USER MANUAL

ZB Iambic Keyer

Iambic mode A/B memory CW keyer with Microchip ATtiny4313

DL6ZB

Rolf L. Heine

Edition 2.2 · October 2026

for firmware version 2.1.0 (November 11, 2024)

schematic 04-NOV-24-001

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Document information

Document	ZB Iambic Keyer – User Manual
Edition	2.2, October 2026 (English, US)
Applies to	ZB Keyer firmware version 2.1.0, file `dl6zb-keyer-11-nov-24-001.hex` (November 11, 2024), and schematic “ZB KEYER – Iambic mode A/B memory CW keyer”, 04-NOV-24-001 (November 11, 2024)
Author and publisher	Rolf L. Heine, DL6ZB Kirchenäcker 6, 84048 Mainburg, Germany E-mail: dl6zb@dl6zb.de Web: https://www.dl6zb.de
Project page	www.dl6zb.de/projects/zb-keyer.html – firmware download, schematic, updates
Nature of the design	Non-commercial do-it-yourself (homebrew) project for radio amateurs. Not a commercial product; no CE marking (see section 2.7).

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How to use this manual

Read sections 2 (safety) and 5 (getting started) before you connect the keyer to a transmitter. Keep this manual for later reference. The latest firmware and information are available on the project page.

Button numbers `1` … `5` refer to the push buttons as numbered in the schematic. The button colors and front-panel labels shown in the photos belong to the author's example build; your build may look different.

WARNING

Indicates a hazard that can cause injury, fire, or serious damage to the keyer or the connected equipment.

CAUTION

Indicates a situation that can damage the keyer or the connected equipment or cause malfunction.

NOTE

Useful hints and additional information.

Contents

1 Introduction and intended use 4
- 1.1 About the ZB Keyer 4
- 1.2 Intended use 4
- 1.3 About this manual 5

2 Safety and legal notices 5
- 2.1 General safety 5
- 2.2 Electrical ratings and connections 5
- 2.3 Coin cell safety 6
- 2.4 Li-ion battery and charger 6
- 2.5 Electrostatic discharge (ESD) 7
- 2.6 Radio-frequency interference 7
- 2.7 Homebrew design – your responsibility 7

3 Features and technical data 7
- 3.1 Features 7
- 3.2 Technical data 8

4 Controls and connections 9
- 4.1 Push buttons and LEDs 9
- 4.2 Connections 10

5 Getting started 11
- 5.1 Before first use 11
- 5.2 Power supply and charging 11
- 5.3 Connecting the paddle and a straight key 12
- 5.4 Connecting the transceiver (CW and PTT) 12
- 5.5 First steps 12

6 Operation 13
- 6.1 Operating principle 13
- 6.2 Button functions 13
- 6.3 Iambic keying: mode A and mode B 14
- 6.4 Speed (WPM) and sidetone 14
- 6.5 Tune and straight key 15
- 6.6 Memory (callsign or standard text) 15
- 6.7 Sending “QRL?” 16
- 6.8 PTT delay 16
- 6.9 Dash/dot ratio adjustment 16
- 6.10 Speaker on/off 16
- 6.11 Using the keyer together with a PC 16
- 6.12 Stored parameters and full reset 17

7 Settings reference 17
- 7.1 Factory defaults 17
- 7.2 Settings and procedures 18
- 7.3 Transmit functions 18

8 Sleep mode and power management 19

9 Firmware and programming 19
- 9.1 Firmware download 19
- 9.2 Option 1: PonyProg (Windows/Linux) 20
- 9.3 Option 2: USBasp (Windows/Linux) 20
- 9.4 Option 3: Arduino as ISP (Linux) 20
- 9.5 Notes on programming 21

10 Schematic and theory of operation 22
- 10.1 Block diagram 22
- 10.2 Theory of operation 22
- 10.3 Main components 23
- 10.4 Schematic 24

11 Troubleshooting 25

12 Disposal, warranty, license and contact 26
- 12.1 Disposal 26
- 12.2 Warranty and liability 26
- 12.3 License and copyright 26
- 12.4 Trademarks 27
- 12.5 Acknowledgments 27
- 12.6 Contact 27

A Quick reference card 28

B Revision history 28

1 Introduction and intended use

1.1 About the ZB Keyer

The ZB Keyer is a low-cost iambic memory CW keyer designed by Rolf L. Heine, DL6ZB, and published as a weekend project: a memory CW keyer that upgrades your classic transceiver or homebrew rig.

The keyer is built around a Microchip ATtiny4313 microcontroller running at 1 MHz. It works with single- and dual-lever paddles and a straight key, offers iambic squeeze mode A and mode B, a memory for your callsign or a standard text, an auto-CQ function with a CQ loop, adjustable speed, sidetone and dash/dot ratio, separate CW and PTT keying lines, and an automatic sleep mode that makes battery operation practical.

The complete version shown in this manual contains an internal rechargeable LIR2450 Li-ion battery and a TP4056 charger module. A minimized version of the circuit can also be built into a transceiver, as shown in Figure 2 for a classic Icom IC-730.

Figure 1: Example layout of the complete version: perforated board with the ATtiny4313 microcontroller and the LIR2450 Li-ion battery. The TP4056 charging electronics are located underneath the board.

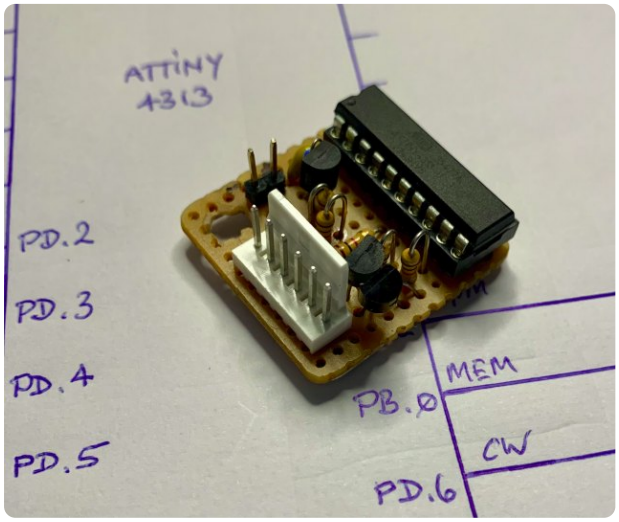


Figure 2: Minimized keyer version for a classic Icom IC-730.

1.2 Intended use

The ZB Keyer is intended exclusively for

- generating Morse code (CW) from a paddle, a straight key, the built-in memory, or the keying lines of a PC, and
- keying the CW and PTT lines of amateur radio transmitters and transceivers,

by licensed radio amateurs, within the limits given in the technical data (section 3.2). Transmitting is permitted only to holders of an amateur radio license within the frequencies, modes and power limits of their license and national regulations.

Any other use is considered improper. This includes in particular: operating the keyer from supply voltages above the specified range, switching keying or PTT circuits with voltages or currents above 35 V / 0.2 A, connecting RS-232 lines directly to the straight-key input, and charging the internal battery with an unmodified TP4056 module (see section 2.4).

1.3 About this manual

This edition describes firmware version 2.1.0 (November 11, 2024) and the schematic 04-NOV-24-001 dated November 11, 2024. It combines the information from the keyer's web page and the previous online manual (version 2.0.9) and adds illustrations, safety and legal notices, a settings reference, troubleshooting hints and a quick reference card.

This is a hobby project. The technical data are approximate values and may change with future firmware or hardware versions. Check the project page for updates.

2 Safety and legal notices

Read these notices before building, charging, or connecting the keyer. They are general information for a hobbyist design and do not replace your own judgment or legal advice.

2.1 General safety

WARNING – THE KEYER SWITCHES YOUR TRANSMITTER

Because this CW keyer keys up the transmitter, caution is advised. Do not use the keyer with your setup until you are familiar with the transmitter's CW/PTT switching voltages and switching currents. Classic transmitters in particular may have excessive switching voltages, which can cause serious injury to you and damage to the connected equipment.

- Connect the transmitter to an antenna or a dummy load before keying it (for example with the tune function).
- Keep the keyer, the coin cell and small parts away from children.
- Do not operate the keyer if it, its cables, or the battery are damaged, wet, or overheated.
- Operate the keyer only within the operating temperature range of –10 to +70 °C (14 to 158 °F) and protect it from moisture.

2.2 Electrical ratings and connections

Supply voltage	2.5 to 5.5 V
Max. supply voltage	6 V – absolute maximum, never exceed
Max. keyed CW/PTT	35 V / 0.2 A
Charging input	5 V USB via the Micro-USB socket of the TP4056 module (side wall) – use only 5 V USB supplies; charging only, no data connection

CAUTION – CHECK THE KEYING VOLTAGE FIRST

Check your transmitter's PTT voltage before connecting it to the ZB Keyer; otherwise, excessive voltages may seriously damage your transmitter or the keyer. The keying outputs are NPN transistors (BC546A) that switch the CW and PTT lines to ground. Do not connect keying circuits that carry more than 35 V or 0.2 A, or a negative voltage with respect to ground.

> **CAUTION – RS-232 SIGNALS**
> RS-232 serial port lines must not be connected directly to the straight-key input, because RS-232 voltage levels exceed the keyer's maximum ratings. Serious damage to the microcontroller will occur. For PC keying, use only pins 2 and 3 of the TRANSCEIVER connector (see section 6.11).

- Never connect any part of the keyer to the mains. Charge only from a 5 V USB supply (USB charger or computer USB port) through the Micro-USB charging socket.
- Observe the polarity of the battery and of all supply connections. Reverse polarity can destroy the microcontroller and the charger.
- Make and change connections only while the transmitter is not transmitting.

2.3 Coin cell safety

> **WARNING – SWALLOWING HAZARD**
> The LIR2450 is a coin cell. Swallowed coin cells can cause severe internal burns within a few hours and can be fatal. Keep new and used cells away from children. If you suspect that a cell has been swallowed or placed inside any part of the body, seek medical attention immediately.

2.4 Li-ion battery and charger

The complete version of the keyer is powered by a rechargeable LIR2450 Li-ion cell that is charged by a TP4056 charger module through its Micro-USB input. The module is mounted so that its Micro-USB socket is accessible through the side wall of the enclosure (sections 4.1 and 5.2).

> **WARNING – ADJUST THE CHARGE CURRENT BEFORE FIRST USE**
> A typical TP4056 module is set to a charge current of 1 A by its programming resistor R(prog) (1.2 kΩ, marked “122”). This is far too high for the small LIR2450 cell. Replace R(prog) with a 22 kΩ resistor, which gives a suitable charge current of about 60 mA (2-hour charge), before you connect the battery.

> **WARNING – RECHARGEABLE CELLS ONLY**
> Use only a rechargeable LIR2450 Li-ion cell. Never insert a non-rechargeable lithium coin cell of the same size (for example CR2450): it would be charged by the charger circuit and could leak, overheat or catch fire.

- Charge only at room temperature, on a non-flammable surface, and under supervision.
- Stop using the battery immediately if it becomes hot during charging or shows swelling, leakage, deformation or an unusual smell.
- Do not short-circuit, crush, puncture, open, heat or burn the battery.
- Use only 5 V USB power supplies (USB chargers or computer USB ports) that comply with the applicable safety standards.
- For storage and transport, insulate the battery terminals (for example with adhesive tape) if the cell is removed.

2.5 Electrostatic discharge (ESD)

The ATtiny4313 microcontroller and the transistors are sensitive to electrostatic discharge. When building, programming or servicing the keyer, discharge yourself on a grounded object first, work on an antistatic mat if possible, handle boards by their edges and avoid touching component pins.

2.6 Radio-frequency interference

The keyer lines are connected to equipment that generates RF energy. The schematic provides RC filtering (470 Ω or 1 kΩ with 4.7 nF capacitors) on the paddle, straight-key, CW and PTT lines. Keep the cables short, use shielded cables, and check that your station does not cause or suffer interference.

2.7 Homebrew design – your responsibility

The ZB Keyer is a non-commercial do-it-yourself design published free of charge by a radio amateur for radio amateurs. It is not a product placed on the market by the author. Therefore, the design carries **no CE marking**, and no EU declaration of conformity is issued for it.

If you build or operate a ZB Keyer, you are responsible for your build and its use, in particular for

- the electrical safety of your build and the correct handling of the Li-ion battery,
- the electromagnetic compatibility (EMC) of your build and your station, and
- compliance with the amateur radio regulations of your country (in Germany: Amateurfunkgesetz – AFuG – and Amateurfunkverordnung – AFuV).

Anyone who makes built units available to others may become a manufacturer with additional legal obligations (for example product safety, EMC, CE marking, and registration for electrical equipment and batteries). Note that the license terms do not allow commercial use of the firmware (section 12.3).

This information is provided for orientation only and does not constitute legal advice.

3 Features and technical data

3.1 Features

- Dash/dot keyer for single- and dual-lever paddles
- Iambic squeeze mode A / mode B option
- Auto CQ
- Auto CQ loop
- Callsign memory
- Standard text memory
- CW speed and sidetone adjustment
- CW and PTT line keying
- Straight key option
- PTT delay options: QSK / 0.5 second / 1 second
- Speaker output
- Dash/dot ratio adjustment
- Option for RTS/DTR CW and PTT connection to a personal computer's serial (RS-232) port
- Auto power-off (sleep mode)

3.2 Technical data

Parameter	Value
Supply voltage	2.5 to 5.5 V
Max. supply voltage	6 V (absolute maximum!)
Current (approx.)	0.1 µA (sleep mode) · 0.8 mA (operation) · 9 mA (transmit)
Operating temperature	–10 to +70 °C (14 to 158 °F)
Max. keyed CW/PTT	35 V / 0.2 A
Speed	5 to 50 WPM
Memory	approx. 35 characters (one callsign or one standard text)
PTT delay	0 (QSK), 500 ms or 1 s, selectable
Auto power-off	sleep mode after 15 minutes without operation
Microcontroller	Microchip® ATtiny4313
System clock	1 MHz
Firmware	version 2.1.0 (November 11, 2024), Intel HEX
Keying outputs	CW and PTT, NPN transistors BC546A switching to ground
Battery (complete version)	LIR2450 rechargeable Li-ion coin cell, 3.6 V, 120 mAh; runtime depends on usage
Charger (complete version)	TP4056 module with Micro-USB input (accessible on the side wall); approx. 60 mA charge current with R(prog) = 22 kΩ (approx. 2-hour charge)
Indicators	red LED (memory), blue LED (WPM / sidetone / CW); 2 mA LED types
Controls	5 push buttons; paddle levers
Factory defaults	20 WPM · dot/dash ratio 1:3 · PTT delay 500 ms (0.5 s) · iambic mode A · sidetone on · speaker on (section 7.1)
Connections	Morse paddle, straight key, transceiver (CW/PTT), PC keying (optional), speaker/buzzer, Micro-USB charging socket (side wall; charging only)

4 Controls and connections

4.1 Push buttons and LEDs

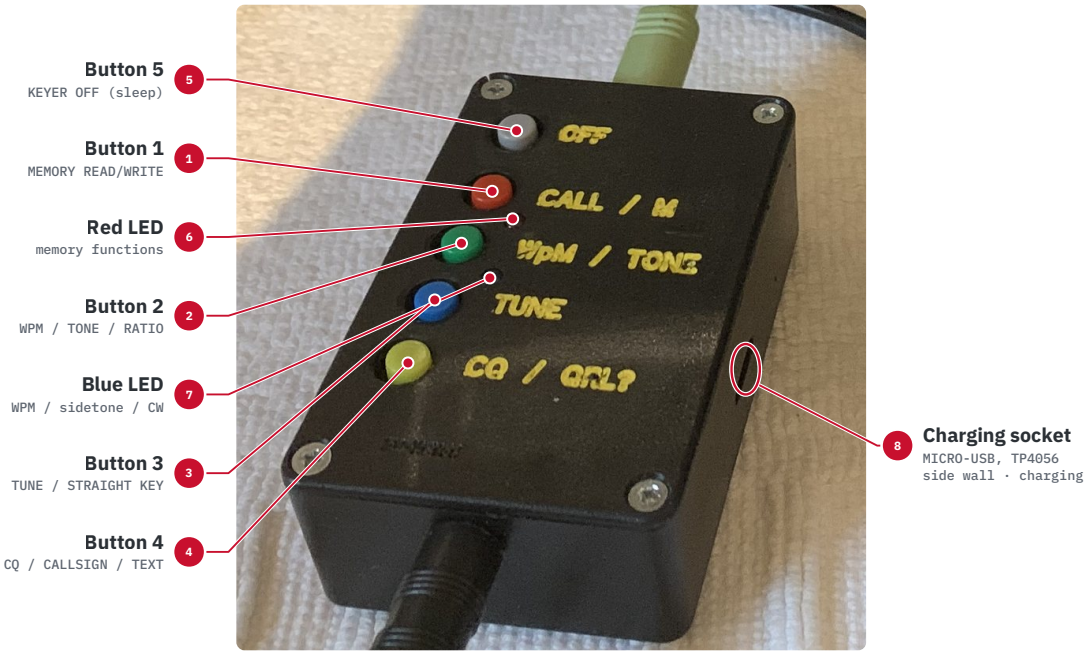


Figure 3: Top view of the author's example build. Callouts 1–5 are the push buttons (button numbers as in this manual), 6–7 the LEDs, and 8 the charging socket: the Micro-USB socket of the TP4056 module, accessible through the right side wall (see section 5.2). The front-panel labels of this build are OFF (5), CALL / M (1), WpM / TONE (2), TUNE (3) and CQ / QRL? (4).

No.	Element (schematic label)	Function
1	Memory read/write button	Memory read and write mode; stops a transmission; PTT delay settings (with long press)
2	WPM / tone / ratio button	Speed, sidetone, dash/dot ratio, iambic mode A/B, speaker on/off
3	Tune / straight key button	Tune / straight key: carrier only while the button is held pressed
4	Callsign / standard text / speaker button	Send CQ, CQ loop, send “QRL?”
5	Keyer off (power-off) button	Switches the keyer off (sleep mode)
6	Red LED	Flashing/continuous: memory functions
7	Blue LED	Flashing/continuous: special functions (WPM / sidetone / CW)
8	Charging socket (Micro-USB on the TP4056 module, side wall)	Charging the internal battery only; no data connection (section 5.2)

4.2 Connections

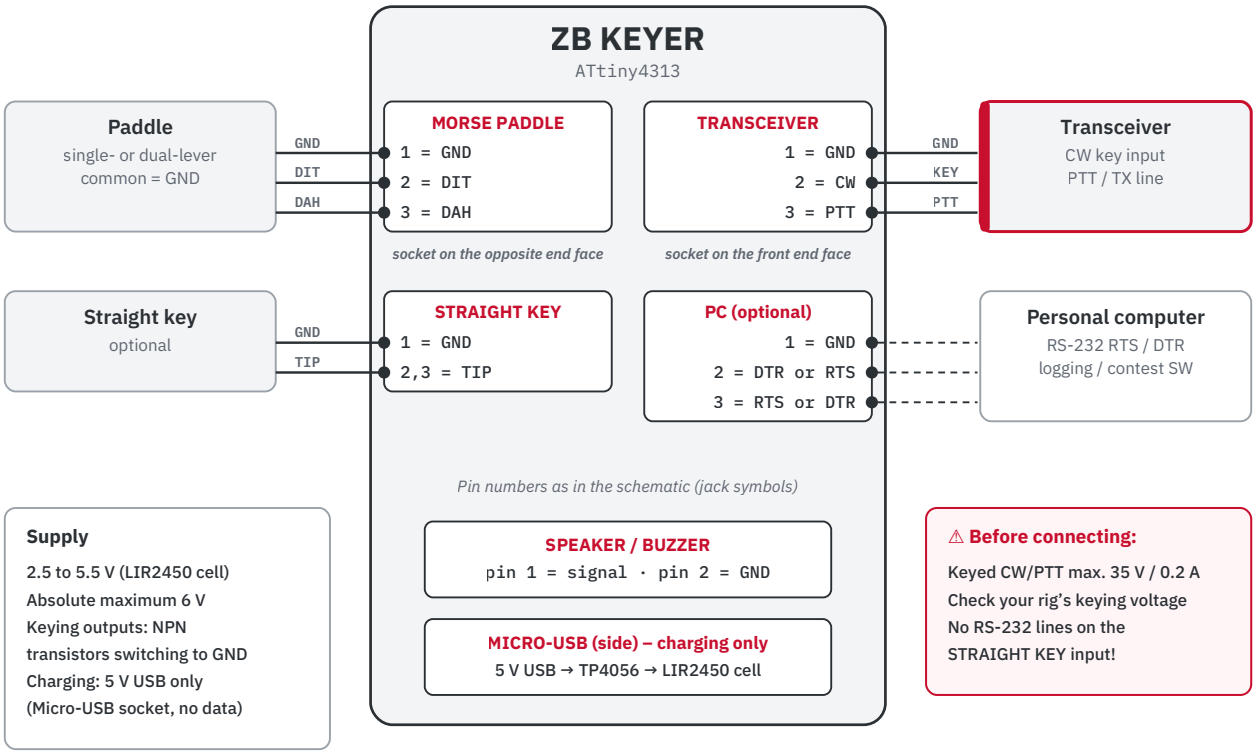


Figure 4: Connection overview. Pin numbers are those of the jack symbols in the schematic; check the contact assignment of the sockets and plugs you use.

Jack positions: on the keyer, the TRANSCEIVER socket is on the front (end) face of the enclosure, and the paddle/key socket is on the opposite end face. The Micro-USB charging socket is on the side wall (section 4.1). The type and size of the jack sockets are not specified; check the plugs that fit your build.

Connector (schematic)	Pins	Connect to
MORSE PADDLE (paddle/key socket, end face opposite the TRANSCEIVER socket)	1 = GND · 2 = DIT · 3 = DAH	Single- or dual-lever paddle
STRAIGHT KEY	1 = GND · 2, 3 = TIP	Straight key (optional)
TRANSCEIVER (front end face)	1 = GND · 2 = CW · 3 = PTT	Key input and PTT line of the transmitter or transceiver
PERSONAL COMPUTER PTT & CW KEYING (optional on-board PC interface)	1 = GND · 2 = PC DTR or RTS · 3 = PC RTS or DTR	RTS/DTR keying lines of a PC serial port, according to the ham radio software instructions
SPEAKER / BUZZER	1 = signal (via 68 Ω and 10 µF/16 V) · 2 = GND	Speaker or buzzer for the sidetone
Micro-USB (Micro-B socket of the TP4056 module, side wall)	5 V USB power input; charging only, no data connection	Standard USB charger (5 V) or computer USB port via a Micro-USB cable

5 Getting started

5.1 Before first use

- ☐ The ATtiny4313 has been programmed with the current firmware (section 9).
- ☐ The programming resistor R(prog) of the TP4056 module has been changed to 22 kΩ (section 2.4).
- ☐ Only a rechargeable LIR2450 Li-ion cell is installed, with correct polarity.
- ☐ You know the CW and PTT keying voltages and currents of your transmitter (max. 35 V / 0.2 A).

5.2 Power supply and charging

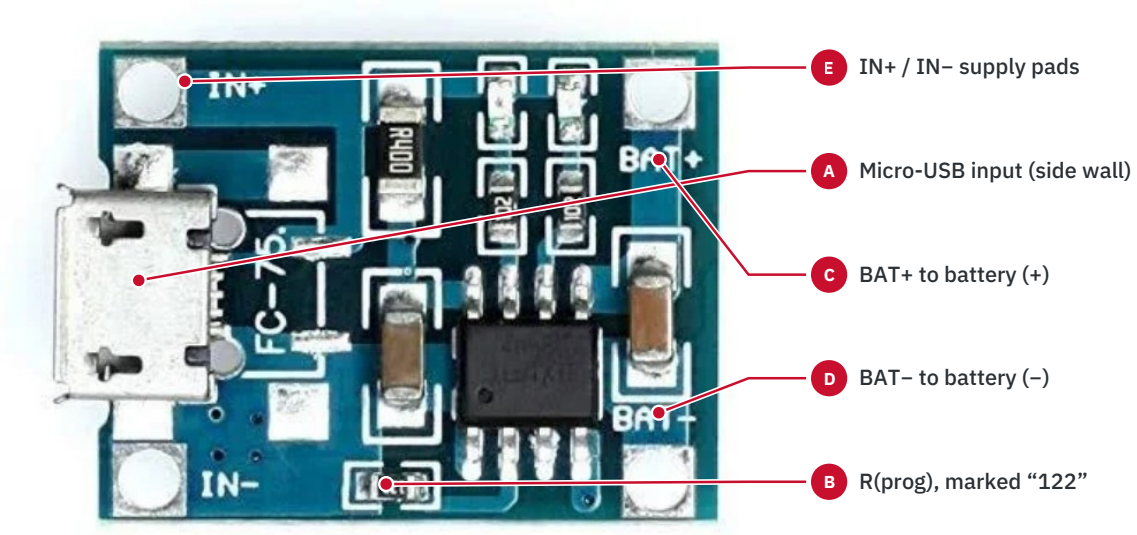


Figure 5: Typical TP4056 charger module for the LIR2450 Li-ion battery. Its Micro-USB input (A) is the charging socket accessible on the side of the enclosure (callout 8 in Figure 3, section 4.1). Replace R(prog) (B, marked “122”, 1.2 kΩ = 1 A) with 22 kΩ for approx. 60 mA.

1. Connect a standard USB charger (5 V) or a computer USB port to the Micro-USB charging socket on the side of the enclosure, using a Micro-USB cable (Figure 6). This socket is the Micro-USB input (A) of the TP4056 module (callout 8 in section 4.1).
2. With R(prog) = 22 kΩ, the battery is charged with about 60 mA; a full charge takes about 2 hours.
3. Disconnect the USB power supply when charging is complete.

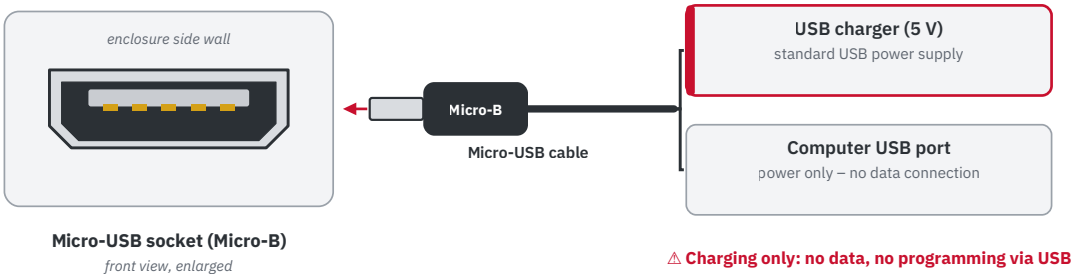


Figure 6: Micro-USB (Micro-B) charging socket on the side of the enclosure and Micro-USB cable to a 5 V USB charger or a computer USB port.

> **NOTE**
> The Micro-USB socket is used exclusively for charging the internal battery. It has no data connection: the keyer cannot be programmed or controlled via USB (for programming, see section 9).

The schematic shows no separate power switch. The keyer wakes up when any keyer function is operated or the paddle or straight key is used, and it is switched off with button 5 or automatically after 15 minutes without operation (section 8). All settings and the memory content are retained.

5.3 Connecting the paddle and a straight key

1. Connect the paddle to the MORSE PADDLE connector: pin 1 = GND (common), pin 2 = DIT, pin 3 = DAH. Single- and dual-lever paddles can be used.
2. Optionally connect a straight key to the STRAIGHT KEY connector: pin 1 = GND, pins 2 and 3 = TIP.
3. Operate the paddle: the keyer wakes up, and you hear the sidetone on the speaker (if the speaker is switched on, section 6.10).

> **NOTE**
> If dots and dashes are swapped, the DIT and DAH wires (pins 2 and 3) of your paddle cable are interchanged.

5.4 Connecting the transceiver (CW and PTT)

1. Check the keying voltage and current of your transmitter's key input and, if used, its PTT line. Both must not exceed 35 V / 0.2 A and must not be negative with respect to ground.
2. Connect the TRANSCEIVER connector: pin 1 = GND, pin 2 = CW (to the key input), pin 3 = PTT (to the PTT/TX line, if your transmitter needs one).
3. Select the PTT delay that suits your transmitter: QSK (0), 500 ms or 1 s (section 6.8).
4. Connect the transmitter to an antenna or a dummy load and check the keying at low power, for example with the tune function (button 3).

5.5 First steps

1. **Set your speed:** press button 2 briefly, adjust with the paddle levers (dot lever = faster, dash lever = slower), press 2 again.
2. **Store your callsign:** press button 1 for more than approx. 0.5 s (red LED on), key your callsign with the paddle, then release the paddle for more than approx. 1 s.
3. **Check the memory:** press button 1 briefly – the keyer sends the stored callsign.
4. **Call CQ:** press button 4 briefly, for example: `CQ CQ CQ CQ CQ DE DL6ZB DL6ZB DL6ZB K`. Stop at any time with the paddle or button 1.

6 Operation

6.1 Operating principle

The keyer is controlled by the five push buttons and by the dash/dot lever(s) of the connected single- or dual-lever paddle. Buttons 1 to 4 have different functions for a **short press** and a **long press** (approx. more than 0.5 s). Additional functions are reached with **two-button procedures**, in which the buttons are pressed one after the other:

press the 1st button → release the 1st button → press the 2nd button → release the 2nd button

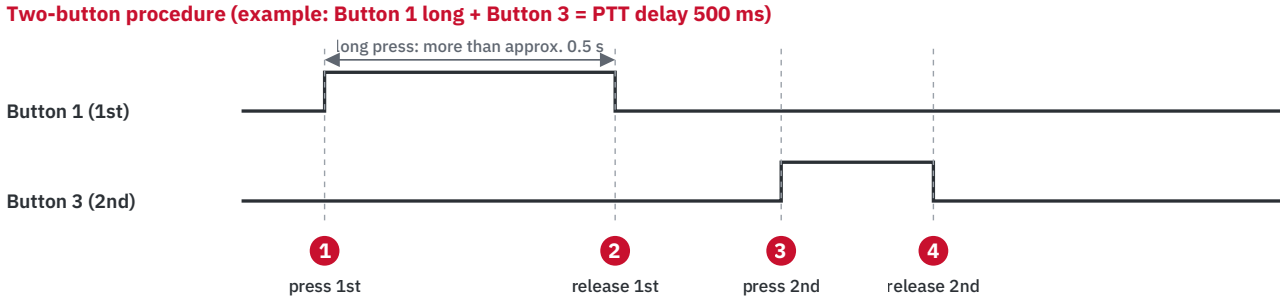


Figure 7: Two-button procedure. The full reset is the only procedure in which two buttons are held at the same time.

6.2 Button functions

Button	Short press	Long press (approx. > 0.5 s)
1	Memory read mode: sends the callsign or standard text; stop with the paddle or button 1	Memory write mode: enter a callsign or standard text of up to 35 characters
2	WPM: dot lever = faster, dash lever = slower; press button 2 again to finish	Sidetone adjustment with the paddles; press button 2 long again to finish
3	Tune / straight key (carrier while held)	Tune / straight key (carrier while held)
4	Send CQ – press once more for the CQ loop (10×); stop with the paddle or button 1	Sends “QRL?”
5	Shuts off the keyer (activates sleep mode)	

Two-button procedure	Function
1 long + 2	PTT delay = 0 (QSK mode)
1 long + 3	PTT delay = 500 milliseconds
1 long + 4	PTT delay = 1 second
2 short + 1	Dash/dot ratio adjustment (section 6.9)
2 short + 3	Toggles the dash/dot memory (iambic mode A/B); LED/speaker signal: A = off, B = on
2 short + 4	Toggles the speaker on/off
1 held + 2	Full reset (section 6.12)

6.3 Iambic keying: mode A and mode B

With a dual-lever paddle, the keyer supports the squeeze technique: while you press both levers, the keyer sends alternating dots and dashes and corrects the timing of your keying.

- **Mode A** – if you do not press one lever long enough and are already working on the opposite lever, the keyer corrects the timing as long as you keep pressing both levers. Not every timing can be corrected, but in general this mode works well for most CW operators.
- **Mode B** – similar to mode A, with an addition: if you press and release the opposite lever while still holding the first one, this lever action is stored by the dash/dot memory, and the dash or dot is sent after you release the first lever.

To switch between the modes, press button 2 briefly, then button 3. This toggles the dash/dot memory. The keyer confirms the new setting with the LED and speaker signal **A** (memory off, mode A) or **B** (memory on, mode B).

6.4 Speed (WPM) and sidetone

Speed

1. Press button 2 briefly. The blue LED flashes dots.
2. Adjust the speed with the paddle levers: the **dot lever increases** the speed, the **dash lever decreases** it (range 5 to 50 WPM).
3. Press button 2 again to finish.

Sidetone

1. Press button 2 for more than approx. 0.5 s.
2. Adjust the sidetone with the paddle levers.
3. Press button 2 for more than approx. 0.5 s again to finish – the sidetone setting is exited the same way it is entered.

6.5 Tune and straight key

Button 3 (short or long press) activates the tune / straight key function. It works like a momentary key: the transmitter is keyed (carrier) only while button 3 is held pressed and is released as soon as you let go of the button. Use it to key the transmitter for tuning. A straight key can also be connected permanently to the STRAIGHT KEY connector.

> **CAUTION**
> The tune function keys the transmitter. Connect an antenna or a dummy load first and observe the duty-cycle limits of your transmitter.

6.6 Memory (callsign or standard text)

Writing the memory

1. Press button 1 for more than approx. 0.5 s. The keyer switches into memory write mode, and the red memory LED turns on.
2. The keyer now waits until either the paddle levers are operated to start loading the memory, or button 1 is pressed once more to exit memory mode without changing the memory.
3. Key your callsign or a standard text with the paddle. Up to about 35 characters can be entered as long as the red memory LED is on. When the memory is full, the red LED turns off automatically.
4. Memory write mode ends when the paddle is released for more than approx. 1 second, or when button 1 is pressed.

> **NOTE**
> If button 1 was pressed unintentionally, simply press button 1 again without touching the paddle. Memory mode is exited without any change, the keyer returns to CW mode, and all previously stored information remains in memory.
>
> The memory holds either a callsign or a standard text. The auto-CQ function inserts the memory content into the CQ call, so it is intended for a stored callsign.

Reading the memory and calling CQ

- Button 1 (short) transmits the standard text or callsign only.
- Button 4 (short) transmits the auto-CQ text with the stored callsign, for example:
  `CQ CQ CQ CQ CQ DE DL6ZB DL6ZB DL6ZB K`

CQ loop

The keyer enters CQ loop mode if button 4 is pressed once more while a CQ call is being sent. In CQ loop mode, the CQ call is repeated approx. every 10 seconds for 10 rounds.

Immediate stop of a transmission

You can stop any transmission at any time by operating the paddle or pressing button 1.

Deleting the memory

The memory is overwritten by loading a new callsign or new standard text as described above. The memory and all parameters are deleted by a full reset (section 6.12).

6.7 Sending “QRL?”

Press button 4 for more than approx. 0.5 s. The keyer sends “QRL?”.

6.8 PTT delay

The PTT line (TRANSCEIVER pin 3) can be operated with three delay settings. Press button 1 long, release it, then press and release the second button:

Procedure	PTT delay
1 long + 2	0 – QSK mode
1 long + 3	500 milliseconds
1 long + 4	1 second

6.9 Dash/dot ratio adjustment

1. Press button 2 (WPM): the blue LED flashes dots.
2. Press button 1 (memory): the blue LED flashes dots, the red LED flashes dashes.
3. Operate the paddle levers to adjust the ratio: the dash lever increases the ratio, the dot lever decreases it.
4. Press button 1 (memory) to end the adjustment and store the ratio in memory.

> **NOTE**
> To restore the standard 1:3 dot/dash ratio, press button 2 once more during the adjustment (step 3).

6.10 Speaker on/off

Press button 2 briefly, then button 4, to toggle the speaker on or off.

6.11 Using the keyer together with a PC

PC software and the ZB Keyer can be used in parallel. The CW and PTT keying lines of the PC's serial port act on the CW and PTT lines of the keyer's TRANSCEIVER connector (pins 2 and 3). Many widely used ham radio programs use the RTS or DTR lines of the RS-232 (serial) port for this purpose. The DTR and RTS behavior can be selected in the ham radio software settings.

The schematic shows an optional on-board PC interface for this connection: its input connector “PERSONAL COMPUTER PTT & CW KEYING” (1 = GND, 2 = PC DTR or RTS, 3 = PC RTS or DTR) feeds the transistors Q3 and Q4 via diodes, 10 kΩ resistors and 5.1 V Zener diodes. Q3 and Q4 switch the CW line (TRANSCEIVER pin 2) and the PTT line (pin 3) in parallel with the keyer's own outputs.

In addition to everyday CW QSO operation, this means that PC software – whether contest software or logbook software with a CW keyer option – can be used as a standard-text keyer, while the ZB Keyer can be used in parallel to send additional Morse code manually when necessary.

> **CAUTION**
> Use only pins 2 and 3 of the ZB Keyer's TRANSCEIVER connector to connect the RTS/DTR keying lines of a PC's serial port. RS-232 serial port lines must not be connected directly to the straight-key input connector, since RS-232 voltage levels exceed the keyer's maximum ratings. Serious damage to the microcontroller will occur if an RS-232 keying line is connected to the straight-key connector.

6.12 Stored parameters and full reset

All adjustable parameters remain in memory after the keyer is switched off and are reloaded when it is switched on again.

> **CAUTION**
> Individually programmed parameters are deleted if a full reset is performed. The keyer parameters are then set to their factory defaults (section 7.1), and the callsign or standard text is erased.

Full reset procedure

1. Press button `1`.
2. Press button `2` while keeping button 1 pressed.
3. The red memory LED turns on. Wait until the memory LED turns off.
4. Release the buttons. Done: all adjustable parameters are set to their default values, and the callsign (or standard text) is erased from memory.

7 Settings reference

All settings below are stored permanently and survive switching off and sleep mode. A full reset restores the factory defaults (section 7.1).

7.1 Factory defaults

A new keyer and a keyer after a full reset (section 6.12) use the following settings.

Setting	Factory default
`Speed`	20 WPM
`Dot/dash ratio`	1:3
`PTT delay`	500 ms (0.5 s)
`Iambic mode`	mode A (dash/dot memory off)
`Sidetone`	on
`Speaker`	on

7.2 Settings and procedures

Setting	Procedure	Adjustment	Indication / notes
Speed (WPM)	2 short	Dot lever: faster; dash lever: slower; 2 again to finish	Blue LED flashes dots; 5 to 50 WPM
Sidetone	2 long	Paddle levers; 2 long again to finish	–
Dash/dot ratio	2 short + 1	Dash lever: ratio up; dot lever: ratio down; 1 to store; 2 restores 1:3	Blue LED flashes dots, red LED flashes dashes
Iambic mode A/B	2 short + 3	Toggles the dash/dot memory	Signal A = off (mode A), B = on (mode B)
Speaker	2 short + 4	Toggles on/off	–
PTT delay QSK	1 long + 2	PTT delay = 0	QSK mode
PTT delay 500 ms	1 long + 3	PTT delay = 500 ms	–
PTT delay 1 s	1 long + 4	PTT delay = 1 s	–
Memory text	1 long	Key up to approx. 35 characters; ends after approx. 1 s pause or with 1	Red LED on while writing; turns off when the memory is full
Full reset	1 held + 2	Wait until the memory LED turns off	All parameters to default; memory erased

7.3 Transmit functions

Procedure	Transmits
1 short	Memory content (callsign or standard text)
4 short	Auto CQ with the stored callsign, e.g. `CQ CQ CQ CQ CQ DE DL6ZB DL6ZB DL6ZB K`
4 again during CQ	CQ loop: CQ call repeated approx. every 10 s for 10 rounds
4 long	`QRL?`
3 held (short or long)	Tune / straight key: carrier only while the button is held pressed
Paddle or 1	Stops any transmission immediately

8 Sleep mode and power management

The auto power-down feature switches the keyer into sleep mode after **15 minutes** without any operation, so you don't need to switch it off manually to save battery life. In sleep mode, the current consumption drops to approx. **0.1 µA**.

- **Wake-up:** the keyer wakes up when any keyer function is operated or the paddle or straight key is used.
- **Manual sleep:** sleep mode can be activated manually by pressing button 5.
- **Settings:** all adjustable parameters and the memory content are retained.
- **Battery:** LIR2450 Li-ion coin cell, 3.6 V, 120 mAh. The runtime per charge depends on usage (time in operation, transmitting and sleep mode; see the currents below).

Operating state	Current (approx.)
Sleep mode	0.1 µA
Operation	0.8 mA
Transmit	9 mA

In the schematic, the microcontroller's supply (VCC) is switched by the transistors Q5 (2N3906) and Q6 (BC546A). The diodes D11–D16 connect the buttons and the paddle and straight-key inputs to this switching stage, so that operating a control wakes the keyer.

> **NOTE**
> Recharge the battery when the keyer no longer responds reliably (section 5.2). If the keyer will not be used for a long time, store it in a cool, dry place.

9 Firmware and programming

9.1 Firmware download

The firmware for the ZB Keyer is available in hex format on the project page. Check the website for updates.

Version	2.1.0 – latest update November 11, 2024
Download	dl6zb-keyer-11-nov-24-001.zip (4,049 bytes)
Content	`dl6zb-keyer-11-nov-24-001.hex` – Intel HEX file, 4,064 bytes of program data for the ATtiny4313 (4 KB flash)
SHA-256 (ZIP)	`5d553388fc374954c3e993dad01e5ea4d67158984806d861122e621e05914183`
SHA-256 (HEX)	`9b32c59d8cdad26a8041357885ffea6561b0bb555829cef91227f1f07d0b34d3`
License	Freeware with restrictions – no modification, no commercial use (section 12.3)

The firmware is supplied as a compiled hex file and is uploaded to the ATtiny4313 through its ISP (in-system programming) interface. Three options are described below.

9.2 Option 1: PonyProg (Windows/Linux)

Probably the easiest way to burn the firmware: if your computer has a real, physical RS-232 port, this may be your choice. Search the web for details about the PonyProg hardware and software; there is quite a lot of information available. It's an easy way to upload hex files.

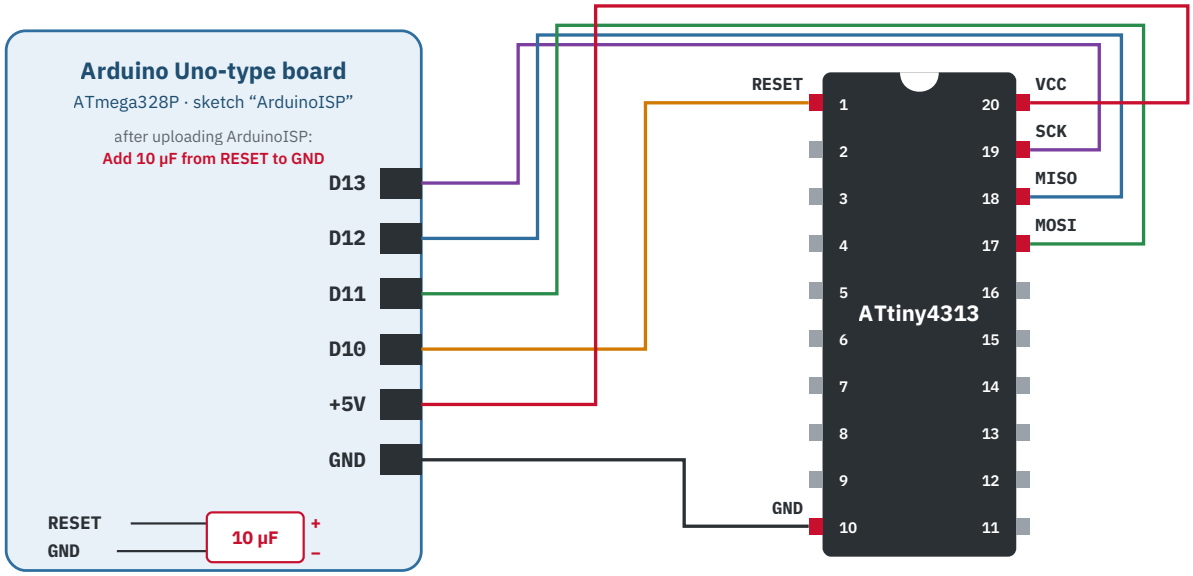
9.3 Option 2: USBasp (Windows/Linux)

1. Get an AVR ISP programmer, for example a USBasp, for about 10 dollars.
2. Install Microchip Studio (formerly Atmel Studio) or AVRDUDE on your computer. Both are free.
3. Configure the software for the programmer/port and the microcontroller type (ATtiny4313).
4. Upload the hex file to the microcontroller via the ISP port. Done.

9.4 Option 3: Arduino as ISP (Linux)

The longest but possibly the safest route.

1. Get an ATmega328P Arduino board (an inexpensive clone works).
2. Install the Arduino IDE on your computer.
3. Go to `File/Preferences` and add this to “Additional Boards Manager URLs”:
   `https://drazzy.com/package_drazzy.com_index.json`
   Click OK.
4. Go to `Tools/Board/Boards Manager`, search for “attiny” and install “ATTinyCore by Spence Konde”.
5. Select the board and microcontroller: `Tools/Board/ATTinyCore/ATtiny2313(a)/4313 (No Bootloader)`.
6. Open the sketch `File/Examples/ArduinoISP/ArduinoISP`, compile it and upload it to the Arduino.
7. Close the Arduino IDE and disconnect the Arduino from USB.
8. Install AVRDUDE: `sudo apt-get install avrdude`
9. **Important:** at this point, connect a 10 µF capacitor on the Arduino board from RESET to GND. The Arduino has now been turned into an ISP programmer.
10. Wire the Arduino to the ATtiny4313 as shown in the figure and the table below.



Wiring per the ZB Keyer web page; ATtiny4313 shown from the top (DIP-20, notch up).

Figure 8: Arduino as ISP: wiring to the ATtiny4313 (DIP-20).

Arduino	ATtiny4313
D13	Pin 19 (SCK)
D12	Pin 18 (MISO)
D11	Pin 17 (MOSI)
D10	Pin 1 (RESET)
+5V	Pin 20 (VCC)
GND	Pin 10 (GND)

Program the ATtiny4313 by entering the command below in a Linux terminal window. Replace `path_to_hex_file.hex` with the path to your keyer hex file. Check the USB port: the Arduino Uno usually appears as `/dev/ttyACM0`, but it may be `/dev/ttyUSBx` instead.

```
avrdude -c arduino -p t4313 -P /dev/ttyACM0 -b 19200 -e -U flash:w:"path_to_hex_file.hex":i
```

For experts: you can use AVRDUDESS (a graphical user interface for AVRDUDE) for more convenient programming instead of the command line.

9.5 Notes on programming

- The commands above write the flash memory only; they do not change the fuse settings. The firmware is documented for a system clock of 1 MHz, which is the factory default of a new ATtiny4313 (internal 8 MHz RC oscillator divided by 8).
- The ISP pins 17, 18 and 19 are also used by the keyer circuit (pin 17: power-switching stage; pins 18 and 19: red and blue LED). The schematic does not show a dedicated ISP connector. If you program the microcontroller in circuit, make sure that only one power source supplies the circuit.
- The Micro-USB socket is for charging only and cannot be used for programming.

- Observe ESD precautions (section 2.5).

10 Schematic and theory of operation

10.1 Block diagram

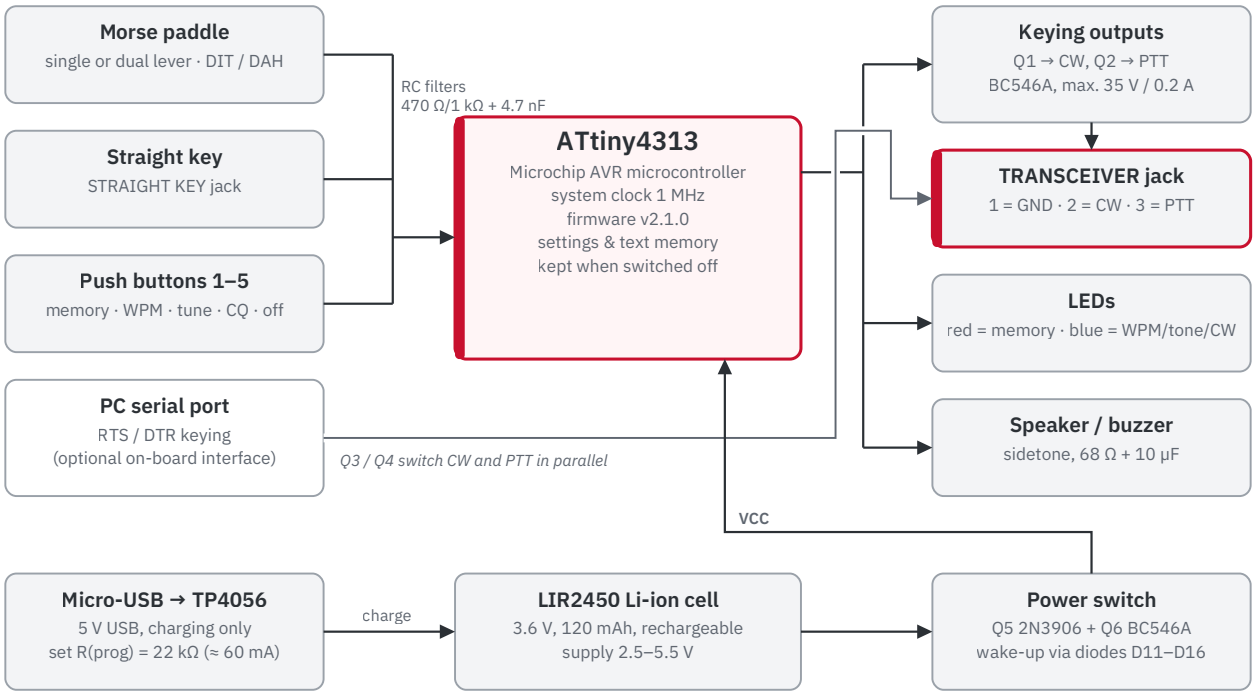


Figure 9: Block diagram of the ZB Keyer, derived from the schematic 04-NOV-24-001.

10.2 Theory of operation

Microcontroller. The ATtiny4313 runs at a system clock of 1 MHz. The firmware generates the Morse elements, handles the buttons, the memory and the settings, and drives the LEDs, the speaker and the keying outputs.

Inputs. The five push buttons switch their port lines to ground. The paddle inputs (DIT, DAH) are connected via 470 Ω resistors and the straight-key input via 1 kΩ; 4.7 nF capacitors to ground suppress RF on the external lines. The diodes D5–D16 (1N4148) decouple the inputs from each other and from the power-switching stage.

Keying outputs. The port lines “CW to radio” and “PTT to radio” drive the NPN transistors Q1 and Q2 (BC546A) via 1 kΩ resistors. Their collectors switch the TRANSCEIVER lines CW (pin 2) and PTT (pin 3) to ground through RC filters (1 kΩ, 4.7 nF).

Optional PC interface. The RTS/DTR signals of a PC serial port reach the transistors Q3 and Q4 (BC546A) via the diodes D1/D2, 10 kΩ series resistors and the 5.1 V Zener diodes D3/D4, with 47 kΩ and 4.7 nF to ground. Q3 and Q4 switch the CW and PTT lines in parallel with Q1 and Q2.

Indicators and sidetone. The blue (WPM/sidetone/CW) and red (memory read/write) LEDs are 2 mA types with 1 kΩ series resistors. The speaker or buzzer is driven via 68 Ω and a 10 µF/16 V capacitor.

Power supply. The LIR2450 Li-ion cell feeds the circuit (2.5–5.5 V) and is charged by the TP4056 module from its Micro-USB socket (5 V USB, accessible on the side wall); the schematic notes that R(prog) must be changed to 22 kΩ. The supply of the microcontroller is switched by Q5 (2N3906) and Q6 (BC546A), which are connected to pin 17 (PB5) of the microcontroller. Operating a button, the paddle or the straight key wakes the keyer via the diodes D11–D16.

10.3 Main components

Reference	Component (as shown in the schematic)
IC	Microchip ATtiny4313 microcontroller (DIP-20)
Q1, Q2, Q3, Q4, Q6	BC546A NPN transistor
Q5	2N3906 PNP transistor
D1, D2, D5–D16	1N4148 diode
D3, D4	5.1 V Zener diode (optional PC interface)
LEDs	blue and red, 2 mA type, series resistors Rv = 1 kΩ
Filters	470 Ω and 1 kΩ resistors, 4.7 nF capacitors
Speaker output	68 Ω, 10 µF/16 V, speaker or buzzer
Battery	LIR2450 Li-ion rechargeable coin cell, 3.6 V, 120 mAh
Charger	TP4056 module with Micro-USB input, R(prog) = 22 kΩ
Buttons	5 push buttons: memory read/write (1), WPM/tone/ratio (2), tune/straight key (3), callsign/standard text/speaker (4), keyer off (5)

This table lists the main components shown in the schematic. It is not a complete parts list; refer to the schematic for all values.

10.4 Schematic

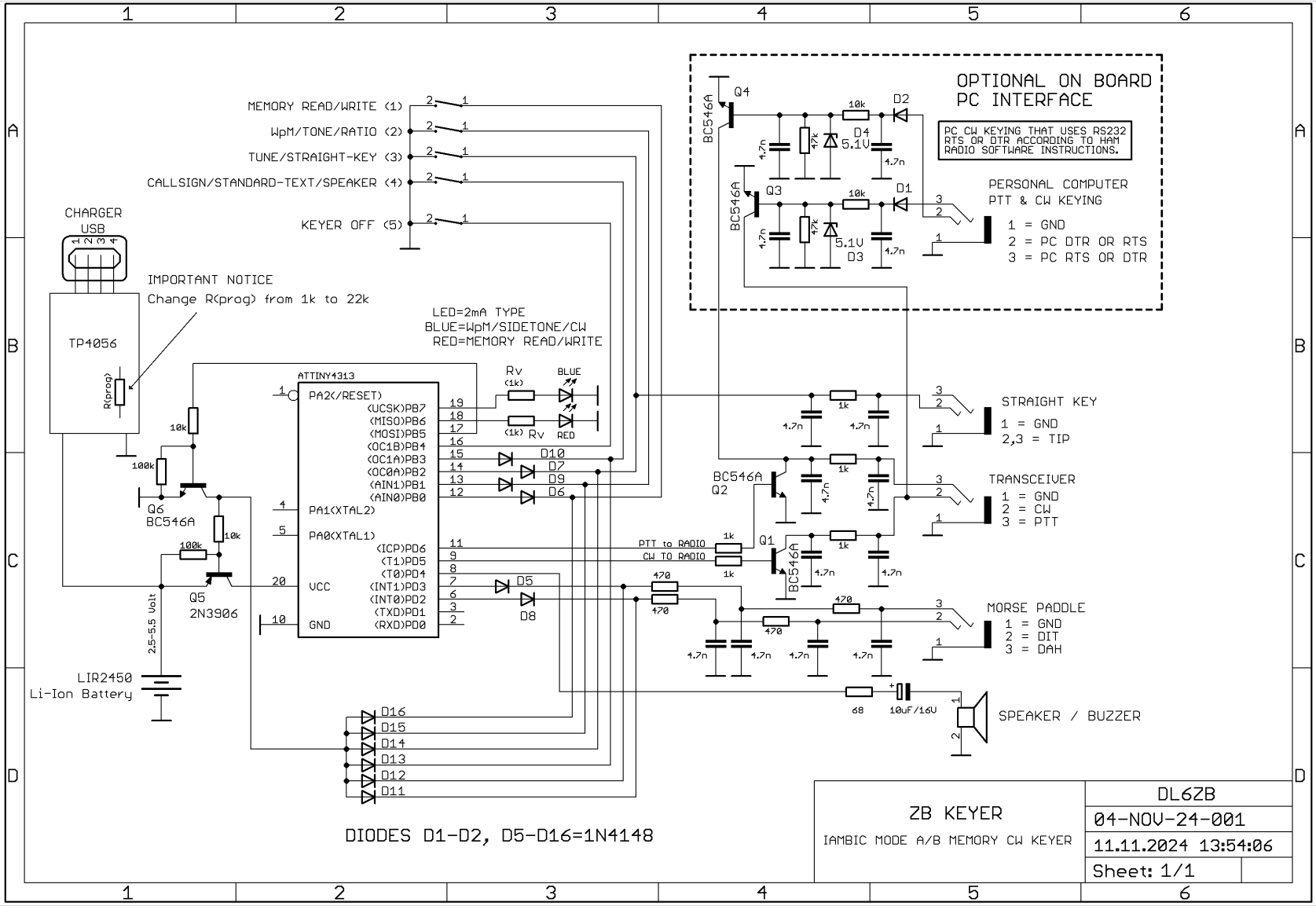


Figure 10: ZB Keyer schematic, iambic mode A/B memory CW keyer, 04-NOV-24-001, dated November 11, 2024. The schematic is also available as a PDF file on the project page.

11 Troubleshooting

Problem	Possible cause	Remedy
Keyer does not respond	Keyer is in sleep mode	Press any button or operate the paddle or straight key.
	Battery discharged	Charge the battery (section 5.2).
	Battery polarity wrong; firmware not programmed	Check the battery polarity; program the firmware (section 9).
No sidetone	Speaker switched off	Press **2** short, then **4** (section 6.10).
Dots and dashes swapped	DIT and DAH wires interchanged	Check the paddle cable: pin 2 = DIT, pin 3 = DAH.
Transmitter is not keyed	Wrong wiring of the TRANSCEIVER connector	Pin 1 = GND, pin 2 = CW, pin 3 = PTT. Check the key input of the transmitter.
	Keying voltage outside the ratings	The outputs switch to ground; max. 35 V / 0.2 A, no negative voltages.
Transmitter drops out between characters or words (PTT)	PTT delay too short for your station	Select 500 ms (**1** long + **3**) or 1 s (**1** long + **4**).
Unexpected extra dot or dash when squeezing	Iambic mode B (dash/dot memory on)	Toggle to mode A: **2** short + **3** (signal A).
Dots and dashes sound too heavy or too light	Dash/dot ratio changed	Adjust the ratio or restore 1:3 (section 6.9).
Memory entry stops early	Memory full (approx. 35 characters) or pause of more than approx. 1 s	Use a shorter text; key without long pauses.
Button 1 was pressed long by mistake	Keyer is in memory write mode (red LED on)	Press **1** again without touching the paddle – the memory remains unchanged.
CQ call does not contain the callsign as expected	A standard text instead of a callsign is stored	Store your callsign (section 6.6).
Settings are unknown or confusing	–	Perform a full reset (section 6.12). Note: the memory is erased.
PC keying does not work	RTS/DTR assignment	Select the DTR/RTS behavior in the ham radio software settings; use only pins 2 and 3 of the TRANSCEIVER connector (section 6.11).
Programming with Arduino as ISP fails	Wiring, missing capacitor or wrong port	Check the wiring (section 9.4), the 10 µF capacitor from RESET to GND on the Arduino, and the port (`/dev/ttyACM0` or `/dev/ttyUSBx`).

If a problem persists, please send a bug report with a description of your build, the firmware version and the observed behavior to dl6zb@dl6zb.de.

12 Disposal, warranty, license and contact

12.1 Disposal

Electrical and electronic equipment. A finished keyer is electrical and electronic equipment. At the end of its life, it must not be disposed of with household waste. Take it to a collection point for waste electrical and electronic equipment (in Germany, for example, the municipal recycling center/Wertstoffhof), in accordance with the WEEE Directive 2012/19/EU and, in Germany, the Electrical and Electronic Equipment Act (ElektroG).

Batteries. Batteries must not be disposed of with household waste either. Remove the LIR2450 Li-ion cell from the keyer before disposal if it can be removed without destroying the device, and hand it in separately at a battery collection point (for example at retailers or municipal collection points), in accordance with the EU Battery Regulation (EU) 2023/1542 and, in Germany, the Battery Act (BattDG, which replaced the former BattG). To prevent short circuits and fire, insulate the terminals of lithium batteries with adhesive tape before disposal.

Personal data. The keyer's memory may contain your callsign. Erase it with a full reset (section 6.12) before passing the keyer on or disposing of it.

12.2 Warranty and liability

The ZB Keyer design, its firmware and this manual are provided free of charge for non-commercial amateur radio purposes. This is a hobby project: the technical data are only rough estimates and can change at any time, and the author cannot guarantee that the project will work without errors. No warranty or guarantee of any kind is given. Builders and operators use the design, the firmware and the information in this manual at their own risk. To the extent permitted by applicable law, the author accepts no liability for any damage arising from the construction or use of the keyer, including damage to connected equipment.

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12.5 Acknowledgments

Special thanks to Volker Herrmann, DL8WIG, for testing and useful comments.

12.6 Contact

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E-mail	dl6zb@dl6zb.de – bug reports, comments and questions
Web	https://www.dl6zb.de – more hardware and software projects and legal information

A Quick reference card

Buttons – short press

1	Send memory (callsign/text)
2	Speed (WPM) – dot lever +, dash lever –, 2 to finish
3	Tune – carrier while held
4	Send CQ · again: CQ loop (10×)
5	Keyer off (sleep)

Buttons – long press (> 0.5 s)

1	Write memory (up to 35 characters)
2	Sidetone – paddles, 2 long to finish
3	Tune – carrier while held
4	Send “QRL?”

Factory defaults

20 WPM · ratio 1:3 · PTT delay 0.5 s · iambic mode A · sidetone on · speaker on

Stop transmission

Operate the paddle or press 1.

LEDs

- Red: memory functions
- Blue: special functions (WPM / sidetone / CW)

Two-button procedures

Press 1st → release → press 2nd → release (L = long, S = short)

1 L + 2	PTT delay 0 (QSK)
1 L + 3	PTT delay 500 ms
1 L + 4	PTT delay 1 s
2 S + 1	Dash/dot ratio: dash lever +, dot lever –, 1 stores, 2 = 1:3
2 S + 3	Iambic mode A/B (A = memory off, B = on)
2 S + 4	Speaker on/off

Charging

Micro-USB socket on the side wall (TP4056 module): 5 V USB charger or computer USB port. Charging only – no data.

Full reset

Hold 1, press 2 → red LED on → wait until it turns off → release. Erases all settings and the memory.

Limits

Supply 2.5–5.5 V (absolute max. 6 V) · keyed CW/PTT max. 35 V / 0.2 A · sleep after 15 min · –10 to +70 °C (14 to 158 °F)

B Revision history

Edition	Date	Changes
2.0.3	March 3, 2024	Text manual for the ATtiny4313 version of the ZB Keyer.
2.0.9	April 2024	Online manual on the keyer web page (last firmware update April 9, 2024). Added: power-off button 5 and sleep mode, speaker on/off, PC connection, new full reset procedure.
2.1	October 2026	First illustrated PDF edition for firmware 2.1.0 (November 11, 2024) and schematic 04-NOV-24-001. Restructured; added safety and legal notices, connection and block diagrams, settings reference, programming wiring diagram, theory of operation, troubleshooting, disposal information and quick reference card. Inconsistent values of the previous edition corrected.
2.2	October 2026	Edition 2.2: charging socket, factory defaults (incl. sidetone and speaker on), jack positions, battery data, tune and sidetone details, speed lever direction.