Manual CT800

a dedicated chess computer

info@ct800.net

document version: v1.51

Table of Contents

1 Initial operation

You can power the CT800 either using batteries or using a wall power adaptor.

1.1 Batteries

Put the main switch on the backside to position "1". Place four batteries of AA type in the battery holder, either rechargeable ones (NiMH, nickel-metal hydride) or disposable ones (alkaline type).

The polarity must match the one indicated on the inside of the battery compartment. With wrong polarity, the CT800 will not start up, but it will not suffer damage.

Put the main switch on the backside to position "2". The CT800 should start now.

The expected running time with 2200 mAh AA batteries is 37.5 hours at regular 168 MHz (100 % speed), assuming 50 % computing time and 50 % user time.

The battery voltage is monitored to prevent damaging NiMH rechargeable batteries by deep discharge, see chapter 4.1. Battery info. Disposable batteries (alkaline type) will also work, though they are not economic in the long run.

Note:

- always put the batteries into the battery holder with the indicated polarity.

- always use identical batteries, i.e. of the same capacity, age and temperature, and by the same manufacturer.

- always keep rechargeable batteries at the same charging state, i.e. charge them together in the same battery charger at the same time until they are fully charged.

- never mix batteries at different discharge levels.

- never mix rechargeable and disposable batteries.

- switch off the CT800 when it tells you to do so, or change to external power.

- remove empty batteries from the CT800.

- remove the batteries from the CT800 when not using it for more than about a month.

Otherwise, the battery monitoring will not work properly, which could damage the batteries. The electrolyte of the batteries could leak outside, which would damage the housing.

1.2 Wall power

Use a mains-to-USB adaptor or USB power bank that delivers at least 200 mA at 5 V DC. The CT800 offers a USB type B socket at the backside. Though it is not strictly guaranteed, most computers and laptops will also be suitable to deliver the necessary power from a USB port.

Put the main switch on the backside to position "1" to have the CT800 run from the external power supply.

Note: running on external power does not recharge the internal batteries. Therefore, you can safely use external power without removing the internal batteries.

1.3 Overvoltage

Putting more than 7.5 V to the CT800 will make the relevant fuse for the power source (external or internal) melt down. Changing the fuse will require qualified personnel. There is a suitable reserve fuse inside the CT800, type 5×20mm / 1 A fast.

2 Technical data

2.1 Hardware

- CPU: ARM Cortex M4 (STM32F405RG in Olimex STM32-H405).

- Speed: 168 MHz (100 %) while computing, 18 MHz while waiting for user input.

- Clocking: the CPU speed during computing can be configured from 10 % to 145 %.

- ROM: 1 MB.

- RAM: 192 kB + 4 kB backup-RAM.

- Display: text display with 4×20 characters, plus a red LED, a green LED and a buzzer.

- Display backlight: controlled by software.

- Input: 4×4 matrix keypad plus one switch for manual backlight activation.

- Power input: 5 V DC (USB) from a power bank, wall power adaptor, or computer. Alternatively, 4×AA NiMH or alkaline batteries.

- Battery running time with 2200 mAh NiMH batteries, assuming 90 % usable battery capacity: 37.5 hours (100 % speed).

- Current consumption at 5 V:
  18 mA while waiting for user input.
  81 mA while computing without overclocking.
  each plus 28 mA with active display backlight.

2.2 Software

- Opening book: 23,300 different plies in 13,200 unique positions. Transpositions are recognised.

- Hash tables: 100 kB.

- Pondering: none.

- Maximum search depth: 22 plies full search plus 10 plies quiescence.

- Maximum game length: 250 moves.

- Free ROM: The firmware image is 384 kB, out of which 262 kB are used. 111 kB are for the opening book data and 24 kB for the endgame bitbase.

- Free RAM: 17 kB.

- Strength: around 2200 ELO (expert class).

- Firmware version: V1.41.

- Operating system: none / bare metal.

- Programming language: mostly C, and some assembly.

- Compiler: GCC 7.3 Q2/2018 ARM none-eabi.

- Author of the ARM-port: Rasmus Althoff.

- Base program: NG-Play v9.86.

- Author of NG-Play v9.86: George Georgopoulos.

- Author of the endgame bitbase for king+pawn vs. king: Marcel van Kervinck.

- Licence: GNU General Public License (GPL), Version 3 or later.

  As per the GPL, those who receive the executable program (e.g. inside the chess computer itself) have the right to also obtain the program source text, the build scripts and the instructions how to install the executable program on the chess computer.

3 Playing

3.1 User moves

You enter moves by giving the from-square and the to-square of a move, followed by the ✔ key, which means "OK" or "Enter". The square keys change their meaning (rank / file) depending on whether a rank or a file is expected.

For example, to start a game with e2-e4, you type E5 B2 E5 D4 ✔ . With the first key, a file is expected, so E5 evaluates to "E". The following key means a rank, in this case the second rank, so B2 gives "2".

There is no difference between entering a piece or a pawn move. So if you instead want to begin the game with Ng1-f3, you enter G7 A1 F6 C3 ✔ .

Taking a piece does not require special markup. The CT800 knows that the destination square is occupied so that the move is automatically recognised as capture. This holds also for taking a pawn "en passant".

Castling is treated as a pure king move e.g. from e1 to g1. The rook position will be updated automatically.

Promoting a pawn means entering the from-square, the to-square and optionally the promotion piece:

- Queen: A1
- Rook: B2
- Bishop: C3
- Knight: D4

If you do not enter a specific promotion piece, a queen will be selected automatically. Imagine that there is a black pawn on c2 and a white rook on d1. Black wants to take the rook and promote the pawn to a knight. Then the sequence is C3 B2 D4 A1 D4 ✔ .

If you have made a typo before pressing the ✔ key and want to correct it, press the ✖ key, which means "Cancel". You can start over entering your move.

The CT800 checks whether an entered move conforms to the chess rules and will refuse invalid moves.

After you have entered a valid move, the coordinate move notation will automatically be converted to a "pretty print" format. E.g. when starting the game with Ng1-f3, you enter

"g1f3", but the display will be "Ng1-f3". Captures will have "x" instead of "-" between the squares. If a move gives check, "+" will be appended. Mate is denoted with "#" instead of "+".

Note: the time only counts while the game screen is active. During any kind of dialogue, position viewer or menu access, the time counting stops.

Note: the CT800 will declare draw after 250 full moves. Most games do not take that long.

3.2 Computer moves

3.2.1 Move output

After entering your move, the CT800 will think about its answer move. While it is thinking, the display in its move line will be "...". When the CT800 has computed its move, it will replace the "..." by its computed move in "pretty print" format.

3.2.2 Quick replies

In time modes other than analysis mode (see chapter 5.5.1. Game mode), the CT800 may reply much faster than what you would expect from the time configuration. These quick replies shall save thinking time for the CT800 and keep opponents from using the CT800's thinking time (pondering) when the move is obvious or forced. Quick replies are triggered if any of the following conditions is true:

- the CT800 has an opening book move available, and the opening book is active (see chapter 5.3.4. Book).
- the CT800 has only one legal move.
- the CT800 has only one move that avoids being mated in the next move.
- the CT800 can mate.
- the CT800 cannot avoid being mated (will choose some random move).
- the CT800 has an obvious move in the middlegame.

The definition of an obvious move is that all the following conditions are true:
- the shallow sorting pre-search of 1 ply depth shows a score drop of at least 2 pawns between the best and second best move.
- the best move has been part of the principal variation in the previous turn, or the result is within a ± 0.5 pawn window of the evaluation from the turn before.

The ± 0.5 pawn window covers two aspects:

- If the CT800 seems to be winning a piece out of nowhere, the CT800 will assume

that a sacrifice may be going on, and that needs serious calculation. That is why the CT800 will not capture quickly if the opponent simply loses a piece by neglect.

- If the seemingly obvious move still makes the CT800 stand much worse than expected from the previous turn, then maybe the CT800 had already seen something better, e.g. a mating attack.

Independently from forced or obvious moves, the CT800 also takes a look at how much thinking time it has left for its move. If it has already used up more than 55 % of the allocated move time when starting the next search depth iteration, it will drop the next depth iteration because it would not be able to complete it anyway.

3.2.3 Status information

Towards the upper right corner of the display, there can be additional notifiers when the CT800 announces its move:

- "b"   : The CT800 took this move from its opening book.

- "+"   : The CT800 thinks it is up by at least 0.5 pawns.

- "-"   : The CT800 thinks it is down by at least 0.5 pawns:

- "++"   : The CT800 thinks it is up by at least 3.0 pawns, which is a decisive advantage.

- "--"   : The CT800 thinks it is down by at least 3.0 pawns, so it is likely to lose the game.

- "+m"   : The CT800 sees a forced mate and will win.

- "-m"   : The CT800 sees that it can be mated.

3.2.4 Resign

The CT800 resigns if it is down by more than 9.5 pawns. It will do so using a dialogue box. You can either confirm the capitulation with ✔ or decline it with ✖ if you want to play until mate. In the latter case, the CT800 will not resign any more in this game.

3.3 Changing sides

If it is your turn and you want the computer to continue in your place, press the ⬚ key. The computer will start thinking immediately. In "game-in" and "tournament" time control modes, the remaining thinking time usually stays with the colour, not with the player. The exception is the first move of the game.

3.4 Cancel computing

If the CT800 is thinking, you can interrupt the calculations and force it to move immediately by pressing the ⬚ key.

3.5 Undo

If it is your turn and you want to undo a move, press the ◀ key. You can only undo a full move, not a single ply. Possible time bookings will be undone, too. If there is nothing to undo, the red "error" LED will blink.

3.6 Redo

If it is your turn and you want to redo a move you have undone using the "undo" functionality, press the ▶ key. You can only redo a full move, not a single ply. Possible time bookings will be redone, too. If there is nothing to redo, the red "error" LED will blink.

3.7 Position display

If it is your turn and you want to check the position on the board, you can press the ⬛ key. A position display will show up where the upper and lower half of the board will be displayed side by side.

Pressing that key again will flip the board. Pressing it once more will display the material list which shows the rough difference in material, counted in pawns. The pawn scoring is queen=9, rook=5, bishop=3, knight=3 and pawn=1.

Press the ✔ or the ✖ key to switch back to the game screen.

3.8 Game info

When it is your turn to move, you can press the ⓘ key to open a dialogue box with some game information. You will get the evaluation of the position in pawns and the computing depth in plies. In case the selective search is deeper than the main depth, the depth display will be "*x* / *y*". x indicates the main depth, and *y* the selective depth.

If a principal variation is available, pressing the ✔ key will display it. The output format, however, will not be the "pretty print" format, but the from-to notation.

During the computer's turn, the ⓘ key toggles between the game screen with the move list and live search information. The output mode will also be remembered for following computer turns. This feature is not available for analysis and mate search, see chapter 5.5.1. Game mode.

The live search information displays the following data:

- **IN** for live information mode.
- move number of the ongoing game.
- **E:** evaluation of the position in pawns, or mate.
- principal variation with up to eight plies (in from-to notation).
- **D:** current depth (main iteration).
- **M:** root move currently being examined.
- thinking time for this move.

3.9 Display light

You can switch on the display backlight using the ☼ key. This will override the configured light settings for 30 seconds. However, the backlight is disabled when the batteries are weak, see chapter 4.1. Battery info.

3.10 Auto-save

After every move, the game will be saved automatically unless you have a manually saved game, which blocks the auto-save. In case of power loss or immediate system shutdown due to failing batteries, you will be able to retrieve the last game status after the next power-on via the menu system, see chapter 5.3.1. Load game.

The CT800 is able to keep a saved game for about one week without being powered.

For power-on auto-save diagnostics, see also chapter 7.2. Auto-save info.

4 Dialogue system

At various points, interactive dialogue boxes can appear. The caption of the box will tell you what it is about, and at the bottom, the available options appear, selectable by different keys.

You confirm info dialogue boxes by pressing ✔ ("OK"). A selection dialogue can also be declined by pressing ✖ ("CL"). Sometimes, also the ⊞ position key may be offered ("POS").

4.1 Battery info

The most important unsolicited dialogue box refers to the battery status. The input voltage is monitored, and if the batteries become weak (at 1.06 V per cell), you will get the "weak batteries" warning.

It is recommended to change the batteries at this point. Assuming 50 % user time and 50 % computing time, the batteries will fail in about 20-30 minutes.

The display backlight and overclocking will be disabled, but otherwise, the system will run as usual. This warning, however, does not work during other dialogues or in menu mode.

If the voltage drops further (to 1.00 V per cell), keeping the system running for much longer would possibly damage the batteries by deep discharge. The CT800 will issue a "failing batteries" warning to inform you that it has to be switched off as to prevent damaging the batteries. This warning works at all times.

After confirming the "failing batteries" warning or after a timeout of 15 minutes, the display will be switched off. The red LED will flash to remind you of actually switching off the system. If the beeper is not configured to "off" (see chapter 5.6.6. Beep), there will be one click per second.

There is enough margin to actual deep discharge that the batteries will not suffer damage as long as you switch off the CT800 when it requests so. However, letting it run long-lastingly in flash/beep shutdown mode will finally damage the batteries.

When starting a new game, the CT800 checks the batteries. The CPU frequency is ramped up for maximum current draw. This load stress test takes about a second.

Upon switching on the device, the startup screen also includes running the battery test. However, when starting another new game, there is a waiting screen with a progress bar.

The acceptable minimum battery voltage (1.10 V per cell) is higher than during the game. If the batteries are unlikely to make it throughout the new game, the CT800 will require

changing the batteries beforehand as to avoid this hassle during the game.

If you put in one of the batteries in the wrong way, it will cancel out the voltage of another battery so that the measured cell voltage will be between 0.6 V and 0.75 V so that the device will immediately ask you to switch it off.

Note: the auto-save feature (see chapter 3.10. Auto-save) allows to change the batteries without losing the ongoing game.

4.2 Power-on self test

The CT800 checks itself after power-on, and if problems are found, a dialogue box will inform you. See chapter 7. Troubleshooting for details.

4.3 Game finished

When the game is finished, a dialogue box shows up telling the reason. You can just confirm it by ✔ , or you can press the ⬒ position key. The latter will show you the final position. Repeated ⬒ will flip the position and display the list of material. After confirming with ✔ or ✖ , the full game notation will appear. You can scroll through the notation with ◀ and ▶ . Quit the notation listing with ✔ or ✖ , and the CT800 will offer a new game.

Note: the CT800 will declare draw after 250 full moves. Most games do not take that long.

5 Menu system

The configuration of the CT800 is done via the menu system. You can access it by pressing the ≡ key if it is your turn. The main menu will open. It is organised as a menu tree, and you can select the different options by pressing the corresponding square keys. It is the file letter that counts. So if an option is offered as "a:", pressing the A1 key will select it.

Inside a selection option, use the ◀ and ▶ keys to change the option value.

For getting up one level, you can press the ✔ or the ✗ key. If you are at the top level already, that will leave the menu system.

If you want to leave the menu, press the ≡ key again. This does not only work at the top level, but from anywhere within the menu system.

In case you leave the menu system and have changed the configuration, a dialogue box will appear asking whether the changes should be saved, or whether you want this configuration just to be active for the ongoing game.

5.1 Menu tree

Here is an overview on the whole menu structure, starting at the main menu:

```
a: new game
b: file
      a: load
      b: save
      c: erase
      d: book
      e: reset
c: position
      a: view position
      b: enter position
      c: view notation
d: time
      a: mode
      b: details
      c: add-ons
            a: Fischer delay
            b: player bonus
            c: player factor
e: misc
      a: colour
      b: noise
      c: speed
      d: disp
      e: light
      f: beep
f: info
```

5.2 New game

Opens a confirmation dialogue box, and if you confirm, a new game will start as per the saved configuration settings.

5.3 File

This menu part contains the load / save features, controls the opening book and offers a device reset.

5.3.1 Load game

Loads the currently saved game from the backup memory. This part of the memory is buffered against loss of power for up to one week. There is only enough space for exactly one saved game.

If the previous game has been interrupted due to loss of power and power has returned, you can use this option to retrieve and continue the game since the auto-save feature has stored the game automatically. See also chapter 5.3.2. Save game.

5.3.2 Save game

Save the current game. This will disable the auto-save feature because a manually saved game has priority. See also chapter 5.3.3. Erase game. If you do not have a manually saved game, the auto-save will save the game after each ply.

Since the file operations do not use flash-memory, but battery buffered RAM, frequent write operations do not cause wear effects. There is no risk for long-term damage.

5.3.3 Erase game

Deletes the currently saved game, no matter whether it is an auto-save or manual one. As a side effect, this will enable auto-save again because after erasure, there is no manually saved game that would block the auto-save.

5.3.4 Book

Allows to turn the opening book off or on. With active opening book, the first few moves will be played instantly, choosing randomly among the stored moves. This leads to more variety in the games and saves time in games with time controls.

<u>Note</u>: in the initial position, the first white ply will be a book move even when the book is turned off. This is rooted in the time management which does not include this first white ply.

5.3.5 Reset

Resets the CT800 to factory settings and erases any saved game. Afterwards, the CT800 will restart.

The factory settings are as follows:

- Book: on.

- Time control mode: time per move.

- Time control details: 10 seconds per move.

- Fischer delay: off.

- Player bonus: 10 seconds.

- Player factor: ×1.

- Mate search depth: 4 moves.

- Colour: CT800 starts as black.

- Blur: off (no blurred evaluation).

- CPU Speed: 100 % (no overclocking).

- Disp: contrast is 50 %.

- Light: automatic.

- Beep: on (keyboard click and computer sounds).

5.4 Position

Here you can view the current board position or enter a new one, as well as display the game notation of the current game.

5.4.1 View position

Works just like the ◨ position key (see chapter [3.7. Position display](#)). It shows the current board position with upper and lower half of the board being displayed side by side. Pressing ◨ flips the board, and pressing it once more displays the list of material.

You can quit this position viewer by pressing ✔ or ✖ . If you press the ≡ key, you will leave the position viewer and the menu system altogether.

5.4.2 Enter position

Allows you to enter a position of your choice. You will be guided through the different pieces step by step. First the white pieces in the order of king, queens, rooks, bishops, knights and pawns, and then the black pieces in the same order.

Use ✔ to confirm the piece squares for the current piece type and move on to the next one. If you want to enter more than one piece of the same type, just enter the next square without pressing ✔ in between.

You can delete the last square of the current piece type by pressing ✖ .

If you enter a piece on a square that is already occupied by another entered piece, that other piece will be overwritten silently, with the exception of kings. Since a position without kings would be illegal, the kings' positions will be retained. If you try to overwrite a king's position when entering the opposite king's position, there will be a warning dialogue box because none of these two pieces can be discarded safely.

For moving back and forth through the pieces types, use ◀ and ▶ .

During entering, the CT800 keeps track of how many promoted pieces have been entered. E.g. if you enter three white rooks, then one of them must be a promoted piece. This means that you can only enter up to seven white pawns. This works also the other way around: if you have already entered eight white pawns, you cannot enter more than two white rooks.

If it is possible to enter at least one more piece of the current piece type, the last character of the enter line will be a comma. Otherwise, this will change to a dot. Since there can only

be one king of each colour, there will always be a dot after entering its position.

The CT800 will check the validity of the entered position; e.g. a position is not allowed when it has a king being in check, but the other side is to move.

After you have entered the pieces, the CT800 asks whose turn it is, white's or black's.

Based on that information, the CT800 determines whether there are potential "en passant" squares. If so, it allows for entering up to one "en passant" square, which is verified and accepted or rejected. Just pressing the ☑ key without entering an "en passant" square selects no "en passant" square. If the position does not allow any "en passant" squares, this step will be skipped.

If castling might be possible, the CT800 will ask for clarification on the castling rights; otherwise, this step will be skipped.

Finally, the position viewer allows to check the entered position. If you find a mistake and decline the following dialogue box, you will start at the position of the white king, but all the entered items are already listed. So you are not forced to enter everything again. Just scroll though the piece types using ◀ and ▶ and correct only the erroneous items.

Note: due to memory constraints, entered positions may not allow for more than 200 possible moves. This is more than enough for any even nearly realistic game situation.

Note: the opening book works also for entered positions, providing that the castling rights match. However, the special minor piece evaluation and the draw avoiding algorithm will not work. If you want to have the same game behaviour as in normal play, do not use the position editor and instead, enter the moves ply by ply. See chapter 5.6.1 Colour for details on how to do this.

5.4.3 View notation

You can scroll through the notation of the ongoing game by using ◀ and ▶ . You can quit this notation viewer by pressing ☑ or ✖ . If you press the ☰ key, you will leave the notation viewer and the menu system altogether.

5.5 Time

Here you can configure various time control options. "Game mode" and "Time details" are closely interrelated.

5.5.1 Game mode

Use the ◀ and ▶ keys to select a time control mode for the whole game.

Note: GMI and TRN modes are only available if the game starts from the initial position, not for entered positions.

Note: live search information via the the the ⓘ key is available in TPM, GMI and TRN modes, but not in AN and MTI modes. See also see chapter 3.8. Game info.

The following game modes are available:

- **TPM: time per move**. The CT800 will limit its thinking time for each move to this time (on average). There is no constraint on the user's thinking time in this mode.

- **GMI: game-in**. The total game time is limited for both sides. For the player factor (especially useful for computer vs. computer games), see also chapter 5.5.3. Add-on time.

- **TRN: tournament**. There are several tournament modes available.

- **AN: analysis**. Pressing the ↗ key will have the CT800 analyse moves for up to nine hours, or until it is interrupted using the ↗ key again.

  The **analysis mode** displays the following data:

  - **AN** for analysis mode.

  - move number of the ongoing game.

  - **E :** evaluation of the position in pawns, or mate.

  - principal variation with up to eight plies (in from-to notation).

  - **D :** current depth (main iteration).

  - **T :** time until the current first ply of the principal variation.

  - thinking time for this move.

Reaching a new search depth will switch on the display backlight for 30 seconds in automatic mode and yield a short beep if the beeper is configured to "on" or "computer".

- **MTI: mate-in**. Pressing the ⬚ key will have the CT800 look for a forced mate for up to 4 days, or until it is interrupted using the ⬚ key again. While the mate-in mode is active, the computer colour will always be set to "none".

  This way, you can manually enter the first move of the solution, then enter a move where you want to see how to continue and press the ⬚ key again.

  The **mate-in mode** displays the following data:

  - status (searching for mate).

  - `depth x:` the configured mate searching depth in moves.

  - the thinking time for the ongoing search.

  If a mate has been found, the mating depth will be announced.

  Pressing the ⬚ key will lead to the game notation screen that will display the main variant until mate. This is the same kind of screen described in chapter 5.4.3. View notation. You can exit this notation screen by pressing ⬚ or ⬚.

  A dialogue box will appear, offering to search for another solution move. Usually, mate problems should only have one initial move that solves the problem, but you can verify this. If you confirm, the CT800 will try to find a mate that does not involve the solution moves that have already been found. You may repeat this for as long as there are different solution moves.

  If no or no further solution move is found, a dialogue box will open telling that no moves have been found. This last search without finding a mate can take much longer than a successful search.

  Also a timeout will end the search, which will happen after 4 days if the CT800 could not complete the search tree. This timeout refers to each individual search; so when you decide to search for another solution, the 4 days timeout will start again.

  Note: the battery running time will not suffice for 4 days. Since the auto-save (see chapter 3.10. Auto-save) only works after making a move, it will not buffer ongoing calculations. For such lengthy computations, running on external power is required.

  Note: the CT800 does use its hash tables during mate search. Therefore, it will solve endgame mating puzzles faster than middlegame ones.

To give an impression of what the CT800 can do, here is a nice composition by Aron Nimzowitsch. The CT800 takes less than a second to solve this puzzle (non-overclocked at 168 MHz).

The re-search for other solution moves fails because there is only one. This re-search takes 1:14 minutes, which is an example of the re-search taking much longer.

As to avoid spoiling you, the solution is not listed right here, but on the last page of this document.

Mate in 7

(white to move)
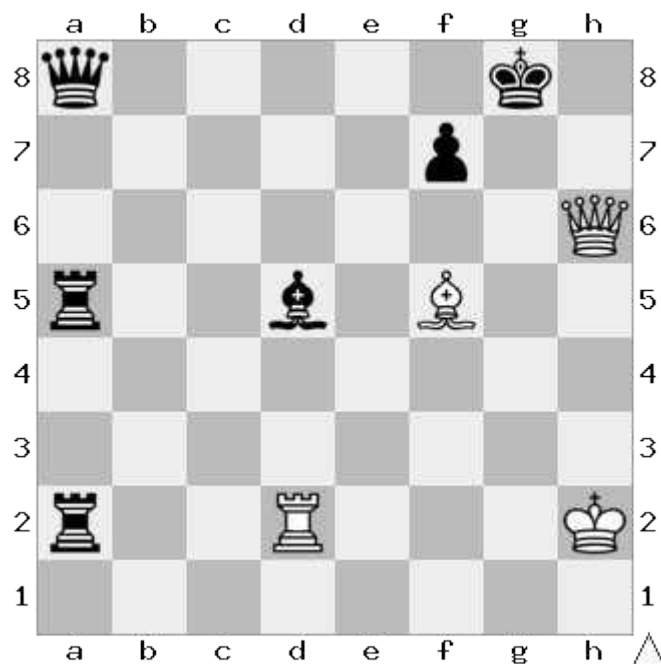
5.5.2 Time details

This option is context sensitive; what you will see here depends on what time control mode you have configured (see chapter 5.5.1 Game mode). So you first have to configure the mode, then the details.

Depending on the active time control mode, the following options are available:

- **time per move**: the average thinking time which the CT800 takes per move, in seconds: minimal, 5, 10, 20, 30, 60, 120, 180.

- **game-in**: the total game time for each player, in minutes: 5, 10, 15, 20, 30, 45, 90. For the player factor (especially useful for computer vs. computer games), see also chapter 5.5.3. Add-on time.

- **tournament**: the game time for each player given in moves in minutes plus minutes: 40/90+30, 40/120+30, 40/120+60, 40/120,20/60+30.

  For example, "40/120+30" means that each player must complete his first 40 moves within 120 minutes of his thinking time. After move 40, 30 minutes are added to the thinking time of each player having passed the time control. The full game may thus take up to 300 minutes (5 hours).

  "40/120,20/60+30" means that each player has to complete his first 40 moves within 120 minutes of his thinking time, in which case 60 minutes additional time are added. The next 20 moves must be completed by 180 minutes total time, in which case 30 minutes are added for the rest of the game. The full game may thus take up to 420 minutes (7 hours).

- **analysis**: always nine hours per move.

- **mate-in**: the maximum mate searching depth, which is 1 to 8 moves (not plies). The searching time is limited to 4 days.

5.5.3 Add-on time

There are different time add-ons available.

- **Fischer delay**: the side that has to make a move will receive a fixed time bonus. This prevents extreme time trouble. The available options are, in seconds: off, 10, 20, 30.

  Note: this option will only affect the "game-in" and the "tournament" time control modes.

- **Player bonus**: since operating the CT800 costs time that the user cannot use for chess-related thinking, the user can receive a bonus before each move. The available options are, in seconds: off, 10.

    Note: this option is independent of the Fischer delay. Both can be used together, in which case the CT800 will receive the Fischer delay while the user will receive both the Fischer delay and the player bonus.

    Note: this option will only affect the "game-in" and the "tournament" time control modes.

- **Player factor**: in time control mode "game-in", the user can configure a factor by which his thinking time is multiplied. So it is possible to have e.g. 15 minutes for the CT800 and 45 minutes for the user. The available options are: x1, x2, x3, x4.

    This is especially useful if you want the CT800 to play against another chess computer. Giving the other computer a x4 player factor means that the CT800 will only check its own time.

    This way, you can keep the CT800 from claiming victory on time and switching to "time per move mode" in case there is some additional operational delay with the other chess computer.

    Note: this option will only affect the "game-in" time control mode.

- **Game pause**: this is not directly a bonus and thus does not show in the menu system. However, there is another hint that might be useful for computer vs. computer games:

    When it is your turn, you easily can pause your thinking time. Just enter the menu system, or open the position viewer, or press the info key for viewing the current position evaluation.

5.6 Misc

There are several general configuration options available in this submenu.

5.6.1 Colour

Controls which colour the CT800 takes when starting a new game. The available options are: always white, always black, random, none.

If you preset "none", this means a play human vs. human. This is useful for entering a game. The difference to entering a position and continuing from thereon is that all game phase dependent features will also work when you enter the game move by move.

When you have reached a position from where the CT800 shall take over one of the sides, press ✄ to get the CT800 going.

5.6.2 Noise

The position evaluation can be blurred with random noise, in percent. 0 % sets no noise, i.e. full playing strength, while 100 % means mostly random moves. Besides, 30 % or more will disable selective deepening of checking moves.

This option allows to throttle the playing strength further than reducing the CPU speed (see chapter 5.6.3. Speed) alone can achieve.

Note: for reducing the playing strength of the CT800, it recommended to first reduce the CPU speed, and only if that is not enough, to add noise. The reason is that reducing the CPU speed does not influence the playing style while adding noise does.

Note: the noise setting does not affect the mate search mode, only normal play.

5.6.3 Speed

When the computer thinks in normal play or mate search, the clock can be configured so that the CPU frequency is different from the regular 168 MHz (i.e. 100 %), ranging from 10 % to 145 %. Overclocking decreases battery life while underclocking increases it.

If overclocking is selected, the CT800 will perform a firmware image check at overclocked speed. If the system should crash, then the overclocking obviously does not work. The worst case, however, is when the system does not crash, but produces wrong results. So the idea is to perform some calculations where the result is known beforehand. While this

is still not completely bulletproof, it is at least a serious indicator.

If the firmware check at overclocked speed fails, but without system crash, then there will be a dialogue box telling "O/C failed". In this case, the CT800 will deactivate the overclocking automatically and fall back to regular system speed (168 MHz). When overclocking is configured, this reliability check will also be performed before every computer move. This is so fast that it does not cause any noticeable slowdown.

If these firmware checks for overclocked operation pass, there will not be any user notifications.

Note (overclocking): clocks greater than 168 MHz are beyond the CPU's specification and not guaranteed to work. However, tests have shown that it will usually work fine. As to prevent "bricking" the device after power-on, overclocking will only be used if the user had had the possibility to access the menu for switching back to 100 % or lower.

Note (underclocking): in all modes except mate searching mode, the CT800 performs a sorting pre-search with 1 ply depth plus quiescence at the root position. Underclocking is only activated afterwards so that there is always a somewhat reasonable move, and the playing style remains the same. Defeating the CT800 is easier, but the win is not just handed over.

Note: for reducing the playing strength of the CT800, it recommended to first reduce the CPU speed, and only if that is not enough, to add noise. The reason is that reducing the CPU speed does not influence the playing style while adding noise does.

5.6.4 Disp

Sets the display contrast in steps of 10 %. Use the setting where you find you can read the display most conveniently. The available range is 0 % to 100 %.

5.6.5 Light

The display backlight costs energy, but can facilitate reading the display. There are three control modes: always off, automatic or always on. Automatic will switch on the display after user key activities or when the CT800 makes a move.

Note: the ☼ key on the front panel will always switch on the light for 30 seconds, even if the display backlight is configured to "always off".

5.6.6 Beep

The internal beeper can be set to four different modes: off, click, computer, on.

- "off" means silent operation.
- "click" will only have the keyboard click active.
- "computer" will the CT800 make announce its moves and activate error signals, but no keyboard click.
- "on" means combining the options "click" and "computer".

5.7 Info

Displays the version of the software and the author of the CT800.

6 Software update

In order to update the software of the CT800, you first need to generate a firmware image. Following the build instructions in the source directory will yield the firmware image as hex file (`ct800fw_crc.hex`). and as binary file (`ct800fw_crc.bin`). Alternatively, you can use the supplied firmware images.

The `.hex` file is recommended, but if your flashing toolchain does not support this, then you can also use the `.bin` file. In this case, you may have to configure the flash start address manually, it has to be `0x08000000`.

Ground yourself to prevent electrostatic discharge to the CT800. You may touch uncoated parts of your room heating. The uncoated parts of your PC's housing are suitable if they are attached to the earth conductor (does not work with laptops; check your wiring and wall power plugs).

Open the CPU port cover at the rear side. A SUBD-15 socket will appear. Use the JTAG-to-SUB15 adaptor (the right one in the picture on page 3) and put the SUBD-15 end of it into the CPU port socket.

Press the ✎ key until the CT800 is out of its opening book and calculates a move. If you try to program the CT800 while it is running idle, some flash tools may refuse to flash the software because they fail to stop the CPU running.

You can now use any JTAG programming adaptor with a suitable toolchain to reprogram the CT800. Under Windows, the CoFlash tool from the Coocox environment is suitable. Under Linux, that will be OpenOCD using the supplied configuration file `openocd.cfg` which is prepared for the Olimex ARM-USB-OCD-H programming adaptor.

Afterwards, the CT800 may boot up with an error message saying it has been reset via PIN, see also chapter 7.3. Reset diagnostics. This is a normal part of the flashing procedure and will only appear once.

Pay attention that no system fault "ROM" is diagnosed, see chapter 7.1. Power-on self test. If this error message appears, the programming has gone wrong and needs to be carried out again.

Remove the programming adaptor and close the CPU port cover as to avoid damage to the system e.g. by electrostatic discharge.

In case that the display seems not to work after a software update, see the troubleshooting chapter, chapter 7.5 General handling.

It is recommended to put the device to the default configuration after a software update. In the game screen, press the ☰ key, then B2, then E5, then ✔.

7 Troubleshooting

In case of problems with the CT800, there are several ways of diagnosis and possible remedy.

7.1 Power-on self test

During power-on, the CT800 checks some hardware functionalities that might fail. A dialogue box will tell about one or more system faults if any are detected:

- **ROM**: the checksum of the firmware is wrong, so stable operation is not guaranteed. Download the firmware image again and make sure that you use the one with appended checksum. Use the "verify after download" functionality of your programming adaptor. If the problem persists, the hardware is damaged and has to be replaced.

  Note: a side effect of a bad firmware checksum is that overclocking (see chapter 5.6.3. Speed) will not work any more. The CT800 uses a firmware check for verifying correct system operation when going overclocked, and if the checksum is bad to begin with, this system stability check will fail.

- **RAM**: the internal RAM test failed. The hardware is damaged and has to be replaced.

- **CLK**: the external quartz oscillator does not work. The system will still run nearly as normal, albeit with slightly less precise timing. At room temperature, a tolerance of about 30 seconds per hour can be expected. This is a hardware damage, and the quartz oscillator has probably been damaged during production.

- **KEY**: one or more keys are in "pressed" state. Either the user has been pressing a key during power-on, in which case there is no actual problem, or the hardware is damaged and has to be replaced since the keypad will not work.

7.2 Auto-save info

When switching on the system, the CT800 checks whether auto-save is possible. See also chapter 3.10. Auto-save.

If auto-save is disabled, an info dialogue box appears, telling that auto-save is off and manual save is active. The reason is that there is a manually saved game in the storage which blocks auto-saving. See also chapter 5.3.2. Save game.

There are several alternative options. You can:

- first load the saved game and then erase the backup area. Now you can continue the saved game with auto-save enabled.

- erase the backup area without loading the saved game. The saved game will be lost, but the new game will enjoy auto-save.

- continue with the new game without erasing the backup area. The saved game will be retained, but no auto-save will protect the new game from data loss in case of power outage.

"Erase" means using the menu system to erase the backup area where saved games are stored: *menu → file → erase*. See also chapter 5.3.3. Erase game.

Note: just starting a new game via *menu → new game* without erasing the saved game will start a new game, but with auto-save still being disabled. Using *menu → file → erase* is the way to re-enable the auto-save.


7.3 Reset diagnostics

When the CT800 starts, it analyses why it has been reset. A normal power-on or an intentional system reset (via *menu → file → reset*, see also chapter 5.3.5. Reset) will not trigger a message box. All other reset causes point to a problem and are reported:

- **WDG**: the internal watchdog has unintentionally reset the system. This points to a software problem – please file a bug report.

- **PIN**: the external reset pin has been triggered. This can happen during programming the CPU, depending on what the programming adaptor does. Otherwise, this points to a hardware problem with the board.

- **SWR**: software reset request. Should not happen because the software does not use this feature. An intentional system reset is being done via the watchdog along with storing the information that the watchdog has purposely reset the system.

7.4 System crash

Should the system crash, a dialogue box will open. The faulting program address will appear along with a fault code, and both are very important pieces of information. Please file a bug report.

7.5 General handling

- The CT800 does not run: check that it has power. If it is powered externally, the main switch must be in position "1". If it shall run on batteries, the main switch must be in position "2", and charged batteries must be in the battery holder.

- There is a waiting screen before a new game: this is the normal battery load stress test, see chapter 4.1. Battery info.

- The display backlight does not work even when pressing the ☀ key: the batteries are weak, change them.

- The CT800 announces weak batteries: change them. Assuming 50 % user time and 50 % computing time, the batteries will fail in about 20-30 minutes.

- The CT800 announces failing batteries: switch the main switch to position "1" and change the batteries. Otherwise, the batteries might suffer damage.

- The CT800 just has the red LED blinking once per second, and if the beeper is configured as active, it is clicking once per second: see the previous point, the batteries are failing. The announcement has been displayed for 15 minutes before timing out.

- The CT800 refuses an input move: check the board position using the ◨ key. Probably, there has been an error in transferring the moves to an external chess board, maybe already some moves ago.

- After startup, the green and the red LEDs light up as usually, but the display does not work: in rare cases, that might happen after a software update. Press ✔ three times for bypassing possible dialogue boxes. Then press the ☰ key, then B2, then E5, then ✔. This sequence will restore the default configuration.

7.6 Software update

- The software update fails because the flash program cannot stop the CPU. There are three ways to solve this problem:

  a) right before flashing the software, press the ✎ key until the CT800 is out of its opening book and is calculating a move. Start the flash programming before the calculation is finished.

     OR

  b) start the flash process within one second after attaching the programming adaptor so that the CT800 is still in the boot sequence.

     OR

  c) first erase the chip content in one step, then start the programming as second step.

Final note: the solution to the mate problem by Aron Nimzowitsch is as follows:

```
1.Bh7+   Kh8          5.Bg6+   Kg8
2.Bc2    Kg8          6.Qh7+   Kf8
3.Rg2+   Bxg2         7.Qxf7#
4.Bh7+   Kh8
```