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STM32F407VE,

TFT ILI9486.

: Proteus,

IDE Eclipse, STM32CubeMX,

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1		09.11.21-12.11.21	
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3		17.11.21-24.11.21	
4		25.11.21-30.11.21	
5	,	01.12.21-09.12.21	
6		10.12.21-12.12.21	
7		13.12.21	

08 2021 .

The diagram consists of a horizontal line. Above the line, there is a bracket labeled  $( \quad )$ . Below the line, there is a vertical line segment on the left, and three dots on the right. Below the line, there is a bracket labeled  $( \quad , \quad , \quad )$  and three dots on the right.

: 78 ., 32 ., 6 .,

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, DSP, EMG, , , ,  
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## ABSTRACT

Master's thesis: 78 pages, 32 figures, 6 tables, 1 appendix, 21 sources.

DSP, EMG, MICROCONTROLLER, AMPLIFIER, MEASUREMENT, FILTER, OPERATING SYSTEM, BIOPOTENTIAL, BIOSIGNAL, MYOGRAPHY.

The major goal of this thesis is the development of software and hardware for reading myograms.

During the qualification work, a general review of the anatomical features of the structure of the muscular system was performed, the classification of methods for determining muscle activity was considered, the basic principles of surface electromyography were described, and modern devices for measuring surface electromyogram were analyzed. In addition, the functional and electrical circuit of the portable electromyograph was designed, its circuit components were selected, and software for the microcontroller was developed.

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1.8				25
1.9				26
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2.2				29
2.3				38
2.4				39
3				43
3.1				43
3.2				44
3.3				47
3.4				50
3.5				53
3.6				65

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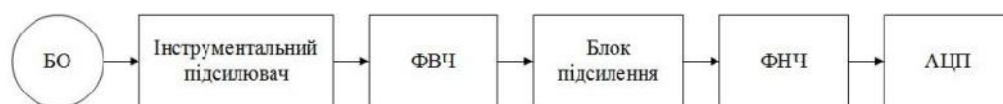
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The MyoTrace 400,

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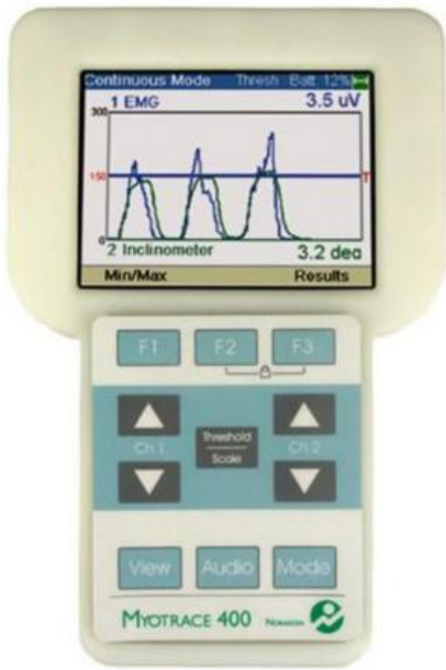
Noraxon



MyoTrace

MyoTrace 400

MyoResearch



1.4 – The MyoTrace 400

Bluetooth MyoTrace 20

sEMG

: Onset, Averaged profiles Frequency analysis.

Shimmer’s wearable sensor platform,

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1.3– «The MyoTrace 400»

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1.5 – Shimmer’s wearable sensor platform

ConsensysPRO,  
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1.4– «Shimmer’s wearable sensor platform»

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Shimmer #,  
Java Android, L LabVIEW.

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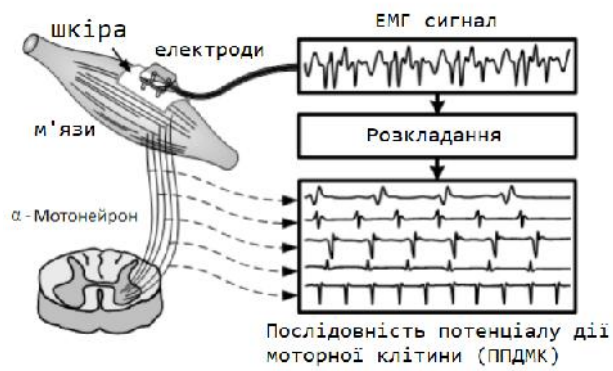
sEMG

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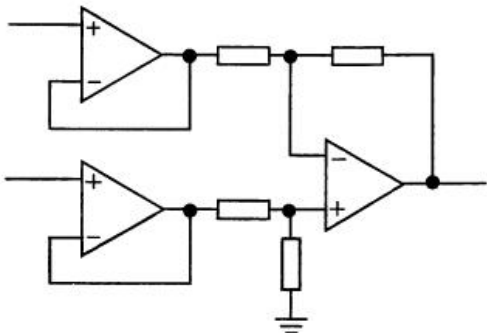
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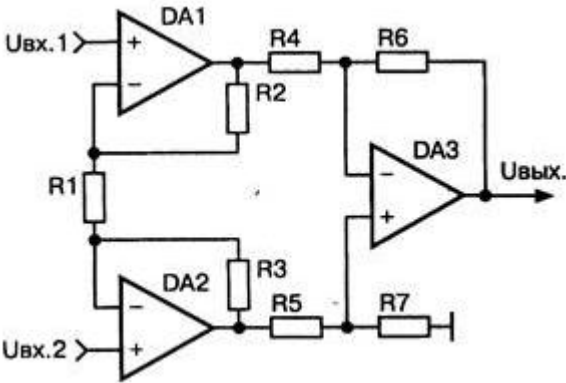
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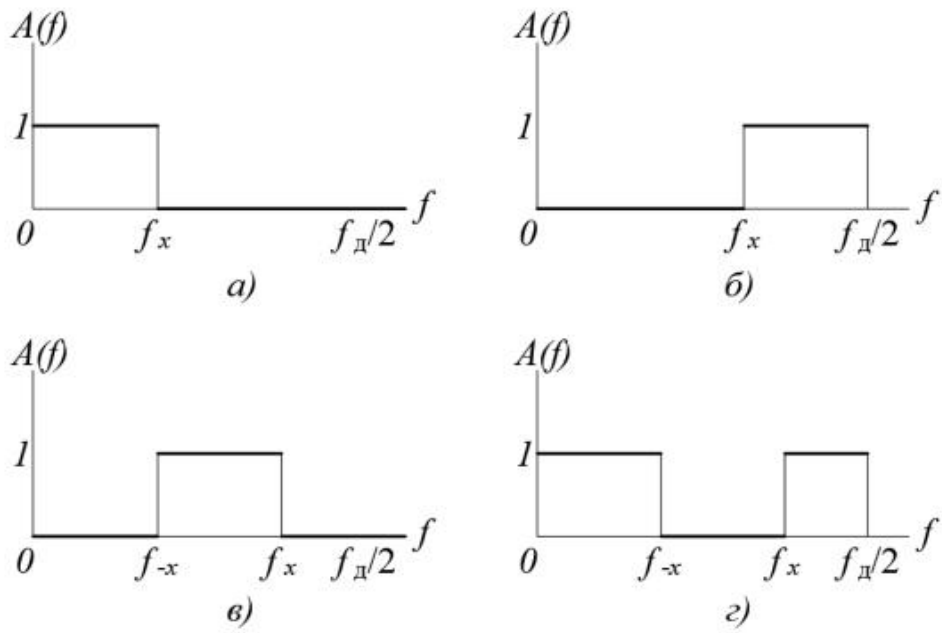
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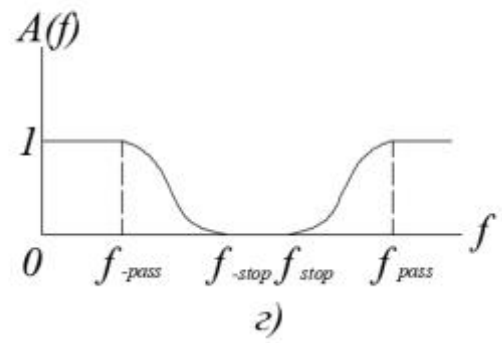
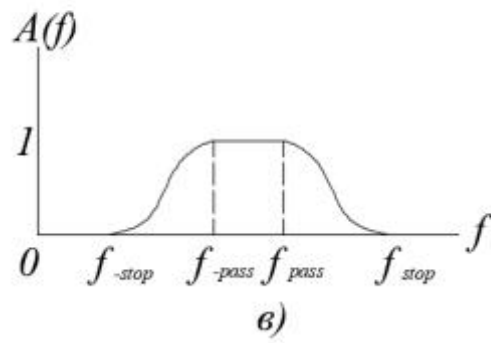
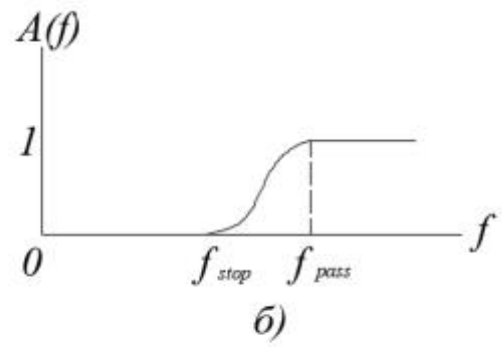
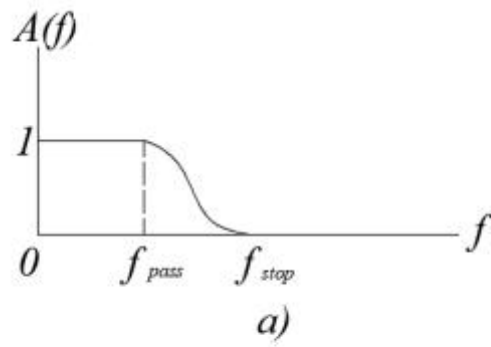
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( 2.4 ) ( 2.4 )  
 $f_x$ ,  
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 $-f_x$   $f_x$  .  
 $f_{\text{д}}/2$ .  
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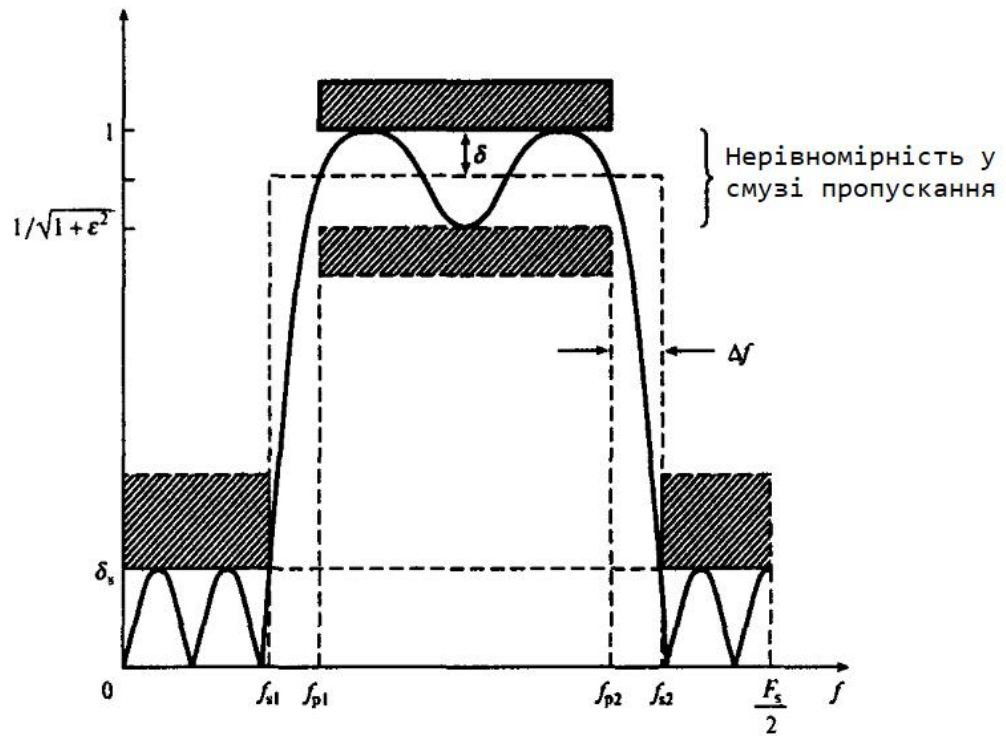


2.5 –  $\frac{1}{2} \left( \frac{1}{2} + \frac{1}{2} \right) = \frac{1}{2}$  ; )

$$\begin{aligned} & \cdot \\ & \vdots \\ & ( \quad - \quad ) \\ & ( \quad - \quad ). \end{aligned}$$







2.6 –

$\epsilon^2 -$  ;  
 $\delta_p -$  ;  
 $\delta_s -$  ;  
 $f_{p1} \quad f_{p2} -$  ;  
 $f_{s1} \quad f_{s2} -$  .  
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 :

$$H(z)=\frac{\sum_{i=0}^{N-1}b_i z^{-i}}{1+\sum_{k=1}^{M-1}a_k z^{-k}},\tag{3.1}$$

$$b_i, a_k = \left( \begin{array}{c} \vdots \\ \vdots \end{array} \right),$$

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$$b_i, \ a_k, \qquad \qquad \qquad ,$$

$$, \qquad \qquad \qquad , \qquad \qquad \qquad .$$

$$, \qquad \qquad \qquad (3.1)$$

:

$$H(z)=\frac{K(z-z_1)(z-z_2)...\hspace{0.1cm}(z-z_n)}{(z-p_1)(z-p_2)...\hspace{0.1cm}(z-p_M)},\tag{3.2}$$

$$z_1, z_2, \ldots = \hspace{0.5cm} H(z), \hspace{0.5cm} p_1, p_2, \ldots = \hspace{0.5cm} H(z).$$

$$\left( \hspace{0.5cm} 2.7 \hspace{0.5cm} \right). \hspace{0.5cm} , \hspace{0.5cm} ,$$

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$$\omega_s$$

$$\left( \hspace{0.5cm} \right). \hspace{0.5cm} , \hspace{0.5cm} , \hspace{0.5cm} \omega_s$$

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$$\left( \hspace{0.5cm} 2.7 \hspace{0.5cm} \right).$$

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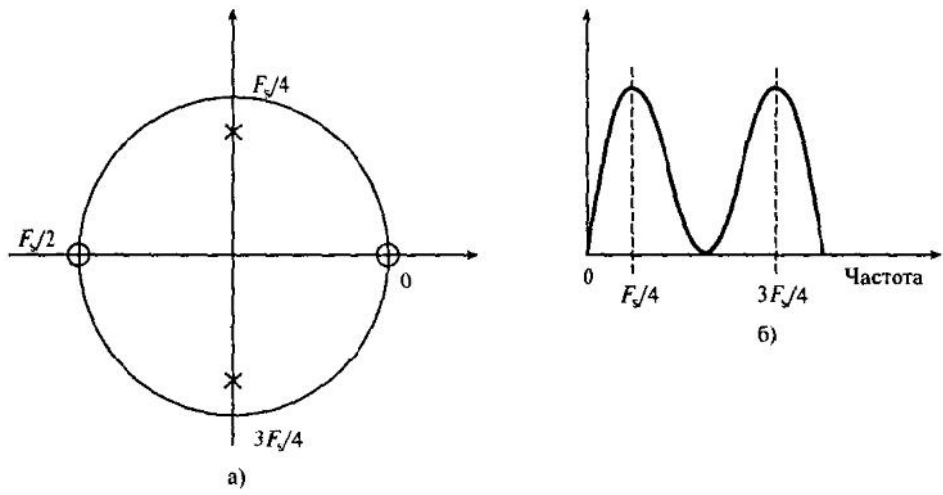
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Computer Science Research Center of Bell Laboratories

At&t 1972 . «C»

PDP11 DEC UNIX.

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C++, C#, Java, PHP .

## 2.4

Eclipse – ,

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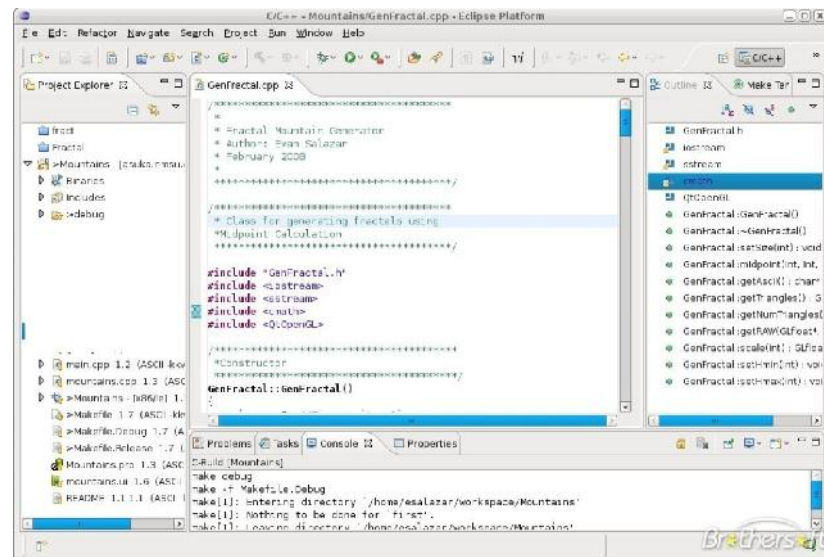
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Eclipse Java,

Java,

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## 2.8 – IDE Eclipse

PROTEUS –

Pspice.

PROTEUS

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SPICE

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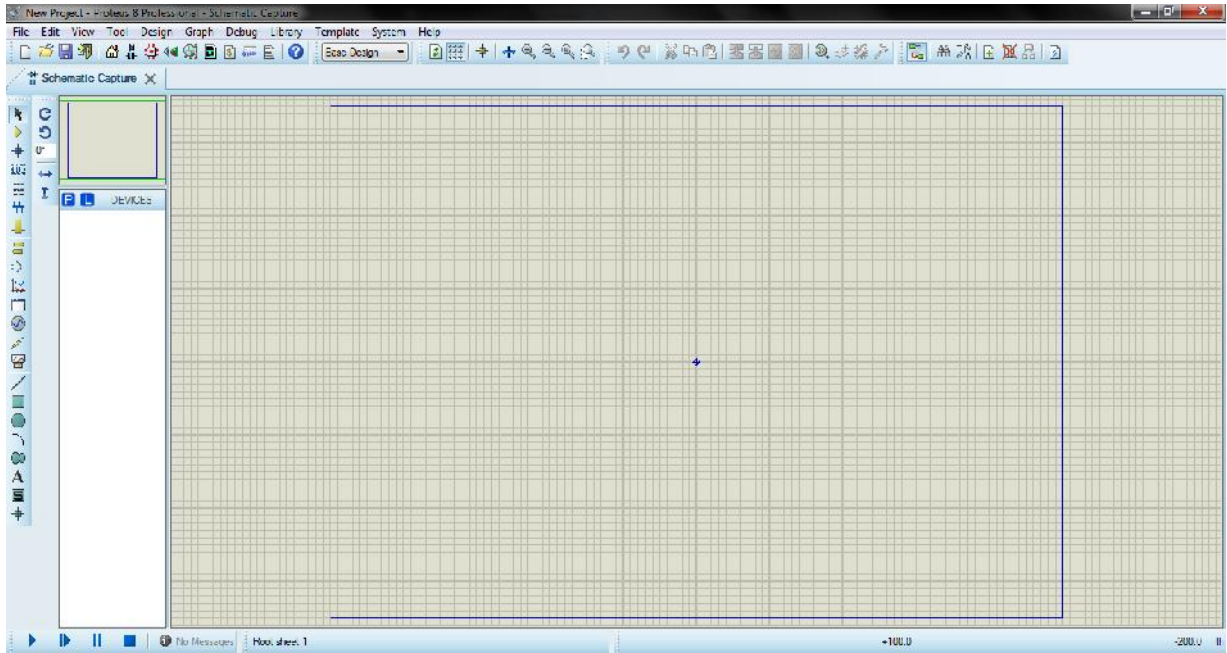
, USARTs

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## 2.9.





2.9 – Proteus

STM32CubeMX.

STM32CubeMX

STM32,

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STMicroelectronics

STM32CubeMX

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STM32,

ARM Cortex.

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. STM32CubeMX

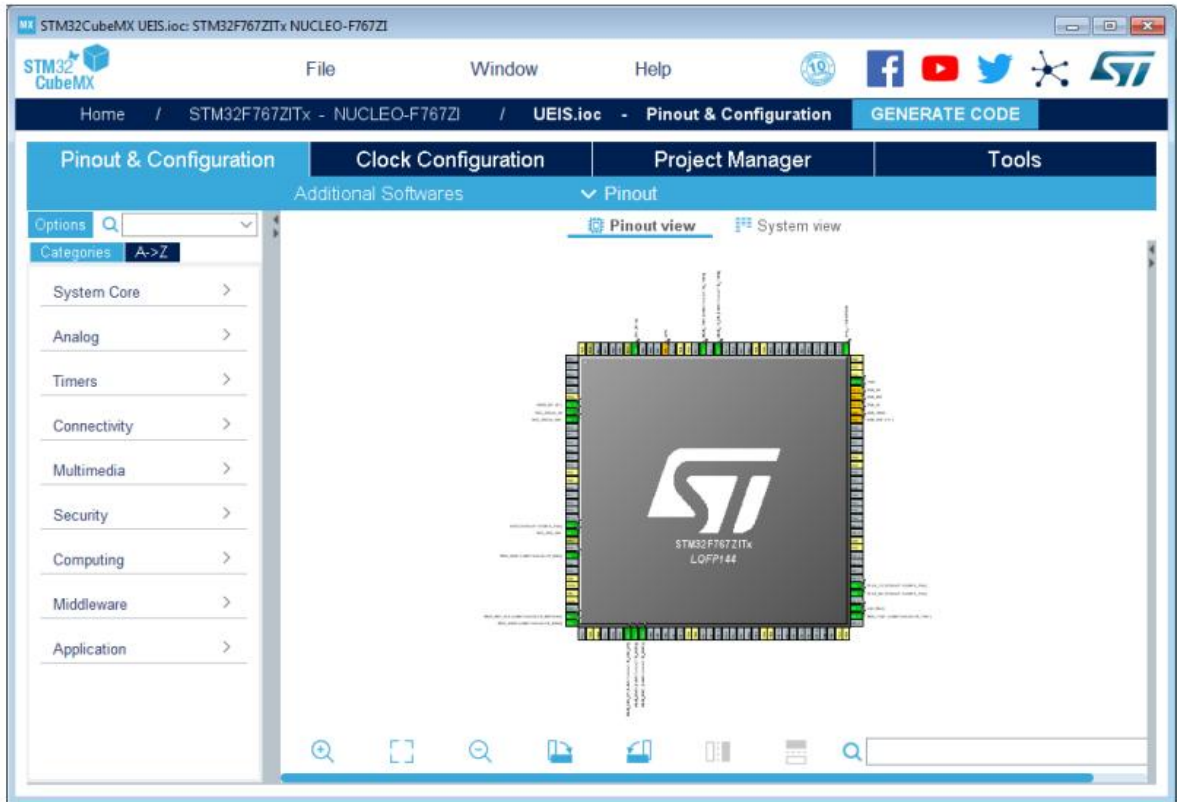
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STM32CubeMX

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STM32CubeMX,

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3.3.

$$K_{\Pi} = \frac{U_{\text{ВНХ}}}{U_{\text{ВХ}}}$$

(3.3)

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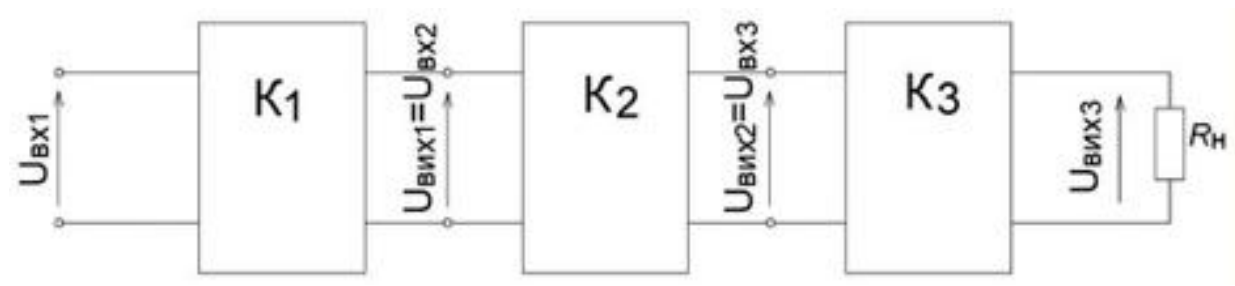
$$K_{\Pi} = \frac{3,3}{0,001} = 3300.$$

(3.4)

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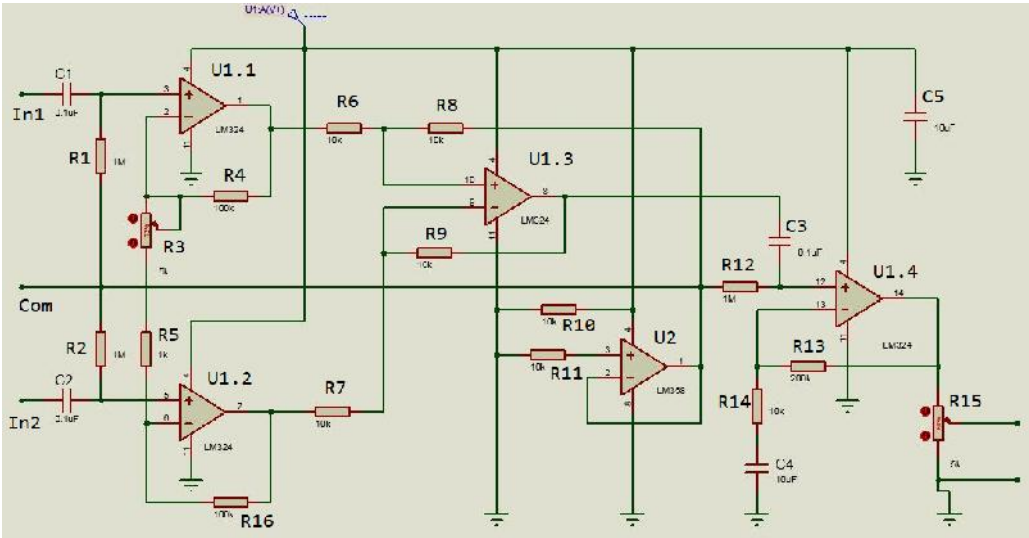
( 3.4).



3.2 –

$$K = K_1 \times K_2 \times K_3. \tag{3.5}$$

3.3.



3.3 –

$U_2$  2  
: 1 – U1.1, U1.2, U1.3, – U1.4.

$$K_{\Pi'} = \left(1 + \frac{R4 + R16}{R3 + R5}\right) \times \frac{R9}{R7} = \left(1 + \frac{100000 + 100000}{1000}\right) \times \frac{10000}{10000} = 201 \quad (3.6)$$

:

$$K_{\Pi''} = \left(1 + \frac{R13}{R14}\right) = \left(1 + \frac{200000}{10000}\right) = 21 \quad (3.7)$$

:

$$K = K_{\Pi} \times K_{\Pi'} = 201 \times 21 = 4221. \quad (3.8)$$

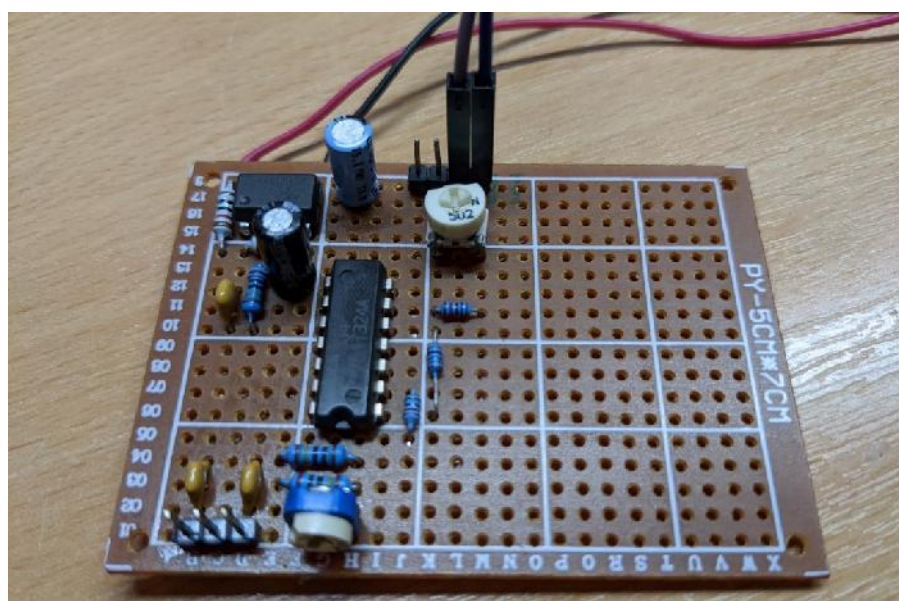
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$360^\circ \times 50 / 500 = \pm 36^\circ.$

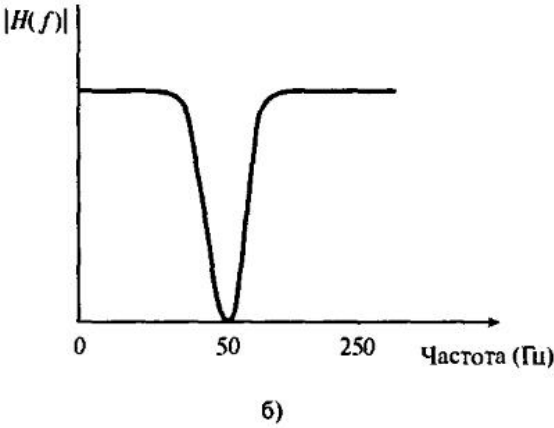
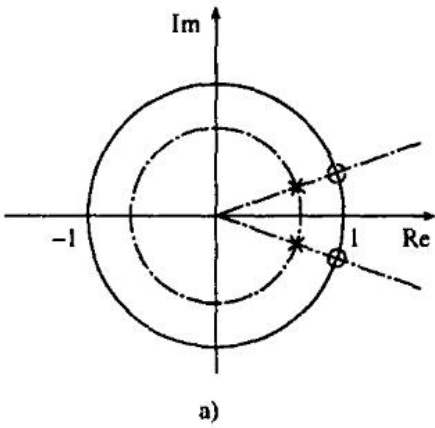
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$r < 1$  ( 3.5).



3.5 -

$r > 0.9$

$$r = 1 - (10 / F_s) \pi, \tag{3.9}$$

$$- \qquad \qquad \qquad , F_s - \qquad \qquad \qquad .$$

$$r = 1 - (10 / 500) \times 3.14 = 0,9372.$$

$$\frac{[z - \exp(-i36^\circ)][z - \exp(i36^\circ)]}{[z - 0,937\exp(-36^\circ)][z - 0,972\exp(36^\circ)]} = \tag{3.10}$$
$$\frac{z^2 - 1,6180z + 1}{z^2 - 1,5164z + 0,8783} = \frac{1 - 1,6180z^{-1} + z^{-2}}{1 - 1,5164z^{-1} + 0,8783z^{-2}}.$$

$$,$$
$$,$$

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$$y(n) = \sum_{k=0}^N a_k x(n-k) - \sum_{k=1}^M b_k y(n-k), \tag{3.11}$$

$$x(n) = \qquad \qquad \qquad , \quad y(n) = \qquad \qquad \qquad , \quad y(n-k) = \qquad \qquad \qquad , \quad a_k, b_k = \qquad \qquad \qquad .$$

:

$$a_k x(n) \leftrightarrow a_k X(z), \quad a_k x(n-k) \leftrightarrow a_k z^{-k} X(z). \tag{3.12}$$

$$, \tag{3.10} \qquad \qquad \qquad :$$



$$Y(z) = \sum_{k=0}^N a_k z^{-k} X(z) - \sum_{k=0}^M b_k z^{-k} Y(z). \quad (3.13)$$

$$H(z) = \frac{Y(z)}{X(z)} = \frac{\sum_{k=0}^N a_k z^{-k}}{1 + \sum_{k=0}^M b_k z^{-k}}. \quad (3.14)$$

$$(3.10) \quad (3.1), \quad :$$

$$y(n) = x(n) - 1,6180x(n-1) + x(n-2) + 1,5164y(n-1) - 0,8783y(n-2).$$

$$: b_0 = 1, b_1 = -1,6180, b_2 = 1, a_1 = -1,5164, a_2 = 0,8783.$$

$$(3.1)$$

3.1 –

```
double mio_processInput(double in)
{
    static double x1 = 0, x2 = 0;
    static double y1 = 0, y2 = 0;

    double y0 = (in - 1.6180 * x1 + x2) + 1.5164 * y1 - 0.8783 *
y2;

    x2 = x1;
    x1 = in;

    y2 = y1;
    y1 = y0;

    return y0;
}
```

## 3.4

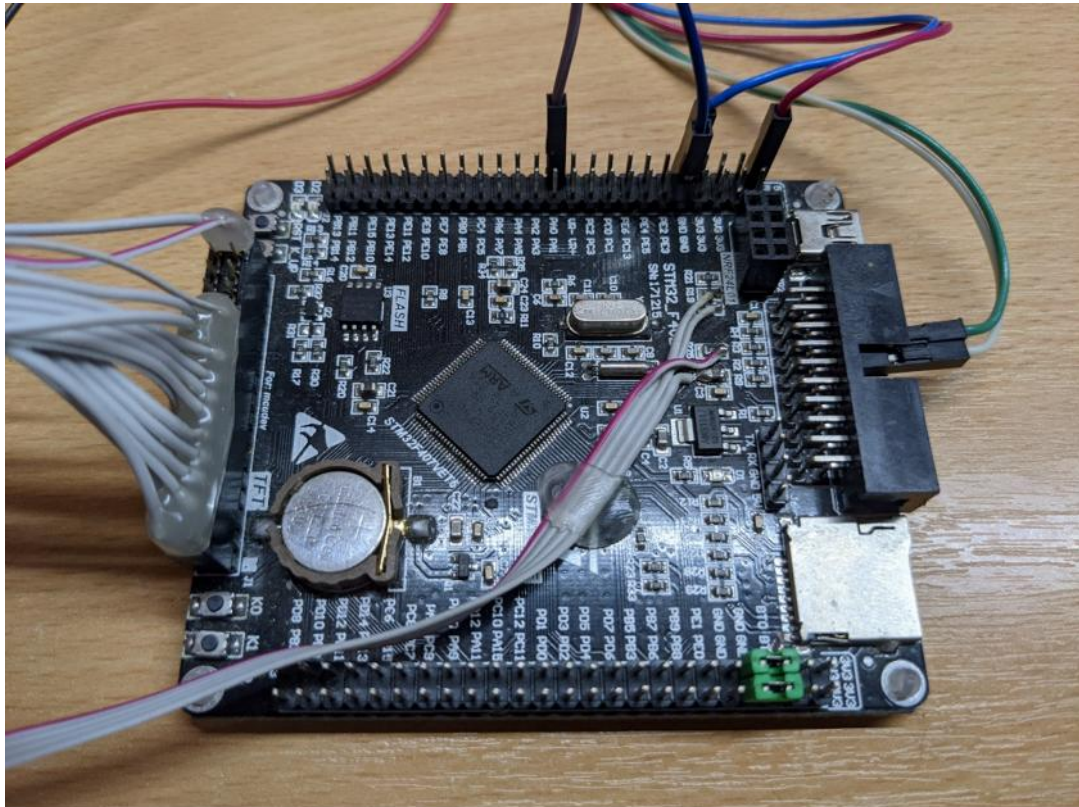
HA17358A, STM32F407VET6, HA17324A, TFT, ILI9486. HA17324A HA17358A, , . , 32- STMMicroelectronics STM32F4. STM32F4 . STM32F4 Cortex– . STM32F4: - 32- Cortex– 4F, DSP– FPU; - 168 , 210 DMIP FLASH; - 1 FLASH ’ ; - 196 SRAM + 64 SRAM ; - 16 DMA , FIFO, ; - ’ LCD, FSMC; - ’ SD, SDIO; - 4 SRAM; - 17- 32/16– , - 3- 12- , 24 , 2.4 , 7.2 12- ; - USB 2.0 Hs/fs OTG USB 2.0 FS OTG; - 10/100 Ethernet MAC;

- 6 x USART, 2 x CAN, 3 I2C, 3 x SPI I2S

( 3.5) 32-

STM32F407VET6 ( ARM Cortex M4).

168 .



3.5 – STM32F407VE

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( 3.6)

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- 3,5 ;
- : 480 320;

- : LCD TFT;
- : 65536;
- : ILI9486;
- : Intel 8080 parallel interface.



3.6 –

ILI9486

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: MCU RGB.

MCU : Intel-8080

Motorola-6800.

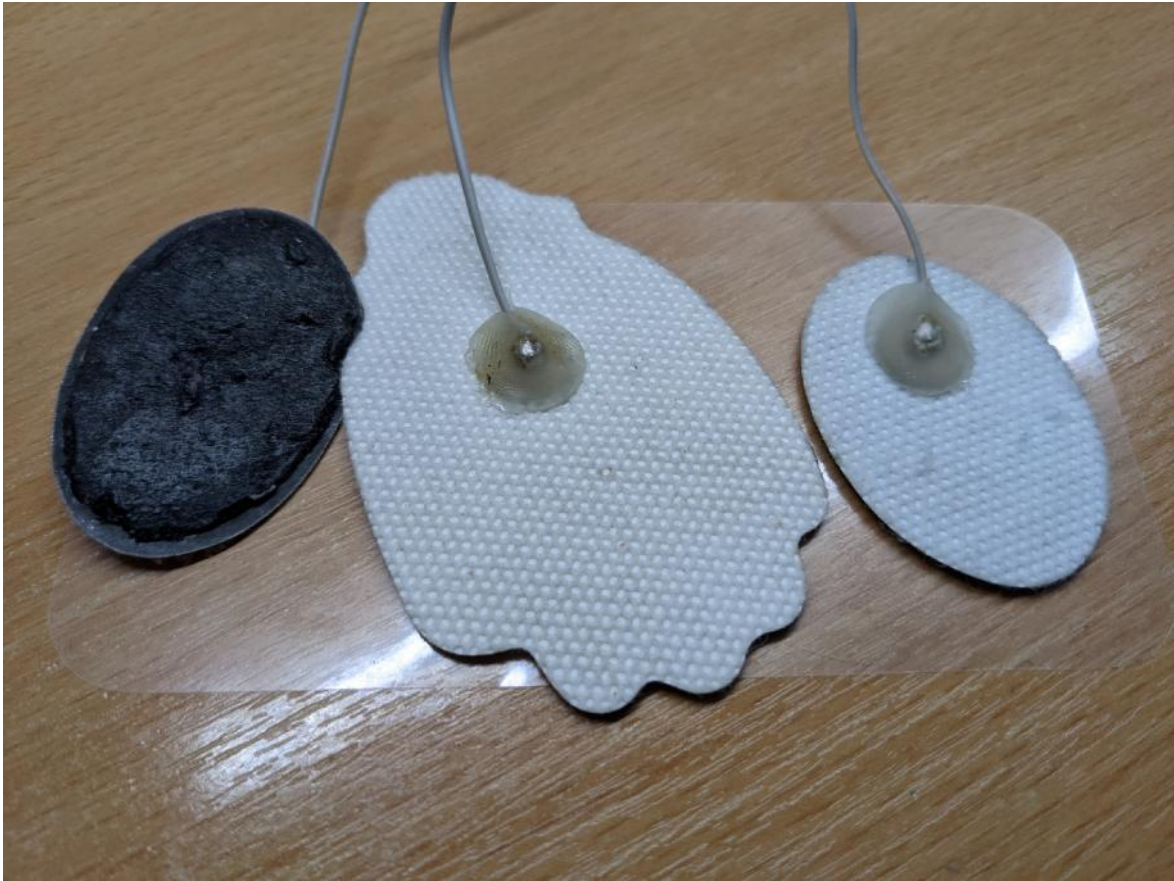
MCU 8/16 bit

FSMC

STM32F407.

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3.7 –

3.5

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, Cmake. CMake  
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CMakeLists.txt ( 3.2),

CMake.

3.2 – – CMakeLists.txt

```
cmake_minimum_required(VERSION 3.15)

project("${TestProj}")

add_subdirectory(${CMAKE_CURRENT_SOURCE_DIR}/drivers)
add_subdirectory(${CMAKE_CURRENT_SOURCE_DIR}/freertos)
add_subdirectory(${CMAKE_CURRENT_SOURCE_DIR}/fatfs)
add_subdirectory(${CMAKE_CURRENT_SOURCE_DIR}/lcd)

add_executable(
    ${PROJECT_NAME}
    main.c
    mio.c
)

target_link_libraries(
    ${PROJECT_NAME} PUBLIC

    stm32f4-std-perif
    freertos
    fatfs
    lcd
)
```

project(\${PROJECT\_NAME}).

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CMakeLists.txt,

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CMakeLists.txt,

add\_subdirectory ,

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CMakeLists.txt
add_subdirectory(${CMAKE_CURRENT_SOURCE_DIR}/drivers).

add_executable. PROJECT_NAME
CMake.
HEADERS, SOURCES
. add_executable(${PROJECT_NAME} ${HEADERS}
${SOURCES} )
target_link_libraries
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drivers.
CMSIS SPL.
Cortex – cortex Microcontroller
SoftwareInterface Standard (CMSIS).
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CMSIS,
CMSIS SPL
(StandardPeripheralsLibrary),
STMicroelectronics

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Cortex – , .

## HAL (Hardware Abstraction Layer)

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SPL

SPL –

CMSIS:

STM32F2xx 3

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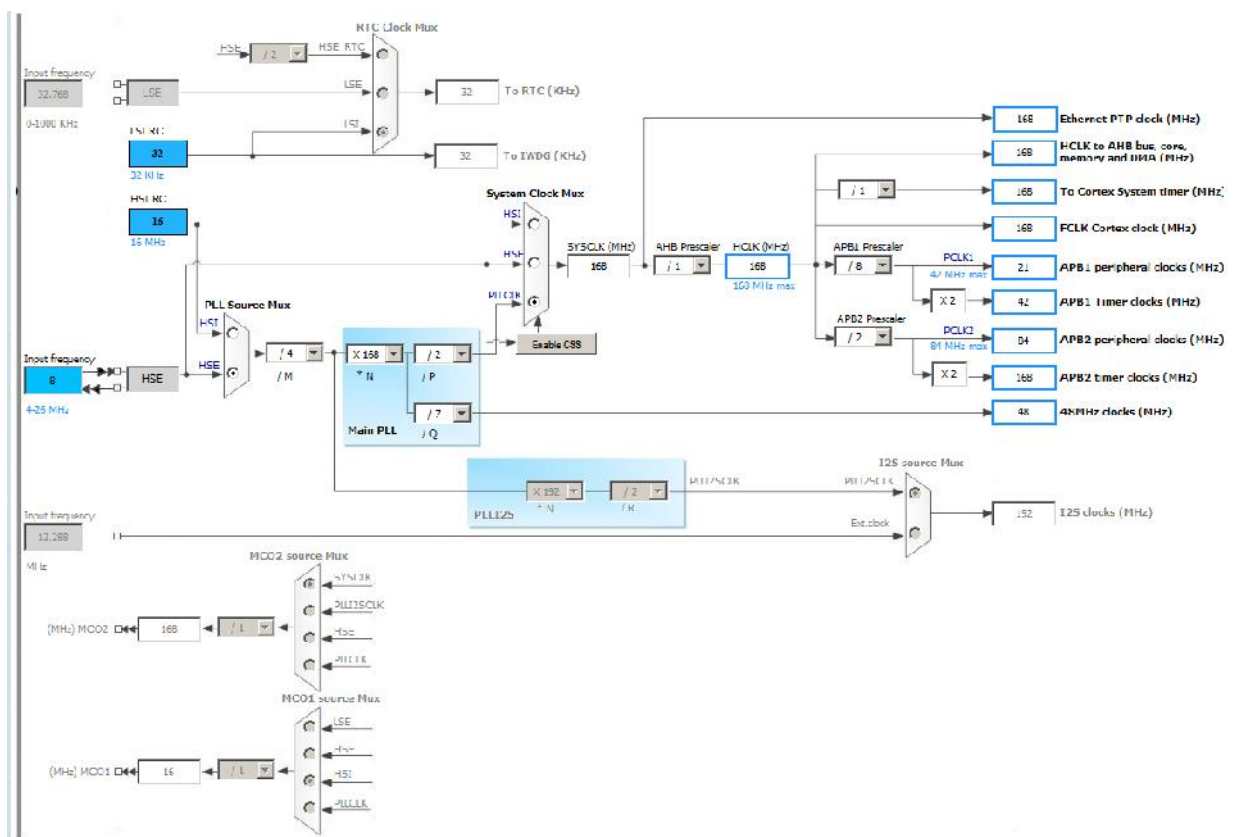
```

#define configUSE_MUTEXES 1
#define configQUEUE_REGISTRY_SIZE 8
#define configCHECK_FOR_STACK_OVERFLOW 2
#define configUSE_RECURSIVE_MUTEXES 1
#define configUSE_MALLOC_FAILED_HOOK 1
#define configUSE_APPLICATION_TASK_TAG 0
#define configUSE_COUNTING_SEMAPHORES 1
#define configGENERATE_RUN_TIME_STATS 0

```

FSMC.

3.9.



3.9 –

STM32F407VE

3.4

## 3.4 –

```

static void initHardware(void)
{
    RCC_DeInit();
    RCC_HSEConfig(RCC_HSE_ON);
    ErrorStatus eL_status = RCC_WaitForHSEStartUp();
    RCC_HCLKConfig(RCC_SYSCLK_Div1);
    RCC_PCLK2Config(RCC_HCLK_Div2);
    RCC_PCLK1Config(RCC_HCLK_Div4);
    RCC_PLLConfig(RCC_PLLSource_HSE, 4, 168, 2, 4);
    RCC_PLLCmd(ENABLE);

    while ((RCC->CR & RCC_CR_PLLRDY) == 0);
    FLASH->ACR = FLASH_ACR_PRFTEN | FLASH_ACR_ICEN | FLASH_ACR_DCEN
    | FLASH_ACR_LATENCY_5WS;
    RCC_SYSCLKConfig(RCC_SYSCLKSource_PLLCLK);
    while ((RCC->CFGR & (uint32_t)RCC_CFGR_SWS) !=
    RCC_CFGR_SWS_PLL);
}

,

.

mio_initMeasureModule(),

```

## 3.5

## 3.5 –

```

void mio_initMeasureModule(void)
{
    RCC_AHB1PeriphClockCmd(RCC_AHB1Periph_GPIOA, ENABLE);
    GPIO_InitTypeDef GPIO_InitStructure;
    GPIO_InitStructure.GPIO_Pin = GPIO_Pin_0;
    GPIO_InitStructure.GPIO_Mode = GPIO_Mode_AN;
    GPIO_InitStructure.GPIO_PuPd = GPIO_PuPd_NOPULL;
    GPIO_Init(GPIOA, &GPIO_InitStructure);
    RCC_APB2PeriphClockCmd(RCC_APB2Periph_ADC1, ENABLE);
    ADC_InitTypeDef adcInit;
    adcInit.ADC_ScanConvMode = DISABLE;
    adcInit.ADC_ContinuousConvMode = ENABLE;
    adcInit.ADC_DataAlign = ADC_DataAlign_Right;
    adcInit.ADC_ExternalTrigConv = ADC_ExternalTrigConv_T1_CC1;
    adcInit.ADC_ExternalTrigConvEdge =
    ADC_ExternalTrigConvEdge_None;
    adcInit.ADC_NbrOfConversion = 1;
    adcInit.ADC_Resolution = ADC_Resolution_12b;
    ADC-RegularChannelConfig(ADC1, ADC_Channel_0, 1,

```

```

ADC_SampleTime_112Cycles);
    ADC_Init(ADC1, &adcInit);
    ADC_Cmd(ADC1, ENABLE); //enable ADC1
    ADC_SoftwareStartConv(ADC1);
}

```

## STM32

```

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ADC_GetConversionValue(ADC1), 0 4095
, 12
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,
xTaskCreate() ( 3.6),
,

```

### 3.6 –

```

int main(void)
{
    initHardware();
    xTaskCreate(mainThread, "mainThread", 10000, NULL, 1,
NULL);
    vTaskStartScheduler();
    return 0;
}

```

- Running.

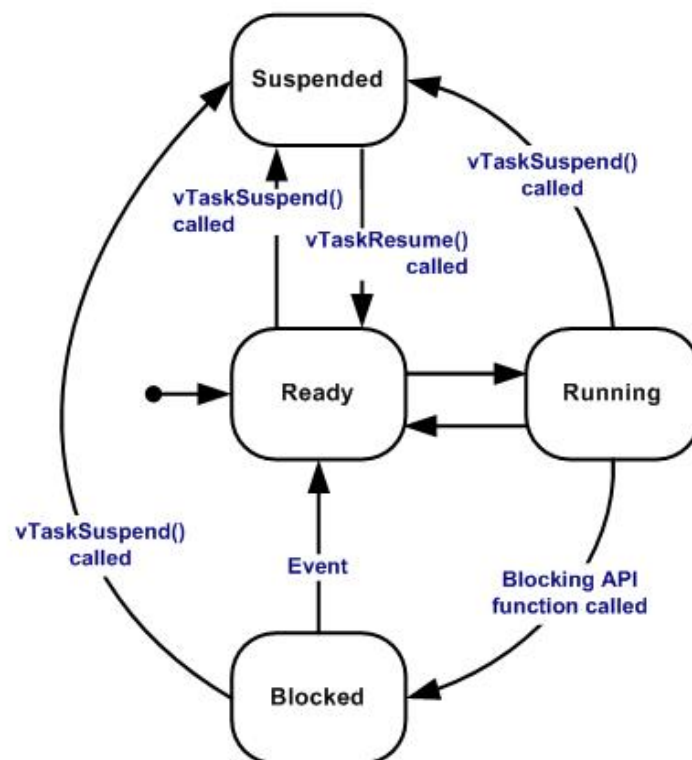
Running.

Running.

- Ready. — , ( «Blocked» «Suspended»), , «Running».

- Blocked. , . , vTaskDelay(), ( «Blocked»), — . , , «Blocked» « — », , , .

- Suspended. , «Blocked» «Suspended», «Running», «Suspended» — . , API vTaskSuspend() xTaskResume() .



3.10.

3.7.

3.7 –

```

void ili9486_initDisplay(void)
{
    RCC_AHB1PeriphClockCmd(RCC_AHB1Periph_GPIOD |
    RCC_AHB1Periph_GPIOE, ENABLE);
    ... GPIO_Init(GPIOE, &GPIO_InitStructure);
    ... RCC_AHB3PeriphClockCmd(RCC_AHB3Periph_FSMC, ENABLE);
        fsmcTiming.FSMC_AddressSetupTime = 0x02;
        fsmcTiming.FSMC_AddressHoldTime = 0x00;
        fsmcTiming.FSMC_DataSetupTime = 0x05;
        FSMC_NORSRAMInit(&fsmc);
        FSMC_NORSRAMCmd(FSMC_Bank1_NORSRAM1, ENABLE);

        ili9486_writeCmd(ILI9486_PIXFMT); // Interface Pixel
        Format, 16 bits / pixel
        ili9486_writeData(0x05);
        ili9486_writeCmd(ILI9486_MADCTL); // Set rotation
        ili9486_writeData(0xA8);
        ili9486_writeCmd(ILI9486_INVCTR); // Display Inversion
        Control
        ili9486_writeData(0x01); // 1 dot inversion
        ili9486_writeCmd(ILI9486_DFUNCTR); // Display Function
        Control
        ili9486_writeData(0x02);
        ili9486_writeData(0x22);
        ili9486_writeData(0x3B);
        ili9486_writeCmd(ILI9486_SLPOUT); // Sleep OUT
        vTaskDelay(pdMS_TO_TICKS(150));
        ili9486_writeCmd(ILI9486_DISPON); // Display ON
}

```

FSMC,

FSMC

4





```

while (1)
{
    double value = ADC_GetConversionValue(ADC1) - 2048;
    ili9486_chartAppendValue(mio_processInput(value / 12.8),
BLUE);
    vTaskDelay(pdMS_TO_TICKS(2));
}
}

```

3, 500 ,

$1 / 500 = 0.002$

· , ,

«Blocked», «Running».

vTaskDelay(pdMS\_TO\_TICKS(2));

3.6

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3.13.

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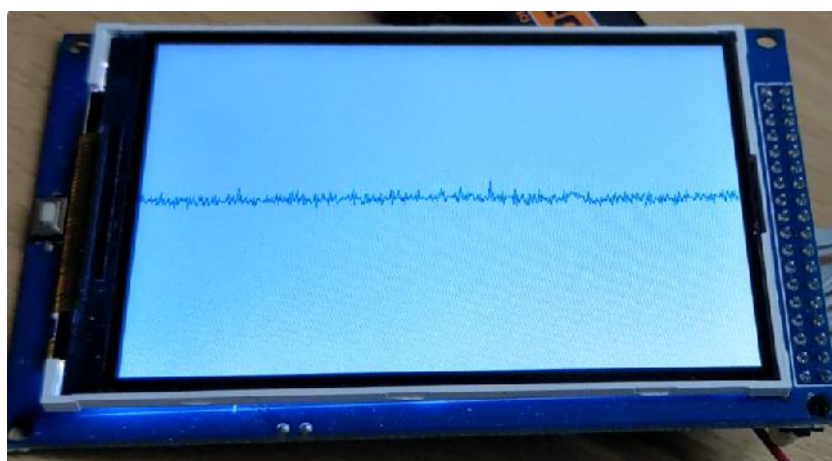
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( 3.14).



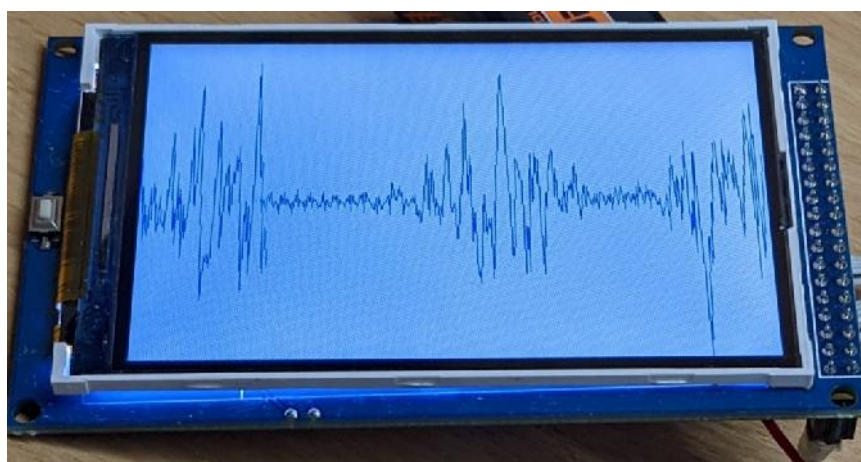
3.13 –

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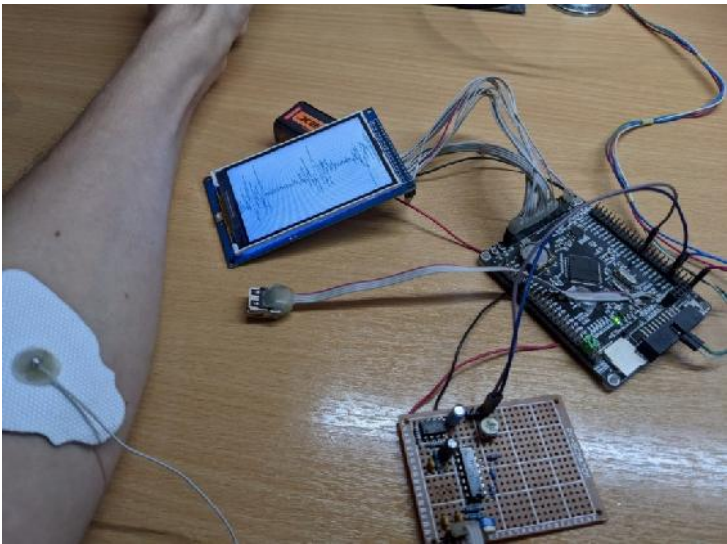
3.14 –

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3.15 –

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3.16 –

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3.16

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19.  $\frac{1}{2} \cdot \frac{1}{3} = \frac{1}{6}$   $\frac{1}{6} \cdot \frac{1}{4} = \frac{1}{24}$   $\frac{1}{24} \cdot \frac{1}{5} = \frac{1}{120}$   $\frac{1}{120} \cdot \frac{1}{6} = \frac{1}{720}$   $\frac{1}{720} \cdot \frac{1}{7} = \frac{1}{5040}$   $\frac{1}{5040} \cdot \frac{1}{8} = \frac{1}{40320}$   $\frac{1}{40320} \cdot \frac{1}{9} = \frac{1}{362880}$   $\frac{1}{362880} \cdot \frac{1}{10} = \frac{1}{3628800}$   $\frac{1}{3628800} \cdot \frac{1}{11} = \frac{1}{39916800}$   $\frac{1}{39916800} \cdot \frac{1}{12} = \frac{1}{479001600}$   $\frac{1}{479001600} \cdot \frac{1}{13} = \frac{1}{6227020800}$   $\frac{1}{6227020800} \cdot \frac{1}{14} = \frac{1}{87178291200}$   $\frac{1}{87178291200} \cdot \frac{1}{15} = \frac{1}{1307674368000}$   $\frac{1}{1307674368000} \cdot \frac{1}{16} = \frac{1}{20922790016000}$   $\frac{1}{20922790016000} \cdot \frac{1}{17} = \frac{1}{355687430272000}$   $\frac{1}{355687430272000} \cdot \frac{1}{18} = \frac{1}{6402373744992000}$   $\frac{1}{6402373744992000} \cdot \frac{1}{19} = \frac{1}{121645091154848000}$   $\frac{1}{121645091154848000} \cdot \frac{1}{20} = \frac{1}{2432901823096960000}$   $\frac{1}{2432901823096960000} \cdot \frac{1}{21} = \frac{1}{51090938285035136000}$   $\frac{1}{51090938285035136000} \cdot \frac{1}{22} = \frac{1}{1124000642270772992000}$   $\frac{1}{1124000642270772992000} \cdot \frac{1}{23} = \frac{1}{25852014772227778816000}$   $\frac{1}{25852014772227778816000} \cdot \frac{1}{24} = \frac{1}{620448354533466691776000}$   $\frac{1}{620448354533466691776000} \cdot \frac{1}{25} = \frac{1}{15511208863336667294400000}$   $\frac{1}{15511208863336667294400000} \cdot \frac{1}{26} = \frac{1}{403291430446753349654400000}$   $\frac{1}{403291430446753349654400000} \cdot \frac{1}{27} = \frac{1}{10888828622052339430668800000}$   $\frac{1}{10888828622052339430668800000} \cdot \frac{1}{28} = \frac{1}{304907201417465504058726400000}$   $\frac{1}{304907201417465504058726400000} \cdot \frac{1}{29} = \frac{1}{8842308841106499617703065600000}$   $\frac{1}{8842308841106499617703065600000} \cdot \frac{1}{30} = \frac{1}{26526926523319498853109196800000}$   $\frac{1}{26526926523319498853109196800000} \cdot \frac{1}{31} = \frac{1}{822334722232904464506385097600000}$   $\frac{1}{822334722232904464506385097600000} \cdot \frac{1}{32} = \frac{1}{26314711111452943664204315110400000}$   $\frac{1}{26314711111452943664204315110400000} \cdot \frac{1}{33} = \frac{1}{868385466677947140918742398643200000}$   $\frac{1}{868385466677947140918742398643200000} \cdot \frac{1}{34} = \frac{1}{2952511086705020283123724155392000000}$   $\frac{1}{2952511086705020283123724155392000000} \cdot \frac{1}{35} = \frac{1}{10383788803467570990933034543872000000}$   $\frac{1}{10383788803467570990933034543872000000} \cdot \frac{1}{36} = \frac{1}{37381640292483255567359024357936000000}$   $\frac{1}{37381640292483255567359024357936000000} \cdot \frac{1}{37} = \frac{1}{1383140710821880456992283901223552000000}$   $\frac{1}{1383140710821880456992283901223552000000} \cdot \frac{1}{38} = \frac{1}{5256134699123155716570676924649504000000}$   $\frac{1}{5256134699123155716570676924649504000000} \cdot \frac{1}{39} = \frac{1}{205489254265803072947256400063530656000000}$   $\frac{1}{205489254265803072947256400063530656000000} \cdot \frac{1}{40} = \frac{1}{8219570170632122917890256002541226240000000}$   $\frac{1}{8219570170632122917890256002541226240000000} \cdot \frac{1}{41} = \frac{1}{337002377055929078633500576104191276800000000}$   $\frac{1}{337002377055929078633500576104191276800000000} \cdot \frac{1}{42} = \frac{1}{14154100846359121383677024206376035430400000000}$   $\frac{1}{14154100846359121383677024206376035430400000000} \cdot \frac{1}{43} = \frac{1}{6086263363955421205921220502711715335072000000000}$   $\frac{1}{6086263363955421205921220502711715335072000000000} \cdot \frac{1}{44} = \frac{1}{26781558801603875206067380212051767476320000000000}$   $\frac{1}{26781558801603875206067380212051767476320000000000} \cdot \frac{1}{45} = \frac{1}{1205170146072174384273032109542329536434400000000000}$   $\frac{1}{1205170146072174384273032109542329536434400000000000} \cdot \frac{1}{46} = \frac{1}{55437827689319521684660489039048058654176000000000000}$   $\frac{1}{55437827689319521684660489039048058654176000000000000} \cdot \frac{1}{47} = \frac{1}{2605578801296017527174942882935258756747272000000000000}$   $\frac{1}{2605578801296017527174942882935258756747272000000000000} \cdot \frac{1}{48} = \frac{1}{125067763263208840294097258380972419322858880000000000000}$   $\frac{1}{125067763263208840294097258380972419322858880000000000000} \cdot \frac{1}{49} = \frac{1}{61283203998972331745088657606686586369200843200000000000000}$   $\frac{1}{61283203998972331745088657606686586369200843200000000000000} \cdot \frac{1}{50} = \frac{1}{3064160199948616587254432880334329318460042160000000000000000}$   $\frac{1}{3064160199948616587254432880334329318460042160000000000000000} \cdot \frac{1}{51} = \frac{1}{156272170197379446948976077297050795141462149120000000000000000}$   $\frac{1}{1562721701973794469489760772$

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