

## Getting started with touch sensing control on STM32 microcontrollers

### Introduction

This document helps customers to quickly locate information regarding touch sensing on STM32 microcontrollers.

This application note lists all the existing application notes and user manuals covering touch sensing. It indicates where the key aspects of touch sensing are documented.

It also explains how to build touch sensing applications on STM32L0538-DISCO and STM32F072B-DISCO discovery boards using the STM32CubeMx graphical interface.

**Table 1. Applicable products**

Type	Product series
STM32 microcontrollers	STM32F0 Series
	STM32F3 Series
	STM32L0 Series
	STM32L1 Series
	STM32L4 Series
	STM32L4+ Series
	STM32L5 Series
	STM32U5 Series
	STM32WB Series

## 1 General information

This document applies to Arm®-based devices.

*Note: Arm is a registered trademark of Arm Limited (or its subsidiaries) in the US and/or elsewhere.*



## 2 Terminology and principle

### 2.1 Terminology

The touch sensing most relevant acronyms are described below:

- Acquisition mode
  - CT: Charge-Transfer acquisition principle. This mode is used on STM32 microcontrollers.
- Touch sensing STM32 peripheral
  - TSC: touch sensing controller peripheral
  - Bank: set of channels acquired simultaneously
  - Channel: elementary acquisition item
  - Group: set of 1..3 channels plus 1 sampling capacitor (Cs)
- Sensors
  - Touchkey or TKey: single channel sensor
  - Linear sensor: multi-channels sensor with the electrodes positioned in a linear way
  - Rotary sensor: multi-channels sensor with the electrodes positioned in a circular way
  - Active shield: track running along or copper plane surrounding the sensor track and/or sensor itself. Active shield is driven similarly to the sensor. Improve noise robustness without decreasing the sensitivity.
- STM32 software
  - TSL: touch sensing library
  - Delta: difference between the measure and the reference
  - Measure or meas: current signal measured on a channel
  - Reference or ref: reference signal based on the average of a sample of measures
  - DTO: detection time out. Time out is defined by TSLPRM.DTO. See TSLPRM.DTO in tsl\_conf.h file.
  - DXS: detection exclusion system. Exclusion system is defined by TSLPRM.USE\_DXS. See TSLPRM.USE\_DXS in tsl\_conf.h file.
  - ECS: environment change system. See TSLPRM.ECS\_DELAY in tsl\_conf.h file.
- Hardware Involved
  - Cx: sensor capacitance (typical value is few pF)
  - Cp: parasitic capacitance (typical value few pF)
  - Ct: equivalent touch capacitance
  - Cs/Cskey/Csshield: sampling capacitor (typical value from 2.2 to 100nF)
  - Rs/Rskey/Rsshield: serial resistor, ESD protection (typical value from 100Ohms to 10K)

### 2.2 Principle

The STM32 touch sensing feature is based on charge transfer.

The surface charge transfer acquisition principle consists in charging a sensor capacitance (Cx) and in transferring the accumulated charge into a sampling capacitor (Cs).

This sequence is repeated until the voltage across Cs reaches  $V_{IH}$ .

The number of charge transfers required to reach the threshold is a direct representation of the size of the electrode capacitance. When the sensor is touched, the sensor capacitance to the earth is increased. This mean the C voltage reaches  $V_{IH}$  with less count and the measurement value decreases. When this measurement goes below a threshold, a detection is reported by the TSL. The schematic below do not take into account the parasitic capacitor.

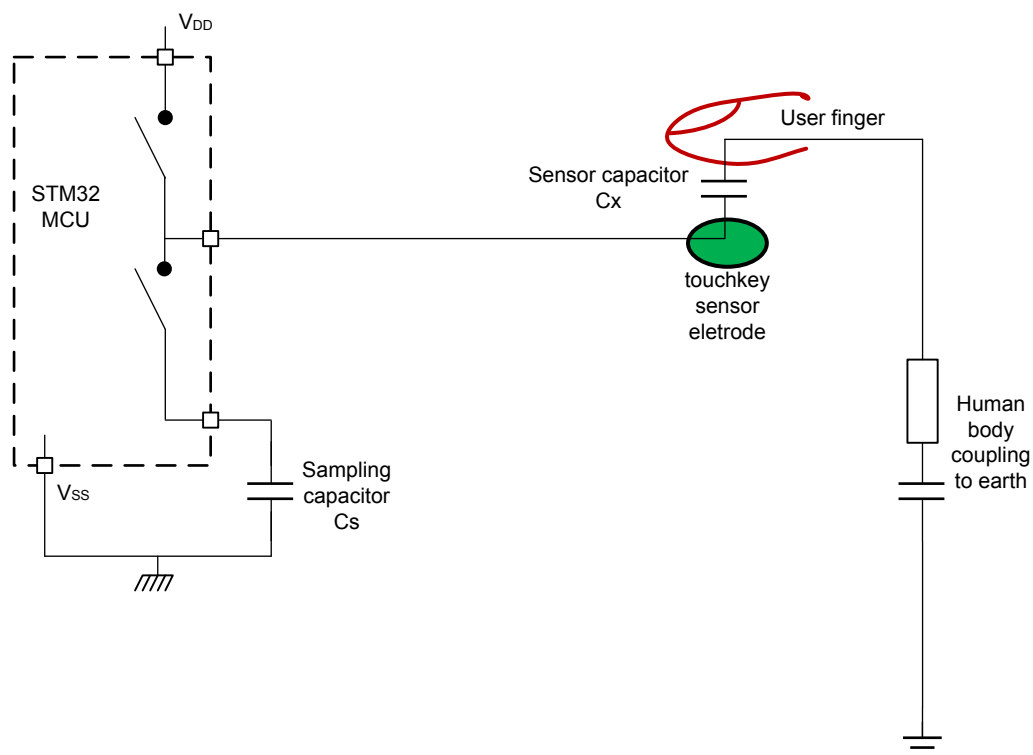
**Figure 1. Change transfer principle**


Table 2 gives a list of documents containing information about the change transfer principle.

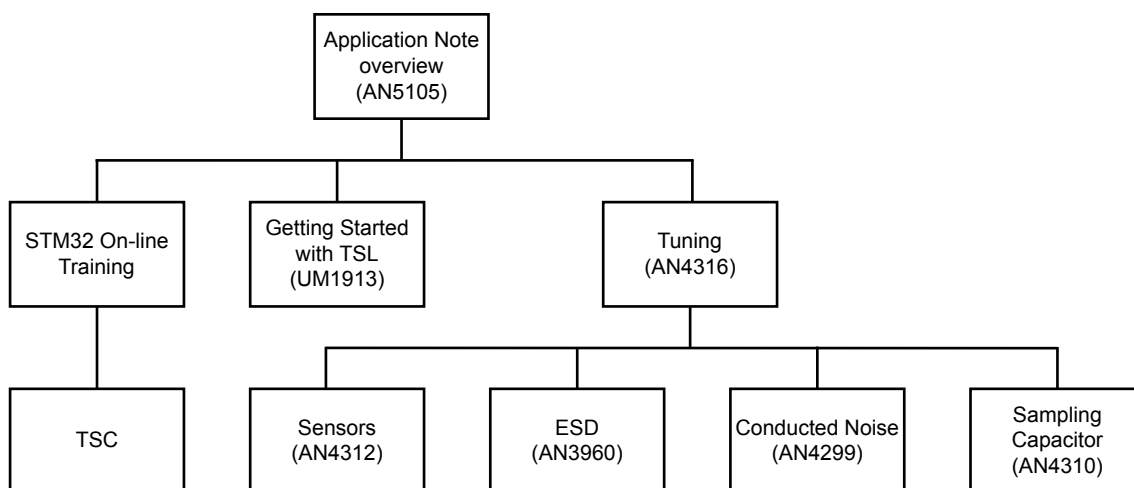
**Table 2. Change transfer principle documentation**

Id	Title	Chapters
AN4299	Improve conducted noise robustness for touch sensing applications on MCUs	Surface charge transfer acquisition principle overview
AN4310	Sampling capacitor selection guide for touch sensing applications on MCUs	Charge transfer acquisition principle overview
AN4312	Design with surface sensors for touch sensing applications on MCUs	Capacitive sensing technology
AN4316	Tuning a touch sensing application on MCUs	Charge transfer period tuning
OLT	STM32L4 On Line Training	Touch sensing controller (TSC)

### 3 Document reference

Figure 2 shows the main documentation tree related to TSC and TSL.

**Figure 2. Main documentation tree**



**Table 3. Reference documentation**

Document name	Document title
UM1913	Developing applications on STM32Cube with STMTouch touch sensing library
AN3960	ESD considerations for touch sensing applications on MCUs
AN4299	Improve conducted noise robustness for touch sensing applications on MCUs
AN4310	Sampling capacitor selection guide for touch sensing applications on MCUs
AN4312	Design with surface sensors for touch sensing applications on MCUs
AN4316	Tuning a touch sensing application on MCUs

## 4 STM32L4 touch sensing controller online presentation

An online training is available from ST website [www.st.com](http://www.st.com).

Insert the "STM32L4 Online Training" string in the "Search" function and press enter.

To find it use the function "Search" and insert the strings "STM32L4 Online Training". The figure below shows the online page available.

Figure 3. STM32L4 online training

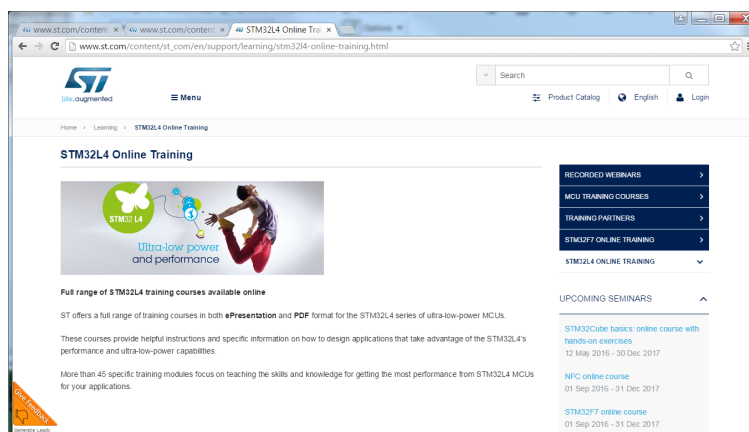
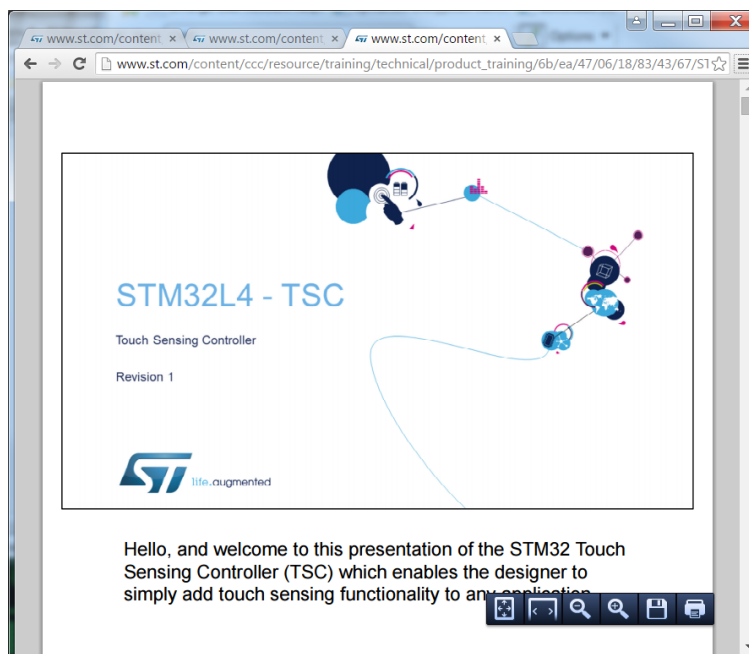


Figure 4. STM32L4 Touch Sensing Controller online training

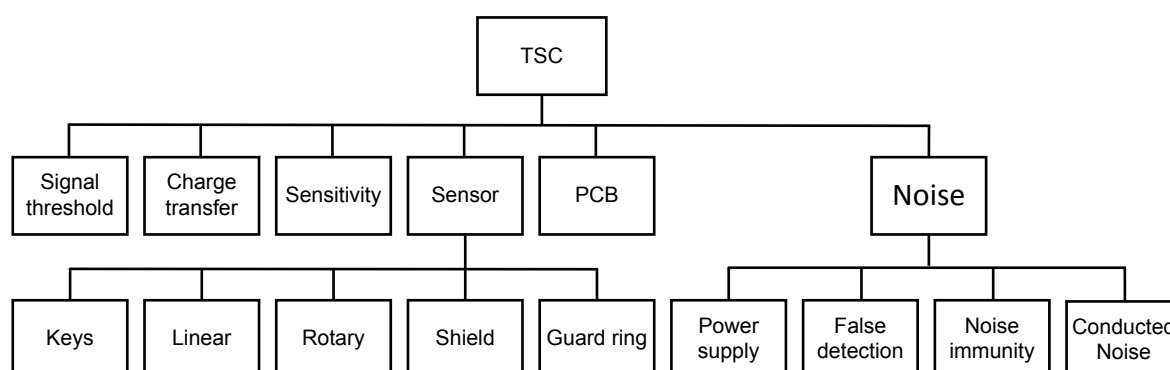


## 5 Main TSC characteristics

### 5.1 Description

The following [Figure 5](#) shows all touch sensing controller (TSC) characteristics and their correlation. The TSC main characteristics are described in the following pages.

**Figure 5. TSC characteristics**



### 5.2 Signal threshold

To tune the detection thresholds, it must determine the sensitivity of each touchkey. For each touchkey, can be used few parameters to adjust these signal thresholds.

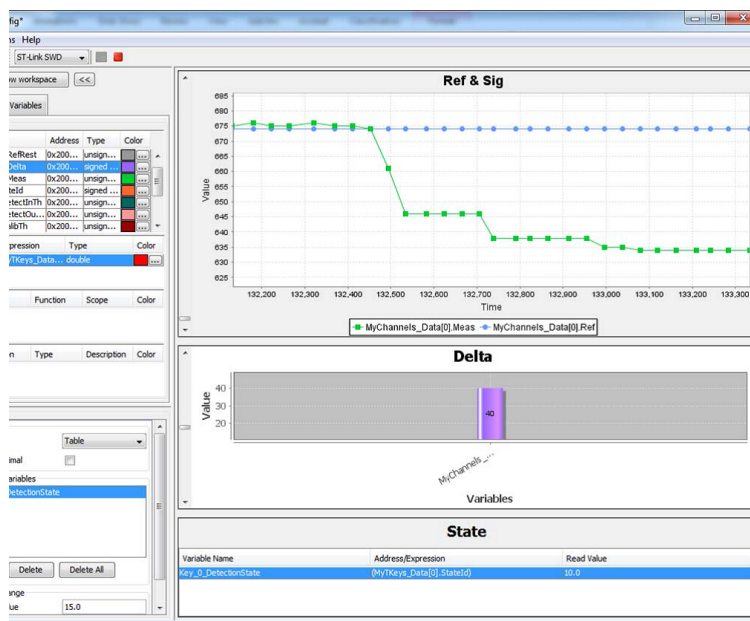
For debug purpose, it can get touchkey parameters using printf or STMStudio tool:

```

for (Index = 0; Index < NUMBER_OF_TOUCHKEYS; Index++)
{
    printf("K%d [%2d] [%4d %3d %3d %4d] %d %d %d %d %d"
        , Index
        , MyTKeys[Index].p_Data->StateId
        , MyTKeys[Index].p_ChD->Ref
        , MyTKeys[Index].p_ChD->RefRest
        , MyTKeys[Index].p_ChD->Delta
        , MyTKeys[Index].p_ChD->Meas
        , MyTKeys[Index].p_Param->ProxInTh
        , MyTKeys[Index].p_Param->ProxOutTh
        , MyTKeys[Index].p_Param->DetectInTh
        , MyTKeys[Index].p_Param->DetectOutTh
        , MyTKeys[Index].p_Param->CalibTh
    );
}
  
```

**Note:** *ProxInTh and ProxOutTh are defined for proximity detection feature only, when TSLPRM\_USE\_PROX = 1.*

Figure 6. STMStudio outputs



- On software side:
  - Relevant information is available in `tsl_conf.h` and `tscl_user.c` files.
  - Threshold (`xx_TH`) can be adjust in `tsl_conf_tsc.h` file.

See below an example:

```
#define TSLPRM_TKEY_DETECT_IN_TH (64)
#define TSLPRM_TKEY_DETECT_OUT_TH (60)
#define TSLPRM_TKEY_CALIB_TH (56)
#define TSLPRM_LINROT_DETECT_IN_TH (50)
#define TSLPRM_LINROT_DETECT_OUT_TH (40)
```

- The TSL api, `tsl_user_SetThresholds`, located in `tsl_user.c` allows to adjust each channel independently. See below an example:

```
void tsl_user_SetThresholds(void)
{
/* USER CODE BEGIN Tsl_user_SetThresholds */
/* Example: Decrease the Detect thresholds for the TKEY 0*/
MyTKeys_Param[0].DetectInTh -= 10;
MyTKeys_Param[0].DetectOutTh -= 10;
/* USER CODE END Tsl_user_SetThresholds */
}
```

Table 4 gives a list of documents containing information about the signal threshold usage.



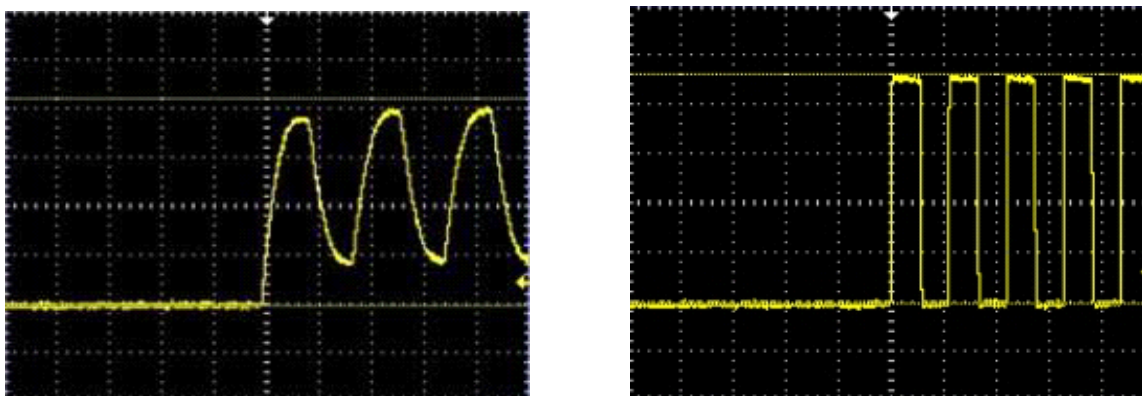
**Table 4. Signal threshold use documentation**

Id	Title	Chapters
UM1913	Developing applications on STM32Cube with STMTouch touch sensing library	Debug with STM Studio
AN4316	Tuning a touch sensing application on MCUs	Monitoring STMTouch driver variables using STM-Studio Tuning the thresholds Touchkeys thresholds Linear and rotary touch sensors thresholds

### 5.3 Charge transfer

The acquisition is based on the measurement of the sensor channel capacitance.

To ensure that the Cx capacitance is correctly charged, it is necessary to monitor the pin connected to the sensor. On sensors and shield sides, it must observe a complete Charge/Discharge cycle.

**Figure 7. Incomplete and complete charge transfer cycle**


In this example , to complete the charge transfer cycles, the following parameter must be modified as below:

- INCREASE:
  - htsc.Init.PulseGeneratorPrescaler
  - htsc.Init.CTPulseHighLength
  - htsc.Init.CTPulseLowLength
- DECREASE:
  - Sysclk

Table 5 gives a list of documents containing information about the charge transfer.

**Table 5. Charge transfer documentation**

Id	Title	Chapters
AN4299	Improve conducted noise robustness for touch sensing applications on MCUs	Active shield
AN4316	Tuning a touch sensing application on MCUs	Charge transfer period tuning

## 5.4 Sensitivity

Sensitivity is a key point in touch sensing applications. The sensitivity can be improved by:

- Reducing the air gap
- Reducing the panel thickness
- Choosing the dielectric with higher  $\epsilon_R$
- a GND plane that is not too close to the shield and sensors
- Avoiding metallic paint near shield and sensors

Table 6 gives a list of documents containing information about the sensitivity.

**Table 6. Sensitivity documentation**

Id	Title	Chapter
UM1913	Developing applications on STM32Cube with STMTouch touch sensing library	Available touch sensing channels
AN4312	Design with surface sensors for touch sensing applications on MCUs	Air gap: <ul style="list-style-type: none"> <li>• Reduce air gap</li> </ul> Panel material: <ul style="list-style-type: none"> <li>• Reduce Panel thickness</li> <li>• Choose dielectric with higher <math>\epsilon_R</math></li> </ul> Metal chassis: <ul style="list-style-type: none"> <li>• GND not too closed from Shield and Sensors</li> <li>• Avoid Metallic paint near Shield and Sensors</li> </ul> Mechanical construction and PCB to panel bonding. Surface sensor design
AN4316	Tuning a touch sensing application on MCUs	All chapters

### Dielectric example

**Table 7. Dielectric constants of common materials used in a panel construction**

Material	$\epsilon_R$
Air	1.00059
Glass	4 to 10
Sapphire glass	9 to 11
Mica	4 to 8
Nylon	3
Plexiglass	3.4
Polyethylene	2.2
Polystyrene	2.56
Polyethylene terephthalate (PET)	3.7
FR4 (fiberglass + epoxy)	4.2
PMMA (Poly methyl methacrylate)	2.6 to 4
Typical PSA	2.0 - 3.0 (approximately)

## 5.5 Sensors

- It is recommended to use the same shape for all electrodes.
- The touchkeys can be customized by the drawing on the panel. TSL compensates capacitance differences.
- Acquisition time and processing parameters can be optimized when electrodes have similar capacitance.

### Sensor size example

**Figure 8. Sensor size**



### 5.5.1 Key

- Key sensors are used in common application
- You can get deeper key information in following documents:

Table 8 gives a list of documents containing information about the key.

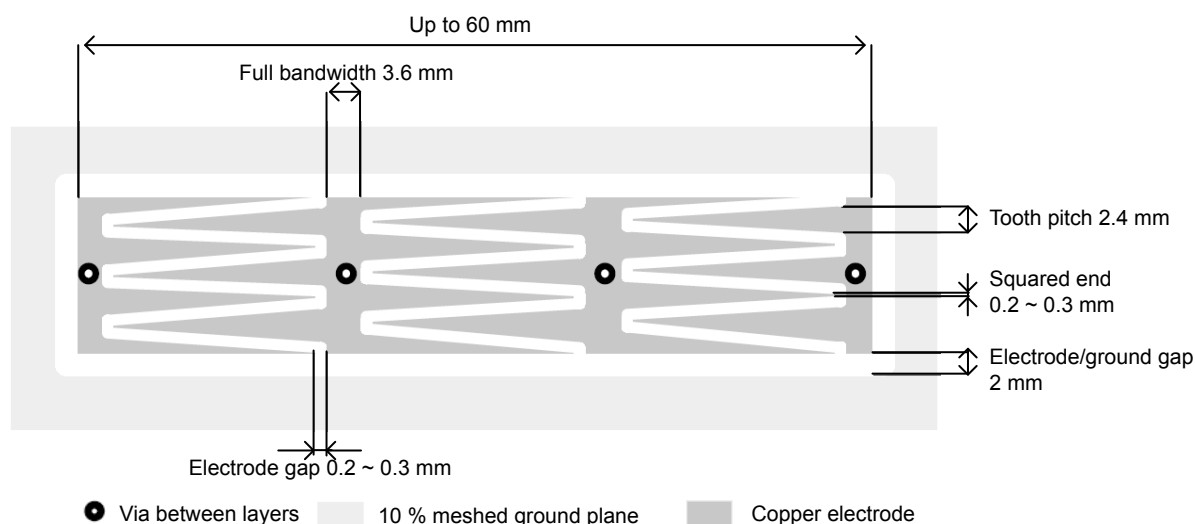
**Table 8. Key documentation**

Id	Title	Chapters
UM1913	Developing applications on STM32Cube with STMTouch touch sensing library	Touchkey sensor
AN4312	Design with surface sensors for touch sensing applications on MCUs	Touchkey sensor

### 5.5.2 Linear or slider

A linear is a set of contiguous capacitive electrodes. [Figure 9](#) shows a slider used on a discovery board.

**Figure 9. Interlaced linear touch sensor with 3 channels / 4 electrodes (half-ended electrodes design)**



Note: The teeth of the interlaced linear touch sensor must be perfectly regular.

[Table 9](#) gives a list of documents containing information about the linear touch sensor.

**Table 9. Linear touch sensor documentation**

Id	Title	Chapters
UM1913	Developing applications on STM32Cube with STMTouch touch sensing library	Linear and rotary touch sensors
AN4312	Design with surface sensors for touch sensing applications on MCUs	Linear sensor

### 5.5.3 Rotary sensor or wheel

A rotary is a set of contiguous capacitive electrodes.

**Figure 10.** Interlaced patterned rotary sensor with 3 channels / 3 electrodes

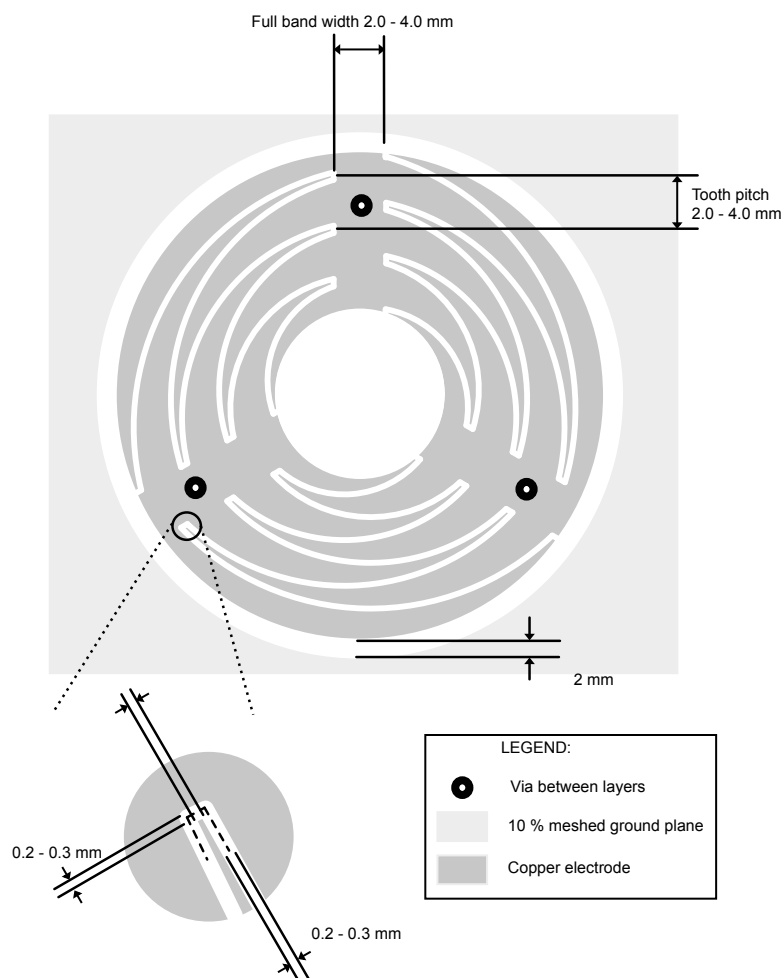


Table 10 gives a list of documents containing information about the rotary sensor.

**Table 10.** Rotary sensor documentation

Id	Title	Chapters
UM1913	Developing applications on STM32Cube with STMTouch touch sensing library	Linear and rotary touch sensors
AN4312	Design with surface sensors for touch sensing applications on MCUs	Rotary sensor

### 5.5.4 Active shield or driven shield

Active shield or driven shield. (this name is used in some application notes) drives the shield plane with the same signal as the electrode.

There are several advantages using Active Shield instead of a grounded shield:

- The parasitic capacitance between the electrode and the shield no longer needs to be charged.
- Protect the touch electrodes from a noise source.
- Increase system stability and performance when a moving metal part is close to the electrode.

**Figure 11. Active shield principle**

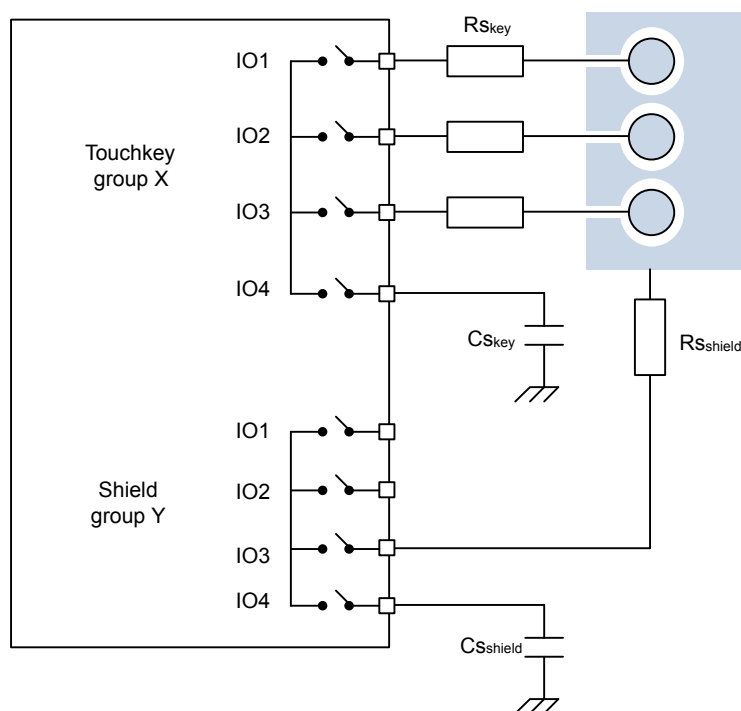


Table 11 gives a list of documents containing information about the active shield.

**Table 11. Active shield documentation**

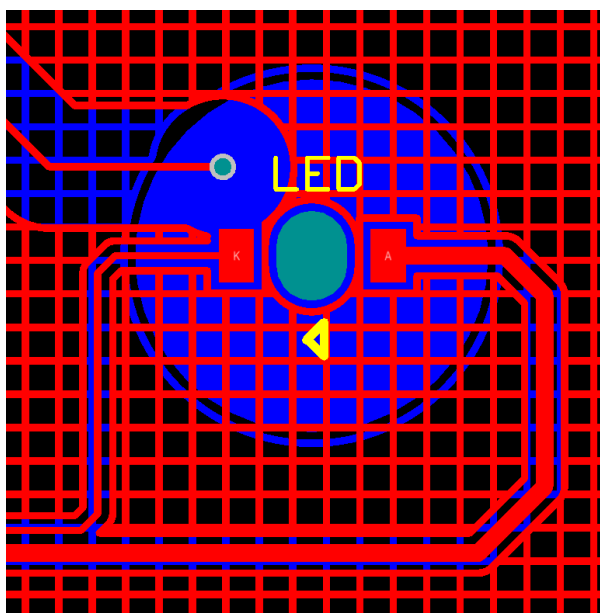
Id	Title	Chapters
AN4299	Improve conducted noise robustness for touch sensing applications on MCUs	Active shield
AN4312	Design with surface sensors for touch sensing applications on MCUs	Driven shield
AN4316	Tuning a touch sensing application on MCUs	Shield adjustment
OLT	STM32L4 Online Training	Touch sensing controller (TSC)

## 5.6 Layout and PCB

Rules to follow to improve TSC systems

### 5.6.1 Led rules

**Figure 12. Led layout example**



**Figure 13. Example of cases where a LED bypass capacitor is required**

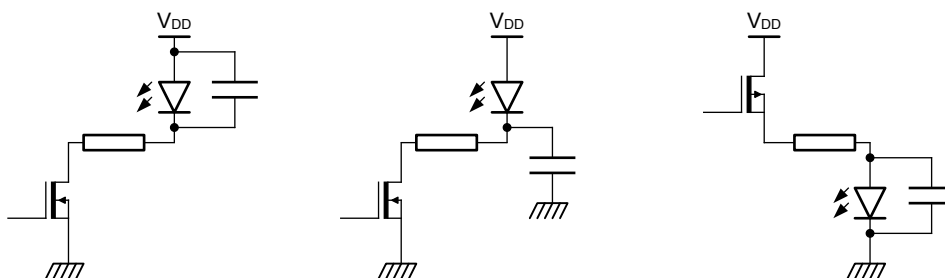


Table 12 gives a list of documents containing information about led rules.

**Table 12. Led rules documentation**

Id	Title	Chapters
AN4312	Design with surface sensors for touch sensing applications on MCUs	<ul style="list-style-type: none"> <li>LEDs and sensors</li> <li>Placing of LEDs close to sensor</li> </ul>

### 5.6.2 Electrode not located on PCB

It is possible but it is not recommended, because when the electrode isn't located on PCB, the sensitivity decreases and additional extra parasitic capacitances are added.

**Figure 14. Electrode not located on PCB example**

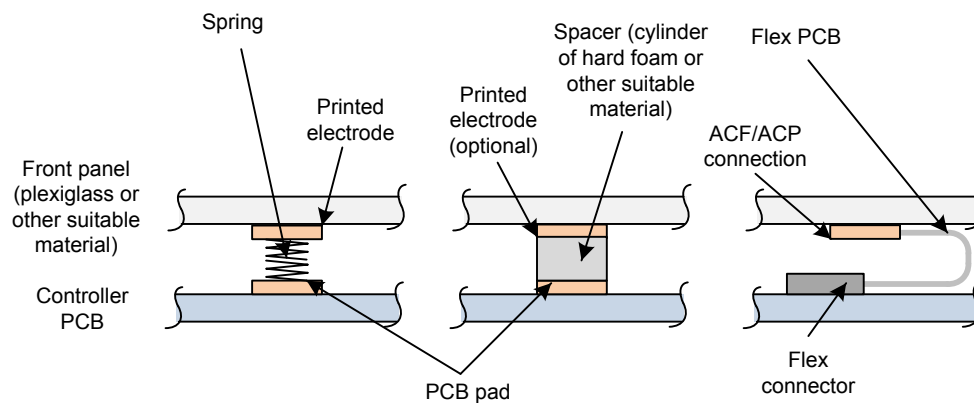


Table 13 gives a list of documents containing information about the electrode.

**Table 13. Electrode documentation**

Id	Title	Chapters
AN4312	Design with surface sensors for touch sensing applications on MCUs	Using electrodes separated from the PCB



### 5.6.3 Ground, shield and sensors

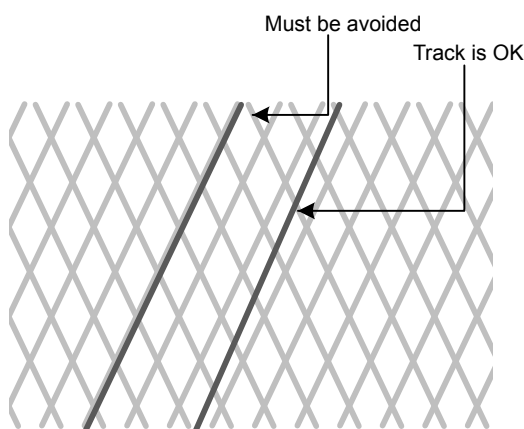
Table 14 gives a list of documents containing information about the layout .

**Table 14. Layout documentation**

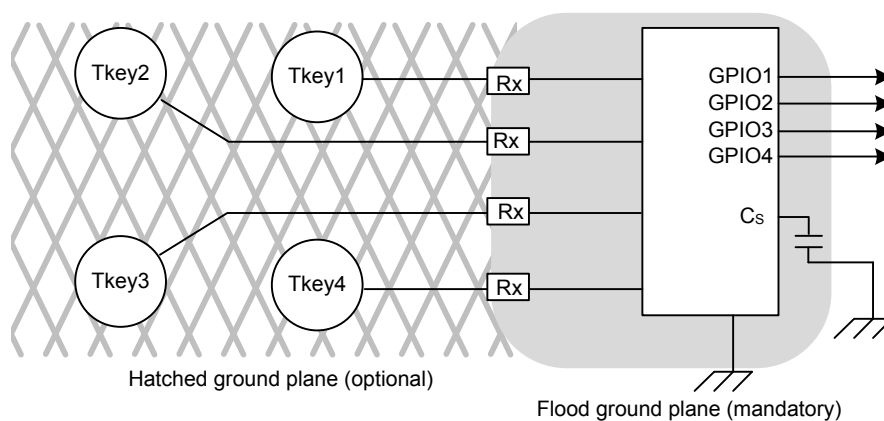
Id	Title	Chapters
AN4312	Design with surface sensors for touch sensing applications on MCUs	<ul style="list-style-type: none"> <li>PCB and Layout</li> <li>Ground considerations</li> <li>Rotary and linear sensor recommendations</li> </ul>

Figure 15 shows the ground plane and the signal tracks.

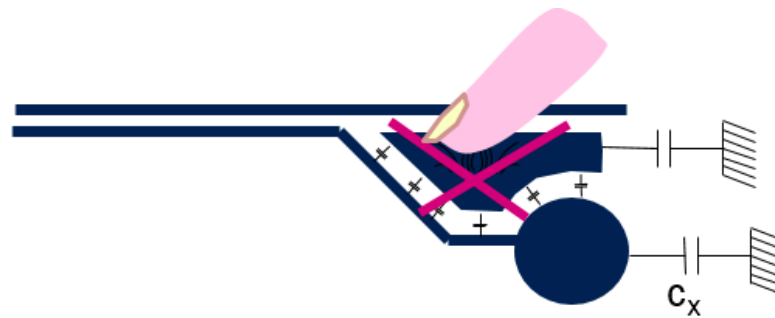
**Figure 15. Hatched ground and signal tracks**



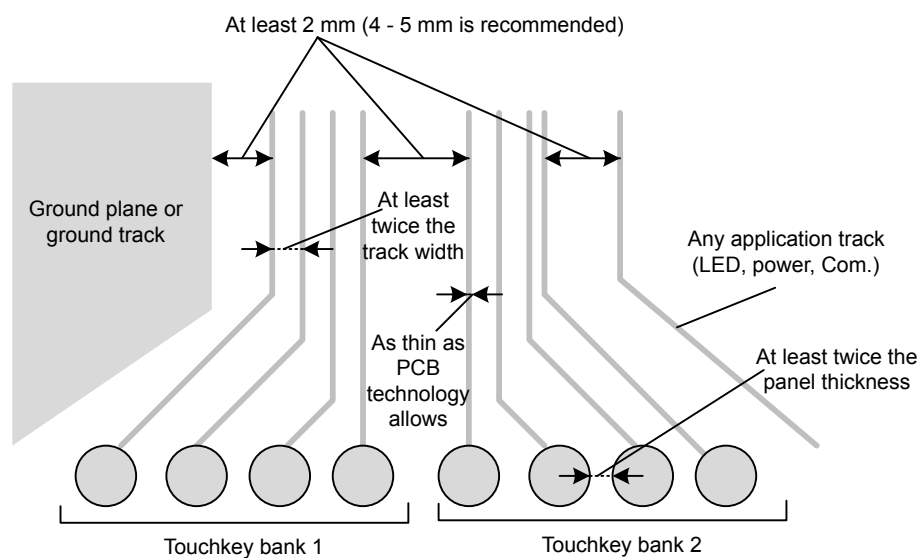
**Figure 16. Ground plane example**



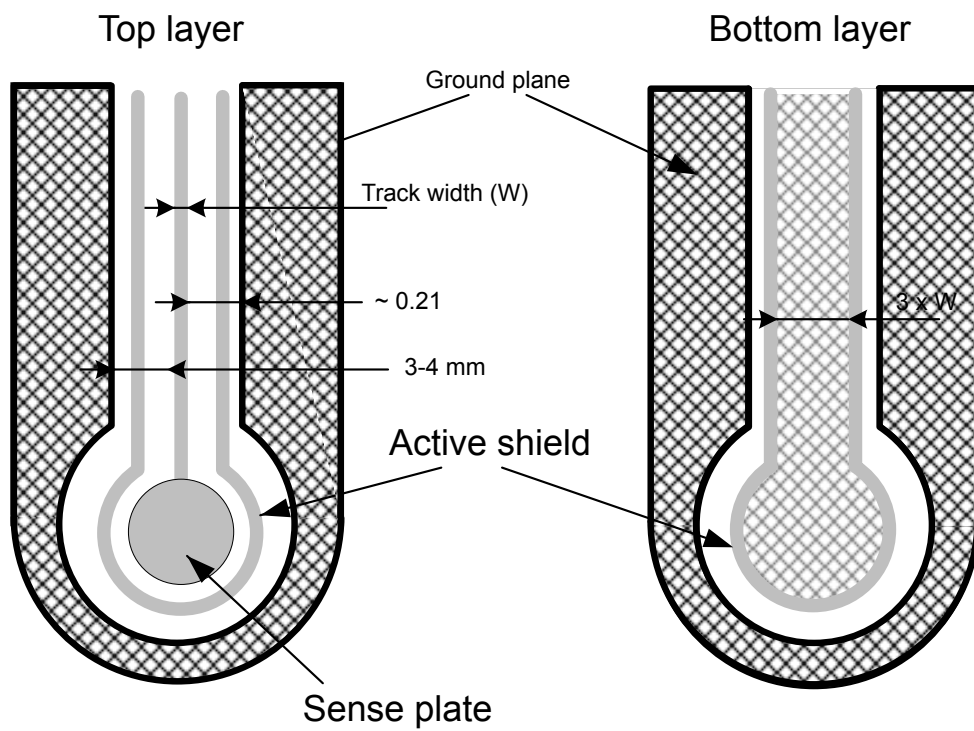
**Figure 17. Track routing**



**Figure 18. Track routing recommendation**



**Figure 19. Shield**



#### 5.6.4

#### FAQ

##### System keys points:

- Direct connection between earth and board ground is required to avoid conducted noise issues.
- Conductive painting on the front panel must be avoid.
- Robust mechanical assembly is required.

##### Layout keys points:

- GND plane is mandatory under MCU, sampling capacitors and up to serial resistors
- Hatched GND plane recommended for sensor traces from both sides of the PCB:
  - minimize parasitic capacitance
  - mesh plane possible with 25% to 40% copper
- Route the sensors and ground on the same layer while the components and other tracks are routed on the other layers

##### Driven shield, or Active shield, is recommended.

- If there are LEDs close to sensors, to indicate a touch event, they must be bypassed by a capacitor whose typical value is 10 nF.
- External LDO regulator should be used to power the MCU only to provide a stable power supply voltage without any ripple, especially all the switching components like transistors, LEDs, in the application mustn't be powered from the same voltage. This regulator should not be placed close to the sensors and their tracks, but close to MCU.
- It is strongly recommended to dedicate pins to be used as touch sensors and do not share them with other features

##### $R_S$ and $C_S$ keys points:

- PPS or NPO sampling capacitors are recommended. Possible X5R or X7R.
- Never use tantalum sampling capacitors.
- Serial ESD 10 K (down to 1 K) resistors are recommended to be placed as close as possible to the MCU
- No track crossing or via between these resistors and the MCU
- The value of sampling capacitor of active shield should be different than the value of the sampling capacitors used for acquisition.
- The capacitance of active shield is higher (larger area) than  $C_X$  of a single touch sensing channel. In order to achieve the same waveform on active shield and active touch sensing channel, the ratios  $C_S/C_X$  of active shield and active touch sensing channel (touchkey). therefore, the  $C_S$  of the active shield should also have higher value ( $k \times C_S$  of touch sensing channel).

##### Sensor key points:

- Other traces must not cross the touch sensing traces or the whole touch sensing area
- The touch sensing traces should be as thin as technology allows and as short as possible.
  - No longer than 10 cm
- The space between traces and GND plane should be ideally 5 mm
- TC pins are more robust against external interference than FT:
- Consider modification of PCB layout to allow connection of external VDD clamping diode to touch sensing electrode traces.
  - Use low-capacitance diode like BAR18, BAS70 with  $C_{max} = 2$  pF.
  - In case it is later needed, add pads and connection to the PCB without assembling components.
- Floating panes must never be placed close to the sensors.

## 5.7 Noise

Noise is a key point for touch sensing applications. Noise can come from power supply.

### 5.7.1 Power supply

Main rules to follow:

- Place Buzzer and LED before LDO.
- Place LDO close to MCU.

**Figure 20. Typical power supply schematic**

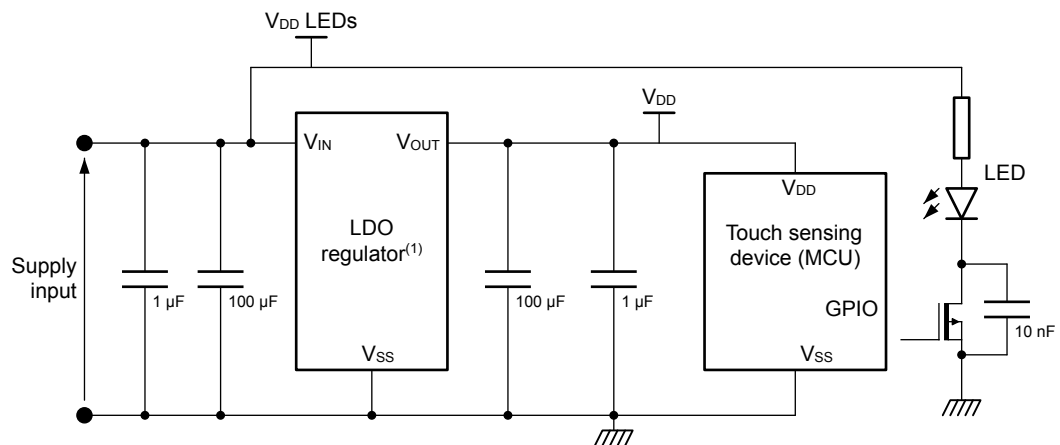


Table 15 gives a list of documents containing information about the power supply.

**Table 15. Power supply documentation**

Id	Title	Chapters
AN4312	Design with surface sensors for touch sensing applications on MCUs	Power supply

### 5.7.2 False detection

To avoid false detection TSL embed ECS, DXS and DTO algorithms.

Table 16 gives a list of documents containing information about the false detection.

**Table 16. False detection documentation**

Id	Title	Chapters
UM1913	Developing applications on STM32Cube with STMTouch touch sensing library	<ul style="list-style-type: none"> <li>• Environment change system (ECS)               <ul style="list-style-type: none"> <li>– Power supply voltage, temperature and air humidity</li> </ul> </li> <li>• Detection exclusion system (DXS)</li> <li>• Detection time out (DTO)</li> </ul>

### 5.7.3 Noise immunity

Noise filtering can be done on hardware and software (TSL) sides.

Table 17 gives a list of documents containing information about the noise immunity.

**Table 17. Noise immunity documentation**

Id	Title	Chapters
UM1913	Developing applications on STM32Cube with STMTouch touch sensing library	Noise filters
AN4299	Improve conducted noise robustness for touch sensing applications on MCUs	How to improve noise immunity
OLT	STM32L4 Online Training	Touch sensing controller (TSC)

### 5.7.4 Conducted noise

- Touch sensing systems require the conducted noise immunity.
- A key point is the signal to noise ratio (SNR).
- The test condition to be followed by the user is described in the standard IEC61000-4-6.

Table 18 gives a list of documents containing information about the conducted noise.

**Table 18. Conducted noise documentation**

Id	Title	Chapters
AN4299	Improve conducted noise robustness for touch sensing applications on MCUs	All chapters

## 6 Tuning

For tuning purpose dedicated application note are available.

### Sensors

Table 19 gives a list of documents containing information about the sensor.

**Table 19. Sensors documentation**

Id	Title	Chapters
AN4312	Design with surface sensors for touch sensing applications on MCUs	All chapters

### ESD

Table 20 gives a list of documents containing information about the ESD

**Table 20. ESD documentation**

Id	Title	Chapters
AN3960	ESD considerations for touch sensing applications on MCUs	All chapters

### CN

Table 21 gives a list of documents containing information about the conducted noise.

**Table 21. Conducted noise documentation**

Id	Title	Chapters
AN4299	Improve conducted noise robustness for touch sensing applications on MCUs	All chapters

### CS

Table 22 gives a list of documents containing information about the sampling capacitor.

**Table 22. Sampling capacitor documentation**

Id	Title	Chapters
AN4310	Sampling capacitor selection guide for touch sensing applications on MCUs	All chapters

## 7 Getting started TSC with STM32CubeMX

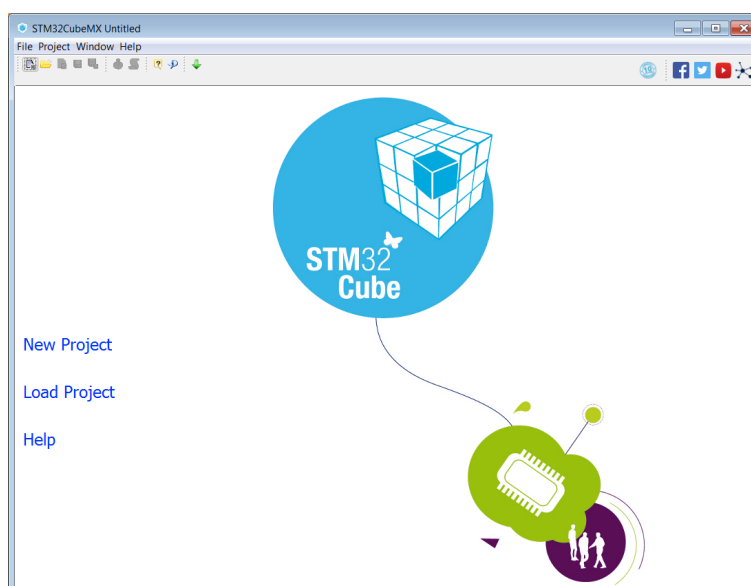
### 7.1 Uses cases

How to set up an TSC application based on TSL is explained in the following two examples. These examples describe the way to set up TLS on STM32F072B-DISCO and STM32L0538-DISCO discovery boards.

This description can be used as example to set up other TSC series such as L4, F3, L0, L1 and L4+.

A STM32CubeMX new feature is available from version 4.24.0. This new feature can help to speed up TSL, TouchSensingLib, installation.

Figure 21. Main project panel





## 7.2 Discovery board: STM32F072B-DISCO

The STM32F072 Discovery kit helps the user to discover the STM32F072, which has the full set of features available in the STM32F0 Series, and to develop his applications easily. It includes everything required for beginners and experienced users to get started quickly.

Based on the STM32F072RBT6, it includes an ST-LINK/V2 embedded debug tool interface, an ST MEMS gyroscope, LEDs, push-buttons, linear touch sensor, RF EEPROM connector and a USB mini-B connector.

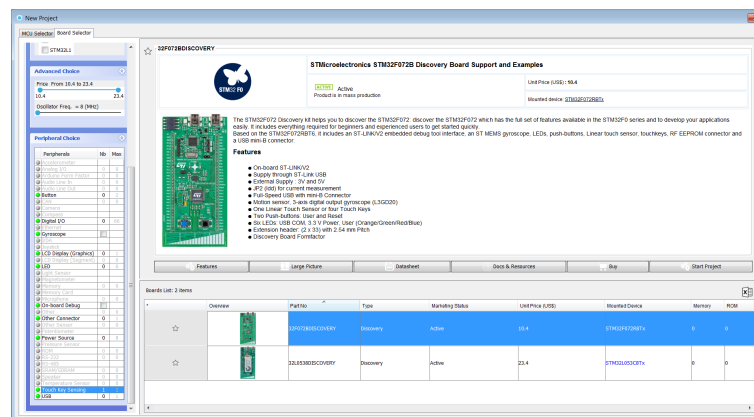
This discovery board provide a three channels linear (or slider) sensor. the main characteristics of these sensor are:

- On-board ST-LINK/V2
- Supply through ST-Link USB
- External Supply: 3V and 5V
- JP2 (Idd) for current measurement
- Full-Speed USB with mini-B Connector
- Motion sensor, 3-axis digital output gyroscope (L3GD20)
- One Linear Touch Sensor or four Touch Keys
- Two Push-buttons: User and Reset
- Six LEDs: USB COM, 3.3 V Power, User (Orange/Green/Red/Blue)
- Extension header: (2 x 33) with 2.54 mm Pitch
- Discovery Board Formfactor

### 7.2.1 STM32F072B-DISCO board selection

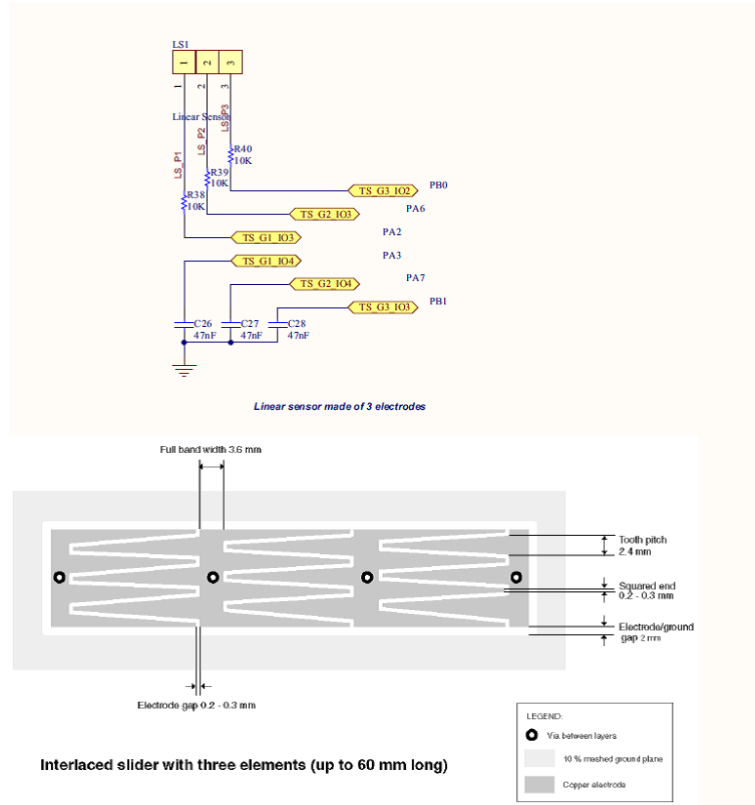
Start to select STM32F072B-DISCO board.

Figure 22. STM32F072B-DISCO board selection



To start Linear Touch Sensor channel acquisition at the same time, three groups are used. (See [Figure 23](#)).

**Figure 23. STM32F072B-DISCO board schematics**



## 7.2.2

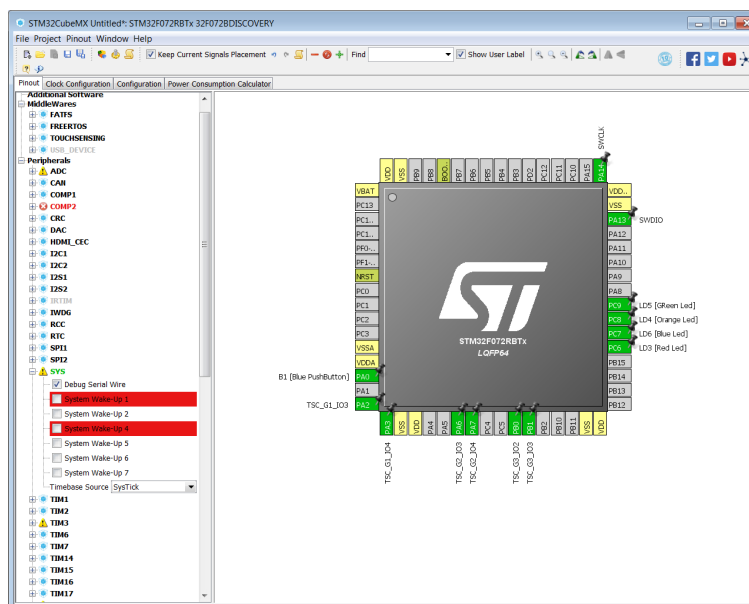
### STM32F072B-DISCO TSC group and sensor activation

To activate the TSC group, sampling capacitors and sensor channels follows the below steps:

- activate TSC according schematics information.
- deactivate unrelevant peripheral like USB, SPI, NCF(L0), EPaper(L0), MFX(L0)

SWD peripheral must be set according to Figure 24.

Figure 24. STM32F072B-DISCO pinout SWD



TSC peripheral must be set according to Figure 25.

Figure 25. STM32F072B-DISCO pinout TSC

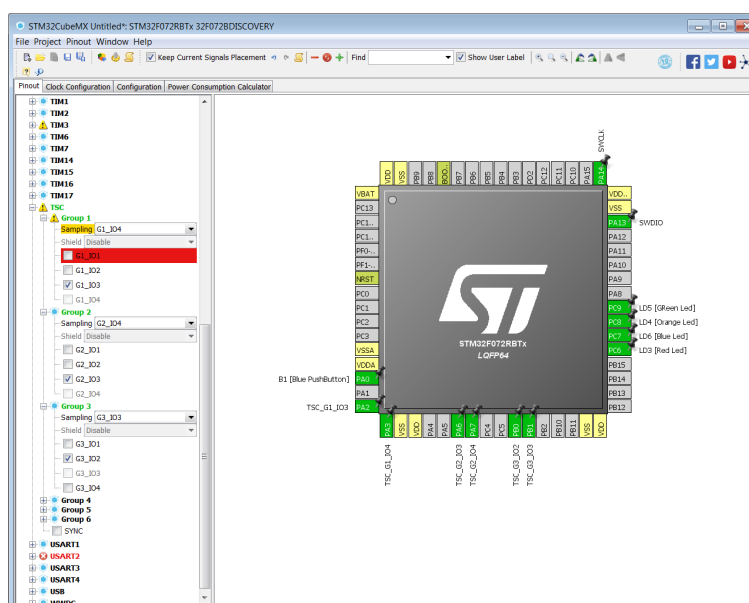
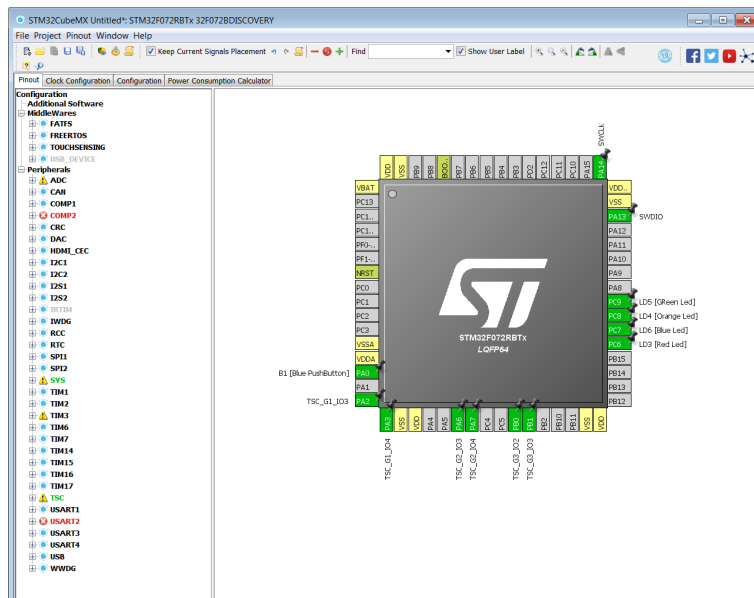


Figure 26 shows the results obtained.

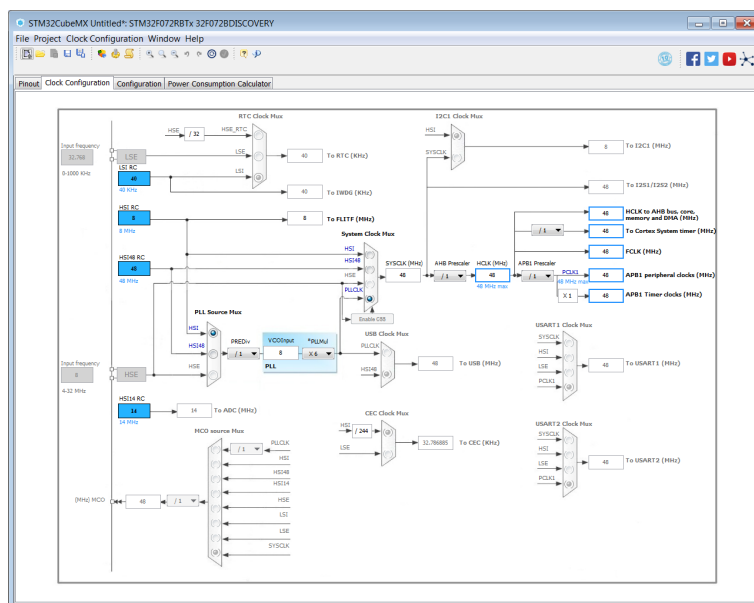
**Figure 26. STM32F072B-DISCO pinout overview**



### 7.2.3 STM32F072B-DISCO clock tree

It uses the default clock tree setting.

**Figure 27. STM32F072B-DISCO clock configuration**

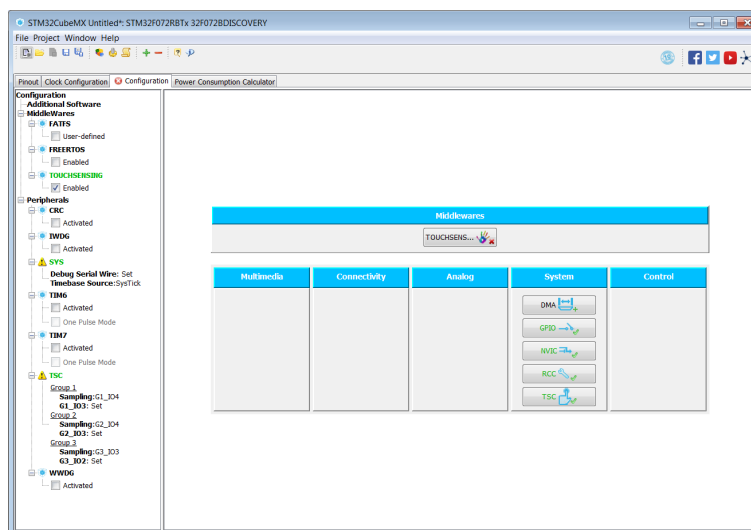


## 7.2.4

### STM32F072B-DISCO touchsensing library

To activate the TLS usage, switch on TOUCHSENSING box configuration.

Figure 28. TOUCHSENSING box configuration



Select three channels Linear slider and assign dedicated Gx\_I0y.

- For training purpose, the user can use three channels Linear slider as three keys sensors
- Select three keys and assign dedicated Gx\_I0y

Figure 29 to Figure 33 show these steps.

Figure 29. STM32F072B-DISCO sensor selection

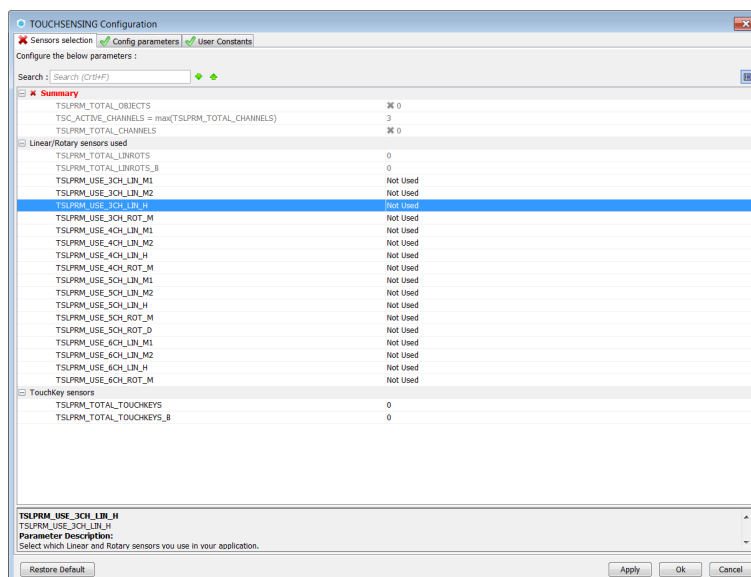


Figure 30. STM32F072B-DISCO sensor selection step2

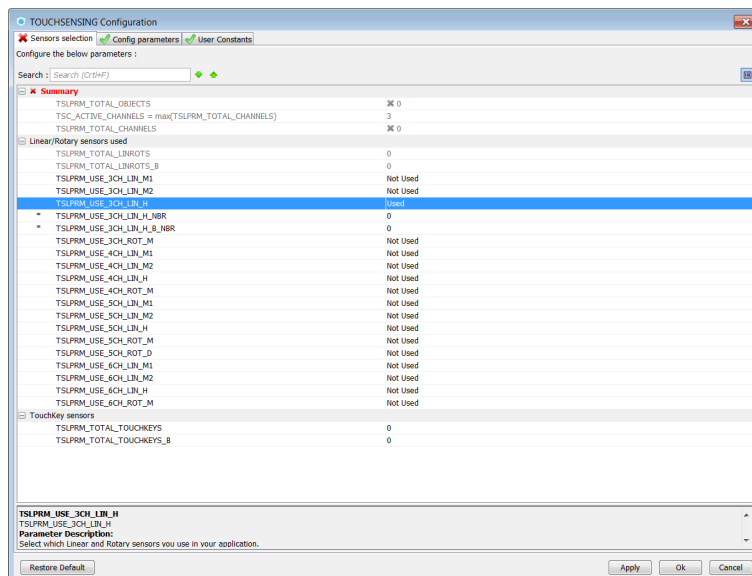


Figure 31. STM32F072B-DISCO sensor selection step3

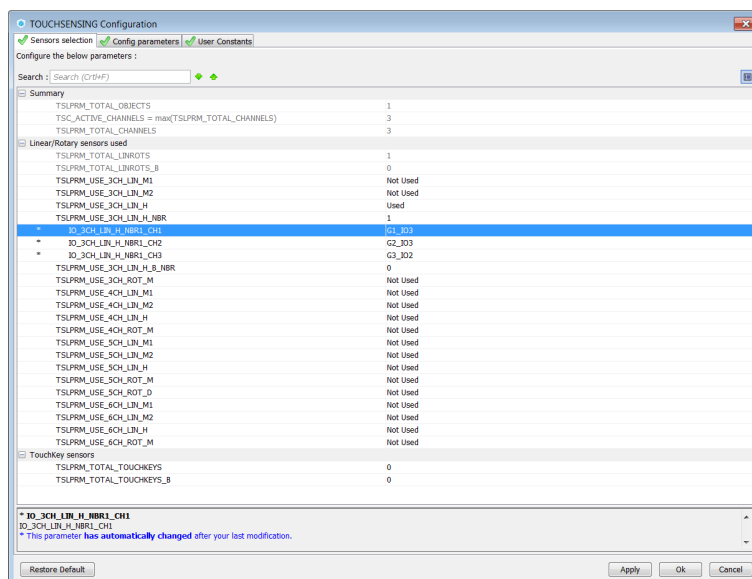


Figure 32. STM32F072B-DISCO sensor selection step4

**TOUCHSENSING Configuration**

☒ Sensors selection ☒ Config parameters ☒ User Constants

Configure the below parameters :

Search:

TSLPRM_TKEY_DETECT_INL_TH	120
TSLPRM_TKEY_DETECT_OUT_TH	110
TSLPRM_TKEY_CALB_TH	120
TSLPRM_COEFF_TH	0
<b>Thresholds for Linear and Rotary sensors</b>	
TSLPRM_LINROT_PROX_INL_TH	10
TSLPRM_LINROT_PROX_OUT_TH	5
TSLPRM_LINROT_DETECT_INL_TH	80
TSLPRM_LINROT_DETECT_OUT_TH	75
TSLPRM_LINROT_CALB_TH	80
TSLPRM_LINROT_USE_NORMDELTA	0
<b>Linear/Rotary sensors position</b>	
<b>TSLPRM_LINROT_RESOLUTION</b>	<b>7</b>
TSLPRM_LINROT_DIR_CHG_POS	10
TSLPRM_LINROT_DIR_CHG_DEB	1
<b>Debounce counters</b>	
TSLPRM_DEBOUNCE_PROX	2
TSLPRM_DEBOUNCE_DETECT	2
TSLPRM_DEBOUNCE_RELEASE	2
TSLPRM_DEBOUNCE_CALB	3
TSLPRM_DEBOUNCE_ERROR	3
<b>Environment Change System (ECS)</b>	
TSLPRM_ECS_K_SLOW	10
TSLPRM_ECS_K_FAST	20
TSLPRM_ECS_DELAY	500
<b>Detection Time Out (DTO)</b>	
TSLPRM DTO	0
<b>Detection Exclusion System (DXS)</b>	
TSLPRM_USE_DXS	0
<b>Miscellaneous parameters</b>	
TSLPRM_TICK_FREQ	1000
TSLPRM_DELAY_DISCHARGE_ALL	1000
TSLPRM_JDDEF	TSC_JDDEF_OUT_FP_LOW

**TSLPRM\_LINROT\_RESOLUTION**  
TSLPRM\_LINROT\_RESOLUTION must be between 1 and 8.  
Parameter Description:  
Position resolution in number of bits (range=1..8)

Figure 33. STM32F072B-DISCO sensor selection step5

**TOUCHSENSING Configuration**

☒ Sensors selection ☒ Config parameters ☒ User Constants

Configure the below parameters :

Search:

<b>Version and modes</b>	
TouchSensing version	2.2.0
<b>Optional features</b>	
TSLPRM_USE_MEAS	1
TSLPRM_USE_PROX	1
TSLPRM_USE_ZONE	0
<b>Acquisition limits</b>	
TSLPRM_ACQ_MIN	10
TSLPRM_ACQ_MAX	TSC_MCV_B191
<b>Calibration</b>	
TSLPRM_CALB_SAMPLES	4
TSLPRM_CALB_DELAY	0
<b>Thresholds for Touchkey sensors</b>	
TSLPRM_TKEY_PROX_INL_TH	10
TSLPRM_TKEY_PROX_OUT_TH	5
TSLPRM_TKEY_DETECT_INL_TH	120
TSLPRM_TKEY_DETECT_OUT_TH	110
TSLPRM_TKEY_CALB_TH	120
TSLPRM_COEFF_TH	0
<b>Thresholds for Linear and Rotary sensors</b>	
TSLPRM_LINROT_PROX_INL_TH	10
TSLPRM_LINROT_PROX_OUT_TH	5
<b>TSLPRM_LINROT_DETECT_INL_TH</b>	<b>10</b>
TSLPRM_LINROT_DETECT_OUT_TH	35
TSLPRM_LINROT_CALB_TH	40
TSLPRM_LINROT_USE_NORMDELTA	0
<b>Linear/Rotary sensors position</b>	
TSLPRM_LINROT_RESOLUTION	7
TSLPRM_LINROT_DIR_CHG_POS	10
TSLPRM_LINROT_DIR_CHG_DEB	1
<b>Debounce counters</b>	
TSLPRM_DEBOUNCE_PROX	2
TSLPRM_DEBOUNCE_DETECT	2
TSLPRM_DEBOUNCE_RELEASE	2

**TSLPRM\_LINROT\_DETECT\_INL\_TH**  
TSLPRM\_LINROT\_DETECT\_INL\_TH must be between 0 and 255.  
Parameter Description:  
Linear/Rotary Detect state input threshold (range=0..255)

## 7.2.5 STM32F072B-DISCO software project generation

It is possible to generate the complete software project based on TSC HAL and TSL.  
Figure 34 to Figure 37 show all these steps.

**Figure 34. STM32F072B-DISCO software generation step1**

**Project Settings**

Project | Code Generator | Advanced Settings

**Project Settings**

Project Name  
STM32F072B-DISCO-M4.24.0

Project Location  
C:\Users\richardo\Desktop\TSC\_Evolution Browse

Toolchain Folder Location  
C:\Users\richardo\Desktop\TSC\_Evolution\STM32F072B-DISCO-M4.24.0\

Toolchain / IDE  
EWARM Generate Under Root

**Linker Settings**

Minimum Heap Size  
0x200

Minimum Stack Size  
0x400

**Mcu and Firmware Package**

Mcu Reference  
STM32F072RBTx

Firmware Package Name and Version  
STM32Cube FW\_F0 V1.9.0

☒ Use Default Firmware Location  
C:\Users\richardo\STM32Cube\Repository\STM32Cube\_FW\_F0\_V1.9.0 Browse

Ok Cancel

**Figure 35. STM32F072B-DISCO software generation step2**

**Project Settings**

Project | Code Generator | Advanced Settings

**STM32Cube Firmware Library Package**

☒ Copy all used libraries into the project folder  
☐ Copy only the necessary library files  
☐ Add necessary library files as reference in the toolchain project configuration file

**Generated files**

☐ Generate peripheral initialization as a pair of '.c/.h' files per peripheral  
☐ Backup previously generated files when re-generating  
☒ Keep User Code when re-generating  
☒ Delete previously generated files when not re-generated

**HAL Settings**

☒ Set all free pins as analog (to optimize the power consumption)  
☐ Enable Full Assert

**Template Settings**

Select a template to generate customized code Settings...

Ok Cancel



Figure 36. STM32F072B-DISCO software generation step3

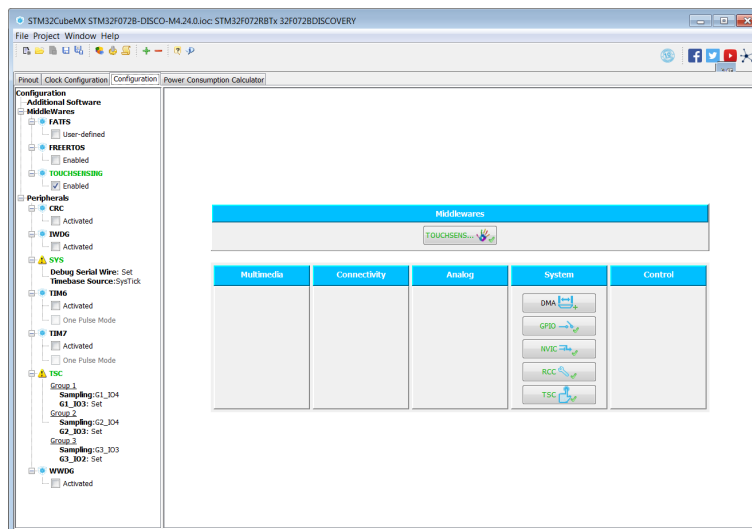
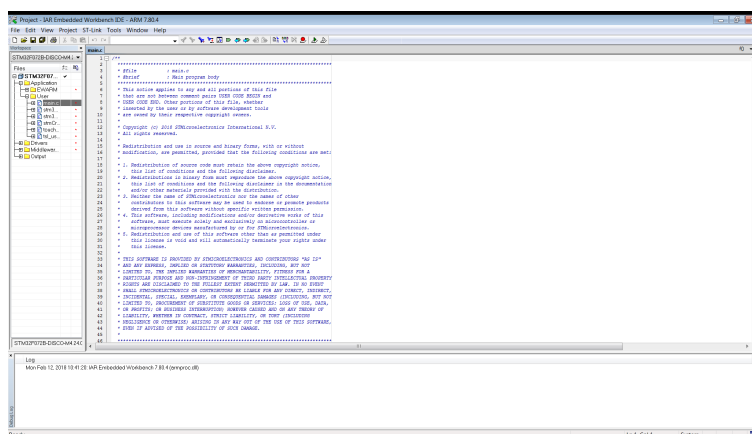


Figure 37. STM32F072B-DISCO IDE workspace



## 7.2.6 STM32F072B-DISCO software basic algorithm

The user needs to write the main application loop.

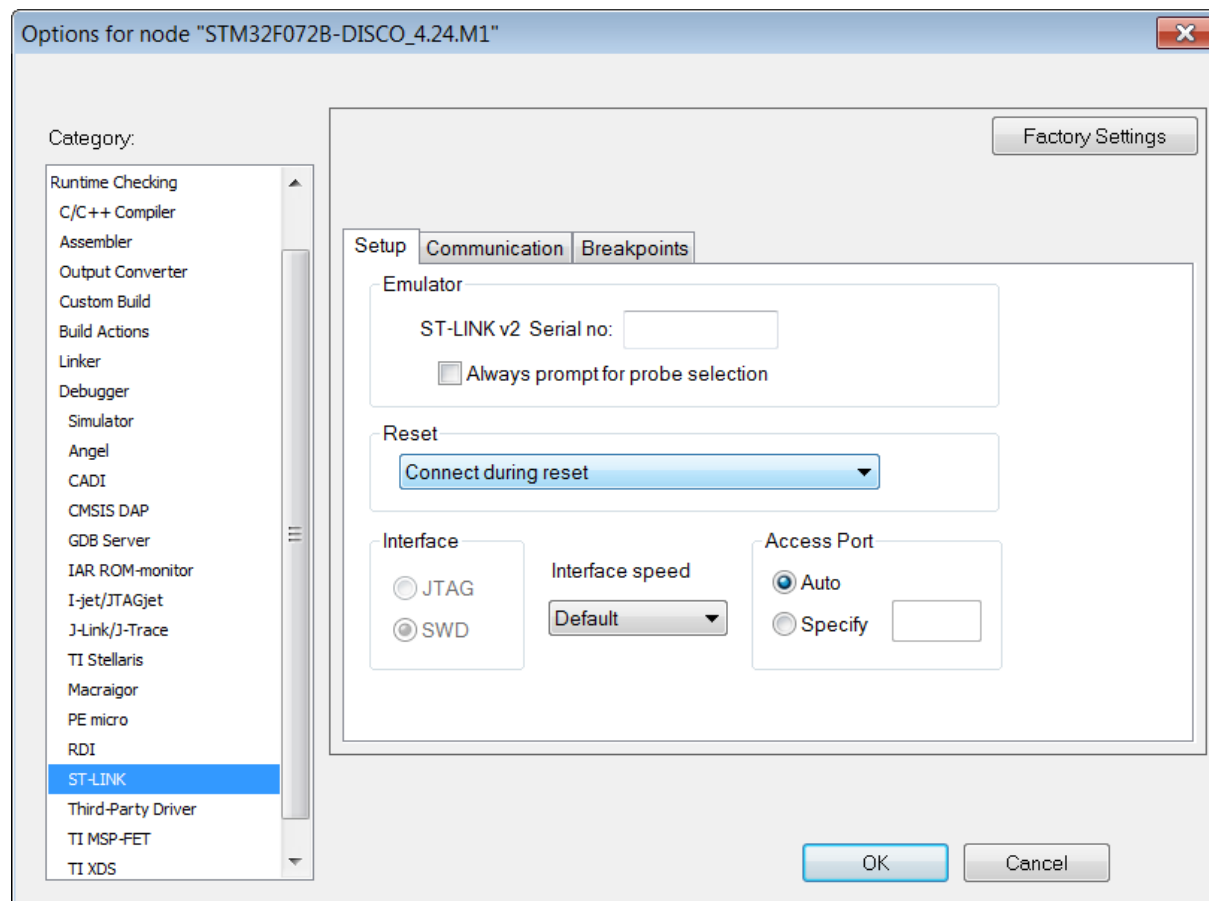
**Example to show keys usage instead of slider usage.**

- Open the IDE and in `main.c` file add the following lines:

```
/* USER CODE BEGIN 3 */
extern TSL_LinRot_T MyLinRots[];
static uint32_t cnt=0;
tsl_user_status_t status = TSL_USER_STATUS_BUSY;
status = tsl_user_Exec();
if(TSL_USER_STATUS_BUSY == status)
{
    // Nothing to do
    if(cnt++%50==0){
        HAL_GPIO_TogglePin(LD3_GPIO_Port, LD3_Pin);
    }
    HAL_Delay(1);
}
else
{
    if(MyLinRots[0].p_Data->StateId == TSL_STATEID_DETECT)
    {
        //TSLPRM_LINROT_RESOLUTION
        if(MyLinRots[0].p_Data->Position >= 5 && MyLinRots[0].p_Data->Position < 50)
        {
            HAL_GPIO_WritePin(LD4_GPIO_Port, LD4_Pin, GPIO_PIN_SET);
            HAL_GPIO_WritePin(LD6_GPIO_Port, LD6_Pin, GPIO_PIN_RESET);
            HAL_GPIO_WritePin(LD5_GPIO_Port, LD5_Pin, GPIO_PIN_RESET);
        }
        if(MyLinRots[0].p_Data->Position >= 50 && MyLinRots[0].p_Data->Position < 80)
        {
            HAL_GPIO_WritePin(LD6_GPIO_Port, LD6_Pin, GPIO_PIN_SET);
            HAL_GPIO_WritePin(LD4_GPIO_Port, LD4_Pin, GPIO_PIN_RESET);
            HAL_GPIO_WritePin(LD5_GPIO_Port, LD5_Pin, GPIO_PIN_RESET);
        }
        if(MyLinRots[0].p_Data->Position >= 80 && MyLinRots[0].p_Data->Position < 120)
        {
            HAL_GPIO_WritePin(LD5_GPIO_Port, LD5_Pin, GPIO_PIN_SET);
            HAL_GPIO_WritePin(LD4_GPIO_Port, LD4_Pin, GPIO_PIN_RESET);
            HAL_GPIO_WritePin(LD6_GPIO_Port, LD6_Pin, GPIO_PIN_RESET);
        }
    }
    else //if(MyLinRots[0].p_Data->StateId == TSL_STATEID_RELEASE)
    {
        HAL_GPIO_WritePin(LD4_GPIO_Port, LD4_Pin, GPIO_PIN_RESET);
        HAL_GPIO_WritePin(LD5_GPIO_Port, LD5_Pin, GPIO_PIN_RESET);
        HAL_GPIO_WritePin(LD6_GPIO_Port, LD6_Pin, GPIO_PIN_RESET);
    }
}
/* USER CODE END 3 */
```

To take care of ST-Link setup, see [Figure 38](#).

**Figure 38. STM32F072B-DISCO setup**



The system is functional and ready to be used. The led blinks according to finger position on the slider.

## 7.3 Discovery board: STM32L0538-DISCO

The STM32L053 discovery kit helps you to discover the ultra-low-power microcontrollers of the STM32L0 series. It offers everything required for beginners and experienced users to get started quickly and develop applications easily.

Based on an STM32L053C8T6, it includes an ST-LINK/V2-1 embedded debug tool interface, linear touch sensor, IDD current measurement, 2.04" E-paper display, NFC connector for PLUG-CR95HF-B board, LEDs, pushbuttons and a USB Mini-B connector.

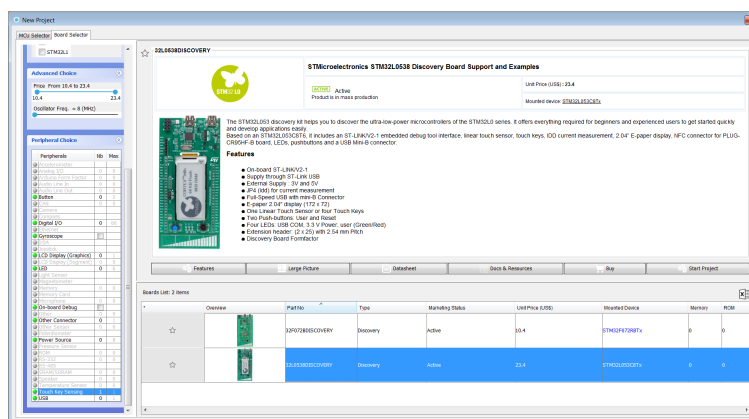
This discovery board provide a three channels linear (or slider) sensor. Their main characteristics are:

- On-board ST-LINK/V2-1
- Supply through ST-Link USB
- External Supply : 3V and 5V
- JP4 (Idd) for current measurement
- Full-Speed USB with mini-B Connector
- E-paper 2.04" display (172 x 72)
- One Linear Touch Sensor or four Touch Keys
- Two Push-buttons: User and Reset
- Four LEDs: USB COM, 3.3 V Power, user (Green/Red)
- Extension header: (2 x 25) with 2.54 mm Pitch
- Discovery Board Formfactor

### 7.3.1 STM32L0538-DISCO board selection

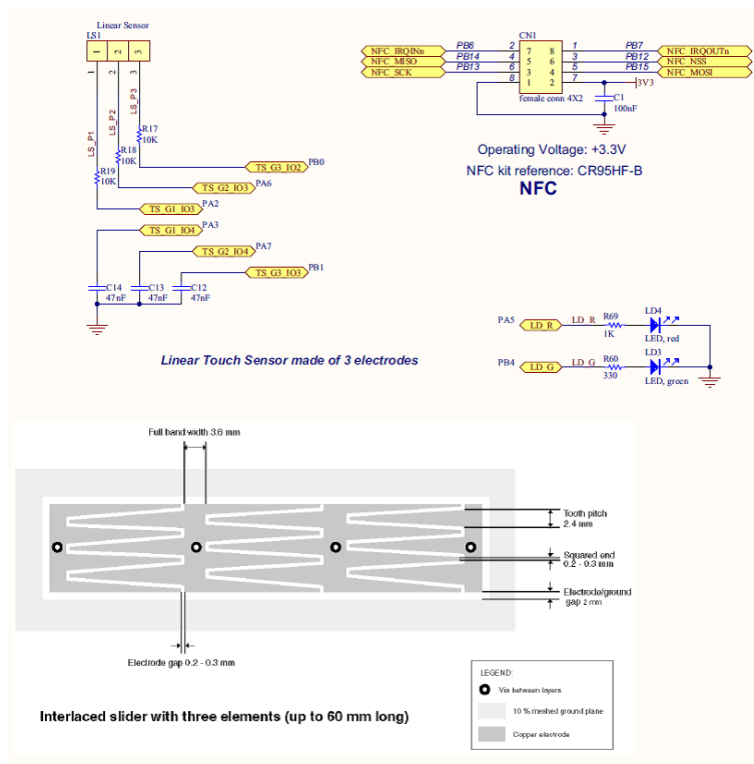
Start to select STM32L0538-DISCO board.

Figure 39. STM32L0538-DISCO board selection



To start linear touch sensor channel acquisition at the same time, three groups are used.

**Figure 40. STM32L0538-DISCO board schematics**



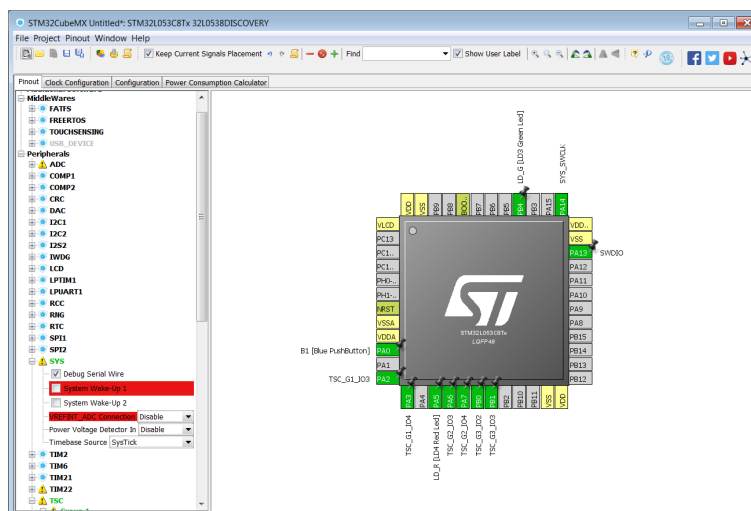
### 7.3.2 STM32L0538-DISCO TSC group and sensor activation

To activate the TSC group, sampling capacitors and sensor channels follows the below steps:

- Activate TSC according schematics information.
- You can deactivate irrelevant peripheral like USB, SPI, NCF(L0), EPaper(L0), MFX(L0)

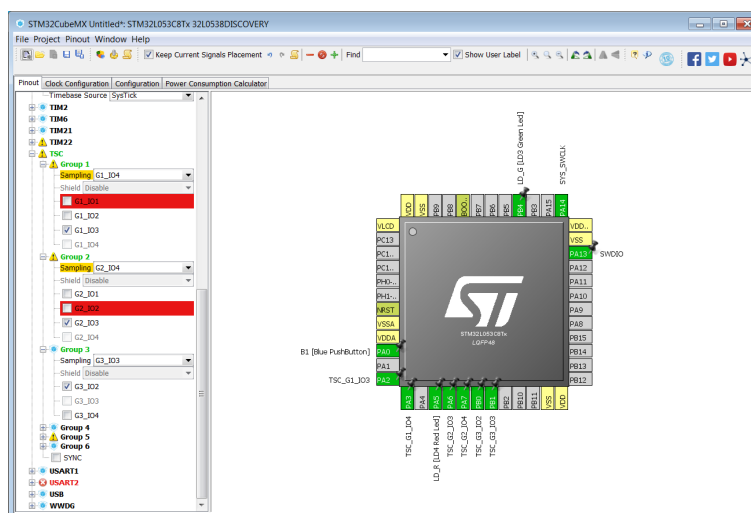
SWD peripheral must be set according to Figure 41.

Figure 41. Pinout SWD

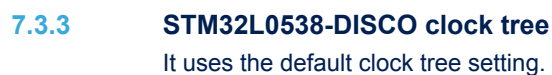


TSC peripheral must be set according to Figure 42.

Figure 42. Pinout TSC



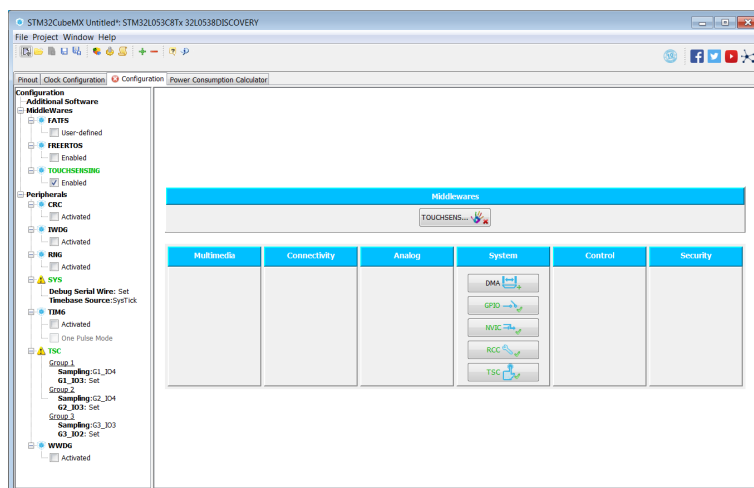
### Figure 43. Pinout overview



### 7.3.4 STM32L0538-DISCO touchsensing library

To activate the TLS usage, switch on TOUCHSENSING box configuration.

Figure 45. TOUCHSENSING box configuration



Select three channels Linear slider and assign dedicated Gx\_I0y.

- For training purpose, the user can use three channels linear slider as three keys sensors
- Select three keys and assign dedicated Gx\_I0y

Follow Figure 46 to Figure 50 to set sensors.

Figure 46. STM32L0538-DISCO sensor selection step1

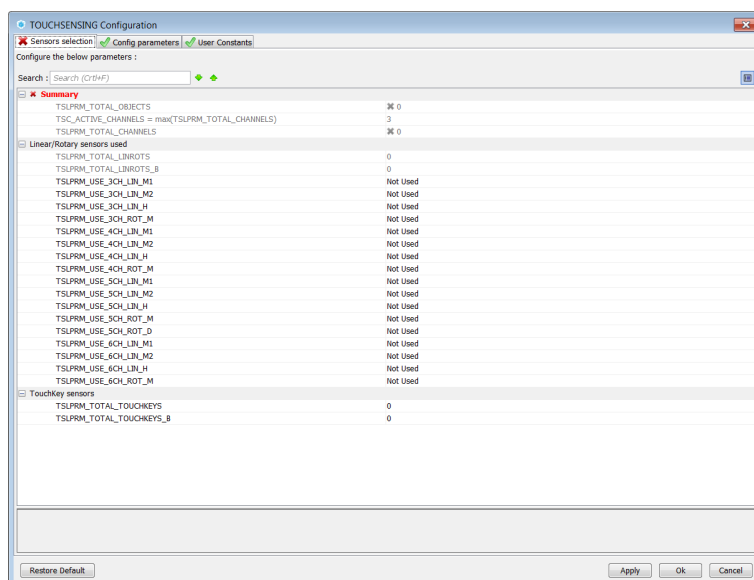




Figure 47. STM32L0538-DISCO sensor selection step2

**TOUCHSENSING Configuration**

☒ Sensors selection ☒ Config parameters ☒ User Constants

Configure the below parameters :

Search : Search (Ctrl+F)

**Summary**

TSLPRM_TOTAL_OBJECTS	3
TSC_ACTIVE_CHANNELS = max(TSLPRM_TOTAL_CHANNELS)	3
TSLPRM_TOTAL_CHANNELS	3

**Linear/Rotary sensors used**

TSLPRM_TOTAL_LINROTS	0
TSLPRM_TOTAL_LINROTS_B	0
TSLPRM_USE_3CH_LIN_M1	Not Used
TSLPRM_USE_3CH_LIN_M2	Not Used
TSLPRM_USE_3CH_LIN_H	Not Used
TSLPRM_USE_3CH_ROT_M	Not Used
TSLPRM_USE_4CH_LIN_M1	Not Used
TSLPRM_USE_4CH_LIN_M2	Not Used
TSLPRM_USE_4CH_LIN_H	Not Used
TSLPRM_USE_4CH_ROT_M	Not Used
TSLPRM_USE_5CH_LIN_M1	Not Used
TSLPRM_USE_5CH_LIN_M2	Not Used
TSLPRM_USE_5CH_LIN_H	Not Used
TSLPRM_USE_5CH_ROT_M	Not Used
TSLPRM_USE_6CH_LIN_M1	Not Used
TSLPRM_USE_6CH_LIN_M2	Not Used
TSLPRM_USE_6CH_LIN_H	Not Used
TSLPRM_USE_6CH_ROT_M	Not Used

**Touchkey sensors**

TSLPRM_TOTAL_TOUCHKEYS	3
* ID_TOUCHKEY1	G1_J03
* ID_TOUCHKEY2	G2_J03
* ID_TOUCHKEY3	G3_J02
TSLPRM_TOTAL_TOUCHKEYS_B	0

**TSLPRM\_TOTAL\_TOUCHKEYS**  
TSLPRM\_TOTAL\_TOUCHKEYS must be between 0 and 3.  
**Parameter Description:**  
Total number of "Extended" Touchkeys in application

Restore Default Apply Ok Cancel

Figure 48. STM32L0538-DISCO sensor selection step3

**TOUCHSENSING Configuration**

☒ Sensors selection ☒ Config parameters ☒ User Constants

Configure the below parameters :

Search : Search (Ctrl+F)

**Version and modes**

TouchSensing version	2.2.0
----------------------	-------

**Optional features**

TSLPRM_USE_MEAS	1
TSLPRM_USE_PROX	1
TSLPRM_USE_ZONE	0

**Acquisition limits**

TSLPRM_ACQ_MIN	10
TSLPRM_ACQ_MAX	TSC_MCVR_8191

**Calibration**

TSLPRM_CALB_SAMPLES	4
TSLPRM_CALB_DELAY	0

**Thresholds for touchkey sensors**

TSLPRM_TKEY_PROX_IN_TH	10
TSLPRM_TKEY_PROX_OUT_TH	5
TSLPRM_TKEY_DETECT_IN_TH	140
TSLPRM_TKEY_DETECT_OUT_TH	120
TSLPRM_TKEY_CALB_TH	40
TSLPRM_COEFF_TH	0

**Thresholds for Linear and Rotary sensors**

TSLPRM_LINROT_PROX_IN_TH	10
TSLPRM_LINROT_PROX_OUT_TH	5
TSLPRM_LINROT_DETECT_IN_TH	80
TSLPRM_LINROT_DETECT_OUT_TH	75
TSLPRM_LINROT_CALB_TH	80
TSLPRM_LINROT_USE_NORMDELTA	0

**Linear/Rotary sensors position**

TSLPRM_LINROT_RESOLUTION	4
TSLPRM_LINROT_DIR_CHG_POS	10
TSLPRM_LINROT_DIR_CHG_DEB	1

**Debounce counters**

TSLPRM_DEBOUNCE_PROX	2
TSLPRM_DEBOUNCE_DETECT	2
TSLPRM_DEBOUNCE_RELEASE	7

**TSLPRM\_TKEY\_DETECT\_IN\_TH**  
TSLPRM\_TKEY\_DETECT\_IN\_TH must be between 0 and 255.  
**Parameter Description:**  
Touchkeys Detect stable input threshold (range=0..255)

Restore Default Apply Ok Cancel

Figure 49. STM32L0538-DISCO sensor selection step4

**Project Settings**

Project | Code Generator | Advanced Settings

**Project Settings**

Project Name  
STM32L0538-DISCO-4.24.0

Project Location  
C:\Users\richardo\Desktop\TSC\_Evolution\ Browse

Toolchain Folder Location  
C:\Users\richardo\Desktop\TSC\_Evolution\STM32L0538-DISCO-4.24.0\

Toolchain / IDE  
EWARM ☐ Generate Under Root

**Linker Settings**

Minimum Heap Size  
0x200

Minimum Stack Size  
0x400

**Mcu and Firmware Package**

Mcu Reference  
STM32L0538Tx

Firmware Package Name and Version  
STM32Cube\_FW\_L0\_V1.10.0

☒ Use Default Firmware Location  
C:\Users\richardo\STM32Cube\Repository\STM32Cube\_FW\_L0\_V1.10.0 Browse

Ok Cancel

Figure 50. STM32L0538-DISCO sensor selection step5

**Project Settings**

Project | Code Generator | Advanced Settings

**STM32Cube Firmware Library Package**

☒ Copy all used libraries into the project folder  
☐ Copy only the necessary library files  
☐ Add necessary library files as reference in the toolchain project configuration file

**Generated files**

☐ Generate peripheral initialization as a pair of '.c/.h' files per peripheral  
☐ Backup previously generated files when re-generating  
☒ Keep User Code when re-generating  
☒ Delete previously generated files when not re-generated

**HAL Settings**

☒ Set all free pins as analog (to optimize the power consumption)  
☐ Enable Full Assert

**Template Settings**

Select a template to generate customized code Settings...

Ok Cancel

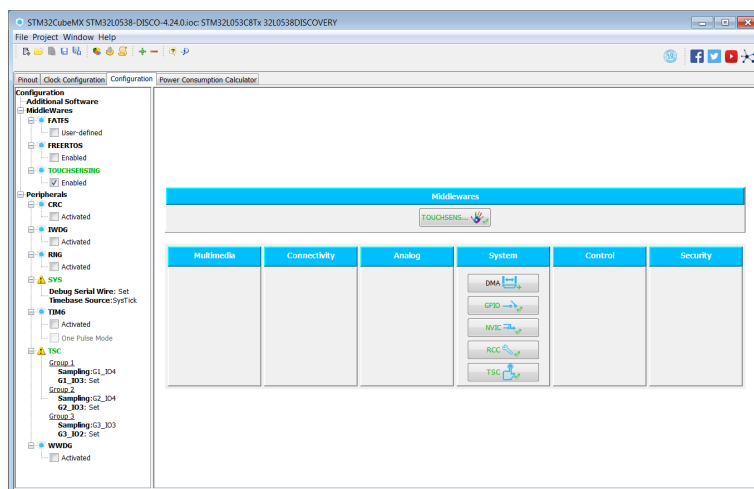
### 7.3.5 STM32L0538-DISCO software project generation

It is possible to generate the complete software project based on TSC HAL and TSL.  
See details in Figure 51 to Figure 55.

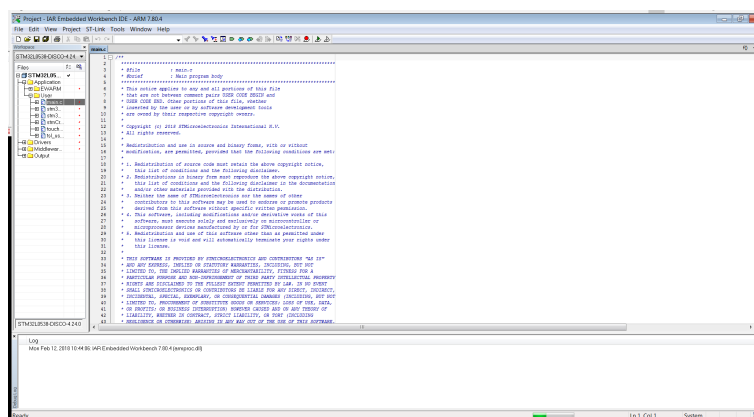
Figure 51. STM32L0538-DISCO software generation step1

Figure 52. STM32L0538-DISCO software generation step2

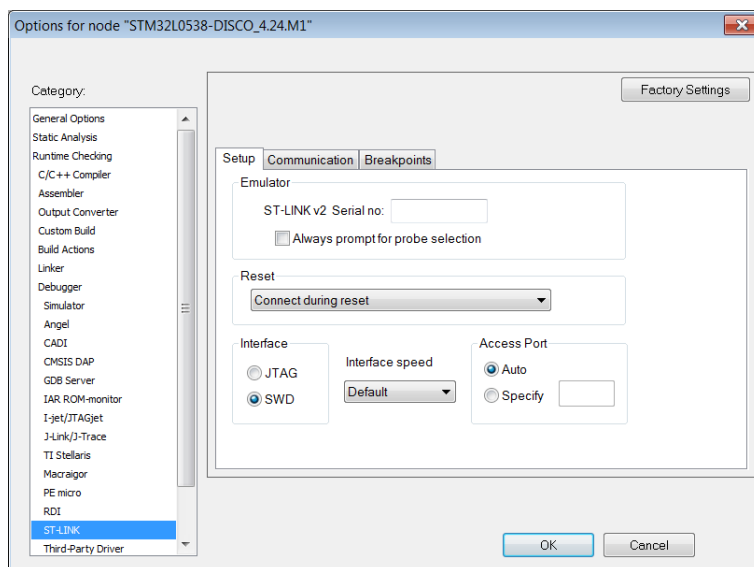
**Figure 53. STM32L0538-DISCO complete project overview**



**Figure 54. STM32L0538-DISCO IDE workspace**



### Figure 55. SWD settings



### 7.3.6 STM32L0538-DISCO software basic algorithm

Below is showed an example to show keys usage instead of slider usage.

- Open the IDE and in `main.c` file add the following lines:

```
/* USER CODE BEGIN 3 */
extern TSL_TouchKey_T MyTKeys[];
static uint32_t cnt=0;
tsl_user_status_t status = TSL_USER_STATUS_BUSY;

status = tsl_user_Exec();
if(TSL_USER_STATUS_BUSY == status)
{
    // Nothing to do
    if(cnt++%50==0){
    }
    HAL_Delay(1);
}
else
{
    HAL_GPIO_WritePin(LD_R_GPIO_Port, LD_R_Pin, GPIO_PIN_RESET); //00
    HAL_GPIO_WritePin(LD_G_GPIO_Port, LD_G_Pin, GPIO_PIN_RESET);
    if(MyTKeys[0].p_Data->StateId == TSL_STATEID_DETECT)
    {
        HAL_GPIO_WritePin(LD_R_GPIO_Port, LD_R_Pin, GPIO_PIN_SET); //11
        HAL_GPIO_WritePin(LD_G_GPIO_Port, LD_G_Pin, GPIO_PIN_SET);
    }
    if(MyTKeys[1].p_Data->StateId == TSL_STATEID_DETECT)
    {
        HAL_GPIO_WritePin(LD_R_GPIO_Port, LD_R_Pin, GPIO_PIN_SET); //01
        HAL_GPIO_WritePin(LD_G_GPIO_Port, LD_G_Pin, GPIO_PIN_RESET);
    }
    if(MyTKeys[2].p_Data->StateId == TSL_STATEID_DETECT)
    {
        HAL_GPIO_WritePin(LD_R_GPIO_Port, LD_R_Pin, GPIO_PIN_RESET); //01
        HAL_GPIO_WritePin(LD_G_GPIO_Port, LD_G_Pin, GPIO_PIN_SET);
    }
}
}
/* USER CODE BEGIN 3 */
```

The system is functional and ready to be used.

The Led is blink according to the position of the on slider.

## Revision history

**Table 23. Document revision history**

Date	Version	Changes
19-Sep-2018	1	Initial release.
23-Jul-2021	2	<p>Added:</p> <ul style="list-style-type: none"> <li>• STM32L4+, STM32L5, STM32U5 and STM32WB Series</li> <li>• <a href="#">Table 1. Applicable products</a></li> </ul> <p>Updated:</p> <ul style="list-style-type: none"> <li>• <a href="#">Section Introduction</a></li> <li>• <a href="#">Table 2. Charge transfer principle documentation</a></li> <li>• <a href="#">Table 3. Reference documentation</a></li> <li>• <a href="#">Table 4. Signal threshold use documentation</a></li> <li>• <a href="#">Table 5. Charge transfer documentation</a></li> <li>• <a href="#">Table 6. Sensitivity documentation</a></li> <li>• <a href="#">Table 8. Key documentation</a></li> <li>• <a href="#">Table 9. Linear touch sensor documentation</a></li> <li>• <a href="#">Table 10. Rotary sensor documentation</a></li> <li>• <a href="#">Table 11. Active shield documentation</a></li> <li>• <a href="#">Table 12. Led rules documentation</a></li> <li>• <a href="#">Table 13. Electrode documentation</a></li> <li>• <a href="#">Table 14. Layout documentation</a></li> <li>• <a href="#">Table 15. Power supply documentation</a></li> <li>• <a href="#">Table 17. Noise immunity documentation</a></li> <li>• <a href="#">Table 18. Conducted noise documentation</a></li> <li>• <a href="#">Section 6 Tuning</a></li> </ul>

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