stepper_driver design

This document will describe the design criteria and considerations

1. Criteria

The goal this system is trying to achieve is feedback control for a NEMA17 stepper motor the requirements are as follows:

Name	Description	
Stepper control	The stepper motor should be controlled / moved by the system	
Stepper sensing	The position of the stepper motor should be able to be read by a sensor	
Feedback control	The micro controller should run a PID controller to use the sensor data to correct the stepper position	
Settings flash unit	The system should have a flash module to store configurations for the PID controller	

Name	Description	
Control input bus	The micro controller should listen on a SPI bus for commands from a master device	

2. component selection

i. Stepper driver

for the stepper driver I chose the TMC2226 due to the large amount of features and easy to solder package (HTSSOP28) the features include:

Feature	Description	
High power	High power output capabilities (2.8A, 29V)	
High surface area	High surface area to effectively dissipate the heat generated from the high output power	
Precise micro stepping	Up to 1/64 micro step setting allowing a precision of 360/(200 * 64) = 0.028125 deg	
Stall guard 4	A built in system from TRINAMIC that prevents stalling and notifies the microcontroller on occurance	
UART connectivity	UART connectivity for precise setting control	
Builtin 5V regulator	This feature converts the motor source voltage to a stable 5V supply from which the rest of the system is run	

ii. Sensor

for the Sensor I chose the AS5600 because of the ease of use and availability. additionally my microcontroller only allows up to 12-bit analog signal precision. the features include:

Feature	Description	
HAL effect rotary encoding	The sensor uses a magnet to find the rotation of the motor allowing contactless operation	
I2C communication	The sensor is initialized and can be read using I2C which is quite fast and easy to implement	
Analog output	The sensor can output its reading as an analog signal allowing the microcontroller to quicly read it without using I2C with the ADC	

iii. Flash module

for the Flash module I chose the W25Q128JVS due to its large capacity and speed. the features include:

Feature	Description	
Large capacity	The W25Q128JVS has a capacity of 16MB which is more than enough for any application	
SPI communication	The module communicates with SPI which is even faster than I2C allowing the config to be quicly read	

iv. Micro controller

I chose the STM32F412CGU6 as the microcontroller due to its small package and refined USB capabilities. Most development of this project was done on a STM32F411 which is very similar to the 412 but has an USB hardware error. To allow possible setting updates via USB I chose the STM32F412CGU6. Features include:

Feature	Description	Use	
I2C	I2C device up to 1MHz	init phase of the AS5600	
ADC	12-bit ADC	continuous AS5600 readout	
2x SPI	multiple SPI devices	1. Flash module init and use 2. Control input from master	
TIM	32-bit Timer	Used to time the start of the ADC conversion	
USB	Improved USB hardware	Settings interface	
Fast	system clock up to 100MHz	Quick response and calculations	
Small	Small QFN48 package	Easy to solder and small package	

3. Physical design

Physical design documents:

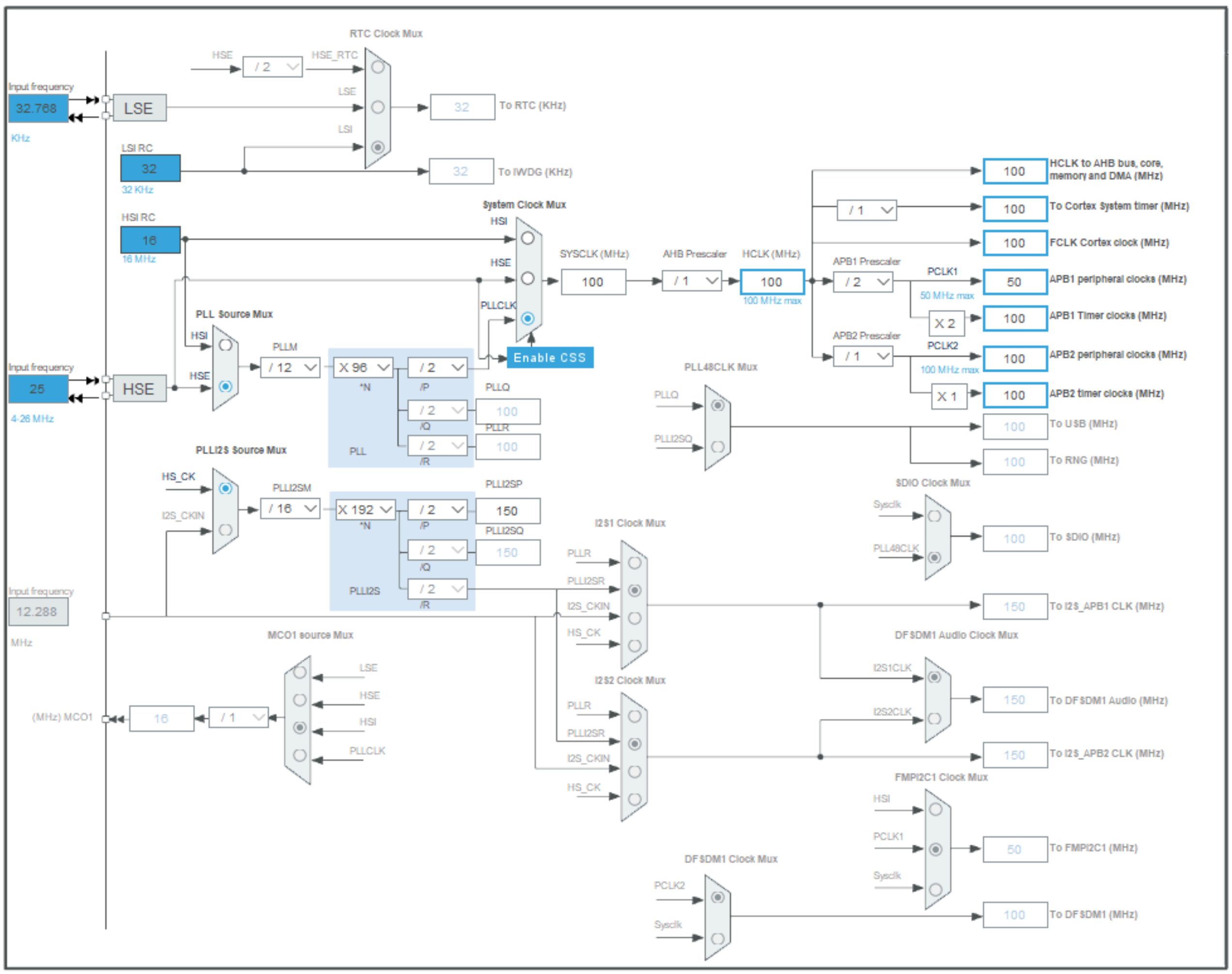
File	Description	
schematic.pdf	PDF for the PCB circuit diagram	
layout.pdf	PDF for the PCB layout and layers	

4. Software design

i. sys init

```
set_SYS_hardware_config(PWR_LVL_NOM, 25000000);                                          //
set_SYS_oscilator_config(0, 1, 0, 0, 1, 0, 0, 0, 0);                                     //
set_SYS_PLL_config(PLL_CLK_SRC_HSE, 12U, 96U, PLL_P_DIV_4, 0, 0);                        //
set_SYS_clock_config(SYS_CLK_SRC_PLL_P, AHB_CLK_NO_DIV, APBx_CLK_DIV2, APBx_CLK_NO_DIV);  //
set_SYS_tick_config(1);                                                                  //
sys_init();                                                                              //
```

1. This code starts off declaring the physical configuration: Power level and HSE(High Speed External oscillator) clock-speed.
2. It moves on by enabling certain internal clock systems seen in the clock diagram



.

3. Then the PLL's are configured (also seen in the clock diagram).
4. Then it sets the sys clock source and configures the peripheral clocks
5. Finally, the sys-tick mechanism is configured and enabled
6. The configuration is written at once so that correct order of operations is ensured To see the code behind the functions see: https://github.com/MarijnVerschuren/STM32F412/blob/main/src/sys.c

ii. GPIO config

```
config_GPIO(TMC_MS1_PORT, TMC_MS1_PIN, GPIO_output | GPIO_no_pull | GPIO_push_pull);
config_GPIO(TMC_MS2_PORT, TMC_MS2_PIN, GPIO_output | GPIO_no_pull | GPIO_push_pull);
config_GPIO(TMC_NEN_PORT, TMC_NEN_PIN, GPIO_output | GPIO_no_pull | GPIO_push_pull);
config_GPIO(STATUS_LED_PORT, STATUS_LED_PIN, GPIO_output | GPIO_no_pull | GPIO_push_pull);
config_GPIO(FLASH_NWP_PORT, FLASH_NWP_PIN, GPIO_output | GPIO_no_pull | GPIO_push_pull);
config_GPIO(FLASH_NRST_PORT, FLASH_NRST_PIN, GPIO_output | GPIO_no_pull | GPIO_push_pull);
config_GPIO(TMC_STEP_PORT, TMC_STEP_PIN, GPIO_output | GPIO_no_pull | GPIO_push_pull);
config_GPIO(TMC_DIR_PORT, TMC_DIR_PIN, GPIO_output | GPIO_no_pull | GPIO_push_pull);
config_GPIO(TMC_SPREAD_PORT, TMC_SPREAD_PIN, GPIO_output | GPIO_no_pull | GPIO_push_pull);
config_GPIO(TMC_STDBY_PORT, TMC_STDBY_PIN, GPIO_output | GPIO_no_pull | GPIO_push_pull);
GPIO_write(TMC_NEN_PORT, TMC_NEN_PIN, 1);
GPIO_write(TMC_MS1_PORT, TMC_MS1_PIN, 0);
GPIO_write(TMC_MS2_PORT, TMC_MS2_PIN, 0);
GPIO_write(STATUS_LED_PORT, STATUS_LED_PIN, 1);
```

GPIO pins used for the driver control, status led and flash module are configured and set to their default state To see the code behind the functions see: https://github.com/MarijnVerschuren/STM32F412/blob/main/src/GPIO.S

iii. EXTI config

```
config_EXTI_GPIO(TMC_DIAG_PORT, TMC_DIAG_PIN, 1, 0);          // TMC_DIAG
NVIC_set_IRQ_priority(EXTI0_IRQn, 0);                          // TMC_DIAG-IRQ
config_EXTI_GPIO(TMC_INDEX_PORT, TMC_INDEX_PIN, 1, 0);        // TMC_INDEX
NVIC_set_IRQ_priority(EXTI1_IRQn, 2);                          // TMC_INDEX-IRQ
start_EXTI(TMC_DIAG_PIN); start_EXTI(TMC_INDEX_PIN);          // start TMC interrupts
```

1. the EXTI (EXTernal Interrupt) is enabled on the TMC_DIAG pin, this pin goes high if stall or other error is detected
2. the interrupt priority for the DIAG interrupt is set
3. the EXTI is enabled on the TMC_INDEX pin, this pin goes high every full step
4. the interrupt priority for the INDEX interrupt is set
5. both interrupts are started To see the code behind the functions see: https://github.com/MarijnVerschuren/STM32F412/blob/main/src/EXTI.S

DIAG interrupt:

```
void EXTI0_handler(void) {
  EXTI->PR = 0x00000001UL;
  return;
}
```

TODO

INDEX interrupt

```
void EXTI1_handler(void) {
  EXTI->PR = 0x00000002UL;
  return;
}
```

TODO

iv. ADC config

```
config_ADC(ADC_CLK_DIV2 | ADC_INJ_DISC | ADC_RES_12B | ADC_EOC_SINGLE | ADC_INJ_TRIG_TIM1_TRG
config_ADC_watchdog(AS5600_OUT_PIN, ADC_WDG_TYPE_INJECTED, 200, 3900);
config_ADC_IRQ(1, ADC_IRQ_JEOC | ADC_IRQ_WDG);
config_ADC_GPIO_inj_channel(AS5600_OUT_PORT, AS5600_OUT_PIN, ADC_SAMPLE_28_CYCLES, 409, 0);
```

1. the ADC is enabled to work in injected mode with a resolution of 12-bit and be triggered by the TIM1_TRGO event
2. the ADC watchdog is configured to raise an error if the signal ventures outside the `0.05*VCC - 0.95*VCC` window
3. the JEOC (inJecte End Of Conversion) and WDG interrupts are enabled with a priority of 1
4. the channel for the AS5600 out pin is configured with an offset of `0.1*VCC` (which will automatically be subtracted in hardware) To see the code behind the functions see: https://github.com/MarijnVerschuren/STM32F412/blob/main/src/ADC.c

ADC interrupt:

```
uint8_t status = ADC1->SR;
ADC1->SR = ~status;
if (status & 0b000001) {
  return;  // watchdog
}
if (status & 0b000100) {
  uint32_t a = ADC1->JDR1;
  angle = a + (a / 4);
  return;
}
```

TODO

v. TIM config

```
config_TIM_master(TIM1, 10000, 100, TIM_TRGO_UPDATE);         // 100 Hz
start_TIM_update_irq(TIM1);
```

1. the timer is configured to run at 10KHz and generate a TRGO event at 100Hz
2. start the timer update interrupt (for status led) To see the code behind the functions see: https://github.com/MarijnVerschuren/STM32F412/blob/main/src/tim.c

TIM interrupt:

```
void TIM1_update_handler(void) {
  TIM1->SR &= ~0x00000001UL;
  GPIO_toggle(STATUS_LED_PORT, STATUS_LED_PIN);
  return;
}
```

TODO

vi. UART config

```
config_UART(TMC_UART_TX_DEV_PIN, TMC_UART_RX_DEV_PIN, 115200);    // TMC_UART
```

Configures the UART for the TMC driver at 115200 bits/s To see the code behind the functions see: https://github.com/MarijnVerschuren/STM32F412/blob/main/src/USART.S and: https://github.com/MarijnVerschuren/STM32F412/blob/main/src/USART.c

vii. I2C config

```
config_I2C(AS5600_I2C_SCL_DEV_PIN, AS5600_I2C_SDA_DEV_PIN, 0x00); // AS5600_I2C
```

Configures the I2C for the AS5600 at the default rate of 100KHz To see the code behind the functions see: https://github.com/MarijnVerschuren/STM32F412/blob/main/src/I2C.c

viii. AS5600 config

```
while (config_AS5600(
  I2C2, AS5600_POW_NOM | AS5600_HYST_2LSB | AS5600_MODE_REDUCED_ANALOG |
  AS5600_SFILTER_2 | AS5600_FFILTER_10LSB | AS5600_WDG_ON, 10
)) { delay_ms(10); }
```

Configures the AS5600 to work at 3v3 with fast filter mode, reduced analog signal `0.1*VCC - 0.9*VCC` and watchdog until successful To see the code behind the functions see: https://github.com/MarijnVerschuren/STM32F412/blob/main/lib/AS5600/AS5600.c

ix. main loop

```
start_ADC(0, 1);                          // start ADC injected channels
start_TIM(TIM1);                          // start ADC polling timer
GPIO_write(TMC_NEN_PORT, TMC_NEN_PIN, 0); // enable TMC chip

while (1) {
  GPIO_toggle(TMC_STEP_PORT, TMC_STEP_PIN);
  delay_ms(1);
```

> ```
> }
> ```
>
> 1. starts the injected ADC channels
> 2. start the ADC trigger timer
> 3. enable the TMC driver
>
> TODO