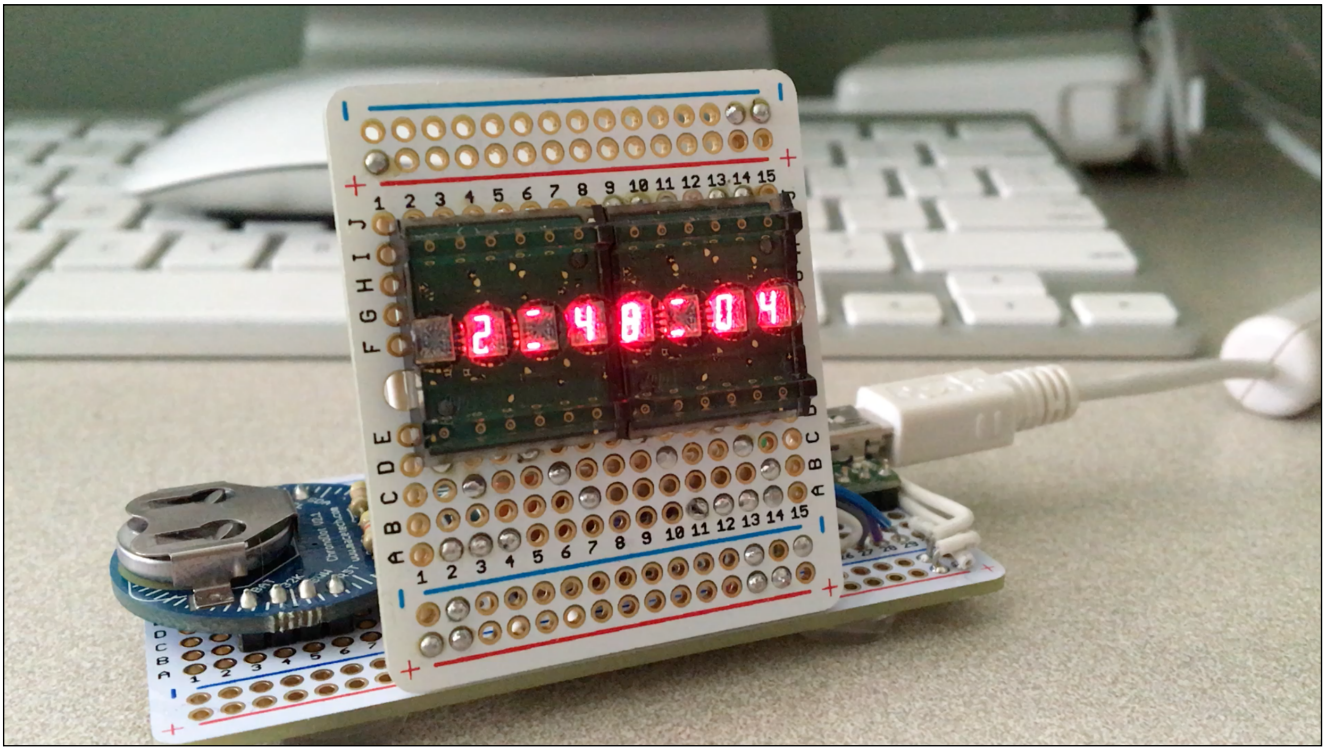
Digital Clock DC-001

User Guide

Software Version 1.0 - December 23, 2015



Digital Clock DC-001 1

User Guide

Warranty 3

Contacting the Manufacturer 3

Features 4

Specifications 4

Interface and Hardware Overview 5

Installation 6

Using your Clock 7

Theory of Operation 10

Maintenance 11

Appendix 1: Daylight Savings Time 12

Appendix 2: Bill Of Materials 13

Warranty

Joey warrants that the product will be free of defects in materials and workmanship for the lifetime of the product. If the product proves defective during this warranty period, Joey, at his option, either will repair the defective product without charge for parts and labor, or will provide a replacement in exchange for the defective product. Batteries are excluded from this warranty. Parts, modules, and replacement products used by Joey for warranty work may be new or reconditioned to like new performance. All replaced parts, modules, and products become the property of Joey.

In order to obtain service under this warranty, Customer must notify Joey of the defect before the expiration of the warranty period and make suitable arrangements for the performance of service. Customer shall be responsible for packaging and shipping the defective product to the service center designated by Joey.

Contacting the Manufacturer

For product information, sales, service, and technical support:

- In North America, call: 1-XXX-XXX-XXXX
- Worldwide email: joey@joeyhagedorn.com
- On the web: https://www.joeyhagedorn.com

An electronic copy of this manual is available online at:

`https://www.joeyhagedorn.com/download/DC-001/UserGuide.pdf`

Features

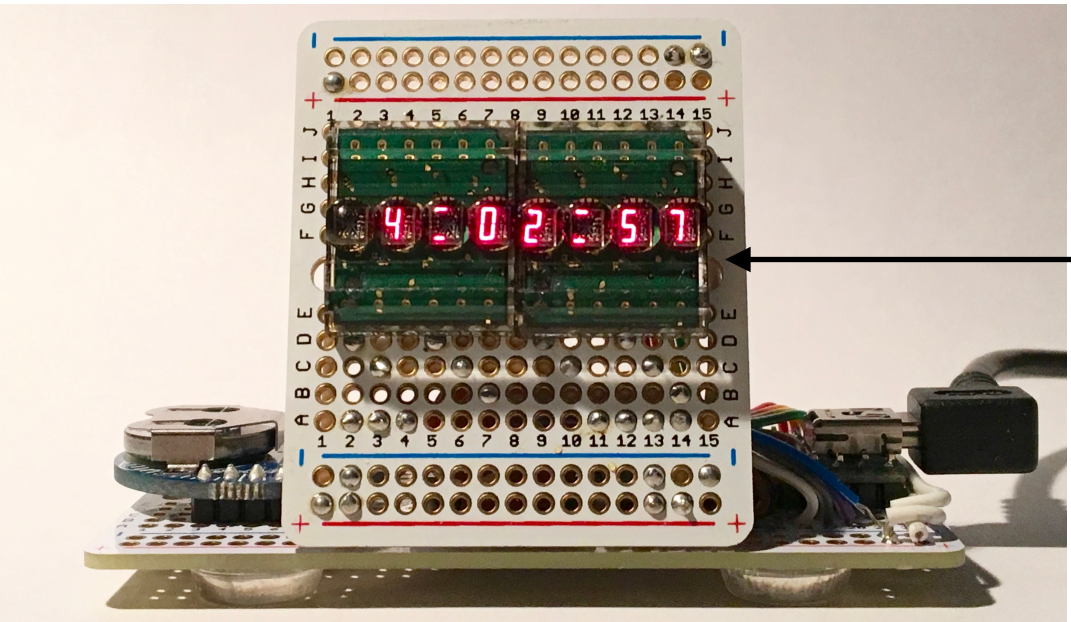
This Digital Clock DC-001 has been custom built for Mara and Scott. All features and clock design are bespoke and not derived from any existing commercial product. The primary features of this clock are:

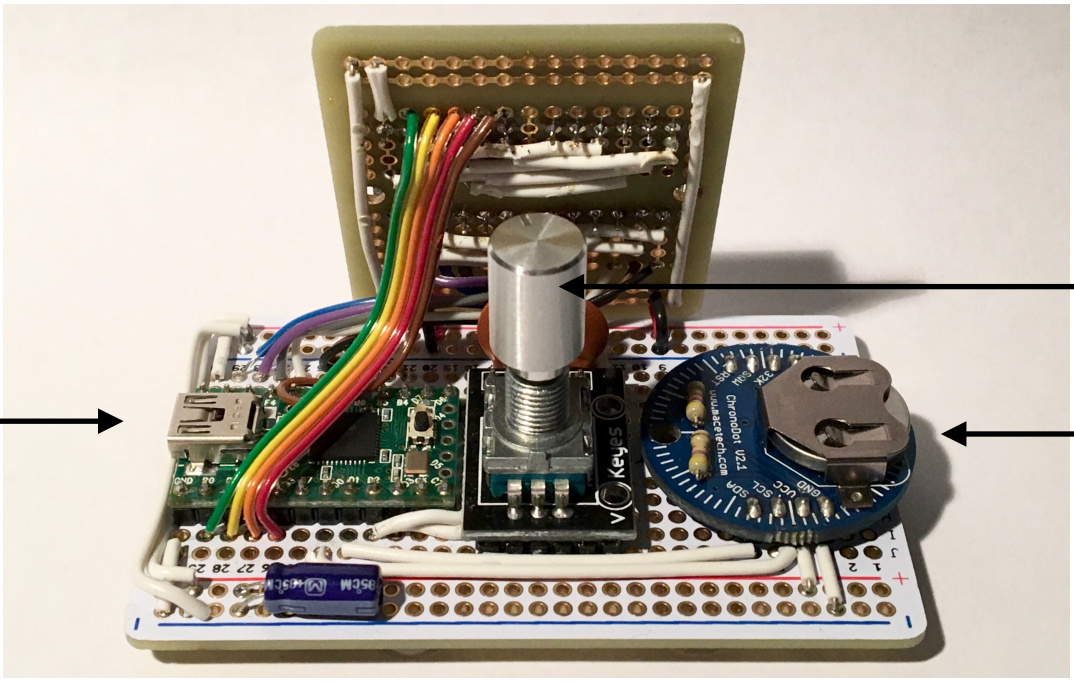
- High-precision high-stability temperature compensated timekeeping
- Persistent settings and battery backup for timekeeping when unplugged
- Caseless design to provide visibility of internal construction
- Bright and clear retro-styled LED display
- Date Display and calendar function supporting fully supporting leap years
- Easy-to-use knob based menu UI
- Temperature Display
- Customizable time display with Seconds, AM/PM indicator, and 12/24h modes.
- Firmware upgradability
- USB interface for precision time synchronization
- Made in USA

Specifications

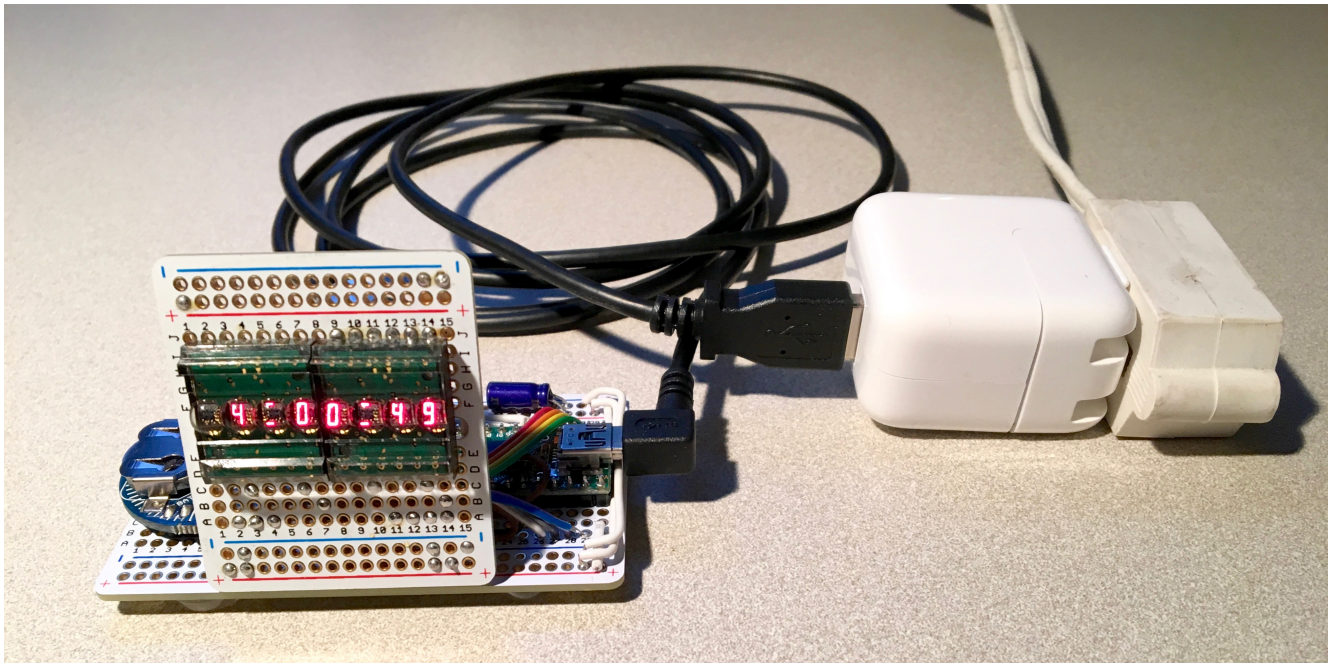
- Teensy 2.0
  - 16 MHz ATMEGA32U4 MCU, 8 bit AVR
  - 32K Flash, 2.5K RAM, 1K EEPROM
- USB-Mini type B Connector for power and programming
- Time Synchronization offset of less than 10ms from USB sync source
- Time drift of less than one minute per year
- ChronoDot v2.1 – DS3231SN Temperature Compensated RTC
  - -40°C to <0°C ±3.5 ppm frequency stability
  - 0°C to +40°C ± 2 ppm frequency stability
  - >40°C to +85°C ± 3.5 ppm frequency stability
  - -40°C to +85°C ± 3°C temperature stability
- 2 module HPDL-1414 display assembly
  - 8 character 16-segment per character LED display
  - 2.85 mm character height
  - Integrated magnifying lenses
  - ± 40° off-axis viewing angle, Typical 1.0 mcd luminous intensity
  - 655nm peak wavelength, 640nm dominant wavelength
- KY-040 Rotary Encoder with 20 Cycles per Rotation with Momentary Switch

Interface and Hardware Overview





Installation



The Digital Clock DC-001 can be installed on a desk or shelf with the included right-angle Mini-USB cable and USB power adapter. Simply plug the cable into the clock and USB power supply and plug into a standard household socket. The plug included works in the United States, but additional plugs are available to use worldwide from Apple as the “Apple World Travel Adapter Kit”, an optional accessory. More information available at https://support.apple.com/en-us/HT202114

If you need to unplug the clock to move it, don’t hesitate; timekeeping is maintained through the backup battery.

Using your Clock

Displaying Time, Date, Temperature

The default mode for the clock when it is powered on is Display mode. Cycle through the different display modes; Time, Date, and Temperature, by rotating the knob. Each of the displays remains persistent until changed or power is removed from the clock.

```
[ 9:41:28] )
[10/11/15] )
[  67 F  ] )
<  loop  >
```

Navigating the Menu[1] & Configuring Preferences

Menu Map

```
[ 9:41:28]     ⟶   [SET TIME])     ⟶   <Time Set Mode>

                   [AUTO DST])     ⟶   [ENABLED ])     ⟶   <return>
                                       [DISABLED]      ⟶   <return>
                   [12/24 HR])     ⟶   [12 HR   ])     ⟶   <return>
                                       [24 HR   ]      ⟶   <return>
                   [SHOW SEC])     ⟶   [SECONDS ])     ⟶   <return>
                                       [AM/PM   ]      ⟶   <return>
                   [TEMP F/C])     ⟶   [DEG F   ])     ⟶   <return>
                                       [DEG C   ]      ⟶   <return>
                   [EXIT    ]      ⟶   <return>
```

Pressing the knob while in Display mode enters the Menu mode. Settings available include Set Time, Auto DST, 12/24 Hr, Show Sec, and Temp F/C. Selecting each of these options shows a submenu allowing for configuration of particular preferences. If left on the menu (excluding the Time Set Mode), the clock will automatically return to Display mode after 10 seconds of inactivity.

[1] The ")" symbol represents rotating the knob, "⟶" represents a click.

Set Time: See the “Setting the Time” section below.

Auto DST: This setting should be enabled for all localities observing Daylight Savings Time. Time will be adjusted automatically at the beginning and ending DST periods.

12/24 Hr: This display preference determines if the time readout will be shown in 12H format or 24H format. The Time Set interface is always displayed in 12H format.

Show Sec: This display preference determines if the clock shows seconds or the AM/PM indicator. If the clock has been configured for 24H format, the AM/PM choice simply hides the seconds instead of showing the day period indicator.

Temp F/C: This display preference determines if temperature is shown in Fahrenheit or Celsius scale.

Setting the Time

It is recommended to synchronize the time programmatically using a computer over the USB connection for the greatest accuracy. The time source of the computer should be synchronized correctly before beginning the process. On a Mac, it is often effective to open the “Date & Time” settings and toggle “Set Date & Time Automatically” off and back on again to encourage an accurate clock synchronization via NTP.

Setting Time via Computer (recommended)

1) The time and date of the computer should be verified to be accurate.
2) Install prerequisite pySerial library. On a Mac this can be accomplished by opening the Terminal program and running the following command:

```
sudo easy_install -U pyserial
```

3) Download the setTime.py program from the following URL and unzip it:

```
https://www.joeyhagedorn.com/download/DC-001/setTime.py.zip
```

4) Using Terminal, go to the directory in which the setTime.py file exists and ensure it has the correct permissions by running the following command:

```
chmod 755 setTime.py
```

5) Connect the Digital Clock DC-001 to the USB port of the computer. The clock need not display a specific screen, however it can be helpful to display the time with seconds while setting the time programmatically to verify it has been synchronized.

6) Run the following command:

```
./setTime.py
```

7) If the time has not been set, try running the command an additional time.

At this point the time should be accurately synchronized to the computer within a few ms.

Setting Time via the Knob

Menu Map <Time Set Mode>

`[SET TIME]` ⟶ `[MM/DD/YY]` ⟶ `[HH:MM:XM]` ⟶ `<return>`

Time may be set directly using the knob as well. To set the time, begin by choosing the Set Time option from the main menu. Once in the Set Time interface, use the knob to select Month, Day, Year, Hour, Minute, and Day Period by rotating the knob then clicking to move to the next field. In order to set the time most accurately, it is best to choose the subsequent minute then wait on the AM/PM selection. Immediately as the clock ticks over to the next minute, click the button to commit the time. The seconds will start at zero upon selection of the AM/PM day period and return to the Display mode. The Digital Clock DC-001 is implemented to recognize button clicks on “button-up.”

Theory of Operation

The Digital Clock DC-001 is designed to be a maintenance free device. It is a fully digital product implemented on top of a realtime system to meet the high precision requirements accurate timekeeping demands.

Four main components dominate the design of the Digital Clock DC-001: the Teensy CPU, the ChronoDot TXCO RTC, the rotary encoder, and the HPDL-1414 display modules. The 16 MHz ATMEGA32U4 CPU (Teensy) runs a custom monolithic timekeeping program that implements user interface as well as handles DST and other timekeeping features. The internal oscillator of the CPU is used to keep time between synchronizations with the RTC, which happen at startup and periodically every 5 minutes. The Teensy communicates via a 400khz I2C Serial interface with a DS3231 TXCO RTC (ChronoDot) to re-sync CPU time to the master clock. This refresh rate provides excellent long term and short term drift characteristics. A specially developed algorithm has been employed to lock the CPUs internal time to that of the RTC with enhanced accuracy, beyond that provided in the more widely available TimeLib timekeeping library.

When in Temperature mode, the Teensy also queries the ChronoDot for ambient Temperature, as the RTC module also includes a temperature sensor. The DS3231 has an internal crystal and a switched bank of tuning capacitors (TCXO). The temperature of the crystal is continuously monitored, and the capacitors are adjusted to maintain a stable frequency internal to the RTC.

In addition to communicating with the RTC, the Teensy drives the two HPDL-1414 alphanumeric display units directly. The Teensy monitors the rotary encoder for input using an interrupt based mechanism for rotation and a simple polling mechanism for button clicks. Bouncing of the pushbutton has been fully characterized and compensated for using software. The USB interface on the Teensy emulates a serial connection and is the most precise mechanism for synchronizing the RTC to an external time source. The protocol used is simply a text string prefixed with “T” and followed by a unix timestamp in local time representing the current time.

Maintenance

Replacing the Battery

The CR1632 battery supplied in your Digital Clock DC-001 is expected to last at least 8 years, but likely many more if the clock is left running. The battery is only used to keep time when the clock is not plugged in, and therefore only needs to be replaced to avoid resetting the time when it is not powered.

Procedure: It is recommended to replace the battery while the clock is plugged in and running to avoid the need to reset the time after replacement. Simply eject the old battery using a ballpoint pen or other blunt object, and slide in a replacement CR1632 in its place.

Firmware Updates

The USB port that is normally used to power your clock may also be used for firmware updates. If in the future a firmware update is released by the manufacturer, it may be necessary to send the clock back to the manufacturer to upgrade the firmware. Alternatively, you may be able to perform a firmware upgrade in-the-field by installing the Arduino and Teensyduino software packages, as well as downloading dependent libraries. If you are interested in performing your own firmware upgrades, or developing your own software for your Digital Clock DC-001, contact the manufacturer for more specific instructions on getting started. Firmware source code access is granted upon request.

Appendix 1: Daylight Savings Time

International DST

Daylight Savings Time rules vary around the world. The Digital Clock DC-001 is programmed from the factory with DST rules for the United States, but has been architected to be easily reprogrammed through firmware update to fall back and spring ahead at different dates, and of different offsets. If you move to an international location and take your clock with you, please send it back to the factory or arrange for an in-the-field firmware update.

DST in the United States

According to the Uniform Time Act of 1966, the dates at which daylight savings time begins and ends, and the offset of DST is mandated by the federal government and uniform across the US. Some states, however, choose to exempt themselves from DST, such as Arizona and Hawaii, as of this writing. Support for this is built in to your clock and may be enabled by simply disabling the “Auto DST” option within the settings menu. Historically, the dates at which DST begins and ends have changed several times, most recently in 2005. If Congress makes a further change to the dates at which DST is observed, please send your clock back to the factory or arrange for an in-the-field firmware update.

Appendix 2: Bill Of Materials

For repair and replacement information:

Qty	Part
2	HPDL-1414 LED Display Modules
1	Teensy 2.0 (ATMEGA32U4 CPU based development board)
1	ChronoDot v2.1 Ultra-Precise Real Time Clock (DS3231 based Module)
1	CR1632 Battery
1	KY-040 Rotary Encoder
1	Aluminum Knob
2	0.33µF Ceramic Disc Capacitors
1	47µF 25V Electrolytic Capacitor
1	Adafruit Perma-Proto 1/2 Sized Breadboard
1	Adafruit Perma-Proto 1/4 Sized Breadboard
1	Apple 10W USB Power Supply
1	Right Angle Mini-USB cable
-	Assorted Wires and Solder
-	2.54mm Header Pins
4	Rubber Feet