

DO-178

Heart rate monitor



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System requirements

This study will describe the certification process of a heart rate monitor like those found in hospitals. This monitor will be made using a STM32F429 with an LCD screen and a MAX30100 heartbeat sensor.



This project's goal is to display some data collected from the heartbeat sensor on the STM32F4's LCD screen.

Software requirement data

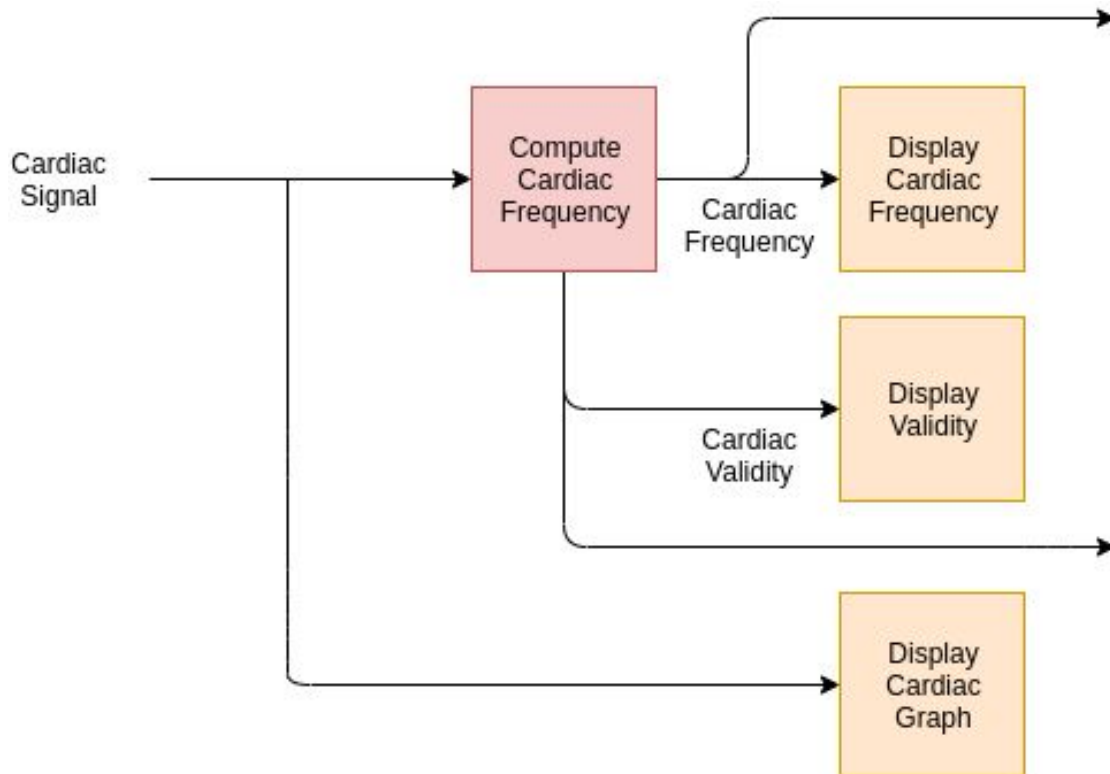
Traceability methodology

To obtain the requirements we started by deducing high level requirements (HLR) from the software's system level requirements. From those high level requirements we stated the low level requirements (LLR) and the verification tests.

High Level Requirements (HLR)

- HLR.1: The cardiac frequency needs to be computed using the sensor's signal.
- HLR.2: The frequency needs to be computed in less than a second.
- HLR.3: The cardiac frequency needs to be displayed on the monitor at all times.
- HLR.4: The electrocardiogram needs to be displayed on the monitor at all times.
- HLR.5: The LED needs to blink.
- HLR.6: Cardiac Validity shows if the computed heartbeat is valid or not.
- HLR.7: Display a message when the computed heartbeat is invalid.
- HLR.8: The data displayed needs to be at most a second old.

Software architecture



Low Level Requirements (LLR)

- LLR.1.1: Cardiac Frequency's value needs to be 0 by default (disconnected or dead).
- LLR.1.2: Cardiac Frequency is computed by getting the time between 2 QRS (ventricular depolarization).
- LLR.2.1: Cardiac Frequency needs to be computed at least once per second.
- LLR.3.1: The Cardiac Frequency needs to be displayed.
- LLR.4.1: The Cardiac Graph needs to be displayed no matter the Cardiac Signal.
- LLR.4.2: The sensor's data needs to be updated every 50ms.
- LLR.5.1: The LED needs to be off if Cardiac Validity is False.
- LLR.5.2: The LED blinks for each heartbeat in the Cardiac Signal.
- LLR.6.1: Cardiac Validity needs to be True if Cardiac Signal is valid (between 60 and 200 bpm).
- LLR.6.2: If Cardiac Validity is False, the frequency is null or invalid.
- LLR.7.1: If Cardiac Validity is False, a message needs to be displayed.
- LLR.8.1: The screen needs to be updated at least once every second.

Verification process

Traceability methodology

Software verification test cases

HLR

- TC.1.1: Check that the Cardiac Frequency is coherent and adapted to the sensor's output.
- TC.2.1: Check that the Cardiac Frequency is often updated (1s).
- TC.3.1: Check that the display is always on.
- TC.4.1: Check that the graph is always displayed.
- TC.4.2: Check that the graph is updated at least every 500ms.
- TC.5.1: Check that the LED blinks at the same time as the heartbeat.
- TC 7.1: Check that when the sensor's output is invalid, Cardiac Validity is false.
- TC.8.1: Check that the displayed data is updated at least every 500 ms.

LLR

- TC.1.1.1: Check that the Cardiac Frequency's default is not displayed when the Cardiac Signal is invalid.
- TC.1.2.1: Check that Cardiac Frequency is computed by getting the time between 2 QRS.
- TC.2.1.1: Check that Cardiac Frequency is computed at least once per second.
- TC.3.1.1: Check that the Cardiac Frequency is displayed.
- TC.4.1.1: Check that the Cardiac Graph is displayed no matter the Cardiac Signal.
- TC.5.1.1: Check that the LED is off when Cardiac Validity is False.
- TC.5.2.1: Check that the LED blinks for each heartbeat in the Cardiac Signal.
- TC.6.1.1: Check that the Cardiac Validity is True if Cardiac Signal is valid.
- TC.6.1.2: Check that when Cardiac Validity is False, the frequency is null or invalid.
- TC.7.1.1: Check that when Cardiac Validity is False, a message is displayed.
- TC.7.1.2: Check that when Cardiac Signal is valid, the message is not displayed.
- TC.8.1.1: Check that the screen is refreshing every 500 ms.

Test procedure for HLR and LLR

HLR

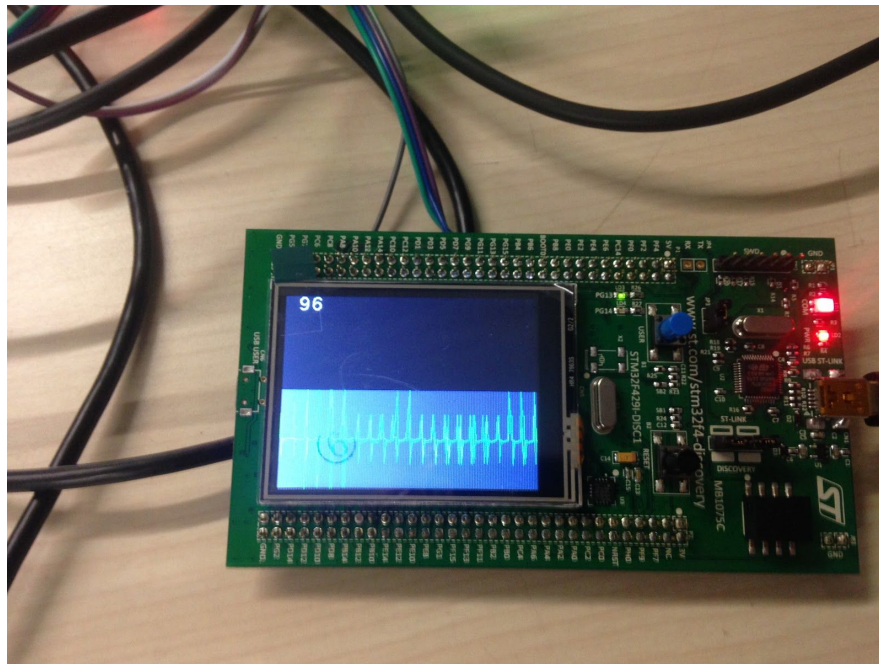
- TC.1.1: We alternate putting a thumb on and off the heartbeat sensor to send incoherent heartbeat signals and check that the incoherence is detected.
- TC.2.1: We compute and display the BPM update frequency to see if the BPM is updated at least every second.
- TC.3.1: We look at the screen to check that it is always on.
- TC.4.1: We look at the screen while changing the sensor's input.
- TC.4.2: We compute the frequency of the calls of the function that display the graph.
- TC.7.1: We check that the message "Invalid BPM" is displayed on the screen when the cardiac frequency is incorrect.
- TC.8.1: We compute the frequency of the loop which is refreshing the screen.

LLR

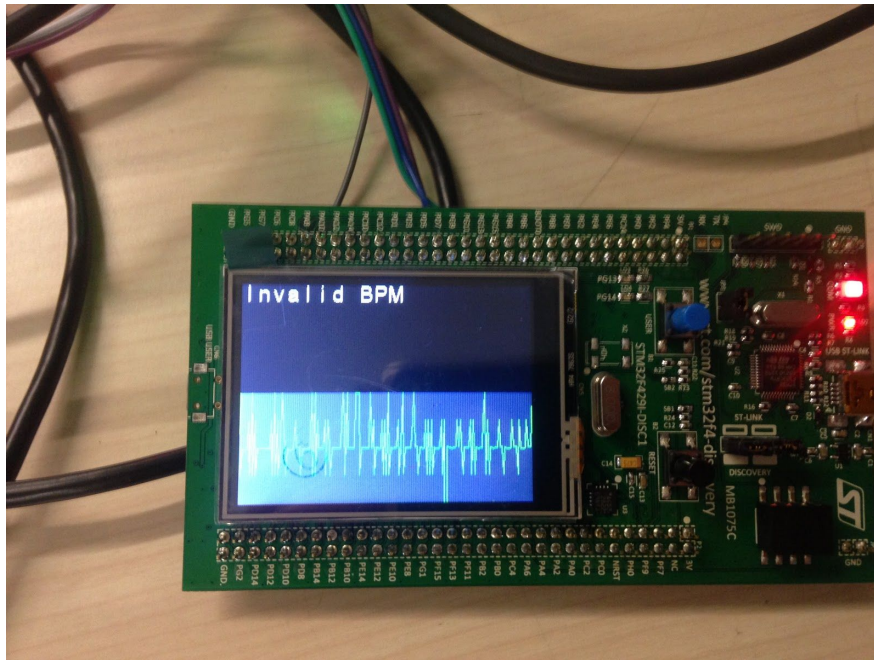
- TC.1.1.1: We look at the screen which displays an error message instead of the Cardiac Frequency's value.
- TC.1.2.1: We use a code snippet which gets the sensor's output, identifies heartbeats and then computes the time between 2 heartbeats.
- TC.2.1.1: We display the computation frequency when debugging.
- TC.3.1.1: By looking at the screen we can see that the Cardiac Frequency is displayed in the upper-left corner.
- TC.4.1.1: By looking at the screen we can see that the graph is always displayed regardless of the Cardiac Validity.
- TC.5.1.1: We see that the led is off while the error message is shown.
- TC.5.2.1: We look at the led blinking rhythmically.
- TC.6.1.1: By looking at the screen we can see the signals validity. If the message does not appear, Cardiac Validity is True.
- TC.6.1.2: By looking at the screen we can see the signals validity. If the message appears Cardiac Validity is False.
- TC.7.1.1: We check that the message appears if Cardiac Validity is False.
- TC.7.1.2: We check that the message does not appear if Cardiac Validity is True.
- TC.8.1.1: We compute the screen's refresh rate.

Tests results

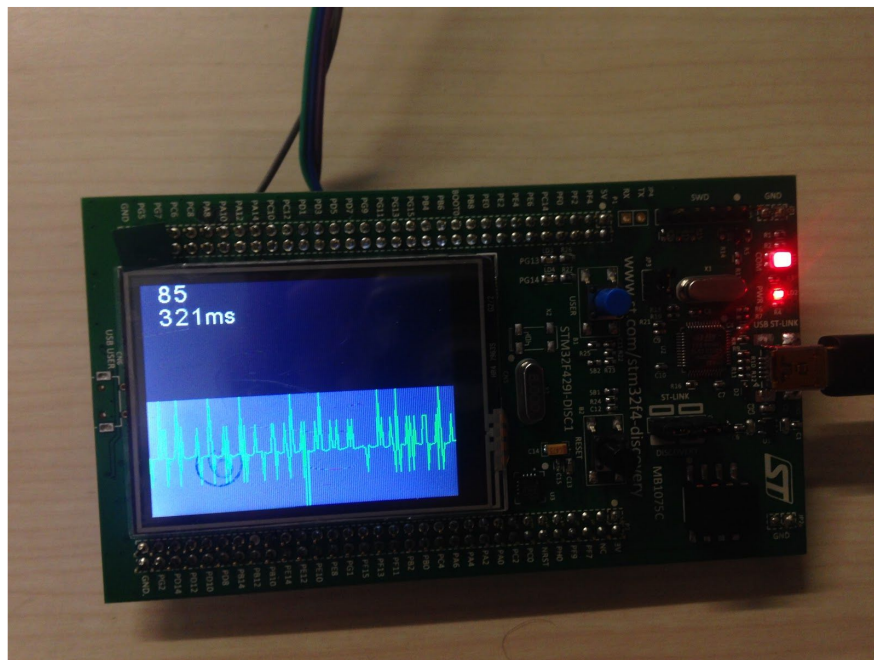
The tests results were mostly successful, the only issue found was a lack of precision from the heartbeat sensor.



Basic case: Valid BPM, LED is blinking and the graph is drawn.



Error case 1: Invalid BPM (error message shown), LED is off, and graph is drawn



Normal Case (Debug mode): Valid BPM, screen refresh rate shown, LED is blinking and the graph is drawn.