

**Thunderbolt Monitor Kit**  
**User's Manual**  
**Version 4.2.2-1 February 11, 2018**  
**(firmware version 4.2.2 and later)**  
© 2013-2018, Didier Juges  
Check KO4BB.com for updates



**Description:**

The Thunderbolt Monitor Kit (the kit) is a microprocessor-based device able to capture the Primary and Supplemental Packets from a Trimble Thunderbolt GPS Timing Receiver, extract critical operating parameters of the receiver and send them to an LCD display.

Optionally, the kit may be equipped with a WiFi module which gives it the capability to operate as an internet server compatible with the Lady Heather [1] control and monitoring software.

The kit is also able to send a Self Survey command to the Thunderbolt.

The kit contains an independent pulse stretcher circuit which converts the nominally short (10uS), 0-5V PPS pulse of the Thunderbolt into a ~1mS, RS-232 compliant +/-9V pulse more appropriate for many applications such as NTP. The Pulse Extender function is totally independent of the monitor/display function other than it uses the same supply voltage.

The kit can also optionally monitor and display ambient temperature, captured using a standard 10k Ohm NTC thermistor (B factor of 3380).

Operation of the kit is automatic. However the kit can be configured in several different ways to make operation more convenient depending on user preferences. Configuration is done through a menu of options, activated and operated through two push-button switches. No configuration is required to get the kit up and running.

The kit operates at 9600 bauds with 8 data bits, one stop bit and no parity over the Trimble TSIP binary protocol. This is the default configuration for the Trimble Thunderbolt. NMEA format is not supported.

### **Attention:**

The kit contains semiconductors that can be damaged by static electricity and excessive voltages. Safe static electricity practices shall be observed while wiring or using the kit. Particular care should be exercised to never apply voltages outside the range of 0 to +5VDC (with respect to the power supply return) on any exposed part, trace or conductor, including J2, J3, J4, J5, J6 and J7.

The supply voltage on J1 shall never exceed 16VDC.

The voltage on the PPS input shall not exceed the supply voltage.

The RS-232 connections on J1 are safe with voltages up to +/- 25VDC.

### **Requirements:**

The kit requires a 6-12V DC @ ~100mA average supply to operate. Fine regulation or low ripple are not necessary or even advantageous, as long as voltage excursions do not exceed the specified range. A 250mA supply is recommended without the WiFi option. While the WiFi module's average current consumption is very low (about 12mA), it draws high current peaks when transmitting, so a 400mA rated supply with sufficient filtering capacitors is recommended when the WiFi module is installed.

Essential connections to the Thunderbolt are made through a row of screw terminals J1. If the "Self Survey" function is not used, the kit needs only two connections to the Thunderbolt's serial port: Ground (pin 5) to J1-1 and Tx Data (pin 2) to J1-2. If the "Self Survey" function is used, a third connection is required to the Rx Data line (pin 3) to J1-3.

If the "Self Survey" function is not used and the WiFi option is not installed, the kit can be wired in parallel to a direct RS-232 connection between the Thunderbolt and a PC for other uses such as running Mark Sims/John Miles' Lady Heather [1] or Trimble's `tboltmon.exe` [2] utility.

The Lady Heather software regularly sends commands to the Thunderbolt (several commands each second), so when the WiFi option is used, the kit shall be wired with both Tx and Rx data to the Thunderbolt and it will not be possible to have a second serial port connected in parallel.

**Getting Started:**

The minimum required to operate the kit is a power supply and a connection to the Thunderbolt's Serial Data output per the table below (connections 1, 2 and 3).

As delivered, the kit comes up in GPS mode. If you want instead to have it display local time, you need to check and change if necessary the time zone and the display mode using the menu as described later in this document.

As delivered, the time zone is set for -6 (US Central Time).

To enable and configure the WiFi option, see Appendix A.

**Connections:**

The table below shows the connections required to operate the kit with a Thunderbolt receiver.

Item	Function:	Thunderbolt (DB-9)	PC (DB-9)	Kit:
1	Ground	Pin 5		J1-1 (note 1)
2	Data to kit	Pin 2		J1-2
3	Command from kit	Pin 3		J1-3 (note 3)
4	PPS return (chassis)	BNC (shield)	Ground Pin 5	J1-4 (note 1)
5	PPS from Thunderbolt	BNC (pin)		J1-5
6	PPS to PC	As required	DCD Pin 1	J1-6 (note 2)
7	Supply return (negative)			J1-7
8	Supply 6-12V (positive)			J1-8
9	Major Alarm output			J6-2 (notes 4, 5)
10	Minor Alarm output			J6-3 (notes 4, 5)
11	Alarm return (ground)			J6-1 (notes 1, 5)
12	Menu Up key			
13	Menu Down key			
14	WiFi Associated			D1 (note 6)
15	WiFi Connected			D2 (note 7)
16	Thermistor (10k@25°C)			J4-1 and J4-2 (note 8)

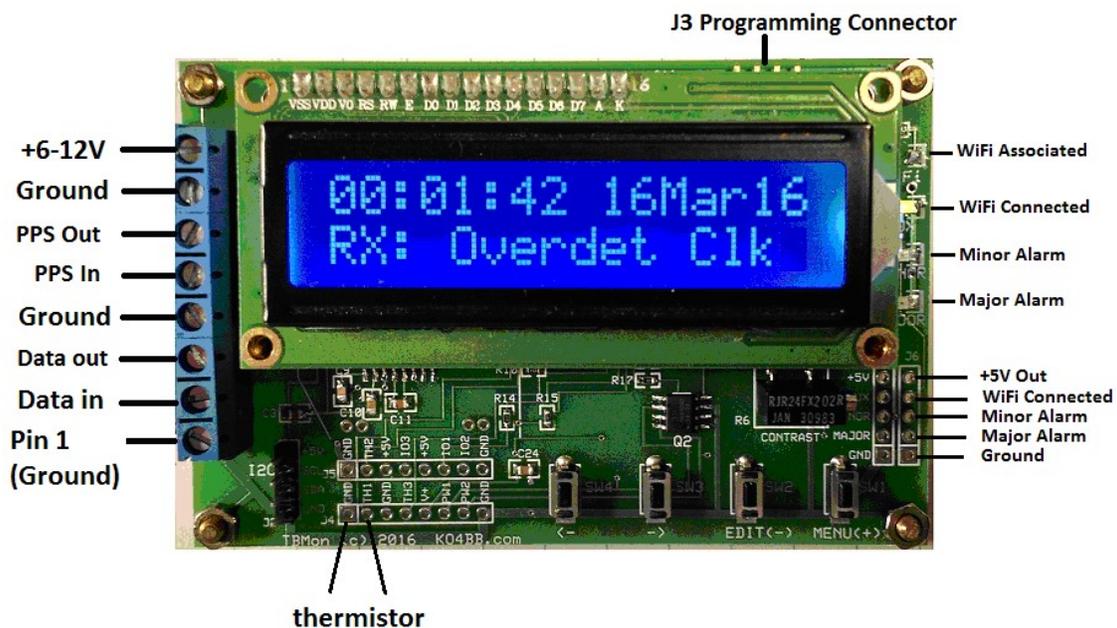
**Notes:**

- 1) All ground and return terminals are connected together on the kit and connected to the power supply return.
- 2) Note that not all NTP software expects the PPS signal on DCD (Pin 1). This is usually configuration dependant in your NTP software.
- 3) This connection is only required if you want to use the Self Survey command from the kit and cannot be used simultaneously with the Lady Heather [1] or tboltmon [2] applications.
- 4) The alarm outputs are intended to drive an LED or a relay board as described in appendix 3. Please note that the outputs are not internally current limited, so these pins should not be shorted to either rail or to each other and they should

not be directly connected to an LED, a series resistor is required. The open voltage is 5V when the alarm is active, 0V when not. The current capability is about 10mA. A 330 Ohm series resistor will therefore be the lowest value practical to drive an LED. Most LEDs give sufficient brightness with 3 to 5mA, therefore a 1 kOhm resistor should be adequate in most cases (see wiring below.)

- 5) J6 pin 1 has a square solder pad, visible from the solder side. Pin 1 is at the end near SW1.
- 6) D1 turns on when the WiFi module is associated with an access point
- 7) D2 turns on and J5-3 goes high when the WiFi module has acquired an IP address from the access point. D2 blinks and J5-3 pulses high when the WiFi module is connected to a PC running the Lady Heather software.
- 8) See thermistor wiring below

### Pinout:



Note about the optional thermistor: A suitable part number is the Murata NXRT15XH103FA1B040 available from Digikey. With this thermistor, the external temperature display's accuracy will be better than 1°C between 25°C and 50°C.

### Features:

#### **Display:**

The kit is provided with a connectorized, backlit 2x16 LCD display, allowing the user to easily replace the stock display with a different device compatible with the very popular Hitachi HD44780 specification.

Backlight intensity is controlled by resistor R7 (the only leaded resistor on the kit, located near the right end of the LCD connector.) The default value is adequate for use with relatively low ambient light. Bypassing R7 with a short jumper wire will significantly increase the brightness (and the current consumption) and will make the display more visible in brightly lit areas.

The contrast adjustment potentiometer (R6) has been adjusted for the standard 2x16 LCD display. There should be no need to change the setting unless a different display is used. Please note that VFD devices do not use the contrast adjustment potentiometer or the backlight resistor R7.

### **Parameters displayed:**

During normal operation, the kit displays the current time and date (in the selected mode: GPS, UTC or Local) on the first line of the LCD. If a display with 20 characters is used, the first line also displays the time mode. The second line displays the following status information in sequence:

1. Disciplining mode
2. Disciplining activity
3. Receiver mode
4. GPS Decode status
5. Internal Thunderbolt temperature
6. DAC voltage
7. 10 MHz offset
8. WiFi module status (when the WiFi option is enabled through the menu)
9. External temperature (when enabled through the menu)
10. Critical Alarms, if any (see notes)
11. Minor Alarms, if any (see notes)

### **Notes:**

If any Critical Alarm is present, the display of normal status information (items 1 through 9 in the list above) will be suspended.

All Minor Alarms that are present are displayed on line 2 of the display at the end of the sequence.

Details of the various modes reported by the Thunderbolt are described in the Thunderbolt User's Guide [6].

### **Alarm outputs:**

The kit has two alarm outputs, one for the Critical (Major) alarms and one for the Minor alarms. If a single indicator is preferred, the kit can be configured via the menu to activate the Major alarm output for any alarm, Major or Minor. The kit can also be configured via the menu to set a Minor alarm when a Leap Second is pending.

### **Time mode:**

The kit can be configured to display GPS time, UTC time or Local time.

The difference between GPS time and UTC time is referred to as the “GPS Offset” or sometimes the “UTC Offset”. As of October 2013, the GPS offset is 16 seconds. It increases by one second typically every 18 to 24 months (Leap second events), on the last day of June or December. The Thunderbolt receiver provides the current GPS offset in its Primary Data Packet so the kit can decode it and there is normally no need to worry about it, but the kit can be configured manually if preferred.

The difference between UTC time and Local time is set by the Time Zone offset and then Daylight Savings Time option, which are dependent on your location and laws in your region. Therefore the Time Zone and Daylight Savings Time options are also adjustable through the menu. You will need to adjust these settings if Local Time is selected.

### **Self Survey:**

To perform its duty as a precision instrument, the Thunderbolt receiver needs to know its position accurately. This is done through a Self-Survey. When completing a Self Survey, the Thunderbolt may be instructed to store its position in non-volatile memory. If moved, the Thunderbolt may have difficulty reacquiring proper timing information unless Self-Survey is performed again. In such cases, use the kit’s Self Survey command (accessible through the menu) to start the self survey. Note that the duration of self survey is typically 2000 seconds, during which timing information from the Thunderbolt may be unreliable.

### **Test Alarms:**

The kit can display all the available alarm messages (and trigger the alarm outputs) when the Test Alarm menu setting is used. This is convenient for testing any logic or indicator you may have hooked up to the Alarm outputs. When you select Test Alarms through the menu, make sure you exit without saving (select ‘No’ when asked to Save Settings.) Otherwise, the kit will reboot in normal mode (Test Alarm mode is not saved to EEPROM and does not survive a power cycle or a forced reboot.)

### **Menu:**

To activate the menu, press the Menu (+) key briefly.

Once the first menu item is displayed, navigate through the various options using short presses on the Menu (+) and Edit (-) keys. The parameter name is displayed on the top row with an arrow in front of it, and the current setting is displayed on the second row.

When the setting you want to change is displayed, press the Edit (-) with a long press (typically at least 800mS) until the arrow moves to the second line in front of the value. Release the Edit (-) key and use short presses on the Menu (+) and Edit (-) keys to adjust the parameter to the desired value.

When the desired value has been selected, press the Edit (-) with a long press until the arrow moves back on the top row. Continue the process until you have changed all the parameters you wished to change.

When done with changing parameters, press the Menu (+) with a long press until the “Save Settings?” prompt appears. The default setting for “Save Settings?” is “No”. That

means if you exit at this point, the setting you have changed will only be in effect until power is recycled (note that Self Survey requires to select “Yes” for “Save Settings”, otherwise it will not be executed). If you select “Yes” for “Save Settings?” (by sending a short press on the Menu (+) or Edit (-) switch), the new settings will be saved to non-volatile memory (EEPROM) and will be restored automatically the next time power is recycled. Once you have selected Yes or No for “Save Settings?”, exit the menu by pressing the Menu (+) key (SW4) with a long press again. The kit is rebooted after saving to EEPROM.

Not all settings can be saved to memory. Table 1 below gives a list of all settings, the default value as shipped and whether they can be saved to non-volatile memory.

### **Menu Settings:**

Settings available through the menu are normally saved to EEPROM and restored automatically after a power off cycle. A few parameters cannot be saved.

<b>Parameter</b>	<b>Note</b>	<b>Default Value</b>	<b>Saved to EEPROM</b>
Time Reference	1	GPS	Yes
Time Zone		-6	Yes
GPS Week Fix	2	1	Yes
GPS Offset Auto		Yes	Yes
GPS Offset	3	16	Yes (see note 3)
Self Survey	4	Off	No
Combine Alarms	5	No	Yes
Leap Sec. Alarm		Yes	Yes
GPS Week Alarm	2	No	Yes
Test Alarms	6	Off	No
Enable WiFi	7	Off	Yes
IP Address	8	N/A	No (read only)
Reset WiFi		No	No
Display Ext Temperature	9	Off	Yes
Passthrough Mode	10	N/A	No

### **Notes:**

- 1) GPS, UTC or Local time can be selected.
- 2) GPS Week Fix is used to convert the erroneous date provided by the Thunderbolt after July 30, 2017. Add 1 every 19.7 years using this menu option. See Reference 7. When GPS Week Alarm is selected, the minor alarm will turn on one week prior to the next GPS Week Rollover.
- 3) GPS Offset value is only used if GPS Offset Auto is NOT selected and if UTC or Local Time is selected. If GPS Offset Auto is selected, the GPS Offset menu displays the actual value of GPS offset provided by the Thunderbolt and the value cannot be edited. If GPS Offset Auto is not selected, the GPS Offset can be changed and is saved to EEPROM.
- 4) Self Survey command is sent to the Thunderbolt when the menu is exited after the setting has been changed to On and you have selected “Save Settings.”

- 5) When selected, both Minor and Major (Critical) alarms activate the Critical alarm output. Please note that when this option is selected, the Minor Alarm output is still driven when a Minor Alarm condition exists.
- 6) When this setting is changed to On, the kit will display all the alarm messages in sequence on line 2 of the display, and activate the Alarm outputs. Line 1 of the display will continue to display the current time.
- 7) When selected, the WiFi module is enabled. The WiFi module is probed at power up and IP address is displayed on line 2 of the LCD at power up. If this option is not selected, the WiFi module will still allow connections (if properly configured for your network, see Appendix A) but will not supply data.
- 8) IP Address is read from the WiFi module at power up when the WiFi option is selected.
- 9) When selected, the kit will acquire and display the external temperature on line 2 of the LCD using the thermistor. If no thermistor is installed, the display will be meaningless.
- 10) When selected, serial traffic between the WiFi module and the COM port is enabled. This allows communication with the WiFi module for configuration (see Appendix A.)

### **Expansion headers:**

Additional 0.1" headers are provided for optional functions such as JTAG programming of the processor (not required in the main use case), third party indicators or relay boards (see Appendix 3.)

### **Software:**

The kit's software source code is copyrighted © 2013-2017 by Didier Juges, KO4BB.com. The software is released as limited distribution to purchasers of the kit. Purchasers of the kit are issued a non-exclusive license to use the software as they wish on the kit hardware but are restricted from further distribution, publication or usage of the software, in all or in part, in source or executable form.

### **Software upgrades:**

The kit's software may be upgraded over time but it is not a certainty. New releases may be announced on the kit's web page. When a new software version is made available, you may send back your kit(s) for software upgrade with a prepaid self-addressed padded envelop for the return. Overseas customers should contact me first before returning their kit(s).

Alternately, the Silabs processor used on the kit can be reflashed using the \$35 USB Debug Adapter available at Silabs [4] and other sources, the free Silabs Production Programmer software [5] and a binary file I will provide upon request.

### **TBolt Simulator Software:**

You are encouraged to download the TBolt Simulator Software [3] to demonstrate and verify operation of the kit. The software allows you to simulate various conditions and to verify the response of the kit. The simulator software is not specifically designed to be used with the kit. Please note that you will need to use a serial cross over cable (null

modem) to connect the PC's serial port to the cable that would normally plug into the Thunderbolt. The Thunderbolt simulator does not emulate all the functionality of the Thunderbolt, it only emulates some of the functionality supported by the kit. The connections are as follows:

Kit	Function	PC serial port (DB-9)
J1-1		5
J1-2		3

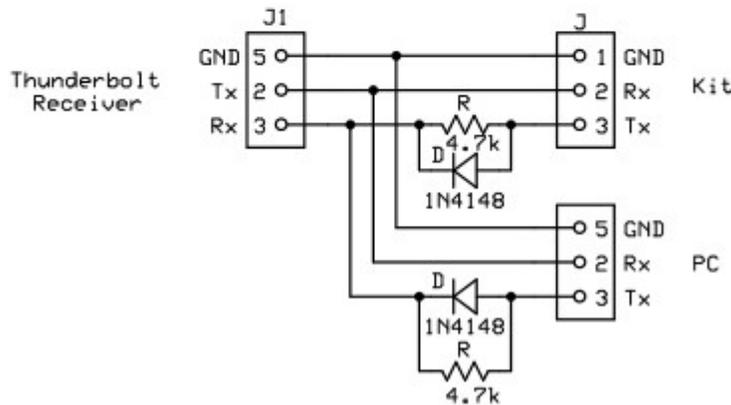
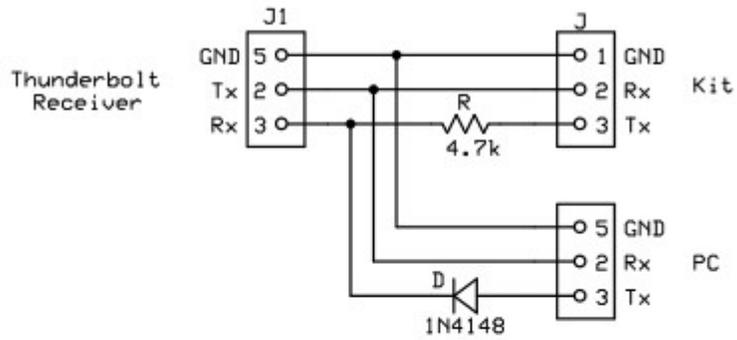
### Using a different display:

As mentioned earlier, the kit can drive different kinds of displays as long as they use a Hitachi HD44780 interface chip or compatible. Some users may want to use larger LCD devices while others may prefer a Vacuum Fluorescent display (VFD). The kit was designed to make this not only possible but easy. There are several notes of caution related to using a different display.

- 1) **Power consumption:** The kit has a 250mA rated 5V low dropout voltage regulator on board (U4), and a similar but separate 3.3V voltage regulator (U7) for the WiFi module. It is important not to exceed the current rating or the power rating of the regulators. The regulators are mounted on lands of copper planes acting as heat sinks, with sufficient power dissipation capability to support operation with the default display with supply voltages as high as 14V, but the regulator may overheat when driving larger displays, particularly if powered from a supply voltage near the top of the range. Therefore it is recommended to reduce the maximum supply voltage when driving larger displays. The kit will work fine with as low as 5.5V supply (when measured at the kit's J1 connector).
- 2) **VFD displays:** Some VFDs may draw more current than LCDs and may exceed the power dissipation capability of the built-in regulator U2. If using a VFD, make sure you select a VFD with 150mA maximum current consumption.
- 3) **Contrast adjustment:** When using a different type of LCD, the contrast may have to be readjusted. Note that the adjustment range is fairly narrow and it is quite possible that replacing the LCD with another may initially give absolutely no visible information. That is normal, simply power up the kit and adjust R6 until the display contrast is satisfactory. VFDs typically do not use the contrast adjustment.
- 4) **Backlight:** When using a different LCD display, the backlight resistor R7 may have to be adjusted or bypassed. Refer to the display's datasheet for more information. VFDs typically do not use the backlight inputs.
- 5) **Header:** The kit uses a 0.1" spaced 16 pin, single row header to connect to the display. Compatible headers are available from a wide variety of sources.
- 6) **Mounting:** The standard LCD is mounted on the kit's PWB using standard threaded male-female standoffs (metric size). When using an alternate display, you may have to devise a different mounting arrangement as the mounting holes may not line up.

**Using the TBolt Monitor kit with Lady Heather [1] or TBoltmon.exe [2] software:**

To use the kit conjointly with a direct serial connection to Lady Heather or TBoltmon.exe software, you need an adapter to prevent contention between the PC and the kit on the Transmit line. You can use either of the types described below:



*Simultaneous interfacing with a PC*

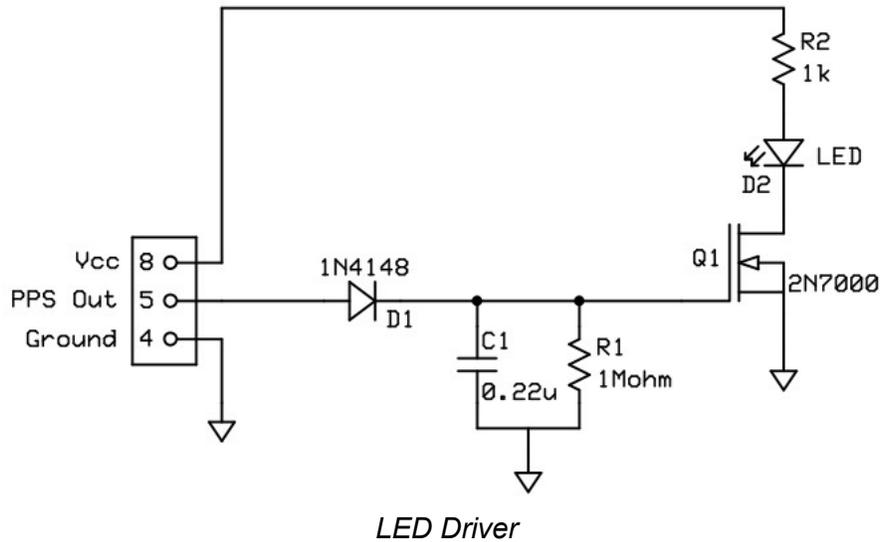
The top schematic shows a simple adapter to be used when the kit is permanently plugged into the Thunderbolt receiver while the PC may be plugged or unplugged as desired. This device will not work if only the PC is connected to the Thunderbolt.

The bottom schematic shows an adapter that will allow either the kit or the PC to be plugged or unplugged independently.

Please note that Lady Heather keeps the serial port busy such that sending a Self Survey command from the kit while Lady Heather is running may not always work (the commands may interfere with each other). If you intend to keep Lady Heather running all the time while being able to send Self Survey commands from the kit, it would be best to use a DPDT switch to eliminate all risk of interference between the two signals.

**Driving an LED with the PPS signal:**

The pulse from the MAX3232 is fairly narrow still to properly drive an LED. You may get enough light from a high brightness LED with a 470 ohm resistor and a diode (to prevent reverse biasing the LED) in series but it would be better to add a simple pulse stretcher as described below. Adjust resistor R1 for best effect.

**Contact and Support information:**

Support to customers and non-customers is provided exclusively via the email link at the bottom of every page on my web site, KO4BB.com. Simply indicate Tbolt Kit in the subject line. Any other email may or may not reach me.

I subscribe to a number of mailing lists, but please do not use these mailing lists for support requests or routine communication about the kit.

**References:**

[1] Lady Heather: <http://www.ke5fx.com/heather/readme.htm>

[2] tboltmon.exe:  
[http://www.ko4bb.com/Manuals/05\) GPS Timing/Trimble/Thunderbolt/tboltmon.exe](http://www.ko4bb.com/Manuals/05) GPS Timing/Trimble/Thunderbolt/tboltmon.exe)

[3] Tbolt Simulator: <http://www.ko4bb.com/Timing/GPSMonitor/TBoltSim.php>

[4] Silabs Programming Adapter:  
<http://www.silabs.com/products/mcu/Pages/USBDebug.aspx>

[5] Silabs Production Programmer software:  
<http://www.silabs.com/Support%20Documents/Software/MCUProductionProgrammer.zip>

[6] Thunderbolt User's Guide:  
[http://www.ko4bb.com/Manuals/05\) GPS Timing/Trimble/Thunderbolt/Thunderbolt\\_Users\\_Guide\\_2002-v4.pdf](http://www.ko4bb.com/Manuals/05) GPS Timing/Trimble/Thunderbolt/Thunderbolt_Users_Guide_2002-v4.pdf)

[7] GPS Week Rollover Issue with Trimble Thunderbolt:  
<http://www.ko4bb.com/getsimple/index.php?id=gps-week-rollover-of-july-30-2017-and-thunderbolt-monitor>

### **Manual versions**

V3.1 (March 4, 2014): corrected schematic (WiFly connection to U1 changed)

V3.2 (March 10, 2014): updated links to WiFly documentation

V4.0 (December 28, 2015): new TBMon hardware v4

V4.0.4 (May 2016): Update for firmware version 4.0.4

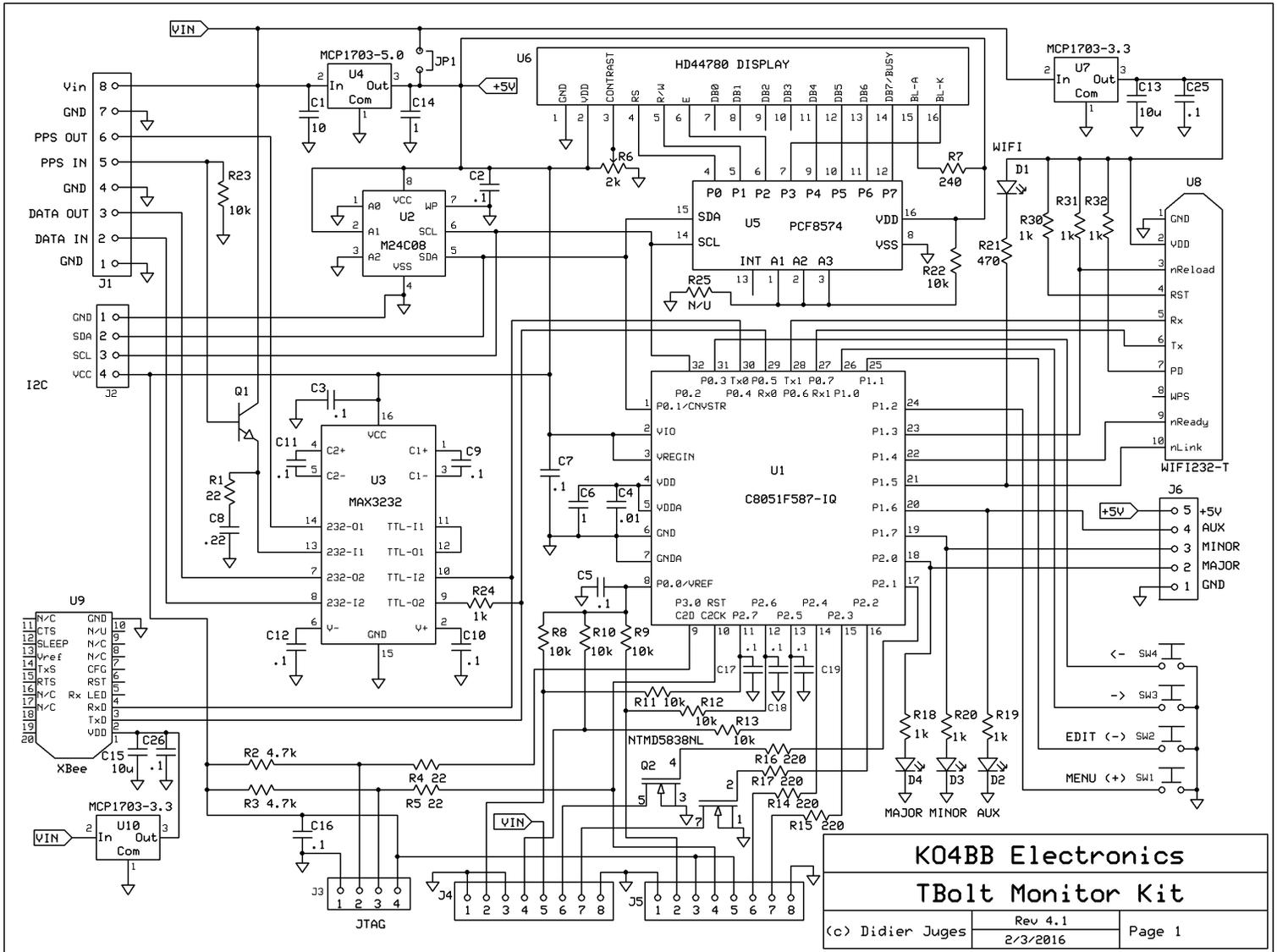
V4.0.5 (October 2016): Update to Table on page 3

V4.2.0 (August 5, 2017): Update to firmware version 4.2.0 supporting GPS Week Rollover.

V4.2.2 (August 27, 2017): Fix issue with GPS Week rollover and issue with WiFi module

V4.2.2-1 (February 11, 2018): Fix PC Adapter cable wiring

### Appendix 2: Schematic



<b>K04BB Electronics</b>		
<b>TBolt Monitor Kit</b>		
(c) Didier Juges	Rev 4.1 2/3/2016	Page 1