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The Master Clock

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ABSTRACT: The clock outlined in this report provides a common time base for all subsystems in the Array as well as a measure of the UTC. The zero point accuracy of the clock is $\pm 1\,\mu s$ and its stability is better than 1×10^{-8} or 1 ms/day.

1. INTRODUCTION

The CHARA Array requires accurate UTC and different timing signals during observations. In particular, the OPLE system needs two timing signals to operate, a 16 MHz and a 1 Hz square TTL wave. About a half second before each rising edge on the 1 Hz signal, the OPLE time[2], valid at the rising edge, has to be sent to the OPLE cart control electronics. The OPLE time is used for setting the position and speed of the carts at a given moment. The smoothness of motion of the carts depends on the accuracy of information provided by the master clock. Other servo systems in the Array require a common 1 kHz signal or some derivative of that (see TR68) to synchronize their operations.

2. THE FUNCTIONS OF THE MASTER CLOCK

The functions of the master clock (MC) are

- to provide a common time base for every subsystem in the Array and generate synchronous timing signals
  - 16 MHz and 1 Hz TTL signal to OPLE control
  - 1 kHz TTL signal to other servo systems
- to generate the message sent to the OPLE controller once a second
- to measure the UTC

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[2]The number of 16 MHz ticks since midnight

The MC will be based on a local, freely running 16 MHz ovenized crystal oscillator (OCXO). All timing signals will be generated by dividing the output of this local oscillator. This fact assures that all timing signals in the Array will be synchronous within one 16 MHz tick. The local time will be connected to the UTC via GPS[3] before starting an observing session or at least once a day. The zero point error will be approximately $\pm 1\,\mu$s due to the accuracy of the GPS receiver. Between synchronizations GPS is not used. The OPLE time and the UTC is computed once a second and validated by the raising edge of the 1 Hz signal. Using a freely running oscillator rather than GPS ticks during observations assures the smoothness of the OPLE time which is directly related to the smoothness of cart motion. There will be a slow drift from UTC during an observing session which should notbe more than 0.5 ms per 12 hours [4], i.e., an oscillator with relative frequency stability of 1×10^{-8} is necessary.

3. OPERATION OF THE MASTER CLOCK

The hardware for the MC will be implemented on an 8 bit ISA card (see Figure 1). The master oscillator of the clock will be a 16 MHz OCXO by Vectron Laboratories[5]. The output of the oscillator is directly connected to the OPLE controller via an RS422 line. The output of the master oscillator is also divided by two and 8 MHz is connected to two i8254 counters. The first counter is used for calibrating the OCXO. The second counter is used for generating the 1 kHz and a 2 Hz signal synchronous with the master oscillator. The 1 kHz signal is distributed among the different systems in the Array via RS422 lines. The 2 Hz signal is used for generating two 1 Hz signals sihifted in phase by 180°. The 1 Hz signal which is synchronous with the master clock (T1) is connected to the OPLE electronics via RS422. The other 1 Hz signal (T2) requests interrupt from the host PC once a second. The interrupt service routine (ISR) computes the OPLE time and sends the message to the OPLE controller. The computed OPLE time will be valid at the next rising edge on T1. The ISR also generates the UTC and local sidereal time (LMST) for the Array.

3.1. Frequency Calibration

The master oscillator has to be set to 16 MHz and checked periodically in order to compensate any change in frequency which would directly affect the motion of the OPLE carts and the accuracy of our time. The calibration is done by counting the pulses from the oscillator for a known amount of time. The known amount of time is computed from GPS time messages. The 1 second tick from the Jupiter GPS receiver is accurate within $\pm 1\,\mu$s. The calibration is handled by a process which can be started asynchronously. The process has one initial parameter which can be START or STOP. At START, the process initializes the first i8254 counter and receives the messages from the GPS. If the reception is stable, CAL is set high in the command register. The next GPS tick enables the first i8254 counter.

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[3] Jupiter GPS Receiver by Rockwell.

[4] A drift in the local time results in an offset in the position of the carts. In order to be able to detect fringes, the path length difference between any two interfering beams has to be smaller then the width of the fringe envelope or coherence length $\lambda^2/\Delta\lambda$. At $\lambda = 600$ nm and $\Delta\lambda = 5$ nm the coherence length is 72μm. Taking the largest separation between two telescopes (270 m) into account, $72\,\mu$m translates to 55 mas position difference on the sky. In order to have much smaller position error than 55 mas we need to know the UTC much better than 3.6 ms at any given moment.

[5] If necessary one can switch to the internal 16 MHz oscillator in the OPLE crate.

The first i8254 counts the divided by 2 (8 MHz) pulses from the oscillator. The start time T_{start} of counting is stored and the process exits. After some time T, the process is called with STOP. The process receives and stores GPS messages and if the reception is stable, it sets CAL to low. The next GPS tick stops the counting. The stop time T_{stop} is stored and the contents N of the counter is read out. The difference $\Delta T = T_{stop} - T_{start}$ gives the total time of counting with an accuracy of $\pm 2 \mu s$. The frequency of the oscillator is obtained from

$$f = \frac{2N}{\Delta T[s]} [\mathrm{Hz}] \tag{1}$$

with relative accuracy of $2 \times 10^{-6}/\Delta T[s]$. At 1000 s measuring time the relativ error is about 2×10^{-9} which can be further decreased by increasing ΔT.

3.2. OPLE Time

GPS receiver provides the UTC as a serial message once a second.The message preceeds the rising edge of a 1 Hz pulse (GPS tick) by 400 to 500 ms, typically.

After reset the line drivers are disabled so the clock is invisible from the OPLE system. The interrupt request (IRQ) is cleared and ITEN and the i8254 timers are disabled. The clock accepts pulses from either an internal or an external oscillator. After reset, the internal oscillator is selected.

A process is started by the operator which initializes the second i8254 and then receives and stores the messages from the GPS. If the reception is stable, the program sets CEN high in the control register and stores the last GPS message. This is the zero point of our time scale. The next raising edge on the GPS tick enables the second i8254. The counting starts within 125 ns (one 8 MHz tick) which is much less than the uncertainty in the GPS tick ($\pm 1\,\mu$s). The i8254 generates a 1 kHz and a 2 Hz signals by dividing its 8 MHz input by 8000 and then by 500, respectively. The 1 kHz signal is sent out through a RS422 line driver to other servo systems. The 2 Hz signal is used for generating two 1 Hz signals. The first (T1) is synchronous to the master oscillator is sent to the OPLE controller. The other (T2) is shifted in phase by 180° and it requests periodical interrupts if ITEN is high. The ISR computes the OPLE time from the stored zero point, increments it by 16 million each time the ISR is called and sends the time to the OPLE controller which time is latched by the next raising edge of T1.

3.3. The UTC and LMST

The UTC is computed from the stored zero point by incrementing a software counter once a second in the ISR. The LMST is computed from the UTC by using the formula in the Astronomical Almanach.