | "0" - "F" most significant nibble |
| byte | 7 | sense: "1" = positive, "0" = negative |
| byte | 8 | ETB |



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### 4.1.16 PACKET "S" SET YEAR

This packet allows users to set the year in Modes 0, 1, and 2. This is necessary to get the leap year calculator to function in these modes. After writing the year you must wait at least one full second before reading it back using the "O" packet. At powerup the TFP defaults to year 00.

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "S" |
| byte | 3 | years tens |
| byte | 4 | years units |
| byte | 5 | ETB |

### 4.1.17 PACKET "U" USER LED DECIMAL POINT

This packet allows users to control the end panel LED decimal point named User. See Table 6-1 in section 6.0 for a description of the User decimal point. At powerup the User decimal point defaults to the off state.

| | | |
|---|---|---|
| byte | 1 | SOH |
| byte | 2 | "U" |
| byte | 3 | state |
| byte | 4 | ETB |

**State Options**

| | |
|---|---|
| "1" | LED Decimal point on |
| "0" | LED Decimal point off (default) |



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# CHAPTER FIVE
# PROGRAMMING EXAMPLES

## 5.0 GENERAL

The example code fragments in this chapter are written in the C programming language. The examples have been tested at Symmetricom, and should be transportable to most programming environments. A system dependent base address is defined below where "YYYY" indicates a 64 kbyte page of memory used for A16 data and "SSSS" indicates the SW1 and SW2 switch settings.

```
#define BASE            0xYYYYSSSS
```

The following definitions pertain to FIFO data transfer.

```
#define SOH             0x01
#define ETB             0x17
#define FIFO            (short*)(BASE+0x27)
```

The following global variables are also declared and used throughout this chapter.

```
short   dummy, *readptr, time[5] ;
long    i ;
```

## 5.1 READING TIME ON DEMAND

The following example reads the time from the TFP registers TIME0 through TIME4 and loads this data into the array time[ ]. The time is latched by reading the TIMEREQ register, and the register is assigned to a global variable. In most cases assignment to a global avoids the possibility that the dummy read operation will be removed by an optimizing compiler (beware).

```
readptr = (short*)(BASE + 0x0A) ;               /* initialize pointer */
dummy = *readptr++ ;                            /* latch time increment pointer */
for(i=0 ; i<5 ; i++)  time[i] = *readptr++ ;    /* read the time registers */
```



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## 5.2 EXTERNAL EVENT TIME CAPTURE

This example sets up the TFP event capture to occur on a rising edge and generate an interrupt. The time capture lockout mechanism is also used.

```
#define EVENT0                  (short*)(BASE+0x16)
#define CMD                     (short*)(BASE+0x24)
#define VECTOR                  (short*)(BASE+0x2C)
#define MASK (short*)           (BASE+0x28)
 #define INTSTAT                (short*)(BASE+0x2A)
#define LEVEL                   (short*)(BASE+0X2E)
#define UNLOCK                  (short*)(BASE+0x20

/* INITIALIZE TFP EVENT HARDWARE */

*CMD = 0x09 ;                   /* enable event and lockout */
*VECTOR = 0x40 ;                /* interrupt vector */
*LEVEL = 0x03 ;                 /* interrupt level set */
*INSTAT = 0x01 ;                /* clear INSTAT bit */
*MASK = 0x01 ;                  /* enable the interrupt */

/* INTERRUPT SERVICE ROUTINE FRAGMENT */

readptr = EVENT0 ;
for(i=0 ; i<5 ; i++)  time[i] = *readptr++;
dummy = *UNLOCK ;               /* release capture lockout */
*INTSTAT = 0x01 ;               /* clear INSTAT bit */
```



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## 5.3 PROGRAM PERIODIC FREQUENCY OF 1,000 HZ

This example uses a generalized send_packet( ) function to program a 1,000 Hz output periodic synchronized to the TFP 1pps epoch.

```
#define ACK          (short*)(BASE+0x22)

void send_packet(char *charptr)
{
*FIFO = SOH ;
while(*charptr) *FIFO = *charptr++ ;      /* load body of packet */
*FIFO = ETB ;
*ACK = 0x81 ;                             /* command TFP & clear ACK */
while(!(*ACK & 0x01)) ;                   /* wait for TFP acknowledge */
}
/* CODE FRAGMENT WHICH SETS PERIODIC */

        send_packet("F500630063") ;              /* 0x0063 = 99 = (100-1) */
```

## 5.4 SET MODE 1 AND THE MAJOR TIME

This example selects the free running mode and sets the TFP major time, using the “B” packet.

```
send_packet("A1") ;                       /* select mode 1 */
*INSTAT = 0x08 ;                          /* clear INSTAT 1pps bit */
while(!(*INSTAT & 0x08) ;                 /* wait for 1pps */
send_packet("B123112233") ;               /* set the days through seconds */
```

## 5.5 SELECT MODE 0 (IRIGB) AND ADVANCE TFP 2.5 MILLISECONDS

The following code fragment selects the mode, timecode, and offset. The last “P" packet is used to disable jamsynchs since the required offset is larger than 990 microseconds. See the “G” packet description for additional details on the jamsynch function.

```
send_packet("A0") ;                       /* select mode 0 */
send_packet("HB") ;                       /* select IRIGB timecode */
send_packet("G+0025000")   ;              /* advance 2.5 milliseconds */
send_packet("P04") ;                      /* disable jamsynchs */
```



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# CHAPTER SIX
# INPUTS AND OUTPUTS

## 6.0 INPUTS AND OUTPUTS

The front panel I/O for the TTM635VME and the TTM350VXI (B-size) consists of an LED time and status display, a BNC timecode input, a BNC timecode output, a 15 pin "D" plug. Two different GPS devices are supported. In the configuration that uses the ACE GPS module a SMB GPS ANT connector is provided. The configuration that uses the Acutime 2000 Smart Antenna has a 15 pin "D" socket. This configuration can also support the now obsolete Acutime Smart Antenna.

The TTM350VXI (C-size) front panel I/O consists of the LED time and status display, a 15 pin "D" plug, a 15 pin "D" socket, and a SMB frequency output (corresponding to J1, pin 13). The C-size unit does not carry the BNC connectors for timecode in/out.

The current TFP time *hr:min:sec* is displayed using seven segment LED digits. The time display is incremented at 990 milliseconds into the current frame. The six LED decimal points indicate the TFP status as shown in Table 6-1. The Tracking, Phase and Frequency decimal points correspond to the three status bits of the TIME0 register (see Table 3-3).

**Table 6-1**
**LED Decimal Point Functions**

| Position | Name | On Indication | Off Indication |
|---|---|---|---|
| Top | GPS Time (1) | No GPS information | TFP has GPS Time |
| 2nd | Tracking (2) | TFP In Flywheel State | TFP Tracking |
| 3rd | Phase | Time offset exceeds limits | Time offset within limits |
| 4th | Frequency | Frequency offset exceeds limits | Frequency offset within limits |
| 5th | RTC Battery | Battery Failed or not installed | Battery OK |
| Bottom | User | Turned on using Packet "U" | Turned off using Packet "U" |

(1) In modes 0-3, the GPS Time LED has the same function as the Tracking LED.
(2) In GPS Mode, the Tracking LED will go off when the TFP has UTC time.

Timecode is input using BNC connector J3 or J1-7 for the TTM635VME and the TTM350VXI (B-size). The TTM350VXI (C-size) requires the timecode input via the J1 15 pin socket. Timecode is output on BNC connector J2 or J1-5. The optional J4 15 pin "D" socket connector can also be configured to support differential DCLS input and output using jumpers JP1, JP2A and JP3. The signals on socket J1 and plug J4 are summarized in Table 6-2 on the following page.



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**Table 6-2**
**Socket J1 and Plug J4 Signals**

| Signals On J1 15 Pin "DS" | | Signals On Optional J4 15 Pin "DP" | |
|---|---|---|---|
| **Pin** | **Signal** | **Pin** | **Signal** |
| 1 | *External 10 MHz Input or Ovenized Oscillator Output | 1 | RS-422 Rx(+) |
| 2 | Ground | 2 | RS-422 Rx(-) |
| 3 | Strobe Output | 3 | RS-422 Tx(+) or DCLS Out(+) |
| 4 | 1 PPS Output | 4 | RS-422 Tx(-) or DCLS Out(-) |
| 5 | Time Code Output (AM) | 5 | Ground |
| 6 | External Event Input | 6 | Not Used |
| 7 | Time Code Input | 7 | GPS 1 PPS |
| 8 | Time Code Return | 8 | GPS RS-422 1 PPS(+) or DCLS In (+) |
| 9 | Oscillator Control Output | 9 | GPS RS-422 1 PPS(-) or DCLS In (-) |
| 10 | Not Used | 10 | Ground |
| 11 | Time Code Output (DCLS) | 11 | GPS RS-422 Tx(-) |
| 12 | Ground | 12 | GPS RS-422 Tx(+) |
| 13 | 1,5,10 MHz Output | 13 | Not Used |
| 14 | External 1 PPS Input | 14 | Ground |
| 15 | Periodics Output | 15 | GPS +12 VDC |

* Pin 1 is an output when the optional ovenized oscillator is installed.



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**Table 6-2**
**TFP Signals on the Optional P2 Connector**

| TFP Signals On VMEbus P2 | |
|---|---|
| **Pin** | **Signal** |
| C1 | Time Code Input |
| C2 | Time Code Return |
| C3 | Time Code Output (DCLS) |
| C4 | Time Code Output (AM) |
| C6 | External Event Input |
| C8 | Strobe Output |
| C9 | Periodic Output |
| C10 | External 1pps Input |
| C11 | 1 PPS Output |
| C12 | 1,5,10MHz Output |
| C22 | 10 MHz Input |
| C24 | Oscillator Control Output |
| C18 C20 | RS-422 Tx(+) Rx(+) |
| A18 A20 | RS-422 Tx(-) Rx(-) |
| A26 | RS-422 Rx(-) GPS |
| C26 | RS-422 Rx(+) GPS |
| A28 | GPS 1 PPS (Note 1) |



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# CHAPTER SEVEN
# ADJUSTMENTS

## 7.0 GENERAL

There is only one adjustment on the TFP module, VR1.

## 7.1 TIME CODE OUTPUT AMPLITUDE ADJUSTMENT

The time code output amplitude is adjusted using the ten turn potentiometer VR1 located just below J2, and is accessible with the TFP in place. A value of one volt RMS is common, as is three volts peak-to-peak on the high cycles. Adjust this value to suit the equipment being driven. The range is zero to twenty-four volts peak-to-peak. For some configurations the output amplitude is fixed by resistors R14 and R15 instead of VR1.



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# CHAPTER EIGHT
# GPS PROCEDURES

## 8.0 ANTENNA MOUNTING

Choose a location for the antenna/receiver as close as possible to vertical, which has a relatively unobstructed view of the horizon, an which will be safe from damage during normal operation of the host vehicle. Dense wood or metal structures will shield the antenna/receiver from satellite signals. The Acutime can receive satellite signals through glass, canvas, and thin fiberglass. If you plan to install the unit in an partially enclosed environment, determine the ability of the Acutime to receive satellite signals before committing to a permanent mount. The unit is designed to withstand the full rigors of the elements and can be mounted in an exposed external location. The only limitation is that the unit's extended performance at temperatures below -40$^{o}$ (C or F) is not warranted. The unit will perform also when partially snow covered, provided the snow is dry. Ice accumulations will eventually shut off performance, only if the ice sheet is continuous. The shape of the unit has been selected partially to minimize rain, snow, and ice accumulation.

The antenna/receiver is an active head antenna. For optimal performance, avoid locating the Acutime within two feet (sixty centimeters) of other antennas, near high vibration areas like engine housings, or near radar installations. If there is a limitation on available mounting locations, ensure that the Acutime is position outside the radar's cone of transmission. Follow the same guidelines when installing the Acutime near satellite communication equipment (e.g., Inmarsat A or C) or microwave dishes. For best results, mount the Acutime below and at least ten feet (three meters) away from satellite communication equipment.

If the unit is being mounted permanently in a microwave installation, e.g., for timing purposes, then care should be exercised to shield the unit from random back-scatter from microwave dishes. Difficulties will be immediately apparent if the unit cannot lock on to satellites or shows a poor ability to track. Protection is afforded by use of ground plane, a metallic shield which is mounted below the desired minimum viewing angle of the antenna unit. In extreme cases, a cone shield extending up to a ten degree horizontal viewing angle may be tried (make allowance for snow and rain drainage). This takes advantage of the fact that low elevation satellites have lowers signal/noise ratios due to increased ionospheric absorption and therefore are less desirable for timing purposes. Such a cone shield will not work well on a moving vehicle such as a marine vessel because of it's rolling and pitching motion.

The Acutime is designated for a pole mount. The threaded socket at the base of the Acutime will accept both a 1" - 14 threads per inch (TPI) straight thread, and a standard ¾" - 14 TPI (NPT) pipe thread. The Acutime only requires hand tightening on the pole mount. For temporary installations on a metallic surface, a magnetic mount may be used (part number 12920-00) together with an adapter (part number 17030). The adapter is threaded 5/8 11 (TPI), the standard survey instrument mounting thread.



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The connector cable should be firmly secured to the support using cable ties so that there is little or no mechanical strain on the seven pin connector.

***Note*:** The Acutime is a valuable instrument and for permanent installations it may be prudent to drill and pin the Acutime mount to discourage theft and prevent accidental loosening. If the Acutime is easily removed, store it in a secure location when not in use.

### 8.0.1 HARDWARE INSTALLATION

**Parts required:**

| PART NUMBER | 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 for installation:**

Small Phillips screwdriver
¼ inch nut driver or open end wrench

**Installation:** (See Figure 1 for visual aid)

1. Remove hole plug from front panel location GPS ANT.
2. 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.
3. Remove nut and washer from 55183 SMB connector.
4. Install two #10 washers (Part number 8029) on 55183 SMB connector.
5. Install 55183 on bc635PCI module. Insert the 55183 SMB connector through front panel and secure the standoffs to the bc635PCI module using four 4001 screws and four 4048 washers. Note that some of the mounting holes on the bc635PCI 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.
6. Install washer and nut to 55183 SMB connector. WARNING: DO NOT OVER TIGHTEN. SMB CONNECTOR CAN BE DAMAGED IF TOO MUCH TORQUE IS APPLIED TO THE NUT.
7. Run cable to the roof and install antenna. Antenna needs clear view of the sky.
8. Hardware installation is complete.



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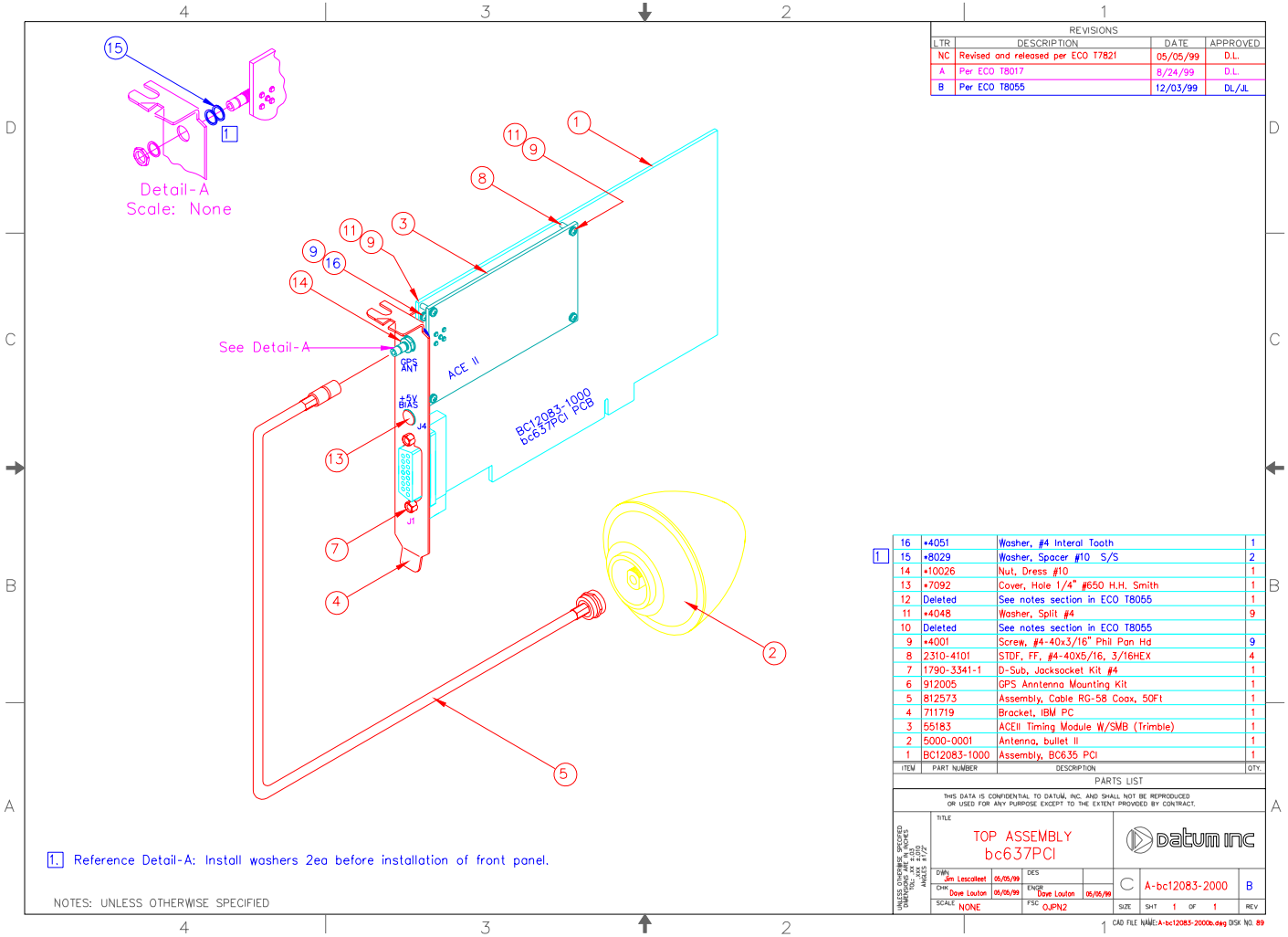



**Figure 1**

## 8.1 GPS INTERFACE

The TTM637VME GPS System consists of a TTM637VME Time and Frequency Module (TFP) equipped with special firmware, an Acutime GPS receiver/antenna module manufactured by Trimble Navigation Ltd., and an interconnecting cable. The TTM637VME module communicates with the Acutime via RS-422 serial (9600 bps) lines. The Acutime also provides a 1pps signal to the TTM637VME.

***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.

## 8.2 GPS TIMING MODE (MODE 6) CHARACTERISTICS

In order to function with the Acutime GPS Receiver the TTM637VME module must operate in Timing Mode 6 (GPS Timing Mode.) This is the default timing mode for the TTM637VME when equipped with the special GPS firmware which is a standard part of the TTM637VME GPS System. The GPS Timing Mode is characterized by the following:

- The 1 PPS signal generated by the Acutime 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 Acutime is tracking a sufficient number of satellites. If too few satellites are tracked then the TTM637VME will flywheel.

- The TTM637VME extracts major time and satellite tracking status information from data packets sent from the Acutime. By default, the TTM637VME 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 Five.

- The TTM637VME provides a communications pathway between the user and the Acutime GPS Receiver. This pathway is most often used to receive GPS data packets for position, velocity, and GPS system status.

- The TTM637VME ignores all other timing sources (i.e. the time code input and external 1 PPS input signals.)



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## 8.3 COMMUNICATING WITH THE GPS RECEIVER

The dual-port RAM (DPRAM) interface described in Chapter Five provides the communications pathway between the user and the Acutime 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 Acutime manuals. The user can determine the packet length from the Acutime documentation. The Acutime 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 TTM637VME automatically adds (when sending packets) and removes (when receiving packets) the header and trailer bytes and handles all byte-stuffing/unstuffing operations. The TTM637VME user should be concerned with the packet length, packet ID, and packet data bytes only.

### 8.3.1 SENDING GPS DATA PACKETS TO THE GPS RECEIVER

To send a GPS data packet to the Acutime 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.



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### 8.3.2 RECEIVING GPS DATA PACKETS FROM THE GPS RECEIVER

The DPRAM GPS Packet Area holds packets received from the Acutime. The TTM637VME 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 TTM637VME 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.

### 8.3.3 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 Acutime to the TTM637VME either periodically (e.g. position fix) or whenever they change (e.g. satellite selection.) The TTM637VME 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 Acutime by the TTM637VME whenever the user requests them. Note that it can take 10's or 100's of milliseconds for the TTM637VME to retrieve a packet from the Acutime. GPS packets that are monitored by the TTM637VME are identified below.



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| 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 | Acutime Firmware Version |
| 0x46 | Yes | Health of Acutime |
| 0x47 | No | Signal Level For All Satellites (***Note***: The first byte returned will be the length of the packet) |
| 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 |

The retrieve packet command works as follows:

- If the requested packet is being monitored and a local copy exists, then the TTM637VME 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 TTM637VME has not yet received a monitored packet, then the TTM637VME must request the packet from the Acutime by sending the appropriate request packet to the Acutime. Once the request has been sent to the Acutime the TTM637VME sets ACK bit 0 to acknowledge the retrieve packet command. Later, when the Acutime responds with the retrieved packet, the TTM637VME transfers the packet to the DPRAM GPS Packet Area and sets ACK bit 2. If the Acutime does not respond to the request within a timeout period (typically 3 seconds), then the TTM637VME 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 TTM637VME sets the packet length byte in the DPRAM GPS Packet Area to zero, sets ACK bit 2, then sets ACK bit 0.



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### 8.3.4 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 Acutime (response packet) and specifies the packet length, ID, and data for the packet to be sent to the Acutime (request packet.) The TTM637VME sends the request packet to the Acutime and transfers the response packet to the DPRAM GPS Packet Area when it arrives. If the response packet ID is 0x00 then the TTM637VME will ignore the response, in which case, this command would be functionally identical to command 0x30. The TTM637VME sets ACK bit 0 once the request packet is sent to the Acutime. Later, when the response packet has been transferred to the DPRAM GPS Packet Area, the TTM637VME sets ACK bit 2. As with command 0x31, if the Acutime fails to respond within a timeout period, the TTM637VME 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 Acutime 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 |



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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 |

## 8.4 ACUTIME GPS RECEIVER

The Acutime GPS Receiver module is manufactured by Trimble Navigation Ltd. in Sunnyvale, Ca. The current generation of the Acutime is a six channel C/A code receiver and antenna integrated in a compact weatherproof housing which mounts like an antenna. Table B-1 lists the Acutime performance specifications.

**Table B-1**
**Acutime Performance Summary**

| Item | Description |
|---|---|
| Number of channels | 6 |
| Receiver Frequency | 1.575 GHz C/A Code |
| Time to First Fix | |
| 1> Brief power off | 1.5 Minutes |
| 2> Needs ephemeris | 3.5 Minutes |
| 3> Needs Almanac | 5 to 15 Minutes |
| Dynamics | |
| 1> Velocity | 300 Meters/Sec (600 Knots) |
| 2> Acceleration | 19.5 m/s/s (2 g's) |
| 3> Jerk | 20 m/s/s/s |
| Position Accuracy | 25 Meters CEP (PDOP < 6) |
| Velocity Accuracy | 0.2 Meters/sec (PDOP < 6) |
| 1pps Accuracy | - 2 Microseconds |
| Solution Modes | |
| 4 Satellite | 3-D Position, Velocity, And Time |
| 3 Satellite | Same As Above (Altitude Hold) |
| 1 Satellite | Static Position Time Only |
| Auto | 1,3,4 Sat. Auto Transitions |
| Power | +12VDC @ 0.2 Amp |



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## 8.5 POSITION FIX MODES

One of the most confusing aspects of GPS operation is the selection of the position fix mode (GPS packet 0x22.) The Acutime 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.



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## 8.6 TTM637VME GPS DEFAULT PARAMETERS

The TTM637VME sends the following GPS packets to the Acutime 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 information in mind:

- The TTM637VME monitors position and velocity packets so the “position” and “velocity” options should be sent with bits 0 and 1 set; the TTM637VME extracts major time from time packets broadcast by the Acutime so the “timing” option should be sent with bits zero, one, and two cleared.



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## 8.7 GPS SYSTEM OVERVIEW

The GPS system consists of three parts called segments:

- The space segment consists of 18 satellites and three spares broadcasting the radio navigation signals.

- The control segment tracks the satellites and uploads orbital information (ephemerides) 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 Acutime operates on the C/A code.

The Acutime 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.

## 8.8 GPS PACKET DEFINITIONS

The following pages describe the GPS packets available with the Acutime GPS Receiver. These pages were taken directly from Trimble Navigation's Acutime Manual (Rev A, 1992). Symmetricom Inc does not take responsibility for the form or content of the folowing pages. Additionally, the section numbers do not follow the same order as this appendix.



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**Trimble Standard Interface Protocol (TSIP)**

**Version 1.15**

## 1.0 INTRODUCTION

Depending how the system designer uses Trimble Standard Interface Protocol (TSIP) to configure the GPS receiver, final system performance can be optimized for any number of applications. For example, an aircraft or vessel operating with an unobstructed view of the sky, will most likely have different GPS operating requirements than vehicle operations in a downtown "urban canyon" environment, where frequent satellite blockages are the rule rather than the exception.

TSIP gives the system designer and unprecedented degree of freedom in choosing settings most appropriate to the task at hand; however, along with this flexibility, comes the responsibility of making intelligent selections which are consistent with each other and the overall system objective.

The GPS receiver is provided with certain factory default settings, which will suffice for a great number of applications. For those requiring customization, application hints are provided for each packet, in the sections that follow. The key operative is to make judicious use of the powerful features TSIP has to offer the system designer. The system designer will greatly enhance overall system performance while reducing development time.

## 1.1 INTERFACE SCOPE

The Trimble Standard Interface Protocol is used in a large number of Trimble 3 and 6 channel board and navigation sensor designs. The protocol was originally defined for the Trimble Advanced Navigation Sensor (TANS) and is colloquially known as the TANS protocol even though applying to many other devices. References in this document to the TANS protocol should not thus be taken to apply to the TANS unit only, but to the whole range of Acutime sensors with the exception of those devices operating with an ASCII interface only. One important difference is that the RS422 version has one bi-directional port only.

For the RS232 Acutime range of sensors there are some particular considerations for the setup of Serial Channel A and Channel B (or Channels 1 & 2).Channel 1 operates in the same way as for all other Trimble 2, 3 and 6 satellite channel sensors, i.e. there is a series of automatic outputs described in the attached Table. Do not confuse the number of satellite channels with the number of serial channels (or ports) - there is no relationship between the two; reference is often made to serial channel or port interchangeably.

The second serial channel is a receive only, i.e. it is intended normally for receipt of RTCM corrections. The default setting on start-up is 9600 baud, 8 bit, odd parity, and 1 stop bit.

This document describes in detail the format of the transmitted data, the packet identification codes, and all available information over the output channel to allow the user to choose the data required for his particular application. As will be discussed, the Acutime transmits some of the information (position and velocity solutions, etc.) automatically when it is available, while other information is transmitted only on request. Additional packets may be defined for



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particular products and these will be covered in the specifications for those products as necessary.



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Some knowledge of the theory of the GPS system is assumed; those readers wishing to refresh their knowledge of the theory are directed to Section 2 of this document for references. The bi-directional channel is the interface for command, control, and data output, for integration with control systems, vehicle tracking and management systems, navigation processors, displays, and other user equipment. The channel protocol is based on the transmission of packets of information between the user equipment and the unit. Each packet includes an identification code (1 byte, representing 2 hexadecimal digits) that identifies the meaning and format of the data that follows. Each packet begins and ends with ASCII control characters.

The PKTMON utility, part of the GPS Software Toolkit, is designed to exercise many of the TSIP packets. The system integrator can use the utility to test the reaction of the sensor to these commands.

## 1.2 KEY ACUTIME SETUP PARAMETERS

Correct selection of the right operating parameters is a major factor in getting the best performance from the sensor. Packets **22** (set fix mode), **2C** (set operating parameters), **35** (set I/O options), and packet **62** (set DGPS mode) are provided to change the receiver setup to the specific conditions of a particular user. The default values for the parameters in these packets are chosen to allow the receiver to operate well under the most varied and demanding conditions. A user may choose to change the default parameters if the receiver is only required to perform in a specific or limited environment. The user should be warned that when the receiver is exposed to operating conditions which are different from the conditions described by the user setup, then the performance may be degraded. A brief description of the main parameters in these packets is given below so that a designer may understand the trade-off involved with a particular setup.

Initially the system designer needs to consider carefully the environment in which the receiver is expected to operate. There is a trade-off between how frequently a position fix is output versus the absolute accuracy of the fix. The system designer needs to decide which takes priority and then make the appropriate selections. This becomes increasingly important when frequent satellite blockages are expected, as in downtown "urban canyon" environments and heavily foliated areas.

If one contrasts the sensor performance required for an aircraft, flying level, or a marine vessel, in a calm sea, with that of a truck or bus being driven in an area of partial or complete blockage due to buildings and trees, then it is clear that different demands are being made on the sensor. Accuracy of the position fix is optimized when the 'Synchronized Measurements' (Packet 35) option is ON. By so doing, the GPS will only output a position fix when it has continuous lock on three or more satellites simultaneously.

In a downtown urban canyon, however, it is difficult to maintain continuous lock on a given satellite constellation for any length of time. The sensor may find it almost impossible to pick up signals simultaneously from 3 or 4 satellites and will also be subject to continuous constellation shifts, since the satellites are frequently blocked from view by tall buildings. Other limitations are also set by the masks for PDOP, elevation and signal strength (SNR). Therefore, the system designer would be satisfied with a lower accuracy provided that fix density (or frequency) is at an acceptable level. Switching the 'Synchronized Measurements' options to OFF, gives the receiver more latitude in selecting and propagating old measurements to yield a position fix, albeit with less accuracy than one which maintained continuous lock.



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The user can check for this condition occurring by setting the Additional Fix Status ON. Packet 5E will identify the number of old measurements being used. Such data is most useful where the sensor is being used as part of a DR system; checking the independence of measurements can be used as a weighting parameter in computing the overall solution from the combined sensor suite. Note also that Minimize Projection is set ON by default; in this case where obscuration occurs, new positions will be computed for 3-4 seconds using the last velocity vector before obscuration occurred. This may not be desirable in combined sensor systems and should therefore be set OFF.

One should also resist the temptation to set the elevation and SNR masks too low. The satellite geometry is sometimes improved considerably by selecting low elevation satellites. They are, however, subject to significant signal degradation by the greater ionospheric and tropospheric attenuation that occurs. They are also subject to more obscuration by the passing scenery when the sensor is in a moving vehicle. The code phase data from those satellites is therefore more difficult to decode and therefore has more noise. If possible the elevation mask should set between 5 and 10 degrees minimum.

The Vehicle Dynamics should also be correctly set so that the search algorithm for satellites operates in optimum fashion if there has been a complete loss of lock with the satellites due to short periods of obscuration. A more detailed discussion of the effects of the various parameters is set out below.

1. **Fix Mode** The preferable fix mode is 3-D, where altitude is calculated along with the latitude, longitude, and time. However, this requires four satellites with a PDOP below the PDOP mask set in packet 2C in order to obtain a position. Normally, this will provide the most accurate solution. Thus, if only 3-D solutions are desired, then the user should request 3-D manual mode. Depending on how the PDOP mask is set, this may be restrictive when the receiver is subjected to frequent obscuration, or when the geometry is poor due to an incomplete constellation.

   Alternatively, if the user only wants a 2-D solution, then 2-D manual should be requested. In this case, the sensor uses either the last altitude obtained in a 3-D fix, or the altitude supplied by the user. However, any error in the assumed altitude will effect the accuracy of the latitude and longitude solution. High accuracy users should avoid this mode and should expect fixes with accuracy's which are at best as accurate as the supplied altitude. If a marine user enters sea-level as the altitude, then small errors in the horizontal solution will occur when the sea state is rough or there are high tidal variations. However, these errors may be smaller than the altitude errors induces by SA, so 2-D may be preferable for a marine user who does not want to observe "unusual" altitudes.

   The default mode is AUTO 2-D/3-D, where the receiver first attempts to obtain a 3-D solution with a PDOP below both the PDOP mask and PDOP switch. If this is not possible, then the receiver attempts to obtain a 2-D solution with a PDOP less than the PDOP mask. This mode supplies fairly continuous position fixes even when there is frequent obscuration. This mode is preferable for most land or air applications, where altitude changes are occurring and there is occasional obscuration.



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2. **Operating Parameters** These parameters are used to define the maximum dynamics the user expects to experience, and also to define the set of satellites which are usable based on the satellite geometry at the user's position.

   (a) **Dynamics Code** The default is AIR mode, where the receiver assumes a high dynamic environment. In this case, the satellite search and reacquisition routines are optimized to tolerate high accelerations. A user which is subject to only benign accelerations (less than 1g) may benefit by selection of LAND or SEA mode where the search and reacquisition routines assume a low acceleration environment. In this case, satellite loss-of-lock is due more often to obscuration rather than extreme dynamics.

   (b) **Elevation Mask** This is the minimum elevation angle for satellites to be used in a solution output by the receiver. Satellites which are near the horizon are typically more difficult to track due to signal attenuation and are also generally less accurate due to higher variability in the ionospheric and tropospheric corruption of the signal. When there are no obstructions, the receiver can generally track a satellite down to near the horizon. However, when this mask is set to low, the receiver may experience frequent constellation switching due to low elevation satellites being obscured. Frequent constellation switching is undesirable because small position jumps may be experienced when SA is present and DGPS is not available to remove these effects. The benefit of a low elevation mask is that more satellites are available for use in a solution and a better PDOP may be yielded. The current mask is set to five degrees and provides a reasonable tradeoff of the benefits and drawbacks. High accuracy users may prefer a mask angle around ten degrees, where the ionosphere and troposphere begin to be more predictable.

   (c) **Signal Level Mask** This mask defines the minimum signal strength for a satellite to be used in a solution. There is some internal hysteresis on this threshold which allows brief excursions below the threshold if lock is maintained and the signal was previously above the mask. The mask has been set to 4.0 in V1.14 and higher versions due to increased tracking capability now included. The mask should only be lowered cautiously since this mask is also used to minimize the effects of jammers on the receiver. High accuracy users may use a slightly higher mask of 5.0-6.0 since weaker measurements may be slightly noisier. However, good performance is available with the default setting.

   (d) **PDOP Mask and Switch** The PDOP mask is the maximum PDOP for which any 2-D or 3-D solution will be made. The switch is the level at which the receiver stops attempting a 3-D solution, and tries for a 2-D solution when in automatic 2-D, 3-D mode. The switch level has no affect on either manual mode. Raising the PDOP mask will generally increase the fix density during obscuration, but the fixes with the higher PDOP will be less accurate (especially with SA present). Lowering the mask will improve the average accuracy at the risk of lowering the fix density.



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3. **Time of Fix Parameters** There are basically three options available for specifying the time of the GPS solution. When a satellite is in a normal continuous tracking mode, the time-of-applicability of the measurements is at 0.25 seconds and 0.75 seconds within each GPS second.

   (a) **Default Mode** In the default mode, the time of solution is the time at which the GPS solution is computed. Thus, all measurements are projected by an interval which is roughly the amount of time it takes to compute the solution. The benefit of this approach is that the receiver provides a solution which is applicable as close to the time of transmission as possible, which minimizes the burden on the user's computer. The drawback is that the measurement projection (which is exactly the same as dead-reckoning with velocity) may induce some error during high accelerations.

   (b) **Integer Second** In the integer second mode, the most recent measurements are projected to next integer second, and the solution is then valid at this time. The benefit of this mode is obviously the standard fix time. The drawbacks are that some measurement projection is performed and that the fix may be slightly older than with the default option.

   (c) **Minimized Projection** In this mode, the time of solution is the time of the most recent measurements. Thus, if all measurements are taken at exactly the same time, then there is no measurement projection. If a selected satellite's measurement time is lagging the most recent measurement, then it is projected to this time. The only penalty is that the fix will be older than a fix provided with the above timing options. This is the best choice for users performing non real-time error analysis, or non real-time DGPS solution-space corrections. This is also the preferable mode for users integrating GPS with other sensors, where communication lags are the dominant latencies, and thus the time lag between the applicability and availability of the fix is small. This option is only available in version 1.14 and higher.

4. **Synchronized Measurements** In this mode, all measurements are required to have the same time tag. This only applies to a six channel receiver, where selected satellites are tracked continuously on their own channel. If a satellite is lost which is in the selected set for the solution, then no fix will be made until a new selection is made. In the usual case (when the Synchronized measurement if off), slightly older measurements are tolerated (on the order of 3-5 seconds) in order to provide solutions when obscurations make it impossible to obtain exactly concurrent measurements from each satellite. The Synchronized measurement mode combined with the minimized projection timing mode allows absolutely no measurement projection. This mode is ideal for vehicles which experience high accelerations and want the highest accuracy. However, obscurations may reduce the fix density when there are limited satellites, so this mode should be used cautiously.

5. **Additional Fix Status** Setting bit three of the auxiliary byte in packet 35 will cause packet 5E to be output with each fix. Packet 5E has been added to give additional information about the fix concerning measurement latency. Packet 3E can be used to request packet 5E. These packets are in versions 1.14 and higher.



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The least significant three bits of byte one of this packet contain the number of measurements used in the fix which were considered old. (Use of an old measurement will immediately cause a new satellite selection.) It turns out that some latency is desirable to "self-aid" the receiver, since a solution which has some projection error is probably good enough to help re-acquisition of lost satellites, and is probably better than no fix at all. These fixes are now flagged as containing old measurements with this packet.

The least significant three bits (Bits 0-2) of byte zero of packet 5E contain the number of measurements used in the current solution that were also used in a previous solution. This gives an indication of how much independent information is contained in each fix. (NB for a three channel sequencing receiver, the channel allocation and fix rate may make it impossible for a new measurement to be taken from each satellite between fixes which are less than a second apart. Thus, it is possible to re-use a measurement in consecutive fixes even though the measurement is not considered old based on the current satellite distribution on sequencing channels). This information is useful when integrating the receiver with additional sensors. The fourth bit (Bit 3) of this byte flags fixes whether Differential Doppler velocity was available.

The fifth bit (Bit 4) of byte zero is used to flag fixes which are computed but are not output since the receiver is converging after being in an approximate position mode. In this case, the receiver says that it is doing fixes but no positions are being output. This condition is now flagged with this bit.

6. **DGPS Mode** In manual DGPS mode, the receiver only computes solutions if corrections are available for the satellites which are selected. This is the most accurate mode, but it is also the most selective, since the fix density is dependent on the availability of corrections. The auto mode avoids the fix density problem but opens the door to the possibility of going in and out of DGPS mode, which will cause position and velocity jumps. If accuracy is critical, one should stick with manual mode. On the other hand, if fix density is critical, auto DGPS is probably safer.

In summary, the default parameters chosen allow the receiver to perform well in almost any environment. The user can optimize the receiver to a particular application if the vehicle dynamics and expected level of obscuration are understood. If the receiver is then taken out of this environment, then a specifically tuned receiver may not operate as well a receiver with the default options. Table 1 shows some possible parameter selections as a function of the dynamics, obscuration, and whether accuracy or fix density is important. (NA: not applicable, DC: don't care, i.e., could be set either way)

**Table 1: Suggested Parameter Settings**

| | High Obscuration | | Low Obscuration | |
|---|---|---|---|---|
| Parameter | Accuracy | Fixes | Accuracy | Fixes |
| Fix mode | man 3D | Auto | man 3D | Auto |
| Elevation mask | 10 | 5 | 10 | 5 |
| Signal mask | 6.0 | 4.0 | 6.0 | 4.0 |
| PDOP mask | 6.0 | 12.0 | 6.0 | 12.0 |
| PDOP switch | NA | 8.0 | NA | 8.0 |
| Timing mode | min proj | DC | min proj | DC |
| Sync meas. | OFF | OFF | ON | ON |
| Min. projection | ON | DC | ON | DC |
| DGPS mode | man ON | DC | man ON | DC |



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## 2.0 APPLICABLE DOCUMENTS

Unless otherwise indicated, the issue of each document which was in effect on 1 May 1987, is the issue to be used.

SS-GPS-300B System Specification for the NAVSTAR Global Positioning System

ICD-GPS-200 NAVSTAR GPS Space Segment/Navigation User Interfaces

17035 Trimble Advanced Navigation Sensor, Specification and User's Manual, Rev. A, October 1990

RTCM (SC-104) RTCM Recommended Standards For Differential NAVSTAR GPS Service, Version 2.0. RTCM Special Committee No. 104. Published by the Radio Technical Commission For Maritime Services, Washington, D.C. January 1, 1990.

GPS - A Guide to the Next Utility - Trimble 1990 - an introduction in non-mathematical terms to the GPS system.

Proceedings - Institute of Navigation Washington DC - A series of 3 abstracts published between 1980 & 1986 of papers from the Journal of the Institute of Navigation. Essential source material for any system designer.

## 3.0 SIGNAL CHARACTERISTICS

### 3.1 General

The user interface signals are EIA RS-422 balanced conductor pairs. For the short line lengths anticipated, the user's receive-end need not be terminated. The format is standard serial, sent least-significant-bit first, at 9,600 baud, with 8 data bits, odd parity, and one stop-bit. "Clear to send" flow control signals are included in the design and should be used to eliminate the possibility of over-run. For details, see Section 3.7 of the manual, *Digital Communication Interface*.

TSIP will also operate with RS-232 configurations.

**Note: Several packets have significant effects on the operation of the Acutime sensor where an external battery back-up is used for the internal memory. These are noted in the text and the system designer should be aware of these effects in the structure of the software.**



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## 3.2 Packet Data Format

Each packet type is described below. Where necessary, specific data formats are given.

The **INTEGER** data type is a 16-bit signed number sent in 2s-complement format, most significant byte first.

A floating-point number, sometimes called "scientific notation" (for decimal numbers), or a **REAL** number, consists of a signed mantissa and a signed exponent. The precision is determined by the number of digits in the mantissa, and the range of expressible values is determined by the number of digits in the exponent. In a non-zero binary floating-point number, the mantissa consists of a "1," followed by the binary point, followed by the fractional part of the mantissa. Note that the leading binary "1" is redundant.

For floating-point numbers, the Acutime uses the ANSI/IEEE Std 754 *IEEE Standard for Binary Floating-Point Arithmetic*, in which the formatted exponent is biased to avoid the use of an exponent sign, the mantissa's redundant leading "1" is omitted, and various special cases are specified. The IEEE 754 standard specifies two degrees of precision, "SINGLE" and "DOUBLE," both of which are used in the Acutime; the DOUBLE-precision format uses more bits both in the mantissa (for greater precision) and in the exponent (for greater range). The IEEE 754 format is described briefly below.

The sign-bit is 1 for a negative number and is 0 for a positive number.

To ensure that the formatted exponent is non-negative, and thus to avoid the use of an exponent sign, the formatted exponent (the *biased exponent*) is the sum of the actual (signed, unbiased) exponent plus a constant (the bias).

The redundant leading "1" is not included; only the fractional part of the mantissa is included and is called the "fraction."

The value *zero* is formatted by setting both the biased exponent and the fraction to zero. Note that this special case must be recognized as zero and not interpreted as described above for a non-zero number.

The IEEE 754 standard specifies various other special cases. For programming and for detailed data analysis, the user should consult the IEEE standard.

The Acutime "SINGLE" data type is a 32-bit (4-byte) single-precision floating-point number in the ANSI/IEEE Std 754 SINGLE (short) format. The first byte sent contains the sign-bit of the mantissa and the 7 most-significant bits of the biased exponent. The second byte contains the least-significant bit of the biased exponent, followed by the 7 most-significant bits of the fraction (the part of the mantissa to the right of the binary point). The remaining 2 bytes complete the fraction. The exponent bias is +127; i.e., the biased exponent is the actual exponent +127. With the implied (unformatted) leading "1," the single-precision mantissa contains 24 significant bits.

The Acutime "DOUBLE" data type is a 64-bit (8-byte) double-precision floating-point number in the ANSI/IEEE Std 754 DOUBLE (long) format. The first byte sent contains the sign-bit of the mantissa and the 7 most-significant bits of the biased exponent. The second byte contains the 4 least-significant bits of the biased exponent, followed by the 4 most-significant bits of the fraction. The remaining 6 bytes complete the fraction. The exponent bias is +1,023. With the implied (unformatted) leading "1," the double-precision mantissa contains 52 significant bits.



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## 3.3 Packet Structure

In both directions of information transmission, the data format conforms to a packet structure as follows. Each packet starts with the two-character sequence.

**<DLE>** the ASCII "data link escape" character, 1 byte, value 10 hex

**<id>** the packet type identification number, 1 byte, expressed as 2 hexadecimal digits. This byte can have any value other than 10 hex (ASCII <DLE>) or 03 hex (ASCII <ETX>). The values and their meanings are given in the remainder of this appendix.

Each packet ends with the two-character sequence.

**<DLE>** the ASCII "data link escape" character, 1 byte, value 10 hex

**<ETX>** the ASCII "end-of-text" character, 1 byte, value 03 hex.

The packet format is shown below.

```
------------------------------------------------------------
<DLE>  <id>   ... data bytes ...  <DLE>  <ETX>
------------------------------------------------------------
```

Each packet data byte can have any 8-bit value, with the one requirement that any data byte of value 10 hex (<DLE>) must be sent twice. The receiving devices (in both the Acutime and the user's data terminal) must compress all occurrences of two <DLE> characters into one <DLE> data byte. The data portion of the packet may be from 0 to 255 bytes long, not counting <DLE> stuffing

### 3.3.1 Packets Sent By The User To Acutime

The table below provides the packet ID numbers sent by the user to Acutime, a short description of each packet, and the identities of the packets which Acutime sends in response. In some cases, the response packets depend on user-selected options. These selections are covered in the packet descriptions below. Details are provided for each packet type in the following sections. Descriptions of some packets assume availability of battery-backed memory; the battery has to be provided externally through pin 5 if required.

| <id> (hex) | Description | Response Packet Sent By Acutime |
|---|---|---|
| 1D | clear oscillator offset | -- |
| 1E | clear battery back-up, then reset | -- |
| 1F | request software versions | 45 |
| 20 | request almanac | 40 |
| 21 | request current time | 41 |
| 22 | mode select (2-D, 3-D, auto) | -- |
| 23 | initial position (XYZ ECEF) | -- |
| 24 | request Acutime position fix mode | 44 |
| 25 | initiate soft reset & self-test (equivalent to cycling power) | 45,46, 4B, 42 or 83 4A or 84 |
| 26 | request health | 46, 4B |
| 27 | request signal level | 47 |



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| | | |
|---|---|---|
| 28 | request GPS system message | 48 |
| 29 | request almanac health page | 49 |
| 2A | altitude for 2-D mode | -- |
| 2B | initial position (Lat, Lon, Alt) | -- |
| 2C | set/request operating parameters | 4C |
| 2D | request oscillator offset | 4D |
| 2E | set GPS time | 4E |
| 31 | accurate initial position (XYZ Cartesian ECEF) | -- |
| 32 | accurate initial position (lat, lon, alt) | |
| 34 | satellite number for 1-sat mode | -- |
| 35 | set/request I/O options | 55 |
| 36 | velocity aiding of acquisition | -- |
| 37 | request status and values of last pos & vel | 57; 42 or 83 or 4A or 84; 43 or 56 |
| 38 | request/load satellite system data | 58 |
| 39 | set/request satellite disable or ignore health | 59 |
| 3A | request last raw measurement | 5A |
| 3B | request satellite ephemeris status | 5B |
| 3C | request tracking status | 5C |
| 3D | configure channel A for RTCM (SC-104) differential GPS | 3D |
| 3E | request additional fix parameters | 5D |
| 62 | set/request differential GPS position fix mode | 82 |
| 65 | request differential correction status | 85 |

#### 3.3.1.1 **1D** Clear Oscillator Offset

This packet commands the Acutime to clear the oscillator offset stored in battery-backed memory. This packet contains one data byte equal to the ASCII letter "C," 43 hex. Note that packet 2D hex can be used to request the current value of the offset; this information is used mainly for service. In normal use, there is no need to send this packet.

#### 3.3.1.2 **1E** Clear Battery Back-up, then Reset

This packet commands the Acutime to clear all battery back-up data and to perform a software reset. This packet contains one data byte equal to the ASCII letter "K," 4B hex.

**CAUTION**

**All almanac, ephemeris, current position, mode, and calibration, information is lost by the execution of this command. In normal use this packet should not be sent.**

#### 3.3.1.3 **1F** Request Software Versions

This packet requests information about the version of software running in the Navigation and Signal Processors. This packet contains no data bytes. The Acutime returns packet 45 hex.



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3.3.1.4 **20** Request Almanac

This packet requests almanac data for one satellite from the Acutime. This packet contains one data byte specifying the satellite PRN number. The Acutime returns packet 40 hex.

3.3.1.5 **21** Request Current Time

This packet requests current GPS time. This packet contains no data. The Acutime returns packet 41 hex.

3.3.1.6 **22** Position Fix Mode Select

This packet commands the Acutime to operate in a specific position fix mode. This packet contains one data byte indicating the mode, as follows:

| Mode | Data byte value | PKTMON key command |
|---|---|---|
| Automatic | 0 (default value) | ^N |
| 1-satellite (0-D) | 1 | ^T |
| 3-satellite (2-D) | 3 | n |
| 4-satellite (3-D) | 4 | N |

This selection is held in battery-backed memory

The 1-satellite (0-D) mode uses a single satellite to determine receiver clock error (time) and error rate (frequency) when the position is known precisely. In this mode, the Acutime computes no positions or velocities. Instead, the Acutime sends packet 54 hex with the clock bias and bias rate. This can be used for time transfer applications and to enable the Acutime to maintain the accuracy of the one pps (Pulse Per Second) output even if a full position fix cannot be done.

3.3.1.7 **23** Initial Position (XYZ Cartesian ECEF)

This packet provides the Acutime with an approximate initial position in Cartesian ECEF (Earth Centered, Earth Fixed) WGS-84 coordinates.
This packet causes a world-wide search for the user's position, starting at the position entered via this packet. That takes about 6 to 10 seconds before the Acutime can provide more fixes. This packet is useful if the user has moved more than about 1,000 miles after the previous fix. (Note that the Acutime can initialize itself without any data from the user; this packet merely reduces the time required for initialization.) This packet does not cause a software reset.

The data format is shown below.

The X-axis points toward the intersection of the equator and the Greenwich meridian, the Y-axis points toward the intersection of the equator and the 90 degree meridian, and the Z-axis points toward the North Pole.



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| Byte # | Item | Type | Units |
|---|---|---|---|
| 0-3 | X | SINGLE | meters |
| 4-7 | Y | SINGLE | meters |
| 8-11 | Z | SINGLE | meters |

3.3.1.8 **24** Request Acutime Position Fix Mode

This packet requests current position fix mode of the Acutime. This packet contains no data. The Acutime returns packet 44 hex.

3.3.1.9 **25** Initiate Soft Reset & Self Test

This packet commands the Acutime to perform a software reset. This is equivalent to cycling the power. The Acutime performs a self-test as part of the reset operation. This packet contains no data. The Acutime returns packets 41, 45, 46, 4B, (42 and 4A) or (83 and 84), all hex. The Acutime sends packet 45 hex only on power-up and reset (or on request); thus if packet 45 appears unrequested, then either the Acutime power was cycled or the Acutime was reset.

3.3.1.10 **26** Request Health

This packet requests health and status information from the Acutime. This packet contains no data. The Acutime returns packet 46 hex and 4B hex.

3.3.1.11 **27** Request Signal Levels

This packet requests signal levels for all satellites currently being tracked. This packet contains no data. The Acutime returns packet 47 hex.

3.3.1.12 **28** Request GPS System Message

This packet requests the GPS system ASCII message sent with the navigation data by each satellite. This packet contains no data. The Acutime returns packet 48 hex.

3.3.1.13 **29** Request Almanac Health Page

This packet requests the Acutime to send the health page from the almanac. This packet contains no data. The Acutime returns packet 49 hex.

3.3.1.14 **2A** Altitude for 2-D Mode

This packet provides the altitude to be used for Manual 2-dimensional (3 satellite) mode. This altitude is used for Auto 2-D mode until a 3-D fix is performed. This packet contains one SINGLE number (4 bytes) specifying the altitude in meters, using the WGS-84 model of the earth or MSL geoid altitude depending on I/O options (set by packet 35). This altitude value is held in battery-backed memory.



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3.3.1.15 **2B** Initial Position (Latitude, Longitude, Altitude)

This packet provides the Acutime with an approximate initial position in latitude and longitude coordinates (WGS-84). This packet causes a world-wide search for the user's position, starting at the position entered via this packet. That takes about 6 to 10 seconds before the Acutime can provide more fixes. This packet is useful if the user has moved more than about 1,000 miles after the previous fix. (Note that the Acutime can initialize itself without any data from the user; it merely requires more time.) This packet does not cause a software reset.

The data format is shown below.

| Byte # | Item | Type | Units |
|---|---|---|---|
| 0-3 | latitude | SINGLE | radians, north |
| 4-7 | longitude | SINGLE | radians, east |
| 8-11 | altitude | SINGLE | meters |

3.3.1.16 **2C** Set/Request Operating Parameters

This packet optionally sets the operating parameters of the Acutime receiver and requests the current values after setting them. The data format is shown below. The Acutime returns packet 4C hex.

The dynamics code indicates the expected vehicle dynamics and is used to assist the initial solution.

The elevation angle mask determines the lowest angle at which the Acutime tries to track a satellite.

The signal level mask sets the required signal level for a satellite to be used for position fixes.

The PDOP mask sets the maximum PDOP with which position fixes are calculated. The PDOP switch selects the 2-D and 3-D mode. If 4 or more satellites are available and the resulting PDOP is not greater than the PDOP switch value, then 3-dimensional fixes are calculated. The PDOP switch is effective only in the automatic 2-D/3-D mode.

| Byte # | Item | Type | Units | Default value |
|---|---|---|---|---|
| 0 | Dynamics code | BYTE | 3 (see table) | |

| Value | Meaning | Assumed velocity |
|---|---|---|
| 0 | Current value is left unchanged. | |
| 1 | land | < 120 knots |
| 2 | sea | < 50 knots |
| 3 | air (default) | < 800 knots |
| 4 | static | stationary |

| | | | | |
|---|---|---|---|---|
| 1-4 | Elevation angle mask | SINGLE | radians | 0.1745 (10 degrees) |
| 5-8 | Signal level mask | SINGLE | --- | 6 |
| 9-12 | PDOP mask | SINGLE | --- | 12 |
| 13-16 | PDOP switch (3-D or 2-D) | SINGLE | --- | 8 |



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A negative value in a SINGLE field leaves that current setting unchanged.

This information is held in memory.

Mode 4 selection informs the Acutime that it is stationary. Any position fix computed or provided via the data channels is assumed to be accurate indefinitely. When the dynamics code is set to static (byte value = 4) and the fix mode is automatic (set by packet 22 hex), then the Acutime enters automatic 1-satellite mode when a position fix cannot be performed but there is at least one usable satellite. In this mode, no positions or velocities are computed. Instead, the Acutime sends packet 54 hex with the clock bias and bias rate. As long as the Acutime is truly stationary, this mode can be used for time transfer applications and to enable the Acutime to maintain the accuracy of the one pps (Pulse Per Second) output even if a full position fix cannot be done.

### 3.3.1.17 **2D** Request Oscillator Offset

This packet requests the calculated offset of the Acutime master oscillator. This packet contains no data. The Acutime returns packet 4D hex. This packet is used mainly for service. The permissible oscillator offset varies with the particular Acutime unit.

### 3.3.1.18 **2E** Set GPS Time

This packet provides the approximate GPS time of week and the week number to the Acutime. The Acutime returns packet 4E hex. The data format is shown below. The GPS week number reference is Week # 0 starting January 6, 1980. The seconds count begins at the midnight which begins each Sunday morning.

| Byte # | Item | Type | Units |
|---|---|---|---|
| 0-3 | GPS time of week | SINGLE | seconds |
| 4-5 | GPS week number | INTEGER | weeks |

This packet normally is not needed as the internal battery-powered clock keeps time to sufficient accuracy for finding position rapidly.

### 3.3.1.19 **31** Accurate Initial Position (XYZ Cartesian ECEF)

This packet is identical in content to packet 23 hex. This packet provides an initial position to the Acutime in XYZ coordinates. However, the Acutime assumes the position provided in this packet to be accurate. This packet is used for satellite acquisition aiding in systems where another source of position is available and in time transfer (one-satellite mode) applications. For acquisition aiding, the position provided by the user to the Acutime in this packet should be accurate to a few kilometers. For high-accuracy time transfer, position should be accurate to a few meters.



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3.3.1.20 **32** Accurate Initial Position (Latitude, Longitude, Altitude)

This packet is identical in content to packet 2B hex. This packet provides the Acutime with an approximate initial position in latitude, longitude, and altitude coordinates. However, the Acutime assumes the position provided in this packet to be accurate. This packet is used for satellite acquisition aiding in systems where another source of position is available and in time transfer (one-satellite mode) applications. For acquisition aiding, the position provided by the user to the Acutime in this packet should be accurate to a few kilometers. For high-accuracy time transfer, position should be accurate to a few meters.

3.3.1.21 **33** Request A-to-D Readings

Since the Acutime does not have an internal A-to-D chip, this function is not supported.

3.3.1.22 **34** Satellite Number For One-Satellite Mode

This packet allows the user to control the choice of the satellite to be used for the one-satellite mode. This packet contains one byte. If the byte value is 0, the Acutime chooses the usable satellite with the highest elevation above the horizon. This automatic selection of the highest satellite is the default action, and the Acutime does this unless it receives this packet. If the byte value is from 1 to 32, the packet specifies the PRN number of the satellite to be used. This selection is not kept in battery-backed memory.

3.3.1.23 **35** Set/Request I/O Options

This packet requests the current I/O option states and optionally allows the I/O option states to be set as desired. Please review the discussion in Section 1.2 to help in selection of the right settings. To request the option states without changing them, the user sends only the packet "<DLE> (35 hex) <DLE> <ETX>" with no data bytes included. To change any option states, the user includes 4 data bytes with the values indicated below in the packet. The I/O options, their default states, and the byte values for all possible states are shown below. A glossary is given at the end of the table. These option states are held in battery-backed memory. The Acutime returns packet 55 hex.



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| Byte # | Parameter Name | Bit Position | Default Bit Value | Option | Associated Packet |
|---|---|---|---|---|---|
| 0 | position | 0 (LSB) | 1 | XYZ ECEF Output<br>0: off<br>1: on | 42 or 83 |
| | | 1 | 0 | LLA Output<br>0: off<br>1: on | 4A or 84 |
| | | 2 | 0 | LLA ALT Output<br>0: HAE WGS-84<br>1: MSL geoid | 4A or 84<br>or 8F-01<br>or 8F-02 |
| | | 3 | 0 | ALT input<br>0: HAE WGS-84<br>1: MSL geoid | 2A |
| | | 4 | 0 | precision-of-position output<br>0: Send single-precision packet 42 and/or 4A.<br>1: Send double-precision packet 83 and/or 84. | |
| | | 5 | 0 | Superpacket output<br>0: off<br>1: on | |
| | | 6 | 0 | Superpacket format<br>0: binary<br>1: ASCII | |
| | | 7 | 0 | unused | |

Note: If bit 5 is 0 then no Superpackets are output. If bit 5 and 6 are 1 then packet 8E-01 is output. If bit 5 is 1 and 6 is 0 then packet 8F-02 is. If Superpacket output is selected then 8F-01 or 8F-02 packets are output instead of the standard 4A or 84 packets.

| | | | | | |
|---|---|---|---|---|---|
| 1 | velocity | 0 | 1 | XYZ ECEF Output<br>0: off<br>1: on | 43 |
| | | 1 | 0 | ENU Output<br>0: off<br>1: on | 56 |
| | | 2-7 | 0 | unused | |
| 2 | timing | 0 | 0 | time type<br>0: GPS time<br>1: UTC | |
| | | 1 | 0 | fix computation time<br>0: ASAP<br>1: next integer sec | |
| | | 2 | 0 | output time<br>0: when computed<br>1: only on request | 37 |
| | | 3 | 0 | Synchronized measurements<br>0: off<br>1: on | |



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| | | | | | |
|---|---|---|---|---|---|
| | | 4 | 0 | Minimize Projection | (V1.14 onwards) |
| | | | | 0: on | |
| | | | | 1: off | |
| | | 5-7 | 0 | unused | |
| 3 | Auxiliary | 0 | 0 | raw measurements | 5A |
| | | | | 0: off | |
| | | | | 1: on | |
| | | 1 | 0 | Doppler smoothed codephase (V1.12 onwards) | |
| | | | | 0: raw | |
| | | | | 1: smoothed | |
| | | 2 | 0 | Additional Fix Status(V1.14 onwards) | 5E |
| | | | | 0: off | |
| | | | | 1: on | |
| | | 3 - 7 | unused | | |

Glossary for the table above:

| | |
|---|---|
| ALT: | Altitude |
| ECEF: | Earth-centered, Earth-fixed |
| XYZ: | Cartesian coordinates |
| LLA: | latitude, longitude, altitude |
| HAE: | height above ellipsoid |
| WGS-84: | Earth model (ellipsoid) |
| MSL geoid: | Earth (mean sea level) mode |
| UTC: | coordinated universal time |

### 3.3.1.24 **36** Velocity Aiding of Acquisition

In this packet the user provides velocity information to the Acutime from an external source to aid in satellite acquisition and reacquisition.

| Byte | Item | Type | Units |
|---|---|---|---|
| 0 | Coordinate select | BYTE | |

| Byte Value | Meaning |
|---|---|
| 0 | XYZ |
| 1 | ENU (East, North, Up) |

| | | | |
|---|---|---|---|
| 1 | Velocity aiding enable flag | BYTE | |

| Byte Value | Meaning |
|---|---|
| 0 | disable velocity aiding |
| 1 | enable velocity aiding (See note below.) |

| Byte Value | Meaning | | |
|---|---|---|---|
| 2-5 | X or East velocity | SINGLE | meters/second |
| 6-9 | Y or North velocity | SINGLE | meters/second |



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| | | | |
|---|---|---|---|
| 10-13 | Z or Up velocity | SINGLE | meters/second |

If the velocity aiding enable flag is set to "1," the Acutime assumes that the velocity data is accurate to 25 meters per second or better and that it can be used for aiding. The Acutime continues to use this data until another packet 36 hex is sent with the aiding enable flag set to "0" (to disable velocity aiding).
Once aiding has begun, the Acutime must be informed (via a new packet 36) of any velocity changes greater than 25 meters per second until velocity aiding is disabled. Once acquisition occurs, the aiding data is ignored; but if acquisition later is lost, then the aiding data is used again.

### 3.3.1.25 **37** Request Status and Values of Last Position and Velocity

This packet requests information regarding the source codes, time of last fix, and GPS week and UTC offset. The Acutime returns packet 57 and the appropriate position packet 42 or 4A, or 83 or 84, and the appropriate velocity packet 43 or 56, based on the I/O options in effect.

### 3.3.1.26 **38** Request/Load Satellite System Data

This packet is not supported by the GPS Software Toolkit - PKTMON. This packet requests current satellite data (almanac, ephemeris, etc.) or permits loading initialization data from an external source (for example, by extracting initialization data from an operating Acutime unit via a data logger or computer and then using that data to initialize a second Acutime unit). The Acutime returns packet 58. (Note that the Acutime can initialize itself without any data from the user; it merely requires more time.)

To request data without loading data, use only bytes 0 through 2; to load data, use all bytes. Before loading data, observe the caution notice below.

| Byte # | Item | Type | Byte value | Meaning |
|---|---|---|---|---|
| 0 | Operation | BYTE | | |
| | | | 1 | Request data from Acutime |
| | | | 2 | Load data into Acutime |
| 1 | Type of data | BYTE | | |
| | | | 1 | not used |
| | | | 2 | Almanac |
| | | | 3 | Health page, T_oa, WN_oa |
| | | | 4 | Ionosphere |
| | | | 5 | UTC |
| | | | 6 | Ephemeris |
| 2 | Sat PRN # | BYTE | | |
| | | | 0 | data that is not satellite-ID-specific |
| | | | 1 to 32 | satellite PRN number |
| 3 | length (n) | BYTE | number of bytes of data to be loaded | |
| 4 to n+3 | data | n BYTES | | |



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**CAUTION**

**Proper structure of satellite data is critical to Acutime operation. Dataformat, content, and protocol should be obtained through consultation with Trimble Navigation before use of this feature.**

3.3.1.27 **39** Set/Request Satellite Disable or Ignore Health

Normally the Acutime selects satellites for use in GPS solution according to whether the candidate satellites are in good health and whether they satisfy the mask values for elevation angle, signal level, and PDOP. This packet allows the user to tell the Acutime either to disable unconditionally the selection of any particular satellite or to ignore the health of any particular satellite that otherwise is acceptable for selection. The Acutime returns packet 59.

It should be noted that when viewing the satellite disables list, the satellites are not numbered but are in numerical order. The disabled satellites are signified by a "1" and enabled satellites are signified by a "0".

| Byte # | Item | Type | Byte value | Meaning |
|---|---|---|---|---|
| 0 | Operation | BYTE | 1 | Enable for selection (default) |
| | | | 2 | Disable for selection |
| | | | 3 | Request enable-or-disable status of all 32 satellites |
| | | | 4 | Heed health on satellite (default) |
| | | | 5 | Ignore health on satellite |
| | | | 6 | Request heed-or-ignore status on all 32 satellites |
| 1 | Satellite # | BYTE | 0 | all 32 satellites |
| | | | 1 to 32 | any one satellite PRN number |

This information is not held in battery-backed memory. At power-on and after a reset the default values are set for all satellites.

**CAUTION**

**Improperly ignoring health can cause the Acutime software to lock up, as an unhealthy satellite may contain defective data. Generally, such software lock-up is cleared by the Acutime user, although improper data can cause the Acutime software to lock up immediately after turn-on, so that the battery-backed memory cannot be cleared except by instrument service. (The Acutime is not damaged physically by this, but it may be unusable until it is serviced). Use extreme caution in ignoring satellite health.**



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3.3.1.28 **3A** Request Last Raw Measurement

This packet requests the most recent raw measurement data for one specified satellite. The Acutime returns packet 5A hex.

| Byte # | Item | Type | Byte value | Meaning |
|---|---|---|---|---|
| 0 | Satellite # | BYTE | 0 | All satellites in the current tracking set |
| | | | 1-32 | Desired satellite |

3.3.1.29 **3B** Request Current Status Of Satellite Ephemeris Data

This packet requests the current status of satellite ephemeris data. The Acutime returns packet 5 B hex.

| Byte # | Item | Type | Byte value | Meaning |
|---|---|---|---|---|
| 0 | Satellite # | BYTE | 0 | All satellites in the current tracking set |
| | | | 1-32 | Desired satellite |

3.3.1.30 **3C** Request Current Satellite Tracking Status

This packet requests the current satellite tracking status. The Acutime returns packet 5C hex.

| Byte # | Item | Type | Byte value | Meaning |
|---|---|---|---|---|
| 0 | Satellite # | BYTE | 0 | All satellites in the current tracking set |
| | | | 1-32 | Desired satellite |

3.3.1.31 **3D** Request or Set Data Channel A Configuration for Differential Corrections

This packet is not supported by the GPS Software Toolkit - PKTMON. This packet requests, and optionally sets, the data channel A configuration for differential corrections. This configuration includes the baud rate, number of bits, parity, and number of stop bits for channel A and also the language mode. When this packet is used only to request the configuration the packet contains no data bytes. When this packet is used to set the configuration, the packet contains the data bytes shown below.

The language mode is defined as follows. For transmission, the language mode specifies whether packets are output on channel A. For reception, the language mode specifies whether packets or RTCM data are received on channel A.(1)

The baud rate for the transmitter and the receiver can be set independently; but the number of bits, parity, and the stop bits are common between them. The default mode is packets for both transmission and reception at 9,600 baud with 8 data bits, odd parity, and one stop bit.



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When the language mode for reception is set to RTCM (SC-104), raw RTCM (SC-104) data is accepted on channel A for differential GPS corrections. These corrections are used only if the GPD mode is set to manual GPD or automatic with packet 62.

When a Acutime receives a packet 3D with no data bytes, it responds with packet 3D with current settings.

(1) Note: The default of byte 5 is set to RTCM automatically on start-up, with default settings for the port at; 9600, 8, o, and 1.

| Byte | Item | Type | Units | | | |
|---|---|---|---|---|---|---|
| 0 | XMT Baud Rate code | BYTE | 0: | 50 | 8: | 2400 |
| | | | 1: | 110 | 9: | 4800 |
| | | | 4: | 300 | 11: | 9600 |
| | | | 5: | 600 | 12: | 38.4K |
| | | | 6: | 1200 | 28: | 19.2K |
| 1 | RCV Baud Rate code | BYTE | 0: | 50 | 8: | 2400 |
| | | | 1: | 110 | 9: | 4800 |
| | | | 4: | 300 | 11: | 9600 |
| | | | 5: | 600 | 12: | 38.4K |
| | | | 6: | 1200 | 28: | 19.2K |

| Byte | Item | Type | Units | | |
|---|---|---|---|---|---|
| 2 | Parity and # bits/char code | BYTE | xxxpppbb | | |
| | | | ppp: | | |
| | | | | 0: | even parity |
| | | | | 1: | odd parity |
| | | | | 4: | no parity |
| | | | bb: | | |
| | | | | 2: | 7 |
| | | | | 3: | 8 |
| 3 | Stop bits code | BYTE | 7: | 1 stop bit | |
| | | | 15: | 2 stop bits | |
| 4 | Language mode for Transmission | BYTE | 0: | Packets | |
| | | | 1: | off | |
| | | | 5: | NMEA | |
| 5 | Language mode for Reception | BYTE | 0: | Packets | |
| | | | 1: | RTCM (SC-104) | |

Notes: 1) In most RS232 versions of the sensor, RTCM input for the second channel is the default mode at power-on to allow for direct connection to a radio modem. Note that the default speed is 9600,8,o,1.

2) If the bit is set to 5, then output is standard NMEA ASCII, GGA + VTG. See Appendix 3 for syntax.

This information is held in battery-backed memory. After loss of battery-backed memory, the default values are set.



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### 3.3.1.32 **3E** Request Additional Fix Parameters

This packet is sent to request the attributes of a position fix, i.e. the number of old measurements used in the fix, whether differential Doppler velocity is available, and whether the fix has converged. The response is Packet 5E. Note also that Packet 35 can be set to request Packet 5E automatically.

### 3.3.1.33 **62** Request/Set Differential Position Fix Mode

This packet requests and optionally sets the differential position fix mode of the Acutime. When this packet is used to request the mode the packet contains no data bytes. When this packet is used to set the mode the packet contains only one data byte to specify the mode. In response, the Acutime always sends packet 82 which contains the current mode.

The following modes can be set:

| | |
|---|---|
| 0 | Manual GPS (Differential off) (default) |
| 1 | Manual GPD (Differential on) |
| 2 or 3 | Automatic |

"Manual GPS" (mode 0) sets the Acutime to do position solutions without differential corrections, even if the differential corrections are available.

"Manual GPD" (mode 1) sets the Acutime to do position solutions only if valid differential correction data are available.

"Automatic" (data byte value = either 2 or 3): The Acutime automatically sets itself to mode 2 (differential currently off) if the Acutime is not receiving differential correction data for all satellites in a constellation which meets all other masks; and the Acutime automatically sets itself to mode 3 (differential currently on) if the Acutime is receiving differential correction data for all satellites in a constellation which meets all other masks. Packet 82 which the Acutime sends in response to receiving packet 62, indicates whether the Acutime currently is in mode 2 or 3.

An attempt to set a mode outside this set results in simply requesting packet 82.

The selected mode (manual GPS, manual GPD, or automatic) is held in battery-backed memory.

### 3.3.1.34 **65** Request Differential Correction Status

This packet requests the status of differential corrections for a specific satellite or for all satellites for which data is available. This packet contains only one byte specifying the PRN number of the desired satellite or zero to request all available. The response is a packet 85 for each satellite.



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### 3.3.2 Packets Sent By Acutime To The User

The table below provides the packet ID numbers sent by the Acutime to the user, a short description of each packet, and an indication of when the packet is sent. Details are provided for each packet type in the following sections.

| Id (hex) | Description | When Sent | | | |
|---|---|---|---|---|---|
| | | Power-up | Auto-matic | If selected | Response to Packet Number |
| 40 | almanac data for specified sat | | X | | 20 |
| 41 | GPS time | X (1) | X (1) | | 21 |
| 42 | single-precision XYZ position | X (2) | | X | 25, 37 |
| 43 | velocity fix (XYZ ECEF) | | | X | 37 |
| 44 | satellite selection, PDOP, mode | | | X | 24 |
| 45 | software version information | X | | | 1F, 25 |
| 46 | health of Acutime | | X | X | 25, 26 |
| 47 | signal level for all satellites | | | | 27 |
| 48 | GPS system message | | | | 28 |
| 49 | almanac health page for all sats | | | X | 29 |
| 4A | single-precision LLA position | X (2) | | X | 25, 37 |
| 4B | machine code/status | X | X | | 25, 26 |
| 4C | report operating parameters | | | | 2C |
| 4D | oscillator offset | | | X | 2D |
| 4E | response to set GPS time | | | | 2E |
| 54 | one-satellite bias & bias rate | | X | | 22 |
| 55 | I/O options | | | | 35 |
| 56 | velocity fix (ENU) | | | X | 37 |
| 57 | information about last computed fix | | | | 37 |
| 58 | GPS system data/acknowledge | | | | 38 |
| 59 | sat enable/disable & health heed | | | | 39 |
| 5A | raw measurement data | | X | | 3A |
| 5B | satellite ephemeris status | | X | | 3B |
| 5C | satellite tracking status | | | | 3C |
| 5E | additional fix status | | | X | 3E, 35 |
| 5F | severe failure report | | X | | |
| 82 | differential position fix mode | | | | 62 |
| 83 | double-precision XYZ position | X (2) | | X | 25, 37 |
| 84 | double-precision LLA position | X (2) | | X | 25, 37 |
| 85 | differential correction status | | | | 65 |

**Notes:** (1) If the current GPS time is not known, this packet is not sent at power-up or automatically.

(2) At turn-on, the Acutime sends packets 42 and 4A if the I/O single-precision-of-position option is selected and sends packets 83 and 84 if the I/O double-precision-of-position option is selected. At power-up, these packets are sent with negative time-of-fix.

3) Channel A is silent unless a request for data is received. The automatic outputs shown above apply only to Channel B.



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3.3.2.1 **40** Almanac Data Page

This packet provides almanac data for a single satellite. The Acutime sends this packet on request (packet 20 hex) and when the data is received from a satellite. The data format is shown below.

| Byte # | Item | Type | Units |
|---|---|---|---|
| 0 | satellite | BYTE | (identification number) |
| 1 | T_zc | SINGLE | seconds |
| 5 | week number | INTEGER | weeks |
| 7 | eccentricity | SINGLE | (dimensionless) |
| 11 | T_oa | SINGLE | seconds |
| 15 | i_o | SINGLE | radians |
| 19 | OMEGA_dot | SINGLE | radians/second |
| 23 | square root A | SINGLE | $(\text{meters})^{1/2}$ |
| 27 | OMEGA o | SINGLE | radians |
| 31 | omega | SINGLE | radians |
| 35 | M o | SINGLE | radians |

These symbols are defined in ICD-GPS-200.

*T*_zc is normally positive. If no almanac data is available for this satellite, then T_zc is negative. T_zc and the week number in this packet refer to the Z-count time and week number at the time the almanac was received. The remaining items are described in the ICD-GPS-200.

3.3.2.2 **41** GPS Time

This packet provides the current GPS time of week and the week number. The Acutime sends this packet in response to packet 21 hex and during an update cycle. Update cycles occur every 15 seconds when not doing fixes and occur every 150 seconds when doing fixes. The data format is shown below.

| Byte # | Item | Type | Units |
|---|---|---|---|
| 0-3 | GPS time of week | SINGLE | seconds |
| 4-5 | GPS week number | INTEGER | weeks |
| 6-9 | GPS/UTC offset | SINGLE | seconds |

Note that GPS time differs from UTC by a variable integral number of seconds. UTC = (GPS time) - (GPS/UTC offset).

The GPS week number reference is Week # 0 starting January 6, 1980.

The seconds count begins with "0" each Sunday morning at midnight. A negative indicated time-of-week indicates that time is not yet known; in that case, the packet is sent only on request. The following table shows the relationship between the information in packet 41, and the packet 46 status code.

approx. time packet 46



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| accuracy | time source | sign (TOW) | status code |
|---|---|---|---|
| none | no time at all | - | 01 hex |
| unknown | approximate time from real-time clock or packet 2E | + | 01 hex |
| 20 to 50 msec + clock drift | time from satellite | + | not 01 hex |
| full accuracy | time from GPS solution | + | 00 hex |

**Application note:**

Acutime has no real-time clock hardware. For the most accurate GPS time, before using the GPS time from packet 41, verify that the packet 46 status code is 00 hex ("Doing position fixes").

### 3.3.2.3 **42** Single-precision Position Fix, XYZ ECEF

This packet provides current GPS position fix in XYZ ECEF coordinates. If the I/O "position" option is set to "XYZ ECEF" and the I/O "precision-of-position output" is set to single-precision, then the Acutime sends this packet each time a fix is computed. The data format is shown below.

| Byte # | Item | Type | Units |
|---|---|---|---|
| 0-3 | X | SINGLE | meters |
| 4-7 | Y | SINGLE | meters |
| 8-11 | Z | SINGLE | meters |
| 12-15 | time-of-fix | SINGLE | seconds |

The time-of-fix is in GPS time or UTC as selected by the I/O "timing" option. At start-up, this packet or packet 83 is also sent with a negative time-of-fix to report the current known position.
Packet 83 provides a double-precision version of this information.

### 3.3.2.4 **43** Velocity Fix, XYZ ECEF

This packet provides current GPS velocity fix in XYZ ECEF coordinates. If the I/O "position" option is set to "XYZ ECEF, then the Acutime sends this packet each time a fix is computed if selected by the I/O "timing" option. The data format is shown below.

| Byte # | Item | Type | Units |
|---|---|---|---|
| 0-3 | X velocity | SINGLE | meters/second |
| 4-7 | Y velocity | SINGLE | meters/second |
| 8-11 | Z velocity | SINGLE | meters/second |
| 12-15 | bias rate | SINGLE | meters/second |
| 16-19 | time-of-fix | SINGLE | seconds |



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The time-of-fix is in GPS time or UTC as selected by the I/O "timing" option.

### 3.3.2.5 **44** Satellite Selection

This packet provides a list of satellites used for position fixes by the Acutime; the packet also provides the PDOP, HDOP, and VDOP of that set and provides the current mode (automatic or manual, 3-D or 2-D). The Acutime sends this packet in response to packet 24 hex and whenever a new satellite selection is attempted. The Acutime attempts a new selection every 30 seconds and whenever satellite availability and tracking status change. The data format is shown below.

| Byte # | Item | Type | Value | Meaning |
|---|---|---|---|---|
| 0 | Mode | BYTE | 01 hex | Auto, 1-satellite, 0-D |
| | | | 03 hex | Auto, 3-satellite, 2-D |
| | | | 04 hex | Auto, 4-satellite, 3-D |
| | | | 11 hex | Manual, 1-satellite, 0-D |
| | | | 13 hex | Manual, 3-satellite, 2-D |
| | | | 14 hex | Manual, 4-satellite, 3-D |
| 1-4 | 4 satellite numbers | 4 BYTES | | 4 satellite numbers |
| 5-8 | PDOP | SINGLE | | PDOP |
| 9-12 | HDOP | SINGLE | | HDOP |
| 13-16 | VDOP | SINGLE | | VDOP |
| 17-20 | TDOP | SINGLE | | TDOP |

PDOP value of zero indicates that the Acutime is not doing fixes, usually because there are not enough healthy usable satellites for position fixes. In this case, the satellite number list contains up to four of the satellites which are usable. Empty satellite number-bytes contain zero. Negative PDOP values indicate that the PDOP is greater than the PDOP mask value and therefore the Acutime is not performing fixes.

### 3.3.2.6 **45** Software Version Information

This packet provides information about the version of software in the Navigation and Signal Processors. The Acutime sends this packet after power-on and in response to packet 1F hex. The data format is two 5-byte sequences, each of which has the format shown below.

| Byte # | Item | Type |
|---|---|---|
| 0 | Major version number | BYTE |
| 1 | Minor version number | BYTE |
| 2 | Month | BYTE |
| 3 | Day | BYTE |
| 4 | Year number minus 1900 | BYTE |

The first 5 bytes refer to the Navigation Processor and the second 5 bytes refer to the Signal Processor.

### 3.3.2.7 **46** Health of Acutime

This packet provides information about the satellite tracking status and the operational health of the Acutime. The Acutime sends this packet after power-on or software-initiated resets, in response to packet 26 hex, during an update cycle, when a new satellite selection is



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attempted, and when the Acutime detects a change in its health. Packet 4B hex is always sent with this packet. The data format is given in the following table.

| Byte # | Item | Byte Type | value | Meaning |
|---|---|---|---|---|
| 0 | Status code | BYTE | | |
| | | | 00 hex | Doing position fixes |
| | | | 01 hex | Don't have GPS time yet |
| | | | 02 hex | Not used |
| | | | 03 hex | PDOP is too high |
| | | | 08 hex | No usable satellites |
| | | | 09 hex | Only 1 usable satellite |
| | | | 0A hex | Only 2 usable satellites |
| | | | 0B hex | Only 3 usable satellites |
| | | | 0C hex | The chosen satellite is unusable (4) |
| 1 | Error codes | BYTE | | |

The error codes are encoded into individual bits within the byte. The bit positions and their meanings are shown below.

| Bit Position | Meaning if bit value = 1 |
|---|---|
| 0 (LSB) | Battery back-up failed **(1)(5)** |
| 1 | Signal Processor error **(1)** |
| 2 | Alignment error, channel or chip 1 **(1)** |
| 3 | Alignment error, channel or chip 2 **(1)** |
| 4 | Antenna feed line fault **(2)** |
| 5 | Excessive ref freq. error **(3)** |
| 6 | (Unused) |
| 7 (MSB) | (Unused) |

**Notes:** **(1)** After this error is detected, its bit remains set until the Acutime is reset.

**(2)** This bit follows the current status of the antenna feed line fault-detection circuitry. Since Acutime has an integral antenna assembly, this information is of itself of little import; it is only shown here for sake of completeness, being important for sensors with separate antennas.

**(3)** This bit is "1" if the last computed reference frequency error indicated that the

reference oscillator is out of tolerance. (Packet 2D requests the oscillator offset and packet 4D returns the oscillator offset to the user.)

**(4)** This message occurs when the one-satellite mode is in effect and a specific satellite has been chosen with packet 34 hex but that satellite is unusable.

**(5)** **This bit is always set as the Accutime receiver battery backup is not installed.**

3.3.2.8 **47** Signal Levels for all Satellites



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This packet provides received signal levels for all satellites currently being tracked or on which tracking is being attempted (i.e., above the elevation mask and healthy according to the almanac). The Acutime sends this packet only in response to packet 27 hex. The data format is shown below

| Byte # | Item | Type |
|---|---|---|
| 0 | Count | BYTE |
| 1 | Satellite number 1 | BYTE |
| 2- 5 | Signal level 1 | SINGLE |
| 6 | Satellite number 2 | BYTE |
| 7-10 | Signal level 2 | SINGLE |
| (etc.) | (etc.) | (etc.) |

Up to 12 satellite number/signal level pairs may be sent, indicated by the count field. Signal level is normally positive. If it is zero then that satellite has not yet been acquired. If it is negative then that satellite is not currently in lock. The absolute value of signal level field is the last known signal level of that satellite.
The signal level provided in this packet is a linear measure of the signal strength after correlation or de spreading.

### 3.3.2.9 **48** GPS System Message

This packet provides the 22-byte ASCII message carried in the GPS satellite navigation message. The Acutime sends this packet in response to packet 28 hex and when this data is received from a satellite.

The message effectively is a bulletin board from the Air Force to GPS users. The format is free-form ASCII. The message may be blank.

### 3.3.2.10 **49** Almanac Health Page

This packet provides health information on 32 satellites. Packet data consists of 32 bytes each containing the 6-bit health from almanac page 25. First byte is for satellite #1, and so on. The Acutime sends this packet in response to packet 29 hex and when this data is received from a satellite.

| Byte # | Item |
|---|---|
| 1 | health of satellite # 1 |
| 2 | health of satellite # 2 |
| . | . |
| . | . |
| . | . |
| 32 | health of satellite # 32 |

In each data byte of this packet, a value "0" indicates that the satellite is healthy; all other values indicate that the satellite is unhealthy.



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### 3.3.2.11 **4A** Single-precision LLA Position Fix

This packet provides current GPS position fix in LLA (latitude, longitude, and altitude) coordinates. If the I/O "position" option is set to "LLA" and the I/O "precision-of-position output" is set to single-precision, then the Acutime sends this packet each time a fix is computed. The data format is shown below

| Byte # | Item | Type | Units |
|---|---|---|---|
| 0-3 | Latitude | SINGLE | radians; + for north, - for south |
| 4-7 | Longitude | SINGLE | radians; + for east, - for west |
| 8-11 | Altitude | SINGLE | meters |
| 12-15 | Clock Bias | SINGLE | meters |
| 16-19 | Time-of-Fix | SINGLE | seconds |

Altitude is referred to the WGS-84 ellipsoid or the MSL Geoid, depending on which I/O "LLA altitude" option is selected.

The time-of-fix is in GPS time or UTC, depending on which I/O "timing" option is selected.

This packet also is sent at start-up with a negative time-of-fix to report the current known position.

Packet 84 provides a double-precision version of this information.

**CAUTION**

**When converting from radians to degrees, significant and readily visible errors will be introduced by use of an insufficiently precise approximation for the constant p(PI). The value of the constant PI as specified in ICD-GPS-200 is 3.1415926535898.**

### 3.3.2.12 **4B** Machine/Code ID and Additional Status

The Acutime transmits this packet in response to packets 25 and 26 and following a change in state. In conjunction with packet 46, "health of Acutime," this packet identifies the Acutime and may present error messages. The machine ID can be used by equipment communicating with the Acutime to determine the type of Acutime to which the equipment is connected. Then the interpretation and use of packets can be adjusted accordingly.

| Byte # | Item | Type | Value | Meaning |
|---|---|---|---|---|
| 0 | Machine ID | BYTE | 20 | 6-channel Acutime |
| 1 | Status 1 | BYTE | | |

The error codes are encoded into individual bits within the byte. The bit positions and their meanings are shown below.



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| Bit Position | | Meaning if bit value = 1 | |
|---|---|---|---|
| 0 (LSB) | | Synthesizer Fault | |
| 1 | | Battery Powered Time Clock Fault | |
| 2 | | A-to-D Converter Fault (Not Used) | |
| 3 | | The almanac stored in the Acutime, is not complete and current. | |
| 4-7 | Not used | | |
| 2 | Status 2 | BYTE | Superpackets supported |

3.3.2.13 **4C** Report Operating Parameters

This packet provides several operating parameter values of the Acutime. The Acutime sends this packet in response to packet 2C hex. The data format is shown below.

The dynamics code indicates the expected vehicle dynamics and is used to assist the initial solution.

The elevation angle mask determines the lowest angle at which the Acutime tries to track a satellite.

The signal level mask sets the required signal level for a satellite to be used for position fixes.

The PDOP mask sets the maximum PDOP with which position fixes are calculated. The PDOP switch sets the threshold for automatic 3-D/2-D mode. If 4 or more satellites are available and the resulting PDOP is not greater than the PDOP mask value, then 3-dimensional fixes are calculated.

| Byte # | Item | Type | Units | Default |
|---|---|---|---|---|
| 0 | Dynamics code | BYTE | | |

| Value | Meaning | Assumed velocity |
|---|---|---|
| 0 | Current value is left unchanged. | |
| 1 | land | < 120 knots |
| 2 | sea | < 50 knots |
| 3 | air (default) | < 800 knots |
| 4 | static | stationary |

| Byte # | Item | Type | Units | Default |
|---|---|---|---|---|
| 1-4 | Elevation angle mask | SINGLE | radians | 0.1745 or 10° |
| 5-8 | Signal level mask | SINGLE | --- | 6 |
| 9-12 | PDOP mask | SINGLE | --- | 12 |
| 13-16 | PDOP switch (3-D or 2-D) | SINGLE | --- | 8 |

A negative value in a SINGLE field leaves that current setting unchanged.



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This information is held in battery-backed memory.

### 3.3.2.14 **4D** Oscillator Offset

This packet provides the current value of the Acutime master oscillator offset in Hertz at carrier. This packet contains one SINGLE number. The Acutime sends this packet in response to packet 2D hex. The permissible offset varies with the Acutime unit.

### 3.3.2.15 **4E** Response to Set GPS Time

Indicates whether the Acutime accepted the time given in a Set GPS time packet. The Acutime sends this packet in response to packet 2E hex. This packet contains one byte.

| Value | Meaning |
|---|---|
| ASCII "Y" | The Acutime accepts the time entered via packet 2E. The Acutime has not yet received the time from a satellite. |
| ASCII "N" | The Acutime does not accept the time entered via packet 2E. The Acutime has received the time from a satellite and uses that time. The Acutime disregards the time in packet 2E. |



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3.3.2.17 **54** One-Satellite Bias and Bias Rate

The Acutime sends this packet to provide the computed clock-only solution when the Acutime is in the manual or automatic one-satellite mode.

| Byte | Item | Type | Units |
|---|---|---|---|
| 0-3 | Bias | SINGLE | meters |
| 4-7 | Bias rate | SINGLE | meters/second |
| 8-11 | Time of fix | SINGLE | seconds |

The bias is the offset of the Acutime internal time clock from GPS time. Bias is expressed as meters of apparent range from the satellites. It is used to correct the one pps output. Bias rate is the frequency error of the Acutime internal oscillator. It is expressed as apparent range rate.

**CAUTION**

**For accurate interpretation of the propagation delay, the precise constant for the speed of light must be used. The WGS-84 value for the speed of light is 299,792,458 meters per second.**

3.3.2.18 **55** I/O Options

This packet provides current I/O options in effect in response to packet 35 request. The data format is the same as for packet 35 hex and is repeated below for convenience.

| Byte # | Parameter Name | Bit Position | Default Bit Value | Associated Option | Packet |
|---|---|---|---|---|---|
| 0 | position | 0 (LSB) | 1 | XYZ ECEF Output<br>0: off<br>1: on | 42 or 83 |
| | | 1 | 0 | LLA Output<br>0: off<br>1: on | 4A or 84<br>or 8F-01<br>or 8F-02 |
| | | 2 | 0 | LLA ALT Output<br>0: HAE WGS-84<br>1: MSL geoid | 4A or 84 |
| | | 3 | 0 | ALT input<br>0: HAE WGS-84<br>1: MSL geoid | 2A |
| | | 4 | 0 | precision-of-position output<br>0: Send single-precision packet 42 and/or 4A.<br>1: Send double-precision packet 83 and/or 84. | |
| | | 5 | 0 | Superpacket output<br>0: off<br>1: on | |
| | | 6 | 0 | Superpacket format<br>0: binary | |



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| | | | | | |
|---|---|---|---|---|---|
| | | | | 1: ASCII | |
| | | 7 | 0 | unused | |

**Note:** If bit 5 is 0 then no Superpackets are output. If bit 5 and 6 are 1 then packet 8E-01 is output. If bit 5 is 1 and 6 is 0 then packet 8F-02 is. If Superpacket output is selected then 8F-01 or 8F-02 packets are output instead of the standard 4A or 84 packets.

| | | | | | |
|---|---|---|---|---|---|
| 1 | velocity | 0 | 1 | XYZ ECEF Output | 43 |
| | | | | 0: off | |
| | | | | 1: on | |
| | | 1 | 0 | ENU Output | 56 |
| | | | | 0: off | |
| | | | | 1: on | |
| | | 2 - 7 | 0 | unused | |
| 2 | timing | 0 | 0 | time type | |
| | | | | 0: GPS time | |
| | | | | 1: UTC | |
| | | 1 | 0 | fix computation time | |
| | | | | 0: ASAP | |
| | | | | 1: next integer sec | |
| | | 2 | 0 | output time | 37 |
| | | | | 0: when computed | |
| | | | | 1: only on request | |
| | | 3 | 0 | Synchronized measurements (V1.14 onwards) | |
| | | | | 0: off | |
| | | | | 1: on | |

| Byte # | Parameter Name | Bit Position | Default Bit Value | Associated Option | Packet |
|---|---|---|---|---|---|
| | | 4 | 0 | Minimize Projection | (V1.14 onwards) |
| | | | | 0: on | |
| | | | | 1: off | |
| | | 5-7 | 0 | unused | |
| 3 | Auxiliary | 0 | 0 | raw measurements | 5A |
| | | | | 0: off | |
| | | | | 1: on | |
| | | 1 | 0 | Doppler smoothed codephase (V1.14 onwards) | |
| | | | | 0: raw | |
| | | | | 1: smoothed | |
| | | 2 | 0 | Additional Fix Status | (V1.12 onwards) |
| | | | | 0: off | |
| | | | | 1: on | |
| | | 3 - 7 | unused | | |

Glossary for the table above:(from 3.3.2.18)

| | |
|---|---|
| ALT: | Altitude |
| ECEF: | Earth-centered, Earth-fixed |
| XYZ: | Cartesian coordinates |
| LLA: | latitude, longitude, altitude |



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HAE: height above ellipsoid
WGS-84: Earth model (ellipsoid)
MSL geoid: Earth (mean sea level) model
ENU: East-North-up (same as LLA)
UTC: coordinated universal time

### 3.3.2.19 **56** Velocity Fix, East-North-Up (ENU)

If East-North-Up (ENU) coordinates have been selected for the I/O "position" option, the Acutime sends this packet under the following conditions: (1) each time that a fix is computed; (2) in response to packet 37 hex (last known fix). The data format is shown below.

| Byte # | Item | Type | Units |
|---|---|---|---|
| 0-3 | East Velocity | SINGLE | m/s; + for east, - for west |
| 4-7 | North Velocity | SINGLE | m/s; + for north, - for south |
| 8-11 | Up Velocity | SINGLE | m/s; + for up, - for down |
| 12-15 | Clock Bias Rate | SINGLE | m/s |
| 16-19 | Time-of-Fix | SINGLE | seconds |

The time-of-fix is in GPS or UTC time as selected by the I/O "timing" option.

### 3.3.2.20 **57** Information About Last Computed Fix

This packet provides information concerning the time and origin of the previous position fix. The Acutime sends this packet, among others, in response to packet 37 hex. The data format is shown below.

| Byte # | Item | Type | Units |
|---|---|---|---|
| 0 | Source of information | BYTE | --- |

| Value | Meaning |
|---|---|
| 00 hex | none |
| 01 hex | regular fix |
| 02 hex | initialization diagnostic |
| 04 hex | initialization diagnostic |
| 05 hex | entered by packet 23 or 2B |
| 06 hex | entered by packet 31 or 32 |
| 08 hex | default position after RAM battery fail |

| Byte # | Item | Type | Units |
|---|---|---|---|
| 1 | Manuf. diagnostic | BYTE | --- |
| 2-5 | Time of last fix | SINGLE | seconds, GPS time |
| 6-7 | Week of last fix | INTEGER | weeks, GPS time |

### 3.3.2.21 **58** Satellite System Data/Acknowledge from Acutime

This packet provides GPS data (almanac, ephemeris, etc.). The Acutime sends this packet under the following conditions: (1) on request; (2) in response to packet 38 hex (acknowledges the loading of data). The data format is shown below.



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| Byte # | Item | Type | Byte Value | Meaning |
|---|---|---|---|---|
| 0 | Operation | BYTE | | |
| | | | 0 | Acknowledge, can't use |
| | | | 1 | Acknowledge |
| | | | 2 | Data Out |
| | | | 3 | No Data on SV |
| 1 | Type of data | BYTE | | |
| | | | 1 | not used |
| | | | 2 | Almanac |
| | | | 3 | Health page, T_oa, WN_oa |
| | | | 4 | Ionosphere |
| | | | 5 | UTC |
| | | | 6 | Ephemeris |
| 2 | Sat PRN # | BYTE | | |
| | | | 0 | data that is not satellite-ID-specific |
| | | | 1 to 32 | satellite PRN number |
| 3 | length *(n)* | BYTE | | number of bytes of data to be loaded |
| 4 to n+3 | dat | *n* BYTES | | |

3.3.2.22 **59** Status of Satellite Disable or Ignore Health

Normally the Acutime selects satellites for use in GPS solution according to whether the candidate satellites are in good health and whether they satisfy the mask values for elevation angle, signal level, and PDOP. This packet reads back whether the user has told the Acutime to disable unconditionally the selection of any particular satellite and whether the user has told the Acutime to ignore the health of any particular satellite that otherwise is acceptable for selection. The Acutime sends this packet in response to packet 39 hex. The data format is shown below.

| Byte # | Item | Type | Byte Value | Meaning |
|---|---|---|---|---|
| 0 | Operation | BYTE | | |
| | | | 3 | The remaining bytes tell whether Acutime is allowed to select each satellite. |
| | | | 6 | The remaining bytes tell whether Acutime heeds or ignores each satellite's health as a criterion for selection. |
| 1 to 32 | Satellite # (1 byte per satellite) | 32 BYTES | (Depends on byte 0 value.) | |
| | | | 0 | Enable satellite selection or heed satellite's health. |



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| | |
|---|---|
| | Default value. |
| 1 | Disable satellite selection or ignore satellite's health. |

This information is not held in battery-backed memory. At power-on and after a reset, the default values are set for all satellites.

### 3.3.2.23 **5A** Raw Measurement Data

This packet provides raw GPS measurement data. If the I/O "auxiliary" option has been selected, the Acutime sends this data automatically as measurements are taken. The Acutime also sends this packet in response to packet 3A hex. The data format is shown below.

| Byte # | Item | Type | Units |
|---|---|---|---|
| 0 | Satellite PRN Number | BYTE | ----- |
| 1 | Sample Length | SINGLE | msec |
| 5 | Signal Level | SINGLE | |
| 9 | Code phase | SINGLE | 1/16th chip |
| 13 | Doppler | SINGLE | Hertz |
| 17 | Time of Measurement | DOUBLE | sec |

**Application Note:**

Packet 5A provides the raw satellite signal measurement information used in computing a fix.

The satellite PRN (Byte 0) number is a unique identification for each of the 32 GPS satellites.

The sample length (Byte 1) is the number of milliseconds over which the measurement was averaged. Thus if the sample length is 428, then the receiver tracked the satellite and collected the measurement over a 428 millisecond period. Acutime uses a 500 millisecond dwell time per satellite, however, if the channel is sequencing on several satellites, the sample length will be closer to 400 milliseconds due to reacquisition and loop setting times.

The signal level (Byte 5) is a linear approximation of C/N0 which is stated in antenna amplitude measurement units (AMU's), a Trimble devised unit. An approximate correlation of AMU levels to C/N0 follows:

| | | |
|---|---|---|
| 5 AMU's | -20 dB SNR | |
| 16 AMU's | -10 dB SNR | or AMU's 51 * |
| 26 AMU's | - 5 dB SNR | |

The C/N0 is affected by five basic parameters: 1) signal strength from the GPS satellite, 2) receiver/antenna gain, 3) pre-amplifier noise figure, 4) receiver noise bandwidth, and 5) accumulator sample rate and statistics. The approximation is very accurate from 0 to 25 AMU's.

The codephase (Byte 9) value is the average delay over the sample interval of the received C/A code and is measured with respect to the receiver's millisecond timing reference. Thus, it includes all receiver, satellite, and propagation biases and errors. It is expressed in 1/16th of a C/A code chip.



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The doppler (Byte 13) value is apparent carrier frequency offset averaged over the sample interval. It is measured with respect to the nominal GPS L1 frequency of 1575.42 MHz, referenced to the receiver's internal oscillator (TCXO). Thus, it includes all receiver and satellite clock frequency errors. It is expressed in Hertz at the L1 carrier.

The time of measurement (Byte 17) is the center of the sample interval and measured by adding the Acutime supplied codephase (modulo mS) to a user determined integer number of mS between user and satellite.

Since the Acutime codephase resolution is 1/16th of a C/A code chip, this corresponds to:

1/16 * C/A code chip 977.517ns/16 61.0948 ns

61.0948* speed of light, m/s
18.3158 meter



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The integer millisecond portion of the pseudo-range must then be derived by utilizing the approximate user and satellite positions. Rough user position (within a few hundred kilometers) must be known; the satellite position can be found in its almanac / ephemeris data.

Each mS integer corresponds to:

| | | |
|---|---|---|
| C/A code epoch * speed of light | = | 1 ms* speed of light, m/s<br>300km (approx.)<br>299.792458 km (precise) |

3.3.2.24 **5B** Satellite Ephemeris Status

This packet is sent in response to packet 3B and when a new ephemeris (based on IODE) is received. It contains information on the status of the ephemeris in the receiver for a given satellite. The structure of packet 5B is as follows.

| Byte # | Item | Type | Meaning or Units |
|---|---|---|---|
| 0 | SV PRN Number | BYTE | |
| 1-4 | Time of Collection | REAL | seconds |
| 5 | Health | BYTE | |
| 6 | IODE | BYTE | |
| 7 | toe | REAL | seconds |
| 11 | Fit Interval Flag | BYTE | |
| 12-15 | SV Accuracy (URA) | REAL | meters |

SV PRN Number is from 1 to 32 representing the satellite PRN number. Time of Collection is the GPS time when this ephemeris data was collected from the satellite. Health is the 6-bit ephemeris health. IODE, toe, and Fit Interval Flag are as described in ICD-GPS-200. SV Accuracy (URA) is converted to meters from the 4-bit code as described in ICD-GPS-200.

3.3.2.25 **5C** Satellite Tracking Status

This packet provides tracking status data for a specified satellite. Some of the information is very implementation-dependent and is provided mainly for diagnostic purposes. The Acutime sends this packet in response to packet 3C hex. The data format is shown below.

| Byte # | Item | Type | Units |
|---|---|---|---|
| 0 | satellite PRN number | BYTE | number, 1 to 32 |
| 1 | channel and slot code | BYTE | |

---

This is an internal coding of the hardware tracking channel and of the slot within the channel to which the specified satellite currently is assigned.



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| Bit Position | Value | Meaning |
|---|---|---|
| 2 to 0 (LSB) | 210 | |
| | 000 (LSB) | slot 1 |
| | 001 | slot 2 |
| | 010 | slot 3 |
| | 011 | slot 4 |
| | 100 | slot 5 |
| | 101 | slot 6 |

7(MSB) to 3: channel number, starting with zero

| Bits 7-3 | Channel | Used by |
|---|---|---|
| 00000 | 1 | all Acutime |
| 00001 | 2 | 6-channel Acutime only |
| 00010 | 3 | 6-channel Acutime only |
| 00011 | 4 | 6-channel Acutime only |
| 00100 | 5 | 6-channel Acutime only |
| 00101 | 6 | 6-channel Acutime only |
| 76543 | | |

---

| Byte # | Item | Type | Units |
|---|---|---|---|
| 2 | acquisition flag | BYTE | |

---

| Byte Value | Meaning |
|---|---|
| 0 | never acquired |
| 1 | acquired |
| 2 | re-opened search |

---

| | | | |
|---|---|---|---|
| 3 | ephemeris flag | BYTE | |

---

| Byte Value | Meaning |
|---|---|
| 0 | flag not set |
| =0 | good ephemeris for this satellite (< 4 hours old, good health) |

---

| | | | |
|---|---|---|---|
| 4-7 | signal level | SINGLE | same as in packet 46 hex |
| 8-11 | GPS time of last msmt | SINGLE | seconds |

---

| Byte Value | Meaning |
|---|---|
| <0 | no measurements have been taken |
| ≥0 | center of the last measurement taken from this satellite |

---

| | | | |
|---|---|---|---|
| 12-15 | elevation | SINGLE | radians |

---

Approximate elevation of this satellite above the horizon. Updated about every 15 seconds. Used for searching and computing measurement correction factors.

---

| | | | |
|---|---|---|---|
| 16-19 | azimuth | SINGLE | radians |

---



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Approximate azimuth from true north to this satellite. Updated typically about every 3 to 5 minutes. Used for computing measurement correction factors.

---

| | | |
|---|---|---|
| 20 | old measurement flag | BYTE |

---

| Byte Value | Meaning |
|---|---|
| 0 | flag not set |
| >0 | The last measurement is too old to use for a fix computation. |

---

| | | |
|---|---|---|
| 21 | integer msec flag | BYTE |

---

| Byte Value | Meaning |
|---|---|
| 0 | don't have good knowledge of integer millisecond range to this satellite |
| 1 | msec from sub-frame data collection |
| 2 | verified by a bit crossing time |
| 3 | verified by a successful position fix |
| 4 | suspected msec error |

---

| | | |
|---|---|---|
| 22 | bad data flag | BYTE |

---

| Byte Value | Meaning |
|---|---|
| 0 | flag not set |
| 1 | bad parity |
| 2 | bad ephemeris health |

---

| | | |
|---|---|---|
| 23 | data collect flag | BYTE |

---

| Byte Value | Meaning |
|---|---|
| 0 | flag not set |
| >0 | The Acutime currently is trying to collect data from this satellite. |

---

### 3.3.2.25.5 **5E** Additional Fix Status

This packet describes attributes of a position fix. The information is requested by packet 3E or sent after each fix if bit 2 of AUX BYTE in packet 35 is set.

| BYTE | BIT | Meaning |
|---|---|---|
| 0 | 0-2 | # of measurements in current fix that were used in a previous fix. |
| | 3 | 1: No differential doppler velocity available<br>0: Differential doppler velocity available |
| | 4 | 1: Fix still converging (when status code = , i.e. doing fixes)<br>0: Fix converged |
| | 5-7 | Unused |
| 1 | 0-2 | # of measurements in current fix that are old (3-5 s) |
| | 3-7 | Unused |



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3.3.2.26 **5F** Failure Report

If a severe failure prevents the Acutime from operating, the Acutime sends this packet at turn-on if the failure does not preclude doing so. Generally, the Acutime sends nothing following this packet. The packet data bytes consist of "02" followed by an ASCII text message which describes the failure.

3.3.2.27 **82** Differential Position Fix Mode

This packet provides the differential position fix mode of the Acutime. This packet contains only one data byte to specify the mode.

This packet is sent in response to packet 62 and whenever a satellite selection is made and the mode is Auto GPS/GPD (modes 2 and 3).

The Acutime switches automatically between modes 2 and 3 based on the availability of differential corrections for a constellation which meets all other masks. If such a constellation is not available, then the Acutime stays in its current automatic mode (2 or 3), and does not do position solutions.

Valid modes are:

| | |
|---|---|
| 0 | Manual GPS (Differential off) |
| 1 | Manual GPD (Differential on) |
| 2 | Auto GPS (Differential currently off) |
| 3 | Auto GPD (Differential currently on) |

"Manual GPS" (mode 0) means that the Acutime does position solutions without differential corrections, even if the differential corrections are available.

"Manual GPD" (mode 1) means that the Acutime only does position solutions if valid differential correction data are available.

"Automatic GPS" (mode 2) means that the Acutime is not receiving differential correction data for all satellites in constellation which meets all other masks, and is doing non-differential position solutions.

"Automatic GPD" (mode 3) means that the Acutime is receiving differential correction data for all satellites in a constellation which meets all other masks, and is doing differential position solutions.



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### 3.3.2.28 **83** Double-precision XYZ Position Fix And Bias Information

This packet provides current GPS position fix in XYZ ECEF coordinates. If the I/O "position" option is set to "XYZ ECEF" and the I/O double-precision-of-position option is selected, the Acutime sends this packet each time a fix is computed. The data format is shown below.

| Byte # | Item | Type | Units |
|---|---|---|---|
| 0-7 | X | DOUBLE | meters |
| 8-15 | Y | DOUBLE | meters |
| 16-23 | Z | DOUBLE | meters |
| 24-31 | clock bias | DOUBLE | meters |
| 32-35 | time-of-fix | SINGLE | seconds |

The time-of-fix is in GPS time or UTC, as selected by the I/O "timing" option. At start-up, if the I/O double-precision-of-position option is selected, this packet is also sent with a negative time-of-fix to report the current known position.

Packet 42 provides a single-precision version of this information.

### 3.3.2.29 **84** Double-precision LLA Position Fix And Bias Information

This packet provides current GPS position fix in LLA coordinates. If the I/O "position" option is set to "LLA" and the double-precision-of-position option is selected, the Acutime sends this packet each time a fix is computed. The data format is shown below.

| Byte # | Item | Type | Units |
|---|---|---|---|
| 0-7 | latitude | DOUBLE | radians; + for north, - for south |
| 8-15 | longitude | DOUBLE | radians; + for east, - for west |
| 16-23 | altitude | DOUBLE | meters |
| 24-31 | clock bias | DOUBLE | meters |
| 32-35 | time-of-fix | SINGLE | seconds |

The time-of-fix is in GPS time or UTC, as selected by the I/O "timing" option. At start-up, this packet is also sent with a negative time-of-fix to report the current known position.

Packet 4A provides a single-precision version of this information.

**CAUTION**

**When converting from radians to degrees, significant and readily visible errors will be introduced by use of an insufficiently precise approximation for the constant p (PI). The value of the constant PI as specified in ICD-GPS-200 is 3.1415926535898.**



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3.3.2.30 **85** Differential Corrections Status

This packet provides the status of differential corrections for a specific satellite. It is sent in response to packet 65. The format of this packet is as follows:

| Byte | Item | Type | Units |
|---|---|---|---|
| 0 | Satellite PRN number | BYTE | |
| 1 | Summary status code | BYTE | |
| 2 | Station health | BYTE | |
| 3 | Satellite health (UDRE) | BYTE | |
| 4 | IODE 1 | BYTE | |
| 5 | IODE 2 | BYTE | |
| 6 | Z-count as Time-of-Week | SINGLE | seconds |
| 10 | Range correction | SINGLE | meters |
| 14 | Range-rate correction | SINGLE | m/sec |
| 18 | Delta range correction | SINGLE | meters |

The summary status code is encoded as follows:

| | |
|---|---|
| 0 | good correction data |
| 1 | good delta correction data |
| 2 | station health bad (5 or 7) |
| 3 | data too old (60 seconds) |
| 4 | UDRE too high (>4) |
| 5 | IODE mismatch with ephemeris |



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