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# **open source watch Documentation**

***Release 1.1.0***

**jj**

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## COPYRIGHT

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### 1.2 LICENSE:

All the software is subject to the Apache 2.0 license (same as the Zephyr RTOS)



## ZEPHYR SMARTWATCH FRAMEWORK

this document started off **in** setting up zephyr RTOS on the PineTime smartwatch.

<https://wiki.pine64.org/index.php/PineTime>

It evolved to accomodate other nordic nrf52832 based watches (Desay D6....) **and** a **Virtual watch** (native\_posix\_64)

the approach **in** this manual **is** to get quick results :

- minimal effort install
- **try** out the samples
- inspire you to modify **and** enhance

**suggestion :**

- follow the installation instructions
- try some examples
- try out bluetooth
- try out the display





## INSTALL ZEPHYR

### 3.1 update on 31-12-2020

Pinetime has become part of the standard zephyr distribution! This manual was initially created with Pinetime as an external application. As from today you can install zephyr and execute a pinetime sample!

In addition the /app directory can be copied under same directory as the /zephyr directory. It contains extra board definitions and updated basic samples, and(!) the opensource smartwatch framework.

However the drivers for the Heartrate sensor, the acceleration sensor and touch screen are not - yet - part of the standard zephyr-distribution. These drivers are work in progress.

```
west build -p -b pinetime_devkit0 samples/boards/pine64_pinetime
```

A second and important sample is provided. Zephyr and the LVGL graphics library play together, using the touchscreen. The standard Focaltech touchscreen driver has been adapted slightly, as well as the board definition files. To get the sample up and running copy both the adapted board definition files and touchscreen driver, replacing the standard zephyr ones.

```
west build -p -b pinetime_devkit0 samples/display/lvgl
```

The focaltech touchscreen driver is more recent/better than the cst816s touchscreendriver. Still, there is room for improvement (slide events .....

The battery driver was provided as a module and is not working yet.

The acceleration sensor bma421 driver is working, and work has been done to distill a stepcounter out of it.

The heartrate sensor hrs3300, could work, but is kind of useless without a proper algorithm (open source) to distill a heartbeat out of it. You can still play around with it's capabilities as a lightsensor / led device.

### 3.2 In case you already have zephyr installed:

Pinetime works as external (out of tree) application. You can clone pinetime next to zephyr in the working directory and update manifest and west.

```
west config manifest.path pinetime
```

### 3.3 In case you start from scratch :

[https://docs.zephyrproject.org/latest/getting\\_started/index.html](https://docs.zephyrproject.org/latest/getting_started/index.html)

the documentation describes an installation process under Ubuntu/macOS/Windows

I picked Debian (which is not listed) .... and soon afterwards ran into trouble

*this behaviour is known as : stubborn or stupid, but I remain convinced it could work*

In the Zephyr getting started page :

- 1) select and update OS
- 2) install dependencies
- 3) Get the source code

instead of following the procedure:

```
cd ~
west init zephyrproject
cd zephyrproject
west update
```

you should do this :

```
cd ~
mkdir work
cd work
west init -m https://github.com/najnesnaj/pinetime-zephyr
west update
```

- 4) complete the other steps

to test if your install works :

```
cd ~/work/pinetime
```

```
west build -p -b pinetime samples/basic/blinky
```

**TIP : sometimes you run into trouble compiling: removing the build directory can help in that case**

## STARTING WITH SOME BASIC APPLICATIONS

The best way to get a feel of zephyr for the smartwatch, is to start building applications.

The gpio ports, i2c communication, memory layout, stuff that is particular for the watch is defined in the board definition file.

The provided samples are standard zephyr application, with some minor modifications.

The watch framework is under /app. This framework provides a clock, a button, bluetooth, touchscreen and 4 screens, where you can add stuff.

### 4.1 Blinky example

The pinetime watch does **not** contain a led **as** such, but it has a vibrator-motor which ↪ makes some noise.  
The Desay D6 can blink it's **heartrate sensor**.  
The virtual POSIX can **print** out to the screen.

#### 4.1.1 Building and Running

```
west build -p -b pinetime app/blinky
west build -p -b ds_d6 app/blinky
west build -p -b native_posix_64 app/blinky
```

### 4.2 Reading out the button on the watch

The pinetime does have a button on the side.  
The desay D6 has a touchbutton **in** front.  
The virtual POSIX watch has a touchbutton

### 4.2.1 Building and Running

*Note:: The pinetime watch has a button out port (15) and button in port (13). You have to set the out-port high. Took me a while to figure this out...*

```
west build -p -b pinetime app/button
west build -p -b ds_d6 app/button
west build -p -b native_posix_64 app/button
```



## BLUETOOTH (BLE) EXAMPLE

The PineTime uses a Nordic nrf52832 chip, which has BLE functionality build into it.

To test, you can compile a standard application : Eddy Stone.

The watch will behave as a bluetooth beacon, and you should be able to detect it with your smartphone or with bluez under linux.

### 5.1 Using a standard zephyr application under pinetime:

Each sample has its own directory. In this directory you will notice a file : "CMakeLists.txt".

In order to use a standard, you can just copy it under the pinetime directory.

In order to be able to compile it, you just have to add one line in the CMakeList.txt :

```
include($ENV{ZEPHYR_BASE}/../pinetime/cmake/boilerplate.cmake)
```

Have a look in the samples/bluetooth/eddytone directory.

### 5.2 Eddy Stone

see: *Bluetooth: Eddystone*

**Note:** compile the provided example, so a build directory gets created

```
$ west build -p -b pinetime samples/bluetooth/eddytone
```

this builds an image, which can be found under the build directory

### 5.3 Using the created bluetooth sample:

I use linux with a bluetoothadapter 4.0. You need to install bluez.

```
#bluetoothctl  
[bluetooth] #scan on
```

And your Eddy Stone should be visible.

If you have a smartphone, you can download the nrf utilities app from nordic.

## 5.4 Ble Peripheral

this example is a demo of the services under bluetooth

first build the image

```
$ west build -p -b pinetime samples/bluetooth/peripheral
```

With linux you can have a look using bluetoothctl:

```
#bluetoothctl
[bluetooth]#scan on

[NEW] Device 60:7C:9E:92:50:C1 Zephyr Peripheral Sample Long
once you see your device
[blueooth]#connect 60:7C:9E:92:50:C1 (the device mac address as displayed)

then you can already see the services
```

same thing with the app from nordic, you could try to connect and display value of e.g. heart rate

## 5.5 using Python to read out bluetoothservices

In this repo you will find a python script : readbat.py In order to use it you need bluez on linux and the python *bluepy* module.

It can be used in conjunction with the peripheral bluetooth demo. It just reads out the battery level, and prints it.

```
import binascii
from bluepy.btle import UUID, Peripheral

temp_uuid = UUID(0x2A19)

p = Peripheral("60:7C:9E:92:50:C1", "random")

try:
    ch = p.getCharacteristics(uuid=temp_uuid)[0]
    print binascii.b2a_hex(ch.read())
finally:
    p.disconnect()
```

## DISPLAY (ST7789)

### 6.1 Display example

This is just a simple display test. It displays colored squares, but it allows you to check if the screen is OK.

**TIP: While connecting 5V, do not connect 3.3V at the same time**

The watch has background leds **for** the LCD.

They need to be on (LOW) to visualize the display.  
Have a look **in** the source code.

```
$ west build -p -b pinetime samples/display/st7789v
```

Once the compilation is completed you can upload the firmware.

If all goes well, you should see some colored squares on your screen.

**Note : in order to get the display st7789 Picture-Perfect, you might need a zephyr patch**

have a look at : <https://github.com/zephyrproject-rtos/zephyr/pull/20570/files> You will find them in this repo under patches-zephyr.



## GFX LIBRARY SAMPLE

### 7.1 Overview

This sample is built on top of the ST7789 display sample (*display (st7789)*), extending it with the [Adafruit GFX Library](#). The library was ported from Arduino and has the same functionality and API. See `src/main.cpp` for examples on the GFX API usage.

See *display (st7789)* for more details on working with the display itself.

### 7.2 Usage

Add the gfx sample from this repo into your project:

```
$ cp samples/gui/gfx ~/zephyrproject/zephyr/samples/gui/
```

**Note:** In order to make the library work the sample is built with C++ support. This is achieved by having the following line in the sample's *prj.conf* configuration:

```
CONFIG_CPLUSPLUS=y
```

Build & flash the sample:

```
$ west build -p -b pinetime samples/gui/gfx
$ west flash
```

If all goes well, you should see a looping graphical test: drawing lines, rectangles, triangles etc.



## LITTLEVGL BASIC SAMPLE

### 8.1 Overview

This sample application displays "Hello World" in the center of the screen and a counter at the bottom which increments every second.

LittlevGL is a free and open-source graphics library providing everything you need to create embedded GUI with easy-to-use graphical elements, beautiful visual effects and low memory footprint.

### 8.2 Simulation

In order to avoid uploading to check what the display looks like, there is a simple way to simulate this. I've tested this on Ubuntu 18.04 64bit. You'll need the SDL2 library.

```
west build -p -b native_posix_64 samples/display/lvgl -DCONF=board/native-posix_64
```

after the building, you can find build/zephyr/zephyr.exe (and execute this to see display-layout)

the sample is provided as samples/display/lvgl-posix

### 8.3 Requirements

The program has been modified to light up the background leds.

**TIP: matching label : DISPLAY**

```
Matching labels are necessary!  
pinetime.conf:CONFIG_LVGL_DISPLAY_DEV_NAME="DISPLAY"  
pinetime.overlay:          label = "DISPLAY"; (spi definition)
```

## 8.4 Building and Running

```
west build -p -b pinetime samples/gui/lvgl
```

### 8.4.1 modifying the font size :

```
west build -t menuconfig
```

**goto:**

- additional libraries
- lvgl gui library

(look for fonts, and adapt according to your need)

### 8.4.2 apply changes of the changed config:

```
west build
```

(instead of west build -p (pristine) which wipes out your customisation)

## 8.5 Todo

- Create a button
- touchscreen activation (problem cause zephyr does not support this yet)
- lvgl supports lv\_canvas\_rotate(canvas, &imd\_dsc, angle, x, y, pivot\_x, pivot\_y) should be cool for a clock, chrono...

## 8.6 References

<https://docs.littlevgl.com/en/html/index.html>

LittlevGL Web Page: <https://littlevgl.com/>



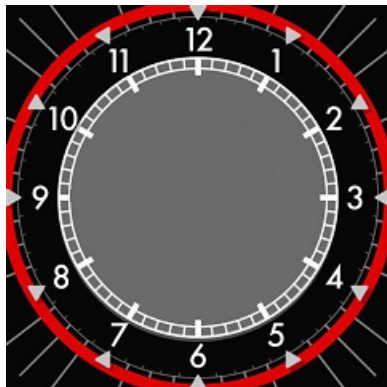
## LITTLEVGL CLOCK SAMPLE

see : *LittlevGL Clock Sample*

### 9.1 Overview

This sample application displays a "clockbackground" in the center of the screen.

LittlevGL is a free and open-source graphics library providing everything you need to create embedded GUI with easy-to-use graphical elements, beautiful visual effects and low memory footprint.



### 9.2 Requirements

Make sure the prj.conf contains the following :

```
CONFIG_LVGL=y
CONFIG_LVGL_OBJ_IMAGE=y
```

LittlevGL uses a "c" file to store the image. You need to convert a jpg, or png image to this c file. There is an online tool : <https://littlevgl.com/image-to-c-array>

## 9.3 Building and Running

```
west build -p -b pinetime samples/gui/clock
```

## 9.4 Todo

- create an internal clock (and adjustment mechanism, eg. bluetooth cts)
- lvgl supports `lv_canvas_rotate(canvas, &imd_dsc, angle, x, y, pivot_x, pivot_y)` should be cool for a clock, chrono...

## 9.5 References

<https://docs.littlevgl.com/en/html/index.html>

LittlevGL Web Page: <https://littlevgl.com/>

## REAL TIME CLOCK

### 10.1 Overview

This sample application "clock" uses the RTC2 timer. (the standard sample with RTC0 is not usable together with bluetooth)

It uses the counter driver. (based on the alarm sample)

Basically an interrupt is set to go off after 1 second. The number of seconds is incremented and the interrupt is launched again.

It will serve as a building block for a "time of the day" clock.

In addition it will need a function to set the time.

In bluetooth one can use CTS (central time service)

**\*\*NOTE:** as I found out there is a conflict between RTC0 and bluetooth \*\*

### 10.2 Requirements

Make sure the prj.conf contains the following :

CONFIG_COUNTER=y
------------------

### 10.3 Building and Running

### 10.4 Todo

- time of day clock
- setting the time

## 10.5 References

## CURRENT TIME SERVICE

<https://www.bluetooth.com/specifications/gatt/services/characteristics/> 0x1805 current time service 0x2A2B current time characteristic

### 11.1 Requirements:

You need :

- a CTS server (use of bluez on linux explained)
  - start the CTS service (python script)
  - connect to the CTS client
- a CTS client (the pinetime watch)

### 11.2 BLE Peripheral CTS sample for zephyr

This example demonstrates the basic usage of the current time service. It is based on the <https://github.com/Dejvino/pinetime-hermes-firmware>. It starts advertising its UUID, and you can connect to it. Once connected, it will read the time from your CTS server (bluez on linux running the gatt-cts-server script in my case)

first build the image

```
$ west build -p -b pinetime samples/bluetooth/peripheral-cts
```

### 11.3 Using bluez on linux to connect

The pinetime zephyr sample behaves as a peripheral:

- first of all start the cts service
  - connect to the pinetime with bluetoothctl

Using bluetoothctl:

```
#bluetoothctl
[bluetooth] #scan on

[NEW] Device 60:7C:9E:92:50:C1 Zephyr Peripheral Sample Long
```

(continues on next page)

(continued from previous page)

```
once you see your device  
[blueooth] #connect 60:7C:9E:92:50:C1 (the device mac address as displayed)
```

## 11.4 Howto use Bluez on linux to set up a time service

Within the bluez source distribution there is an example GATT (Generic Attribute Profile)server. It advertises some standard service such as heart rate, battery ... Koen zandberg adapted this script, so it advertises the current time : <https://github.com/bosmoment/gatt-cts/blob/master/gatt-cts-server.py>

You might have to install extra packages:

```
apt-get install python-dbus  
apt-get install python-gi  
apt-get install python-gobject
```

## 11.5 Howto use Android to set up a time service

As soon as a device is bonded, Pinetime will look for a CTS server (Current Time Service) on the connected device. Here is how to do it with an Android smartphone running NRFConnect:

Build and program the firmware on the Pinetime Install NRFConnect (<https://www.nordicsemi.com/Software-and-Tools/Development-Tools/nRF-Connect-for-desktop>)

Start NRFConnect and create a CTS server : Tap the hamburger button on the top left and select "Configure GATT server" Tap "Add service" on the bottom Select server configuration "Current Time Service" and tap OK Go back to the main screen and scan for BLE devices. A device called "PineTime" should appear Tap the button "Connect" next to the PineTime device. It should connect to the PineTime and switch to a new tab. On this tab, on the top right, there is a 3 dots button. Tap on it and select Bond. The bonding process begins, and if it is successful, the PineTime should update its time and display it on the screen.

## 12.1 configuring I2C

### 12.1.1 board level definitions

under boards/arm/pinetime are the board definitions

- pinetime.dts
- pinetime\_defconfig

The sensors **in** the pinetime use the I2C bus.

```
&i2c1 {  
    compatible = "nordic,nrf-twi";  
    status = "okay";  
    sda-pin = <6>;  
    scl-pin = <7>;  
  
};
```

### 12.1.2 definition on project level

In the directory of a sample, you will find a prj.conf file. Here you can set values specific for you project/sample.

In the "prj.conf" file we define the sensor (eg adxl372)

```
CONFIG_STDOUT_CONSOLE=y  
CONFIG_LOG=y  
CONFIG_I2C=y  
CONFIG_SENSOR=y  
CONFIG_ADXL372=y  
CONFIG_ADXL372_I2C=y  
CONFIG_SENSOR_LOG_LEVEL_WRN=y
```

**note:** this gets somehow merged (overlaid) with the board definition pinetime\_defconfig

## 12.2 sensors on the I2C bus

0x18: Accelerometer: BMA423-DS000 <https://github.com/BoschSensortec/BMA423-Sensor-API>

0x44: Heart Rate Sensor: HRS3300\_Heart

0x15: Touch Controller: Hynitron CST816S Touch Controller

## 12.3 Bosch BMA421

this driver does not exist, so it has been created. Still work in progress ....

```
west build -p -b pinetime samples/gui/lvaccel
```

### 12.3.1 Overview

BMA421 is not a part number available to the general public, and therefore all the supporting documentation and design resources are neither discussed in public forums, nor disclosed on GitHub.

CHIP\_ID=0X11 (so the Bosch BMA423 drivers need to be adapted)

The Bosch documentation on the bma423 seems to apply to the bma421.

### 12.3.2 Requirements

for this sensor does not exist any driver, so here's what I did to create one under zephyr

#### adapt CMakeLists.txt

```
~/zephyrproject-2/zephyr/drivers/sensor      add_subdirectory_ifdef(CONFIG_BMA280      bma280)
add_subdirectory_ifdef(CONFIG_BMA421 bma421)
```

#### adapt Kconfig

```
~/zephyrproject-2/zephyr/drivers/sensor
```

#### add yaml file

```
~/zephyrproject-2/zephyr/dts/bindings/sensor cp bosch,bma280-i2c.yaml bosch,bma421-i2c.yaml
```



## edit KConfig

```
source "drivers/sensor/bma280/Kconfig" source "drivers/sensor/bma421/Kconfig"
source "drivers/sensor/bmc150_magn/Kconfig"
source "drivers/sensor/bme280/Kconfig"
```

## create driver

see under drivers/sensor/bma421

complement the pinetime.dts file with the following (under samples/sensor/bma280)

```
&i2c1 {
    bma421@18 {
        compatible = "bosch,bma421";
        reg = <0x18>;
        label = "BMA421";
        int1-gpios = <&gpio0 8 0>;
    };
};
```

Create a file: */dts/bindings/sensor/bosch,bma421-i2c.yaml*. Which contains:

```
compatible: "bosch,bma421"
include: i2c-device.yaml
properties:
    int1-gpios:
        type: phandle-array
        required: false
```

## 12.3.3 Building and Running

### 12.3.4 Todo

- the driver is interrupt driven as well -- need to test software
- the sensor has algorithm for steps -- read out register
- temperature some attempt has been made, but ... (OK, temp can be read)

### 12.3.5 References

Bosch has documented the BMA423 very well. I kind of hope it will apply to the bma421.

A mechanism to adapt the 0x5E register is provided. (burst read/write)

All kind of parameters can be set to trigger an interrupt. (e.g. number of steps taken : think of the 10000 steps threshold)

## 12.4 HYNITRON CST816S

update on 5-1-2021: Zephyr has evolved and now there is something that serve as a touchscreen device.

the board definition file has been adapted slightly, using the focaltech ft5336 as a touch\_controller. A minor change in this driver is enough to get data from the hynitron cst816S.

The big advantage : almost standard zephyr install!

```
west build -p -b pinetime_devkit0 samples/display/lvgl
```

this driver does not exist, so it has been created. Still work in progress ....

there is a sample in this repository which can be copied to the zephyr samples directory

```
west build -p -b pinetime samples/sensor/cst816s
```

### 12.4.1 Overview

the Hynitron cst816s is a touchscreen. Zephyr doesn't handle touchscreens yet. In order to investigate, the touchscreen driver has been created as a sensor. In fact it senses your finger ;)

### 12.4.2 Requirements

for this sensor does not exist any driver, so here's what I did to create one under zephyr

adapt CMakeLists.txt adapt Kconfig add yaml file

#### create driver

The driver reads only one position. Multitouch is possible, but the screen is small....

see under drivers/sensor/cst816s

have a look at the pinetime.dts (under board/arm/pinetime) file:

```
&i2c1 {
    cst816s@15 {
        compatible = "hynitron,cst816s";
        reg = <0x15>;
        label = "CST816S";
    };
};
```

### 12.4.3 Building and Running

There are two samples :

- samples/gui/lvtouch (graphical)
- samples/sensor/cst816s (no graphics)

#### 12.4.4 Todo

The graphical sample doesn't handle interrupts.

#### 12.4.5 References

There is little available for this touchscreen.

### 12.5 HX HRS3300

this driver does not exist, so it has been created. Still work in progress ....

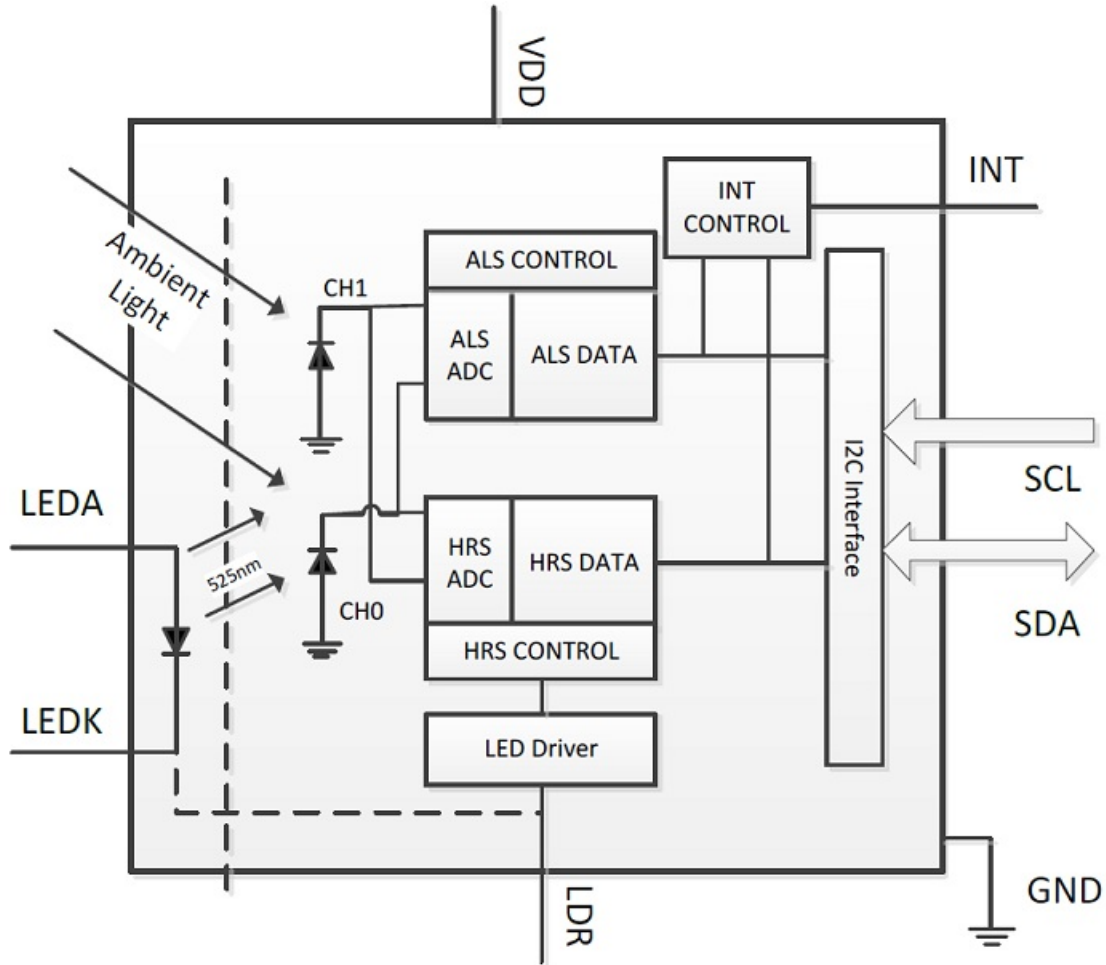
there is a sample in this repository which can be copied to the zephyr samples directory

```
west build -p -b pinetime samples/sensor/hrs3300
```

#### 12.5.1 Overview

The HX HRS3300 sensor is a heart rate sensor, it produces 2 values: ALS and HRS. Ambient LIGHT SENSOR and HEART RATE SENSOR. Which have to be processed by an algorithm. I have no knowledge of a good open source algorithm yet.

I have used the settings of an arduino port of this library.



## 12.5.2 Requirements

for this sensor does not exist any driver, so here's what I did to create one under zephyr

### adapt CMakeLists.txt

```
~/zephyrproject-2/zephyr/drivers/sensor add_subdirectory_ifdef(CONFIG_HRS3300 hrs3300)
```

### adapt Kconfig

```
~/zephyrproject-2/zephyr/drivers/sensor
```

### add yaml file

~/zephyrproject-2/zephyr/dts/bindings/sensor add hx,hrs3300.yaml

### edit KConfig

source "drivers/sensor/hrs3300/Kconfig"

### create driver

see under drivers/sensor/hrs3300

complement the pinetime.dts file with the following (under samples/sensor/bma280)

```

&i2c1 {
    hrs3300@44 {
        compatible = "hx,hrs3300";
        reg = <0x44>;
        label = "HRS3300";
    };
};

```

Create a file: `/dts/bindings/sensor/hx,hrs3300.yaml`. Which contains:

```

compatible: "hx,hrs3300"
properties:

```

## 12.5.3 Building and Running

### 12.5.4 Todo

- algorithm for heartrate
- power saving
- switching off/on mechanism

### 12.5.5 References

HRS3300 Heart Rate Sensor.pdf <https://github.com/atc1441/HRS3300-Arduino-Library>

## 12.6 Serial Nor Flash

```
west build -p -b pinetime samples/drivers/spi_flash -DCONF=prj.conf
```

## 12.6.1 Overview

This sample application should unlock the serial nor flash memory. This can be very usefull to store e.g. background for the watch.

compilation problematic ....

```
/root/zephyrproject/zephyr/samples/drivers/spi_flash/src/main.c:17:22: error: 'DT_INST_0_JEDEC_SPI_NOR_LABEL' undeclared (first use in this function); did you mean 'DT_INST_0_NORDIC_NRF_RTC_LABEL'?
```

Turns out this is some problem with the board definition file.

I found it to be very useful to consult the generated dts file. Here you can check if everything is present.

Guess the dts-file has to be well intended.(structured)

**\*\*TIP: consult the generated dts board file \*\***

### consulting the generated board definition file

```
vi /root/zephyrproject/zephyr/build/zephyr/include/generated/generated_dts_board.conf
```

## 12.6.2 Requirements

complement the pinetime.dts file with the following (under spi) #define JEDEC\_ID\_MACRONIX\_MX25L64 0xC22017

```
&spi0 {
    compatible = "nordic,nrf-spi";
    status = "okay";
    sck-pin = <2>;
    mosi-pin = <3>;
    miso-pin = <4>;
    cs-gpios = <&gpio0 27 0>,<&gpio0 5 0>;
    st7789v@0 {
        compatible = "sitronix,st7789v";
        label = "DISPLAY";
        spi-max-frequency = <8000000>;
        reg = <0>;
        cmd-data-gpios = <&gpio0 18 0>;
        reset-gpios = <&gpio0 26 0>;
        width = <240>;
        height = <240>;
        x-offset = <0>;
        y-offset = <0>;
        vcom = <0x19>;
        gctrl = <0x35>;
        vrhs = <0x12>;
        vdvs = <0x20>;
        mdac = <0x00>;
        gamma = <0x01>;
        colmod = <0x05>;
        lcm = <0x2c>;
        porch-param = [0c 0c 00 33 33];
        cmd2en-param = [5a 69 02 01];
        pwctrl1-param = [a4 a1];
    }
}
```

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```

    pvgam-param = [D0 04 0D 11 13 2B 3F 54 4C 18 0D 0B 1F 23];
    nvgam-param = [D0 04 0C 11 13 2C 3F 44 51 2F 1F 1F 20 23];
    ram-param = [00 F0];
    rgb-param = [CD 08 14];

};

mx25r64: mx25r6435f@1 {
    compatible = "jedec,spi-nor";
    reg = <1>;
    spi-max-frequency = <1000000>;
    label = "MX25R64";
    jedec-id = [0b 40 16];
    size = <67108864>;
    has-be32k;
};

```

### 12.6.3 Building and Running

```
west build -p -b pinetime samples/drivers/spi_flash
```

### 12.6.4 Todo

- detect ID memory : it is not the macronix one as suggestion on the pinetime website  
I found the following : jedec-id = [0b 40 16]; (OK: can execute sample program)
- create working board definition (OK: see above)

### 12.6.5 References

<http://files.pine64.org/doc/datasheet/pinetime/MX25L6433F,%203V,%2064Mb,%20v1.6.pdf>

## 12.7 Battery

the samples just gets an analog reading from the battery

```
west build -p -b pinetime samples/sensor/battery
```

### 12.7.1 Overview

The battery level is measured on port 31, trough an ADC conversion.

$\text{voltage} = (\text{value} * 6) / 1024$  percentage remaining  $((\text{voltage} - 3.55) * 100) * 3.9;$

A module should be able to report battery status in millivolts and charge level in percentage. Additionally, it should notify when external power is connected and when battery is being charged. Module will use adc (saadc peripheral) to measure battery voltage and gpio driver to monitor charge indication pin (pin 0.12) and power presence pin (0.19). Battery voltage can be in range from 3.0V - 4.2V (?). Unfortunately, internal reference (0.6V) can only be used for

voltages up to 3.6V (due to minimal gain of 1/6). VDD/4 reference can be used with 1/6 gain to measure voltages up to 4.95V. Test is needed to check how accurate is VDD as reference. Discharge curve (<https://forum.pine64.org/showthread.php?tid=8147>) will be used to calculate charge level in percent. Things to consider: saadc periodical calibration (spec suggests calibration if temperature changes by 10°C) inaccuracy of results: oversampling? never report higher level than before (if charge not connected), etc.

### 12.7.2 Todo

check pin when charging

### 12.7.3 References

<https://forum.pine64.org/showthread.php?tid=8147>

## 12.8 Watchdog

```
west build -p -b pinetime samples/drivers/watchdog
```

### 12.8.1 Overview

Once the pinetime is closed and on your wrist, you still want access.

see : *Firmware Over The Air (FOTA)*

Suppose you upload an application which contains a bug, the watch freezes, and ... you will have to open it up, connect the SWD ...

Here comes the watchdog:

- you launch the watchdog
- you launch the application
- the application feeds the watchdog
- if it cannot feed the watchdog, reset to fota, and you can upload another better version ...

### 12.8.2 Todo

testing

### 12.8.3 References



## FIRMWARE OVER THE AIR (FOTA)

### 13.1 Wireless Device Firmware Upgrade

#### 13.1.1 Overview

In order to perform a FOTA (firmware over the air) update on zephyr you need 2 basic components:

- MCUboot (a bootloader)
- SMP Server (a bluetooth service)

### 13.2 MCUboot with zephyr

Clone MCUBOOT for zephyr from github. Install additional packages required for development with mcuboot:

```
cd ~/mcuboot # or to your directory where mcuboot is cloned
pip3 install --user -r scripts/requirements.txt
```

To build MCUboot, create a build directory in boot/zephyr, and build it as follows:

```
cd boot/zephyr
mkdir build && cd build
cmake -GNinja -DBOARD=pinetime ..
ninja
```

After building the bootloader, the binaries should reside in *build/zephyr/zephyr.{bin,hex,elf}*.

This image can be flashed as a normal application.

Some additional configuration is required to build applications for MCUboot.

This is handled internally by the Zephyr configuration system and is wrapped in the *CONFIG\_BOOTLOADER\_MCUBOOT* Kconfig variable, which must be enabled in the application's *prj.conf* file.

The Zephyr *CONFIG\_BOOTLOADER\_MCUBOOT* configuration option [documentation]([http://docs.zephyrproject.org/reference/kconfig/CONFIG\\_BOOTLOADER\\_MCUBOOT.html](http://docs.zephyrproject.org/reference/kconfig/CONFIG_BOOTLOADER_MCUBOOT.html)) provides additional details regarding the changes it makes to the image placement and generation in order for an application to be bootable by MCUboot.

In order to upgrade to an image (or even boot it, if *MCUBOOT\_VALIDATE\_PRIMARY\_SLOT* is enabled), the images must be signed.

To make development easier, MCUboot is distributed with some example keys. It is important to stress that these should never be used for production, since the private key is publicly available in this repository. See below on how to make your own signatures.

Images can be signed with the `scripts/imgtool.py` script. It is best to look at `samples/zephyr/Makefile` for examples on how to use this.

Since the bootloader is already in place, you cannot flash your `application.bin` to `0x00000`.

Eg. in `openocd` : `program application.bin 0x0c000`. (which corresponds to the flash layout of slot 0)

These images can also be marked for upgrade, and loaded into the secondary slot, at which point the bootloader should perform an upgrade.

## 13.3 Partitions

have a look at `boards/arm/pinetime/pinetime.dts`

### 13.3.1 Defining partitions for MCUboot

The first step required for Zephyr is making sure your board has flash partitions defined in its device tree. These partitions are:

- *boot\_partition*: for MCUboot itself
- *image\_0\_primary\_partition*: the primary slot of Image 0
- *image\_0\_secondary\_partition*: the secondary slot of Image 0
- *scratch\_partition*: the scratch slot

The flash partitions are defined in the `pinetime` boards folder, in a file named `boards/arm/pinetime/pinetime.dts`.

### 13.3.2 Using NOR flash in partitions

The flash space on the Nordic `nrf52` is 512K. Basically with the partitioning you end up with less space for your program.

As the `pinetime` has an extra `spi nor` flash chip, we can use this.

The flash-layout can be modified so as 1 chunk is on system flash and 1 chunk is on SPI NOR flash. This way the space for your firmware remains almost the same.

```
chosen {
    zephyr,flash = &flash0;
    //zephyr,flash = &flash1;
    zephyr,code-partition = &slot0_partition;
};

Rename the SPI JEDEC NOR Flash definition to : flash1

flash1: mx25r6435f@1 {
    compatible = "jedec,spi-nor";
    reg = <1>;
    spi-max-frequency = <80000000>;
    label = "MX25R64";
    jedec-id = [0b 40 16];
    size = <67108864>;
    has-be32k;
```

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```

        erase-block-size = <4096>;
        write-block-size = <4>;
};

&flash0 {
    /*
     * For more information, see:
     * http://docs.zephyrproject.org/latest/guides/dts/index.html#flash-partitions
     */
    partitions {
        compatible = "fixed-partitions";
        #address-cells = <1>;
        #size-cells = <1>;

        boot_partition: partition@0 {
            label = "mcuboot";
            reg = <0x00000000 0xc000>;
        };
        slot0_partition: partition@c000 {
            label = "image-0";

            change the size of partition 0 from 0x32000 to 0x64000

            reg = <0x0000C000 0x64000>;
        };

        move slot1 partition to &flash1

        //slot1_partition: partition@3e000 {
        //    label = "image-1";
        //    reg = <0x0003e000 0x32000>;
        //};
        scratch_partition: partition@70000 {
            label = "image-scratch";
            reg = <0x00070000 0xa000>;
        };
        storage_partition: partition@7a000 {
            label = "storage";
            reg = <0x0007a000 0x00006000>;
        };
    };
};

&flash1 {
    partitions {
        compatible = "fixed-partitions";
        #address-cells = <1>;
        #size-cells = <1>;
        slot1_partition: partition@3e000 {
            label = "image-1";
            reg = <0x00000000 0x64000>;
        };
    };
};

```

## 13.4 Signing an application

In order to improve the security, only signed images can be uploaded.

There is a public and private key. The Bootloader is compiled with the public key. Each time you want to upload firmware, you have to sign it with a private key.

**NOTE: it is important to keep the private key hidden**

### 13.4.1 Generating a new keypair

Generating a keypair with `imgtool` is a matter of running the `keygen` subcommand:

```
$ ./scripts/imgtool.py keygen -k mykey.pem -t rsa-2048
```

### 13.4.2 Extracting the public key

The generated keypair above contains both the public and the private key. It is necessary to extract the public key and insert it into the bootloader.

```
$ ./scripts/imgtool.py getpub -k mykey.pem
```

This will output the public key as a C array that can be dropped directly into the `keys.c` file.

### 13.4.3 Example

sign the compiled `zephyr.bin` firmware with the `root-rsa-2048.pem`, private key:

```
imgtool.py sign --key ../../root-rsa-2048.pem \  
  --header-size 0x200 \  
  --align 8 \  
  --version 1.2 \  
  --slot-size 0x60000 \  
  ../mcuboot/samples/zephyr/build/ds_d6/hello1/zephyr/zephyr.bin \  
  signed-hello1.bin
```

## 13.5 SMP Server Sample

### 13.5.1 Overview

This sample application implements a Simple Management Protocol (SMP) server. SMP is a basic transfer encoding for use with the MCUMgr management protocol.

This sample application supports the following `mcumgr` transports by default:

- Shell
- Bluetooth

### 13.5.2 Requirements

In order to communicate with the smp server sample installed on your pinetime, you need mcumgr.

Here is a procedure to install mcumgr on a raspberry pi (or similar)

It is written in the go-language. You need to adapt the path : `PATH=$PATH:/root/go/bin`.

### 13.5.3 Building and Running

The sample will let you manage the pinetime over bluetooth. (via SMP protocol)

There are slot0 and slot1 which can both contain firmware.

Suppose you switch from slot0 to slot1, you still want to be able to communicate.

So both slots need smp\_svr software!

#### Step 1: Build smp\_svr

smp\_svr can be built for the nRF52 as follows:

**NOTE: to perform a firmware update over the air, you have to build a second sample**

#### Step 2: Sign the image

Using MCUboot's `imgtool.py` script, sign the `zephyr.(bin|hex)` file you built in Step 3. In the below example, the MCUboot repo is located at `~/src/mcuboot`.

```
~/src/mcuboot/scripts/imgtool.py sign \
  --key ~/src/mcuboot/root-rsa-2048.pem \
  --header-size 0x200 \
  --align 8 \
  --version 1.0 \
  --slot-size <image-slot-size> \
  <path-to-zephyr.(bin|hex)> signed.(bin|hex)
```

The above command creates an image file called `signed.(bin|hex)` in the current directory.

#### Step 3: Flash the smp\_svr image

Upload the bin-file from Step 2 to image slot-0. For the pinetime, slot-0 is located at address `0xc000`.

```
in openocd : program zephyr.bin 0xc000
```

## Step 4: Run it!

---

**Note:** If you haven't installed `mcumgr` yet, then do so by following the instructions in the `mcumgr_cli` section of the Management subsystem documentation.

---

The `smp_svr` app is ready to run. Just reset your board and test the app with the `mcumgr` command-line tool's `echo` functionality, which will send a string to the remote target device and have it echo it back:

```
sudo mcumgr --conntype ble --connstring ctlr_name=hci0,peer_name='Zephyr' echo hello
hello
```

## Step 5: Device Firmware Upgrade

Now that the SMP server is running on your pinetime, you are able to communicate with it using `mcumgr`.

You might want to test "OTA DFU", or Over-The-Air Device Firmware Upgrade.

To do this, build a second sample (following the steps below) to verify it is sent over the air and properly flashed into slot-1, and then swapped into slot-0 by MCUboot.

```
* Build a second sample
* Sign the second sample
* Upload the image over BLE
```

Now we are ready to send or upload the image over BLE to the target remote device.

```
sudo mcumgr --conntype ble --connstring ctlr_name=hci0,peer_name='Zephyr' image_
↪upload signed.bin
```

If all goes well the image will now be stored in slot-1, ready to be swapped into slot-0 and executed.

---

**Note:** At the beginning of the upload process, the target might start erasing the image slot, taking several dozen seconds for some targets. This might cause an NMP timeout in the management protocol tool. Use the `-t <timeout-in-seconds>` option to increase the response timeout for the `mcumgr` command line tool if this occurs.

---

## List the images

We can now obtain a list of images (slot-0 and slot-1) present in the remote target device by issuing the following command:

```
sudo mcumgr --conntype ble --connstring ctlr_name=hci0,peer_name='Zephyr' image list
```

This should print the status and hash values of each of the images present.

## Test the image

In order to instruct MCUboot to swap the images we need to test the image first, making sure it boots:

```
sudo mcumgr --conntype ble --connstring ctlr_name=hci0,peer_name='Zephyr' image test  
↪ <hash of slot-1 image>
```

Now MCUBoot will swap the image on the next reset.

## Reset remotely

We can reset the device remotely to observe (use the console output) how MCUboot swaps the images:

```
sudo mcumgr --conntype ble --connstring ctlr_name=hci0,peer_name='Zephyr' reset
```

Upon reset MCUboot will swap slot-0 and slot-1.

You can confirm the new image and make the swap permanent by using this command:

```
sudo mcumgr --conntype ble --connstring ctlr_name=hci0,peer_name='Zephyr' image_↵  
↪ confirm
```

**Note** that if you try to send the very same image that is already flashed in slot-0 then the procedure will not complete successfully since the hash values for both slots will be identical.





## SAMPLES AND DEMOS

In each sample directory is a Readme file. This is just a collection of them.

### 14.1 Basic Samples

#### 14.1.1 Blinky Application

##### Overview

The Blinky example shows how to configure GPIO pins as outputs which can also be used to drive LEDs on the hardware usually delivered as "User LEDs" on many of the supported boards in Zephyr.

##### Requirements

The demo assumes that an LED is connected to one of GPIO lines. The sample code is configured to work on boards that have defined the led0 alias in their board devicetree description file. Doing so will generate these variables:

- DT\_ALIAS\_LED0\_GPIOS\_CONTROLLER
- DT\_ALIAS\_LED0\_GPIOS\_PIN

##### Building and Running

This samples does not output anything to the console. It can be built and flashed to a board as follows:

After flashing the image to the board, the user LED on the board should start to blink.

#### 14.1.2 Button demo

##### Overview

A simple button demo showcasing the use of GPIO input with interrupts. If the button is pressed, it will set a value at the location 0x2000F000 in memory. With openocd or any other debugger you can peek at this location.

## Requirements

The demo assumes that a push button is connected to one of GPIO lines. The sample code is configured to work on boards with user defined buttons and that have defined the `SW0_*` variables.

To use this sample, you will require a board that defines the user switch in its header file. The `board.h` must define the following variables:

- `SW0_GPIO_NAME` (or `DT_ALIAS_SW0_GPIOS_CONTROLLER`)
- `DT_ALIAS_SW0_GPIOS_PIN`

Alternatively, this could also be done by defining 'sw0' alias in the board devicetree description file.

## Building and Running

This sample can be built for multiple boards, in this example we will build it for the pinetime

After startup, the program looks up a predefined GPIO device, and configures the pin in input mode, enabling interrupt generation on falling edge. During each iteration of the main loop, the state of GPIO line is monitored and printed to the serial console. When the input button gets pressed, the interrupt handler will print an information about this event along with its timestamp.

### 14.1.3 I2C Scanner sample

#### Overview

This sample sends I2C messages without any data (i.e. stop condition after sending just the address). If there is an ACK for the address, it prints the address as `FOUND`.

**Warning:** As there is no standard I2C detection command, this sample uses arbitrary SMBus commands (namely SMBus quick write and SMBus receive byte) to probe for devices. This sample program can confuse your I2C bus, cause data loss, and is known to corrupt the Atmel AT24RF08 EEPROM found on many IBM Thinkpad laptops. See also the [i2cdetect man page](#)

## Building and Running

### 14.1.4 Touchscreen IRQ

#### Overview

The touchscreen generates an interrupt when touched.

## Requirements

A counter that keeps track of the number of times touched.

This value is stored at a fixed location in memory, because I have a simple test setup.

## Building and Running

### 14.1.5 Touchpoints

#### Overview

When touched the touchscreen triggers an interrupt, it's address 0x15 becomes visible.

#### Requirements

Catch the interrupts and act upon it.

Only the first touchpoint is usable.

But a sequence of 64 has to be read.

#### Building and Running

the purpose is just testing howto read the touchpoints of the touchscreen

## 14.2 Sensor Samples

### 14.2.1 BMA280: Three Axis High-g I2C/SPI Accelerometer

#### Description

This sample application produces slightly different outputs based on the chosen driver configuration mode:

- In **Measuring Mode with trigger support**, the acceleration on all three axis is printed in  $\text{m/s}^2$  at the sampling rate (ODR).
- In **Polled Measuring Mode**, the instantaneous acceleration is polled every 2 seconds.
- In **Max Peak Detect Mode**, the device returns only the over-threshold peak acceleration between two consecutive sample fetches or trigger events. (In most high-g applications, a single 3-axis acceleration sample at the peak of an impact event contains sufficient information about the event, and the full acceleration history is not required.) Instead of printing the acceleration on all three axis, the sample application calculates the vector magnitude (root sum squared) and displays the result in g's rather than in  $\text{m/s}^2$ , together with an bar graph.

## References

- BMA280: <http://www.analog.com/bma280>

## Wiring

This sample uses the BMA280 sensor controlled either using the I2C or SPI interface. Connect supply **VDD**, **VS** and **GND**. The supply voltage can be in the 1.6V to 3.5V range.

### I2C mode

Connect Interface: **SDA**, **SCL** and optionally connect the **INT1** to a interrupt capable GPIO. It is a requirement that **SCLK** must be connected to **GND** in I2C mode. Depending on the baseboard used, the **SDA** and **SCL** lines require Pull-Up resistors. With the **MISO** pin low, the I2C address for the device is 0x1D, and an alternate I2C address of 0x53 can be chosen by pulling the **MISO** pin high.

I2C Address:

- **0x1D**: if MISO is pulled low
- **0x53**: if MISO is pulled high

---

**Note:** When sharing an SDA bus, the BMA280 Silicon Revision < 3 may prevent communication with other devices on that bus.

---

### SPI mode

Connect Interface: **SCLK**, **MISO**, **MOSI** and **/CS** and optionally connect the **INT1** to a interrupt capable GPIO.

## Building and Running

This project outputs sensor data to the console. It requires an BMA280 sensor. It should work with any platform featuring a I2C/SPI peripheral interface. It does not work on QEMU.

### Sample Output: Max Peak Detect Mode

### Sample Output: Measurement Mode

## 14.2.2 CST816S HYNITRON TOUCHSCREEN

### Description

When touched the touchscreen triggers an interrupt. This is handled in the driver.

In the sample a handler is defined. This one gets activated by the driver.

## References

## Wiring

## I2C mode

## Building and Running

## Sample Output: X & Y coordinates

## Sample Output: Measurement Mode

### 14.2.3 HRS3300 Heart Rate Sensor

#### Overview

A sensor application that demonstrates how to poll data from the hrs3300 heart rate sensor.

It is based on the max30101 sample.

#### Building and Running

#### Sample Output

### 14.2.4 HRS3300 Heart Rate Sensor

#### Overview

A sensor application that demonstrates how to poll data from the hrs3300 heart rate sensor.

#### Building and Running

This project configures the hrs3300 sensor on the pinetime\_devkit0 board to enable the green LED and measure the reflected light with a photodiode. The raw ADC data prints to the console. Further processing (not included in this sample) is required to extract a heart rate signal from the light measurement.

#### Sample Output

```
GREEN=5731
GREEN=5750
GREEN=5748
GREEN=5741
GREEN=5735
GREEN=5737
GREEN=5736
GREEN=5748
```

<repeats endlessly>

## 14.3 Driver Samples

The following samples demonstrate how to use various drivers supported by Zephyr.

### 14.3.1 I2C Scanner sample

#### Overview

This sample sends I2C messages without any data (i.e. stop condition after sending just the address). If there is an ACK for the address, it prints the address as `FOUND`.

**Warning:** As there is no standard I2C detection command, this sample uses arbitrary SMBus commands (namely SMBus quick write and SMBus receive byte) to probe for devices. This sample program can confuse your I2C bus, cause data loss, and is known to corrupt the Atmel AT24RF08 EEPROM found on many IBM Thinkpad laptops. See also the [i2cdetect man page](#)

#### Building and Running

### 14.3.2 I2C Scanner sample

#### Overview

This sample sends I2C messages without any data (i.e. stop condition after sending just the address). If there is an ACK for the address, it prints the address as `FOUND`.

**Warning:** As there is no standard I2C detection command, this sample uses arbitrary SMBus commands (namely SMBus quick write and SMBus receive byte) to probe for devices. This sample program can confuse your I2C bus, cause data loss, and is known to corrupt the Atmel AT24RF08 EEPROM found on many IBM Thinkpad laptops. See also the [i2cdetect man page](#)

#### Building and Running

## 14.4 Display Samples

### 14.4.1 LittlevGL Basic Sample

#### Overview

This sample application displays a button on top of the screen and a counter at the bottom which increments every second.

The KSCAN input driver is defined in the board-definition.

## Requirements

this is a posix sample - so no dev board necessary

## Building and Running

west build -p -b native\_posix\_64 samples/display/lvgl -DCONF=board/native-posix\_64

## References

### 14.4.2 LittlevGL Basic Sample

#### Overview

This sample application displays "Hello World" in the center of the screen and a counter at the bottom which increments every second.

If an input driver is supported, such as the touch panel controller on the pinetime boards, "Hello World" is enclosed in a button that changes to the toggled state when touched.

## Requirements

a pinetime or similar watch

## Building and Running

---

**Note:** When deferred logging is enabled you will likely need to increase `CONFIG_LOG_STRDUP_BUF_COUNT` and/or `CONFIG_LOG_STRDUP_MAX_STRING` to make sure no messages are lost or truncated.

---

Example building for nrf52840dk\_nrf52840:

Example building for native\_posix:

## References

### 14.4.3 ST7789V Display driver

make sure this patch is applied : <https://github.com/zephyrproject-rtos/zephyr/pull/20570/files>

## Overview

This sample will draw some basic rectangles onto the display. The rectangle colors and positions are chosen so that you can check the orientation of the LCD and correct RGB bit order. The rectangles are drawn in clockwise order, from top left corner: Red, Green, Blue, grey. The shade of grey changes from black through to white. (if the grey looks too green or red at any point then the LCD may be endian swapped).

Note: The display driver rotates the display so that the 'natural' LCD orientation is effectively 270 degrees clockwise of the default display controller orientation.

## Building and Running

## References

- [ST7789V datasheet](#)

# 14.5 GUI Samples

## 14.5.1 Clock Sample Current Time Service

### Overview

This program gets the time of the bluetooth cts server and displays it. Once it gets the time, it uses the RTC2 to generate the time.

### Requirements

A cts server. On linux, bluez together with a python script was used.

You need to connect to the pinetime first! (bluetoothctl, connect <MAC>)

## Building and Running

## References

## 14.5.2 Clock Sample Current Time Service

### Overview

This program gets the time of the bluetooth cts server and displays it.



## Requirements

A cts server. On linux, bluez together with a python script was used.

You need to connect to the pinetime first! (bluetoothctl, connect <MAC>)

## Building and Running

## References

### 14.5.3 LittlevGL Clock Sample

#### Overview

This sample application displays a clock background.

This samples demonstrates the use of the counter.

Have a look at the test\_counter\_interrupt\_fn function in src/main.c

#### Requirements

You have to convert a graphical file to a "C" file, which is like a giant array.

Have a look at the prj.conf file.

It should contain CONFIG\_LVGL=y and CONFIG\_LVGL\_OBJ\_IMAGE=y.

For the clock function it needs CONFIG\_COUNTER=y.

## Building and Running

## References

### 14.5.4 Adafruit GFX Library on ST7789V Display

#### Overview

This is a sample C++ firmware running Adafruit GFX Library on a ST7789V display. The library is ported from Arduino.

### 14.5.5 Display accel values

#### Overview

This sample application displays "Hello World" in the center of the screen and a counter at the bottom which increments every second.

It display the values x,y,z from the bosch BMA421 accel sensor.

## Requirements

Pinetime watch definitions can be found under the boards sub-directory

- pinetime.conf
- pinetime.overlay

## Building and Running

```
west build -p -b pinetime samples/gui/lvgl
```

## References

### 14.5.6 LittlevGL Basic Sample

#### Overview

This sample application displays "Hello World" in the center of the screen and a counter at the bottom which increments every second.

#### Requirements

Pinetime watch definitions can be found under the boards sub-directory

- pinetime.conf
- pinetime.overlay

#### Building and Running

```
west build -p -b pinetime samples/gui/lvgl
```

#### References

### 14.5.7 Touchscreen Basic Sample

#### Overview

This sample application displays touchscreen-values x and y in the center of the screen.

The touchscreen triggers an interrupt when touched. This means that data is ready and can be collected.

However, using the interrupt with the handler, does not seem to work within the GUI. When used in samples/sensor/cst816s, it runs....

## Requirements

Pinetime watch zephyr cst816s driver

## Building and Running

west build -p -b pinetime samples/gui/lvtouch

## References

# 14.6 Bluetooth Samples

## 14.6.1 Bluetooth: Central / Heart-rate Monitor

### Overview

Similar to the Central sample, except that this application specifically looks for heart-rate monitors and reports the heart-rate readings once connected.

### Requirements

- BlueZ running on the host, or
- A board with BLE support

### Building and Running

This sample can be found under **zephyr\_file: `samples/bluetooth/central\_hr`** in the Zephyr tree.

See *bluetooth samples section* for details.

## 14.6.2 Bluetooth: Eddystone

### Overview

Application demonstrating **Eddystone Configuration Service**

The Eddystone Configuration Service runs as a GATT service on the beacon while it is connectable and allows configuration of the advertised data, the broadcast power levels, and the advertising intervals. It also forms part of the definition of how Eddystone-EID beacons are configured and registered with a trusted resolver.

## Requirements

- BlueZ running on the host, or
- A board with BLE support

## Building and Running

This sample can be found under `:zephyr_file: `samples/bluetooth/eddystone`` in the Zephyr tree.

See *bluetooth samples section* for details.

### 14.6.3 Bluetooth: Peripheral\_cts

#### Overview

Application demonstrating reading the time from a CTS service.

I used bluez on linux + a gatt server script that presents a current time service.

This program tests if it can get the time of a cts service. In order to get the time, you will have to connect the device first.

#### Requirements

- a bluetoothdevice running the CTS service
- a board with this software (pinetime)

You will need a serial port to read the output of the "printk" messages.

## Building and Running

### 14.6.4 Bluetooth: Peripheral

#### Overview

Application demonstrating the BLE Peripheral role. It has several well-known and vendor-specific GATT services that it exposes.

#### Requirements

- BlueZ running on the host, or
- A board with BLE support

## Building and Running

This sample can be found under `:pinetime_file: `samples/bluetooth/peripheral`` in the Zephyr tree.

See *bluetooth samples section* for details.



## MENUCONFIG

### 15.1 Zephyr is like linux

**TIP:** the pinetime specific drivers are located under Modules

**Note:** to get a feel, compile a program, for example

```
west build -p -b pinetime samples/bluetooth/peripheral -D CONF_FILE="prj.conf"
```

the pinetime contains an external 32Kz crystal now you can have a look in the configurationfile (and modify if needed)

```
$ west build -t menuconfig
```

```
Modules --->
Board Selection (nRF52832-MDK) --->
Board Options --->
SoC/CPU/Configuration Selection (Nordic Semiconductor nRF52 series MCU) --->
Hardware Configuration --->
ARM Options --->
Architecture (ARM architecture) --->
General Architecture Options --->
[ ] Floating point ----
General Kernel Options --->
Device Drivers ---> *****SELECT THIS ONE*****
C Library --->
Additional libraries --->
[*] Bluetooth --->
[ ] Console subsystem/support routines [EXPERIMENTAL] ----
[ ] C++ support for the application ----
System Monitoring Options --->
Debugging Options --->
[ ] Disk Interface ----
File Systems --->
-- Logging --->
Management --->
Networking --->
```

```
[ ] IEEE 802.15.4 drivers options ----
(UART_0) Device Name of UART Device for UART Console
[*] Console drivers --->
[ ] Net loopback driver ----
[*] Serial Drivers --->
```

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[illegible]

```
[*] NRF Clock controller support ---> <<<<<<<<<<<<<<<<<<<SELECT THIS ONE<<<<<<<<<
```



## DEBUGGING

### 16.1 debugging

#### 16.1.1 Segger JLink

The pinetime smartwatch does **not** have a serial port.  
A way around this **is** to use a Segger Jlink debug-probe **and** enable logging **and** shell\_  
↳over RTT:

**in** prj.cfg:

```
CONFIG_LOG=y  
CONFIG_USE_SEGGER_RTT=y  
CONFIG_SHELL=y  
CONFIG_SHELL_BACKEND_RTT=y
```

start the debugger :  
west debug  
**and** enter : **continue**

This starts up **in** the background "Segger Jlink Processes"

---

**Note:** What happens when you type : west debug? You could type this on the command prompt.

---

```
(this start the server)  
JLinkGDBServer -select usb -port 2331 -if swd -speed 4000 -device nRF52832_xxAA -  
↳silent -singlerun  
(this starts the debug session)  
~/zephyr-sdk/arm-zephyr-eabi/bin/arm-zephyr-eabi-gdb /root/zephyrproject/app/build/  
↳zephyr/zephyr.elf -ex target :2331 -ex halt -ex reset -ex load  
telnet 127.0.0.1 19021 (putty on linux) start the rtt console and shows the debug-log
```

## 16.1.2 Black Magic

The ds-D6 smartwatch has a serial port.

The blackmagicprobe can launch a debugger : `west debug --runnerblackmagicprobe`.  
The probe has a serial port `/dev/ttyACM1` (linux : `minicom -b 115200 -D /dev/ttyACM1`)

## 16.1.3 STM32 - Raspberry - OpenOCD

If you do **not** have a Segger debug probe nor a serial port, you can put a value **in** memory at a fixed location.  
With openocd you can peek at this memory location.  
If you own a raspberry pi **or** an orange pi, you can use the GPIO header.  
Another cheap option **is** an stm32 debug probe.

---

**Note:** `#define MY_REGISTER (*(volatile uint8_t*)0x2000F000)`

in the program you can set values: `MY_REGISTER=1; MY_REGISTER=8;`

this way you know till where the code executes

---

```
#telnet 127.0.0.1 4444
```

programming

```
once your telnet sessions started:
Trying 127.0.0.1...
Connected to 127.0.0.1.
Escape character is '^]'.
Open On-Chip Debugger
>mdw 0x2000F000 0x1
```

the last byte shows the value of your program trace value

## 16.2 The black magic probe

### 16.2.1 probes in zephyr

You can program the nrf52832 with a debuggerprobe. The standard-setup is jlink (segger).

`/root/zephyrproject/zephyr/boards/arm/id107plus/board.cmake` (adapt the runner here)

in our case : instead of jlink specify : blackmagicprobe

The cool thing about this probe that it has a serial port (3.3V) and a debug (upload) port on the same usb-port.

- `/dev/ttyACM1` is serial port (pb6 pb7)

`minicom -b 115200 -D /dev/ttyACM1`

- `/dev/ttyACM0` is used as debugger/uploading

`west debug --runner blackmagicprobe west flash --runner blackmagicprobe`

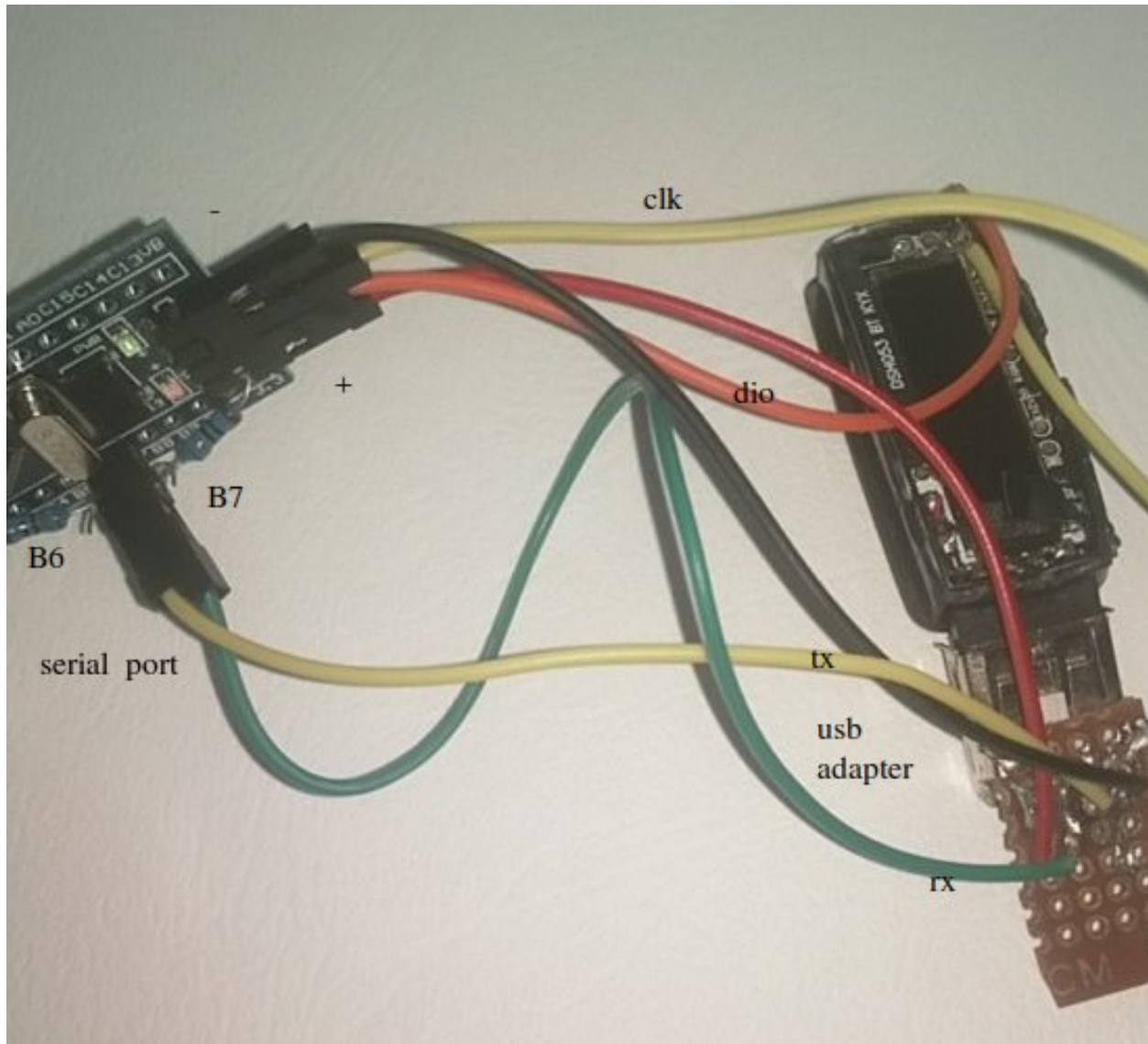
## 16.2.2 howto setup a blackmagicprobe

You can buy this probe and support the developers. (make this world a better place)

I bought a "cheapo" "blue pill" stm32 board for future projects ... soldered a 1.8K resistor between 3.3K and PA12

downloaded from <https://jeelabs.org/docs/software/bmp/> - blackmagic.bin (79 ko) - blackmagic\_dfu.bin (7 ko)

in jlink : loadbin blackmagic\_dfu.bin 0x8000000 (specify jlink no options ...) switch boot0 or boot1 or whatever  
connect usb in linux dfu-util -v -R -d 0483:df11 -s 0x08002000 -D blackmagic.bin (uploading in jlink was a problem  
cause memory restrictions)



(removed boot0 and boot1 connectors on the stm afterwards)

plugged it in the USB port and it pops up (had to enable it first in virtual box usb : black sphere technologies .....



## HACKING STUFF

### 17.1 hacking the pinetime smartwatch

The pinetime **is** preloaded **with** firmware.  
This firmware **is** secured, you cannot peek into it.

**Note:** The pinetime has a swd interface. To be able to write firmware, you need special hardware. I use a stm-link which is very cheap(2\$). You can also use the GPIO header of a raspberry pi. (my repo: <https://github.com/najnesnaj/openocd> is adapted for the orange pi)

To flash the software I use openocd : example for stm-link usb-stick

```
# openocd -s /usr/local/share/openocd/scripts -f interface/stlink.cfg -f target/nrf52.  
↪ cfg
```

example for the orange-pi GPIO header (or raspberry)

```
# openocd -f /usr/local/share/openocd/scripts/interface/sysfsgpio-raspberrypi.cfg -c 'transport select swd'  
-f /usr/local/share/openocd/scripts/target/nrf52.cfg -c 'bindto 0.0.0.0'
```

once you started the openocd background server, you can connect to it using:

```
#telnet 127.0.0.1 4444
```

programming

```
once your telnet sessions started:  
Trying 127.0.0.1...  
Connected to 127.0.0.1.  
Escape character is '^]'.  
Open On-Chip Debugger  
> program zephyr.bin  
  
target halted due to debug-request, current mode: Thread  
xPSR: 0x01000000 pc: 0x00001534 msp: 0x20004a10  
** Programming Started **  
auto erase enabled  
using fast async flash loader. This is currently supported  
only with ST-Link and CMSIS-DAP. If you have issues, add  
"set WORKAREASIZE 0" before sourcing nrf51.cfg/nrf52.cfg to disable it  
target halted due to breakpoint, current mode: Thread  
xPSR: 0x61000000 pc: 0x2000001e msp: 0x20004a10
```

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```
wrote 24576 bytes from file zephyr.bin in 1.703540s (14.088 KiB/s)
** Programming Finished **

And finally execute a reset :
>reset
```

removing write protection see: [howto flash your zephyr image](#)

## 17.2 scanning the I2C\_1 port

The pinetime does **not** have a serial port.  
I do **not** have a segger debugging probe.  
A way around this, it to put a value **in** memory at a fixed location.  
With openocd you can peek at this memory location.

### 17.2.1 Building and Running

In this repo under samples you will find an adapted i2c scanner program.

```
west build -p -b pinetime samples/drivers/i2c_scanner
```

**Note:** #define MY\_REGISTER (\*(volatile uint8\_t\*)0x2000F000)

in the program you can set values: MY\_REGISTER=1; MY\_REGISTER=8;

this way you know till where the code executes

```
#telnet 127.0.0.1 4444
```

#### Peeking

```
once your telnet sessions started:
Trying 127.0.0.1...
Connected to 127.0.0.1.
Escape character is '^]'.
Open On-Chip Debugger
>mdw 0x2000F000 0x1
0x2000f000: 00c24418
```

*Note::*

this corresponds to 0x18, 0x44 and 0xC2 (which is endvalue of scanner, so it does not detect touchscreen, which should be touched first....)

## 17.3 howto flash your zephyr image

Once you completed your west build , your image is located under the build directory

```
$ cd ~/work/pinetime/zephyr/build/zephyr
here you can find zephyr.bin which you can flash

I use Openocd to flash.
Just connect : telnet 127.0.0.1 4444

.. code-block:: console

    program zephyr.bin
```

## 17.4 howto remove the write protection

:: the PineTime watch is read/write protected (at least the one I got) executing the following : nrf52.dap apreg 1 0x0c shows 0x0

Mind you, st-link does not allow you to execute that command, for this you will need a J-link.

There is a workaround using the GPIO of a raspberry pi or an OrangePi. (in this case you won't need an external programmer at all) (You can find an example for the orange pi in my repo :<https://github.com/najnesnaj/openocd>.) You have to reconfigure Openocd with the --enable-cmsis-dap option.

Unlock the chip by executing the command: > nrf52.dap apreg 1 0x04 0x01

## 17.5 howto configure gateway

Once you completed your west build , your image is located under the build directory

```
$ cd ~/work/pinetime/zephyr/build/zephyr
here you can find zephyr.bin which you can flash
```

```
I use an orange pi single board computer.
The pinetime watch is attached to this.
My development is done on a laptop.
```

```
How can you copy from one environment (laptop) to another (SBC) without typing
↪password?
```

On the laptop :

```
ssh-keygen -b 8092 -t rsa -C "fota gw access key" -f ~/.ssh/orange
Generating public/private rsa key pair.
Enter passphrase (empty for no passphrase): (LEAVE EMPTY!)
Enter same passphrase again:
Your identification has been saved in /root/.ssh/orange.
Your public key has been saved in /root/.ssh/orange.pub.
```

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```
The key fingerprint is:
SHA256:xCM5FklLAVjEWqrM6LKM8Y6+Y12ONt6eV8vDa/KdRUM fota gw access key
The key's randomart image is:
+---[RSA 8092]-----+
|      ==+.      |
|B*B.o+. +ooo    |
+----[SHA256]-----+
```

(the standard port is 22 and not 9988 which is my custom port)

```
copy the certificate to the SBC (which name is orange in my case):
ssh-copy-id -p 9988 -i ~/.ssh/orange.pub root@orange
```

```
create config file : ~/.ssh/config
    Host orange
    HostName orange
    User root
    Port 9988
    IdentityFile ~/.ssh/orange
```

```
Now you can copy without a password :
scp build/zephyr/zephyr.bin orange:/usr/src
```

w

## 17.6 howto use 2 openocd sessions

Once you completed your west build , your image is located under the build directory

```
$ cd ~/work/pinetime/zephyr/build/zephyr
here you can find zephyr.bin which you can flash

I use Openocd to flash.
Just connect : telnet 127.0.0.1 4444

.. code-block:: console

    program zephyr.bin
```



### 17.6.1 Suppose you have 2 microcontrollers

Just connect : telnet 127.0.0.1 7777 for the second.

### 17.6.2 Howto setup a second openocd session on a different port?

In this case an ST-LINK/V2 an in-circuit debugger and programmer is used.

```
openocd -c 'telnet_port 7777' -c 'tcl_port 6667' -c 'gdb_port 3332' -s /usr/local/  
share/openocd/scripts -f interface/stlink.cfg -f target/nrf52.cfg
```

### 17.6.3 Howto use the GPIO header of a Single Board computer

This works really well, and does not require a seperate programmer.

```
openocd -f /usr/local/share/openocd/scripts/interface/sysfsgpio-raspberrypi.cfg -c  
'transport select swd' -f /usr/local/share/openocd/scripts/target/nrf52.cfg -c  
'bindto 0.0.0.0'
```

## 17.7 howto generate pdf documents

sphinx cannot generate pdf directly, and needs latex

```
apt-get install latexmk  
apt-get install texlive-fonts-recommended  
apt-get install xzdec  
apt-get install cmap  
apt-get install texlive-latex-recommended  
apt-get install texlive-latex-extra
```



## BEHIND THE SCENE

### 18.1 Behind the scene

#### 18.1.1 Overview

I'm not a zephyr expert and am learning on the way.

In this chapter I let you glimpse behind the scene. (and notice all the struggle)

In case of the accel sensor, I used the bosch bma280 as a template.

In case of the touchscreen, I soon ran into trouble. So I tried splitting a complex problem into simpler ones.

This allowed me to detect problems easier.

The created samples might be of some use, if you run into trouble or if you want to extend the functionality.

### 18.2 development trajectory

The final goal is to use the accel-sensor in the watch (BMA423), which does not exist yet. In order to minimize the effort:

- we'll use something that looks like it (ADXL372), because there exists an example.
- next we adapt it to use the existing BMA280 sensor (under drivers/sensor), so we get a sample that works with the BMA280.
- we create a driver for the BMA423, based upon the BMA280
- we adapt the sample for the BMA280 to BMA423

### 18.3 Bosch BMA280

```
west build -p -b pinetime samples/drivers/bma280
```

### 18.3.1 Overview

This sample application mimics the presence of a bosch, bma280 accel sensor. For this sensor exists a driver in zephyr, but no sample. Remember, I'm not a zephyr expert and am learning on the way.

### 18.3.2 Requirements

complement the pinetime.dts file with the following (under samples/sensor/bma280)

This will supplement / override what's already definition on the board level (boards/arm/pinetime)

```
&i2c1 {
    bma280@18 {
        compatible = "bosch,bma280";
        reg = <0x18>;
        label = "BMA280";
        int1-gpios = <&gpio0 8 0>;
    };
};
```

Create a file: `/dts/bindings/sensor/bosch,bma280-i2c.yaml`. Which contains:

```
compatible: "bosch,bma280"
include: i2c-device.yaml
properties:
  int1-gpios:
    type: phandle-array
    required: false
```

### 18.3.3 Building and Running

#### 18.3.4 Todo

- since no serial port and no J-LINK, I have to print messages to the screen (see sample gui/lvaccel)
- I adapted the BMA driver so it accepts the CHIP\_ID, further registers are subject to investigation, since no doc

#### 18.3.5 References

BMA421 is not a part number available to the general public, and therefore all the supporting documentation and design resources are neither discussed in public forums, nor disclosed on GitHub.

CHIP\_ID=0X11 (so 423 drivers need to be adapted)

## 18.4 Touchscreen Hynitron

```
git clone https://github.com/lupyuen/hynitron_i2c_cst0xxse
```

### 18.4.1 Overview

this does not exist yet in zephyr, but there is work in progress <https://github.com/zephyrproject-rtos/zephyr/pull/16119>

### 18.4.2 Requirements

complement the pinetime.dts file with the following (under samples/sensor/bma280)

```
&i2c1 {
    touch@18 {
    };
};
```

Create a file: `/dts/bindings/sensor/touch.yaml`. Which contains:

```
compatible: "touch"
include: i2c-device.yaml
properties:
  int1-gpios:
    type: phandle-array
  required: false
```

### 18.4.3 Building and Running

### 18.4.4 Todo

-create touchscreen driver -create sample

### 18.4.5 References

## 18.5 Troubleshooting drivers

Drivers, like the one for the accel sensor BMA421 or the touchscreen CST816S, can deal with interrupts.

Adapting existing drivers did not get me the desired quick results.

Even after analyzing the behaviour, setting values at each function step, did not get me any further.

## 18.5.1 Overview

The drivers can use interrupts.

In the settings/config one can choose between OWN\_THREAD and GLOBAL\_THREAD.

This affect the behaviour of how threads are handled.

The tread-handling and interrupt-handling occurs in the driver itself.

An interrupt is handled immediately, the processing is offloaded to the threading.

## 18.5.2 Example

- You touch the touchscreen
- the touchscreen generates an interrupt
- the driver handles the interrupt
- a thread is created by the interrupt
- the threadhandling read the I2C-bus

## 18.5.3 Requirements

In order to create a working driver, I took it apart :

(split a complex problem into simple problems)

### a sample to detect interrupt

`samples/basic/testirq`

Each time the touchscreen gets touched, it increases a counter.

### a sample to scan the I2C-BUS

*(scanning the I2C\_1 port),*

### a sample to read the I2C-BUS

`samples/basic/touched` It is based on the Hynitron touchscreen code. Mass reading 63 bytes was not possible.

I did add a write of 1 to register 0x00.

## a samples to handle semaphores

`samples/basic/testsemaphore`

## 18.6 placing a button on the screen

This sample **is not** really important, but it will teach you that you need to **set** LVGL\_↪CONFIG values, **in** order to be able to use LVGL functions.

### 18.6.1 Building and Running

In this repo under samples you will find an adapted gui/clock program. A button from the LVGL library is placed on the screen.

Later on when the touch-screen driver is ready, we'll be able to manipulate it.

Make sure that `prj.conf` file in clock directory contains the following:

**Note:** `CONFIG_LVGL_OBJ_CONTAINER=y` `CONFIG_LVGL_OBJ_BUTTON=y`

*problem* the canvas height\*width eats up RAM and exceeds once > 40





## ABOUT

I got a pinetime development kit very early. I would like to thank the folks from <https://www.pine64.org/> for the kit.

The Nordic nrf52832 is an Arm based, 32bit microcontroller with a lot of flash, RAM memory and(!) bluetooth! It is a good platform to explore the wonderfull world of opensource RTOS's. I choose the Zephyr platform, because it already contained the display driver, and the bluetooth functionality. Furthermore it can be updated wirelessly.

I started of with adapting simple samples, so they would run on the pinetime watch. Meanwhile I learned how to adapt the board definition file. Gradually this morphed into a pinetime-toolkit. A few experts contributed and improved this kit so it became usable.

I took a long break from this project, zephyr evolved and a project for creating an open source watch, the hypnos firmware flourished.

The drivers for the heartrate sensor, touchpanel that I adapted, became obsolete. The pinetime board definition file is now part of the zephyr RTOS distribution.

Recently I discovered that the standard focaltech touchscreen driver could be adapted easily so it would run on the pinetime and integrate nicely with the LVGL-gui. There were several OLED ssd1306 watches on my desk and I wondered if I could run Zephyr and LVGL (graphical stuff) on them as well. (yes, we can!) I played around with the "native\_posix\_64" board, which is a virtual board that allows you to run firmware on your computer instead of on the watch (no need for flashing).

This gave me the idea for an opensource-watch-framework.

A word of warning: this **is** work **in** progress.  
You're likely to have a better skillset than me.  
You are invited to add the missing pieces **and** to improve what's already there.