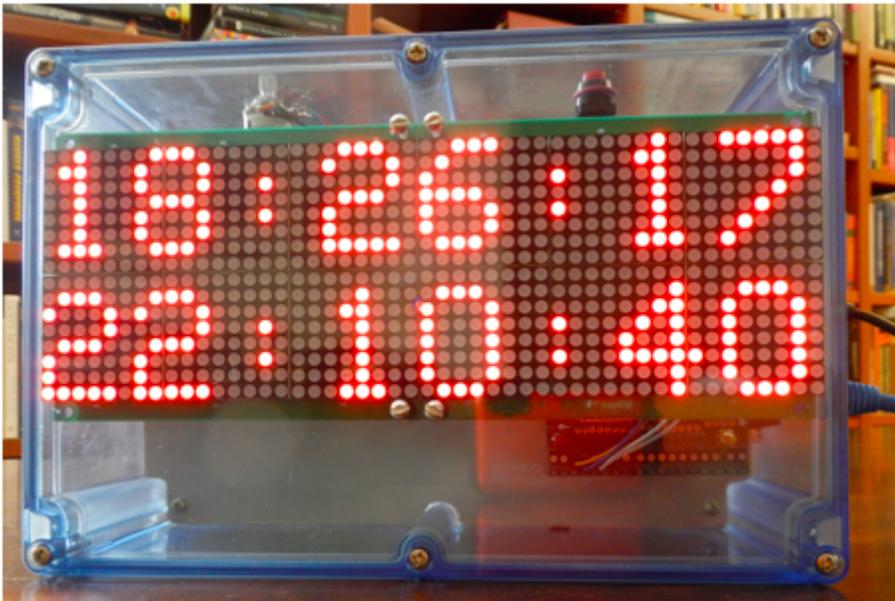


A Low Cost Sidereal Clock

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A clock that displays [UT\(Universal Time\)](#) and [LST \(Local Sidereal Time\)](#) is a useful device to have in an astronomical observatory. Using the [Arduino](#) open source platform it is possible to build a sidereal clock for less than \$200.



Hardware

The clock is implemented using the [Arduino Ethernet](#) board which allows clock synchronization with a reference clock using [NTP \(Network Time Protocol\)](#). In order to operate even when the internet connection fails, the [DS1307 real time clock board](#) from [Adafruit](#) is used, giving a precision of about 2 seconds per day when internet connection is not available.

The display used is the [HT1632C 16x24 Red LED Matrix Panel](#) from [Adafruit](#). Two panels are connected providing a LED matrix of 16 by 48 dots. We use the first line of 8x48 dots to display the UT time and the second line to display the LST time.

The connection of the three modules is given in the following table.

Arduino Board	Real Time Clock	LED matrix panel
GND	GND	GND
5V	5V	5V
Analog A4	SDA	
Analog A5	SCL	
Digital 2		DATA

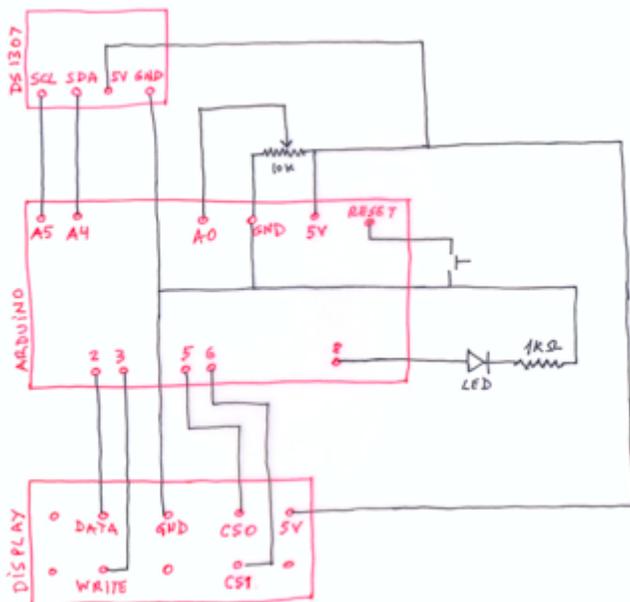
Digital 3		WRITE
Digital 5		CS0
Digital 6		CS1

A potentiometer connected to analog pin 0 is used to control the brightness of the display.

A reset button connected to the RESET pin is used to force NTP time synchronization. A LED connected to pin 8 is used to indicate failure in NTP synchronization.

The clock is assembled in a [transparent NEMA enclosure](#).

The complete clock diagram follows.



Software

The [Arduino clock program](#) uses libraries for the real time clock ([DS1307RTC.h](#)), the LED display ([HT1632.h](#)) and the Ethernet (Ethernet.h).

The header file [gmst0.h](#) defines some constants and should be modified as follows:

longitude use the longitude of the observatory to 1/10-seconds of time by dividing by 15 and multiplying by 36000. As usually West should be negative and East should be positive.

timeServer the name of the [NTP server](#) used to synchronize the clock.

mac is the MAC number of the Arduino Ethernet board

The header file also contains a large array holding the Greenwich Mean Sidereal Time (GMST) at 0h for each day of the year. The Arduino platform supports only single precision floating point numbers and the [formulas for](#)

[calculating GMST](#) requires double precision. The solution is to compute the values in a separate Python [program](#) on a PC or Mac and store them in an array in the Arduino Program Memory . The implemented array has 2000 days starting at 30-NOV-2011 (version 2 30-NOV-2016).

The **setup ()** code synchronizes the Arduino clock which always starts at 00:00:00 of January 1st, 1970 with the real time clock. Next it initiates the internet connection and try to synchronize the real time clock with the selected NTP server. Finally it initializes the LED matrix display.

The **loop ()** code displays UT and LST and wait until the UT second changes. It also tries to sync the clock with the NTP server -- using modified program code from [Arduino playground](#) -- at intervals of 15 minutes. If sync fails the LED is turned on.

The display of UT and LST is handled by the **clockDisplay** function. LST is computed from UT according to the [formula](#)

$$LST = GMST \text{ at } 0h + k \cdot H + longitude$$

H=hours elapsed since 0h UT

GMST at 0h is obtained from the array stored in Program Memory and whenever values are not available LST will be displayed as 00:00:00.

The multiplication of H by the constant $k=1.00273790935$ is implemented in the function **mult1** using variables of data type **long** in order to avoid the loss of precision that would result by using the single precision **float** numbers of the Arduino language.

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