# GPS/RTC/MP3 Chiming Station Clock

Nautically-Themed and Conventional Versions

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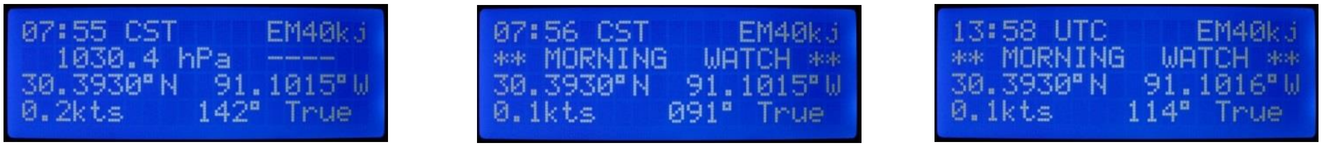
An accurate timepiece is an essential station accessory. This one uses microcontroller and GPS technology for accuracy, adds some extra utility with position, navigation, and weather information, and tops it off with a bit of whimsy with MP3 derived "chimes." The version described here has a nautical flavor, sounding ship's bells on the half hours, and the bo'sun piping the watch changes.

## Features

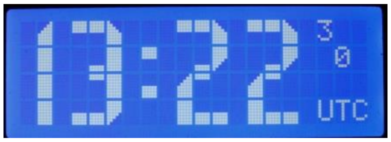
*Time derived directly from GPS – only one satellite needed for time data*
*Option for a crystal-controlled real time clock module in lieu of GPS*
*Four line LCD display with backlight, with option for one line of 21 mm high characters*
*Selectable local or UTC time display (or both, with a small program modification)*
*Selectable Standard Time or Daylight Savings Time whenever local time is displayed*
*Latitude, Longitude, Maidenhead Grid Square, Course, and Speed display whenever GPS fix is valid*
*Barometric pressure display (temperature and humidity available with program additions)*
*Plays MP3 audio clip "chimes," from files stored on an internal µSD memory card, at selected times*
*Multiple sound file directories – to change the "theme" - selected by switch or jumper settings*
*Powered from DC supply of 7 to 13 volts, or optionally a rechargeable battery pack*
*Uses inexpensive functional sub-modules for easy construction and low cost*
*Arduino NANO source code is published to allow builders to modify and enhance the features*
*Expandability - using additional I2C interfaced peripherals, or the spare analog or digital I/O lines*



```
07:55 CST     EM40kj
 1030.4 hPa  ----
30.3930°N  91.1015°W
0.2kts    142°  True
```

```
07:56 CST     EM40kj
** MORNING  WATCH **
30.3930°N  91.1015°W
0.1kts    091°  True
```

```
13:58 UTC     EM40kj
** MORNING  WATCH **
30.3930°N  91.1016°W
0.1kts    114°  True
```



```
13:22 3
      0
    UTC
```

Click here for
[Short A/V clip
of operation]

Figure 1. Sample Display Formats

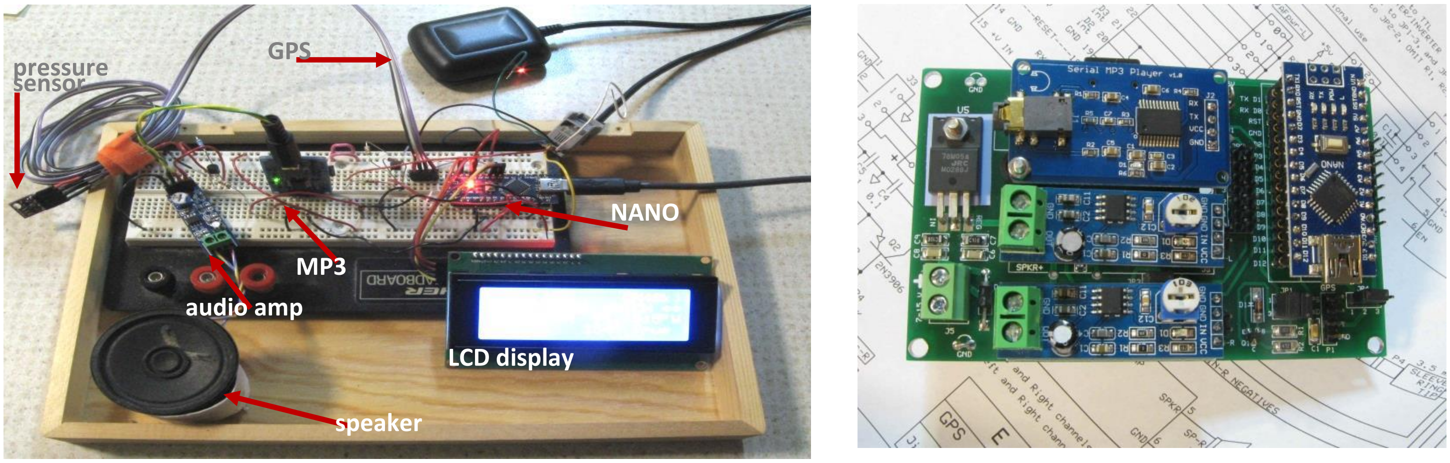


Figure 2. Breadboarded prototype (at left, if there's any doubt) and printed circuit version (right).

## System Description

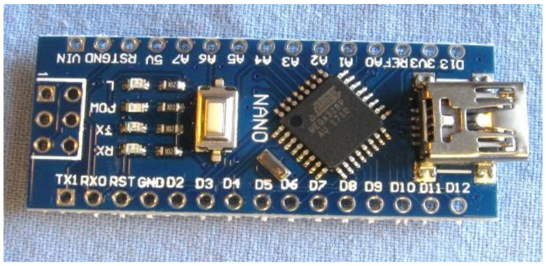


Figure 3. Arduino NANO

**Microcontroller.** The heart of the system is an Arduino NANO microcontroller, which is itself based on the ATMega328P microprocessor chip. It features on-board program, data, and EEPROM memory, a USB connection for communication with a host computer, and a number of analog and digital I/O lines. Programs are loaded into the controller using the USB connection and the Arduino *Integrated Development Environment* (IDE). The programming language is related to C/C++. Complete source code for this version of the project is published as part of the documentation package.

Power supply can be an unregulated DC supply between 7 and 12 volts, a regulated 5V supply, or the device and a modest number of peripherals can be powered via the USB connection with one of the ever-present USB charging wall warts. The module includes a 3.3V regulator that can supply a few mA to other peripherals.

The modules are available from a wide array of vendors – eBay, Amazon, and others – generally for less than $5. They are so useful and easy to design with that it’s worthwhile to buy them by the handful.

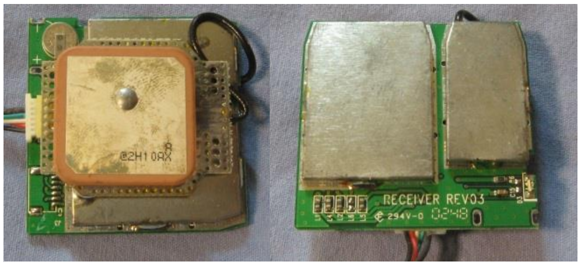


Figure 4. GPS receiver module, top and bottom views

**GPS Receiver**. Timing and navigational data are supplied to the microcontroller by a *Global Positioning System* (GPS) satellite receiver module. The GPS module must be connected to a 1.3GHz antenna, which is usually supplied with, and often physically mounted on the receiver board. The left-hand image in **Figure 5** shows the small active antenna mounted on the receiver.

The GPS receiver communicates its data to the NANO as an asynchronous serial data stream of ASCII characters, formatted in what are called *NMEA Sentences* (NMEA – National Marine Electronics Association). The minimum required data are contained in the **$GPGGA** and **$GPRMC** sentences, examples of which are shown below. Detailed information on how to interpret these sentences is in an ***Appendix*** to this document.

```
$GPGGA,123519,4807.038,N,01131.000,E,1,08,0.9,545.4,M,46.9,M,,*47
$GPRMC,123519,A,4807.038,N,01131.000,E,022.4,084.4,230394,003.1,W*6A
```

While many GPS receivers operate on a 5V supply, this project was designed to accommodate both 5V and 3.3V receivers. That serial data rate (baud rate) is usually 4800 or 9600 baud, but other rates are easily accommodated as well. In addition, level shifting and inverting circuitry is included as a jumper selectable option so that receivers can be used that output either RS-232 levels (+/- voltages) or logic levels (5V or 3.3V). There is a connection on the PC board for a GPS’s one-pulse-per-second output, but it is not used.

Nearly any GPS receiver module can be used, so long as its output is an asynchronous serial ASCII character stream in NMEA format. Suitable modules range in cost from less than $5 to $15 or so, from a variety of vendors – both domestic and offshore. A couple of example sources are shown in the Bill of Materials

**LCD Display**. The human interface for this clock is, of course, a visual display. A backlighted LCD character display panel was chosen since it is easy to read and inexpensive. A 4-line by 20-character display was chosen because that provides enough space to display quite a bit of information. Larger or smaller displays could be used - with programming changes.

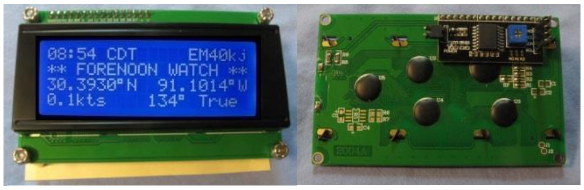


Figure 5. LCD 4x20 display, front and back views

A display panel that communicates using the *Inter-Integrated Circuit* I2C bus protocol was selected. The I2C connection uses only two I/O lines from the NANO, compared to six or more for parallel connected panels. This allows more I/O lines to be saved for extra features such as mode selections and peripheral controls. The program code must specify the correct I2C slave address in order to communicate with the display. The address of the module will vary somewhat from vendor to vendor. Vendors may or may not provide documentation that specifies the address used. **Hexadcimal 27** (decimal 39) is a commonly encountered address, but others have been discovered. The diagnostic/test program ***I2C_Scanner_N5IB*** (see below) can be used to search for and verify which address the LCD is responding to.

Cost of a 4x20 I2C panel varies from $5 to $12 depending on the vendor. There are choices of text and background colors. The main printed circuit board for the clock is designed to mount, with standoffs, directly to the back of the 4x20 display panel.

**MP3 Player**. As mentioned in the introduction, this clock adds a touch of whimsy by including a chiming feature. But in this case the “chimes” are not mechanical, but are pre-recorded MP3 or WAV audio files, stored on a microSD memory card, and played though a Catalex MP3 player module and audio amplifier under control of the Arduino NANO. This particular version uses the sounds of a ships bell and a bos’un pipe to create a nautical flair. It creates just the right atmosphere for settling into a comfy chair with a cup of tea (or ration of grog??) and a Patrick O’Brian or C. S. Forrester novel.

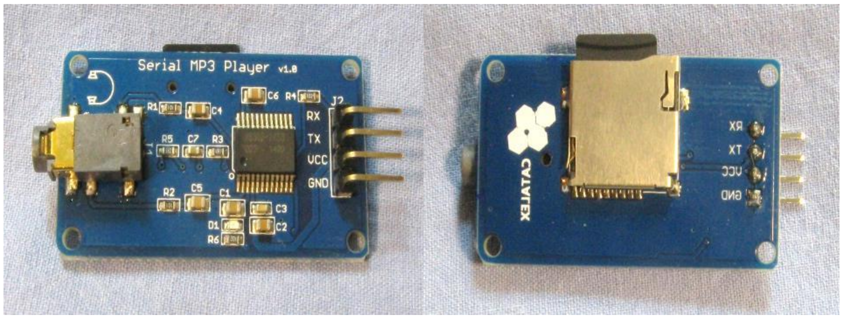


Figure 6. Catalex Serial MP3 Player, top and bottom (with µSD card) views. Note the right angled header pins, which will be removed.

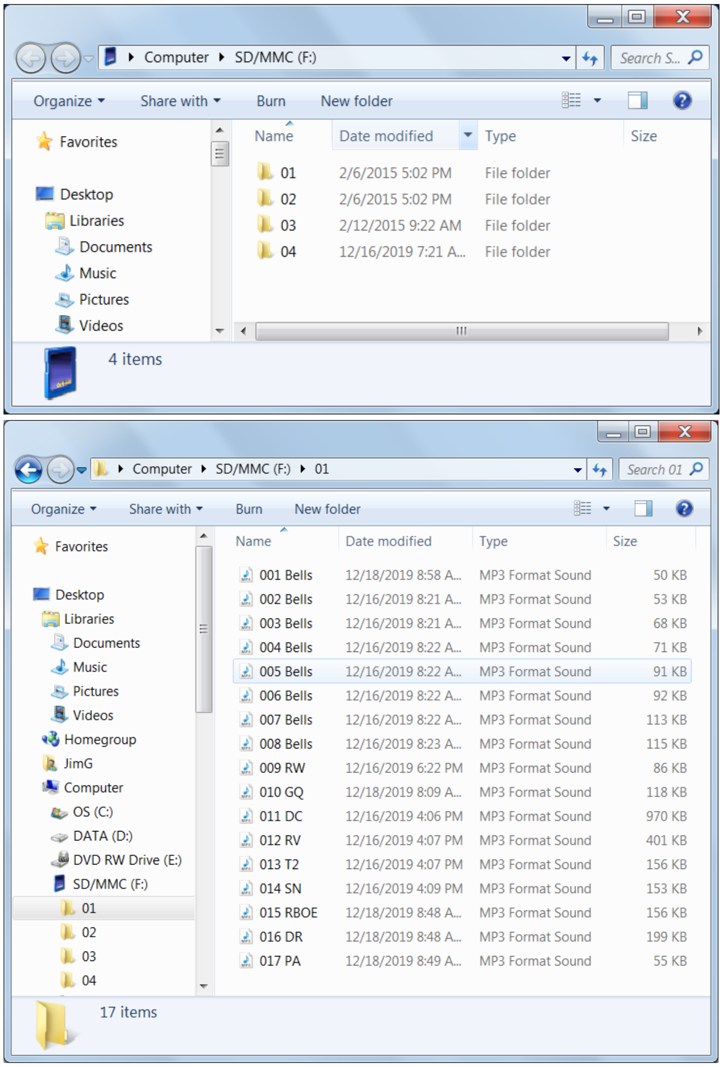
But any sort of sound clips could be used. Indeed the software provides the ability to select among four different sets of sounds using a jumper or switch selection. The free-to-download ***Audacity*** sound editing software allows easy editing and manipulating of sound files. The module's output is a stereo audio signal (capable of directly driving headphones or earbuds) connected to a 3.5mm stereo jack. The sound files themselves may be stereo or mono. This project allows for either one or two channel amplified output to speaker(s).

Detailed information about the operation of the MP3 module is included in the project documentation, but a brief comment about how to organize the sound clips is in order.

The sound files, here in MP3 format, are stored on a µSD memory card on-board the MP3 module. The sound clips can be of any duration, the only requirement is that the files conform to a naming convention, as shown in the two screen captures. The first shows the file folders, which must be placed in the root directory of the memory card. The folders must have two-digit names as shown, from "00" up to "99.'

Within each folder the individual sound clips must also abide by a naming convention. A three digit number must begin each filename, as shown. The numerical values can apparently range from 000 to 255. Extra characters may be included to aid in identification. It's not clear whether there is a limit to the length of filenames, but the ones shown (9 characters) apparently work.  Filenames can be re-used in the other directories.

The MP3 player module is controlled by the NANO via an asynchronous serial data link, much the same way as the GPS receiver. While the module is capable of two-way data communication, in this project it is only required to receive commands from the NANO.



| Name | Date modified | Type | Size |
|---|---|---|---|
| 01 | 2/6/2015 5:02 PM | File folder | |
| 02 | 2/6/2015 5:02 PM | File folder | |
| 03 | 2/12/2015 9:22 AM | File folder | |
| 04 | 12/16/2019 7:21 A... | File folder | |

| Name | Date modified | Type | Size |
|---|---|---|---|
| 001 Bells | 12/18/2019 8:58 A... | MP3 Format Sound | 50 KB |
| 002 Bells | 12/16/2019 8:21 A... | MP3 Format Sound | 53 KB |
| 003 Bells | 12/16/2019 8:21 A... | MP3 Format Sound | 68 KB |
| 004 Bells | 12/16/2019 8:22 A... | MP3 Format Sound | 71 KB |
| 005 Bells | 12/16/2019 8:22 A... | MP3 Format Sound | 91 KB |
| 006 Bells | 12/16/2019 8:22 A... | MP3 Format Sound | 92 KB |
| 007 Bells | 12/16/2019 8:22 A... | MP3 Format Sound | 113 KB |
| 008 Bells | 12/16/2019 8:23 A... | MP3 Format Sound | 115 KB |
| 009 RW | 12/16/2019 6:22 PM | MP3 Format Sound | 86 KB |
| 010 GQ | 12/18/2019 8:09 A... | MP3 Format Sound | 118 KB |
| 011 DC | 12/16/2019 4:06 PM | MP3 Format Sound | 970 KB |
| 012 RV | 12/16/2019 4:07 PM | MP3 Format Sound | 401 KB |
| 013 T2 | 12/16/2019 4:07 PM | MP3 Format Sound | 156 KB |
| 014 SN | 12/16/2019 4:09 PM | MP3 Format Sound | 153 KB |
| 015 RBOE | 12/18/2019 8:48 A... | MP3 Format Sound | 156 KB |
| 016 DR | 12/18/2019 8:48 A... | MP3 Format Sound | 199 KB |
| 017 PA | 12/18/2019 8:49 A... | MP3 Format Sound | 55 KB |

Figure 7. Screen shots of sound file structure

**Audio Amplifier**. To drive speaker(s) and sound the "chimes" one or, optionally, two LM-386 audio amplifier modules are used. These fully assembled modules can often be purchased for little more than the price of a bare LM-386 chip. The main circuit board has space for one or two modules, so stereo sound is possible if the builder wishes. The module includes a volume control.

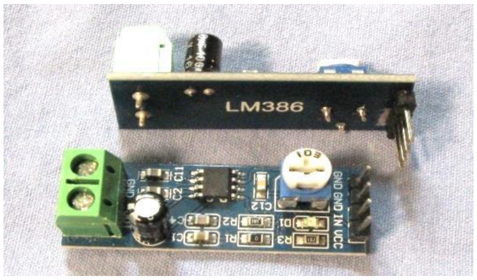


Figure 8.  LM386 audio amplifier modules. With factory pins (bottom), and modified pins (top)

To prevent any annoying background hiss when no sound is being played, the module(s) are powered down under control of the NANO except when needed.

**Environmental Sensor**. Barometric pressure is a useful additional bit of data. It is provided by a tiny Bosch BME-280 module that measures atmospheric pressure, temperature, and relative humidity. It communicates its information to the NANO by sharing the I2C bus with the LCD display. The module is normally configured to respond to an I2C slave address of **hexadecimal 76** (decimal 118) but there is a jumper trace (circled in red on the photo) on the module which, if cut, changes the address to **hex 77** (decimal 119). The diagnostic/test program ***I2C_Scanner_N5IB*** (see below) can be used to verify to which address the module is responding.

The pressure value is normally returned in *hecto-pascals* (hPa), which are numerically the same as the meteorologist's *millibars* (mb). But an easy program modification would convert to inches of mercury if desired.

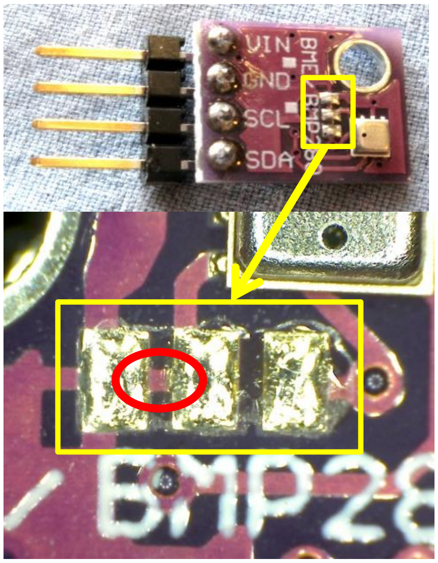


Figure 9. BME-280 pressure, temperature, and humidity sensor

This sensor can simply be omitted if the builder wishes, and the few lines of program code that concern it can be "commented out." And while this implementation does not make use of the temperature or humidity information, it could easily be added to the program. The module supports either °F or °C units, and the software library for the module even includes a calculation of the dew point, based on the temperature and relative humidity.

For barometric pressure readings only, the sensor module can be installed inside the clock enclosure, plugged right onto header P2 on the circuit board. But if the temperature and humidity data are desired it would have to be moved outside the enclosure for accurate indoor readings, or even outdoors if sheltered. The I2C bus is not designed for long distance data transfer, but a meter or two of cable can be tolerated.

## Construction

Extensive use of pre-assembled sub-modules simplifies construction. Aside from connectors, there are only a few discrete components, and some of those are required only for optional features. Most of the discrete parts are surface mount components, but they are the relatively large 1206 sized parts. There are three small SOT-23 transistors, but two of them are part of optional circuit elements.

**Connectors.** Needing careful consideration before construction begins is the selection of connectors for the sub-modules. Some of the modules can be obtained without any connectors mounted, and this is the best option. But others have only been found with pre-mounted header connectors. The Bill of Materials makes note of those that can be purchased without mounted connectors.

The builder will have to decide whether to use the modules with pre-mounted connectors as-is, and adapt the main board connectors to suit, or else to remove  and replace (or possibly just gently bend) the existing connectors and allow the most efficient mounting. The photo of the assembled main board shows the preferred mounting scheme, with the sub-modules parallel to the main board, using header sockets on the main board, and header pins on the sub-modules.

In the ***Appendix*** of this document there is a short photo tutorial showing how to remove an existing connector without damaging the circuit board.

**Mounting front panel, LCD display, and PC board**.  The simplest assembly method is to attach the LCD to the back of the front panel, after an appropriate rectangular opening has been cut. There is a drilling and cutting template in the ***Appendix***. All of the mounting holes are sized for #4-40 machine screws. Standoffs are used between the front panel and the LCD, and again between the LCD and the main circuit board. The height of the standoff between the front panel and the LCD will depend on the builder's choice of front panel, but ¼ inch will work in most cases. Oval head machine screws, countersunk, make a nice clean finish, as shown at right.

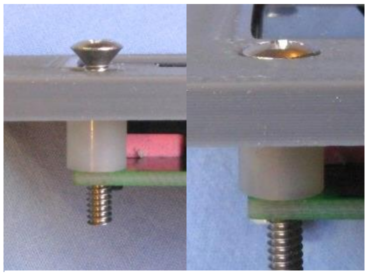


Figure 10. Oval head machine screws

The spacing between the LCD and the main circuit board should be about 0.675 inch. This is not a standard size for standoffs, so an easy solution is to use ½ inch standoffs plus two extra hex nuts on each corner. It's builder's choice whether to use double-female or male-female standoffs. The upper and lower sequences of photos below show both versions of the stackup.

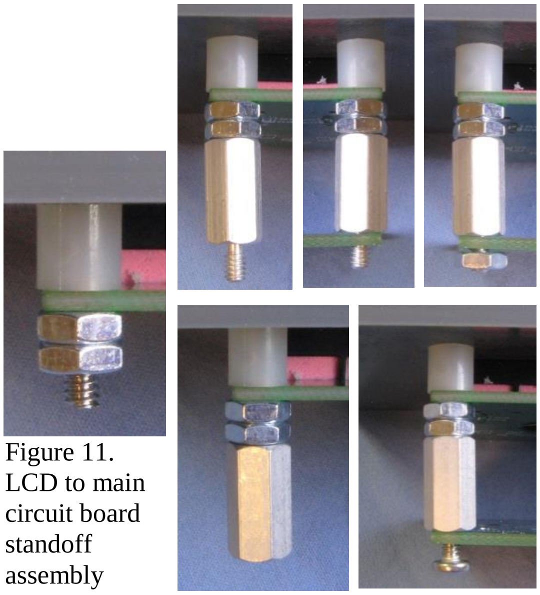


Figure 11. LCD to main circuit board standoff assembly

**Populating the PC board**. When surface mount components are employed, it's generally a good idea to install those components first, so that larger components won't get in the way. Use a soldering iron with a small conical tip and small diameter (0.015" is a good choice) solder. A recommended technique is to tin one of the component's PC board pads, use tweezers to hold the part in position, then re-heat the tinned pad until the solder re-flows. If the position is still satisfactory, solder the remaining pad(s).

Note that the components associated with Q1 and Q3 are some of the optional features and may not be needed (see the Bill of Materials). But if the parts are on hand, it's not a bad idea to install them anyway, since it will be much more convenient than trying to add them later with other, larger parts already installed.

*Start with the bypass capacitors for the voltage regulator*. If polarized capacitors are being used for C7 and C9, be sure to observe the correct polarity orientation when installing them. For the capacitors shown in the picture at right, the white bar indicates the **positive** terminal. Parts from other vendors may be marked differently. **The negative terminal goes onto the pad that has a drilled via hole through it.** C6 and C8 are unpolarized and their orientation does not matter.

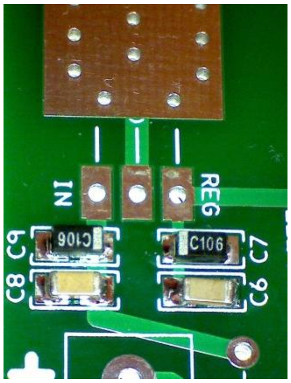


Figure 11. Regulator bypass capacitors

*Next add the transistors*: Q1 (2N3904) and Q2 and Q3 (2N3906). These are the smallest components on the board, so once these are installed, the rest is easy. Best is to tin the collector terminal (marked “C”) and hold the transistor in position while re-flowing the solder on that pad. Hold until the solder solidifies, check the alignment, and if good, solder the remaining two pads.

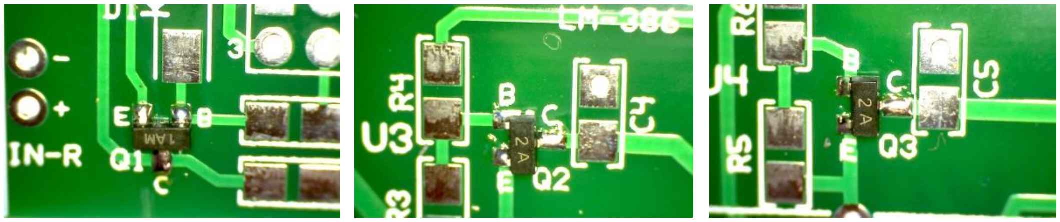


Figure 12. Surface mount transistors installed

*Add all the resistors next*. Surface mount resistors have their value marked on the body. A hand magnifier or loupe is useful for reading them.

*Now add the remaining capacitors*. All of these are unpolarized, so orientation does not matter. Note that surface mount capacitors generally do not have values marked on the body, so be sure to use the proper value. Fortunately all of the remaining capacitors are of the same 0.1 µF value.

*Don’t forget the diode*. Note carefully the polarity of the surface mount diode, D1. The dark band on the body of the diode corresponds to the bar on the silkscreened diode symbol.

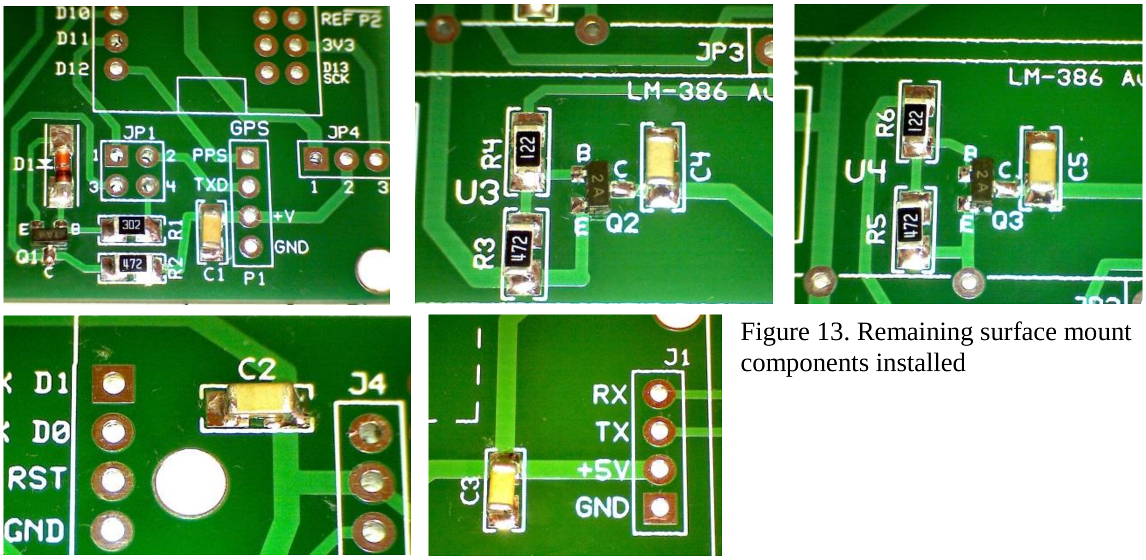


Figure 13. Remaining surface mount components installed

*Test probe loops*. There are three places to install a little hairpin loop of wire or discarded component lead. Two are grounded points and one is a +5V test point. These are convenient places to clip a meter’s test probe for checking the circuit.

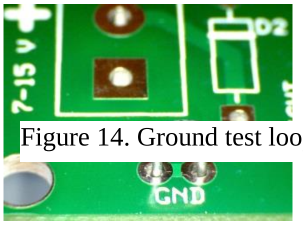


Figure 14. Ground test loop

It might be a good idea to put one of the grounded loops on the bottom side of the board for convenience.

*Header pins and sockets*. To ensure that sockets and pins align properly, it's a good idea to make a dry-fit stackup of the mating parts. Secure the parts in their final positions and solder one or two pins only. Check the alignment and, if acceptable, solder the remaining pins. In all cases, be sure that the pins or sockets are vertical and perpendicular with respect to the board surface, and that the plastic carrier strips are seated flat down upon the board.

The photos below show the use of round, machined-pin socket strips for the Arduino NANO, and conventional socket strips designed for 0.025" square-post headers for the three sub-modules. This is a personal preference of this builder. Square post pins and sockets could certainly be substituted for the NANO.

Note (picture at right) that there are two header strips installed on the BOTTOM side of the board. J4 receives the pins from the I2C interface on the LCD panel. The other is a 3-pin right angled header installed so as to allow access to some of the NANO's pins that might be useful for future enhancements or modifications.

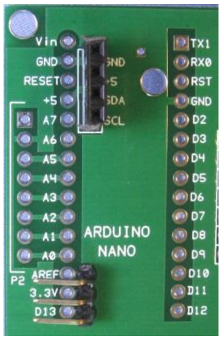


Figure 15. Bottom side headers

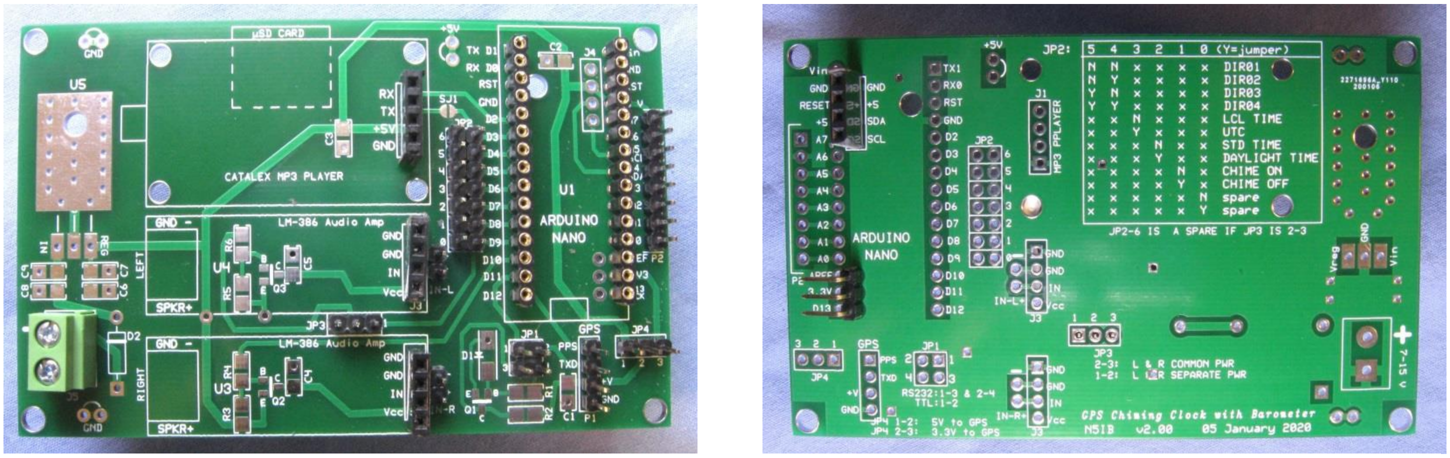


Figure 16. Circuit board top and bottom views with all connectors installed:

| | | |
|---|---|---|
| **Top:** | J1, J2, J3 | 4 position, single row vertical female header strip for 0.025" square posts |
| | P1 | 4 position, single row vertical male header with 0.025" square posts |
| | P2 | 8 position, single row vertical male header with 0.025" square posts |
| | JP1 | 4 position, two-row vertical make header with 0.025" square posts |
| | JP2 | 7 position, two-row (or use a pair of single row) vertical male header woth 0.025" square posts |
| | JP3, JP4 | 3 position, single row vertical male header with 0.025" square posts |
| | IN-R, IN-L | 2 position,vertical male header with 0.025" square posts |
| | U1 | IC socket, 30 pins, 0.6" spacing. Use 2 rows of 15 pin socket strip to match NANO pins (shown here as round machined pin sockets) |
| **Bottom:** | Unlabeled | 3 position, single row right-angled male header with 0.025" square posts (on bottom side) |
| | J4 | 4 position, single row vertical female header strip for 0.025" square posts |

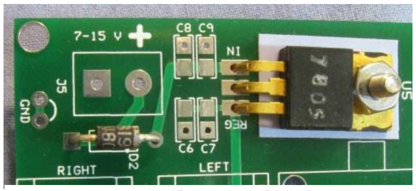


Figure 17. Regulator and polarity protection diode

*Remaining through-hole components*. Install the polarity protection Schottky diode D2, being careful to match the banded end with the outline on the silkscreen. Then install the 5 volt regulator IC, U5. No heat sink is needed, and the tab of the TO-220 package can be connected to the ground plane. Bend the leads to fit, and secure the device to the board with a #4-40 machine screw and nut. Some heat transfer compound, or a silicone pad (as shown here), can be used under the tab is desired. To avoid stress on the leads, snug it down in place BEFORE soldering the pins.

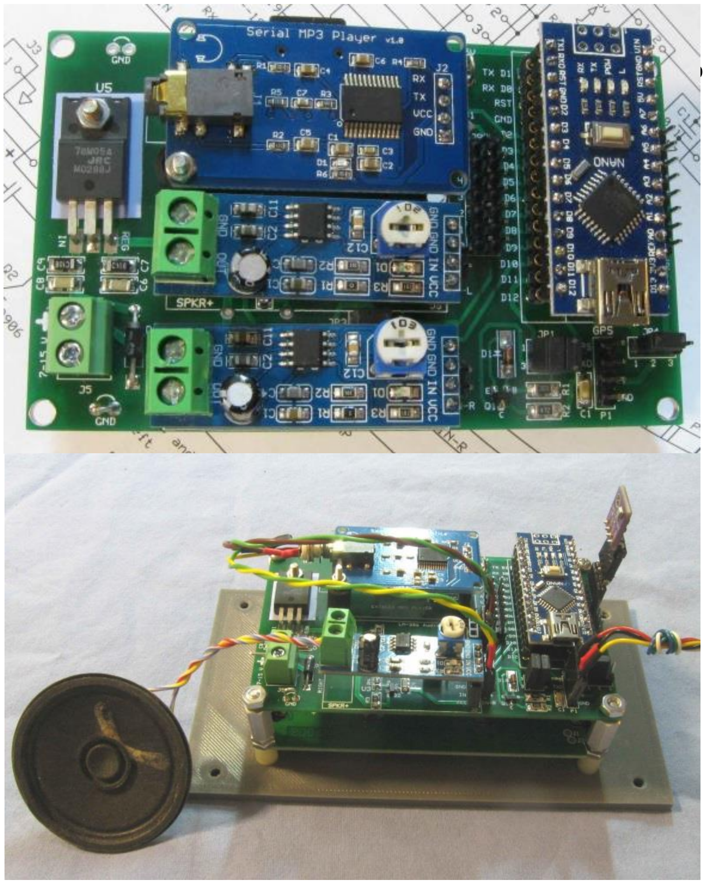


Figure 18. PC board with all modules attached (top) and with wire connections added (bottom). Only one audio amp is shown both connections for both are in place. GPS connection is the cable to the right.

*Mounting the sub-modules*. See the Builder Alert on the page containing the circuit board images. The Arduino NANO simply plugs into its socket, no further mechanical attachment is needed. The audio amplifier module(s) likewise just plug into their headers, there are no mounting screws. The MP3 player module should be secured with at least one standoff and #2-56 machine screw and nut.

Prepare a cable terminated at one end with a 1/8" (3.5 mm) stereo phone plug, with two wires connected to the *sleeve* lug, and one wire each to the *tip* and *ring* lugs. These wires will terminate in two 2-conductor female header sockets which connect at IN-L and IN-R. The right channel (IN-R) receives a ground (sleeve) wire and the ring conductor. The left channel (IN-L) receives a ground and the tip conductor. Observe the marked polarities (+ / -) at these two headers when plugging in the cables.

*Enclosure.* The only restriction is that the top of the enclosure must not shield the GPS receiver from "seeing" the satellites. If the top is metallic, there needs to be an opening at least as large as the GPS antenna, with the receiver mounted closely underneath. The opening can be covered with speaker grill cloth, or wood or plastic sheet. A completely wood or plastic enclosure would, of course, be entirely satisfactory.

*Power Supply*. Diode D2 is included in the circuit for polarity protection, so that the system won't be damaged if a reversed polarity source is accidentally connected. That protection is in force only with power options 1 and 2, below. These are the three options for supplying power to the clock:

1. A filtered (but need not be regulated) DC supply of between 7 and 13.8 V can be connected to the DC power terminals on the main PC board. The current required is about 205 mA with modest audio levels, about 180 mA when no audio is being produced. About 90 mA of that is consumed by the older style GPS receiver used in the prototype. Newer GPS units reduce that to under 50 mA. About 30 mA is drawn by the LED backlight for the LCD panel. If the real time clock module is used instead of a GPS receiver, its current requirement is less than 1 mA.

3. A battery pack supplying between 7 and 13.8 V DC can be connected, via SPDT switch SW1, to the main board's DC power terminals. A pair of 18650 lithium cells will power the clock for about 12 hours of portable operation on a single charge.

3. A regulated, filtered 5 V DC volt source can be supplied directly to the Arduino NANO via its USB connector. This is, in fact, the way the system is powered when loading programs onto the NANO. For normal operation, one of the readily available wall-wart charging units with a USB port can be used. The prototype has been running for over a month in this fashion. In this case the only polarity protection is afforded by the USB connector geometry.

Note that when the system is connected to, and therefore being powered by, a host computer via the USB interface, it should NOT be simultaneously receiving power by either options 1 or 2, above.

## Hardware changes to accommodate version 5.22 and later software

*Refer to the v5.10 schematic later in this document.*

The version 5.22 software provides a button operated menu to select program options. To accommodate the menu process two SPST, normally open, momentary contact pushbuttons must be connected to digital I/O lines D4 (the MENU button) and D5 (the SELect button).They can be wired to pins on header strip JP2.

Version 5.22 also allows for a real-time clock module to be connected in lieu of (or in addition to) a GPS receiver for time keeping. The PCF-8563 RTC module can share the I2C bus with the LCD display and the BME-280 environmental sensor. It can simply be wired in parallel with the BME-280 connection at header P2. The RTC should be set to UTC time and date for proper program operation.

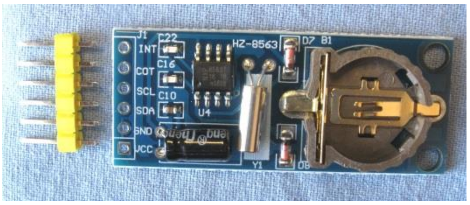


Figure 19. Real Time Clock Module with factory-supplied, but uninstalled header pins

The accuracy of the RTC depends upon the precision of its quartz crystal and the temperature stability inside the clock enclosure. Once set, the clock can maintain accuracy as good as just few seconds per month, but some units may gain or lose as much as a few seconds per day. The software includes a means of making small, automatic, daily corrections to maintain good average accuracy. The backup battery will maintain the timing even when the clock is unpowered.

## Programming

General information about using the Arduino IDE and programming can be found at the Arduino web pages, where also can be found links to download the IDE. https://www.arduino.cc/en/Guide/HomePage Programs, which in Arduino Land are called *sketches*, are uploaded to the microcontroller module via the USB connection to the host computer. Once loaded, the microcontroller can be disconnected from the host. The microcontroller will then execute the resident sketch whenever the module is powered up or is reset.

**Libraries**. Some of the sub-modules used in the clock are much easier to write programs for if their special libraries are used. The Arduino IDE includes a few built-in libraries to handle common tasks, but specialty hardware usually needs its own special library explicitly installed. In the case of this clock, the following libraries have to be available in the IDE before sketches can be compiled and uploaded:

| | |
|---|---|
| **SoftwareSerial** | already installed into the IDE, supports multiple serial ports |
| **SparkFun_BME280_Arduino_Library-master** | user-installed library, supports the environmental sensor |
| **Newliquidcrystal_1.3.5** | user-installed library, supports I2C LCD operation |
| **Rtc_Pcf8563-master** | user installed library, supports the real time clock (used for v5.22 and later) |
| **TinyGPSPlus** | user installed library, supports GPS (used for v5.22 and later) |

The documentation package for this project includes zipped folders that contain the four user-installed libraries, ready to be installed into the IDE with just a mouse click. The Arduino tutorial pages explain how to install a zipped library.

**Source Code**. Apart from the libraries, all of the program code for the clock is contained in single file. By Arduino rules, that file must reside in a folder with exactly the same name as the file. That folder and file are part of the documentation package. There are three clock sketches. One operates only as the nautical clock; the others can be set up to be either the nautical clock or a conventional chiming clock:

| | |
|---|---|
| ***GPS_Chiming_Nautical_Clock_N5IB_v2r22*** | *the folder that contains the nautical clock sketch file* |
| ***GPS_Chiming_Nautical_Clock_N5IB_v2r22.ino*** | *the file that contains the sketch source code* |
| ***GPS_Chiming_Multi_Clock_N5IB_v3r02*** | *folder with the multi-purpose clock sketch file* |
| ***GPS_Chiming_Multi_Clock_N5IB_v3r02.ino*** | *the sketch source code file* |
| ***GPS_RTC_Chiming_Multi_BIG_Clock_N5IB_5r22*** | *folder with new multi-purpose clock: large digit display and menus* |
| ***GPS_RTC_Chiming_Multi_BIG_Clock_N5IB_5r22.ino*** | *the sketch source code file* |

Note the underscore characters in the names. Arduino does not allow spaces in folder or file names.

**Test and diagnostic sketches**. Also included in the documentation package are several folders containing Arduino sketches intended to help test and verify that the various parts of the system are working properly. These sketches individually exercise the sub-modules and write results to the Arduino's Serial Monitor window. Be sure to read the comments at the beginning of each of these sketches for instructions.

| | |
|---|---|
| ***GPS_Tester_N5IB*** | *echoes to Serial Monitor the NMEA sentences sent by the GPS receiver* |
| ***I2C_Scanner_N5IB*** | *scans I2C bus and reports to Serial Monitor the addresses of connected I2C devices* |
| ***HelloWorld_i2c_20x4_LCD_N5IB*** | *writes test messages to the LCD display using I2C protocol* |
| ***Example1_BasicReadings_N5IB*** | *reads values from the BME-280 sensor module and echoes to Serial Monitor* |
| ***Serial_MP3_Command_tests_N5IB*** | *test the playback functions of the MP3 player module* |
| ***Set_8563_clock_and_alarm_N5IB*** | *test and set the real time clock time, date, and alarm registers* |

**Version 3.02 - User-defined parameters within the source code**. Near the beginning of the main sketch there are a group of definitions which tailor the operation to the builder’s needs:

```
// user-defined operating parameters
int UTC_offset = -6;                 // local standard time offset from UTC (-6 hours is Central Standard)
byte dispInt = 12;                   // interval between Watch/Barometer display swaps
const float baro_fix = 0.6;          // fudge factor for barometer to correct for altitude, in hPa, can be plus or minus
bool disp_knots=true;                // 'true' to show speed in knots, 'false' to show mph
bool Navy_mode=true;                 // 'true to operate as nautical clock, 'false' for ordinary chiming clock
#define GPS_baud 4800                // data rate for ASCII data from GPS receiver
#define MP3_baud 9600                // data rate for serial data sent to MP3 player (should not have to be changed)
#define LCD_I2Caddr 0x27             // I2C slave address for LCD display interface (run I2C scan to confirm)
#define sensorA_addr 0x76            // I2C slave address for BME-280s sensor module A, if used (run I2C scan to confirm)
#define sensorB_addr 0x77            // I2C slave address for BME-280s sensor module B, if used (run I2C scan to confirm)
```

The GPS data rate and the I2C addresses must match the hardware in order for the sketch to execute properly. The other parameters can be left with the default values until it’s confirmed that everything is functioning. Then they can be edited to suit the builder’s need

## Operation

**Configuration jumpers – for version 3.02 software only**. Several of the operating characteristics of the clock can be controlled by the presence/absence of shorting jumpers at jumper block JP2. In the table below, a filled circle ● means to install the shorting jumper, and a hollow circle ○ means do not install.

| JP2-6 | JP2-5 | JP2-4 | JP2-3 | JP2-2 | JP2-1 | JP2-0 | Function |
|---|---|---|---|---|---|---|---|
| ○ | | | | | | | *Spare feature selection only if SJ1 is OPEN* |
| ● | | | | | | | *Spare feature selection only if SJ1 is OPEN* |
| | ○ | ○ | | | | | *Use sound files from folder 01 on µSD card* |
| | ○ | ● | | | | | *Use sound files from folder 02 on µSD card* |
| | ● | ○ | | | | | *Use sound files from folder 03 on µSD card* |
| | ● | ● | | | | | *Use sound files from folder 04 on µSD card* |
| | | | ○ | | | | *Display local time* |
| | | | ● | | | | *Display UTC time* |
| | | | | ○ | | | *Display Standard Time if local time display is selected* |
| | | | | ● | | | *Display Daylight Savings Time  if local time display is selected* |
| | | | | | ○ | | *Enable audio output of chimes* |
| | | | | | ● | | *Disable audio output of chimes* |
| | | | | | | ○ | *Spare feature selection if D9 is not controlling AF amp power* |
| | | | | | | ● | *Spare feature selection if D9 is not controlling AF amp power* |

Note that if none of the above shorting jumpers are installed, the clock will default to local standard time, with chime audio enabled, and sounds taken from the files in the µSC card's folder 01.

***These remaining settings apply to both the v3.02 and v5.21 software.***

Other jumper blocks control hardware options such as power and data signal levels:

> **GPS data steam**. Jumper block JP1 selects whether to expect the serial data from the GPS receiver to be an RS-232 bi-polar voltage signal or a unipolar logic level signal. You MUST select one or the other of these options. If JP1 is left open, no GPS signal will be received.
>
> *To use RS-232 levels, jumper JP1-1 to JP1-3, and also jumper JP1-2 to JP1-4*
> *To use logic levels, jumper JP1-1 to JP1-2, and leave JP1-3 and JP1-4 unjumpered.*
>
> **GPS supply voltage**. Jumper JP4 selects whether to power the GPS receiver from +5V  or +3.3V. Again, you MUST select one or the other.
>
> *To power the GPS with +5 V, jumper JP4-1 to JP4-2*
> *To power the GPS with +3.3V, jumper JP4-2 to JP4-3*
>
> **Audio amplifier power control**. Jumper JP3 controls power to the audio amplifies. If two audio amplifiers are used it is possible to cause both amplifiers to be powered up/down together under program control, or to allow separate programmed control of each amplifier.
>
> *To allow separate control of left and right amplifies, jumper JP3-1 to JP3-2*
> *To link the left amplifier power control to the right amplifier, jumper JP3-2 to JP3-3*
> *To power only the Right Channel amplifier, leave JP3 completely open*

Note that the separate control feature is a **hardware configuration only**. The software would have to be modified to support it. The current software turns both channels ON/OFF simultaneously.

**Function of NANO digital I/O pin D3**. "Solder-blob-jumper" JP1 controls how the NANO's digital I/O pin D3 is used. It is assigned in the software as the pin on which serial data from the MP3 player module is received. But the software does not make any use of data coming from the MP3 player, so that pin could be used by a clever programmer for other purposes.

*To allow for independent use of D3, leave JP1* **OPEN**

*To connect D3 to receive serial data from the MP3 player,* **SHORT** *JP1 with a blob of solder*

**Display contrast**. There is a trimmer potentiometer on the I2C interface board attached to the back of the LSC display panel. It controls the contrast and visibility of the display. It is NOT a brightness control. When the display is mounted and connected to the main PC board the trimmer can be accessed through a hole in the main PC board. Unfortunately the NANO will block access to that hole when it is plugged in. Initially, set the trimmer at about 75% of full clockwise rotation.  It may be necessary to plug/unplug the NANO a few times to gain access to the trimmer to get the display set satisfactorily.

Alternatively, a little adjusting tool could be fashioned from a bit of stiff wire with one end bent and flattened as shown on the photo. Since the power pins of the NANO are right above the trimmer, avoid accidental short circuits by making it out of insulated solid wire, exposing only the "blade.". Very likely two such tools will be needed with the "blades" angled 90 degrees apart.

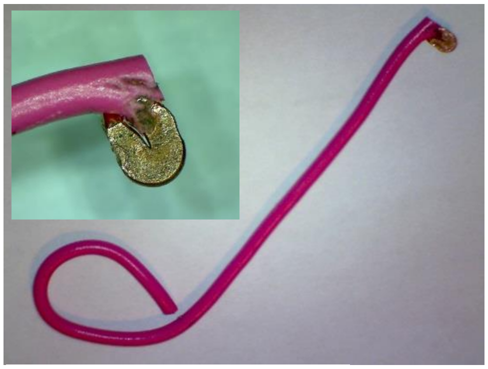


Figure 20. Contrast tool

The elegant way, of course, is to adjust the trimmer while using a short 4-conductor cable to connect to the LCD while it is physically separated from the main board.

**Starting up – see additional instructions below for v5.21 software**.  With the operating sketch uploaded to the NANO, sound files loaded onto the µSD card, and the GPS receiver connected, apply power. After a couple of seconds a "SplashScreen" will appear on the LCD and an audio clip may play. Afterwards, until the GPS receiver acquires some usable data, the display may be in some disarray for a little while, invalid time may appear, and some audio clips may sound . The time display will become correct as soon as at least one satellite is being received. A "NO FIX" message will display until at least three valid satellites are acquired, whereupon the position, course and speed, and grid square will display.

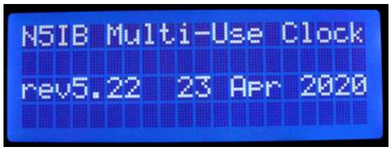
The current sketch, for the nautical clock, sounds the ship's bell on the hours and half hours. At the watch changes the bo'sun pipes ***Relieve the Watch.*** As a special treat, at 1800 hours, instead of the bo'sun piping the hands to supper, we're treated to the fife and drum rendition of ***Roast Beef of Old England***.

Regardless of whether local time or UTC has been selected for the screen display, the "watch names" are displayed according to local time. This is as it was aboard ship where, in the age of sail, the nautical day began at local noon, when the navigator determined the sun had reached its highest elevation.

## Version 5.22 Operation

The newest Arduino sketch, version 5.22, does away with the shorting jumpers for selection of program options. Instead, a menu is displayed on the LCD screen and a pair of momentary contact pushbuttons are used to navigate the menu and to select the program options (see the schematic for version 5.xx).

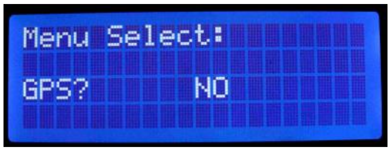
The various LCD display screens are pictured, in the order they appear, and described below:



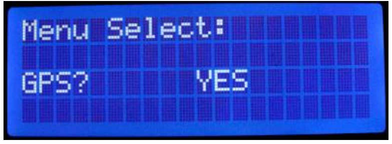
```
N5IB Multi-Use Clock
rev5.22  23 Apr 2020
```

Startup “splash screen” which is displayed for a few seconds after power up or processor reset.

*In the menu screens shown below, note the punctuation mark after each menu item name. A question mark (?) means the item is a binary YES/NO selection only. A colon (:) means that a numeric entry is expected.*

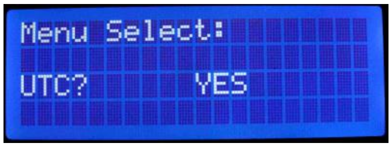


```
Menu Select:
GPS?      NO
```



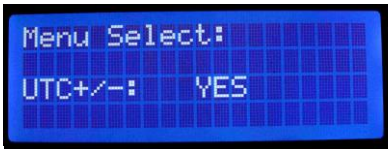
```
Menu Select:
GPS?      YES
```

Selects whether or not to use a GPS receiver for time keeping. *Notice the question mark.* A short press (about a half second) of the SEL button will toggle the selection between YES and NO. A NO selection means the program will expect a real-time-clock module to be connected. A short press of the MENU button will advance to the next menu item. If no action is taken within 10 seconds the program will exit menu mode. The menu may also be exited by a long press (more than 2 seconds) of the MENU button.

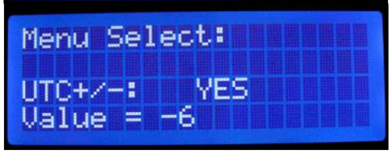


```
Menu Select:
UTC?      YES
```

Selects whether to display local time zone time or Universal Coordinated Time (UTC or Greenwich). Short press of SEL toggles YES/NO.

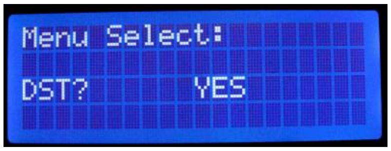


```
Menu Select:
UTC+/-:   YES
```



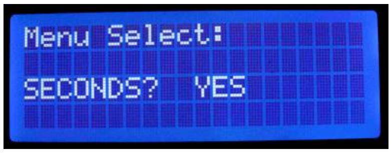
```
Menu Select:
UTC+/-:   YES
Value = -6
```

This is the offset in hours from UTC for the local standard time zone. Here negative 6 was entered to choose Central Standard Time. *Note the colon following the item name*. A numerical value is expected. A long press of the SEL button enters the numeric mode. Then successive short presses of the SEL button cycle through the available values. A short press of the MENU button exits the numeric mode, then another short press of MENU moves on to the next menu item.



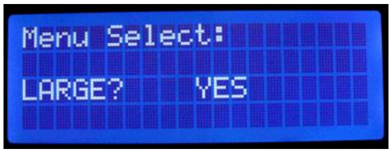
```
Menu Select:
DST?      YES
```

When local time, rather than UTC is chosen for display, this selection determines whether the Daylight Savings Time offset is to be applied. Short press of SEL toggles YES/NO.

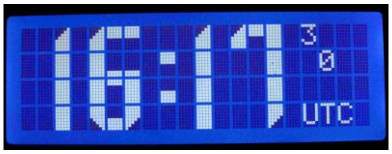


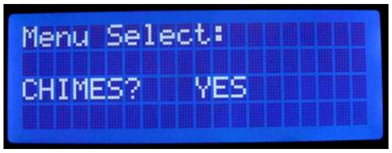
```
Menu Select:
SECONDS?  YES
```

This section enables/disables the display of seconds. Short press of SEL toggles YES/NO.

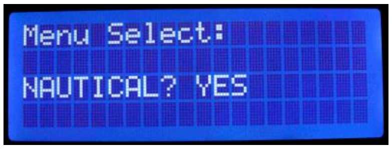

Menu Select:
LARGE? YES

Selecting YES causes the hours and minutes to be displayed in digits about an inch high. If the seconds display has been enabled, they will be shown in small digits. Short press of SEL toggles YES/NO.

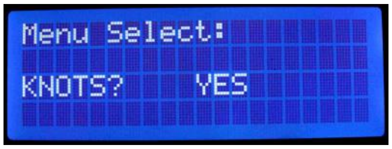



Menu Select:
CHIMES? YES

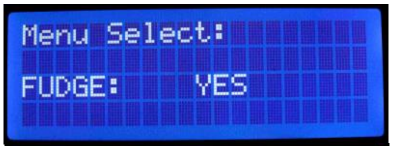
This item enables/disables the sounding of pre-recorded MP3 files as periodic chimes.

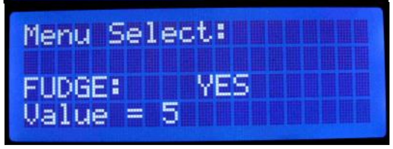

Menu Select:
NAUTICAL? YES

A YES selection causes the chimes (if enabled) to be the nautical variety, where a ship's bell is sounded every 30 minutes, and a bosun's pipe sounds at the start of each watch. A NO selection will cause the chimes to sound every 15 minutes, and the hours to be struck, as in the conventional Westminster style clocks. Short press of SEL toggles YES/NO.

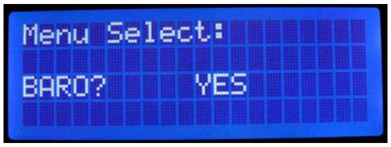

Menu Select:
KNOTS? YES

If a GPS is doing the time keeping, it can also provide a course and speed. A YES selection here displays the speed in knots, NO will display miles per hour. Short press of SEL toggles YES/NO.

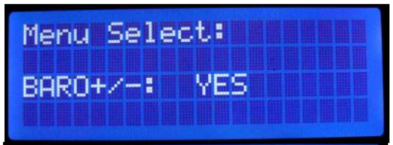

Menu Select:
FUDGE: YES

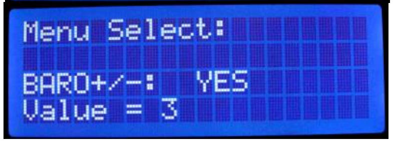

Menu Select:
FUDGE: YES
Value = 5

If a real-time-clock module is doing the time keeping, instead of a GPS, this selection chooses a "fudge factor," in seconds, that will be applied to the real-time-clock once each day at UTC midnight to fine tune its time keeping. It is a numeric value that can be positive or negative. In this example, 5 seconds will be added to the RTC each UTC midnight, since it was determined that this particular module was running 5 seconds slow per day.

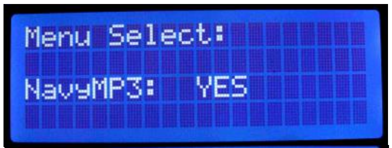

Menu Select:
BARO? YES

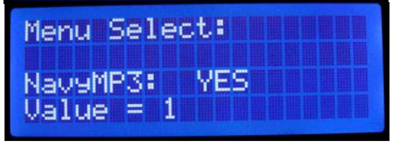
If a BME-280 pressure/temperature/humidity sensor is included, this item enables/disables display of the barometric pressure when the small digit display mode is in use. The units will be hectopascals (hPa) – a meteorological unit numerically equivalent to millibars.


Menu Select:
BARO+/-: YES

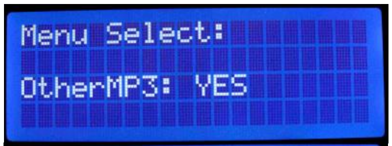

Menu Select:
BARO+/-: YES
Value = 3

Small corrections can be made to the barometric pressure, in steps of tenths of an hPa, to account for altitude above mean sea level. A numeric value entered here is divided by 10 to calculate the positive or negative correction.

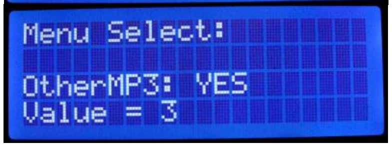

Menu Select:
NavyMP3: YES


Menu Select:
NavyMP3: YES
Value = 1

This numeric selection specifies the folder number on the MP3 player's uSD memory card where the ship's bells sounds are recorded. The values are numbers starting from zero and cannot be negative.

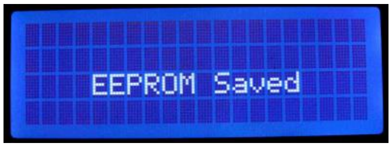


```
Menu Select:

OtherMP3: YES
```



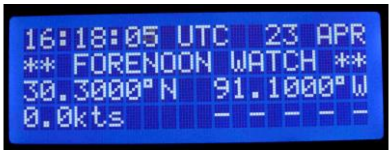
```
Menu Select:

OtherMP3: YES
Value = 3
```

This numeric selection specifies the folder number on the MP3 player's uSD memory card where the conventional chime sounds are recorded. The values are numbers starting from zero and cannot be negative.



```


   EEPROM Saved

```

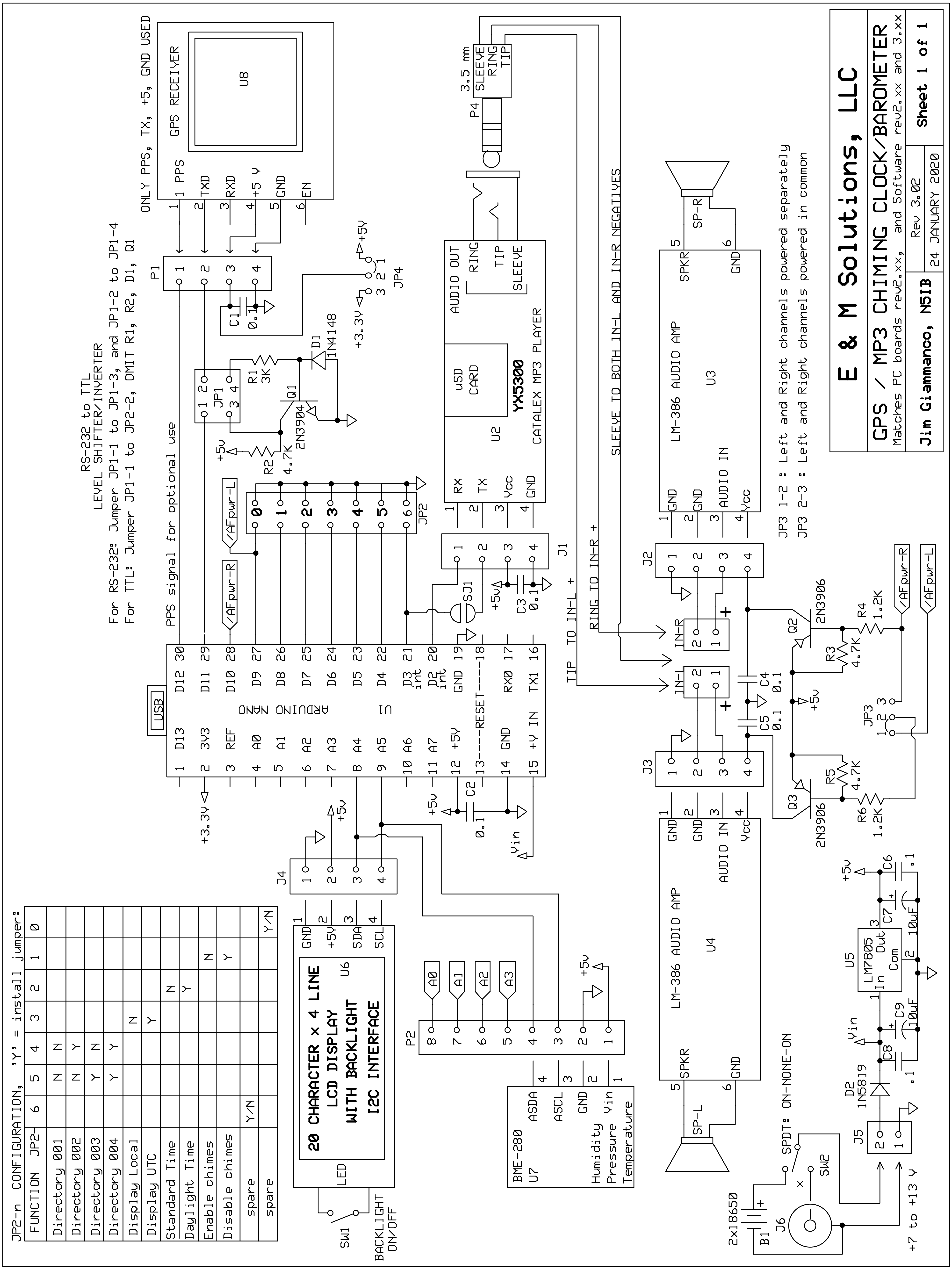
After each exit from the menu selection process, this message will indicate that any updated values have been save to the Arduino's EEPROM non-volatile memory.



```
16:18:05 UTC  23 APR
** FORENOON WATCH **
30.3000°N  91.1000°W
0.0kts     - - - - -
```

When the small digit display has been chosen, and the nautical mode selected, longitude, latitude, course, and speed will be displayed (GPS required) and the watch name will alternate with the barometric pressure display (if the barometer is enabled).

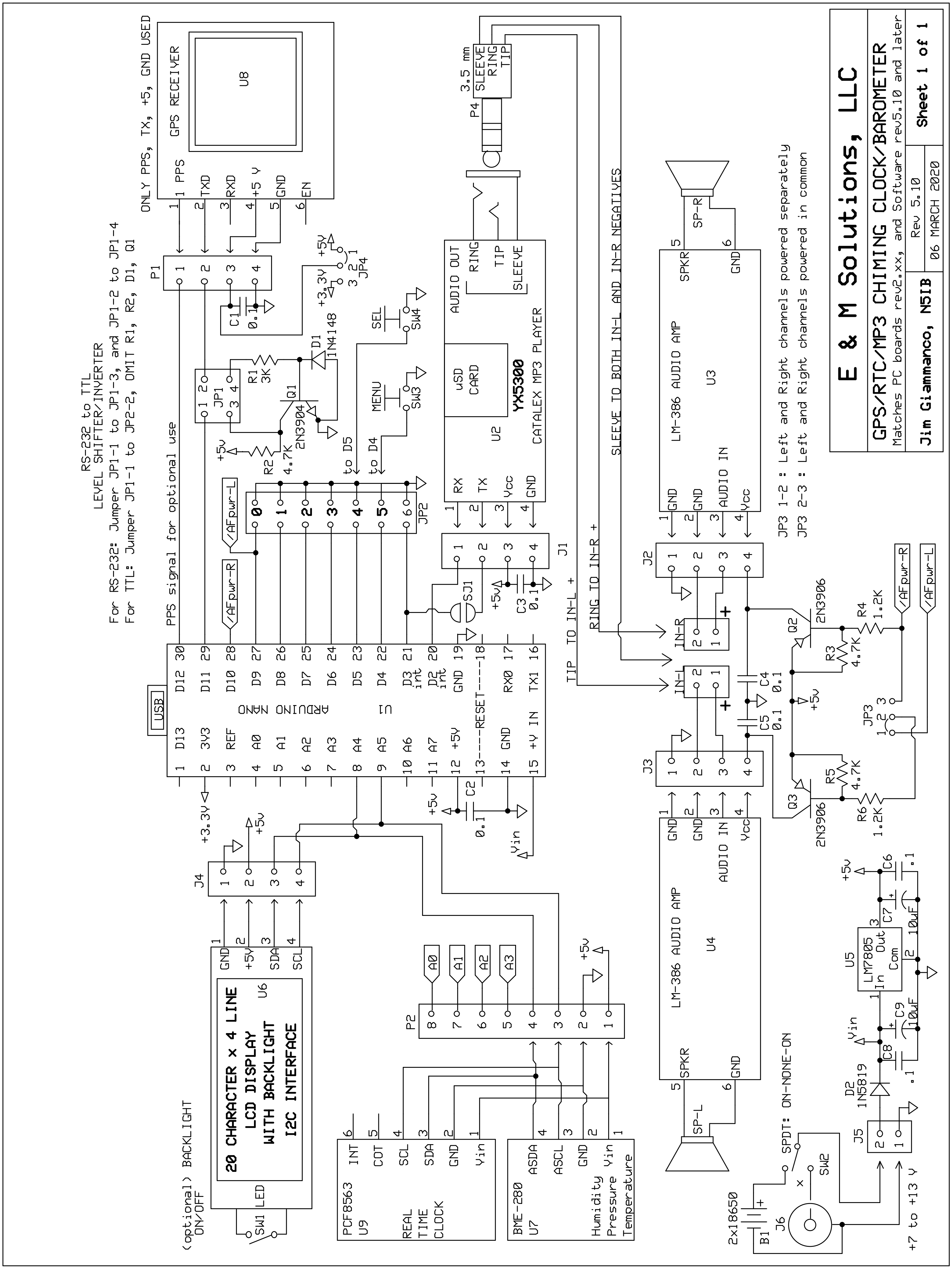
Original version 3.xx schematic



JP2-n CONFIGURATION, 'Y' = install jumper:

| FUNCTION JP2- | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| Directory 001 | | N | N | | | | |
| Directory 002 | | N | Y | | | | |
| Directory 003 | | Y | N | | | | |
| Directory 004 | | Y | Y | | | | |
| Display Local | | | | N | | | |
| Display UTC | | | | Y | | | |
| Standard Time | | | | | N | | |
| Daylight Time | | | | | Y | | |
| Enable chimes | | | | | | N | |
| Disable chimes | | | | | | Y | |
| spare | Y/N | | | | | | |
| spare | | | | | | | Y/N |

Revised version 5.xx schematic

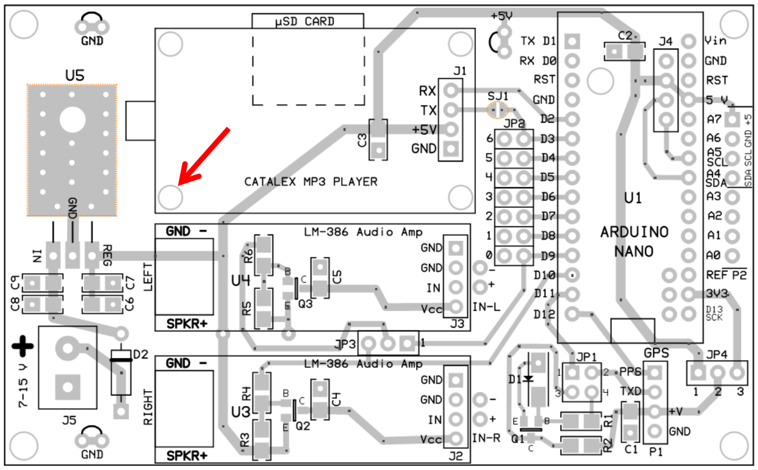


PC Board Images, approximately actual size (98 mm x 60 mm):

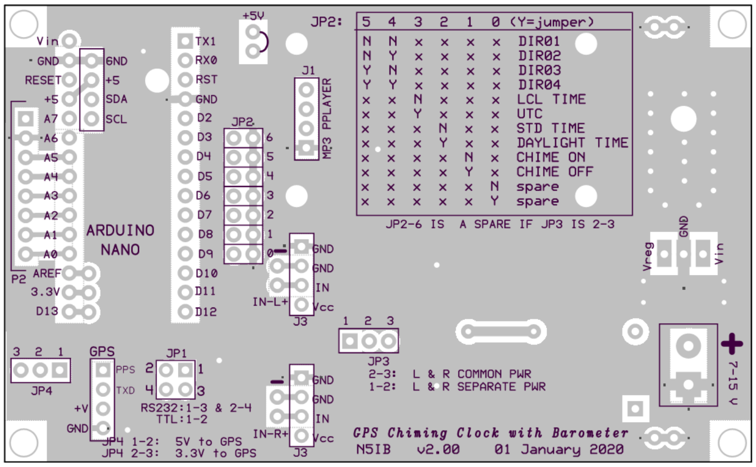
## Builder Alert – version 2.00 PC board only

*There is a drilling error on the v2.00 circuit board. Three of the four mounting holes on the PC board for the MP3 player module do not properly align with the corresponding holes on the module. However the fourth hole, marked with the arrow, is adequately aligned. And a single standoff and machine screw is entirely sufficient to secure the module once it is plugged into its connecting header strip. The v2.01 boards will have only the left-hand two mounting holes for the MP3 module – properly aligned!*

TOP COPPER PATTERN v2.00



BOTTOM COPPER PATTERN v2.00



| 5 | 4 | 3 | 2 | 1 | 0 | (Y=jumper) |
|---|---|---|---|---|---|---|
| N | N | x | x | x | x | DIR01 |
| N | Y | x | x | x | x | DIR02 |
| Y | N | x | x | x | x | DIR03 |
| Y | Y | x | x | x | x | DIR04 |
| x | x | N | x | x | x | LCL TIME |
| x | x | Y | x | x | x | UTC |
| x | x | x | N | x | x | STD TIME |
| x | x | x | Y | x | x | DAYLIGHT TIME |
| x | x | x | x | N | x | CHIME ON |
| x | x | x | x | Y | x | CHIME OFF |
| x | x | x | x | x | N | spare |
| x | x | x | x | x | Y | spare |

JP2-6 IS A SPARE IF JP3 IS 2-3

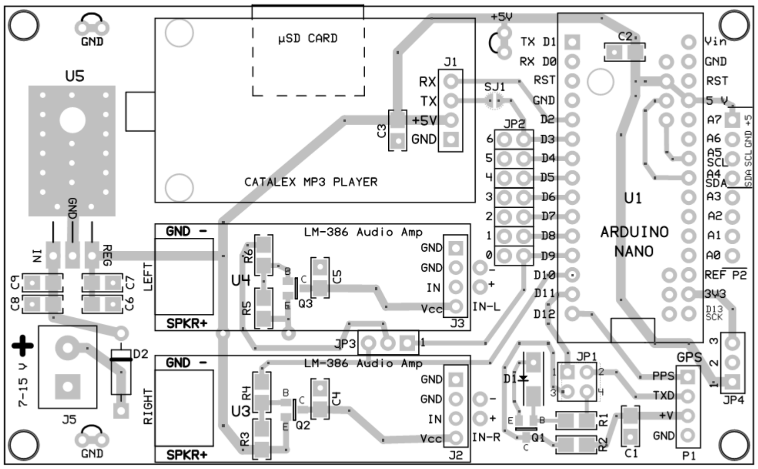
JP3
2-3: L & R COMMON PWR
1-2: L & R SEPARATE PWR

RS232:1-3 & 2-4
TTL:1-2

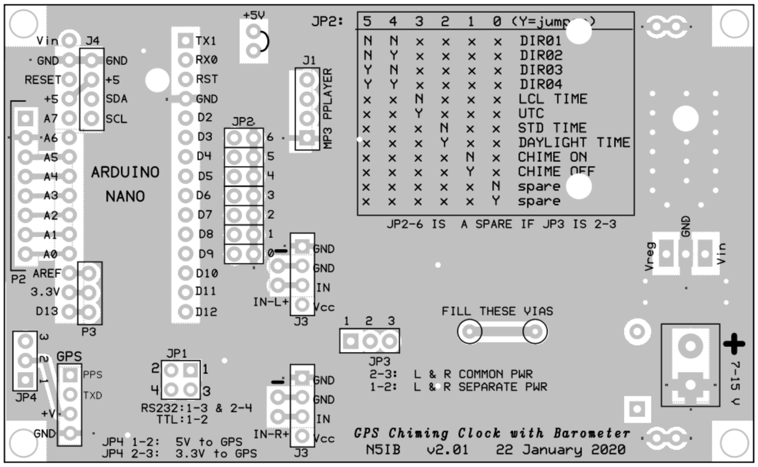
JP4 1-2: 5V to GPS
JP4 2-3: 3.3V to GPS

*GPS Chiming Clock with Barometer*
N5IB v2.00 01 January 2020

## TOP COPPER PATTERN v2.01



## BOTTOM COPPER PATTERN v2.01



# Bill of Materials

| | |
|---|---|
| C1, C2, C3, C4, C6, C8 | 0.1 µF 50V 1206 or 0805 size surface mount ceramic capacitor |
| C7, C9 | 10 µF 25V 1206 or 0805 sized surface mount polarized capacitor |
| D2 | 1N5819 axial lead Schottky rectifier diode |
| J1, J2, J3, J4, P1 | 1 x 4 position header, builder's choice of gender and vertical or right angle |
| J5 | 2-position screw terminal connector block, 5mm (~0.2") lead spacing |
| J6 | coaxial DC power jack, 2.1 mm ID x 5.5 mm OD (to be mounted on enclosure wall) |
| IN-L, IN-R | 1 x 2 position header, builder's choice of gender and vertical or right angle |
| JP2 | 2 x 6 position vertical male header pin array, with 6 removable shunts (shunts not needed for v5.22) |
| JP4 | 3 x 1 position vertical male header pin array, with 1 removable shunt |
| P2 | 1 x 8 position header, builder's choice of gender and vertical or right angle |
| P4 | 3.5 mm stereo plug |
| Q2 | 2N3906 surface mount Si PNP transistor SOT-23 |
| R1 | 3.0K 1206 or 0805 size surface mount resistor |
| R3 | 4.7K 1206 or 0805 size surface mount resistor |
| R4 | 1.2K 1206 or 0805 size surface mount resistor |
| SJ1 | etched "solder blob jumper" on PCB |
| SW1 | SPST switch (optional for LCD display backlight on/off) |
| SP-R | miniature 8Ω or 16Ω speaker (second speaker optional for stereo |
| U1 | Arduino NANO microcontroller, example eBay item # 223789950366 $4.95 each |
| U2 | Catalex MP3 player module with µSD card reader socket, example eBay item # 311566743492 $2.91 each |
| U3 | LM-386 audio amplifier module (2nd module optional for stereo) example Marlin P Jones item # 31805 MI $3.95 each |
| U5 | LM7805 5V linear voltage regulator, TO-220 |
| U6 | LCD display, 4 lines x 20 characters per line, with I2C data interface, example Amazon ASIN # B07DZXPXT5 $7.60 each |
| U7 | BME-280 pressure, temperature, humidity module, example Amazon ASIN # B07KYJNFMD 3 modules for $12.99 |
| U8 | GPS receiver module with integral antenna, example Amazon ASIN # B015R62YHI $12.99 each (logic level data output) |
| U9 | (optional) PCF8563 Real Time Clock module, pre-assembled (example: eBay item # 362714293867) |
| | Battery CR1220 3V Lithium watch battery for clock backup (a CR1216 can be used in a pinch if CR1220 not available) |

| | |
|---|---|
| Memory card: | µSD card, 1 GB or larger, depending on sizes of stored audio files |
| Hardware: | ½" and ¼" standoffs, #4-40 machine screws and nuts to mount PC board to display, and display to front panel |
| | #4-40 machine screw and nut to secure voltage regulator to PC board |
| | #2-56 machine screw, nut, and standoff to secure MP3 player module to PC board |
| | enclosure |
| | printed circuit board |

*Parts needed only if optional RS-232 level shift circuitry is installed:*

| | |
|---|---|
| Q1 | 2N3904 surface mount Si NPN transistor SOT-23 |
| D1 | 1N4148 or equivalent, surface mount small signal Si diode, SOD-80 package (round, barrel-type) |
| R1 | 3K 1/8 W 1206 size surface mount resistor |
| R2, R3, R5 | 4.7K 1206 size surface mount resistor |
| JP1 | 2 x 2 position vertical male header pin array, with 2 removable shunts |
| | (*if this option is not installed, connect a jumper wire form JP1-1 to JP1-2*) |

*Parts needed only the second audio channel is used:*

| | |
|---|---|
| U4 | LM-386 audio amplifier module (the optional second module for stereo) |
| Q3 | 2N3906 surface mount Si PNP transistor SOT-23 |
| R5 | 4.7K 1206 size surface mount resistor |
| R6 | 1.2K 1206 size surface mount resistor |
| C5 | 0.1 µF 50V 1206 size surface mount ceramic capacitor |
| SP-L | miniature 8Ω or 16Ω speaker (second speaker optional for stereo |
| JP3 | 3 x 1 position vertical male header pin array, with 1 removable shunt |
| | (*if this option is not installed, leave all pads of JP3 unconnected*) |

*Parts needed only if battery power option is used:*

| | |
|---|---|
| B1 | pack of two 18650 Li-ion cells |
| SW2 | SPDT, center off switch (ON-NONE-ON) |

Documents and Software: see https://qsl.net/n5ib/

*Note: The vendors suggested above are by no means exclusive. At any given time there are generally several sources for the identical modules. Use the photographs for comparison to assure that the modules purchased are the same physical size and configuration. In many cases other vendors may offer substantial quantity discounts if a group build is planned. The NANOs are so useful that buying them by the half dozen is not a bad idea.*

Some suggestions for vendors for discrete parts….. among very many choices…

Note that the PC board pads for the surface mount resistors and capacitors are designed to accept either 1206 or 0805 sized SMD parts. The 0805 parts are often less costly since they are more commonly used than the larger 1206 parts. Surface mount parts often must be purchased in lots of 10 or more, depending on the vendor.

Mouser Electronics https://www.mouser.com/

- Thick Film Resistors - SMD 1/4watt 1.2 K ohms 5%, 71-CRCW1206J-1.2K-E3, 10 pieces for $0.73
- Thick Film Resistors - SMD 1/4watt 3.0 K ohms 5%, 71-CRCW1206J-3K-E3, 10 pieces for $0.73
- Thick Film Resistors - SMD 1/4watt 4.7 K ohms 5%, 71-CRCW1206J-4.7K-E3, 10 pieces for $0.73
- Ceramic Capacitors MLCC - SMD/SMT 50V 0.1µF X7R 1206 10%, 80-C1206104K5RAC7867, 10 pieces for $0.43
- Ceramic Capacitors MLCC - SMD/SMT 1206 50V 10µF 10% X5R, 963-UMK316BBJ106KL-T, 10 pieces for $1.80
- Bipolar Transistors - BJT NPN Enhanced Complimentary, 610-CMPT3904E, $0.43 each, or 10 for $2.76
- Bipolar Transistors - BJT PNP Gen Purpose Halogen Free, 610-CMPT3906G, $0.68 each, 05 10 for $5.91
- Diodes - General Purpose, Power, Switching Small Signal Diode SMD/SMT, 512-LL4148, $0.10 each, or 10 for $0.87

Tayda Electronics https://www.taydaelectronics.com/

- Header pins and sockets:
  - 40 Pin 2.54mm Single Row Pin Header Strip, SKU: A-197, $0.15 each
  - 40 Pin 2.54mm Right Angle Single Row Pin Header, SKU: A-199, $0.17 each
  - Mini Jumper 2.54mm Gold Plated Closed Cover, SKU: A-1324, $0.02 each
  - 40 Pin 2.54mm Single Row Female Pin Header, SKU: A-196, $0.20 each
- Voltage regulator: LM7805 L7805 7805 Voltage Regulator IC 5V 1.5A, SKU: A-179, $0.23 each
- Diode: 1N5819 SCHOTTKY BARRIER DIODE 1A 40V, SKU: A-484, $0.05 each
- Transistors:
  - BC807 Transistor PNP 45V 0.5A SOT-23-3 BC807-25,215, SKU: A-1336, $0.03 each (sub for 2N3906)
  - BC817 Transistor NPN 45V 0.5A SOT-23-3 BC817-40,215, SKU: A-3192, $0.03 each (sub for 2N3904)

Marlin P. Jones https://www.mpja.com/

- Speaker: 8 Ohm Mini Speaker, 3W, 2in., Stock No: 33056 SP, $1.29 each
- Audio Amp: LM386 200 Gain Audio Amplifier Module, Stock No: 31805 MI, $3.95 each
- Screw Terminal Block: P.C. Board Terminal Strip, 2 Position, Stock No: 18318 TS, $0.39 each
- Pack of 420 transistors : Assortment of Popular SOT23 - SMD Transistors, Stock No: 35726 QT, $8.95 per assortment

Useful accessory software:

Audacity Sound editing
https://www.audacityteam.org/download/

Text to Morse MP3 conversion
http://www.morseresource.com/morse/makemorse.php

# *Appendix*

## GPS NMEA Sentence data interpretation:

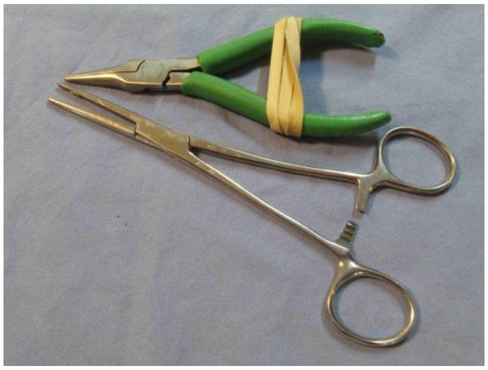
**$GPGGA,123519,4807.038,N,01131.000,E,1,08,0.9,545.4,M,46.9,M,,*47**

```
Where:
     123519       Fix taken at 12:35:19 UTC
     4807.038,N   Latitude 48 deg 07.038' N
     01131.000,E  Longitude 11 deg 31.000' E
     1            Fix quality: 0 = invalid
                               1 = GPS fix (SPS)
                               2 = DGPS fix
                               3 = PPS fix
                                    4 = Real Time Kinematic
                                    5 = Float RTK
                               6 = estimated (dead reckoning) (2.3 feature)
                                    7 = Manual input mode
                                    8 = Simulation mode
     08           Number of satellites being tracked
     0.9          Horizontal dilution of position
     545.4,M      Altitude, Meters, above mean sea level
     46.9,M       Height of geoid (mean sea level) above WGS84
                      ellipsoid
     (empty field) time in seconds since last DGPS update
     (empty field) DGPS station ID number
     *47          the checksum data, always begins with *
```

**$GPRMC,123519,A,4807.038,N,01131.000,E,022.4,084.4,230394,003.1,W*6A**

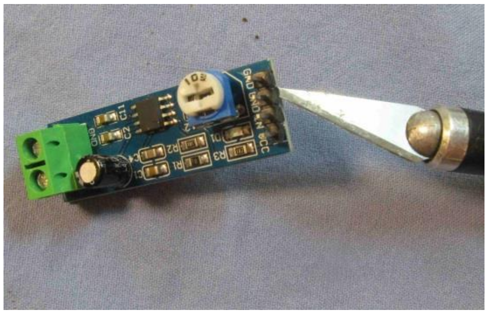
```
Where:
     123519       Fix taken at 12:35:19 UTC
     A            Status A=active or V=Void.
     4807.038,N   Latitude 48 deg 07.038' N
     01131.000,E  Longitude 11 deg 31.000' E
     022.4        Speed over the ground in knots
     084.4        Track angle in degrees True
     230394       Date - 23rd of March 1994
     003.1,W      Magnetic Variation
     *6A          The checksum data, always begins with *
```

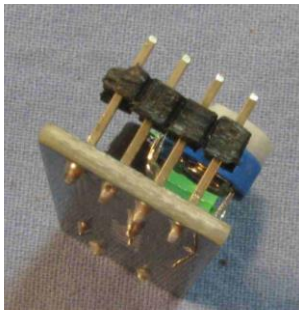
## Replacing or modifying pre-installed header connectors

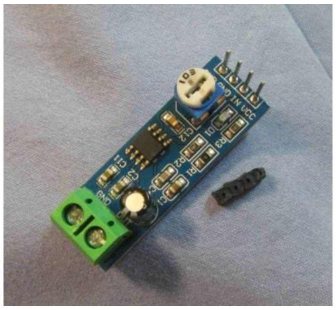


A useful tool for removing pins is the surgeon’s hemostat, or locking forceps. If you don’t have such a tool, improvise with a rubber band and a long-nosed plier. The link below is an inexpensive source.

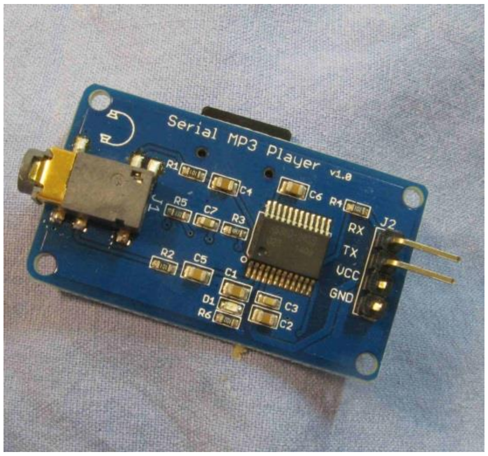
https://www.harborfreight.com/3-1-2-half-inch-locking-clamp-99931.html

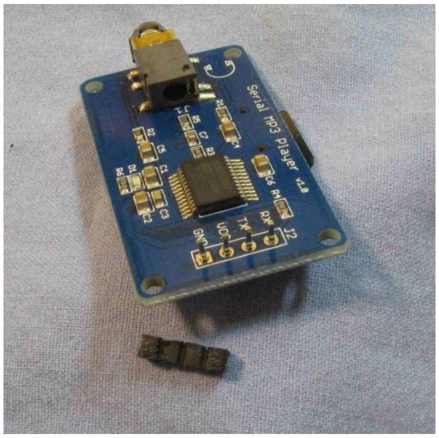






For vertical pins, use a knife edge to gently pry up the plastic carrier strip that joins the header pins. The goal is to remove the plastic strip entirely so that the pins can be removed individually.



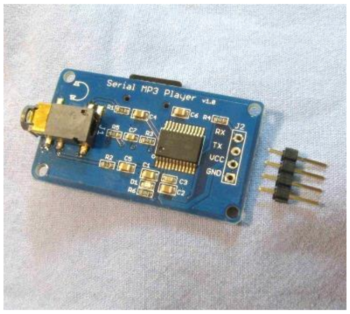


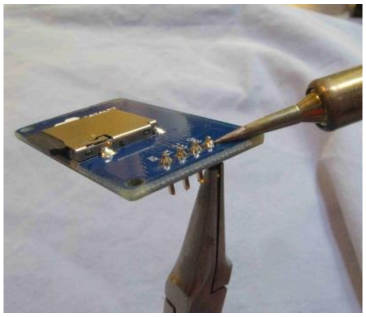
In the case of right-angled pins, first nip off the pins with wire cutters so that only the straight part remains. Then remove the plastic carrier in the same fashion as above.

Once you have the pins isolated, attach the locking plier to a pin. Hold the board so that the plier hangs vertically below the board. Let the plier rest on your work surface while you heat the pin’s solder connection with your iron. The object is to NOT apply any pulling force on the pin until the solder is fully melted. When you see the solder melt and flow, gently lift the board/plier pair off the work surface. The pin should slip out easily.

Use solder wick or a solder sucker to clean out any remaining solder in the holes. Since commercial boards will very often be assembled with lead-free solder, which is harder to remove, sometimes it will help to re-flow some tin-lead solder onto the empty pad before wicking or sucking out the residue.

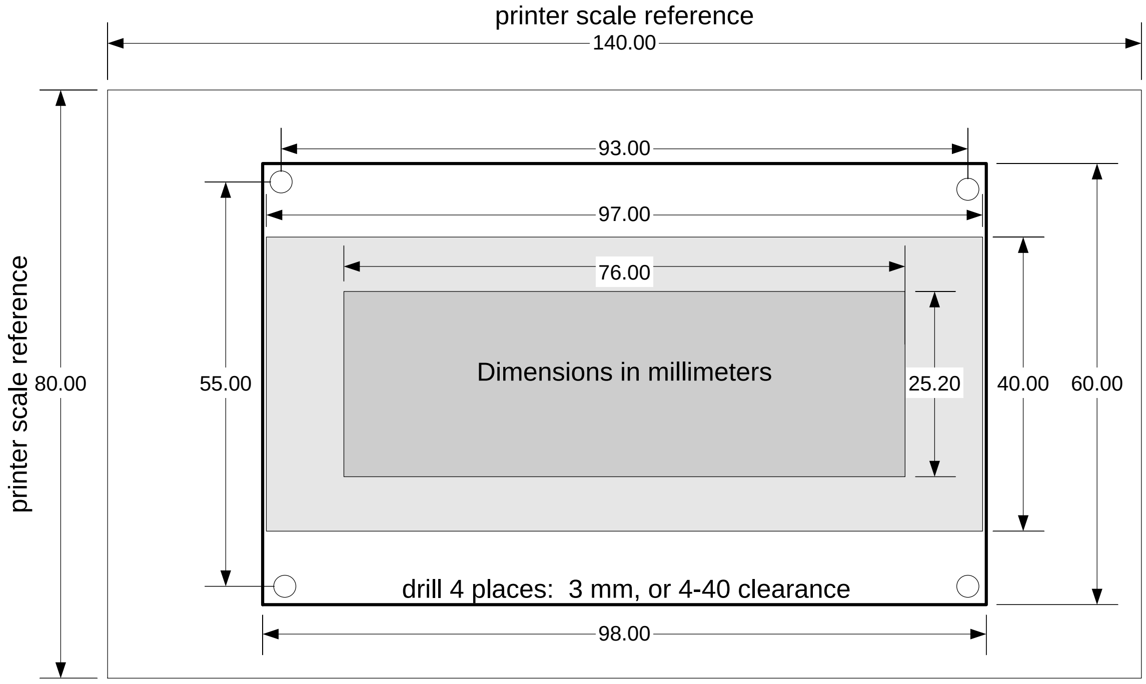
When the holes are free of excess solder, install the new pins in the usual manner.





## LCD cut and drill template

Before using this template, be sure to carefully measure the printer scale reference lines and adjust your printer scaling as needed until the printed copy matches those reference dimensions.


printer scale reference
140.00
printer scale reference
80.00
93.00
97.00
76.00
55.00
Dimensions in millimeters
25.20
40.00
60.00
drill 4 places: 3 mm, or 4-40 clearance
98.00