EMISY PROJECT

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Microprocessor system

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Declaration:

I declare that this piece of work, which is the basis for recognition of achieving and learning outcomes in the Microprocessors Systems (EMISY) course was completed on my own.

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LED display based clock, with calendar, alarm and DCF77 clock signal synchronization

Task Description:

- *The task is to design a LED display based clock, utilizing the external DCF77 radio clock signal for synchronization.*
- *Device should display the time and the date on a single four digit seven segment LED display.*
- *Student has to design the analog circuit for the displays, the circuit for reading the DCF signal, but also has to select the proper microcontroller.*
- *No external communication is needed.*
- *In case of lack of DCF signal, the device should be clocked with its own crystal resonator and adjusted with two micro switches, one for the time, one for the date.*

Project Critical Functions:

- Must include an alarm feature.
    - Requires a buzzer, and switches.
- Must use Intel 8051 family based microcontroller.
- Must display time and date on a single four digit seven segment LED display.
    - **In my project, four single-digit-seven-segment LED displays will be used instead.**
    - Requires analog circuit design for the displays.
- Must utilize DCF77 radio clock signal for synchronization.
    - Requires analog circuit design for reading the DCF signal.
    - In case of lack of DCF signal, the device should be clocked with its own crystal resonator, adjusted with two micro switches.

Hardware Interfaces Requirements analysis:

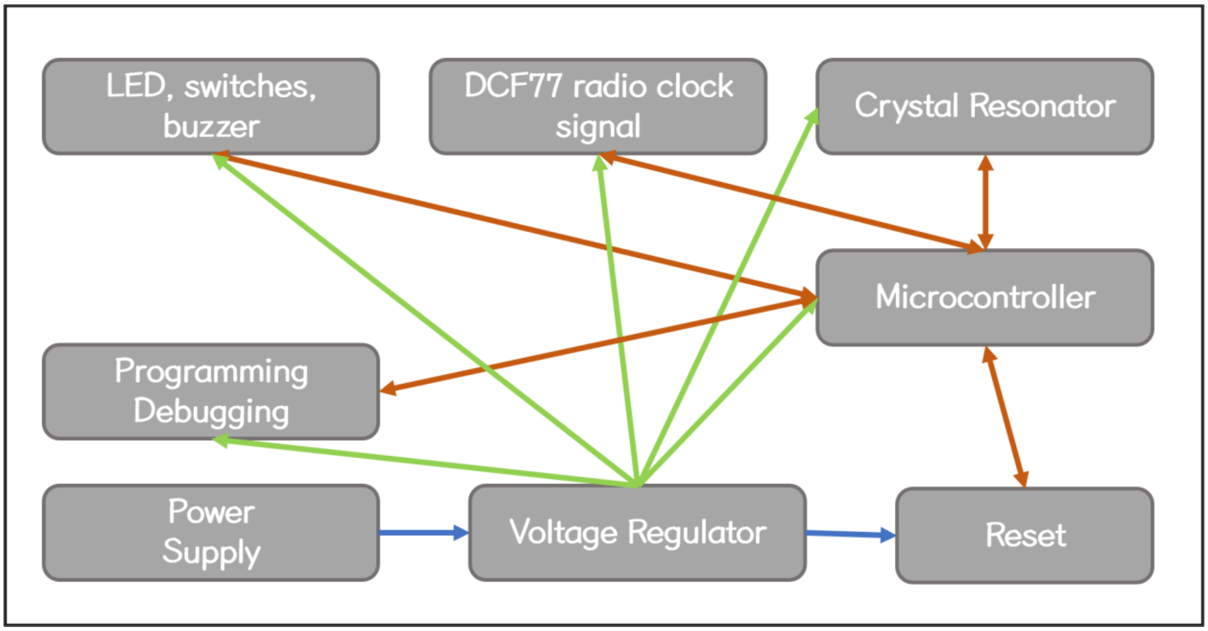
Block diagram of a microprocessor system mainly consists of 6 blocks, which are:
Power supply, reset, clock, microcontroller, external peripherals, communication, program debugging, and communication blocks.
Meanwhile, external communication, programming debugging are not required in the project.
The main requirements for each block of peripherals is discussed below.

1. **Power supply:** since no requirement for the usage of power supply is indicated in the task description, a source of an appropriate voltage level, above the usage throughout the system should be selected.
    a. The choice of power supply is flexible, 12V DC switching power supply (switching power supply: high noise & high efficiency) can be used as this is a common voltage input level for such device. This shall later be scaled down to fit the MCU and the other peripherals.
    b. Voltage regulator should be used for converting the supplied voltage to fit the operating voltage of the system.
        i. A switching voltage regulator can be used here, as it is highly efficient.
2. **Microcontroller:** microcontroller for this project should be one belonging to the Intel 8051 family. The power constraints for storing codes which handle the functionalities including setting up alarm, LED display on/off, interrupts and data handling should be considered.
3. **Program debugging:** this part is not a requirement in the project.
4. **Clock**: when the signal isn't available, the internal crystal resonator adjusted with 2 micro switches should work instead.
    a. This means that microcontroller circuit still requires some kind of clock oscillator to be able to work. Typical crystal resonator based circuit with 4MHz frequency may work.
    b. In the meantime, many of the modern microcontrollers have built-in clock inside the device.
5. **Communication:** DCF77 radio clock signal
    a. This is a German longwave time signal and standard-frequency radio station operating at 77.5kHz frequency.
    b. The signal can be received within a range of around 2,000km away from the transmitter.
    c. For reading the DCF77 radio clock signal, a peripheral circuit, which can process the information should be used. Radio time receiving modules will be suitable.
6. **Reset:** this peripheral forces the system to stay in the predefined state, bringing the registers in microcontroller's to their default state.
    a. The same case as it was for clock; many modern microcontrollers have built-in reset circuit inside.
7. **External Peripherals:**
    a. LED in common anode/common cathode connection.
        i. Connection of 4 symbols to the device, which requires a multiplexing scheme.
        ii. Connection of devices using current switches for the common anodes and cathodes.
    b. Buzzer is needed for alarm to ring.
    c. Switches (2 switches must be enough.)
        i. Micro Switches for internal oscillator – used as GPIO input source, and should allow for manual tuning the time, if for instance the DCF77 signal is lost or weak
        ii. Can detect two buttons pushing at once, or holding a button for some time. We will need 2 buttons.

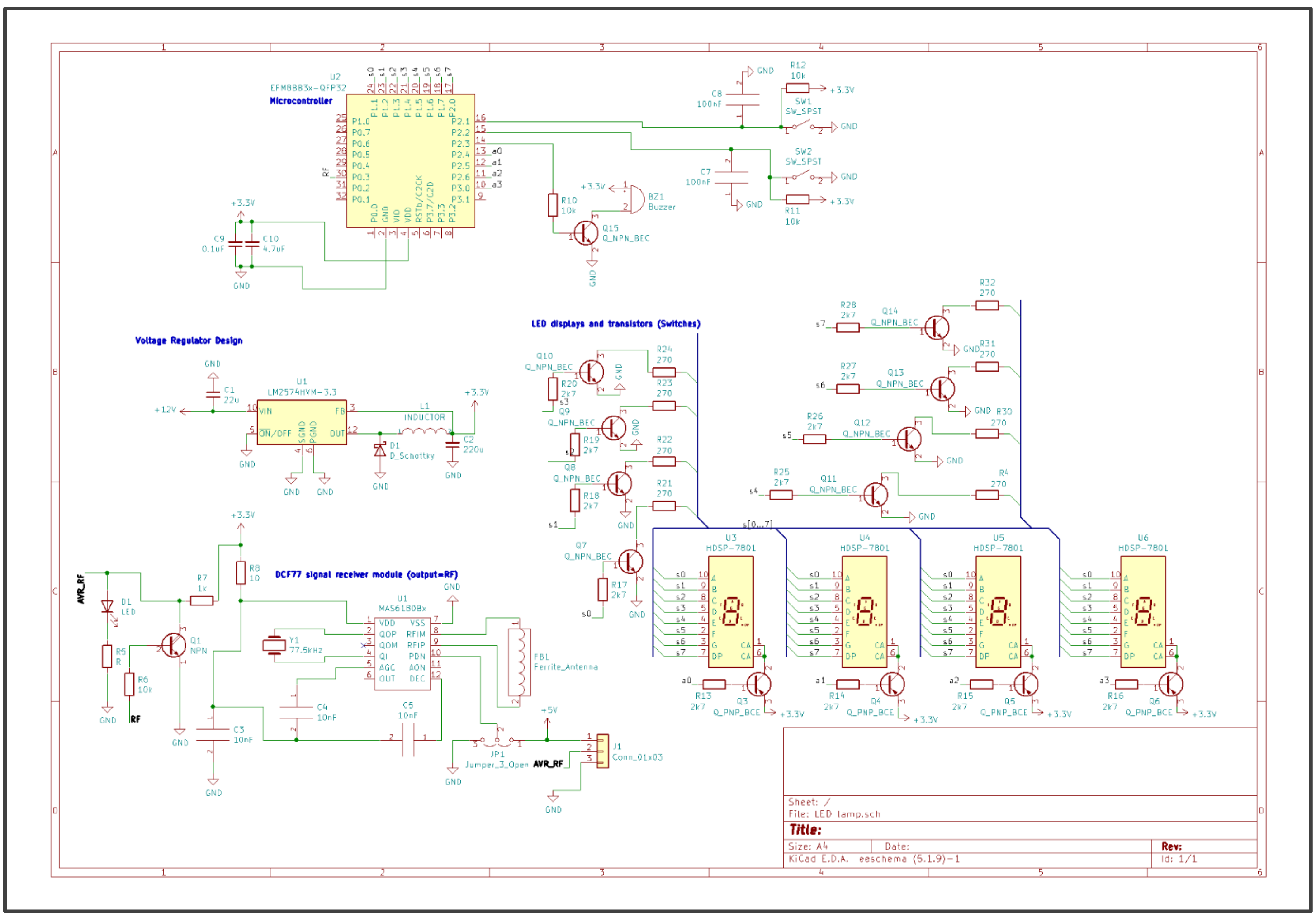
Summary of the Required Components:

In this project, a power supply with a voltage regulator, a 8051 microcontroller, a 4-digit LED display, program debugging connectors, a DCF77 radio signal with a circuit to drive it, a clock circuit with a crystal resonator, a reset circuit, a buzzer, and 2 switches should be used.

Block diagram:

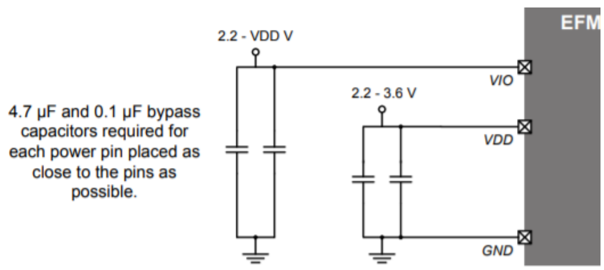


Schema:



Explanation on the Selection of Devices:

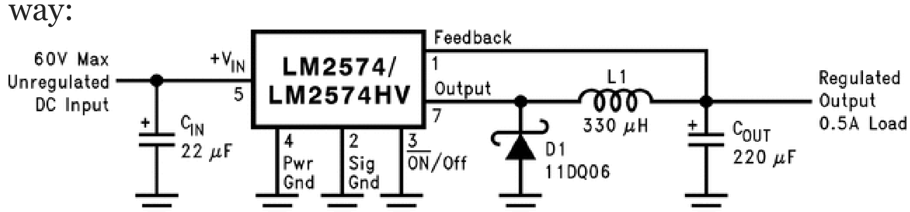
1. **Microcontroller** – a microcontroller with at least 8 kB of internal FLASH memory was recommended. I decided to choose one from the EFM series.
    a. **EFM8BB31F32G-D-QSOP24R** was finally chosen. This product, manufactured by ***Silicon Labs,*** is currently available on the market. It has 32kB internal Flash Program Memory. Therefore, the system will be safe from running out of memory.
    b. Symbol can be found in the KiCAD library.
        i. For the VDD & GND pin connection, the following diagram from the datasheet was used as a reference.



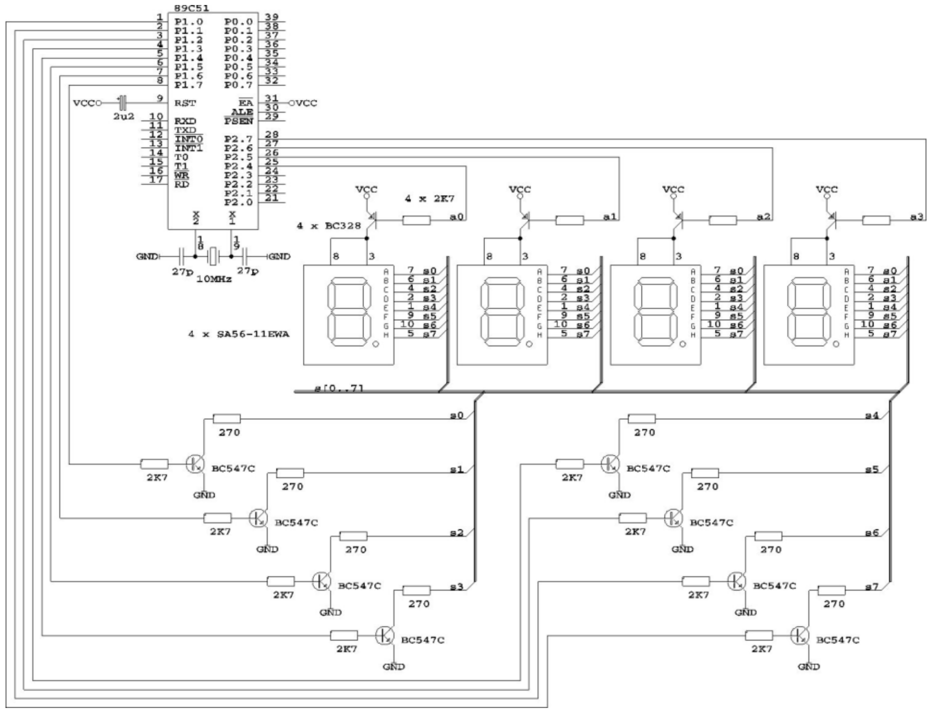
    c. Typically operated at 3.3V and 5mA current.

Operating Supply Voltage on VDD	V_{DD}		2.2	—	3.6	V
Normal Mode-Full speed with code executing from flash	I_{DD}	F_{SYSCLK} = 49 MHz (HFOSC1)[2]	—	5	14.4	mA

2. **Power supply** – a 12V DC switching power supply should be ideal. Since it differs from the supply voltage for the microcontroller, one voltage level is required throughout the circuit, and one voltage regulator is required.
    a. A power supply from the PCA series **PCA1500F-12** can be used. However in the schema, a generic VCC symbol in the default KiCAD library will be used instead.
        i. This is currently available for purchase from the manufacturer.
    b. A switching voltage regulator **LM2574HV** will be used. This device has fixed outputs, and supports 3.3V as one of the output voltages, which means there is no problem using this device in this project. This is currently available for purchase from the manufacturer. According to the datasheet, the converter can be designed in a following way:

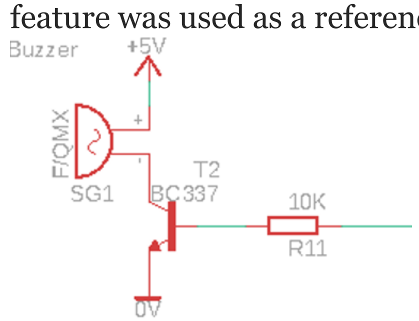


3. **LED display** – Colorless LED display will be used in the project. **HDSP** series – 7 digit single segment display was finally selected. This was found available in the market, and a symbol is also present in the default KiCAD library.
    a. For the connection of the displays, a diagram presented during the lecture was used as a reference.

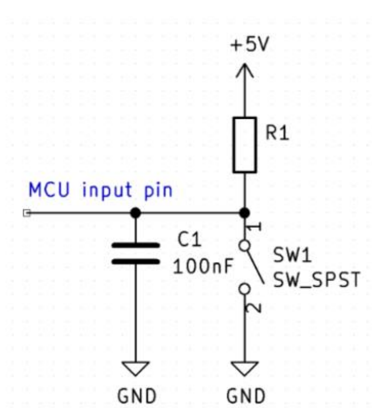


b. This uses multiplexing scheme.
c. Current switches are used for the common anodes and cathodes here.
d. The switches on the lower left handle the anodes.
    i. When these are on, a particular display is enabled.
e. The lower right ones handle the cathodes.
    i. When these are also on, certain segments out of 7 segments can be selected.

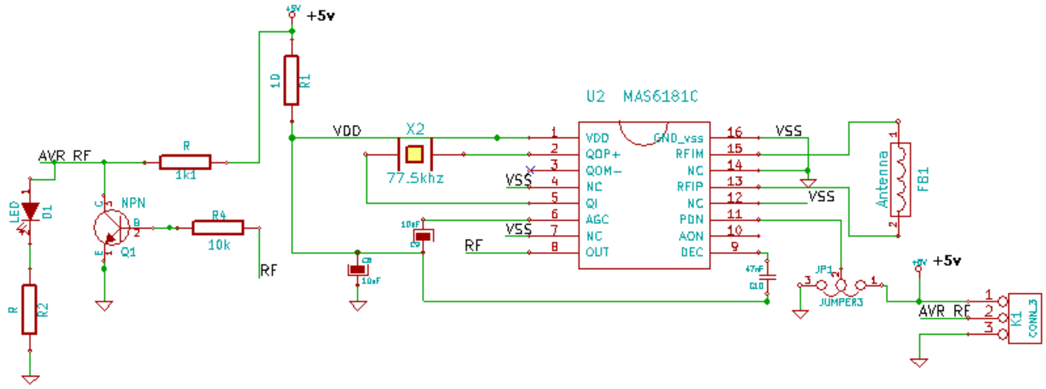
4. **Buzzer** – A symbol in the KiCAD library will be used.
    a. For buzzer, one circuit diagram used in similar clock system that also has an alarm feature was used as a reference



5. **Switches** – These enable the user to modify the displayed data. The circuit was designed in a way that involves debouncing.



6. **Radio time receiving module** – <u>**MAS6180**</u> will be used for receiving the DCF77 signal. This can be purchased on local markets. It requires an additional circuitry to process the signal, the design of which could be found on internet.



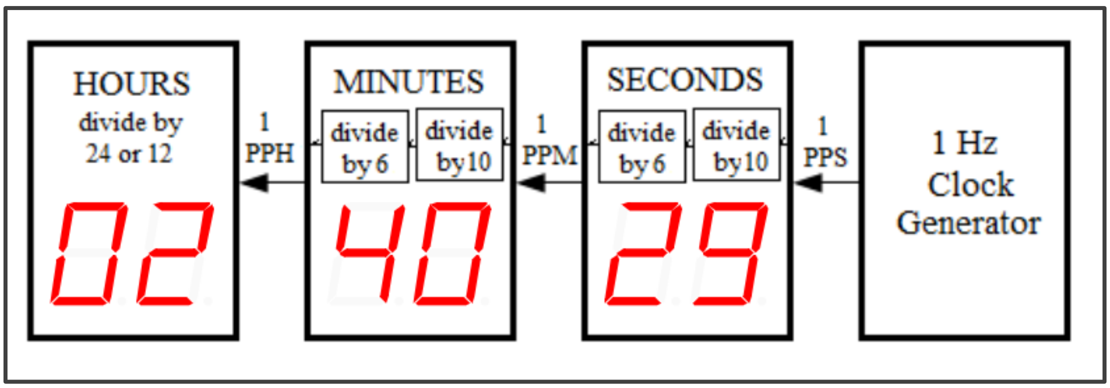
a. The 'MAS6180' and a 'Ferrite Antenna' symbols do not exist in the default KiCAD libraries, and thus had to be created via the symbol editor.

<u>Detailed System Performance Description:</u>

1. Power on/off:
   This clock is supposed to be powered by an external power source, that ideally should power the clock all the time. When power runs out, the device will turn off.
2. Data handling/display
   a. For this project, it was decided that 4 digits 7 segment LED displays will be used.
   b. Daily time display will use 24H formatting.
   c. LED device uses BCD coding system.
   d. Internal oscillator, and DCF77 radio clock signals will provide the information on time to the display, with DCF77 signal taking higher priority in sending data.
   e. Due to the device having 4 digit display, only the hour and minute data will be displayed.
3. Switch modes:
   There will be 2 external switches that toggle between 3 modes, which are: current time mode (displays hour and minute), calendar mode (displays date), and alarm setup mode (displays user input hour and minute for the alarm call).
   - This section is responsible for the 'Manual change in data' part in the algorithm.
   - Default view: [hour : minute] format.
   - 1st button: Switching modes
     - First press: switches to the calendar view; [month : date] format.
       - Default: blinks date (incrementation possible).
       - Second press: blinks month (incrementation possible).
     - Third press: switches to the alarm setup view; [hour : minute] format.
       - Default: blinks minutes (incrementation possible).
       - Fourth press: blinks hours (incrementation possible).
     - Fifth press: back to the default view
   - 2nd button: Incrementation
     - Short press while alarm ringing: turns off the alarm bell.
     - Short press in the default mode: switches off the alarm feature.

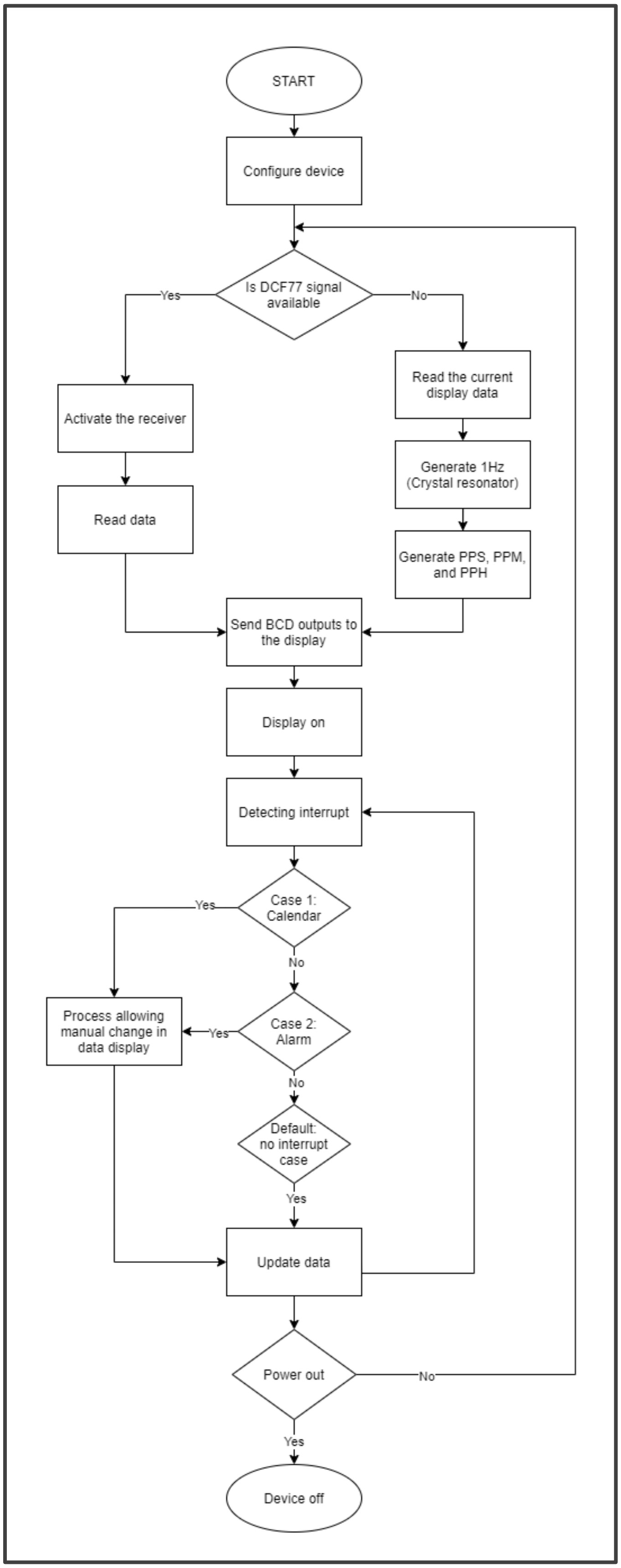
        - Long press in the default mode: displays the alarm time setup while the button is pressed.

4. Clock signal synchronization
    a. DCF77 radio clock signal receiver.
        i. It is a highly sensitive device, designed to receive time signals in the frequency range between 40 kHz to 100 kHz. The output signal can be processed directly by an additional digital circuitry to extract the data from the received signal.
        ii. The ferrite antenna converts the transmitted radio wave into a voltage signal. It has recommended antenna impedance at resonance of around 100kOhm.
        iii. Before power up, the device should have been kept in power down state at least 50ms.
    b. Internal oscillator
        i. The EFM8BB3 microcontroller used in this project consists of internal oscillator at 24.5 MHz, 49 MHz, 80 kHz, and clock divider that allows dividing the selected clock source by 1, 2, 4, 8, 16, 32, 64, or 128.
        ii. Also, HFOSC0, and HFOSC1 include 1.5x pre-scalers for further flexibility in division.



        iii. As can be seen in the figure above, 1 Hz is the default reading for normal digital clock.
        iv. The algorithm for calculating the value for its number string can be described as follows:
            1. 1 Hz clock generator generates 1 PPS (pulse per second) signal, and sends to the SECONDS block
                a. SECONDS block – receives PPS from the 1Hz clock generator
                b. Contains a divide by 10 circuit followed by a divide by 6 circuit
                c. Generates 1 PPM -> sends to the MINUTES block
                d. BCD outputs sent to LED bus
            2. MINUTES block – receives PPM from the SECONDS clock
                a. Contains a divide by 10 circuit followed by a divide by 6 circuit
                b. Generates 1 PPH -> sends to the HOURS block
                c. BCD outputs sent to the LED bus
            3. HOURS block – depends on whether it’s 12H or 24H clock
                a. If 12H: divide by 12 -> counts from 0 to 11
                b. If 24H: divide by 24 -> counts from 0 to 23
                c. BCD outputs sent to the LED bus
            4. Date:
                a. It is supposed that the date will also change every 24h.

Block Diagram for the Algorithm:



Code Concept Description:

- When the device turns on, it first scans for the presence of the DCF77 signal. This detection must be done all the time, in order to prevent the clock from stop displaying the correct time information, and to quickly switch to using an internal oscillator in case the signal is unavailable.
- While clock data is being displayed, the system then should also be ready to detect any external interval (via switch), made by the user. This is done by different combinations of inputs as described in the detailed description above. Each mode has a follow up incrementation process handled with the incrementation button.
- After this interrupt handling stage is over, the system is then updated with the new manually modified data, and goes back to the normal clocking mode.
- Until the device runs out of power, meaning the whole system will be turned off, it consistently repeats the signal & interrupt detection, followed by updating of data.

References:

- https://www.banggood.com/Geekcreit-DIY-4-Digit-LED-Electronic-Clock-Kit-Temperature-Light-Control-Version-p-972289.html?cur_warehouse=CN&ID=528743&rmmds=buy
- http://electronics-course.com/digital-clock
- http://www.electroniccircuitsdesign.com/radio-circuits/dcf77-module-circuit-using-mas6180c1.html
- https://blog.devgenius.io/dcf77-time-sync-how-does-it-work-d4fb4dbe9941
- https://pl.mouser.com/datasheet/2/368/efm8bb3_datasheet-1666228.pdf
- https://en.wikipedia.org/wiki/DCF77
- https://www.compuphase.com/mp3/h0420_timecode.htm
- https://pl.mouser.com/datasheet/2/368/efm8bb3_datasheet-1666228.pdf
- https://download.kamami.pl/p565261-p562522-da6180B.pdf
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- https://www.ti.com/lit/ds/snvs104f/snvs104f.pdf?ts=1622283315623&ref_url=https%253A%252F%252Fwww.google.com%252F
- https://www.eevblog.com/forum/projects/oscillator-for-discrete-digital-clock/