

LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY  
- LIGO -  
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<b>LIGO TIME STANDARD</b>	
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LIGO

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# 1 INTRODUCTION

## 2 TIME REPRESENTATIONS

### 2.1 GPS TIME

GPS (Global Positioning System) time is the fundamental time standard of LIGO. It is based on TAI (international atomic time) and counts seconds starting at Sunday, Jan. 6, 1980, 00:00 UTC (GPS zero).

### 2.2 COORDINATED UNIVERSAL TIME

Coordinated universal time (UTC) represents time in a format suitable for human reading, i.e year, month, day, hour, minute and second. Since an UTC second has exactly the same length as a TAI (GPS) second, leap seconds have to be periodically added to keep UTC synchronized with earth rotation. This has the effect that some minutes have more or less than 60 seconds. Until now leap seconds were only added either in mid year (June 30) or end of the year (December 31). UTC does never adjust for daylight saving time.

### 2.3 LOCAL TIME

Local time is derived from UTC by adding a fixed number of hours to account for the local time zone. Local time is not used in LIGO (except for lunch).

### 2.4 FRAME DATA FILES

Frame files store the time when the data was taken in the following format (see LIGO-970130-B):

Field name	Description	Format
GTimeS	GPS time in sec when data was taken	unsigned long (32 bit)
GTimeN	Residual GPS time in nsec	long (32 bit)
ULeapS	leap second correction (relative to GPS zero)	short (16 bit)
localTime	difference of local time zone relative to UTC in sec	long (32 bit)
dt	length of the frame in sec	double precision floating point

The name of frame files will include information where and when the data was taken. The name consists of the following pieces:

Field	Description	Format (LHO/LLO)
location	site and interferometer information	H1, H2 or L1
time	GPS seconds of the first frame of data in the file	10 digit number
extension	used to characterize the frame type	F (full), A (analysis) or T (trend)

An example is: H1\_0577906524.F which would be a data file containing a full frame taken at the Hanford 4K interferometer, April 29, 1998, 16:35:12 UTC.

## 3 TIME SYNCHRONIZATION AND DISTRIBUTION

LIGO will install at least one primary clock in each building. The primary clock will be used to synchronize all other clocks in the same building using a standard time protocol.

### 3.1 TIME PROTOCOLS

#### 3.1.1 IRIG-B

IRIG-B (Inter Range Instrumentation Group) is a signal standard designed to synchronize various test equipment. It is based on a 1 kHz carrier which is amplitude modulated at a frame rate of 1 Hz. Each frame contains the following bit-coded information: day of year, hour, minute and second. IRIG-B is not based on a particular time standard, but it will be used in LIGO to transport UTC. Typically, an accuracy of better than 10 $\mu$ s can be achieved when a local quartz oscillator is phase locked to an IRIG-B signal.

#### 3.1.2 Network Time Protocol

Workstations and PCs hooked to a network can use NTP (network time protocol) to synchronize their internal clock to UTC. LIGO will either use a publicly accessible NTP server (on the internet) or an in-house NTP server to synchronize the clocks of the control room workstations. Using an external NTP server will give an accuracy of better than 10ms, whereas an internal one will typically yield an accuracy of 1 ms or better. NTP software for UNIX is available freely at the following web address <http://www.eecis.udel.edu/~ntp/>. Software for PCs is available at <http://www.accessone.com/~thinkman/dimension4/index.htm>.

#### 3.1.3 EPICS

One of the problems in LIGO is convert between GPS time and UTC. Since IRIG-B omits the year, an EPICS channel is used to transfer this information. Similarly, since leap seconds can't be predicted, the current leap second correction is broadcasted by an EPICS channel.

##### 3.1.3.1 Year Information

For the on-line system the current year can be read from EPICS channels. To avoid a possible ambiguity during the brief moment when a year changes two EPICS channels will be used at each site. At LHO the channels are as follows:

Channel name	Description	Format
HPM:TIME_YEAR	current year (most of the time) or previous year	4 digit integer; YYYY
HPM:TIME_NEWYEAR	current year or upcoming year	4 digit integer; YYYY

The idea is that for most of the year both channels will represent the current year. However, somewhere in December the TIME\_NEWYEAR field will be increased by one. As soon as the new year starts the TIME\_YEAR field will be updated to represent the new current year. Since it is impossible to update this field at exactly the year change, there will be a brief moment at the beginning of the year when this field will still show the information of the old year. This ambiguity is solved by inspecting the NEWYEAR field which was updated in the old year will show the correct year information:

Condition	Value of TIME_YEAR	Value of TIME_NEWYEAR
TIME_YEAR = TIME_NEWYEAR	current year	current year
TIME_YEAR < TIME_NEWYEAR and month between July and December	current year	upcoming year
TIME_YEAR < TIME_NEWYEAR and month between January and June	old year	current year

The algorithm to obtain the correct year information is given in section 5.1.1.

### 3.1.3.2 Leap Second Correction

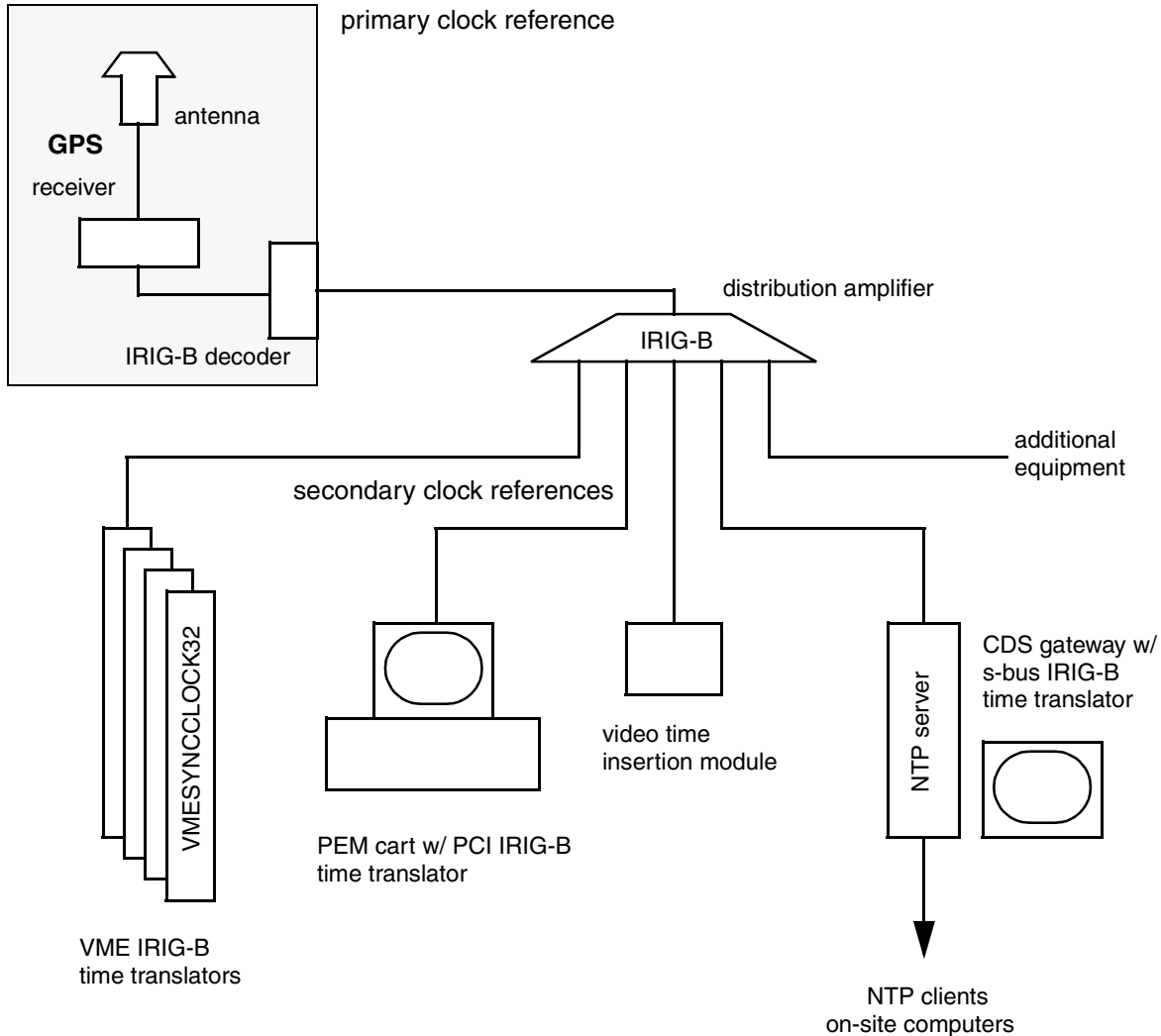
The leap second correction is broadcasted by three EPICS channels per site. At LHO the channels are as follows:

Channel name	Description	Format
HPM:TIME_LEAPS	current leap second correction	(positive) integer
HPM:TIME_NEWLEAPDAY	upcoming leap second day of year	positive integer
HPM:TIME_NEWLEAPS	new leap second correction	(positive) integer

The convention for these channels is similar to the information received by a GPS receiver. The leap second correction is given as the total number of leap seconds added to UTC since GPS zero. The two fields TIME\_NEWLEAPDAY and TIME\_NEWLEAPS are used to resolve a possible ambiguity around the time when a new leap second is added. They also give an early warning when the next leap second occurs, so that clocks which are synchronized to IRIG-B can correctly insert (or remove) the leap second. The algorithm to obtain the current leap correction can be found in section 5.1.2.

## 3.2 PRIMARY REFERENCE

LIGO will use GPS receivers to obtain a primary reference clock. Each experimental building will implement at least one primary reference clock which will be used to synchronize all other clocks (secondary references) in the same building. The primary reference clock will produce an IRIG-B signal which will be distributed in a star topology to the secondary references. The IRIG-B signal will be based on UTC (without the year information). The primary reference clock is also responsible to write the current year and leap second information into the corresponding EPICS channels.



**Figure 1: Time synchronization and time distribution overview.**

### 3.3 SECONDARY REFERENCES

Secondary clock references, such as the VME time decoders, the control room workstations and the PEM cart, will derive their time from the primary reference clock through IRIG-B. Secondary reference clocks will generally have their own local quartz clock phase-locked to the IRIG-B signal.

#### 3.3.1 VME Time Translators

All VME crates will host a JXI2 VME-SYNCCLOCK32 time translator. This board not only has to provide VME CPUs with the current time, but has also to generate the clock signals for the ADCs of the data acquisition system. These boards will return the correct UTC time provided the year information was uploaded at start-up and the leap second information was set ahead of time

in the dual port RAM (see sections “*Setting Leap Year Control in Dual Port RAM*” and “*Specifying Leap Second Day in Dual Port RAM*” of their manual).

A typical VME user can then directly read out UTC from one of the boards data registers and convert it into GPS time. (Since the ADC clocks are running at multiples of 1 Hz, they should not be affected by the occurrence of a leap seconds, even if the leap second correction wasn't uploaded ahead of time.)

### **3.3.2 Control Room Workstations**

Some of the subsystems like the global diagnostics system will run part of their ‘on-line’ analysis processes on workstations in the control room. This will require a timing synchronization with the DAQ system at the level of tens of ms. To avoid complicated synchronization protocols over the network, these workstations will synchronize their internal clock to UTC with an accuracy of better than 10ms. This will be achieved by installing an NTP daemon on every machine and by optionally install an s-bus time translator board (using the IRIG-B signal of the primary reference clock) into the CDS gateway which then acts as a stratum 1 network time server. Since operators and users will typically interface the system using UTC we propose to synchronize all computers on site to UTC using NTP (the typical overhead per computer is very small). This will make it possible for programs running on any on site computer to read UTC from the local clock and convert it into GPS time.

### **3.3.3 PEM Cart**

The PEM cart (and any other mobile data acquisition unit) will have to be synchronized with GPS time in order to be able to correlate its data with the main interferometer output. This is achieved by adding an IRIG-B time translator to the cart. Typically, inside a building the cart will use the IRIG-B signal provided by the primary reference clock, whereas outside a building the cart will use its own GPS receiver with IRIG-B output. To make this work spare IRIG-B signal lines have to be provided at strategically placed locations inside the buildings.

### **3.3.4 Video Time Insertion Modules**

Sometimes it is useful to record the images of the beam modes propagating in the interferometer with a video camera and to be able to correlate this information with other signals of the interferometer. A video time insertion module using an IRIG-B input from the primary reference clock will make it possible to correlate picture-by-picture.

### **3.3.5 Optional Clocks**

Since IRIG-B is a widely used industrial standard it will be easy to hook up additional equipment, such as a wall-mounted clock in the control room, when it is needed.

## 4 VERIFICATION AND CALIBRATION

### 4.1 REFERENCE CLOCKS

#### 4.1.1 Absolute Calibration

TBD.

#### 4.1.2 On-Site Correlation

A test protocol will be developed to verify the synchronization between the primary reference clocks on site. This will be done by continuously writing time stamps into the reflective memory, reading it out at the other locations. After taking out signal propagation delays and averaging an accuracy at the level of several  $\mu\text{s}$  should be achievable.

### 4.2 DATA ACQUISITION

The DAQ ADCs (ICS-110B) have an external test injection capability. This will be used to sample the IRIG-B signal and calibrate the time delay introduced by the acquiring process.

### 4.3 INTERFEROMETER RESPONSE

see LIGO-T970101-A.

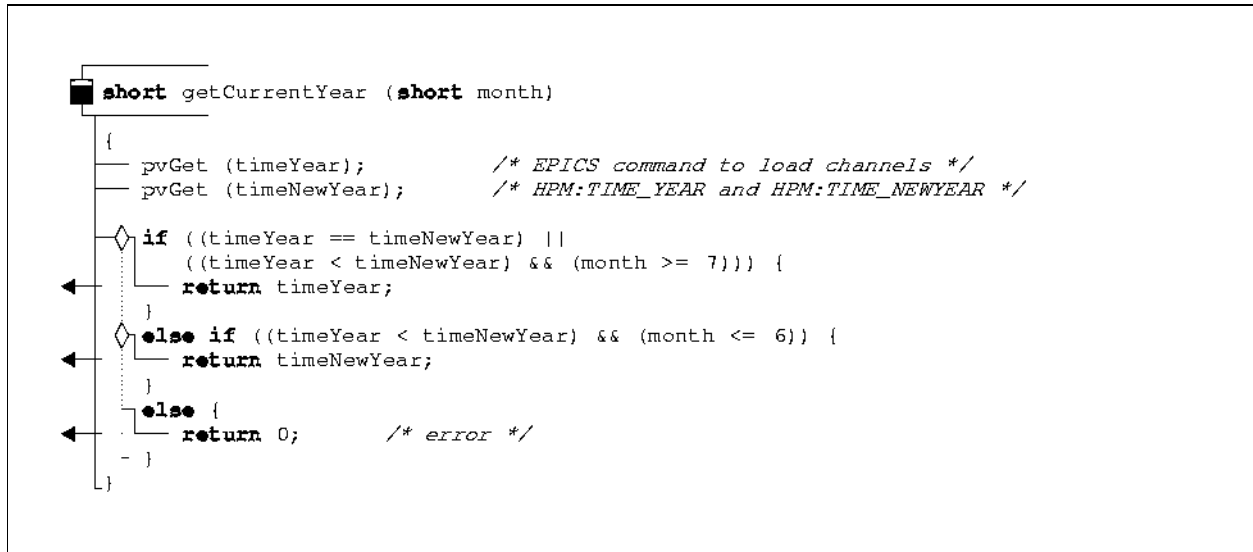
## 5 TIME CONVERSION ALGORITHMS

We distinguish between on-line and off-line applications. On-line applications are typically running real-time and will need the current leap second correction (and sometimes the current year information) to convert between UTC and GPS time. On the other hand applications running off-line may need an additional table of previous of leap second correction in order to work properly with older data files.



## 5.1 ON-LINE

### 5.1.1 Year Information



### 5.1.2 Leap Second Correction

### 5.1.3 GPS to UTC

### 5.1.4 UTC to GPS

## 5.2 OFF-LINE

### 5.2.1 GPS to UTC

### 5.2.2 UTC to GPS

### 5.2.3 Command Line Utilities

#### 5.2.3.1 UTC2GPS

This utility will take a time in the format YYYY MM DD hh mm ss and translate it into GPS seconds.

#### 5.2.3.2 GPS2UTC

This utility will take either a time in GPS seconds or a frame file name and translates it into UTC.

### 5.2.3.3 framedir

This utility will go through the specified directory and generate a listing of all frame files with their creation date.