# UM1913
# User manual

## Developing applications on STM32Cube with STMTouch touch sensing library

## Introduction

STM32Cube is an STMicroelectronics original initiative to improve developer productivity by reducing development effort, time and cost. STM32Cube covers the STM32 portfolio.

STM32Cube includes STM32CubeMX, configuration tool that allows the generation of C initialization code and an embedded software platform, delivered per STM32xx Series:

- the STM32Cube HAL, STM32 abstraction layer embedded software ensuring maximized portability across the STM32 portfolio
- a consistent set of middleware components such as RTOS, USB, TCP/IP, Graphics and STMTouch
- all embedded software utilities coming with a full set of examples

This user manual describes the STMTouch touch sensing library that is part of the STM32Cube firmware package, available from the STMicroelectronics website (http://www.st.com/stm32cube). It is intended for developers who use STM32Cube firmware on STM32 Arm®-based microcontrollers listed in the table below.

The STMTouch touch sensing library (TSL) includes:

- a complete register address mapping with all bits, bitfields and registers declared in C
- a collection of routines and data structures covering all functions to manage the touch sensing technology

The source code is developed using the ANSI-C standard. It is fully documented and is MISRA C® 2004 compliant. Writing the whole library in 'Strict ANSI-C' makes it independent from the development tools. Only the start-up files depend on the development tools. Since this library is generic and covers many functionalities and microcontrollers, the size and/or execution speed of the application code may not be optimized. For many applications, this library may be used as is. However, for applications having tough constraints in terms of code size and/or execution speed, this library may need to be fine tuned.

**Table 1. Applicable products**

| Type | Software package (associated STM32 Series) |
|---|---|
| STM32Cube package | STM32CubeF0, STM32CubeF3 (STM32F0/F3)<br>STM32CubeL0, STM32CubeL1, STM32CubeL4 (STM32L0/L1/L4/L4+)<br>STM32CubeWB (STM32WB) |

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# 1 Coding rules and conventions

## 1.1 Acronyms and abbreviations

The table below summarizes all acronyms and abbreviations used in this document.

**Table 2. Terms and acronyms**

| Name | Definition |
|---|---|
| Bank | Group of channels acquired simultaneously |
| Channel | Elementary acquisition item |
| Cs | Charge-transfer sampling capacitance |
| Ct | Equivalent touch capacitance |
| CT | Charge-transfer acquisition principle |
| Cx | Equivalent sensor capacitance |
| Delta | Difference between the measure and the reference |
| DTO | Detection time-out |
| DXS | Detection exclusion system |
| ECS | Environment change system |
| Linear sensor | Multi-channels sensor with electrodes positioned in a linear way |
| LinRot sensor | Linear or rotary touch sensor |
| Measure or Meas | Current signal measured on a channel |
| Reference or Ref | Reference signal initialized during the calibration and then regularly updated by the ECS |
| Rotary sensor | Multi-channels sensor with electrodes positioned in a circular way |
| Rs | ESD protection serial resistor |
| Sensor or object | Any touch sensor (such as touchkey, linear or rotary) |
| Timer acquisition mode | Acquisition using two timers and PWM signals (also called hardware acquisition mode).<br>*Note: Only available on STM32L1 Series microcontrollers* |
| Touchkey or TKey sensor | Single channel sensor |
| TSC | Touch sensing controller peripheral |

## 1.2 Naming conventions

The following naming conventions are used in the STMTouch touch sensing library source files:

- Source and header files are in lower-case and preceded by 'tsl' or 'tsl_'.
- The microcontroller family is added at the end of the file name if needed.
- Functions, globals, typedefs and defines are preceded by 'TSL'.
- Constants are written in upper case and preceded by 'TSLPRM_'.
- Constants used in one file are defined within this file only.
- Constants used in more than one file are defined in a header file.
- Typedef names are suffixed with '_T'.
- Enum typedefs are suffixed with '_enum_T'.
- Functions are named according to the 'TSL_[module]_[function]' scheme:
  - [module]: abbreviation of the file (such as acq, tim, dxs)
  - [function]: the first letter in each word is in upper case.

## 1.3 Coding rules

This section describes the coding rules used in the STMTouch touch sensing library source files.

### 1.3.1 General

- Source code complies with ANSI C standard.
- No warning after compilation. Any warning that cannot be eliminated is commented in the source code.
- ANSI standard data types are used and defined in the ANSI C header file <stdint.h>.
- No blocking code is present and all required waiting loops (polling loops) are controlled by a timeout.

### 1.3.2 Variable types

Specific variable types are already defined with a fixed type and size:

- The types that are used by all modules are defined in the *tsl_types.h* file.
- Other variable types are defined in their corresponding module header file.

### 1.3.3 Peripheral registers

The peripheral registers are accessed using the pointers described in the CMSIS device peripheral access layer header file.

## 1.4 MISRA C 2004 compliance

### 1.4.1 Generalities

The C programming language importance grows for embedded systems. However, when it comes to developing code for safety-critical applications, this language has many drawbacks. There are several unspecified, implementation-defined, and undefined aspects of the C language that make it unsuited for developing safety-critical systems.

The motor industry software reliability association describes a subset of the C language well suited for developing safety-critical systems in *[1]*.

The STMTouch touch sensing library has been developed to be MISRA C 2004 compliant.

The following section describes how the STMTouch touch sensing library complies with MISRA C 2004 (as described in section 4.4 Claiming compliance of the standard of *[1]*:

- A compliance matrix has been completed which shows how compliance has been enforced.
- The whole STMTouch touch sensing library source code is compliant with MISRA C 2004 rules.
- Deviations are documented. A list of all instances of rules not being followed is being maintained, and for each instance there is an appropriately signed-off deviation.
- All the issues listed in section *4.2,* The programming language and coding context of the standard of *[1]*, that need to be checked during the firmware development phase, have been addressed during the development of the STMTouch touch sensing library and appropriate measures have been taken.

### 1.4.2 Compliance matrix

The compliance of the STMTouch touch sensing library with MISRA C 2004 has been checked in two ways:

- using PC-lint tool for C/C++ (NT) versus 8.00v, copyright gimpel software 1985-2006
- performing regular code reviews

The following table lists the MISRA C 2004 rules that are frequently violated in the code:

**Table 3. MISRA C 2004 rules not followed**

| MISRA C 2004 rule number | Required/ advisory | Summary | Reason of deviance |
|---|---|---|---|
| 1.1<br>1.2 | Required | All code must conform to ISO 9899:1990 standard C, with no extensions permitted. | Compilers extensions are enabled. Comments starting with “//” symbol for code readability. |
| 5.4 | Required | A tag name must be a unique identifier. | Due to the usage of objects methods |
| 8.1 | Required | No prototype seen. Functions must always have prototype declarations and the prototype must be visible at both the function definition. | This rule is violated as there is no functions prototypes for the objects methods. |

**Table 3. MISRA C 2004 rules not followed (continued)**

| MISRA C 2004 rule number | Required/ advisory | Summary | Reason of deviance |
|---|---|---|---|
| 10.1<br>10.2 | Required | The value of an expression of integer/floating type must not be implicitly converted to a different underlying type. | Code complexity |
| 10.3 | Required | The value of a complex expression of integer type may only be cast to a type that is narrower and of the same signedness as the underlying type of the expression. | Code complexity |
| 10.5 | Required | If the bitwise operators are applied to an operand of underlying type unsigned char or unsigned short, the result must be immediately cast to the underlying type of the operand. | Use shift on signed quantity for the linear/rotary position |
| 11.3 | Advisory | A cast must not be performed between a pointer type and an integral type. | Needed when addressing memory mapped registers |
| 12.7 | Required | Bitwise operators must not be applied to operands whose underlying type is signed. | Shift of signed value needed |
| 14.3 | Required | Before preprocessing, a null statement must only occur on a line by itself. | Use of macros to simplify the code |
| 14.5 | Required | The continue statement must not be used. | Used to optimize the code speed execution |
| 19.11 | Required | All macro identifiers in preprocessor directives must be defined before use, except in ifdef and ifndef preprocessor directives and the defined() operator. | All parameters are checked in the check_config files |

# 2 STMTouch touch sensing library

## 2.1 Supported microcontrollers and development tools

### 2.1.1 Supported microcontrollers

This STMTouch touch sensing library version supports the following microcontrollers and acquisition modes:

- **Any STM32** microcontroller using the embedded touch sensing controller (TSC): all Arm®(a)-based devices (see *Table 1*):
  - Surface charge-transfer acquisition principle managed by the touch sensing controller
  - Up to 24 channels (eight groups of three channels maximum)
  - Up to eight channels can be acquired simultaneously
  - Spread spectrum feature
  - Programmable charge transfer frequency and max count value
- **STM32L1 Series** microcontrollers: the surface charge-transfer acquisition principle is managed by:
  - Two timers plus a routing interface (hardware acquisition mode). This mode is not supported on STM32L1 Series microcontrollers featuring 256-Kbyte or less memory.
  - GPIOs plus a routing interface (software acquisition mode). This mode is supported by all microcontrollers.
  - Up to 34 channels
  - Up to 11 channels can be acquired simultaneously

arm

### 2.1.2 Development tools

The STM32 microcontrollers are supported by a full range of development solutions from lead suppliers that deliver start-to-finish control of application development from a single integrated development environment.

The STMTouch touch sensing library has been developed with the following toolchains:

- EWARM (IAR™)
- MDK-ARM (Keil®)
- SW4STM32 (AC6)

For more details about the compilers versions used, see the STM32Cube package release note.

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

## 2.2 Package description

The following snapshots show an example of installation inside the STM32CubeF0 package.

**Figure 1. Installation folder 1/2 (library)**

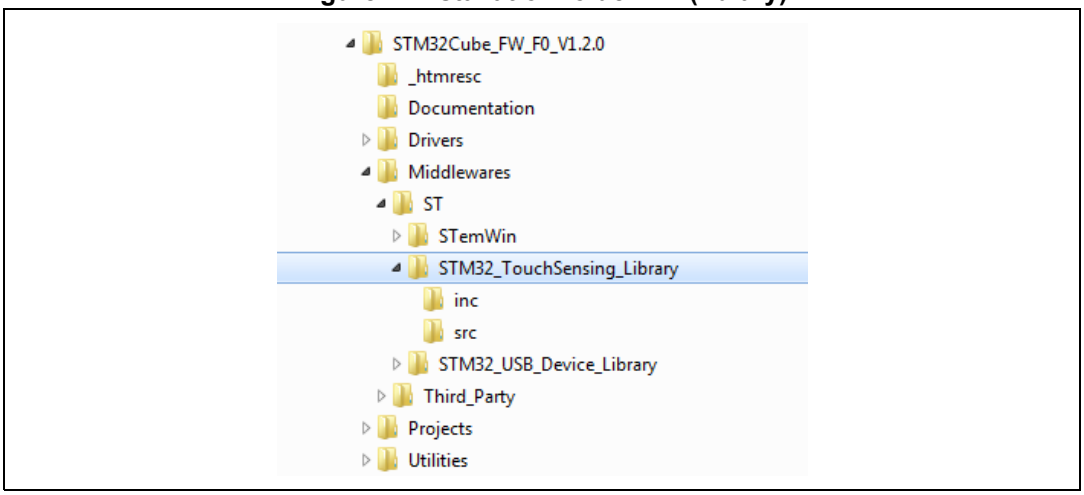
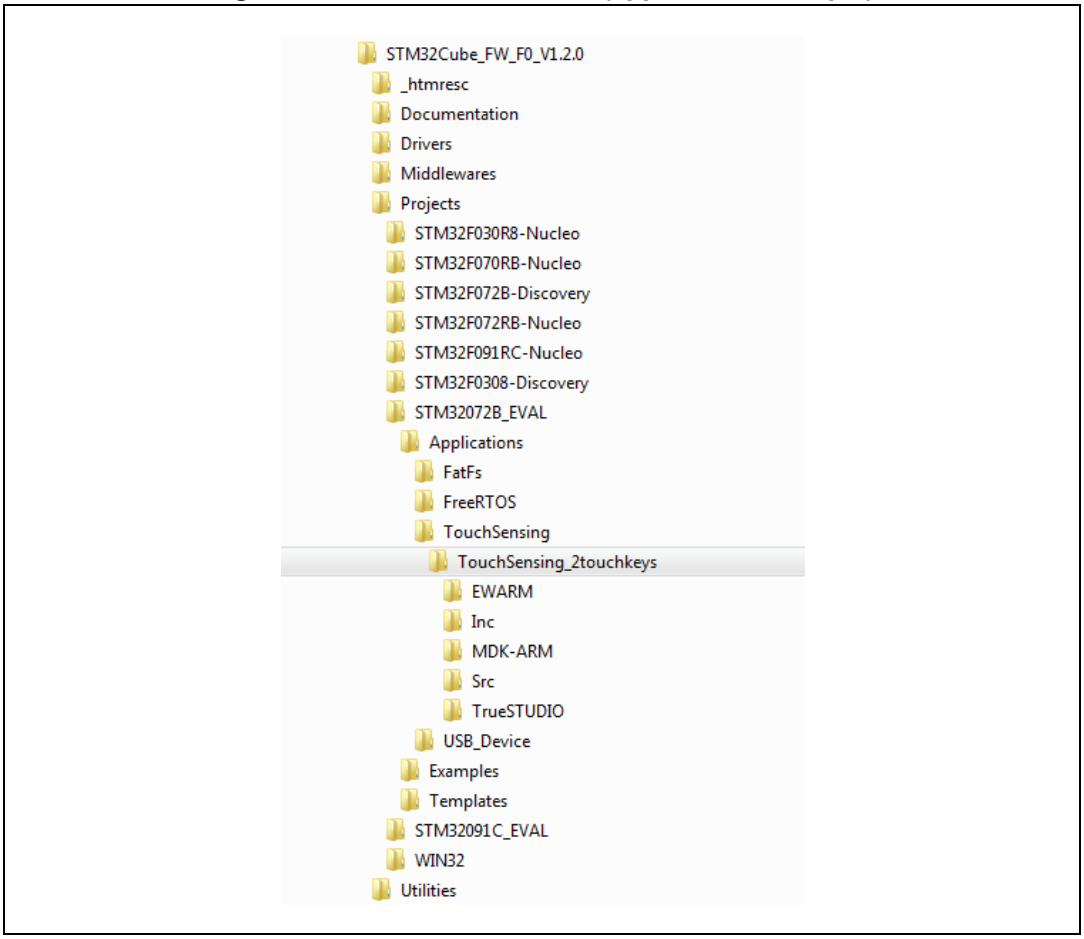



**Figure 2. Installation folder 2/2 (application example)**



## 2.3 Main features

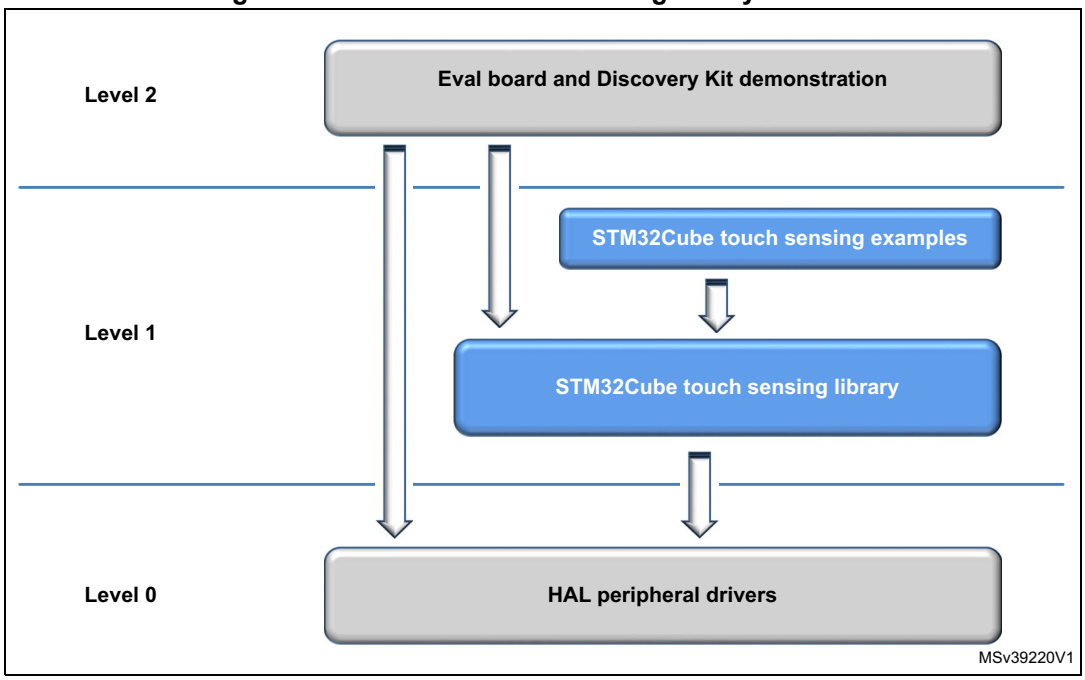
- Supports proximity, touchkeys, linear and rotary touch sensors
- Environment change system (ECS)
- Detection time out (DTO)
- Detection exclusion system (DXS)
- Noise filter
- Unlimited number of sensors
- Modular architecture allowing easy addition of new acquisitions or sensors
- Each sensor having its own state machine
- Simplified timing management
- Management of error during acquisition

## 2.4 Architecture

### 2.4.1 Overview

The following figure shows the interactions between the STMTouch touch sensing library and the other firmware layers.

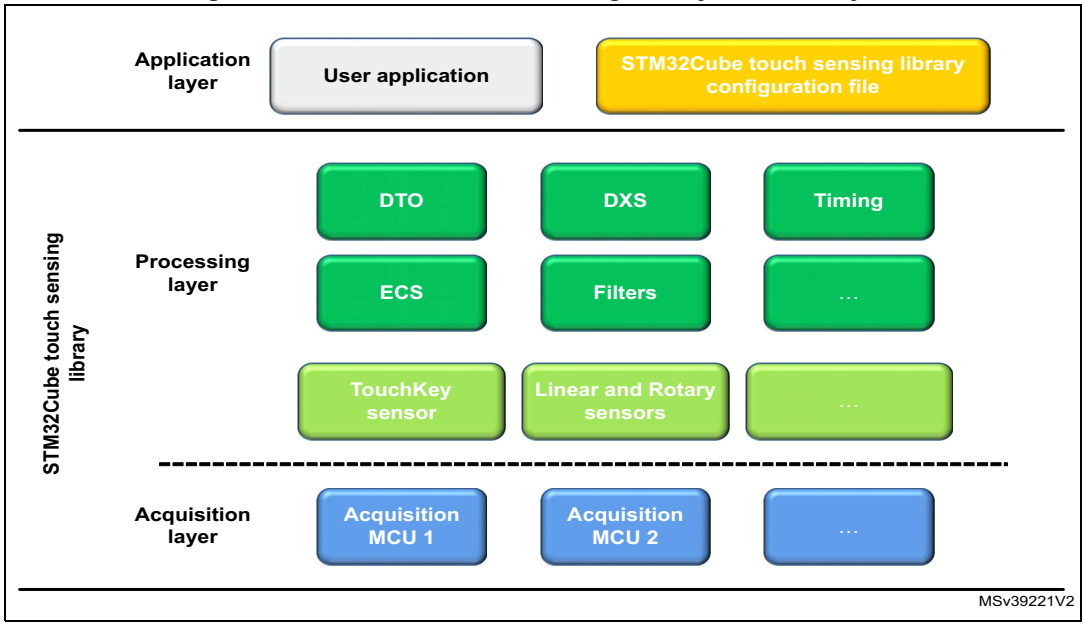
**Figure 3. STM32Cube touch sensing library overview**



### 2.4.2 STMTouch touch sensing library layers

The following figure shows a more detailed view of the different STM32Cube touch sensing library layers.

**Figure 4. STMTouch touch sensing library detailed layers**




The STMTouch touch sensing library is composed of the following main layers:

- acquisition layer
- processing layer
- configuration layer

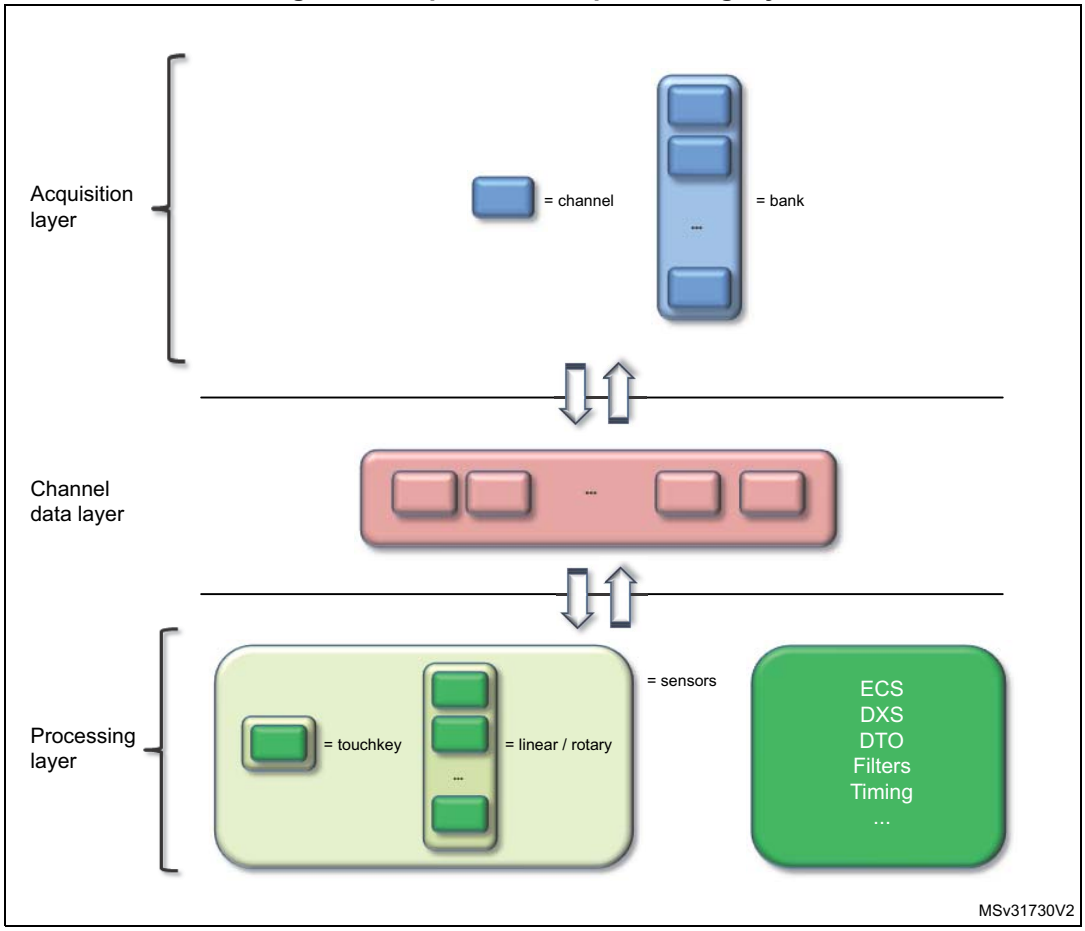
The configuration layer corresponds to what the user needs to write in his application code in order to correctly use the STMTouch touch sensing library. This includes all the channels and sensors declarations and the parameters for example.

The acquisition and processing layers are described in more details below.

### 2.4.3 Acquisition and processing layers

The following figure details the acquisition and processing layers and the different elements used in each layer.

**Figure 5. Acquisition and processing layers**




The **acquisition layer** role is to perform the acquisition of the different channels. The result of the acquisition (measure and flags) is stored inside the channel data layer. These informations are accessed by the processing layer.

The acquisition layer has only access to the channels and banks. It does not have access to the sensors.

The **channel data layer** role is to share information between the acquisition and processing layers. It stores the result of the acquisition (measure) for each channel and store different informations coming from the processing layer (such as reference, delta or flags).

Located in RAM, the ChannelData structure is the only interface between the acquisition and processing layers.

This **processing layer** consists in executing each sensors state machine, executing the different data processing like ECS, DXS, DTO and storing any useful information for the acquisition layer inside the channel data area.

The processing layer does not have direct access to the channels and banks. This access is made through the sensors.

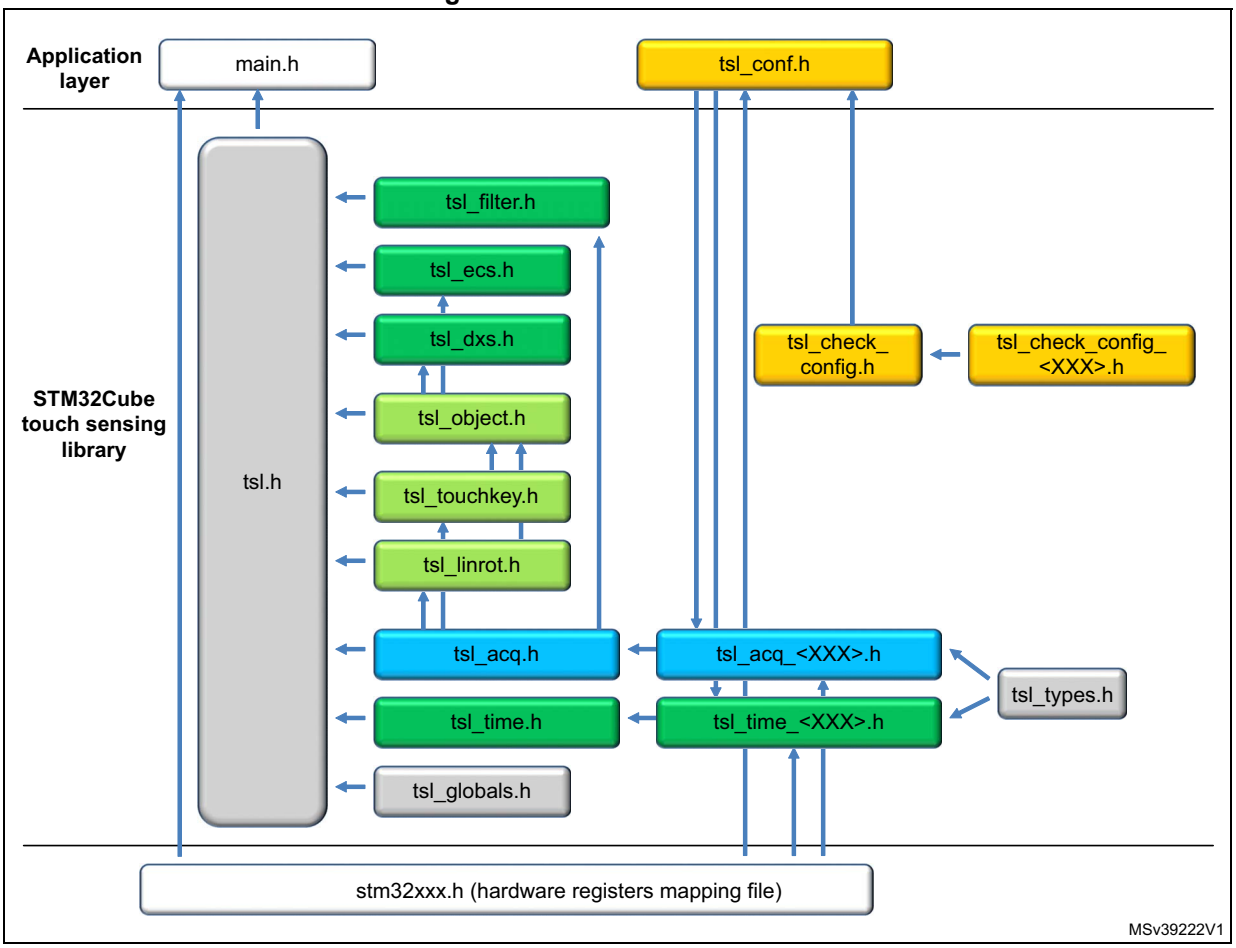
### 2.4.4 Header files inclusion

The figure below provides a global view of the STMTouch touch sensing library usage and the interaction between the different header files.

In the actual version of the STMTouch touch sensing library, the <XXX> is equal to “tsc” or “stm32l1xx”.

*Note: To simplify the drawing, only the most important links are shown. For example the tsl_globals.h file is also included in different files.*

**Figure 6. Header files inclusion**




## 2.5 Channel

### 2.5.1 Principle

A channel is the basic element that is used to store several information like:

- where the source measurement can be found after the acquisition is performed (TSC_IOGxCR registers for TSC acquisition)
- where are stored the measure, the reference, the delta or the flags

### 2.5.2 Resources

A channel is defined by the following data structures:

- **TSL_ChannelSrc_T**: contains all information about the source measurement (such as index of the register containing the measurement or masks)
- **TSL_ChannelDest_T**: contains all information about the measurement destination (index in the channel data array).
- **TSL_ChannelData_T**: contains all data for the channel (such as measure, delta or reference)

The channel depends on the acquisition technology. This is why the contents of this structures are not common for all acquisitions. They are declared in each acquisition header files (tsl_acq_<XXX>.h):

- **tsl_acq_stm32l1xx_hw.h** for STM32L1 Series microcontrollers using the hardware acquisition mode
- **tsl_acq_stm32l1xx_sw.h** for STM32L1 Series microcontrollers using the software acquisition mode
- **tsl_acq_tsc.h** for any STM32 microcontrollers featuring the TSC peripheral

The maximum number of channels is only limited by the device (memory size and channels supported).

The user must declare all the channels arrays in his application code. It can be done directly in the main.c file or in any other file.

### 2.5.3 Parameters

- TSLPRM_TOTAL_CHANNELS

### 2.5.4 Usage example

The channels structures must be declared in the application code.

Example of **channel source** array declaration for microcontrollers featuring TSC peripheral. This structure must always be placed in ROM.

```
const TSL_ChannelSrc_T MyChannels_Src[TSLPRM_TOTAL_CHANNELS] =
{ { CHANNEL_0_SRC },
  { CHANNEL_1_SRC },
  { CHANNEL_2_SRC }};
```

Example of **channel destination** array declaration for microcontrollers featuring TSC peripheral. This structure must always be placed in ROM.

```
const TSL_ChannelDest_T MyChannels_Dest[TSLPRM_TOTAL_CHANNELS] =
{ { CHANNEL_0_DEST },
  { CHANNEL_1_DEST },
  { CHANNEL_2_DEST }};
```

*Note: The "CHANNEL_x_SRC" and "CHANNEL_x_DEST" are "#define" constants and are used for readability. The values are acquisition dependant.*

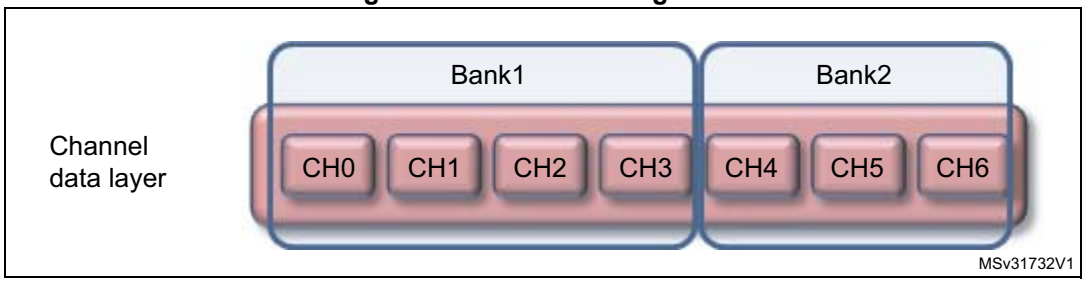
Example of **channel data** array declaration (i.e. channel data layer). This structure must always be placed in RAM.

```
TSL_ChannelData_T MyChannels_Data[TSLPRM_TOTAL_CHANNELS];
```

**Warning: When several banks are present, it is mandatory to declare all channels of each bank consecutively in the source and destination structures.**

Example:

**Figure 7. Channels arrangement**




Example of **channel source** array declaration for microcontrollers featuring TSC peripheral.

```
CONST TSL_ChannelSrc_T MyChannels_Src[TSLPRM_TOTAL_CHANNELS] =
{
// Bank 1
{ CHANNEL_0_SRC, CHANNEL_0_IO_MSK, CHANNEL_0_GRP_MSK },
{ CHANNEL_1_SRC, CHANNEL_1_IO_MSK, CHANNEL_1_GRP_MSK },
{ CHANNEL_2_SRC, CHANNEL_2_IO_MSK, CHANNEL_2_GRP_MSK },
{ CHANNEL_3_SRC, CHANNEL_3_IO_MSK, CHANNEL_3_GRP_MSK },
// Bank 2
{ CHANNEL_4_SRC, CHANNEL_4_IO_MSK, CHANNEL_4_GRP_MSK },
{ CHANNEL_5_SRC, CHANNEL_5_IO_MSK, CHANNEL_5_GRP_MSK },
{ CHANNEL_6_SRC, CHANNEL_6_IO_MSK, CHANNEL_6_GRP_MSK }
};
```

## 2.6 Bank

### 2.6.1 Principle

A bank is a group of channels that are acquired simultaneously. The number of channels in the bank is variable.

### 2.6.2 Resources

The bank data are held by only one structure: TSL_Bank_T

The bank depends also on the acquisition technology. Structures are declared in each acquisition header files (tsl_acq_<XXX>.h):

The maximum number of banks is only limited by the device.

The user must declare all the bank arrays in his application code. It can be done directly in the *main.c* file or in any other file.

The banks are used mainly by the functions described below. Some functions are common whatever the device and acquisition technology. Some others are dependent on the device.

Common functions:

- TSL_acq_BankGetResult()
- TSL_acq_BankCalibrate()

Device dependent functions:

- TSL_acq_BankConfig()
- TSL_acq_BankStartAcq()
- TSL_acq_BankWaitEOC()

### 2.6.3 Parameters

- TSLPRM_TOTAL_BANKS

### 2.6.4 Usage example

Example of three banks declaration for microcontrollers featuring TSC peripheral:

```
CONST TSL_Bank_T MyBanks[TSLPRM_TOTAL_BANKS] = {
  {&MyChannels_Src[0], &MyChannels_Dest[0], MyChannels_Data,
BANK_0_NBCHANNELS, BANK_0_MSK_CHANNELS, BANK_0_MSK_GROUPS},
  {&MyChannels_Src[1], &MyChannels_Dest[1], MyChannels_Data,
BANK_1_NBCHANNELS, BANK_1_MSK_CHANNELS, BANK_1_MSK_GROUPS},
  {&MyChannels_Src[2], &MyChannels_Dest[2], MyChannels_Data,
BANK_2_NBCHANNELS, BANK_2_MSK_CHANNELS, BANK_2_MSK_GROUPS}
};
```

## 2.7 Objects

### 2.7.1 Principle

The term “object” or “sensor” stands for any sensor type (touchkeys, linear and rotary touch sensors) supported by the STMTouch touch sensing library.

### 2.7.2 Resources

All processing that affect the sensors in general are defined in the following files:

- *tsl_object.c*
- *tsl_object.h*

The functions are:

- `TSL_obj_GroupInit()`
- `TSL_obj_GroupProcess()`
- `TSL_obj_SetGlobalObj()`

A sensor is described by the structures:

- TSL_Object_T
- TSL_ObjectGroup_T

### 2.7.3 Parameters

- TSLPRM_TOTAL_OBJECTS

### 2.7.4 Example

First, all touchkeys, linear and rotary touch sensors (described after) used in the application must be described first as 'generic' sensors or objects.

Example:

```
// Mix of touchkeys and Linear touch sensors
const TSL_Object_T MyObjects[TSLPRM_TOTAL_OBJECTS] =
{
  // TKeys
  { TSL_OBJ_TOUCHKEYB, (TSL_TouchKeyB_T *)&MyTKeys[0]   },
  { TSL_OBJ_TOUCHKEYB, (TSL_TouchKeyB_T *)&MyTKeys[1]   },
  // Linear touch sensors
  { TSL_OBJ_LINEARB,   (TSL_LinRotB_T   *)&MyLinRots[0] }
};
```

These objects must be placed in the ROM memory.

Once this is done, it is necessary to create at least one group of sensors. Groups of sensors are used by the different processing routines (such as ECS or DXS).

These groups of objects must be placed in the RAM.

Example:

```
TSL_ObjectGroup_T MyObjGroup_All = {
 MyObjects,
 3,
 0,
 TSL_STATE_NOT_CHANGED
};
```

Then, all the sensors must be initialized and “processed”. This is done in the main function of the application:

```
int main(void) {
  ...
  TSL_obj_GroupInit(&MyObjGroup_All);
  ...
  while (1) {
```

```
    ...
    TSL_obj_GroupProcess(&MyObjGroup_All);
    ...
  }
}
```

## 2.8 Touchkey sensor

### 2.8.1 Principle

The touchkey sensor is composed of only one channel. It acts as a simple “button” with two states RELEASE and DETECT (or TOUCH if DXS is enabled).

### 2.8.2 Resources

All the functions related to this sensor are described in the files:

- *tsl_touchkey.c*
- *tsl_touchkey.h*

Two types of touchkey sensor are available:

- Basic: defined by the **TSL_TouchKeyB_T** structure
- Extended: defined by the **TSL_TouchKey_T** structure

Two functions (called methods) are used to initialize the sensor parameters and to run the sensor state machine:

- `TSL_tkey_Init()`
- `TSL_tkey_Process()`

The difference between the basic and extended types concerns the methods and sensor state machine used:

- For a basic sensor, the methods and state machine are those used in the **TSL_Params** structure.
- For an extended sensor, the methods and state machine are those declared in their own structure.

### 2.8.3 Parameters

- TSLPRM_TOTAL_TKEYS

### 2.8.4 Usage example

The user must declare these methods in the application code.

*Note: User own initialization and process functions can also be used instead:*

```
const TSL_TouchKeyMethods_T MyTKeys_Methods =
{
  TSL_tkey_Init,
  TSL_tkey_Process
};
```

The declaration of the touchkey sensor is done by the user in the application code.

- Example with a basic sensor:

```
// "Basic" touchkeys: Always placed in ROM
const TSL_TouchKeyB_T MyTKeys[TSLPRM_TOTAL_TKEYS] =
{
  { &MyTKeys_Data[0], &MyTKeys_Param[0], &MyChannels_Data[0] },
  { &MyTKeys_Data[1], &MyTKeys_Param[1], &MyChannels_Data[1] },
  { &MyTKeys_Data[2], &MyTKeys_Param[2], &MyChannels_Data[2] }
};
```

- Example with an extended sensor:

```
// "Extended" TouchKeys: Always placed in ROM
const TSL_TouchKey_T MyTKeys[TSLPRM_TOTAL_TKEYS] =
{
  { &MyTKeys_Data[0], &MyTKeys_Param[0], &MyChannels_Data[0],
MyTKeys_StateMachine, &MyTKeys_Methods },
  { &MyTKeys_Data[1], &MyTKeys_Param[1], &MyChannels_Data[1],
MyTKeys_StateMachine, &MyTKeys_Methods },
  { &MyTKeys_Data[2], &MyTKeys_Param[2], &MyChannels_Data[2],
MyTKeys_StateMachine, &MyTKeys_Methods }
};
```

## 2.9 Linear and rotary touch sensors

### 2.9.1 Principle

The linear and rotary touch sensors are like a touchkey sensor except that they are composed of a variable number of channels. The difference between the linear and rotary touch sensors is how the electrodes are organized together.

The linear and rotary touch sensors have additional fields in their structure compared to touchkey sensors:

- Number of channels
- Delta coefficient table
- Position offset table
- Sector computation parameter
- Position correction parameter for linear sensor

*Note: The last three fields are used to calculate the position.*

### 2.9.2 Number of channels

Only 1, 3, 4, 5 and 6 channels are supported today by the STMTouch touch sensing library. Additional number of channels can be added by the end-user.

*Note: A linear touch sensor with one channel is equivalent to one touchkey sensor. When an application uses both touchkey, linear and rotary sensors, it is better to use touchkeys with a 1-channel linear touch sensor. In this case, the gain in memory size is important as the touchkey sensor state machine is not used.*

### 2.9.3 Delta coefficient table

The delta coefficient table is used to adjust each channel of the linear and rotary touch sensors. Each value is a 16-bit integer. The MSB is the integer part, the LSB is the real part.

Examples:

- To apply a factor of 1.10:
  - MSB equal 0x01
  - LSB equal 0x1A (0.10 x 256 = 25.6, rounded to 26 = 0x1A)
- To apply a factor 1.00:
  - MSB equal 0x01
  - LSB equal 0x00
- To apply a factor 0.90:
  - MSB equal 0x00
  - LSB equal 0xE6 (0.90 x 256 = 230.4, rounded to 230 = 0xE6)

This results in the following delta coefficient table:

```
CONST uint16_t MyLinRot0_DeltaCoeff[3] = {0x011A, 0x0100, 0x00E6};
```

The number of delta coefficient table is not limited. The same delta coefficient table can be shared by several linear and rotary touch sensors.

### 2.9.4 Electrodes placement

The placement (design) of the electrodes can be done in three different manners:

- Mono electrode design

  The number of electrodes is equivalent to the number of channels. This design is used for linear and rotary touch sensors.

  Abbreviations: **LIN_M1**, **LIN_M2** and **ROT_M**

  Examples:
  - CH1 CH2 CH3
  - CH1 CH2 CH3 CH4
  - CH1 CH2 CH3 CH4 CH5
- Dual electrode design

  All the electrodes are duplicated and interlaced together in order to increase the touch area.

  This design is used for linear and rotary touch sensors composed **with at least five channels**.

  Abbreviation: **ROT_D**

  Examples with 5 channels:
  - CH1 CH2 CH3 CH4 CH5 CH1 CH3 CH5 CH2 CH4
  - CH1 CH2 CH3 CH4 CH5 CH2 CH4 CH1 CH3 CH5
  - CH1 CH2 CH3 CH4 CH5 CH3 CH1 CH4 CH2 CH5
- Half-ended electrode design

  The first electrode is duplicated and the replica is placed at the end. The size of the first and last electrode is **half the size** of the other electrodes. This design is used for **linear**

**sensors only**. The 0 and 255 positions are obtained more easily compared to the Mono electrodes design.

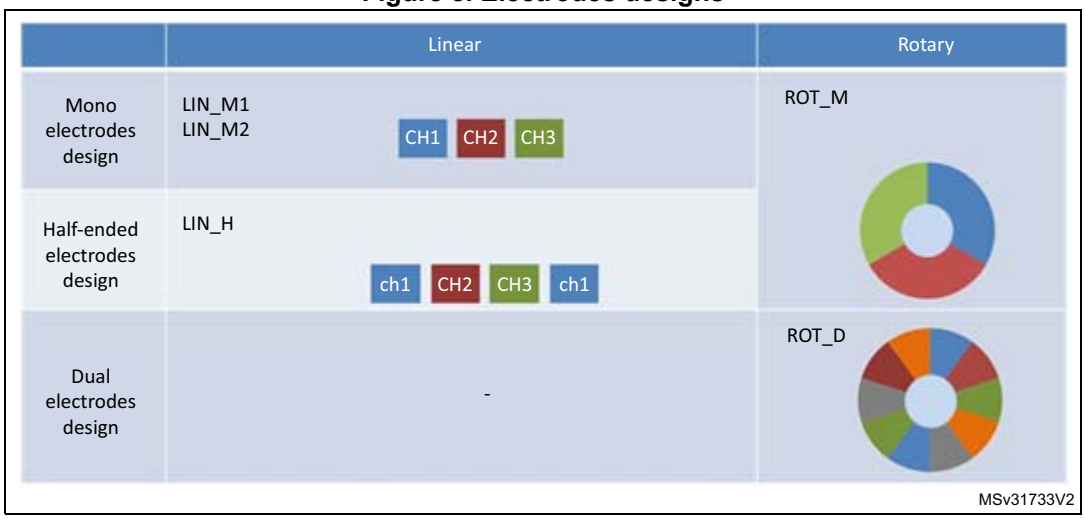
Abbreviation: **LIN_H**

Examples:

– ch1 CH2 CH3 ch1
– ch1 CH2 CH3 CH4 ch1
– ch1 CH2 CH3 CH4 CH5 ch1

The following figure summarizes the different electrodes designs we can have on linear and rotary touch sensors:

**Figure 8. Electrodes designs**



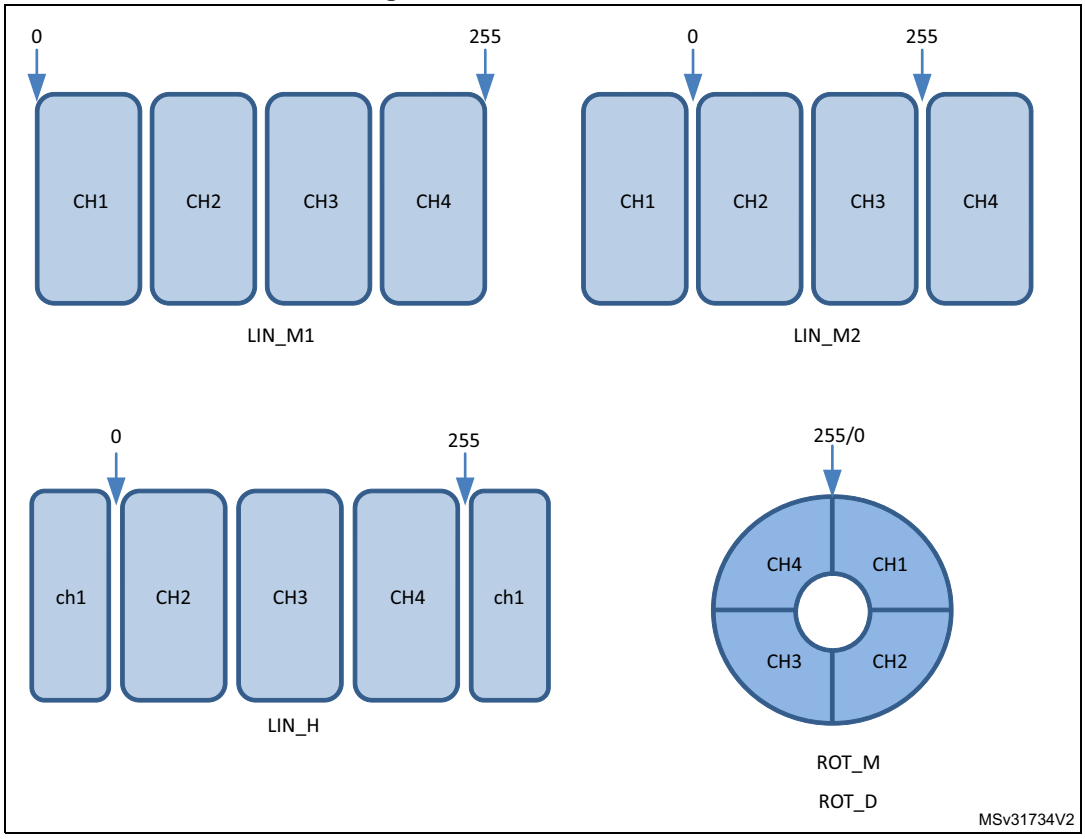

## Positions 0 and 255

Special care must be taken for the 0 and 255 positions on linear sensors. These positions are placed differently depending on the electrodes design used:

- **LIN_M1**: the 0 and 255 positions are placed completely at the sensor's **extremities**. These positions can be obtain with difficulty if the electrodes are too big or if they are separated by an important space.
- **LIN_M2**, **LIN_H**: the 0 position is placed **between the first and second electrodes**. The 255 position is placed **between the last two electrodes**.
- **ROT_M** and **ROT_D**: the 0 and 255 positions are always placed **between the first and the last electrodes**.

The following figures summarizes the different placements of the 0 and 255 positions with 4-channel sensors:

**Figure 9. Positions 0 and 255**




The following table summarizes the different linear and rotary touch sensors electrodes designs supported by the STMTouch touch sensing library:

**Table 4. Supported linear and rotary touch sensors**

| Number of channels | LIN_M1 | LIN_M2 | LIN_H | ROT_M | ROT_D |
|---|---|---|---|---|---|
| 3 | Yes | Yes | Yes | Yes | No |
| 4 | Yes | Yes | Yes | Yes | No |
| 5 | Yes | Yes | Yes | Yes | Yes |
| 6 | Yes | Yes | Yes | Yes | No |

Each supported electrode design is described by the following fields in the **TSL_LinRot_T** or **TSL_LinRotB_T** structures:

- Position offset table
- Sector computation parameter
- Position correction parameter for linear sensor

These fields are defined in the *tsl_linrot.c* and *tsl_linrot.h* files and follow the naming convention:

- position offset table: TSL_POSOFF_nCH_[LIN|ROT]_[M1|M2|H|D]
- sector computation parameter: TSL_SCTCOMP_nCH_[LIN|ROT]_[M1|M2|H|D]
- position correction parameter for linear sensor: TSL_POSCORR_nCH_LIN_[M1|M2|H|D]

with:

- n = number of channels
- LIN = linear sensor
- ROT = rotary sensor
- M1 = mono electrodes design with 0/255 position at extremities
- M2 = mono electrodes design
- H = half-ended electrodes design
- D = dual electrodes design

In order to gain memory space, each table is only compiled if its corresponding parameter is set in the configuration file:

TSLPRM_USE_nCH_[LIN|ROT]_[M1|M2|H|D]

### 2.9.5 Resources

All the functions related to this sensor are described in the files:

- *tsl_linrot.c*
- *tsl_linrot.h*

Two types of linear and rotary sensor are available:

- basic: defined by the **TSL_LinRotB_T** structure
- extended: defined by the **TSL_LinRot_T** structure

The difference between basic and extended is the same as for the touchkey sensor.

Three functions (called methods) are used to initialized the sensor parameters, run the sensor state machine and calculate the position.

- `TSL_linrot_Init()`
- `TSL_linrot_Process()`
- `TSL_linrot_CalcPos()`

### 2.9.6 Parameters

- TSLPRM_TOTAL_LINROTS

### 2.9.7 Usage example

The user must declared these methods in the application code.

*Note: User own initialization and process functions can also be used instead:*

```
CONST TSL_LinRotMethods_T MyLinRots_Methods =
{
  TSL_linrot_Init,
```

```
  TSL_linrot_Process,
  TSL_linrot_CalcPos
};
```

The declaration of the linear and rotary sensor is done by the user in the application code in the same manner as for touchkey sensor.

Example with two basic linear touch sensors, one with three channels half-ended and the other with five channels mono electrodes design:

```
CONST TSL_LinRotB_T MyLinRots[2] =
{
  // LinRot sensor 0
  &MyLinRots_Data[0],
  &MyLinRots_Param[0],
  &MyChannels_Data[CHANNEL_9_DEST],
  3, // Number of channels
  MyLinRot0_DeltaCoeff, // Delta coefficient table
  (TSL_tsignPosition_T *)TSL_POSOFF_3CH_LIN_H, // Position table
  TSL_SCTCOMP_3CH_LIN_H, // Sector compensation
  TSL_POSCORR_3CH_LIN_H, // Position correction
  // LinRot sensor 1
  &MyLinRots_Data[1],
  &MyLinRots_Param[1],
  &MyChannels_Data[CHANNEL_12_DEST],
  5, // Number of channels
  MyLinRot1_DeltaCoeff, // Delta coefficient table
  (TSL_tsignPosition_T *)TSL_POSOFF_5CH_LIN_M2, // Position table
  TSL_SCTCOMP_5CH_LIN_M2, // Sector compensation
  TSL_POSCORR_5CH_LIN_M2  // Position correction
};
```

Example of one extended (having its own state machine and methods) linear touch sensor with three channels half-ended:

```
CONST TSL_LinRot_T MyLinRots[1] =
{
  // LinRot sensor 0
  &MyLinRots_Data[0],
  &MyLinRots_Param[0],
  &MyChannels_Data[CHANNEL_0_DEST],
  3, // Number of channels
  MyLinRot0_DeltaCoeff,
  (TSL_tsignPosition_T *)TSL_POSOFF_3CH_LIN_H,
  TSL_SCTCOMP_3CH_LIN_H,
  TSL_POSCORR_3CH_LIN_H,
  MyLinRots_StateMachine, // Specific state machine
  &MyLinRots_Methods // Specific methods
};
```

Example of one extended rotary touch sensor with three channels mono electrode design:

```
CONST TSL_LinRot_T MyLinRots[0] =
{
  // LinRot sensor 0
  &MyLinRots_Data[0],
  &MyLinRots_Param[0],
  &MyChannels_Data[CHANNEL_0_DEST],
  3, // Number of channels
  MyLinRot0_DeltaCoeff,
  (TSL_tsignPosition_T *)TSL_POSOFF_3CH_ROT_M,
  TSL_SCTCOMP_3CH_ROT_M,
  0, // No position correction needed on a Rotary sensor
  MyLinRots_StateMachine, // Specific state machine
  &MyLinRots_Methods // Specific methods
};
```

## 2.10 Main state machine

The main state machine is managed by the user in the application layer. A set of functions are available to accomplish this task. The main state machine can be defined with polling or with interrupt modes, using one or several banks. The modularity of the STMTouch touch sensing library allows also the application code to be inserted between acquisition and processing tasks. Several examples are given below.

The functions to use for the acquisition are:

- `TSL_acq_BankConfig()`
- `TSL_acq_BankStartAcq()`
- `TSL_acq_BankWaitEOC()`
- `TSL_acq_BankGetResult()`

These functions are device dependent and are described in the *tsl_acq_<XXX>.c* files.

The functions to use for the processing are:

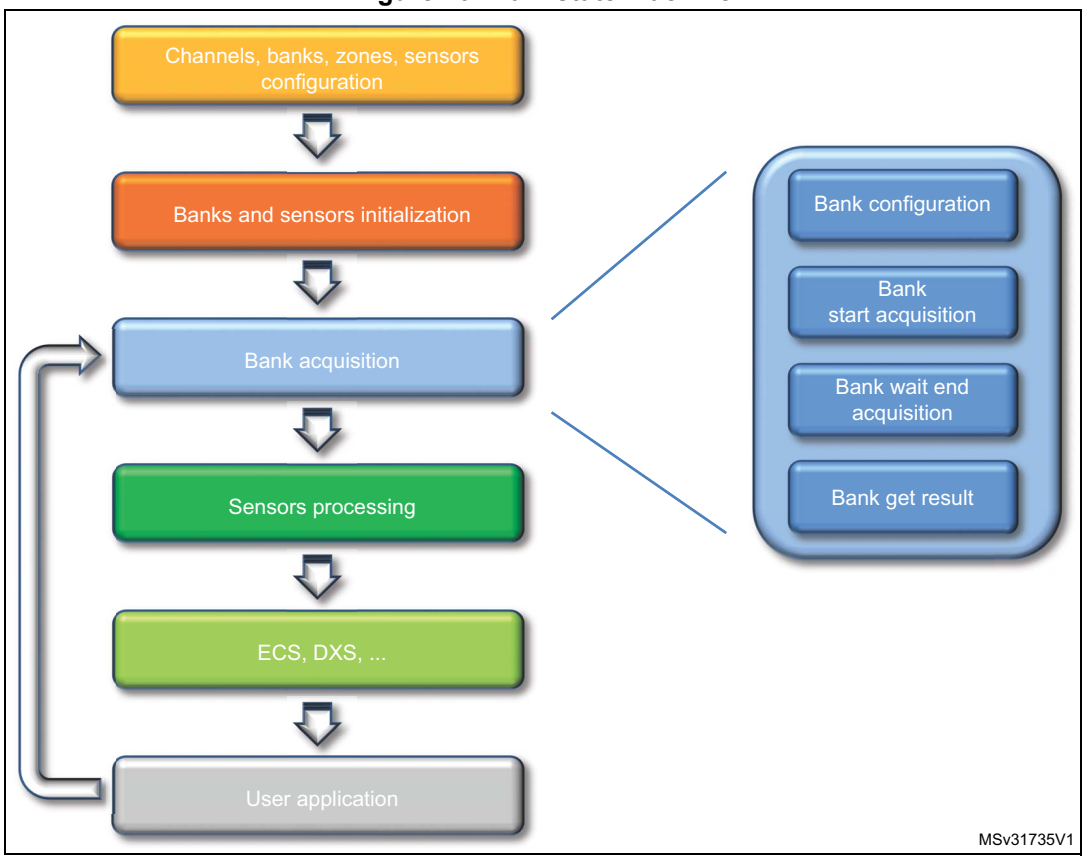
- `TSL_obj_GroupProcess()`
- `TSL_ecs_Process()`
- `TSL_dxs_FirstObj()`

Other functions that can be used during the processing are:

- `TSL_tim_CheckDelay_ms()`
- `TSL_obj_SetGlobalObj()`
- `TSL_tkey_GetStateId()`
- `TSL_tkey_GetStateMask()`
- `TSL_linrot_SetStateOff()`
- `TSL_linrot_SetStateCalibration()`

The main state machine principle is illustrated by the figure below:

**Figure 10. Main state machine**




The main state machine steps are:

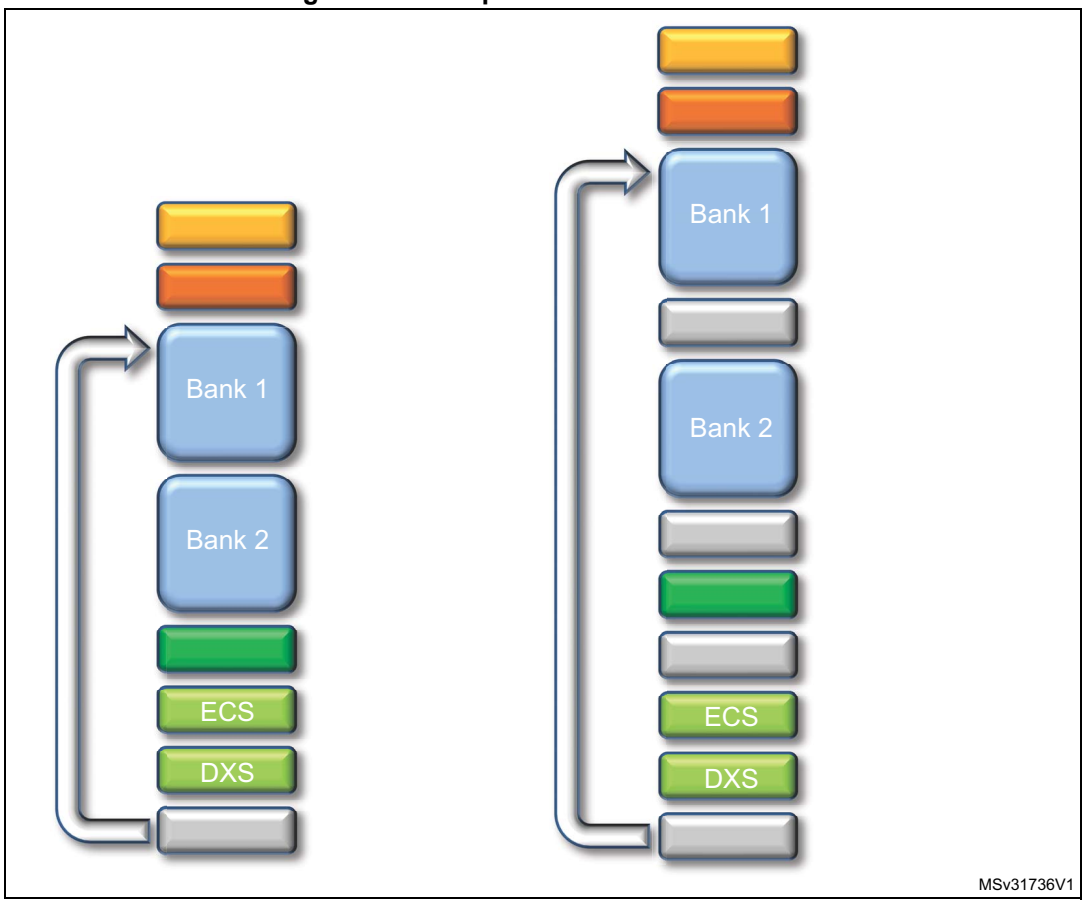
1. The **channels, banks and sensors configuration** step is used to declare all the different elements. This is done in the global declaration section in the main application file. See the section associated to each element for more details.
2. The **banks and sensors initialization** step is used to initialize the STMTouch touch sensing library modules. The sensors parameters are initialized with their default value defined in the configuration files.
3. The **banks acquisition** step is used to perform the acquisition of the banks. It is composed of the following sub-steps:
   - **configuration**: used to configure all channels of the bank
   - **start acquisition**: used to launch the measurement on all channels of the bank
   - **wait end acquisition**: used to wait the end of acquisition of all channels of the bank
   - **get result**: used to read all the channels measurements and to store them in the channel data layer.
4. The **sensors processing** step is used to execute the state machine of the sensors.

*Note: The debouncing, DTO and re-calibration are automatically performed inside this step.*

5. The **ECS, DXS** step is used to execute other algorithms that are not performed in the sensor state machine like the ECS, DXS, other filters, etc. This step is optional and it can be executed at certain time intervals (mainly for ECS).
6. The **user application** step is used to execute the application layer (such as read the sensors state, decide actions to perform, or manage ERROR states). The user application can also be placed between other steps, for example it can be done between the sensors processing step and the ECS/DXS one.

There are multiple manners to perform the main state machine. The following figures show some examples with two banks.

**Figure 11. Example of main state machine**




## 2.11 Sensors state machine

### 2.11.1 Overview

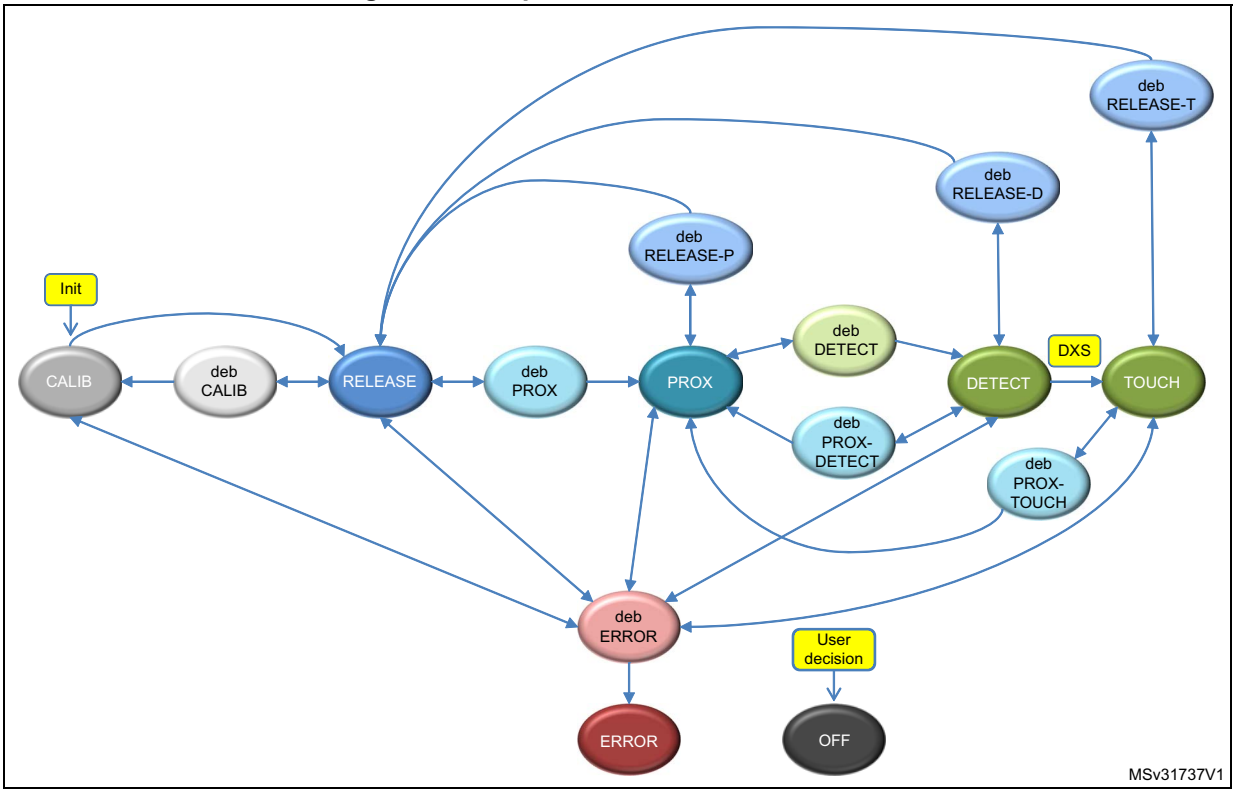
The state machine is managed in the files:

- *tsl_touchkey.c* and *tsl_touchkey.h* for the touchkey sensors
- *tsl_linrot.c* and *tsl_linrot.h* for the linear and rotary touch sensors

There is a total of 20 states defined in the **TSL_StateId_enum_T** structure.

The following figure shows the simplified state machine used by any sensor (for clarity not all the connections between states are shown).

**Figure 12. Simplified sensors state machine**




## 2.11.2 States constant table

Each state ID is associated to a mask and a function. The association STATE_ID-mask-function is made in the user application code using a constant table of the **TSL_State_T** type. The name of this table is free and the user can give any name. If no function is needed, simply put a zero instead of the function name.

Here below an example of touchkey sensors state machine:

```
// Touchkeys state machine
const TSL_State_T MyTKeys_StateMachine[] =
{
//-------------------------------------------------------------------
// ID      MASK                                FUNCTION
//-------------------------------------------------------------------
// Calibration states
/*  0 */ { TSL_STATEMASK_CALIB, TSL_tkey_CalibrationStateProcess },
/*  1 */ { TSL_STATEMASK_DEB_CALIB, TSL_tkey_DebCalibrationStateProcess },
// RELEASE states
/*  2 */ { TSL_STATEMASK_RELEASE,           TSL_tkey_ReleaseStateProcess },
#if TSLPRM_USE_PROX > 0
```

```
/*  3 */ { TSL_STATEMASK_DEB_RELEASE_PROX,
TSL_tkey_DebReleaseProxStateProcess },
#else
/*  3 */ { TSL_STATEMASK_DEB_RELEASE_PROX, 0 },
#endif
/*  4 */ { TSL_STATEMASK_DEB_RELEASE_DETECT,
TSL_tkey_DebReleaseDetectStateProcess },
/*  5 */ { TSL_STATEMASK_DEB_RELEASE_TOUCH,
TSL_tkey_DebReleaseTouchStateProcess },
#if TSLPRM_USE_PROX > 0
// Proximity states
/*  6 */ { TSL_STATEMASK_PROX,              TSL_tkey_ProxStateProcess },
/*  7 */ { TSL_STATEMASK_DEB_PROX,          TSL_tkey_DebProxStateProcess },
/*  8 */ { TSL_STATEMASK_DEB_PROX_DETECT,
TSL_tkey_DebProxDetectStateProcess },
/*  9 */ { TSL_STATEMASK_DEB_PROX_TOUCH,
TSL_tkey_DebProxTouchStateProcess },
#else
/*  6 */ { TSL_STATEMASK_PROX,              0 },
/*  7 */ { TSL_STATEMASK_DEB_PROX,          0 },
/*  8 */ { TSL_STATEMASK_DEB_PROX_DETECT,   0 },
/*  9 */ { TSL_STATEMASK_DEB_PROX_TOUCH,    0 },
#endif
// DETECT states
/* 10 */ { TSL_STATEMASK_DETECT,            TSL_tkey_DetectStateProcess },
/* 11 */ { TSL_STATEMASK_DEB_DETECT,        TSL_tkey_DebDetectStateProcess
},
// TOUCH state
/* 12 */ { TSL_STATEMASK_TOUCH,             TSL_tkey_TouchStateProcess },
// ERROR states
/* 13 */ { TSL_STATEMASK_ERROR,             MyTKeys_ErrorStateProcess },
/* 14 */ { TSL_STATEMASK_DEB_ERROR_CALIB,   TSL_tkey_DebErrorStateProcess
},
/* 15 */ { TSL_STATEMASK_DEB_ERROR_RELEASE, TSL_tkey_DebErrorStateProcess
},
/* 16 */ { TSL_STATEMASK_DEB_ERROR_PROX,    TSL_tkey_DebErrorStateProcess
},
/* 17 */ { TSL_STATEMASK_DEB_ERROR_DETECT,  TSL_tkey_DebErrorStateProcess
},
/* 18 */ { TSL_STATEMASK_DEB_ERROR_TOUCH,   TSL_tkey_DebErrorStateProcess
},
// Other states
/* 19 */ { TSL_STATEMASK_OFF,               MyTKeys_OffStateProcess }
};
```

The STMTouch touch sensing library contains all the functions needed to manage each state. However the user can copy and adapt one or several functions to fit the application requirements.

Example:

```
/*  0 */ { TSL_STATEMASK_CALIB, MyTkeys_CalibrationStateProcess },
```

*Note: The two functions used to manage the ERROR and OFF states are not part of the STMTouch touch sensing library. These functions are managed by the application.*

For linear and rotary sensor state machine, it is the same principle. The functions used to manage each state start with the prefix “TSL_linrot_”:

```
CONST TSL_State_T MyLinRots_StateMachine[] =
{
// Calibration states
/*  0 */ { TSL_STATEMASK_CALIB, TSL_linrot_CalibrationStateProcess },
```

### 2.11.3 States detail

The two tables below show the detail of how each state is entered following the thresholds measured.

**Table 5. Detailed sensors states 1/2**

<table>
<tr><th>Previous state</th><th>all excepted 13</th><th>all excepted 13</th><th>2p,10p,12p,3, 4p,5p,7,8,9, 11p</th><th>2,4,11</th><th>2p,6,4p,7,8,1 1p</th><th>DXS,5</th><th>DXS,5p,9</th><th>2,2p,1</th><th>2,2p,6,10, 10p,12,12p ,0,14..18</th></tr>
<tr><th>State number</th><th>2</th><th>2p</th><th>6</th><th>10</th><th>10p</th><th>12</th><th>12p</th><th>0</th><th>13</th></tr>
<tr><th>Current state</th><th>RELEASE</th><th>RELEASE with PROX</th><th>PROX</th><th>DETECT</th><th>DETECT with PROX</th><th>TOUCH</th><th>TOUCH with PROX</th><th>CALIB</th><th>ERROR</th></tr>
<tr><td>Delta</td><td colspan="9"></td></tr>
<tr><td>DETECT IN Th</td><td>deb DETECT or DETECT+DTO</td><td>deb DETECT or DETECT+DTO</td><td>deb DETECT or DETECT+DTO</td><td>same or CALIB if DTO</td><td>same or CALIB if DTO</td><td>same or CALIB if DTO</td><td>same or CALIB if DTO</td><td rowspan="5">RELEASE or ERROR</td><td rowspan="5">same</td></tr>
<tr><td>-</td><td rowspan="3">same</td><td rowspan="2">deb PROX or PROX+DTO</td><td rowspan="2">same or CALIB if DTO</td><td rowspan="3">deb RELEASE-DETECT or RELEASE</td><td>deb PROX-DETECT or PROX+DTO</td><td rowspan="3">deb RELEASE-TOUCH or RELEASE</td><td>deb PROX-TOUCH or PROX+DTO</td></tr>
<tr><td>DETECT OUT Th<br>PROX IN Th</td><td>deb RELEASE-DETECT or RELEASE</td><td>deb RELEASE-TOUCH or RELEASE</td></tr>
<tr><td>-</td><td rowspan="2">same</td><td rowspan="2">deb RELEASE-PROX or RELEASE</td></tr>
<tr><td>PROX OUT Th</td></tr>
<tr><td>CALIB Th</td><td>deb CALIB or CALIB</td><td>deb CALIB or CALIB</td><td>deb RELEASE-TOUCH or RELEASE</td></tr>
<tr><td>if ACQ ERROR</td><td>deb ERROR or ERROR</td><td>deb ERROR or ERROR</td><td>deb ERROR or ERROR</td><td>deb ERROR or ERROR</td><td>deb ERROR or ERROR</td><td>deb ERROR or ERROR</td><td>deb ERROR or ERROR</td><td>deb ERROR or ERROR</td><td>same</td></tr>
</table>

**Table 6. Detailed sensors states 2/2**

<table>
<tr><th>Previous state</th><th>6</th><th>10</th><th>10p,8</th><th>12</th><th>12p,9</th><th>2p,11p</th><th>10p</th><th>12p</th><th>2</th><th>2p,6,7</th><th>2,2p</th><th>2,2p,6,10, 10p,12,12 p,0</th></tr>
<tr><th>State number</th><th>3</th><th>4</th><th>4p</th><th>5</th><th>5p</th><th>7</th><th>8</th><th>9</th><th>11</th><th>11p</th><th>1</th><th>14..18</th></tr>
<tr><th>Current state</th><th>deb RE LEASE-PROX</th><th>deb RE LEASE-DETECT</th><th>deb RE LEASE-DETECT with PROX</th><th>deb RE LEASE-TOUCH</th><th>deb RE LEASE-TOUCH with PROX</th><th>deb PROX</th><th>deb PROX-DETECT</th><th>deb PROX-TOUCH</th><th>deb DETECT</th><th>deb DETECT with PROX</th><th>deb CALIB</th><th>deb ERROR</th></tr>
<tr><td>Delta</td><td colspan="12"></td></tr>
<tr><td>DETECT IN Th</td><td rowspan="3">PROX</td><td rowspan="3">DETECT</td><td rowspan="3">DETECT</td><td rowspan="3">TOUCH</td><td rowspan="3">TOUCH</td><td>deb DETECT or DETECT+ DTO</td><td rowspan="3">DETECT</td><td rowspan="3">TOUCH</td><td>same or DETECT+ DTO</td><td>same or DETECT+ DTO</td><td rowspan="4">RELEASE</td><td rowspan="6">RE LEASE PROX DETECT TOUCH CALIB</td></tr>
<tr><td>-</td><td rowspan="2">same or PROX+ DTO</td><td rowspan="3">RELEASE</td><td>deb PROX or PROX+ DTO</td></tr>
<tr><td>DETECT OUT Th PROX IN Th</td><td rowspan="3">same or RELEASE</td><td rowspan="2">PROX</td><td rowspan="3">same or RELEASE</td><td rowspan="2">PROX</td><td rowspan="2">same or PROX+ DTO</td><td rowspan="2">same or PROX+ DTO</td></tr>
<tr><td>-</td><td rowspan="3">RELEASE</td></tr>
<tr><td>PROX OUT Th</td><td rowspan="2">same or RELEASE</td><td rowspan="2">same or RELEASE</td><td rowspan="2">deb RELEASE-DETECT or RELEASE</td><td rowspan="2">deb RELEASE-TOUCH or RELEASE</td></tr>
<tr><td>CALIB Th</td><td>same or CALIB</td></tr>
<tr><td>if ACQ ERROR</td><td>PROX</td><td>DETECT</td><td>DETECT</td><td>TOUCH</td><td>TOUCH</td><td>RELEASE</td><td>DETECT</td><td>TOUCH</td><td>RELEASE</td><td>RELEASE</td><td>RELEASE</td><td>ERROR</td></tr>
</table>

### 2.11.4 CALIBRATION state

It consists in calculating the reference for all the channels of a sensor. An average of a certain number of measurements is done.

The number of measurement samples to use for the calibration is defined by the TSLPRM_CALIB_SAMPLES parameter.

After reset, the initialization method of each object is called. This method initializes the sensor parameters and then goes in the CALIBRATION state. After the calibration is done, the sensor goes in the RELEASE state or ERROR state if an error occurred.

Related functions:

- `TSL_tkey_CalibrationStateProcess()`
- `TSL_linrot_CalibrationStateProcess()`
- `TSL_tkey_SetStateCalibration()`
- `TSL_linrot_SetStateCalibration()`

#### Calibration delay

If a noise filter is used, it is necessary to wait a certain amount of measurement samples before to start the reference calculation. This number of samples to wait is defined by the TSLPRM_CALIB_DELAY parameter.

#### Re-calibration

If the calibration threshold is reached while in RELEASE state, a new calibration is performed. This re-calibration prevents the application to get stuck if something touches permanently the sensor, like a drop of water for example or if the sensor is touched upon power-on.

### 2.11.5 RELEASE state

Corresponds to the idle state of the sensor when no presence is detected.

Related functions:

- `TSL_tkey_ReleaseStateProcess()`
- `TSL_linrot_ReleaseStateProcess()`

### 2.11.6 PROXIMITY state

This state is optional and is enabled or disabled using the TSLPRM_USE_PROX parameter.

Related functions:

- `TSL_tkey_ProxStateProcess()`
- `TSL_linrot_ProxStateProcess()`

### 2.11.7 DETECT state

It is the “normal” state when the sensor is touched.

Related functions:

- `TSL_tkey_DetectStateProcess()`
- `TSL_linrot_DetectStateProcess()`

### 2.11.8 TOUCH state

Same as DETECT state, except that this state is entered only by the DXS processing. If the DXS is not used, this state is never entered.

Related functions:

- `TSL_tkey_TouchStateProcess()`
- `TSL_linrot_TouchStateProcess()`

### 2.11.9 ERROR state

It is used to catch all acquisition errors detected in the other states. The management of this state must be performed at application level.

### 2.11.10 OFF state

It is used to inform the acquisition module to stop the burst and/or acquisition on the sensor channels. The management of this state must be performed at application level.

### 2.11.11 DEBOUNCE state

The debounce is optional and is enabled/disabled using the different debounce counters parameters: TSLPRM_DEBOUNCE_PROX, TSLPRM_DEBOUNCE_DETECT, TSLPRM_DEBOUNCE_RELEASE, TSLPRM_DEBOUNCE_CALIB, TSLPRM_DEBOUNCE_ERROR

The debounce is off if the corresponding parameter is equal to zero.

### 2.11.12 Reading the current state

The current state can be obtained by using the following functions:

- For touchkey sensor:
  - `TSL_tkey_GetStateId()`
  - `TSL_tkey_GetStateMask()`
- For linear and rotary sensor:
  - `TSL_linrot_GetStateId()`
  - `TSL_linrot_GetStateMask()`

The functions `TSL_tkey_IsChanged()` or `TSL_linrot_IsChanged()` allows the check if a sensor state has changed.

You can also directly read the state inside the sensor data structure:

```
if MyTKeys[0].p_Data->StateId == TSL_STATEID_DETECT)
```

### 2.11.13 Enabling a specific state

It is possible to enter directly in the CALIBRATION, OFF and OFF-with-burst-only" states. The OFF-with-burst-only state consists in only bursting the electrode without performing acquisition on it. It can be used in specific cases to improve the robustness against noise or to keep optimum sensor sensitivity.

This is done by using the following functions:

- For touchkey sensor:
  - `TSL_tkey_SetStateCalibration()`
  - `TSL_tkey_SetStateOff()`
  - `TSL_tkey_SetStateBurstOnly()`
- For linear and rotary sensor:
  - `TSL_linrot_SetStateCalibration()`
  - `TSL_linrot_SetStateOff()`
  - `TSL_linrot_SetStateBurstOnly()`

## 2.12 Environment change system (ECS)

### 2.12.1 Principle

Power supply voltage, temperature and air humidity may induce a slow variation of the measured signal. The environment change system (ECS) is used to adapt the reference to these environment changes.

The ECS processing is based on an infinite response digital low-pass filter of the first order (IIR filter):

$$Y(n) = K \times X(n) + (1 - K) \times Y(n - 1)$$

with:

- Y = reference
- X = acquisition value (last measurement)
- K = coefficient.

The higher value for K, the faster the response time is. Two default K coefficients are available to obtain fast and slow responses.

The sampling frequency is programmable using a timing utility routine (see example below).

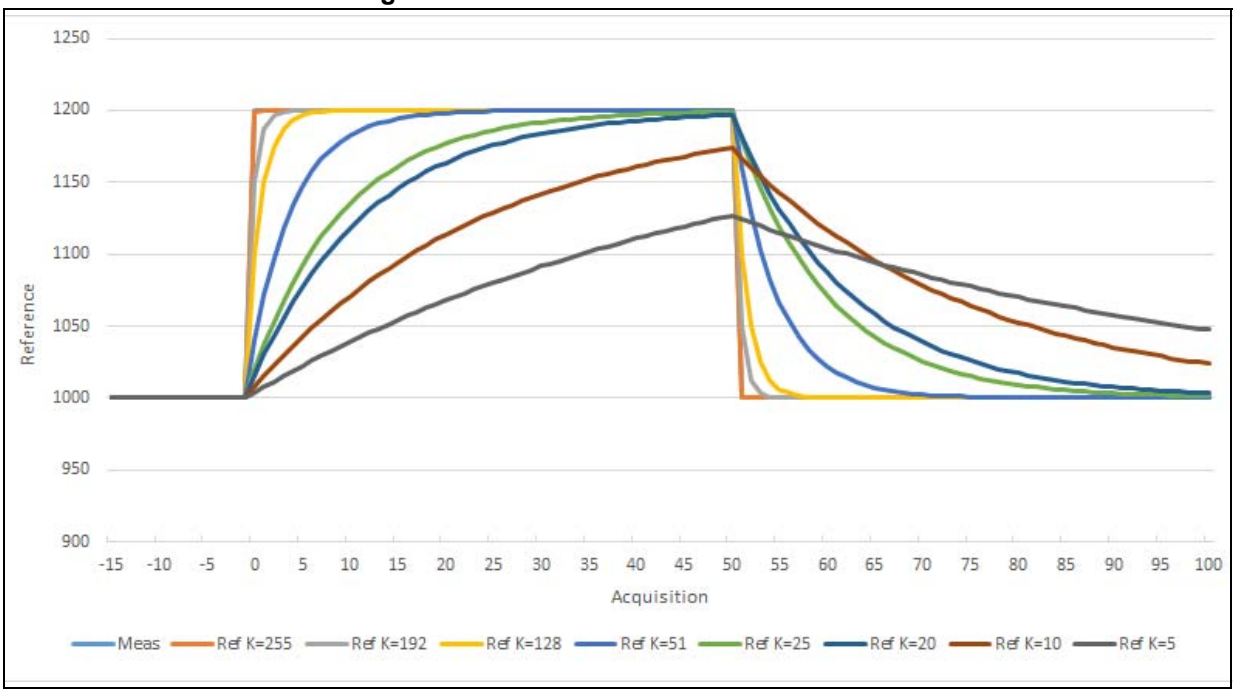
If the sensor is in PROX, DETECT or TOUCH states, the ECS is disabled for the duration of the detection timeout or for the duration of the touch (whichever ends first).

When the ECS is disabled, Yn = Yn - 1.

As soon as the recalibration times out or the detection ends, the filter is set active again.

The figure below shows the K filter effect to staircase on reference.The horizontal axis represents the number of calls to `ECS_process()` API. So the response time depends on the ECS_DELAY.

**Figure 13. Reference versus K filter value**




## 2.12.2 Resources

The ECS functions are provided in the files:

- *tsl_ecs.c*
- *tsl_ecs.h*

The functions are:

- `TSL_ecs_Process()`: main function to be used by the user
- `TSL_ecs_CalcK()`: additional function
- `TSL_ecs_ProcessK()`: additional function

## 2.12.3 Parameters

- TSLPRM_ECS_K_FAST
- TSLPRM_ECS_K_SLOW
- TSLPRM_ECS_DELAY

## 2.12.4 Use example

The ECS processing is usually performed in the main state machine at regular time intervals defined by the user. But it can also be done in interrupt routines. It must be performed after the sensors state machine is processed.

The ECS is activated only when all the sensors are in RELEASE, ERROR or OFF states, with at least one sensor in RELEASE state. It can also be delayed from milli-seconds to few seconds.

The ECS processing is performed on a group of sensors defined by the user. Different groups can be created and ECS can be applied on these groups with different K coefficients. The user decides the best thing to do for his application.

The simplest way is to call the `TSL_ecs_Process()` function in the main application loop, using the default K coefficients defined in the configuration file: *TSL_ecs_Process(&MyObjGroup)*.

To call this function at regular time intervals, you can use the provide timing routine `TSL_ecs_Process()`.

Example with ECS executed every 100 ms:

```
TSL_tTick_ms_T time_ECS_tick;
int main(void) {
  while (1) {
    ...
    // ECS every 100 ms
    if (TSL_tim_CheckDelay_ms(100, &time_ECS_tick) == TSL_STATUS_OK)
    {
      TSL_ecs_Process(&MyObjGroup);
    }
    ...
  }
}
```

The `TSL_ecs_Process()` function allows the use of a K coefficient different than the default value:

```
    if (TSL_tim_CheckDelay_ms(100, &time_ECS_tick) == TSL_STATUS_OK)
    {
      if ((MyObjGroup->StateMask & TSL_STATE_RELEASE_BIT_MASK) &&
         !(MyObjGroup->StateMask & TSL_STATEMASK_ACTIVE))
      {
        TSL_ecs_ProcessK(&MyObjGroup, 120);
      }
    }
```

To update `TSL_ecs_Process()`, the system tick handler must be updated as follows:

```
void SysTick_Handler(void)
{
  /* USER CODE BEGIN SysTick_IRQn 0 */

  /* USER CODE END SysTick_IRQn 0 */
  HAL_IncTick();
  HAL_SYSTICK_IRQHandler();
  /* USER CODE BEGIN SysTick_IRQn 1 */
```

```
  // TSL timing for ECS, DTO, ...
  TSL_tim_ProcessIT();

  /* USER CODE END SysTick_IRQn 1 */
}
```

## 2.13 Detection exclusion system (DXS)

### 2.13.1 Principle

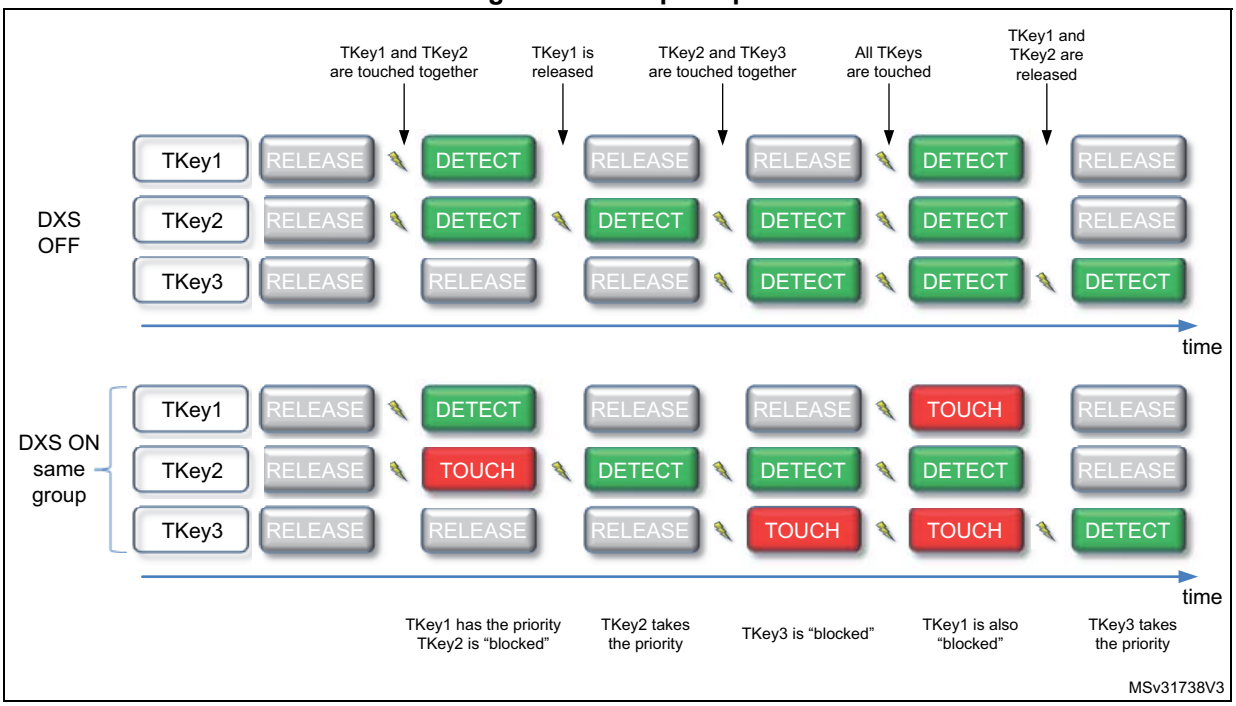
The DXS processing is used to prevent several sensors to be in the DETECT state at the same time. This may happen if the sensors are closed to each other or if their sensitivity is too high. This can be useful also in some applications to prevent the user to touch at the same time several sensors with “opposite” meaning (volume up and volume down for example).

The first sensor in the group of sensors has the priority and enters in the DETECT state (with the DxSLock flag set). The other sensors are “blocked” and enter instead in the TOUCH state.

*Note: A particular care must be taken when designing sensors that are shared between multiple DXS groups. The sensor that is assigned in the DETECT state depends on the sensors position in the DXS groups and also on the order of the DXS groups processing. See the examples 1 and 2 below for more detail.*

The figure below illustrates the difference in behavior for a group of three sensors (touchkeys), part of the same DXS group, when the DXS is off and on (touchkeys can be replaced by linear or rotary sensors).

**Figure 14. DXS principle**



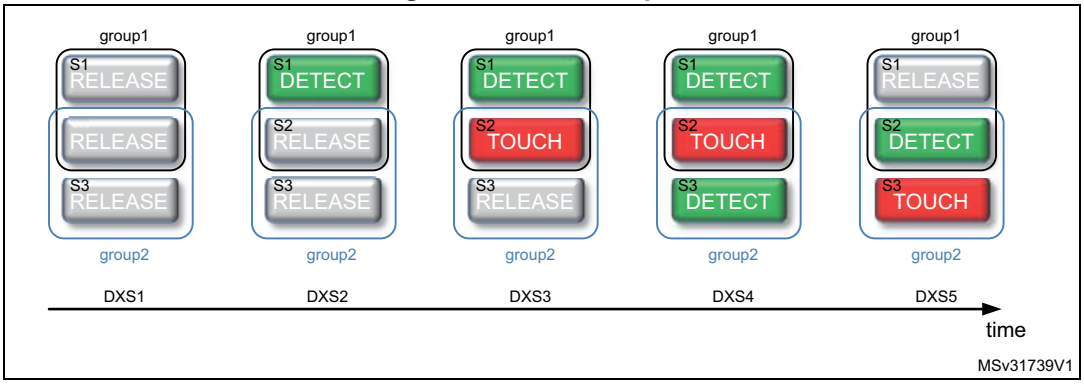
### Example 1: Three sensors with one shared between two groups

In this example, the group1 is composed of the two sensors S1 and S2 in this order, and the group2 of the two sensors S2 and S3 in this order.

The DXS groups are processed in this order: group1 first and then group2.

In the DXS5 step, S2 goes in DETECT state instead of S3. This is simply because S2 is placed first in the group2.

**Figure 15. DXS example 1**




### Example 2: Four sensors with one shared between three groups

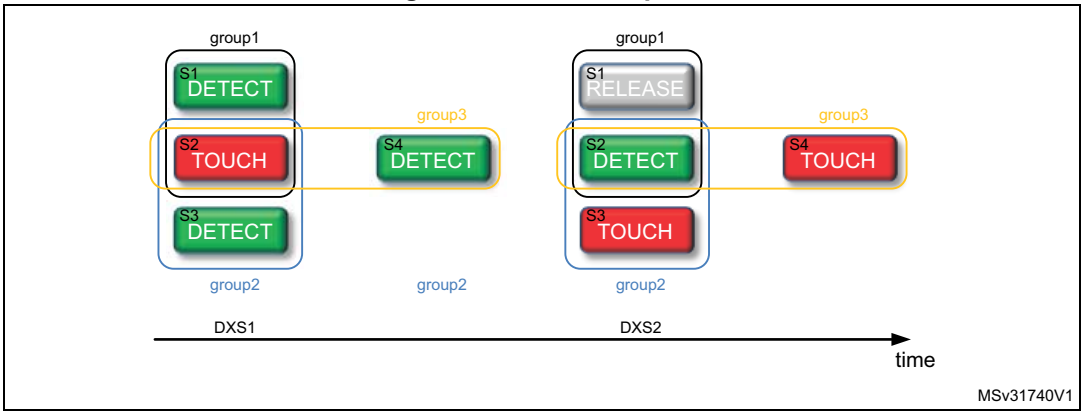
In this example, the group1 is composed of the two sensors S1 and S2 in this order, the group2 of the two sensors S2 and S3 in this order, and the group3 of the two sensors S2 and S4 in this order.

The DXS groups are processed in this order: group1 first, then group2 and finally group3.

In the DXS2 step, S2 takes the priority over S3 and S4.

To summarize, the decision to be in DETECT state depends on the sensors placement inside the group and also on the order of the groups processing.

**Figure 16. DXS example 2**



### 2.13.2 Resources

The DXS functions are provided in the files:

- *tsl_dxs.c*
- *tsl_dxs.h*

The function to use is `TSL_dxs_FirstObj()`.

### 2.13.3 Parameter

- TSLPRM_USE_DXS

### 2.13.4 Use example

The DXS processing is performed usually in the main state machine but it can also be done in interrupt routines.

**Warning: The DXS must be absolutely performed after the sensors state machine is processed, that is after the call to the `TSL_obj_GroupProcess()` function (see the main state machine for more details).**

The DXS processing is performed on a group of sensors defined by the user. Different groups of DXS can be created.

It is up to the user to decide the best partitioning for the application.

Example:

```
int main(void) {
  while (1) {
    ...
    TSL_obj_GroupProcess(&MyObjGroup1);
    TSL_obj_GroupProcess(&MyObjGroup2);
    TSL_dxs_FirstObj(&MyObjGroup1);
    TSL_dxs_FirstObj(&MyObjGroup2);
    ...
  }
}
```

## 2.14 Detection time out (DTO)

### 2.14.1 Principle

The detection time out (DTO) introduces a simple way to cope with water film and any obstacle that may come in contact with a sensor. It introduces a maximum duration for the DETECTED state of any sensor called the DTO.

After this period of time, the sensor is automatically re-calibrated. This allows the sensor to be made touch sensitive again, even if the obstacle or the liquid film is still present on the application front panel.

This feature is application dependent and the time out must be tuned according to the user interface specifications.

The DTO is applied on the PROX, DETECT and TOUCH states and can be disabled.

### 2.14.2 Resources

The DTO functions are provided in the files:

- *tsl_touchkey.c*
- *tsl_touchkey.h*
- *tsl_linrot.c*
- *tsl_linrot.h*

The functions used by the DTO are:

- `TSL_tkey_DTOGetTime()`
- `TSL_linrot_DTOGetTime()`
- `TSL_tim_CheckDelay_sec()`

*Note: The user does not need to call these functions to perform the DTO.*

### 2.14.3 Parameter

- TSLPRM_DTO

### 2.14.4 Use example

The DTO is automatically performed inside the sensor state machine. The user does not need to call any function in the application code.

The DTO is disabled by writing zero in the TSLPRM_DTO parameter.

## 2.15 Noise filters

### 2.15.1 Principle

The STMTouch touch sensing library has been designed to facilitate the implementation of different noise filters. These filters can be used for many purpose and can range from very simple design to very complicated.

### 2.15.2 Resources

The filters are defined in the files:

- *tsl_filter.c*
- *tsl_filter.h*

Each filter is described by a function:

- `TSL_filt_MeasFilter()`: filter on measurement values
- `TSL_filt_DeltaFilter()`: filter on delta values

### 2.15.3 Parameter

There is no parameter for the filter module.

### 2.15.4 Use example

The filter functions can be called at anytime in the main application. In order to speed up the execution time and to gain RAM space, the measure and delta filters are called by the `TSL_acq_BankGetResult()` function.

Examples:

```
// Apply a filter on the measures only
TSL_acq_BankGetResult(0, TSL_filt_MeasFilter, 0);
// Get the measures without applying any filter
TSL_acq_BankGetResult(0, 0, 0);
```

*Note: The user can also create his own filter functions.*

## 2.16 Timing management

### 2.16.1 Principle

The STMTouch touch sensing library needs an internal clock (“timing”), in particular for the ECS and DTO processing.

The timing process consists to increment a global variable at a regular interval. Different functions are then used to compare the current “time” and to check if a certain delay has elapsed.

The SysTick is used as timebase for the STMTouch touch sensing library. Its initialization must be done in the user code layer. Usually it is already done by the `HAL_Init` function. The TSLPRM_TICK_FREQ parameter must be set accordingly.

### 2.16.2 Resources

The common timing routines are described in the files:

- *tsl_time.c*
- *tsl_time.h*

Functions are:

- `TSL_tim_ProcessIT()`
- `TSL_tim_CheckDelay_ms()`
- `TSL_tim_CheckDelay_sec()`

### 2.16.3 Parameter

- TSLPRM_TICK_FREQ: the value must be in line with the SysTick frequency that is initialized in the user code.

### 2.16.4 Use example

The `TSL_tim_CheckDelay_ms()` function can be used in the main application code to execute some code (for example the ECS) at a regular interval.

Example:

```
TSL_tTick_ms_T time_ECS_tick;
TSL_tTick_ms_T time_LED_tick;
int main(void) {
  TSL_Init(MyBanks); // The timing starts...
  while (1) {
    ...
    // Launch the ECS every 100 ms
    if (TSL_tim_CheckDelay_ms(100, &time_ECS_tick) == TSL_STATUS_OK)
    {
      TSL_ecs_Process(&MyObjGroup);
    }
    // Toggle LED every 500 ms
    if (TSL_tim_CheckDelay_ms(500, &time_LED_tick) == TSL_STATUS_OK)
    {
      ToggleLED();
    }
    ...
  }
}
```

## 2.17 Parameters

All the parameters are described in the *tsl_conf.h* file.

*Note: The tsl_conf_<XXX>_template.h file present in the STM32_TouchSensing_Library/inc folder must be copied in the application project inc/tsl_conf.h and adapted to your application (number of channels, banks, debounce, DTO, etc.).*

*The structure TSL_Params_T is used* to hold certain parameters that are common to all sensors. These parameters can be changed by the user while the application is running.

#### Parameters checking

All common parameters are verified (presence and value range) in the *tsl_check_config.h* file.

All device specific parameters are verified in the *tsl_check_config_<XXX>.h* file.

## 2.18 Sensors acquisition timings

Reminders regarding terminology used in this section are given below:

- **Bank**: set of channels acquired simultaneously belonging to different groups
- **Channel**: elementary acquisition item (a GPIO from a group connected to a sensor)
- **Group** (also known as TSC group): set of up to four GPIOs defined as one sampling capacitor (Cs) with up to three channels or an active shield
- **Shield**: set of track and hatched plane used to increase noise robustness
- **Active shield**: a channel connected to an hatched plane driven simultaneously to sensor channels belonging to the same bank. An active shield requires its own sampling capacitor.
- **Passive shield**: a plane preferably hatched connected to the ground

This section details sequences for system with the following configurations:

- Touchkey sensor only
- Linear or rotary sensor only
- Mixed configuration using touchkey, and/or linear and/or rotary sensors

### 2.18.1 Acquisition timing using touchkey sensors

The examples detailed in the tables below summarize dependencies between Group, Bank, sensor number and acquisition timing, for STM32F0, STM32L4 and STM32WB Series.

For example:

- Three sensors can be acquired in:
  - 1 time using 3 groups and 1 bank
  - 2 times using 2 groups and 2 banks
  - 3 times using 1 groups and 3 banks
- Five sensors can be acquired in:
  - 1 time using 5 groups and 1 bank
  - 2 times using 3 groups and 2 banks
  - 3 times using 2 groups and 3 banks
- Six sensors can be acquired in:
  - 1 time using 6 groups and 1 bank
  - 2 times using 3 groups and 2 banks
  - 3 times using 2 groups and 3 banks

#### Using up to three touchkey sensors on the same group

As a group is able to handle up to three channels, this use case can be handled using only one group. An extra group can also be added for the shield.

The main advantages of this configuration are the following:

- reduced number of used GPIOs
- only one sampling capacitor required for three touchkeys

*Table 7* gives an example based on G1 and G2 and *Table 8* details the corresponding acquisition time line.

**Table 7. Example based on G1/G2 (3 touchkey sensors)**

| Group | I/O | Channel[1] | Sampling | Touchkey | Bank |
|---|---|---|---|---|---|
| G1 | IO1 | - | CS = 22 nF | - | - |
| | IO2 | CH1 | - | K1 | B1 |
| | IO3 | CH2 | - | K2 | B2 |
| | IO4 | CH3 | - | K3 | B3 |
| G2 | IO1 | - | CS = 47 nF | - | - |
| | IO2 | SHIELD | - | - | - |
| | IO3 | - | - | - | - |
| | IO4 | - | - | - | - |

1. Green is used for CHx and blue for SHIELD.

**Table 8. Example G1/G2 (3 touchkey sensors) - Acquisition time line**

| Time | T0 | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 |
|---|---|---|---|---|---|---|---|---|---|
| B1/B2/B3 | ↑(1) P1(3) I(4) | P2 I | P3 I eoa(2) | ↑ P1 I | P2 I | P3 I eoa | ↑ P1 I | P2 I | P3 I eoa |
| K1/CH1 | Γ(5) | | | Γ | | | Γ | | |
| K2/CH2 | | Γ | | | Γ | | | Γ | |
| K3/CH3 | | | Γ | | | Γ | | | Γ |
| SHIELD | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ |

1. ↑ = start of bank Bx acquisition.
2. eoa = end of Bx acquisition.
3. Px = program groups and channels for Bank x.
4. I = interrupt.
5. Γ = charge transfer cycle (green for CHx and blue for SHIELD).

the table below provides a synthesis list of features for this example. This is the most simple use case. In this case sensor acquisition is sequential.

**Table 9. Example G1/G2 (3 touchkey sensors) - Synthesis**

| Features | Value |
|---|---|
| Sampling capacitance | 1 + 1 (shield) |
| Pins without shield | 4 |
| Pins with shield | 6 |
| Cost | Low |
| Response time | 3 * T0 |

### Using up to three touchkey sensors on three groups

To speed up the acquisition, the configuration one group per touchkey is better. An extra group can also be added for the shield.

*Table 10* gives an example based on G1, G2, G3 and G4 (3 touchkey sensors) and *Table 11* details the corresponding acquisition time line.

**Table 10. Example based on G1/G2/G3/G4 (3 touchkey sensors)**

| Group | I/O | Channel(1) | Sampling | Touchkey | Bank |
|---|---|---|---|---|---|
| G1 | IO1 | - | CS = 22 nF | - | - |
| | IO2 | CH1 | - | K1 | B1 |
| | IO3 | - | - | - | - |
| | IO4 | - | - | - | - |
| G2 | IO1 | - | CS = 22 nF | - | - |
| | IO2 | CH2 | - | K2 | B1 |
| | IO3 | - | - | - | - |
| | IO4 | - | - | - | - |
| G3 | IO1 | - | CS = 22 nF | - | - |
| | IO2 | CH3 | - | K3 | B1 |
| | IO3 | - | - | - | - |
| | IO4 | - | - | - | - |
| G4 | IO1 | - | CS = 47 nF | - | - |
| | IO2 | SHIELD | - | - | - |
| | IO3 | - | - | - | - |
| | IO4 | - | - | - | - |

1. Green is used for CHx and blue for SHIELD.

**Table 11. Example G1/G2/G3/G4 (3 touchkey sensors) - Acquisition time line**

| Time | T0 | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 |
|---|---|---|---|---|---|---|---|---|---|
| B1 | ↑(1)eoa(2) | ↑ eoa | ↑ eoa | ↑ eoa | ↑ eoa | ↑ eoa | ↑ eoa | ↑ eoa | ↑ eoa |
| | P1(3) I(4) | P1 I | P1 I | P1 I | P1 I | P1 I | P1 I | P1 I | P1 I |
| K1/CH1 | Γ(5) | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ |
| K2/CH2 | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ |
| K3/CH3 | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ |
| SHIELD | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ |

1. ↑ = start of bank Bx acquisition.
2. eoa = end of Bx acquisition.
3. Px = program groups and channels for Bank x.
4. I = interrupt.
5. Γ = charge transfer cycle (green for CHx and blue for SHIELD).

The table below provides a synthesis list of features for this example. This is the way to acquire all sensors at the same time.

**Table 12. Example G1/G2/G3/G4 (3 touchkey sensors) - Synthesis**

| Feature | Value |
|---|---|
| Sampling capacitance | 3+ 1 (shield) |
| Pins without shield | 6 |
| Pins with shield | 8 |
| Cost | Medium |
| Response time | 1 * T0 |

*Note: The Groups pin not used for channel handling (such as IO3/4 in the example above) must not be used for analog features.*

### Using more than three touchkey sensors

To handle more than three touchkey sensors, more than one group is needed as the maximum number of channels per group is three. An extra group can also be used for the shield.

*Table 13* gives an example based on G1, G2, G3 and G4 with 9 touchkey sensors and *Table 14* details the corresponding acquisition time line.

**Table 13. Example based on G1/G2/G3/G4 (9 touchkey sensors)**

| Group | I/O | Channel(1) | Sampling | Key | Bank |
|---|---|---|---|---|---|
| G1 | IO1 | - | CS = 22 nF | - | - |
| | IO2 | CH1 | - | K1 | B1 |
| | IO3 | CH2 | - | K2 | B2 |
| | IO4 | CH3 | - | K3 | B3 |
| G2 | IO1 | - | CS = 22 nF | - | - |
| | IO2 | CH4 | - | K4 | B1 |
| | IO3 | CH5 | - | K5 | B2 |
| | IO4 | CH6 | - | K6 | B3 |
| G3 | IO1 | - | CS = 22 nF | - | - |
| | IO2 | CH7 | - | K7 | B1 |
| | IO3 | CH8 | - | K8 | B2 |
| | IO4 | CH9 | - | K9 | B3 |
| G4 | IO1 | - | CS = 47 nF | - | - |
| | IO2 | SHIELD | - | - | - |
| | IO3 | - | - | - | - |
| | IO4 | - | - | - | - |

1. Green is used for CHx and blue for SHIELD.

**Table 14. Example G1/G2/G3/G4 (9 touchkey sensors) - Acquisition time line**

| Time | T0 | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 |
|---|---|---|---|---|---|---|---|---|---|
| B1/B2/B3 | ↑(1) P1(3) I(4) | P2 I | P3 eoa(2) I | ↑ P1 I | P2 I | P3 eoa I | ↑ P1 I | P2 I | P3 eoa I |
| K1/CH1 | ⌜(5) | | | ⌜ | | | ⌜ | | |
| K2/CH2 | | ⌜ | | | ⌜ | | | ⌜ | |
| K3/CH3 | | | ⌜ | | | ⌜ | | | ⌜ |
| K4/CH4 | ⌜ | | | ⌜ | | | ⌜ | | |
| K5/CH5 | | ⌜ | | | ⌜ | | | ⌜ | |
| K6/CH6 | | | ⌜ | | | ⌜ | | | ⌜ |
| K7/CH7 | ⌜ | | | ⌜ | | | ⌜ | | |
| K8/CH8 | | ⌜ | | | ⌜ | | | ⌜ | |
| K9/CH9 | | | ⌜ | | | ⌜ | | | ⌜ |
| SHIELD | ⌜ | ⌜ | ⌜ | ⌜ | ⌜ | ⌜ | ⌜ | ⌜ | ⌜ |

1. ↑ = start of bank Bx acquisition.
2. eoa = end of Bx acquisition.
3. Px = program groups and channels for Bank x.
4. I = interrupt.
5. ⌜ = charge transfer cycle (green for CHx and blue for SHIELD).

The table below provides a synthesis list of features for this example. This is the most complex use case.

**Table 15. Example G1/G2/G3/G4 (9 keys)- Synthesis**

| Feature | Value |
|---|---|
| Sampling capacitance | 3+ 1 (shield) |
| Pins without shield | 12 |
| Pins with shield | 14 |
| Cost | Medium |
| Response time | 3 * T0 |

### Using only few specific touchkey sensors

If only some touchkey sensors must be acquired, the bank helps to start the acquisition only on these specific touchkeys.

The table below shows an example of the acquisition time line in this case.

**Table 16. Example G1/G2/G3/G4 (specific touch key sensors only) - Acquisition time line**

| Time | T0 | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 |
|---|---|---|---|---|---|---|---|---|---|
| B1/B2/B3 | ↑(1)eoa(2) P1(3) I(4) | | ↑ eoa P1 I | ↑ eoa P1 I | ↑ eoa P2 I | P3 I | ↑ eoa P1 I | P2 I | P3 I |
| K1/CH1 | ⌜(5) | | ⌜ | ⌜ | | | ⌜ | | |
| K2/CH2 | | | | | ⌜ | | | ⌜ | |
| K3/CH3 | | | | | | ⌜ | | | ⌜ |
| K4/CH4 | ⌜ | | ⌜ | ⌜ | | | ⌜ | | |
| K5/CH5 | | | | | ⌜ | | | ⌜ | |
| K6/CH6 | | | | | | ⌜ | | | ⌜ |
| K7/CH7 | ⌜ | | ⌜ | ⌜ | | | ⌜ | | |
| K8/CH8 | | | | | ⌜ | | | ⌜ | |
| K9/CH9 | | | | | | ⌜ | | | ⌜ |
| SHIELD | ⌜ | | ⌜ | ⌜ | ⌜ | ⌜ | ⌜ | ⌜ | ⌜ |

1. ↑ = start of bank Bx acquisition.
2. eoa = end of Bx acquisition.
3. Px = program groups and channels for Bank x.
4. I = interrupt.
5. ⌜ = charge transfer cycle (green for CHx and blue for SHIELD).

## 2.18.2 Acquisition timing using linear or rotary sensors

To handle linear or rotary sensors in a proper way regarding sensitivity, it is recommended to split linear and rotary channels on various groups.

For example, three groups needed to handle three linear/rotary channels.

### Using one linear/rotary sensor

Three groups are used to handle the three channels. An extra group can also be used for the shield.

*Table 17* gives an example based on G1, G2, G3 and G4 (one linear sensor) and *Table 18* details the corresponding acquisition time line.

**Table 17. Example based on G1/G2/G3/G4 (1 linear sensor)**

| Group | I/O | Channel(1) | Sampling | Linear | Bank |
|---|---|---|---|---|---|
| G1 | IO1 | - | CS = 47 nF | - | - |
| | IO2 | CH1 | - | S1 | B1 |
| | IO3 | - | - | - | - |
| | IO4 | - | - | - | - |
| G2 | IO1 | - | CS = 47 nF | - | - |
| | IO2 | CH2 | - | S1 | B1 |
| | IO3 | - | - | - | - |
| | IO4 | - | - | - | - |
| G3 | IO1 | - | CS = 47 nF | - | - |
| | IO2 | CH3 | - | S1 | B1 |
| | IO3 | - | - | - | - |
| | IO4 | - | - | - | - |
| G4 | IO1 | - | CS = 47 nF | - | - |
| | IO2 | SHIELD | - | - | - |
| | IO3 | - | - | - | - |
| | IO4 | - | - | - | - |

1. Green is used for CHx and blue for SHIELD.

**Table 18. Example G1/G2/G3/G4 (1 sensor) - Acquisition time line**

| Time | T0 | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 |
|---|---|---|---|---|---|---|---|---|---|
| B1 | ↑(1)eoa(2) P1(3) I(4) | ↑ eoa P1 I | ↑ eoa P1 I | ↑ eoa P1 I | ↑ eoa P1 I | ↑ eoa P1 I | ↑ eoa P1 I | ↑ eoa P1 I | ↑ eoa P1 I |
| S1/CH1 | Γ(5) | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ |
| S1/CH2 | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ |
| S1/CH3 | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ |
| SHIELD | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ |

1. ↑ = start of bank Bx acquisition.
2. eoa = end of Bx acquisition.
3. Px = program groups and channels for Bank x.
4. I = interrupt.
5. Γ = charge transfer cycle (green for CHx and blue for SHIELD).

The table below provides a synthesis list of features for this example.

**Table 19. Example G1/G2/G3/G4 (1 sensor) - Synthesis**

| Feature | Value |
|---|---|
| Sampling capacitance | 3+ 1 (shield) |
| Pins without shield | 6 |
| Pins with shield | 8 |
| Cost | Medium |
| Response time | 1 * T0 |

### Using two linear and one rotary sensors

The three sensors allows the handling of nine channels.

*Table 20* gives an example based on G1, G2, G3 and G4 (three sensors) and *Table 21* details the corresponding acquisition time line.

**Table 20. Example based on G1/G2/G3/G4 (3 L/R sensors)**

| Group | I/O | Channel(1) | Sampling | Linear/Rotary | Bank |
|---|---|---|---|---|---|
| G1 | IO1 | - | CS = 47 nF | - | - |
| | IO2 | CH1 | - | S1 | B1 |
| | IO3 | CH4 | - | S2 | B2 |
| | IO4 | CH7 | - | R1 | B3 |
| G2 | IO1 | - | CS = 47 nF | - | - |
| | IO2 | CH2 | - | S1 | B1 |
| | IO3 | CH5 | - | S2 | B2 |
| | IO4 | CH8 | - | R1 | B3 |
| G3 | IO1 | - | CS = 47 nF | - | - |
| | IO2 | CH3 | - | S1 | B1 |
| | IO3 | CH6 | - | S2 | B2 |
| | IO4 | CH9 | - | R1 | B3 |
| G4 | IO1 | - | CS = 47 nF | - | - |
| | IO2 | SHIELD | - | - | - |
| | IO3 | - | - | - | - |
| | IO4 | - | - | - | - |

1. Green is used for CHx and blue for SHIELD.

**Table 21. Example G1/G2/G3/G4 (3 L/R sensors) - Acquisition time line**

| Time | T0 | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 |
|---|---|---|---|---|---|---|---|---|---|
| B1 | ↑(1)eoa(2) P1(3) I(4) | | | ↑ eoa P1 I | | | ↑ eoa P1 I | | |
| B2 | | ↑ eoa P2 I | | | ↑ eoa P2 I | | | ↑ eoa P2 I | |
| B3 | | | ↑ eoa P3 I | | | ↑ eoa P3 I | | | ↑ eoa P3 I |
| S1/CH1 | Γ(5) | | | Γ | | | Γ | | |
| S1/CH2 | Γ | | | Γ | | | Γ | | |
| S1/CH3 | Γ | | | Γ | | | Γ | | |
| S2/CH4 | | Γ | | | Γ | | | Γ | |
| S2/CH5 | | Γ | | | Γ | | | Γ | |
| S2/CH6 | | Γ | | | Γ | | | Γ | |
| R1/CH7 | | | Γ | | | Γ | | | Γ |
| R1/CH8 | | | Γ | | | Γ | | | Γ |
| R1/CH9 | | | Γ | | | Γ | | | Γ |
| SHIELD | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ |

1. ↑ = start of bank Bx acquisition.
2. eoa = end of Bx acquisition.
3. Px = program groups and channels for Bank x.
4. I = interrupt.
5. Γ = charge transfer cycle (green for CHx and blue for SHIELD).

The table below provides a synthesis list of features for this example.

**Table 22. Example G1/G2/G3/G4 (3 L/R sensors) - Synthesis**

| Feature | Value |
|---|---|
| Sampling capacitance | 3+ 1 (shield) |
| Pins without shield | 12 |
| Pins with shield | 14 |
| Cost | Medium |
| Response time | 3 * T0 |

### 2.18.3 Acquisition timing using touchkey, linear and rotary sensors

*Table 23* gives an example based on G1, G2, G3 and G4, with three touchkey, one linear and one rotary sensors and *Table 24* details the corresponding acquisition time line.

**Table 23. Example based on G1, G2, G3 and G4 (3 touchkey, 1 linear, 1 rotary sensors)**

| Group | I/O | Channel[1] | Sampling | Touchkey | Linear/Rotary | Bank |
|---|---|---|---|---|---|---|
| G1 | IO1 | - | CS = 47 nF | - | - | - |
| | IO2 | CH1 | - | - | S1 | B1 |
| | IO3 | CH4 | - | K1 | - | B2 |
| | IO4 | CH7 | - | - | R1 | B3 |
| G2 | IO1 | - | CS = 47 nF | - | - | - |
| | IO2 | CH2 | - | - | S1 | B1 |
| | IO3 | CH5 | - | K2 | - | B2 |
| | IO4 | CH8 | - | - | R1 | B3 |
| G3 | IO1 | - | CS = 47 nF | - | - | - |
| | IO2 | CH3 | - | - | S1 | B1 |
| | IO3 | CH6 | - | K3 | - | B2 |
| | IO4 | CH9 | - | - | R1 | B3 |
| G4 | IO1 | - | CS = 47 nF | - | - | - |
| | IO2 | SHIELD | - | - | - | - |
| | IO3 | - | - | - | - | - |
| | IO4 | - | - | - | - | - |

1. Green is used for CHx and blue for SHIELD.

**Table 24. Example G1/G2/G3/G4 (3 touchkey, 1 linear, 1 rotary sensors) - Acquisition time line**

| Time | T0 | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 |
|---|---|---|---|---|---|---|---|---|---|
| B1 | ↑(1) eoa(2) P1(3) I(4) | | | ↑ eoa P1 I | | | ↑ eoa P1 I | | |
| B2 | | ↑ eoa P2 I | | | ↑ eoa P2 I | | | ↑ eoa P2 I | |
| B3 | | | ↑ eoa P3 I | | | ↑ eoa P3 I | | | ↑ eoa P3 I |
| S1/CH1 | Γ(5) | | | Γ | | | Γ | | |
| S1/CH2 | Γ | | | Γ | | | Γ | | |
| S1CH3 | Γ | | | Γ | | | Γ | | |
| K1/CH4 | | Γ | | | Γ | | | Γ | |
| K2/CH5 | | Γ | | | Γ | | | Γ | |
| K3/CH6 | | Γ | | | Γ | | | Γ | |
| R1/CH7 | | | Γ | | | Γ | | | Γ |
| R1/CH8 | | | Γ | | | Γ | | | Γ |
| R1/CH9 | | | Γ | | | Γ | | | Γ |
| SHIELD | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ | Γ |

1. ↑ = start of bank Bx acquisition.
2. eoa = end of Bx acquisition.
3. Px = program groups and channels for Bank x.
4. I = interrupt.
5. Γ = charge transfer cycle (green for CHx and blue for SHIELD).

The table below provides a synthesis list of features for this example.

**Table 25. Example G1/G2/G3/G4 (3 touchkey, 1 linear, 1 rotary sensors) - Synthesis**

| Feature | Value |
|---|---|
| Sampling capacitance | 3+ 1 (shield) |
| Pins without shield | 12 |
| Pins with shield | 14 |
| Cost | Medium |
| Response time | 3 * T0 |

## 2.19 Error management

Top level error management can be done at user application level.

The APIs are described in tsl_user.c where we split keys and linrot error cases.

The customer may decide which action to be done in these cases (such as reboot, re-init or alarm).

The corresponding APIs are detailed in the below code:

```
/**
  * @brief  Executed when a sensor is in Error state
  * @param  None
  * @retval None
  */
  void MyTKeys_ErrorStateProcess(void)
{
  /* Add here your own processing when a sensor is in Error state */
}
void MyLinRots_ErrorStateProcess(void)
{
  /* Add here your own processing when a sensor is in Error state */
}

/**
  * @brief  Executed when a sensor is in Off state
  * @param  None
  * @retval None
  */
void MyTKeys_OffStateProcess(void)
{
  /* Add here your own processing when a sensor is in Off state */
}

void MyLinRots_OffStateProcess(void)
{
  /* Add here your own processing when a sensor is in Off state */
}
```

# 3 Devices with TSC peripheral

This section concerns all STM32 microcontrollers that include the touch sensing controller peripheral (TSC).

## 3.1 Acquisition

The acquisition is done in the files:

- *tsl_acq_tsc.c*
- *tsl_acq_tsc.h*

Functions used by the application layer and that are device dependent:

- `TSL_acq_BankConfig()`
- `TSL_acq_BankStartAcq()`
- `TSL_acq_BankWaitEOC()`
- `TSL_acq_GetMeas()`

The other functions in this file are for internal use and the user does not need to call them directly.

The device selection must be done at the end of the *tsl_conf.h* file:

```
#include "stm32f0xx.h" /* Select the file corresponding to the device in use
(i.e. stm32f3xx.h, stm32f0xx.h, ...) */
```

## 3.2 Timings

The timing management is done in the files:

- *tsl_time.c*
- *tsl_time.h*

The SysTick is used to generate a timebase for the ECS and DTO modules. It must be initialized in the user code (already done by the `HAL_init` function).

## 3.3 Parameters

The parameters are described in the *tsl_conf_tsc_template.h* file (to be copied in the project and rename in *tsl_conf.h*).

Parameters are checked in the *tsl_check_config_tsc.h* file.

## 3.4 MCU resources

The table below shows the peripherals used by the STMTouch touch sensing library on any STM32 microcontroller with the touch sensing controller. Care must be taken when using them to avoid any unwanted behavior.

**Table 26. STM32F0 Series MCU resources used**

| Peripheral | Function |
|---|---|
| GPIOs | Acquisition |
| SysTick | Time base for ECS and DTO |
| Touch sensing controller (TSC) | Acquisition |

## 3.5 STM32F0 Series microcontrollers

### 3.5.1 Memory footprint

#### Conditions

- IAR ANSI C/C++ compiler/linker V7.40.3.8902 for Arm
- Compiler optimization: high size
- Counted files: *tsl*.o*
- STM32 Touch sensing library options: ECS=ON, DTO=ON, DXS=OFF, PROX=OFF
- Each sensor has its own parameters placed in RAM.

The following table summarizes the memory footprint with different configurations.

**Table 27. STM32F0 Series memory footprint(1)**

| Channels | Banks | Sensors | ROM (Kbytes) | RAM (bytes) |
|---|---|---|---|---|
| 1 | 1 | 1 TKey | 3.0 | 100 |
| 2 | 1 | 2 TKeys | 3.0 | 120 |
| 2 | 2 | 2 TKeys | 3.0 | 120 |
| 24 | 3 | 24 TKeys | 4.0 | 620 |
| 3 | 1 | 1 Linear-3ch | 4.1 | 130 |
| 15 | 3 | 12 TKeys + 1 Linear-3ch | 6.2 | 420 |
| 24 | 3 | 18 TKeys + 2 Linear-3ch | 6.5 | 610 |

1. The content of this table is provided for information purposes only.

### 3.5.2 Available touch sensing channels

The tables below provide an overview of the available touch sensing channels for the STM32F0 Series microcontrollers.

*Note: The following tables are not restrictive in term of part numbers supported by the STMTouch touch sensing library. The STMTouch touch sensing library can be used on any new device that may become available as part of ST microcontrollers portfolio. Contact the local ST representative for support.*

*For n available pins in an I/O group, one pin is used as sampling capacitor and n-1 pins are used as channels.*

*The I/O group cannot be used if the number of available pins in less or equal to one.*

**Table 28. Available touch sensing channels for STM32F098xx**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F098Vx | | | | STM32F098Rx | | | | | | STM32F098Cx | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | UFBGA100 | | LQFP100 | | UFBGA64 | | LQFP64 | | WLCSP64 | | LQFP48 UFQFPN48 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | | x | | x | | x | |
| | TSC_G1_IO3 | PA2 | x | | x | | x | | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | | x | | x | | x | |
| | TSC_G2_IO3 | PA6 | x | | x | | x | | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | | x | | x | | x | |
| G3 | TSC_G3_IO1 | PC5 | x | 2 | x | 2 | x | 2 | x | 2 | x | 2 | - | 1 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | | x | | x | | x | |
| | TSC_G3_IO3 | PB1 | x | | x | | x | | x | | x | | x | |
| | TSC_G3_IO4 | - | - | | - | | - | | - | | - | | - | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | | x | | x | | x | |
| | TSC_G4_IO3 | PA11 | x | | x | | x | | x | | x | | x | |
| | TSC_G4_IO4 | PA12 | x | | x | | x | | x | | x | | x | |

**Table 28. Available touch sensing channels for STM32F098xx (continued)**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F098Vx | | | | STM32F098Rx | | | | | | STM32F098Cx | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | UFBGA100 | | LQFP100 | | UFBGA64 | | LQFP64 | | WLCSP64 | | LQFP48 UFQFPN48 | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | | x | | x | | x | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G6_IO2 | PB12 | x | | x | | x | | x | | x | | x | |
| | TSC_G6_IO3 | PB13 | x | | x | | x | | x | | x | | x | |
| | TSC_G6_IO4 | PB14 | x | | x | | x | | x | | x | | x | |
| G7 | TSC_G7_IO1 | PE2 | x | 3 | x | 3 | x | 0 | - | 0 | - | 0 | - | 0 |
| | TSC_G7_IO2 | PE3 | x | | x | | x | | - | | - | | - | |
| | TSC_G7_IO3 | PE4 | x | | x | | x | | - | | - | | - | |
| | TSC_G7_IO4 | PE5 | x | | x | | x | | - | | - | | - | |
| G8 | TSC_G8_IO1 | PD12 | x | 3 | x | 3 | x | 0 | - | 0 | - | 0 | - | 0 |
| | TSC_G8_IO2 | PD13 | x | | x | | x | | - | | - | | - | |
| | TSC_G8_IO3 | PD14 | x | | x | | x | | - | | - | | - | |
| | TSC_G8_IO4 | PD15 | x | | x | | x | | - | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 23 | | 23 | | 17 | | 17 | | 17 | | 16 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 29. Available touch sensing channels for STM32F091xx**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F091Vx | | | | STM32F091Rx | | | | | | STM32F091Cx | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | UFBGA100 | | LQFP100 | | UFBGA64 | | LQFP64 | | WLCSP64 | | LQFP48 UFQFPN48 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | | x | | x | | x | |
| | TSC_G1_IO3 | PA2 | x | | x | | x | | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | | x | | x | | x | |
| | TSC_G2_IO3 | PA6 | x | | x | | x | | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | | x | | x | | x | |
| G3 | TSC_G3_IO1 | PC5 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | - | 2 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | | x | | x | | x | |
| | TSC_G3_IO3 | PB1 | x | | x | | x | | x | | x | | x | |
| | TSC_G3_IO4 | PB2 | x | | x | | x | | x | | x | | x | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | | x | | x | | x | |
| | TSC_G4_IO3 | PA11 | x | | x | | x | | x | | x | | x | |
| | TSC_G4_IO4 | PA12 | x | | x | | x | | x | | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | | x | | x | | x | |

**Table 29. Available touch sensing channels for STM32F091xx (continued)**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F091Vx | | | | STM32F091Rx | | | | | | STM32F091Cx | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | UFBGA100 | | LQFP100 | | UFBGA64 | | LQFP64 | | WLCSP64 | | LQFP48 UFQFPN48 | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G6_IO2 | PB12 | x | | x | | x | | x | | x | | x | |
| | TSC_G6_IO3 | PB13 | x | | x | | x | | x | | x | | x | |
| | TSC_G6_IO4 | PB14 | x | | x | | x | | x | | x | | x | |
| G7 | TSC_G7_IO1 | PE2 | x | 3 | x | 3 | x | 0 | - | 0 | - | 0 | - | 0 |
| | TSC_G7_IO2 | PE3 | x | | x | | x | | - | | - | | - | |
| | TSC_G7_IO3 | PE4 | x | | x | | x | | - | | - | | - | |
| | TSC_G7_IO4 | PE5 | x | | x | | x | | - | | - | | - | |
| G8 | TSC_G8_IO1 | PD12 | x | 3 | x | 3 | x | 0 | - | 0 | - | 0 | - | 0 |
| | TSC_G8_IO2 | PD13 | x | | x | | x | | - | | - | | - | |
| | TSC_G8_IO3 | PD14 | x | | x | | x | | - | | - | | - | |
| | TSC_G8_IO4 | PD15 | x | | x | | x | | - | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 24 | | 24 | | 18 | | 18 | | 18 | | 17 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 30. Available touch sensing channels for STM32F078xx**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F078Vx | | | | STM32F078Rx | | STM32F078Cx | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | UFBGA100 | | LQFP100 | | LQFP64 | | LQFP48 UFQFPN48 | | WLCSP49 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | | x | | x | |
| | TSC_G1_IO3 | PA2 | x | | x | | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | | x | | x | |
| | TSC_G2_IO3 | PA6 | x | | x | | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | | x | | x | |
| G3 | TSC_G3_IO1 | PC5 | x | 2 | x | 2 | x | 2 | - | 1 | - | 1 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | | x | | x | |
| | TSC_G3_IO3 | PB1 | x | | x | | x | | x | | x | |
| | TSC_G3_IO4 | - | - | | - | | - | | - | | - | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | | x | | x | |
| | TSC_G4_IO3 | PA11 | x | | x | | x | | x | | x | |
| | TSC_G4_IO4 | PA12 | x | | x | | x | | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | | x | | x | |

**Table 30. Available touch sensing channels for STM32F078xx (continued)**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F078Vx | | | | STM32F078Rx | | STM32F078Cx | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | UFBGA100 | | LQFP100 | | LQFP64 | | LQFP48 UFQFPN48 | | WLCSP49 | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G6_IO2 | PB12 | x | | x | | x | | x | | x | |
| | TSC_G6_IO3 | PB13 | x | | x | | x | | x | | x | |
| | TSC_G6_IO4 | PB14 | x | | x | | x | | x | | x | |
| G7 | TSC_G7_IO1 | PE2 | x | 3 | x | 3 | - | 0 | - | 0 | - | 0 |
| | TSC_G7_IO2 | PE3 | x | | x | | - | | - | | - | |
| | TSC_G7_IO3 | PE4 | x | | x | | - | | - | | - | |
| | TSC_G7_IO4 | PE5 | x | | x | | - | | - | | - | |
| G8 | TSC_G8_IO1 | PD12 | x | 3 | x | 3 | - | 0 | - | 0 | - | 0 |
| | TSC_G8_IO2 | PD13 | x | | x | | - | | - | | - | |
| | TSC_G8_IO3 | PD14 | x | | x | | - | | - | | - | |
| | TSC_G8_IO4 | PD15 | x | | x | | - | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 23 | | 23 | | 17 | | 16 | | 16 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 31. Available touch sensing channels for STM32F072xx**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F072Vx | | | | STM32F072Rx | | STM32F072Cx | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | UFBGA100 | | LQFP100 | | LQFP64 | | LQFP48 UFQFPN48 | | WLCSP49 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | | x | | x | |
| | TSC_G1_IO3 | PA2 | x | | x | | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | | x | | x | |
| | TSC_G2_IO3 | PA6 | x | | x | | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | | x | | x | |
| G3 | TSC_G3_IO1 | PC5 | x | 3 | x | 3 | x | 3 | - | 2 | - | 2 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | | x | | x | |
| | TSC_G3_IO3 | PB1 | x | | x | | x | | x | | x | |
| | TSC_G3_IO4 | PB2 | x | | x | | x | | x | | x | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | | x | | x | |
| | TSC_G4_IO3 | PA11 | x | | x | | x | | x | | x | |
| | TSC_G4_IO4 | PA12 | x | | x | | x | | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | | x | | x | |

**Table 31. Available touch sensing channels for STM32F072xx (continued)**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F072Vx | | | | STM32F072Rx | | STM32F072Cx | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | UFBGA100 | | LQFP100 | | LQFP64 | | LQFP48 UFQFPN48 | | WLCSP49 | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G6_IO2 | PB12 | x | | x | | x | | x | | x | |
| | TSC_G6_IO3 | PB13 | x | | x | | x | | x | | x | |
| | TSC_G6_IO4 | PB14 | x | | x | | x | | x | | x | |
| G7 | TSC_G7_IO1 | PE2 | x | 3 | x | 3 | - | 0 | - | 0 | - | 0 |
| | TSC_G7_IO2 | PE3 | x | | x | | - | | - | | - | |
| | TSC_G7_IO3 | PE4 | x | | x | | - | | - | | - | |
| | TSC_G7_IO4 | PE5 | x | | x | | - | | - | | - | |
| G8 | TSC_G8_IO1 | PD12 | x | 3 | x | 3 | - | 0 | - | 0 | - | 0 |
| | TSC_G8_IO2 | PD13 | x | | x | | - | | - | | - | |
| | TSC_G8_IO3 | PD14 | x | | x | | - | | - | | - | |
| | TSC_G8_IO4 | PD15 | x | | x | | - | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 24 | | 24 | | 18 | | 17 | | 17 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 32. Available touch sensing channels for STM32F071xx**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F071Vx | | | | STM32F071Rx | | STM32F071Cx | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | UFBGA100 | | LQFP100 | | LQFP64 | | LQFP48 UFQFPN48 | | WLCSP49 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | | x | | x | |
| | TSC_G1_IO3 | PA2 | x | | x | | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | | x | | x | |
| | TSC_G2_IO3 | PA6 | x | | x | | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | | x | | x | |
| G3 | TSC_G3_IO1 | PC5 | x | 3 | x | 3 | x | 3 | - | 2 | - | 2 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | | x | | x | |
| | TSC_G3_IO3 | PB1 | x | | x | | x | | x | | x | |
| | TSC_G3_IO4 | PB2 | x | | x | | x | | x | | x | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | | x | | x | |
| | TSC_G4_IO3 | PA11 | x | | x | | x | | x | | x | |
| | TSC_G4_IO4 | PA12 | x | | x | | x | | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | | x | | x | |

**Table 32. Available touch sensing channels for STM32F071xx (continued)**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F071Vx | | | | STM32F071Rx | | STM32F071Cx | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | UFBGA100 | | LQFP100 | | LQFP64 | | LQFP48 UFQFPN48 | | WLCSP49 | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G6_IO2 | PB12 | x | | x | | x | | x | | x | |
| | TSC_G6_IO3 | PB13 | x | | x | | x | | x | | x | |
| | TSC_G6_IO4 | PB14 | x | | x | | x | | x | | x | |
| G7 | TSC_G7_IO1 | PE2 | x | 3 | x | 3 | - | 0 | - | 0 | - | 0 |
| | TSC_G7_IO2 | PE3 | x | | x | | - | | - | | - | |
| | TSC_G7_IO3 | PE4 | x | | x | | - | | - | | - | |
| | TSC_G7_IO4 | PE5 | x | | x | | - | | - | | - | |
| G8 | TSC_G8_IO1 | PD12 | x | 3 | x | 3 | - | 0 | - | 0 | - | 0 |
| | TSC_G8_IO2 | PD13 | x | | x | | - | | - | | - | |
| | TSC_G8_IO3 | PD14 | x | | x | | - | | - | | - | |
| | TSC_G8_IO4 | PD15 | x | | x | | - | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 24 | | 24 | | 18 | | 17 | | 17 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 33. Available touch sensing channels for STM32F058xx**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F058Rx | | | | STM32F058Cx | |
|---|---|---|---|---|---|---|---|---|
| | | | LQFP64 | | UFBGA64 | | UFQFPN48 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | |
| | TSC_G1_IO3 | PA2 | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | |

Table 33. Available touch sensing channels for STM32F058xx (continued)

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F058Rx | | | | STM32F058Cx | |
|---|---|---|---|---|---|---|---|---|
| | | | LQFP64 | | UFBGA64 | | UFQFPN48 | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | |
| | TSC_G2_IO3 | PA6 | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | |
| G3 | TSC_G3_IO1 | PC5 | x | 2 | x | 2 | - | 1 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | |
| | TSC_G3_IO3 | PB1 | x | | x | | x | |
| | TSC_G3_IO4 | - | - | | - | | - | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | |
| | TSC_G4_IO3 | PA11 | x | | x | | x | |
| | TSC_G4_IO4 | PA12 | x | | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 | x | 3 | x | 3 |
| | TSC_G6_IO2 | PB12 | x | | x | | x | |
| | TSC_G6_IO3 | PB13 | x | | x | | x | |
| | TSC_G6_IO4 | PB14 | x | | x | | x | |

**Table 33. Available touch sensing channels for STM32F058xx (continued)**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F058Rx | | | | STM32F058Cx | |
|---|---|---|---|---|---|---|---|---|
| | | | LQFP64 | | UFBGA64 | | UFQFPN48 | |
| G7 | TSC_G7_IO1 | - | - | 0 | - | 0 | - | 0 |
| | TSC_G7_IO2 | - | - | | - | | - | |
| | TSC_G7_IO3 | - | - | | - | | - | |
| | TSC_G7_IO4 | - | - | | - | | - | |
| G8 | TSC_G8_IO1 | - | - | 0 | - | 0 | - | 0 |
| | TSC_G8_IO2 | - | - | | - | | - | |
| | TSC_G8_IO3 | - | - | | - | | - | |
| | TSC_G8_IO4 | - | - | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 17 | | 17 | | 16 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 34. Available touch sensing channels for STM32F051xx**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F051Rx | | | | STM32F051Cx | | STM32F051Kx | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | LQFP64 | | UFBGA64 | | LQFP48 UFQFPN48 | | LQFP32 | | UFQFPN32 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | | x | | x | |
| | TSC_G1_IO3 | PA2 | x | | x | | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | | x | | x | |
| | TSC_G2_IO3 | PA6 | x | | x | | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | | x | | x | |

**Table 34. Available touch sensing channels for STM32F051xx (continued)**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F051Rx | | | | STM32F051Cx | | STM32F051Kx | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | LQFP64 | | UFBGA64 | | LQFP48 UFQFPN48 | | LQFP32 | | UFQFPN32 | |
| G3 | TSC_G3_IO1 | PC5 | x | 3 | x | 3 | - | 2 | - | 1 | - | 2 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | | x | | x | |
| | TSC_G3_IO3 | PB1 | x | | x | | x | | x | | x | |
| | TSC_G3_IO4 | PB2 | x | | x | | x | | - | | x | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | | x | | x | |
| | TSC_G4_IO3 | PA11 | x | | x | | x | | x | | x | |
| | TSC_G4_IO4 | PA12 | x | | x | | x | | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | | x | | x | |
| G6 | TSC_G6_IO1 | PB11 | - | 3 | - | 3 | - | 3 | - | 0 | - | 0 |
| | TSC_G6_IO2 | PB12 | - | | - | | - | | - | | - | |
| | TSC_G6_IO3 | PB13 | - | | - | | - | | - | | - | |
| | TSC_G6_IO4 | PB14 | - | | - | | - | | - | | - | |
| G7 | TSC_G7_IO1 | - | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 |
| | TSC_G7_IO2 | - | - | | - | | - | | - | | - | |
| | TSC_G7_IO3 | - | - | | - | | - | | - | | - | |
| | TSC_G7_IO4 | - | - | | - | | - | | - | | - | |

**Table 34. Available touch sensing channels for STM32F051xx (continued)**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F051Rx | | | | STM32F051Cx | | STM32F051Kx | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | LQFP64 | | UFBGA64 | | LQFP48 UFQFPN48 | | LQFP32 | | UFQFPN32 | |
| G8 | TSC_G8_IO1 | - | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 |
| | TSC_G8_IO2 | - | - | | - | | - | | - | | - | |
| | TSC_G8_IO3 | - | - | | - | | - | | - | | - | |
| | TSC_G8_IO4 | - | - | | - | | - | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 18 | | 18 | | 17 | | 13 | | 14 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 35. Available touch sensing channels for STM32F048xx**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F048Cx | | STM32F048Tx | | STM32F048Gx | |
|---|---|---|---|---|---|---|---|---|
| | | | UFQFPN48 | | WLCSP36 | | UFQFPN28 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | |
| | TSC_G1_IO3 | PA2 | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | |
| | TSC_G2_IO3 | PA6 | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | |
| G3 | TSC_G3_IO1 | - | - | 1 | - | 1 | - | 0 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | |
| | TSC_G3_IO3 | PB1 | x | | x | | - | |
| | TSC_G3_IO4 | - | - | | - | | - | |

**Table 35. Available touch sensing channels for STM32F048xx (continued)**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F048Cx | | STM32F048Tx | | STM32F048Gx | |
|---|---|---|---|---|---|---|---|---|
| | | | UFQFPN48 | | WLCSP36 | | UFQFPN28 | |
| G4 | TSC_G4_IO1 | PA9(2) | x | 3 | x | 3 | x(2) | 1 |
| | TSC_G4_IO2 | PA10(2) | x | | x | | x(2) | |
| | TSC_G4_IO3 | PA11(2) | x | | x | | x(2) | |
| | TSC_G4_IO4 | PA12(2) | x | | x | | x(2) | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | |
| G6 | TSC_G6_IO1 | - | - | 0 | - | 0 | - | 0 |
| | TSC_G6_IO2 | - | - | | - | | - | |
| | TSC_G6_IO3 | - | - | | - | | - | |
| | TSC_G6_IO4 | - | - | | - | | - | |
| G7 | TSC_G7_IO1 | - | - | 0 | - | 0 | - | 0 |
| | TSC_G7_IO2 | - | - | | - | | - | |
| | TSC_G7_IO3 | - | - | | - | | - | |
| | TSC_G7_IO4 | - | - | | - | | - | |
| G8 | TSC_G8_IO1 | - | - | 0 | - | 0 | - | 0 |
| | TSC_G8_IO2 | - | - | | - | | - | |
| | TSC_G8_IO3 | - | - | | - | | - | |
| | TSC_G8_IO4 | - | - | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 13 | | 13 | | 10 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.
2. Pin pair PA11/PA12 can be remapped instead of pin pair PA9/PA10, using SYS_CTRL register (28- and 20-pin packages only).

**Table 36. Available touch sensing channels for STM32F042xx**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F042Cx | | STM32F042Tx | | STM32F042Kx | | | | STM32F042Gx | | STM32F042Fx | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | LQFP48 UFQFPN48 | | WLCSP36 | | LQFP32 | | UFQFPN32 | | UFQFPN28 | | TSSOP20 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | | x | | x | | x | |
| | TSC_G1_IO3 | PA2 | x | | x | | x | | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | | x | | x | | x | |
| | TSC_G2_IO3 | PA6 | x | | x | | x | | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | | x | | x | | x | |
| G3 | TSC_G3_IO1 | - | - | 2 | - | 2 | - | 1 | - | 2 | - | 1 | - | 0 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | | x | | x | | - | |
| | TSC_G3_IO3 | PB1 | x | | x | | x | | x | | x | | x | |
| | TSC_G3_IO4 | PB2 | x | | x | | - | | x | | - | | - | |
| G4 | TSC_G4_IO1 | PA9(2) | x | 3 | x | 3 | x | 3 | x | 3 | x(2) | 1 | x(2) | 1 |
| | TSC_G4_IO2 | PA10(2) | x | | x | | x | | x | | x(2) | | x(2) | |
| | TSC_G4_IO3 | PA11(2) | x | | x | | x | | x | | x(2) | | x(2) | |
| | TSC_G4_IO4 | PA12(2) | x | | x | | x | | x | | x(2) | | x(2) | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | - | 0 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | | x | | x | | - | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | | x | | x | | - | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | | x | | x | | - | |

Table 36. Available touch sensing channels for STM32F042xx (continued)

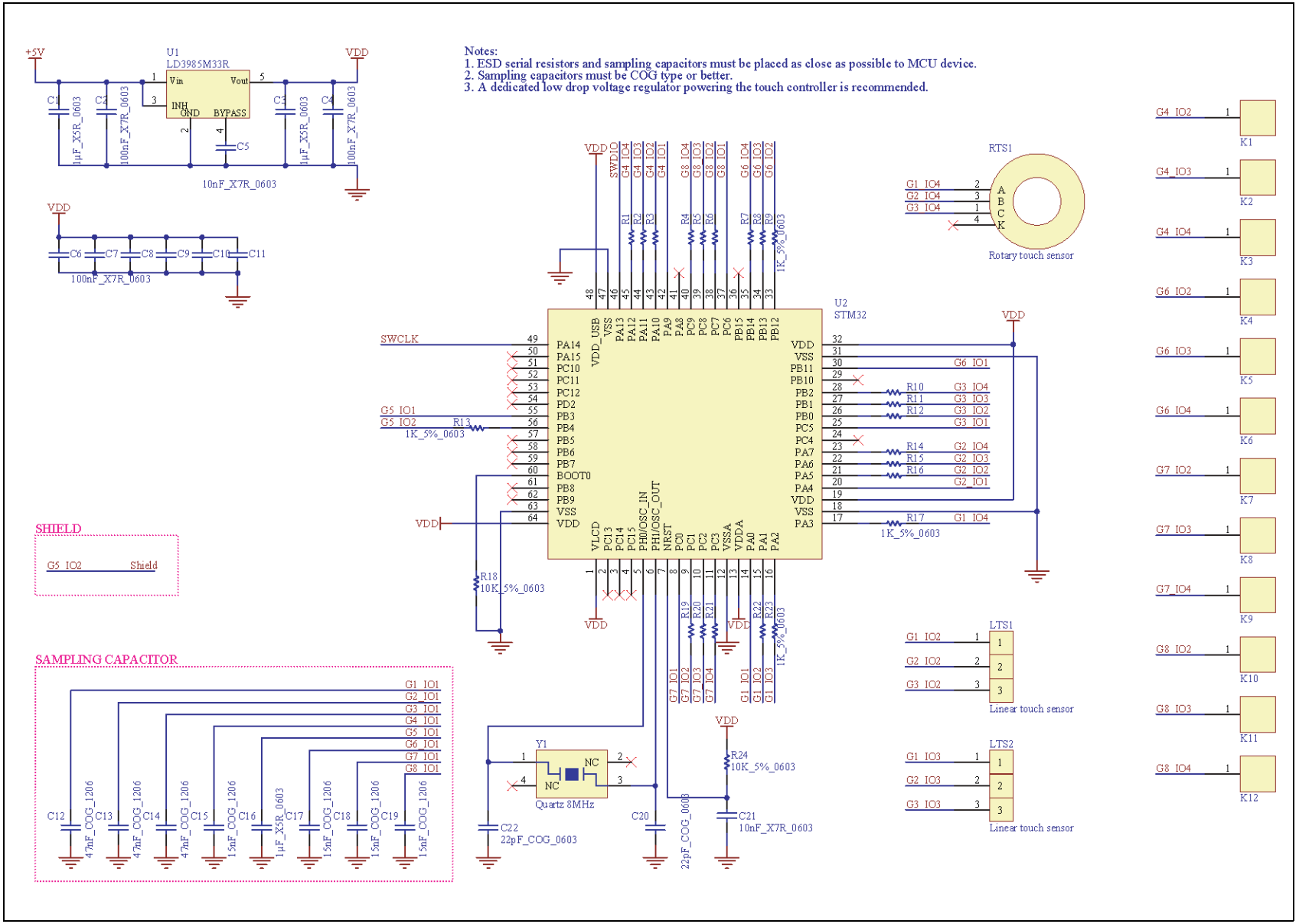
| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F042Cx | | STM32F042Tx | | STM32F042Kx | | | | STM32F042Gx | | STM32F042Fx | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | LQFP48 UFQFPN48 | | WLCSP36 | | LQFP32 | | UFQFPN32 | | UFQFPN28 | | TSSOP20 | |
| G6 | TSC_G6_IO1 | - | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 |
| | TSC_G6_IO2 | - | - | | - | | - | | - | | - | | - | |
| | TSC_G6_IO3 | - | - | | - | | - | | - | | - | | - | |
| | TSC_G6_IO4 | - | - | | - | | - | | - | | - | | - | |
| G7 | TSC_G7_IO1 | - | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 |
| | TSC_G7_IO2 | - | - | | - | | - | | - | | - | | - | |
| | TSC_G7_IO3 | - | - | | - | | - | | - | | - | | - | |
| | TSC_G7_IO4 | - | - | | - | | - | | - | | - | | - | |
| G8 | TSC_G8_IO1 | - | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 |
| | TSC_G8_IO2 | - | - | | - | | - | | - | | - | | - | |
| | TSC_G8_IO3 | - | - | | - | | - | | - | | - | | - | |
| | TSC_G8_IO4 | - | - | | - | | - | | - | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 14 | | 14 | | 13 | | 14 | | 11 | | 7 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.
2. Pin pair PA11/PA12 can be remapped instead of pin pair PA9/PA10, using SYS_CTRL register (28- and 20-pin packages only).

### 3.5.3 Hardware implementation example

*Figure 17* shows an example of hardware implementation on STM32F0 Series microcontrollers.

## Figure 17. STM32F0 Series hardware implementation example



## 3.6 STM32F3 Series microcontrollers

### 3.6.1 Memory footprint

#### Conditions

- IAR ANSI C/C++ compiler/linker V7.40.3.8902 for Arm®
- Compiler optimization: high size
- Counted files: *tsl*.o*
- STM32 Touch sensing library options: ECS=ON, DTO=ON, DXS=OFF, PROX=OFF
- Each sensor has its own parameters placed in RAM.

The following tables summarize the memory footprint with different configurations:

**Table 37. STM32F3 Series memory footprint(1)**

| Channels | Banks | Sensors | ROM (Kbytes) | RAM (bytes) |
|---|---|---|---|---|
| 1 | 1 | 1 TKey | 2.8 | 100 |
| 2 | 1 | 2 TKeys | 2.8 | 120 |
| 2 | 2 | 2 TKeys | 2.8 | 120 |
| 24 | 3 | 24 TKeys | 3.8 | 620 |
| 3 | 1 | 1 Linear-3ch | 3.8 | 130 |
| 15 | 3 | 12 TKeys + 1 Linear-3ch | 5.7 | 420 |
| 24 | 3 | 18 TKeys + 2 Linear-3ch | 6.0 | 610 |

1. The content of this table is provided for information purposes only.

### 3.6.2 Available touch sensing channels

The tables below provide an overview of the available touch sensing channels for the STM32F3 Series microcontrollers.

*Note: The following tables are not restrictive in term of part numbers supported by the STMTouch touch sensing library. The STMTouch touch sensing library can be used on any new device that may become available as part of ST microcontrollers portfolio. Contact the local ST representative for support.*

*For n available pins in an I/O group, one pin is used as sampling capacitor and n-1 pins are used as channels.*

*The I/O group cannot be used if the number of available pins in less or equal to one.*

**Table 38. Available touch sensing channels for STM32F398VE**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F398VE | |
|---|---|---|---|---|
| | | | LQFP100 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | |
| | TSC_G1_IO3 | PA2(1) | x | |
| | TSC_G1_IO4 | PA3 | x | |

**Table 38. Available touch sensing channels for STM32F398VE (continued)**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F398VE | |
|---|---|---|---|---|
| | | | LQFP100 | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | |
| | TSC_G2_IO3 | PA6(1) | x | |
| | TSC_G2_IO4 | PA7 | x | |
| G3 | TSC_G3_IO1 | PC5 | x | 2 |
| | TSC_G3_IO2 | PB0 | x | |
| | TSC_G3_IO3 | PB1(1) | x | |
| | TSC_G3_IO4 | - | - | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | |
| | TSC_G4_IO3 | PA13 | x | |
| | TSC_G4_IO4 | PA14 | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | |
| | TSC_G5_IO3 | PB6 | x | |
| | TSC_G5_IO4 | PB7 | x | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 |
| | TSC_G6_IO2 | PB12(1) | x | |
| | TSC_G6_IO3 | PB13 | x | |
| | TSC_G6_IO4 | PB14 | x | |
| G7 | TSC_G7_IO1 | PE2 | x | 3 |
| | TSC_G7_IO2 | PE3 | x | |
| | TSC_G7_IO3 | PE4 | x | |
| | TSC_G7_IO4 | PE5 | x | |
| G8 | TSC_G8_IO1 | PD12 | x | 3 |
| | TSC_G8_IO2 | PD13 | x | |
| | TSC_G8_IO3 | PD14 | x | |
| | TSC_G8_IO4 | PD15 | x | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 23 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 39. Available touch sensing channels for STM32F378xx**

| Analog I/O group | Capacitive sensing signal | Pin name | STM32F378Vx | | | | STM32F378Rx | | | | STM32F378Cx | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | LQFP100 | | BGA100 | | LQFP64 | | WLCSP66 | | LQFP48 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | | x | | x | |
| | TSC_G1_IO3 | PA2 | x | | x | | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 | x | 3 | x | 2 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | | x | | x | |
| | TSC_G2_IO3 | PA6(1) | x | | x | | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | | x | | - | |
| G3 | TSC_G3_IO1 | PC4 | x | 3 | x | 3 | x | 3 | x | 3 | - | 1 |
| | TSC_G3_IO2 | PC5 | x | | x | | x | | x | | - | |
| | TSC_G3_IO3 | PB0 | x | | x | | x | | x | | x | |
| | TSC_G3_IO4 | PB1 | x | | x | | x | | x | | x | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | | x | | x | |
| | TSC_G4_IO3 | PA13 | x | | x | | x | | x | | x | |
| | TSC_G4_IO4 | PA14 | x | | x | | x | | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | | x | | x | |
| G6 | TSC_G6_IO1 | PB14 | x | 3 | x | 3 | x | 2 | x | 2 | x | 2 |
| | TSC_G6_IO2 | PB15 | x | | x | | x | | x | | x | |
| | TSC_G6_IO3 | PD8 | x | | x | | x | | x | | x | |
| | TSC_G6_IO4 | PD9 | x | | x | | - | | - | | - | |
| G7 | TSC_G7_IO1 | PE2 | x | 3 | x | 3 | - | 0 | - | 0 | - | 0 |
| | TSC_G7_IO2 | PE3 | x | | x | | - | | - | | - | |
| | TSC_G7_IO3 | PE4 | x | | x | | - | | - | | - | |
| | TSC_G7_IO4 | PE5 | x | | x | | - | | - | | - | |
| G8 | TSC_G8_IO1 | PD12 | x | 3 | x | 3 | - | 0 | - | 0 | - | 0 |
| | TSC_G8_IO2 | PD13 | x | | x | | - | | - | | - | |
| | TSC_G8_IO3 | PD14 | x | | x | | - | | - | | - | |
| | TSC_G8_IO4 | PD15 | x | | x | | - | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 24 | | 24 | | 17 | | 17 | | 14 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 40. Available touch sensing channels for STM32F373xx**

| Analog I/O group | Capacitive sensing signal | Pin name | STM32F373Vx | | | | STM32F373Rx | | STM32F373Cx | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | LQFP100 | | BGA100 | | LQFP64 | | LQFP48 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | | x | |
| | TSC_G1_IO3 | PA2 | x | | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 | x | 2 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | | x | |
| | TSC_G2_IO3 | PA6(1) | x | | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | | - | |
| G3 | TSC_G3_IO1 | PC4 | x | 3 | x | 3 | x | 3 | - | 1 |
| | TSC_G3_IO2 | PC5 | x | | x | | x | | - | |
| | TSC_G3_IO3 | PB0 | x | | x | | x | | x | |
| | TSC_G3_IO4 | PB1 | x | | x | | x | | x | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | | x | |
| | TSC_G4_IO3 | PA13 | x | | x | | x | | x | |
| | TSC_G4_IO4 | PA14 | x | | x | | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | | x | |
| G6 | TSC_G6_IO1 | PB14 | x | 3 | x | 3 | x | 2 | x | 2 |
| | TSC_G6_IO2 | PB15 | x | | x | | x | | x | |
| | TSC_G6_IO3 | PD8 | x | | x | | x | | x | |
| | TSC_G6_IO4 | PD9 | x | | x | | - | | - | |
| G7 | TSC_G7_IO1 | PE2 | x | 3 | x | 3 | - | 0 | - | 0 |
| | TSC_G7_IO2 | PE3 | x | | x | | - | | - | |
| | TSC_G7_IO3 | PE4 | x | | x | | - | | - | |
| | TSC_G7_IO4 | PE5 | x | | x | | - | | - | |
| G8 | TSC_G8_IO1 | PD12 | x | 3 | x | 3 | - | 0 | - | 0 |
| | TSC_G8_IO2 | PD13 | x | | x | | - | | - | |
| | TSC_G8_IO3 | PD14 | x | | x | | - | | - | |
| | TSC_G8_IO4 | PD15 | x | | x | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 24 | | 24 | | 17 | | 14 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 41. Available touch sensing channels for STM32F358xC**

| Analog I/O group | Capacitive sensing signal | Pin name | STM32F358Vx | | STM32F358Rx | | STM32F358Cx | |
|---|---|---|---|---|---|---|---|---|
| | | | LQFP100 | | LQFP64 | | LQFP48 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | |
| | TSC_G1_IO3 | PA2(1) | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | |
| | TSC_G2_IO3 | PA6(1) | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | |
| G3 | TSC_G3_IO1 | PC5 | x | 2 | x | 2 | - | 1 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | |
| | TSC_G3_IO3 | PB1(1) | x | | x | | x | |
| | TSC_G3_IO4 | - | - | | - | | - | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | |
| | TSC_G4_IO3 | PA13 | x | | x | | x | |
| | TSC_G4_IO4 | PA14 | x | | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 | x | 3 | x | 3 |
| | TSC_G6_IO2 | PB12(1) | x | | x | | x | |
| | TSC_G6_IO3 | PB13 | x | | x | | x | |
| | TSC_G6_IO4 | PB14 | x | | x | | x | |
| G7 | TSC_G7_IO1 | PE2 | x | 3 | - | 0 | - | 0 |
| | TSC_G7_IO2 | PE3 | x | | - | | - | |
| | TSC_G7_IO3 | PE4 | x | | - | | - | |
| | TSC_G7_IO4 | PE5 | x | | - | | - | |
| G8 | TSC_G8_IO1 | PD12 | x | 3 | - | 0 | - | 0 |
| | TSC_G8_IO2 | PD13 | x | | - | | - | |
| | TSC_G8_IO3 | PD14 | x | | - | | - | |
| | TSC_G8_IO4 | PD15 | x | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 23 | | 17 | | 16 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 42. Available touch sensing channels for STM32F334x4/x6/x8**

| Analog I/O group | Capacitive sensing signal | Pin name | STM32F334Rx LQFP64 | | STM32F334Cx LQFP48 | | STM32F334Kx LQFP32 | |
|---|---|---|---|---|---|---|---|---|
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | |
| | TSC_G1_IO3 | PA2 | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | |
| | TSC_G2_IO3 | PA6(1) | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | |
| G3 | TSC_G3_IO1 | PC5 | x | 3 | - | 2 | - | 1 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | |
| | TSC_G3_IO3 | PB1 | x | | x | | x | |
| | TSC_G3_IO4 | PB2 | x | | x | | - | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | |
| | TSC_G4_IO3 | PA13 | x | | x | | x | |
| | TSC_G4_IO4 | PA14 | x | | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 | x | 3 | - | 0 |
| | TSC_G6_IO2 | PB12 | x | | x | | - | |
| | TSC_G6_IO3 | PB13 | x | | x | | - | |
| | TSC_G6_IO4 | PB14 | x | | x | | - | |
| G7 | TSC_G7_IO1 | - | - | 0 | - | 0 | - | 0 |
| | TSC_G7_IO2 | - | - | | - | | - | |
| | TSC_G7_IO3 | - | - | | - | | - | |
| | TSC_G7_IO4 | - | - | | - | | - | |
| G8 | TSC_G8_IO1 | - | - | 0 | - | 0 | - | 0 |
| | TSC_G8_IO2 | - | - | | - | | - | |
| | TSC_G8_IO3 | - | - | | - | | - | |
| | TSC_G8_IO4 | - | - | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 18 | | 17 | | 13 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 43. Available touch sensing channels for STM32F328C8**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F328C8 | |
|---|---|---|---|---|
| | | | LQFP48 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | |
| | TSC_G1_IO3 | PA2 | x | |
| | TSC_G1_IO4 | PA3 | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | |
| | TSC_G2_IO3 | PA6(1) | x | |
| | TSC_G2_IO4 | PA7 | x | |
| G3 | TSC_G3_IO1 | - | - | 1 |
| | TSC_G3_IO2 | PB0 | x | |
| | TSC_G3_IO3 | PB1 | x | |
| | TSC_G3_IO4 | - | - | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | |
| | TSC_G4_IO3 | PA13 | x | |
| | TSC_G4_IO4 | PA14 | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | |
| | TSC_G5_IO3 | PB6 | x | |
| | TSC_G5_IO4 | PB7 | x | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 |
| | TSC_G6_IO2 | PB12 | x | |
| | TSC_G6_IO3 | PB13 | x | |
| | TSC_G6_IO4 | PB14 | x | |
| G7 | TSC_G7_IO1 | - | - | 0 |
| | TSC_G7_IO2 | - | - | |
| | TSC_G7_IO3 | - | - | |
| | TSC_G7_IO4 | - | - | |
| G8 | TSC_G8_IO1 | - | - | 0 |
| | TSC_G8_IO2 | - | - | |
| | TSC_G8_IO3 | - | - | |
| | TSC_G8_IO4 | - | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 16 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 44. Available touch sensing channels for STM32F318x8**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F318C8 | | STM32F318K8 | |
|---|---|---|---|---|---|---|
| | | | WLCSP49 | | UQFN32 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | |
| | TSC_G1_IO3 | PA2(1) | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | | x | |
| | TSC_G2_IO3 | PA6(1) | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | |
| G3 | TSC_G3_IO1 | - | - | 1 | - | 0 |
| | TSC_G3_IO2 | PB0 | x | | x | |
| | TSC_G3_IO3 | PB1 | x | | - | |
| | TSC_G3_IO4 | - | - | | - | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | |
| | TSC_G4_IO3 | PA13 | x | | x | |
| | TSC_G4_IO4 | PA14 | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 2 |
| | TSC_G5_IO2 | PB4 | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | - | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 | - | 0 |
| | TSC_G6_IO2 | PB12 | x | | - | |
| | TSC_G6_IO3 | PB13 | x | | - | |
| | TSC_G6_IO4 | PB14 | x | | - | |
| G7 | TSC_G7_IO1 | - | - | 0 | - | 0 |
| | TSC_G7_IO2 | - | - | | - | |
| | TSC_G7_IO3 | - | - | | - | |
| | TSC_G7_IO4 | - | - | | - | |
| G8 | TSC_G8_IO1 | - | - | 0 | - | 0 |
| | TSC_G8_IO2 | - | - | | - | |
| | TSC_G8_IO3 | - | - | | - | |
| | TSC_G8_IO4 | - | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 16 | | 11 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 45. Available touch sensing channels for STM32F303xD/xE**

| Analog I/O group | Capacitive sensing signal | Pin name | STM32F303Zx | | STM32F303Vx | | | | STM32F303Rx | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | LQFP144 | | LQFP100 | | UFBGA100 | | LQFP64 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | | x | |
| | TSC_G1_IO3 | PA2(1) | x | | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | | x | |
| | TSC_G2_IO3 | PA6(1) | x | | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | | x | |
| G3 | TSC_G3_IO1 | PC5 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | | x | |
| | TSC_G3_IO3 | PB1(1) | x | | x | | x | | x | |
| | TSC_G3_IO4 | PB2 | x | | x | | x | | x | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | | x | |
| | TSC_G4_IO3 | PA13 | x | | x | | x | | x | |
| | TSC_G4_IO4 | PA14 | x | | x | | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | | x | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G6_IO2 | PB12(1) | x | | x | | x | | x | |
| | TSC_G6_IO3 | PB13 | x | | x | | x | | x | |
| | TSC_G6_IO4 | PB14 | x | | x | | x | | x | |
| G7 | TSC_G7_IO1 | PE2 | x | 3 | x | 3 | x | 3 | - | 0 |
| | TSC_G7_IO2 | PE3 | x | | x | | x | | - | |
| | TSC_G7_IO3 | PE4 | x | | x | | x | | - | |
| | TSC_G7_IO4 | PE5 | x | | x | | x | | - | |
| G8 | TSC_G8_IO1 | PD12 | x | 3 | x | 3 | x | 3 | - | 0 |
| | TSC_G8_IO2 | PD13 | x | | x | | x | | - | |
| | TSC_G8_IO3 | PD14 | x | | x | | x | | - | |
| | TSC_G8_IO4 | PD15 | x | | x | | x | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 24 | | 24 | | 24 | | 18 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 46. Available touch sensing channels for STM32F303xB/xC**

| Analog I/O group | Capacitive sensing signal | Pin name | STM32F303Vx LQFP100 | | STM32F303Rx LQFP64 | | STM32F303Cx LQFP48 | |
|---|---|---|---|---|---|---|---|---|
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | |
| | TSC_G1_IO3 | PA2(1) | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | |
| | TSC_G2_IO3 | PA6(1) | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | |
| G3 | TSC_G3_IO1 | PC5 | x | 3 | x | 3 | - | 2 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | |
| | TSC_G3_IO3 | PB1(1) | x | | x | | x | |
| | TSC_G3_IO4 | PB2 | x | | x | | x | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | |
| | TSC_G4_IO3 | PA13 | x | | x | | x | |
| | TSC_G4_IO4 | PA14 | x | | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 | x | 3 | x | 3 |
| | TSC_G6_IO2 | PB12(1) | x | | x | | x | |
| | TSC_G6_IO3 | PB13 | x | | x | | x | |
| | TSC_G6_IO4 | PB14 | x | | x | | x | |
| G7 | TSC_G7_IO1 | PE2 | x | 3 | - | 0 | - | 0 |
| | TSC_G7_IO2 | PE3 | x | | - | | - | |
| | TSC_G7_IO3 | PE4 | x | | - | | - | |
| | TSC_G7_IO4 | PE5 | x | | - | | - | |
| G8 | TSC_G8_IO1 | PD12 | x | 3 | - | 0 | - | 0 |
| | TSC_G8_IO2 | PD13 | x | | - | | - | |
| | TSC_G8_IO3 | PD14 | x | | - | | - | |
| | TSC_G8_IO4 | PD15 | x | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 24 | | 18 | | 17 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 47. Available touch sensing channels for STM32F303x6/x8**

| Analog I/O group | Capacitive sensing signal | Pin name | STM32F303Rx | | STM32F303Cx | | STM32F303Kx | |
|---|---|---|---|---|---|---|---|---|
| | | | LQFP64 | | LQFP48 | | LQFP32 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | |
| | TSC_G1_IO3 | PA2(1) | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | |
| | TSC_G2_IO3 | PA6(1) | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | |
| G3 | TSC_G3_IO1 | PC5 | x | 3 | - | 2 | - | 0 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | |
| | TSC_G3_IO3 | PB1(1) | x | | x | | - | |
| | TSC_G3_IO4 | PB2 | x | | x | | - | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | |
| | TSC_G4_IO3 | PA13 | x | | x | | x | |
| | TSC_G4_IO4 | PA14 | x | | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 | x | 3 | - | 0 |
| | TSC_G6_IO2 | PB12(1) | x | | x | | - | |
| | TSC_G6_IO3 | PB13 | x | | x | | - | |
| | TSC_G6_IO4 | PB14 | x | | x | | - | |
| G7 | TSC_G7_IO1 | - | - | 0 | - | 0 | - | 0 |
| | TSC_G7_IO2 | - | - | | - | | - | |
| | TSC_G7_IO3 | - | - | | - | | - | |
| | TSC_G7_IO4 | - | - | | - | | - | |
| G8 | TSC_G8_IO1 | - | - | 0 | - | 0 | - | 0 |
| | TSC_G8_IO2 | - | - | | - | | - | |
| | TSC_G8_IO3 | - | - | | - | | - | |
| | TSC_G8_IO4 | - | - | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 18 | | 17 | | 12 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 48. Available touch sensing channels for STM32F302xD/xE**

| Analog I/O group | Capacitive sensing signal | Pin name | STM32F302Zx | | STM32F302Vx | | | | STM32F302Rx | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | LQFP144 | | LQFP100 | | UFBGA100 | | LQFP64 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | | x | |
| | TSC_G1_IO3 | PA2(1) | x | | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | | x | |
| | TSC_G2_IO3 | PA6(1) | x | | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | | x | |
| G3 | TSC_G3_IO1 | PC5 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | | x | |
| | TSC_G3_IO3 | PB1(1) | x | | x | | x | | x | |
| | TSC_G3_IO4 | PB2 | x | | x | | x | | x | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | | x | |
| | TSC_G4_IO3 | PA13 | x | | x | | x | | x | |
| | TSC_G4_IO4 | PA14 | x | | x | | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | | x | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G6_IO2 | PB12(1) | x | | x | | x | | x | |
| | TSC_G6_IO3 | PB13 | x | | x | | x | | x | |
| | TSC_G6_IO4 | PB14 | x | | x | | x | | x | |
| G7 | TSC_G7_IO1 | PE2 | x | 3 | x | 3 | x | 3 | - | 0 |
| | TSC_G7_IO2 | PE3 | x | | x | | x | | - | |
| | TSC_G7_IO3 | PE4 | x | | x | | x | | - | |
| | TSC_G7_IO4 | PE5 | x | | x | | x | | - | |
| G8 | TSC_G8_IO1 | PD12 | x | 3 | x | 3 | x | 3 | - | 0 |
| | TSC_G8_IO2 | PD13 | x | | x | | x | | - | |
| | TSC_G8_IO3 | PD14 | x | | x | | x | | - | |
| | TSC_G8_IO4 | PD15 | x | | x | | x | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 24 | | 24 | | 24 | | 18 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 49. Available touch sensing channels for STM32F302xB/xC**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F302Vx | | STM32F302Rx | | STM32F302Cx | |
|---|---|---|---|---|---|---|---|---|
| | | | LQFP100 | | LQFP64 | | LQFP48 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | |
| | TSC_G1_IO3 | PA2(1) | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | |
| | TSC_G2_IO3 | PA6(1) | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | |
| G3 | TSC_G3_IO1 | PC5 | x | 3 | x | 3 | - | 2 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | |
| | TSC_G3_IO3 | PB1(1) | x | | x | | x | |
| | TSC_G3_IO4 | PB2 | x | | x | | x | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | |
| | TSC_G4_IO3 | PA13 | x | | x | | x | |
| | TSC_G4_IO4 | PA14 | x | | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 | x | 3 | x | 3 |
| | TSC_G6_IO2 | PB12(1) | x | | x | | x | |
| | TSC_G6_IO3 | PB13 | x | | x | | x | |
| | TSC_G6_IO4 | PB14 | x | | x | | x | |
| G7 | TSC_G7_IO1 | PE2 | x | 3 | - | 0 | - | 0 |
| | TSC_G7_IO2 | PE3 | x | | - | | - | |
| | TSC_G7_IO3 | PE4 | x | | - | | - | |
| | TSC_G7_IO4 | PE5 | x | | - | | - | |
| G8 | TSC_G8_IO1 | PD12 | x | 3 | - | 0 | - | 0 |
| | TSC_G8_IO2 | PD13 | x | | - | | - | |
| | TSC_G8_IO3 | PD14 | x | | - | | - | |
| | TSC_G8_IO4 | PD15 | x | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 24 | | 18 | | 17 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 50. Available touch sensing channels for STM32F302x6/x8**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F302Rx | | STM32F302Cx | | | | STM32F302Kx | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | LQFP64 | | LQFP48 | | WLCSP49 | | UQFN32 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | | x | |
| | TSC_G1_IO3 | PA2(1) | x | | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | | x | |
| | TSC_G2_IO3 | PA6(1) | x | | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | | x | |
| G3 | TSC_G3_IO1 | PC5 | x | 3 | - | 2 | - | 2 | - | 0 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | | x | |
| | TSC_G3_IO3 | PB1(1) | x | | x | | x | | - | |
| | TSC_G3_IO4 | PB2 | x | | x | | x | | - | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | | x | |
| | TSC_G4_IO3 | PA13 | x | | x | | x | | x | |
| | TSC_G4_IO4 | PA14 | x | | x | | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | | x | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 | x | 3 | - | 3 | - | 0 |
| | TSC_G6_IO2 | PB12(1) | x | | x | | - | | - | |
| | TSC_G6_IO3 | PB13 | x | | x | | - | | - | |
| | TSC_G6_IO4 | PB14 | x | | x | | - | | - | |
| G7 | TSC_G7_IO1 | - | - | 0 | - | 0 | - | 0 | - | 0 |
| | TSC_G7_IO2 | - | - | | - | | - | | - | |
| | TSC_G7_IO3 | - | - | | - | | - | | - | |
| | TSC_G7_IO4 | - | - | | - | | - | | - | |
| G8 | TSC_G8_IO1 | - | - | 0 | - | 0 | - | 0 | - | 0 |
| | TSC_G8_IO2 | - | - | | - | | - | | - | |
| | TSC_G8_IO3 | - | - | | - | | - | | - | |
| | TSC_G8_IO4 | - | - | | - | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 18 | | 17 | | 17 | | 12 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 51. Available touch sensing channels for STM32F301x6/x8**

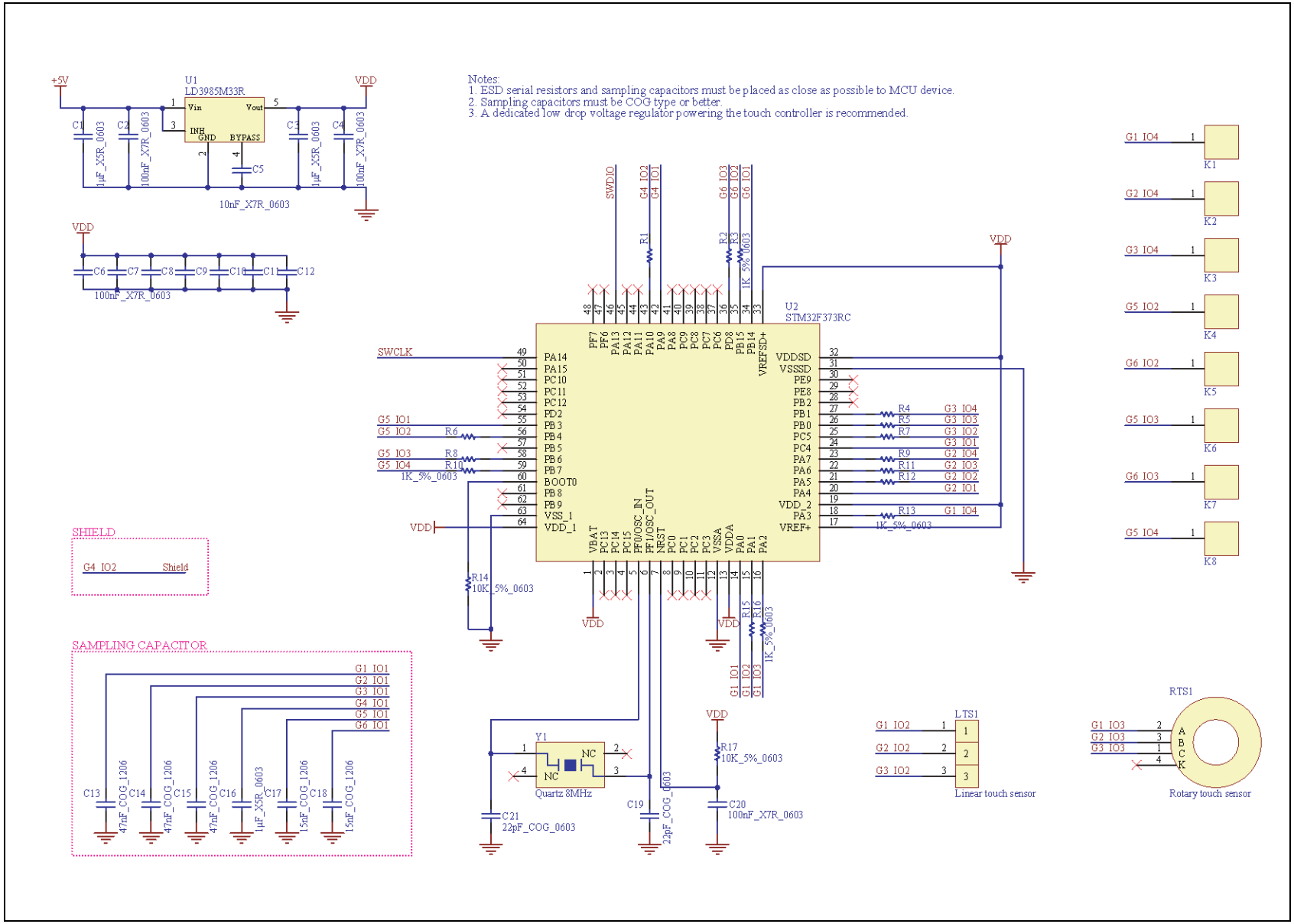
| Analog I/O group | Capacitive sensing signal name | Pin name | STM32F301Rx | | STM32F301Cx | | | | STM32F301Kx | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | LQFP64 | | LQFP48 | | WLCSP49 | | UQFN32 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | | x | |
| | TSC_G1_IO3 | PA2(1) | x | | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5(1) | x | | x | | x | | x | |
| | TSC_G2_IO3 | PA6(1) | x | | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | | x | |
| G3 | TSC_G3_IO1 | PC5 | x | 3 | - | 2 | - | 2 | - | 0 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | | x | |
| | TSC_G3_IO3 | PB1(1) | x | | x | | x | | - | |
| | TSC_G3_IO4 | PB2 | x | | x | | x | | - | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | | x | |
| | TSC_G4_IO3 | PA13 | x | | x | | x | | x | |
| | TSC_G4_IO4 | PA14 | x | | x | | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | | x | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 | x | 3 | - | 3 | - | 0 |
| | TSC_G6_IO2 | PB12(1) | x | | x | | - | | - | |
| | TSC_G6_IO3 | PB13 | x | | x | | - | | - | |
| | TSC_G6_IO4 | PB14 | x | | x | | - | | - | |
| G7 | TSC_G7_IO1 | - | - | 0 | - | 0 | - | 0 | - | 0 |
| | TSC_G7_IO2 | - | - | | - | | - | | - | |
| | TSC_G7_IO3 | - | - | | - | | - | | - | |
| | TSC_G7_IO4 | - | - | | - | | - | | - | |
| G8 | TSC_G8_IO1 | - | - | 0 | - | 0 | - | 0 | - | 0 |
| | TSC_G8_IO2 | - | - | | - | | - | | - | |
| | TSC_G8_IO3 | - | - | | - | | - | | - | |
| | TSC_G8_IO4 | - | - | | - | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 18 | | 17 | | 17 | | 12 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

### 3.6.3 Hardware implementation example

*Figure 18* shows an example of hardware implementation on STM32F3 Series microcontrollers.

**Figure 18. STM32F3 Series hardware implementation example**



## 3.7 STM32L0 Series microcontrollers

### 3.7.1 Memory footprint

#### Conditions

- IAR ANSI C/C++ compiler/linker V7.40.3.8902 for Arm
- Compiler optimization: high size
- Counted files: tsl*.o
- STM32 touch sensing library options: ECS=ON, DTO=ON, DXS=OFF, PROX=OFF
- Each sensor has its own parameters placed in RAM.

The following table summarize the memory footprint with different configurations.

**Table 52. STM32L0 Series memory footprint(1)**

| Channels | Banks | Sensors | ROM (Kbytes) | RAM (bytes) |
|---|---|---|---|---|
| 1 | 1 | 1 TKey | 3.0 | 100 |
| 2 | 1 | 2 TKeys | 3.0 | 120 |
| 2 | 2 | 2 TKeys | 3.0 | 120 |
| 24 | 3 | 24 TKeys | 4.0 | 620 |
| 3 | 1 | 1 Linear-3ch | 4.1 | 130 |
| 15 | 3 | 12 TKeys + 1 Linear-3ch | 6.2 | 420 |
| 24 | 3 | 18 TKeys + 2 Linear-3ch | 6.5 | 610 |

1. The content of this table is provided for information purposes only.

### 3.7.2 Available touch sensing channels

The tables below provide an overview of the available touch sensing channels for the STM32L0 Series microcontrollers.

*Note: The following tables are not restrictive in term of part numbers supported by the STMTouch touch sensing library. The STMTouch touch sensing library can be used on any new device that may become available as part of ST microcontrollers portfolio. Contact the local ST representative for support.*

*For n available pins in an I/O group, one pin is used as sampling capacitor and n-1 pins are used as channels.*

*The I/O group cannot be used if the number of available pins in less or equal to one.*

**Table 53. Capacitive sensing GPIOs available on STM32L083xx devices**

| Group | Capacitive sensing signal name | Pin name | Group | Capacitive sensing signal name | Pin name |
|---|---|---|---|---|---|
| 1 | TSC_G1_IO1 | PA0 | 5 | TSC_G5_IO1 | PB3 |
| | TSC_G1_IO2 | PA1 | | TSC_G5_IO2 | PB4 |
| | TSC_G1_IO3 | PA2 | | TSC_G5_IO3 | PB6 |
| | TSC_G1_IO4 | PA3 | | TSC_G5_IO4 | PB7 |
| 2 | TSC_G2_IO1 | PA4 | 6 | TSC_G6_IO1 | PB11 |
| | TSC_G2_IO2 | PA5 | | TSC_G6_IO2 | PB12 |
| | TSC_G2_IO3 | PA6 | | TSC_G6_IO3 | PB13 |
| | TSC_G2_IO4 | PA7 | | TSC_G6_IO4 | PB14 |
| 3 | TSC_G3_IO1 | PC5 | 7 | TSC_G7_IO1 | PC0 |
| | TSC_G3_IO2 | PB0 | | TSC_G7_IO2 | PC1 |
| | TSC_G3_IO3 | PB1 | | TSC_G7_IO3 | PC2 |
| | TSC_G3_IO4 | PB2 | | TSC_G7_IO4 | PC3 |
| 4 | TSC_G4_IO1 | PA9 | 8 | TSC_G8_IO1 | PC6 |
| | TSC_G4_IO2 | PA10 | | TSC_G8_IO2 | PC7 |
| | TSC_G4_IO3 | PA11 | | TSC_G8_IO3 | PC8 |
| | TSC_G4_IO4 | PA12 | | TSC_G8_IO4 | PC9 |

**Table 54. Capacitive sensing GPIOs available on STM32L082xx devices**

| Group | Capacitive sensing signal name | Pin name |
|---|---|---|
| 1 | TSC_G1_IO1 | PA0 |
| | TSC_G1_IO2 | PA1 |
| | TSC_G1_IO3 | PA2 |
| | TSC_G1_IO4 | PA3 |
| 2 | TSC_G2_IO1 | PA4 |
| | TSC_G2_IO2 | PA5 |
| | TSC_G2_IO3 | PA6 |
| | TSC_G2_IO4 | PA7 |
| 3 | - | - |
| | TSC_G3_IO2 | PB0 |
| | TSC_G3_IO3 | PB1 |
| | TSC_G3_IO4 | PB2 |
| 4 | TSC_G4_IO1 | PA9 |
| | TSC_G4_IO2 | PA10 |
| | TSC_G4_IO3 | PA11 |
| | TSC_G4_IO4 | PA12 |
| 5 | TSC_G5_IO1 | PB3 |
| | TSC_G5_IO2 | PB4 |
| | TSC_G5_IO3 | PB6 |
| | TSC_G5_IO4 | PB7 |
| 6 | TSC_G6_IO1 | PB11 |
| | TSC_G6_IO2 | PB12 |
| | TSC_G6_IO3 | PB13 |
| | TSC_G6_IO4 | PB7 |
| 7 | TSC_G7_IO1 | PC0 |
| | TSC_G7_IO2 | PC1 |
| | TSC_G7_IO3 | PC2 |
| | - | - |

**Table 55. Available touch sensing channels for STM32L063x8**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32L063R8 | | STM32L063C8 | |
|---|---|---|---|---|---|---|
| | | | LQFP64 | | LQFP48 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | |
| | TSC_G1_IO3 | PA2 | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5 | x | | x | |
| | TSC_G2_IO3 | PA6 | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | |
| G3 | TSC_G3_IO1 | PC5 | x | 3 | - | 2 |
| | TSC_G3_IO2 | PB0 | x | | x | |
| | TSC_G3_IO3 | PB1 | x | | x | |
| | TSC_G3_IO4 | PB2 | x | | x | |

**Table 55. Available touch sensing channels for STM32L063x8 (continued)**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32L063R8 | | STM32L063C8 | |
|---|---|---|---|---|---|---|
| | | | LQFP64 | | LQFP48 | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | |
| | TSC_G4_IO3 | PA11 | x | | x | |
| | TSC_G4_IO4 | PA12 | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 | x | 3 |
| | TSC_G6_IO2 | PB12 | x | | x | |
| | TSC_G6_IO3 | PB13 | x | | x | |
| | TSC_G6_IO4 | PB14 | x | | x | |
| G7 | TSC_G7_IO1 | PC0 | x | 3 | - | 0 |
| | TSC_G7_IO2 | PC1 | x | | - | |
| | TSC_G7_IO3 | PC2 | x | | - | |
| | TSC_G7_IO4 | PC3 | x | | - | |
| G8 | TSC_G8_IO1 | PC6 | x | 3 | - | 0 |
| | TSC_G8_IO2 | PC7 | x | | - | |
| | TSC_G8_IO3 | PC8 | x | | - | |
| | TSC_G8_IO4 | PC9 | x | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 24 | | 17 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 56. Available touch sensing channels for STM32L062K8**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32L062K8 | |
|---|---|---|---|---|
| | | | UFQFPN32 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | |
| | TSC_G1_IO3 | PA2 | x | |
| | TSC_G1_IO4 | PA3 | x | |

**Table 56. Available touch sensing channels for STM32L062K8 (continued)**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32L062K8 | |
|---|---|---|---|---|
| | | | UFQFPN32 | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 |
| | TSC_G2_IO2 | PA5 | x | |
| | TSC_G2_IO3 | PA6 | x | |
| | TSC_G2_IO4 | PA7 | x | |
| G3 | TSC_G3_IO1 | PC5 | - | 2 |
| | TSC_G3_IO2 | PB0 | x | |
| | TSC_G3_IO3 | PB1 | x | |
| | TSC_G3_IO4 | PB2 | x | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | |
| | TSC_G4_IO3 | PA11 | x | |
| | TSC_G4_IO4 | PA12 | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | |
| | TSC_G5_IO3 | PB6 | x | |
| | TSC_G5_IO4 | PB7 | x | |
| G6 | TSC_G6_IO1 | PB11 | - | 0 |
| | TSC_G6_IO2 | PB12 | - | |
| | TSC_G6_IO3 | PB13 | - | |
| | TSC_G6_IO4 | PB14 | - | |
| G7 | TSC_G7_IO1 | PC0 | - | 0 |
| | TSC_G7_IO2 | PC1 | - | |
| | TSC_G7_IO3 | PC2 | - | |
| | TSC_G7_IO4 | PC3 | - | |
| G8 | TSC_G8_IO1 | PC6 | - | 0 |
| | TSC_G8_IO2 | PC7 | - | |
| | TSC_G8_IO3 | PC8 | - | |
| | TSC_G8_IO4 | PC9 | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 14 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 57. Available touch sensing channels for STM32L053x6/x8**

| Analog I/O group | Capacitive sensing | Pin name | STM32L053Rx LQFP64 | | STM32L053Rx TFBGA64 | | STM32L053Cx LQFP48 | |
|---|---|---|---|---|---|---|---|---|
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | |
| | TSC_G1_IO3 | PA2 | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5 | x | | x | | x | |
| | TSC_G2_IO3 | PA6 | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | |
| G3 | TSC_G3_IO1 | PC5 | x | 3 | x | 3 | - | 2 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | |
| | TSC_G3_IO3 | PB1 | x | | x | | x | |
| | TSC_G3_IO4 | PB2 | x | | x | | x | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | |
| | TSC_G4_IO3 | PA11 | x | | x | | x | |
| | TSC_G4_IO4 | PA12 | x | | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 | x | 3 | x | 3 |
| | TSC_G6_IO2 | PB12 | x | | x | | x | |
| | TSC_G6_IO3 | PB13 | x | | x | | x | |
| | TSC_G6_IO4 | PB14 | x | | x | | x | |
| G7 | TSC_G7_IO1 | PC0 | x | 3 | x | 2 | - | 0 |
| | TSC_G7_IO2 | PC1 | x | | x | | - | |
| | TSC_G7_IO3 | PC2 | x | | x | | - | |
| | TSC_G7_IO4 | PC3 | x | | - | | - | |
| G8 | TSC_G8_IO1 | PC6 | x | 3 | x | 3 | - | 0 |
| | TSC_G8_IO2 | PC7 | x | | x | | - | |
| | TSC_G8_IO3 | PC8 | x | | x | | - | |
| | TSC_G8_IO4 | PC9 | x | | x | | - | |
| Number of capacitive sensing channels | | | 24 | | 23 | | 17 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

**Table 58. Available touch sensing channels for STM32L052x6/x8**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32L052Rx | | STM32L052Rx | | STM32L052Cx | | STM32L052Tx | | STM32L052Kx | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | LQFP64 | | TFBGA64 | | LQFP48 | | WLCSP36 | | LQFP32 | | UFQFPN32 | |
| G1 | TSC_G1_IO1 | PA0 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PA1 | x | | x | | x | | x | | x | | x | |
| | TSC_G1_IO3 | PA2 | x | | x | | x | | x | | x | | x | |
| | TSC_G1_IO4 | PA3 | x | | x | | x | | x | | x | | x | |
| G2 | TSC_G2_IO1 | PA4(1) | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PA5 | x | | x | | x | | x | | x | | x | |
| | TSC_G2_IO3 | PA6 | x | | x | | x | | x | | x | | x | |
| | TSC_G2_IO4 | PA7 | x | | x | | x | | x | | x | | x | |
| G3 | TSC_G3_IO1 | PC5 | x | 3 | x | 3 | - | 2 | - | 2 | - | 1 | - | 2 |
| | TSC_G3_IO2 | PB0 | x | | x | | x | | x | | x | | x | |
| | TSC_G3_IO3 | PB1 | x | | x | | x | | x | | x | | x | |
| | TSC_G3_IO4 | PB2 | x | | x | | x | | x | | - | | x | |
| G4 | TSC_G4_IO1 | PA9 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PA10 | x | | x | | x | | x | | x | | x | |
| | TSC_G4_IO3 | PA11 | x | | x | | x | | x | | x | | x | |
| | TSC_G4_IO4 | PA12 | x | | x | | x | | x | | x | | x | |
| G5 | TSC_G5_IO1 | PB3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G5_IO2 | PB4 | x | | x | | x | | x | | x | | x | |
| | TSC_G5_IO3 | PB6 | x | | x | | x | | x | | x | | x | |
| | TSC_G5_IO4 | PB7 | x | | x | | x | | x | | x | | x | |

**Table 58. Available touch sensing channels for STM32L052x6/x8 (continued)**

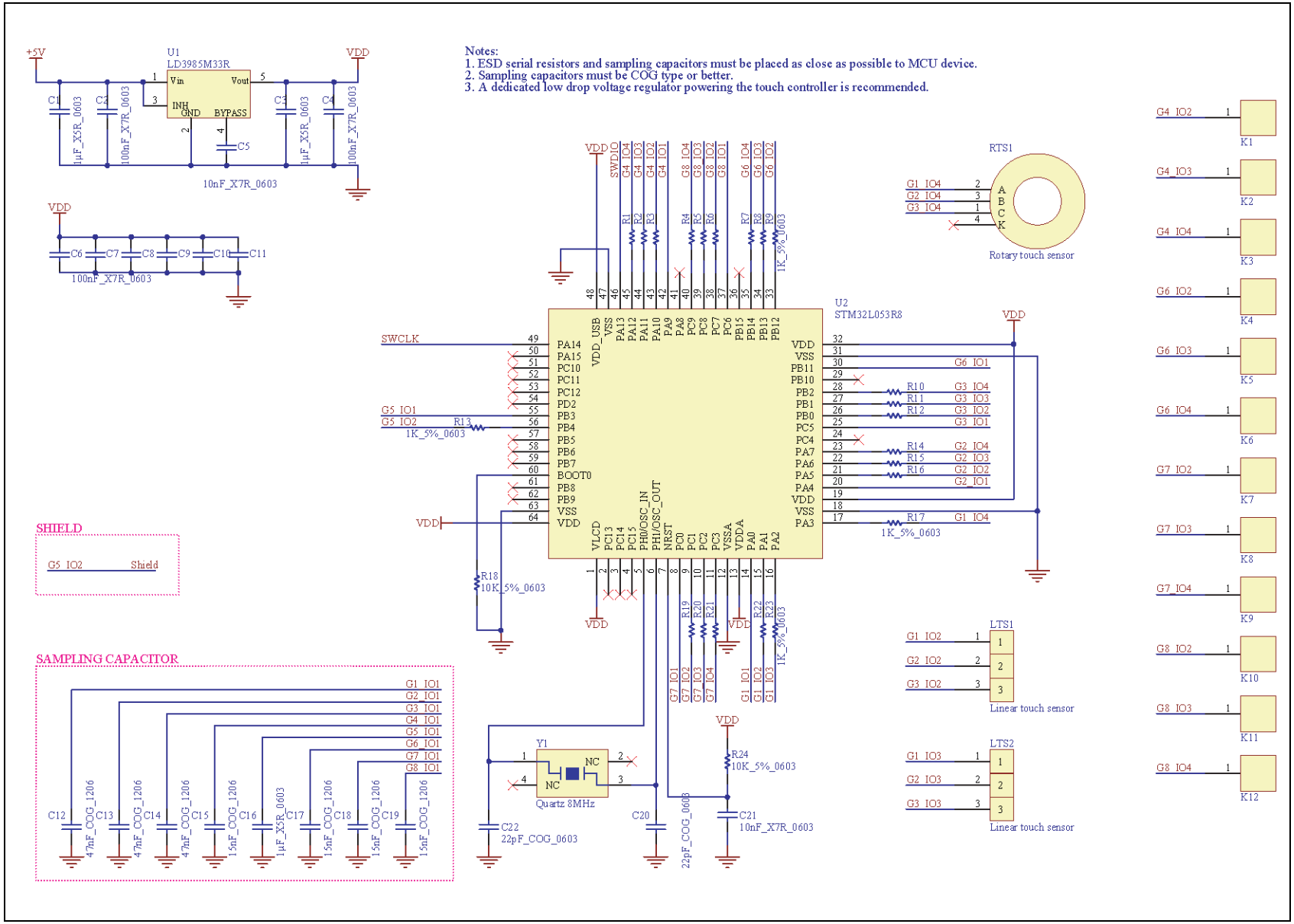
| Analog I/O group | Capacitive sensing signal name | Pin name | STM32L052Rx | | STM32L052Rx | | STM32L052Cx | | STM32L052Tx | | STM32L052Kx | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | LQFP64 | | TFBGA64 | | LQFP48 | | WLCSP36 | | LQFP32 | | UFQFPN32 | |
| G6 | TSC_G6_IO1 | PB11 | x | 3 | x | 3 | x | 3 | x | 0 | - | 0 | - | 0 |
| | TSC_G6_IO2 | PB12 | x | | x | | x | | - | | - | | - | |
| | TSC_G6_IO3 | PB13 | x | | x | | x | | - | | - | | - | |
| | TSC_G6_IO4 | PB14 | x | | x | | x | | - | | - | | - | |
| G7 | TSC_G7_IO1 | PC0 | x | 3 | x | 2 | - | 0 | - | 0 | - | 0 | - | 0 |
| | TSC_G7_IO2 | PC1 | x | | x | | - | | - | | - | | - | |
| | TSC_G7_IO3 | PC2 | x | | x | | - | | - | | - | | - | |
| | TSC_G7_IO4 | PC3 | x | | - | | - | | - | | - | | - | |
| G8 | TSC_G8_IO1 | PC6 | x | 3 | x | 3 | - | 0 | - | 0 | - | 0 | - | 0 |
| | TSC_G8_IO2 | PC7 | x | | x | | - | | - | | - | | - | |
| | TSC_G8_IO3 | PC8 | x | | x | | - | | - | | - | | - | |
| | TSC_G8_IO4 | PC9 | x | | x | | - | | - | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 24 | | 23 | | 17 | | 14 | | 13 | | 14 | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.

### 3.7.3 Hardware implementation example

*Figure 19* shows an example of hardware implementation on STM32L0 Series microcontrollers.

**Figure 19. STM32L0 Series hardware implementation example**



## 3.8 STM32L4 Series microcontrollers

### 3.8.1 Memory footprint

#### Conditions

- IAR ANSI C/C++ compiler/linker V7.40.3.8902 for Arm®
- Compiler optimization: high size
- Counted files: tsl*.o
- STM32 TouchSensing library options: ECS=ON, DTO=ON, DXS=OFF, PROX=OFF
- Each sensor has its own parameters placed in RAM

The following table summarizes the memory footprint with different configurations:

**Table 59. STM32L4 Series memory footprint(1)**

| Channels | Banks | Sensors | ROM (~ Kbyte) | RAM (~ byte) |
|---|---|---|---|---|
| 1 | 1 | 1 TKey | 2.8 | 100 |
| 2 | 1 | 2 TKeys | 2.8 | 120 |
| 2 | 2 | 2 TKeys | 2.8 | 120 |
| 24 | 3 | 24 TKeys | 3.8 | 620 |
| 3 | 1 | 1 Linear-3ch | 3.8 | 130 |
| 15 | 3 | 12 TKeys + 1 Linear-3ch | 5.7 | 420 |
| 24 | 3 | 18 TKeys + 2 Linear-3ch | 6.0 | 610 |

1. The content of this table is provided for information purposes only.

### 3.8.2 Available touch sensing channels

The tables below provide an overview of the available touch sensing channels for the STM32L4 Series microcontrollers.

*Note: The following tables are not restrictive in term of part numbers supported by the STMTouch touch sensing library. The STMTouch touch sensing library can be used on any new device that may become available as part of ST microcontrollers portfolio. Please contact your ST representative for support.*

*Note: For n available pins in an I/O group, one pin is used as sampling capacitor and n-1 pins are used as channels.*

*The I/O group cannot be used if the number of available pins in less or equal to one.*

**Table 60. Available touch sensing channels for STM32L4A6xG**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32L4A6AG | | STM32L4A6ZG | | STM32L4A6QG | | STM32L4A6VG | | | | STM32L4A6RG | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | UFBGA169 | | LQFP144 | | UFBGA132 | | LQFP100 | | WLCSP100 | | LQFP64 | |
| G1 | TSC_G1_IO1 | PB12 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PB13 | x | | x | | x | | x | | x | | x | |
| | TSC_G1_IO3 | PB14 | x | | x | | x | | x | | x | | x | |
| | TSC_G1_IO4 | PB15 | x | | x | | x | | x | | x | | x | |
| G2 | TSC_G2_IO1 | PB4 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PB5 | x | | x | | x | | x | | x | | x | |
| | TSC_G2_IO3 | PB6 | x | | x | | x | | x | | x | | x | |
| | TSC_G2_IO4 | PB7 | x | | x | | x | | x | | x | | x | |
| G3 | TSC_G3_IO1 | PA15 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G3_IO2 | PC10 | x | | x | | x | | x | | x | | x | |
| | TSC_G3_IO3 | PC11 | x | | x | | x | | x | | x | | x | |
| | TSC_G3_IO4 | PC12 | x | | x | | x | | x | | x | | x | |
| G4 | TSC_G4_IO1 | PC6 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PC7 | x | | x | | x | | x | | x | | x | |
| | TSC_G4_IO3 | PC8 | x | | x | | x | | x | | x | | x | |
| | TSC_G4_IO4 | PC9 | x | | x | | x | | x | | x | | x | |
| G5 | TSC_G5_IO1 | PE10 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | - | 0 |
| | TSC_G5_IO2 | PE11 | x | | x | | x | | x | | x | | - | |
| | TSC_G5_IO3 | PE12 | x | | x | | x | | x | | x | | - | |
| | TSC_G5_IO4 | PE13 | x | | x | | x | | x | | x | | - | |

**Table 60. Available touch sensing channels for STM32L4A6xG (continued)**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32L4A6AG | | STM32L4A6ZG | | STM32L4A6QG | | STM32L4A6VG | | | | STM32L4A6RG | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | UFBGA169 | | LQFP144 | | UFBGA132 | | LQFP100 | | WLCSP100 | | LQFP64 | |
| G6 | TSC_G6_IO1 | PD10 | x | 3 | x | 3 | x | 3 | x | 3 | - | 0 | - | 0 |
| | TSC_G6_IO2 | PD11 | x | | x | | x | | x | | - | | - | |
| | TSC_G6_IO3 | PD12 | x | | x | | x | | x | | - | | - | |
| | TSC_G6_IO4 | PD13 | x | | x | | x | | x | | - | | - | |
| G7 | TSC_G7_IO1 | PE2 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | - | 0 |
| | TSC_G7_IO2 | PE3 | x | | x | | x | | x | | x | | - | |
| | TSC_G7_IO3 | PE4 | x | | x | | x | | x | | x | | - | |
| | TSC_G7_IO4 | PE5 | x | | x | | x | | x | | x | | - | |
| G8 | TSC_G8_IO1 | PF14 | x | 3 | x | 3 | x | 3 | - | 0 | - | 0 | - | 0 |
| | TSC_G8_IO2 | PF15 | x | | x | | x | | - | | - | | - | |
| | TSC_G8_IO3 | PG0 | x | | x | | x | | - | | - | | - | |
| | TSC_G8_IO4 | PG1 | x | | x | | x | | - | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 24 | | 24 | | 24 | | 21 | | 18 | | 12 | |

**Table 61. Available touch sensing channels for STM32L496xx**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32L496Ax | | STM32L496Zx | | STM32L496Qx | | STM32L496Vx | | | | STM32L496Rx | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | UFBGA169 | | LQFP144 | | UFBGA132 | | LQFP100 | | WLCSP100 | | LQFP64 | |
| G1 | TSC_G1_IO1 | PB12 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PB13 | x | | x | | x | | x | | x | | x | |
| | TSC_G1_IO3 | PB14 | x | | x | | x | | x | | x | | x | |
| | TSC_G1_IO4 | PB15 | x | | x | | x | | x | | x | | x | |
| G2 | TSC_G2_IO1 | PB4 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PB5 | x | | x | | x | | x | | x | | x | |
| | TSC_G2_IO3 | PB6 | x | | x | | x | | x | | x | | x | |
| | TSC_G2_IO4 | PB7 | x | | x | | x | | x | | x | | x | |
| G3 | TSC_G3_IO1 | PA15 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G3_IO2 | PC10 | x | | x | | x | | x | | x | | x | |
| | TSC_G3_IO3 | PC11 | x | | x | | x | | x | | x | | x | |
| | TSC_G3_IO4 | PC12 | x | | x | | x | | x | | x | | x | |
| G4 | TSC_G4_IO1 | PC6 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PC7 | x | | x | | x | | x | | x | | x | |
| | TSC_G4_IO3 | PC8 | x | | x | | x | | x | | x | | x | |
| | TSC_G4_IO4 | PC9 | x | | x | | x | | x | | x | | x | |
| G5 | TSC_G5_IO1 | PE10 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | - | 0 |
| | TSC_G5_IO2 | PE11 | x | | x | | x | | x | | x | | - | |
| | TSC_G5_IO3 | PE12 | x | | x | | x | | x | | x | | - | |
| | TSC_G5_IO4 | PE13 | x | | x | | x | | x | | x | | - | |

**Table 61. Available touch sensing channels for STM32L496xx (continued)**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32L496Ax | | STM32L496Zx | | STM32L496Qx | | STM32L496Vx | | | | STM32L496Rx | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | UFBGA169 | | LQFP144 | | UFBGA132 | | LQFP100 | | WLCSP100 | | LQFP64 | |
| G6 | TSC_G6_IO1 | PD10 | x | 3 | x | 3 | x | 3 | x | 3 | - | 0 | - | 0 |
| | TSC_G6_IO2 | PD11 | x | | x | | x | | x | | - | | - | |
| | TSC_G6_IO3 | PD12 | x | | x | | x | | x | | - | | - | |
| | TSC_G6_IO4 | PD13 | x | | x | | x | | x | | - | | - | |
| G7 | TSC_G7_IO1 | PE2 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | - | 0 |
| | TSC_G7_IO2 | PE3 | x | | x | | x | | x | | x | | - | |
| | TSC_G7_IO3 | PE4 | x | | x | | x | | x | | x | | - | |
| | TSC_G7_IO4 | PE5 | x | | x | | x | | x | | x | | - | |
| G8 | TSC_G8_IO1 | PF14 | x | 3 | x | 3 | x | 3 | - | 0 | - | 0 | - | 0 |
| | TSC_G8_IO2 | PF15 | x | | x | | x | | - | | - | | - | |
| | TSC_G8_IO3 | PG0 | x | | x | | x | | - | | - | | - | |
| | TSC_G8_IO4 | PG1 | x | | x | | x | | - | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 24 | | 24 | | 24 | | 21 | | 18 | | 12 | |

**Table 62. Available touch sensing channels for STM32L486xx**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32L486Zx | | STM32L486Qx | | STM32L486Vx | | STM32L486Jx | | STM32L486Rx | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | LQFP144 | | UFBGA132 | | LQFP100 | | WLCSP72 | | LQFP64 | |
| G1 | TSC_G1_IO1 | PB12 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PB13 | x | | x | | x | | x | | x | |
| | TSC_G1_IO3 | PB14 | x | | x | | x | | x | | x | |
| | TSC_G1_IO4 | PB15 | x | | x | | x | | x | | x | |
| G2 | TSC_G2_IO1 | PB4 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PB5 | x | | x | | x | | x | | x | |
| | TSC_G2_IO3 | PB6 | x | | x | | x | | x | | x | |
| | TSC_G2_IO4 | PB7 | x | | x | | x | | x | | x | |
| G3 | TSC_G3_IO1 | PA15 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G3_IO2 | PC10 | x | | x | | x | | x | | x | |
| | TSC_G3_IO3 | PC11 | x | | x | | x | | x | | x | |
| | TSC_G3_IO4 | PC12 | x | | x | | x | | x | | x | |
| G4 | TSC_G4_IO1 | PC6 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PC7 | x | | x | | x | | x | | x | |
| | TSC_G4_IO3 | PC8 | x | | x | | x | | x | | x | |
| | TSC_G4_IO4 | PC9 | x | | x | | x | | x | | x | |
| G5 | TSC_G5_IO1 | PE10 | x | 3 | x | 3 | x | 3 | - | 0 | - | 0 |
| | TSC_G5_IO2 | PE11 | x | | x | | x | | - | | - | |
| | TSC_G5_IO3 | PE12 | x | | x | | x | | - | | - | |
| | TSC_G5_IO4 | PE13 | x | | x | | x | | - | | - | |

**Table 62. Available touch sensing channels for STM32L486xx (continued)**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32L486Zx | | STM32L486Qx | | STM32L486Vx | | STM32L486Jx | | STM32L486Rx | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | LQFP144 | | UFBGA132 | | LQFP100 | | WLCSP72 | | LQFP64 | |
| G6 | TSC_G6_IO1 | PD10 | x | 3 | x | 3 | x | 3 | - | 0 | - | 0 |
| | TSC_G6_IO2 | PD11 | x | | x | | x | | - | | - | |
| | TSC_G6_IO3 | PD12 | x | | x | | x | | - | | - | |
| | TSC_G6_IO4 | PD13 | x | | x | | x | | - | | - | |
| G7 | TSC_G7_IO1 | PE2 | x | 3 | x | 3 | x | 3 | - | 0 | - | 0 |
| | TSC_G7_IO2 | PE3 | x | | x | | x | | - | | - | |
| | TSC_G7_IO3 | PE4 | x | | x | | x | | - | | - | |
| | TSC_G7_IO4 | PE5 | x | | x | | x | | - | | - | |
| G8 | TSC_G8_IO1 | PF14 | x | 3 | x | 3 | - | 0 | - | 0 | - | 0 |
| | TSC_G8_IO2 | PF15 | x | | x | | - | | - | | - | |
| | TSC_G8_IO3 | PG0 | x | | x | | - | | - | | - | |
| | TSC_G8_IO4 | PG1 | x | | x | | - | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 24 | | 24 | | 21 | | 12 | | 12 | |

**Table 63. Available touch sensing channels for STM32L476xx**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32L476Zx | | STM32L476Qx | | STM32L476Vx | | STM32L476Mx | | STM32L476Jx | | STM32L476Rx | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | LQFP144 | | UFBGA132 | | LQFP100 | | WLCSP81 | | WLCSP72 | | LQFP64 | |
| G1 | TSC_G1_IO1 | PB12 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G1_IO2 | PB13 | x | | x | | x | | x | | x | | x | |
| | TSC_G1_IO3 | PB14 | x | | x | | x | | x | | x | | x | |
| | TSC_G1_IO4 | PB15 | x | | x | | x | | x | | x | | x | |

**Table 63. Available touch sensing channels for STM32L476xx (continued)**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32L476Zx | | STM32L476Qx | | STM32L476Vx | | STM32L476Mx | | STM32L476Jx | | STM32L476Rx | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | LQFP144 | | UFBGA132 | | LQFP100 | | WLCSP81 | | WLCSP72 | | LQFP64 | |
| G2 | TSC_G2_IO1 | PB4 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G2_IO2 | PB5 | x | | x | | x | | x | | x | | x | |
| | TSC_G2_IO3 | PB6 | x | | x | | x | | x | | x | | x | |
| | TSC_G2_IO4 | PB7 | x | | x | | x | | x | | x | | x | |
| G3 | TSC_G3_IO1 | PA15 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G3_IO2 | PC10 | x | | x | | x | | x | | x | | x | |
| | TSC_G3_IO3 | PC11 | x | | x | | x | | x | | x | | x | |
| | TSC_G3_IO4 | PC12 | x | | x | | x | | x | | x | | x | |
| G4 | TSC_G4_IO1 | PC6 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 | x | 3 |
| | TSC_G4_IO2 | PC7 | x | | x | | x | | x | | x | | x | |
| | TSC_G4_IO3 | PC8 | x | | x | | x | | x | | x | | x | |
| | TSC_G4_IO4 | PC9 | x | | x | | x | | x | | x | | x | |
| G5 | TSC_G5_IO1 | PE10 | x | 3 | x | 3 | x | 3 | - | 0 | - | 0 | - | 0 |
| | TSC_G5_IO2 | PE11 | x | | x | | x | | - | | - | | - | |
| | TSC_G5_IO3 | PE12 | x | | x | | x | | - | | - | | - | |
| | TSC_G5_IO4 | PE13 | x | | x | | x | | - | | - | | - | |
| G6 | TSC_G6_IO1 | PD10 | x | 3 | x | 3 | x | 3 | - | 0 | - | 0 | - | 0 |
| | TSC_G6_IO2 | PD11 | x | | x | | x | | - | | - | | - | |
| | TSC_G6_IO3 | PD12 | x | | x | | x | | - | | - | | - | |
| | TSC_G6_IO4 | PD13 | x | | x | | x | | - | | - | | - | |

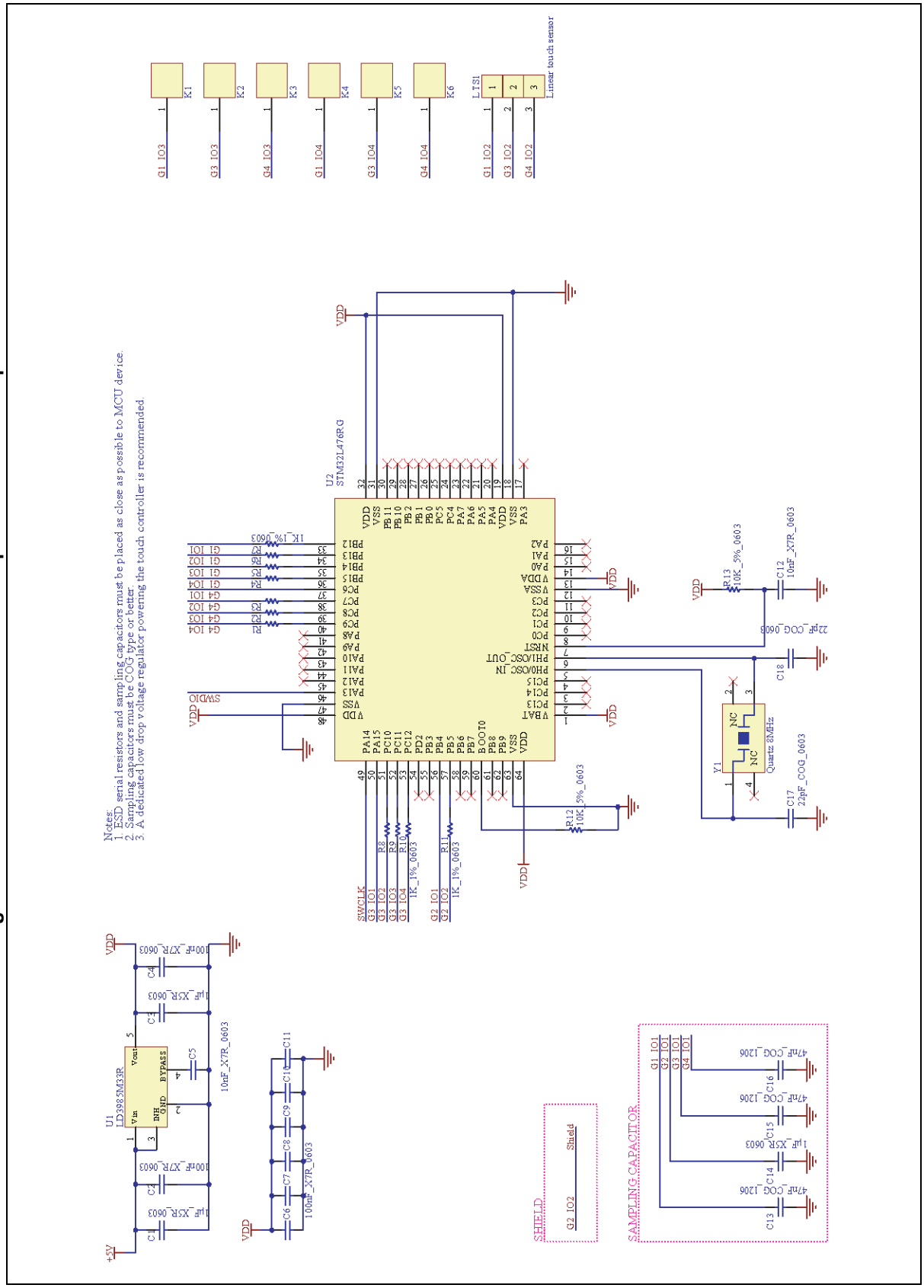
**Table 63. Available touch sensing channels for STM32L476xx (continued)**

| Analog I/O group | Capacitive sensing signal name | Pin name | STM32L476Zx | | STM32L476Qx | | STM32L476Vx | | STM32L476Mx | | STM32L476Jx | | STM32L476Rx | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | LQFP144 | | UFBGA132 | | LQFP100 | | WLCSP81 | | WLCSP72 | | LQFP64 | |
| G7 | TSC_G7_IO1 | PE2 | x | 3 | x | 3 | x | 3 | - | 0 | - | 0 | - | 0 |
| | TSC_G7_IO2 | PE3 | x | | x | | x | | - | | - | | - | |
| | TSC_G7_IO3 | PE4 | x | | x | | x | | - | | - | | - | |
| | TSC_G7_IO4 | PE5 | x | | x | | x | | - | | - | | - | |
| G8 | TSC_G8_IO1 | PF14 | x | 3 | x | 3 | - | 0 | - | 0 | - | 0 | - | 0 |
| | TSC_G8_IO2 | PF15 | x | | x | | - | | - | | - | | - | |
| | TSC_G8_IO3 | PG0 | x | | x | | - | | - | | - | | - | |
| | TSC_G8_IO4 | PG1 | x | | x | | - | | - | | - | | - | |
| Number of capacitive sensing channels (sampling I/Os not counted) | | | 24 | | 24 | | 21 | | 12 | | 12 | | 12 | |

### 3.8.3 Hardware implementation example

*Figure 20* shows an example of hardware implementation on STM32L4 Series microcontrollers.

Figure 20. STM32L4 Series hardware implementation example



# 4 STM32L1 Series microcontrollers

These microcontrollers support two different acquisition modes: hardware and software.

## 4.1 Acquisition

The STM32L1 Series microcontrollers **hardware acquisition mode** (using two timers) is done in the files:

- tsl_acq_stm32l1xx_hw.c
- tsl_acq_stm32l1xx_hw.h

---

**Warning:** **This acquisition mode is only available for the STM32L1 Series microcontrollers featuring a minimum of 384 K of Flash.**

---

The STM32L1 Series microcontrollers **software acquisition mode** is done in the files:

- tsl_acq_stm32l1xx_sw.c
- tsl_acq_stm32l1xx_sw.h

This acquisition is available for all STM32L1 Series microcontrollers.

*Note: The hardware acquisition mode is selected per default for the STM32L1 Series microcontrollers featuring a minimum of 384 K of Flash. If you want to use the software acquisition mode you must add the following constant in the toolchain compiler preprocessor:*

- TSLPRM_STM32L1XX_SW_ACQ

Functions used by the application layer and that are device dependent:

- TSL_acq_BankConfig()
- TSL_acq_BankStartAcq()
- TSL_acq_BankWaitEOC()
- TSL_acq_GetMeas()

The other functions in this file are for internal use and the user doesn't need to call them directly.

## 4.2 Timings

The timing management is done in the files:

- tsl_time.c
- tsl_time.h

The **Systick** is used to generate a timebase for the ECS and DTO modules. It must be initialized in the user code (already done by the HAL_init function).

## 4.3 Parameters

The parameters specific to the STM32L1 Series microcontrollers are described in the file:

- tsl_conf_stm32l1xx_template.h (to be copied in project and rename in **tsl_conf.h**)

and are checked in the file:

- tsl_check_config_stm32l1xx.h

## 4.4 Memory footprint

### Conditions

- IAR ANSI C/C++ compiler/linker V7.40.3.8902 for Arm®
- Compiler optimization: high size
- Counted files: tsl*.o
- STM32 TouchSensing library options: ECS=ON, DTO=ON, DXS=OFF, PROX=OFF
- Each sensor has its own parameters placed in RAM

The following tables summarize the memory footprint with different configurations

**Table 64. STM32L1 Series with hardware acquisition mode memory footprint(1)**

| Channels | Banks | Sensors | ROM (~ Kbyte) | RAM (~ byte) |
|---|---|---|---|---|
| 1 | 1 | 1 TKey | 5.3 | 340 |
| 2 | 1 | 2 TKeys | 5.3 | 360 |
| 2 | 2 | 2 TKeys | 5.5 | 360 |
| 24 | 3 | 24 TKeys | 6.2 | 870 |
| 3 | 1 | 1 Linear-3ch | 6.3 | 370 |
| 15 | 3 | 12 TKeys + 1 Linear-3ch | 8.3 | 660 |
| 24 | 3 | 18 TKeys + 2 Linear-3ch | 8.5 | 850 |

1. The content of this table is provided for information purposes only.

**Table 65. STM32L1 Series with software acquisition mode memory footprint(1)**

| Channels | Banks | Sensors | ROM (~ Kbyte) | RAM (~ byte) |
|---|---|---|---|---|
| 1 | 1 | 1 TKey | 5.5 | 410 |
| 2 | 1 | 2 TKeys | 5.5 | 430 |
| 2 | 2 | 2 TKeys | 5.5 | 430 |
| 24 | 3 | 24 TKeys | 6.2 | 930 |
| 3 | 1 | 1 Linear-3ch | 6.5 | 440 |

**Table 65. STM32L1 Series with software acquisition mode memory footprint(1)**

| Channels | Banks | Sensors | ROM (~ Kbyte) | RAM (~ byte) |
|---|---|---|---|---|
| 15 | 3 | 12 TKeys + 1 Linear-3ch | 8.2 | 730 |
| 24 | 3 | 18 TKeys + 2 Linear-3ch | 8.5 | 920 |

1. The content of this table is provided for information purposes only.

## 4.5 MCU resources

The tables below show the peripherals that are used by the STMTouch touch sensing library on STM32L1 Series microcontrollers. Care must be taken when using them to avoid any unwanted behavior.

**Table 66. MCU resources used on STM32L1 Series with hardware acquisition**

| Peripheral | Function |
|---|---|
| GPIOs | Acquisition |
| Systick | Time base for ECS and DTO |
| 2 Timers (TIM9, TIM11) | Acquisition |
| Routing interface | Acquisition |

**Table 67. MCU resources used on STM32L1 Series with software acquisition**

| Peripheral | Function |
|---|---|
| GPIOs | Acquisition |
| Systick | Time base for ECS and DTO |
| Routing interface | Acquisition |

## 4.6 Available touch sensing channels

The tables below provide an overview of the available touch sensing channels for the STM32L1 Series microcontrollers.

*Note: The following tables are not restrictive in term of part numbers supported by the STMTouch touch sensing library. The STMTouch touch sensing library can be used on any new device that may become available as part of ST microcontrollers portfolio. Please contact your ST representative for support.*

*Note: For n available pins in an I/O group, one pin is used as sampling capacitor and n-1 pins are used as channels. The I/O group cannot be used if the number of available pins in less or equal to one.*

**Table 68. Available touch sensing channels for STM32L1 Series 512K**

| Subfamily | | | STM32L1 Series 512K | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Packages | | | LQFP64 | | | LQFP100 / WLCSP104 | | | | UFBGA132 | | | LQFP144 | | | |
| Part numbers | | | STM32L151RE STM32L152RE STM32L162RE | | | STM32L151VE STM32L152VE STM32L162VE | | | | STM32L151QE STM32L152QE STM32L162QE | | | STM32L151ZE STM32L152ZE STM32L162ZE | | | |
| Analog I/O group | Gx_IOy | GPIO | LQFP pin | Number of available pins | Usage | LQFP Pin | WLCSP ball | Number of available pins | Usage | BGA ball | Number of available pins | Usage | LQFP pin | Number of available pins | Usage |
| Group 1 | G1_IO1 | PA0 | 14 | 4 | 3 channels with 1 sampling capacitor | 23 | K9 | 4 | 3 channels with 1 sampling capacitor | L2 | 4 | 3 channels with 1 sampling capacitor | 34 | 4 | 3 channels with 1 sampling capacitor |
| | G1_IO2 | PA1 | 15 | | | 24 | L9 | | | M2 | | | 35 | | |
| | G1_IO3 | PA2 | 16 | | | 25 | J8 | | | K3 | | | 36 | | |
| | G1_IO4 | PA3(1) | 17 | | | 26 | H7 | | | L3 | | | 37 | | |
| Group 2 | G2_IO1 | PA6 | 22 | 2 | 1 channel with 1 sampling capacitor | 31 | H6 | 2 | 1 channel with 1 sampling capacitor | L4 | 4(2) | 3 channels with 1 sampling capacitor | 42 | 4(2) | 3 channels with 1 sampling capacitor |
| | G2_IO2 | PA7 | 23 | | | 32 | K7 | | | J5 | | | 43 | | |
| | G2_IO3 | PF15 | - | | | - | - | | | J9 | | | 55 | | |
| | G2_IO4 | PG0 (3) | - | | | - | - | | | H9 | | | 56 | | |
| | G2_IO5 | PG1(3) | - | | | - | - | | | G9 | | | 57 | | |
| Group 3 | G3_IO1 | PB0(1) | 26 | 3 | 2 channels with 1 sampling capacitor | 35 | J6 | 3 | 2 channels with 1 sampling capacitor | M5 | 5 | 4 channels with 1 sampling capacitor | 46 | 5 | 4 channels with 1 sampling capacitor |
| | G3_IO2 | PB1 | 27 | | | 36 | K6 | | | M6 | | | 47 | | |
| | G3_IO3 | PB2 | 28 | | | 37 | M6 | | | L6 | | | 48 | | |
| | G3_IO4 | PF11 | - | | | - | - | | | K6 | | | 49 | | |
| | G3_IO5 | PF12 | - | | | - | - | | | J7 | | | 50 | | |

Table 68. Available touch sensing channels for STM32L1 Series 512K (continued)

| Subfamily | | | STM32L1 Series 512K | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Packages | | | LQFP64 | | | LQFP100 / WLCSP104 | | | | UFBGA132 | | | LQFP144 | | | |
| Part numbers | | | STM32L151RE STM32L152RE STM32L162RE | | | STM32L151VE STM32L152VE STM32L162VE | | | | STM32L151QE STM32L152QE STM32L162QE | | | STM32L151ZE STM32L152ZE STM32L162ZE | | | |
| Analog I/O group | Gx_IOy | GPIO | LQFP pin | Number of available pins | Usage | LQFP Pin | WLCSP ball | Number of available pins | Usage | BGA ball | Number of available pins | Usage | LQFP pin | Number of available pins | Usage | |
| Group 4 | G4_IO1 | PA8 | 41 | 3 | 2 channels with 1 sampling capacitor | 67 | F3 | 3 | 2 channels with 1 sampling capacitor | D11 | 3 | 2 channels with 1 sampling capacitor | 100 | 3 | 2 channels with 1 sampling capacitor | |
| | G4_IO2 | PA9 | 42 | | | 68 | F1 | | | D10 | | | 101 | | | |
| | G4_IO3 | PA10 | 43 | | | 69 | F2 | | | C12 | | | 102 | | | |
| Group 5 | G5_IO1 | PA13 | 46 | 3 | 2 channels with 1 sampling capacitor | 72 | E3 | 3 | 2 channels with 1 sampling capacitor | A11 | 3 | 2 channels with 1 sampling capacitor | 105 | 3 | 2 channels with 1 sampling capacitor | |
| | G5_IO2 | PA14 | 49 | | | 76 | D3 | | | A10 | | | 109 | | | |
| | G5_IO3 | PA15 | 50 | | | 77 | B1 | | | A9 | | | 110 | | | |
| Group 6 | G6_IO1 | PB4 | 56 | 4 | 3 channels with 1 sampling capacitor | 90 | A5 | 4 | 3 channels with 1 sampling capacitor | A7 | 4 | 3 channels with 1 sampling capacitor | 134 | 4 | 3 channels with 1 sampling capacitor | |
| | G6_IO2 | PB5 | 57 | | | 91 | A6 | | | C5 | | | 135 | | | |
| | G6_IO3 | PB6 | 58 | | | 92 | C5 | | | B5 | | | 136 | | | |
| | G6_IO4 | PB7 | 59 | | | 93 | C7 | | | B4 | | | 137 | | | |

Table 68. Available touch sensing channels for STM32L1 Series 512K (continued)

| Subfamily | | | STM32L1 Series 512K | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Packages | | | LQFP64 | | | LQFP100 / WLCSP104 | | | | UFBGA132 | | | LQFP144 | | |
| Part numbers | | | STM32L151RE STM32L152RE STM32L162RE | | | STM32L151VE STM32L152VE STM32L162VE | | | | STM32L151QE STM32L152QE STM32L162QE | | | STM32L151ZE STM32L152ZE STM32L162ZE | | |
| Analog I/O group | Gx_IOy | GPIO | LQFP pin | Number of available pins | Usage | LQFP Pin | WLCSP ball | Number of available pins | Usage | BGA ball | Number of available pins | Usage | LQFP pin | Number of available pins | Usage |
| Group 7 | G7_IO1 | PB12 | 33 | 4 | 3 channels with 1 sampling capacitor | 51 | J4 | 4 | 3 channels with 1 sampling capacitor | L12 | 5(2) | 4 channels with 1 sampling capacitor | 73 | 5(2) | 4 channels with 1 sampling capacitor |
| | G7_IO2 | PB13 | 34 | | | 52 | J3 | | | K12 | | | 74 | | |
| | G7_IO3 | PB14 | 35 | | | 53 | L1 | | | K11 | | | 75 | | |
| | G7_IO4 | PB15 | 36 | | | 54 | K2 | | | K10 | | | 76 | | |
| | G7_IO5 | PG2(3) | - | | | - | - | | | G10 | | | 87 | | |
| | G7_IO6 | PG3(3) | - | | | - | - | | | F9 | | | 88 | | |
| | G7_IO7 | PG4(3) | - | | | - | - | | | F10 | | | 89 | | |
| Group 8 | G8_IO1 | PC0 | 8 | 4 | 3 channels with 1 sampling capacitor | 15 | F6 | 4 | 3 channels with 1 sampling capacitor | H1 | 4 | 3 channels with 1 sampling capacitor | 26 | 4 | 3 channels with 1 sampling capacitor |
| | G8_IO2 | PC1 | 9 | | | 16 | H9 | | | J2 | | | 27 | | |
| | G8_IO3 | PC2 | 10 | | | 17 | G9 | | | J3 | | | 28 | | |
| | G8_IO4 | PC3 | 11 | | | 18 | G8 | | | K2 | | | 29 | | |
| Group 9 | G9_IO1 | PC4 | 24 | 2 | 1 channel with 1 sampling capacitor | 33 | L7 | 2 | 1 channel with 1 sampling capacitor | K5 | 4 | 3 channels with 1 sampling capacitor | 44 | 4 | 3 channels with 1 sampling capacitor |
| | G9_IO2 | PC5 | 25 | | | 34 | M7 | | | L5 | | | 45 | | |
| | G9_IO3 | PF13 | - | | | - | - | | | K7 | | | 53 | | |
| | G9_IO4 | PF14 | - | | | - | - | | | J8 | | | 54 | | |

**Table 68. Available touch sensing channels for STM32L1 Series 512K (continued)**

| Subfamily | | | STM32L1 Series 512K | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Packages | | | LQFP64 | | | LQFP100 / WLCSP104 | | | | UFBGA132 | | | LQFP144 | | |
| Part numbers | | | STM32L151RE STM32L152RE STM32L162RE | | | STM32L151VE STM32L152VE STM32L162VE | | | | STM32L151QE STM32L152QE STM32L162QE | | | STM32L151ZE STM32L152ZE STM32L162ZE | | |
| Analog I/O group | Gx_IOy | GPIO | LQFP pin | Number of available pins | Usage | LQFP Pin | WLCSP ball | Number of available pins | Usage | BGA ball | Number of available pins | Usage | LQFP pin | Number of available pins | Usage |
| Group 10 | G10_IO1 | PC6 | 37 | 4 | 3 channels with 1 sampling capacitor | 63 | H1 | 4 | 3 channels with 1 sampling capacitor | E12 | 4 | 3 channels with 1 sampling capacitor | 96 | 4 | 3 channels with 1 sampling capacitor |
| | G10_IO2 | PC7 | 38 | | | 64 | G1 | | | E11 | | | 97 | | |
| | G10_IO3 | PC8 | 39 | | | 65 | G2 | | | E10 | | | 98 | | |
| | G10_IO4 | PC9 | 40 | | | 66 | F4 | | | D12 | | | 99 | | |
| Group 11 | G11_IO1 | PF6 | - | 0 | Cannot be used for touch sensing | - | - | 0 | Cannot be used for touch sensing | G3 | 4 | 3 channels with 1 sampling capacitor | 18 | 5 | 4 channels with 1 sampling capacitor |
| | G11_IO2 | PF7 | - | | | - | - | | | G4 | | | 19 | | |
| | G11_IO3 | PF8 | - | | | - | - | | | H4 | | | 20 | | |
| | G11_IO4 | PF9 | - | | | - | - | | | J6 | | | 21 | | |
| | G11_IO5 | PF10 | - | | | - | - | | | - | | | 22 | | |
| Maximum number of channels | | | 23 channels with 10 sampling capacitors | | | 23 channels with 10 sampling capacitors | | | | 33 channels with 11 sampling capacitors | | | 34 channels with 11 sampling capacitors | | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.
2. Not all the pins are available simultaneously on this group.
3. This GPIO can only be configured as sampling capacitor I/O when using HW acquisition mode and as channel I/O when using SW acquisition mode.

**Table 69. Available touch sensing channels for STM32L1 Series 384K**

| Subfamily | | | STM32L1 Series 384K | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Packages | | | LQFP64 / WLCSP64 | | | | LQFP100 | | | UFBGA132 | | | LQFP144 | | |
| Part numbers | | | STM32L151RD<br>STM32L152RD<br>STM32L162RD | | | | STM32L151VD<br>STM32L152VD<br>STM32L162VD | | | STM32L151QD<br>STM32L152QD<br>STM32L162QD | | | STM32L151ZD<br>STM32L152ZD<br>STM32L162ZD | | |
| Analog I/O group | Gx_IOy | GPIO | LQFP pin | WLCSP ball | Number of available pins | Usage | LQFP Pin | Number of available pins | Usage | BGA ball | Number of available pins | Usage | LQFP pin | Number of available pins | Usage |
| Group 1 | G1_IO1 | PA0 | 14 | F6 | 4 | 3 channels with 1 sampling capacitor | 23 | 4 | 3 channels with 1 sampling capacitor | L2 | 4 | 3 channels with 1 sampling capacitor | 34 | 4 | 3 channels with 1 sampling capacitor |
| | G1_IO2 | PA1 | 15 | E6 | | | 24 | | | M2 | | | 35 | | |
| | G1_IO3 | PA2 | 16 | H8 | | | 25 | | | K3 | | | 36 | | |
| | G1_IO4 | PA3(1) | 17 | G7 | | | 26 | | | L3 | | | 37 | | |
| Group 2 | G2_IO1 | PA6 | 22 | G5 | 2 | 1 channel with 1 sampling capacitor | 31 | 2 | 1 channel with 1 sampling capacitor | L4 | 4(2) | 3 channels with 1 sampling capacitor | 42 | 4(2) | 3 channels with 1 sampling capacitor |
| | G2_IO2 | PA7 | 23 | G4 | | | 32 | | | J5 | | | 43 | | |
| | G2_IO3 | PF15 | - | - | | | - | | | J9 | | | 55 | | |
| | G2_IO4 | PG0(3) | - | - | | | - | | | H9 | | | 56 | | |
| | G2_IO5 | PG1(3) | - | - | | | - | | | G9 | | | 57 | | |
| Group 3 | G3_IO1 | PB0(1) | 26 | H4 | 3 | 2 channels with 1 sampling capacitor | 35 | 3 | 2 channels with 1 sampling capacitor | M5 | 5 | 4 channels with 1 sampling capacitor | 46 | 5 | 4 channels with 1 sampling capacitor |
| | G3_IO2 | PB1 | 27 | F4 | | | 36 | | | M6 | | | 47 | | |
| | G3_IO3 | PB2 | 28 | H3 | | | 37 | | | L6 | | | 48 | | |
| | G3_IO4 | PF11 | - | - | | | - | | | K6 | | | 49 | | |
| | G3_IO5 | PF12 | - | - | | | - | | | J7 | | | 50 | | |

Table 69. Available touch sensing channels for STM32L1 Series 384K (continued)

| Subfamily | | | STM32L1 Series 384K | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Packages | | | LQFP64 / WLCSP64 | | | | LQFP100 | | | UFBGA132 | | | LQFP144 | | |
| Part numbers | | | STM32L151RD STM32L152RD STM32L162RD | | | | STM32L151VD STM32L152VD STM32L162VD | | | STM32L151QD STM32L152QD STM32L162QD | | | STM32L151ZD STM32L152ZD STM32L162ZD | | |
| Analog I/O group | Gx_IOy | GPIO | LQFP pin | WLCSP ball | Number of available pins | Usage | LQFP Pin | Number of available pins | Usage | BGA ball | Number of available pins | Usage | LQFP pin | Number of available pins | Usage |
| Group 4 | G4_IO1 | PA8 | 41 | E4 | 3 | 2 channels with 1 sampling capacitor | 67 | 3 | 2 channels with 1 sampling capacitor | D11 | 3 | 2 channels with 1 sampling capacitor | 100 | 3 | 2 channels with 1 sampling capacitor |
| | G4_IO2 | PA9 | 42 | D2 | | | 68 | | | D10 | | | 101 | | |
| | G4_IO3 | PA10 | 43 | D3 | | | 69 | | | C12 | | | 102 | | |
| Group 5 | G5_IO1 | PA13 | 46 | D4 | 3 | 2 channels with 1 sampling capacitor | 72 | 3 | 2 channels with 1 sampling capacitor | A11 | 3 | 2 channels with 1 sampling capacitor | 105 | 3 | 2 channels with 1 sampling capacitor |
| | G5_IO2 | PA14 | 49 | B2 | | | 76 | | | A10 | | | 109 | | |
| | G5_IO3 | PA15 | 50 | C3 | | | 77 | | | A9 | | | 110 | | |
| Group 6 | G6_IO1 | PB4 | 56 | B4 | 4 | 3 channels with 1 sampling capacitor | 90 | 4 | 3 channels with 1 sampling capacitor | A7 | 4 | 3 channels with 1 sampling capacitor | 134 | 4 | 3 channels with 1 sampling capacitor |
| | G6_IO2 | PB5 | 57 | A5 | | | 91 | | | C5 | | | 135 | | |
| | G6_IO3 | PB6 | 58 | B5 | | | 92 | | | B5 | | | 136 | | |
| | G6_IO4 | PB7 | 59 | C5 | | | 93 | | | B4 | | | 137 | | |

Table 69. Available touch sensing channels for STM32L1 Series 384K (continued)

| Subfamily | | | STM32L1 Series 384K | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Packages | | | LQFP64 / WLCSP64 | | | | LQFP100 | | | UFBGA132 | | | LQFP144 | | | |
| Part numbers | | | STM32L151RD<br>STM32L152RD<br>STM32L162RD | | | | STM32L151VD<br>STM32L152VD<br>STM32L162VD | | | STM32L151QD<br>STM32L152QD<br>STM32L162QD | | | STM32L151ZD<br>STM32L152ZD<br>STM32L162ZD | | | |
| Analog I/O group | Gx_IOy | GPIO | LQFP pin | WLCSP ball | Number of available pins | Usage | LQFP Pin | Number of available pins | Usage | BGA ball | Number of available pins | Usage | LQFP pin | Number of available pins | Usage |
| Group 7 | G7_IO1 | PB12 | 33 | G2 | 4 | 3 channels with 1 sampling capacitor | 51 | 4 | 3 channels with 1 sampling capacitor | L12 | 5(2) | 4 channels with 1 sampling capacitor | 73 | 5(2) | 4 channels with 1 sampling capacitor |
| | G7_IO2 | PB13 | 34 | G1 | | | 52 | | | K12 | | | 74 | | |
| | G7_IO3 | PB14 | 35 | F2 | | | 53 | | | K11 | | | 75 | | |
| | G7_IO4 | PB15 | 36 | F1 | | | 54 | | | K10 | | | 76 | | |
| | G7_IO5 | PG2(3) | - | - | | | - | | | G10 | | | 87 | | |
| | G7_IO6 | PG3(3) | - | - | | | - | | | F9 | | | 88 | | |
| | G7_IO7 | PG4(3) | - | - | | | - | | | F10 | | | 89 | | |
| Group 8 | G8_IO1 | PC0 | 8 | E8 | 4 | 3 channels with 1 sampling capacitor | 15 | 4 | 3 channels with 1 sampling capacitor | H1 | 4 | 3 channels with 1 sampling capacitor | 26 | 4 | 3 channels with 1 sampling capacitor |
| | G8_IO2 | PC1 | 9 | F8 | | | 16 | | | J2 | | | 27 | | |
| | G8_IO3 | PC2 | 10 | D6 | | | 17 | | | J3 | | | 28 | | |
| | G8_IO4 | PC3(1) | 11 | F7 | | | 18 | | | K2 | | | 29 | | |
| Group 9 | G9_IO1 | PC4 | 24 | H6 | 2 | 1 channel with 1 sampling capacitor | 33 | 2 | 1 channel with 1 sampling capacitor | K5 | 4 | 3 channels with 1 sampling capacitor | 44 | 4 | 3 channels with 1 sampling capacitor |
| | G9_IO2 | PC5 | 25 | H5 | | | 34 | | | L5 | | | 45 | | |
| | G9_IO3 | PF13 | - | - | | | - | | | K7 | | | 53 | | |
| | G9_IO4 | PF14 | - | - | | | - | | | J8 | | | 54 | | |

**Table 69. Available touch sensing channels for STM32L1 Series 384K (continued)**

| Subfamily | | | STM32L1 Series 384K | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Packages | | | LQFP64 / WLCSP64 | | | | LQFP100 | | | UFBGA132 | | | LQFP144 | | |
| Part numbers | | | STM32L151RD STM32L152RD STM32L162RD | | | | STM32L151VD STM32L152VD STM32L162VD | | | STM32L151QD STM32L152QD STM32L162QD | | | STM32L151ZD STM32L152ZD STM32L162ZD | | |
| Analog I/O group | Gx_IOy | GPIO | LQFP pin | WLCSP ball | Number of available pins | Usage | LQFP Pin | Number of available pins | Usage | BGA ball | Number of available pins | Usage | LQFP pin | Number of available pins | Usage |
| Group 10 | G10_IO1 | PC6 | 37 | E1 | 4 | 3 channels with 1 sampling capacitor | 63 | 4 | 3 channels with 1 sampling capacitor | E12 | 4 | 3 channels with 1 sampling capacitor | 96 | 4 | 3 channels with 1 sampling capacitor |
| | G10_IO2 | PC7 | 38 | E2 | | | 64 | | | E11 | | | 97 | | |
| | G10_IO3 | PC8 | 39 | E3 | | | 65 | | | E10 | | | 98 | | |
| | G10_IO4 | PC9 | 40 | D1 | | | 66 | | | D12 | | | 99 | | |
| Group 11 | G11_IO1 | PF6 | - | - | 0 | Cannot be used for touch sensing | - | 0 | Cannot be used for touch sensing | G3 | 4 | 3 channels with 1 sampling capacitor | 18 | 5 | 4 channels with 1 sampling capacitor |
| | G11_IO2 | PF7 | - | - | | | - | | | G4 | | | 19 | | |
| | G11_IO3 | PF8 | - | - | | | - | | | H4 | | | 20 | | |
| | G11_IO4 | PF9 | - | - | | | - | | | J6 | | | 21 | | |
| | G11_IO5 | PF10 | - | - | | | - | | | - | | | 22 | | |
| Maximum number of channels | | | 23 channels with 10 sampling capacitors | | | | 23 channels with 10 sampling capacitors | | | 33 channels with 11 sampling capacitors | | | 34 channels with 11 sampling capacitors | | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.
2. Not all the pins are available simultaneously on this group.
3. This GPIO can only be configured as sampling capacitor I/O when using HW acquisition mode and as channel I/O when using SW acquisition mode.

**Table 70. Available touch sensing channels for STM32L1 Series 256K (table 1/2)**

| Subfamily | | | STM32L1 Series 256K | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Packages | | | LQFP48 or UFQFPN48 | | | WLCSP63 | | | LQFP64 / WLCSP64 | | | |
| Part numbers | | | STM32L152CC | | | STM32L151UC | | | STM32L151RC<br>STM32L152RC<br>STM32L162RC | | | |
| Analog I/O group | Gx_IOy | GPIO | Pin | Number of available pins | Usage | WLCSP ball | Number of available pins | Usage | LQFP pin | WLCSP ball | Number of available pins | Usage |
| Group 1 | G1_IO1 | PA0 | 10 | 4 | 3 channels with 1 sampling capacitor | E4 | 4 | 3 channels with 1 sampling capacitor | 14 | F6 | 4 | 3 channels with 1 sampling capacitor |
| | G1_IO2 | PA1 | 11 | | | G5 | | | 15 | E6 | | |
| | G1_IO3 | PA2 | 12 | | | H6 | | | 16 | H8 | | |
| | G1_IO4 | PA3(1) | 13 | | | J7 | | | 17 | G7 | | |
| Group 2 | G2_IO1 | PA6 | 16 | 2 | 1 channel with 1 sampling capacitor | G4 | 2 | 1 channel with 1 sampling capacitor | 22 | G5 | 2 | 1 channel with 1 sampling capacitor |
| | G2_IO2 | PA7 | 17 | | | J5 | | | 23 | G4 | | |
| | G2_IO3 | PF15 | - | | | - | | | - | - | | |
| | G2_IO4 | PG0(2) | - | | | - | | | - | - | | |
| | G2_IO5 | PG1(2) | - | | | - | | | - | - | | |
| Group 3 | G3_IO1 | PB0(1) | 18 | 3 | 2 channels with 1 sampling capacitor | J3 | 3 | 2 channels with 1 sampling capacitor | 26 | H4 | 3 | 2 channels with 1 sampling capacitor |
| | G3_IO2 | PB1 | 19 | | | H3 | | | 27 | F4 | | |
| | G3_IO3 | PB2 | 20 | | | G3 | | | 28 | H3 | | |
| | G3_IO4 | PF11 | - | | | - | | | - | - | | |
| | G3_IO5 | PF12 | - | | | - | | | - | - | | |
| Group 4 | G4_IO1 | PA8 | 29 | 3 | 2 channels with 1 sampling capacitor | E3 | 3 | 2 channels with 1 sampling capacitor | 41 | E4 | 3 | 2 channels with 1 sampling capacitor |
| | G4_IO2 | PA9 | 30 | | | C1 | | | 42 | D2 | | |
| | G4_IO3 | PA10 | 31 | | | D2 | | | 43 | D3 | | |

Table 70. Available touch sensing channels for STM32L1 Series 256K (table 1/2) (continued)

| Subfamily | | | STM32L1 Series 256K | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Packages | | | LQFP48 or UFQFPN48 | | | WLCSP63 | | | LQFP64 / WLCSP64 | | | |
| Part numbers | | | STM32L152CC | | | STM32L151UC | | | STM32L151RC<br>STM32L152RC<br>STM32L162RC | | | |
| Analog I/O group | Gx_IOy | GPIO | Pin | Number of available pins | Usage | WLCSP ball | Number of available pins | Usage | LQFP pin | WLCSP ball | Number of available pins | Usage |
| Group 5 | G5_IO1 | PA13 | 34 | 3 | 2 channels with 1 sampling capacitor | C2 | 3 | 2 channels with 1 sampling capacitor | 46 | D4 | 3 | 2 channels with 1 sampling capacitor |
| | G5_IO2 | PA14 | 37 | | | C3 | | | 49 | B2 | | |
| | G5_IO3 | PA15 | 38 | | | A2 | | | 50 | C3 | | |
| Group 6 | G6_IO1 | PB4 | 40 | 4 | 3 channels with 1 sampling capacitor | D4 | 4 | 3 channels with 1 sampling capacitor | 56 | B4 | 4 | 3 channels with 1 sampling capacitor |
| | G6_IO2 | PB5 | 41 | | | A5 | | | 57 | A5 | | |
| | G6_IO3 | PB6 | 42 | | | B5 | | | 58 | B5 | | |
| | G6_IO4 | PB7 | 43 | | | C5 | | | 59 | C5 | | |
| Group 7 | G7_IO1 | PB12 | 25 | 4 | 3 channels with 1 sampling capacitor | G2 | 4 | 3 channels with 1 sampling capacitor | 33 | G2 | 4 | 3 channels with 1 sampling capacitor |
| | G7_IO2 | PB13 | 26 | | | G1 | | | 34 | G1 | | |
| | G7_IO3 | PB14 | 27 | | | F3 | | | 35 | F2 | | |
| | G7_IO4 | PB15 | 28 | | | F2 | | | 36 | F1 | | |
| | G7_IO5 | PG2(2) | - | | | - | | | - | - | | |
| | G7_IO6 | PG3(2) | - | | | - | | | - | - | | |
| | G7_IO7 | PG4(2) | - | | | - | | | - | - | | |

Table 70. Available touch sensing channels for STM32L1 Series 256K (table 1/2) (continued)

| Subfamily | | | STM32L1 Series 256K | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Packages | | | LQFP48 or UFQFPN48 | | | WLCSP63 | | | LQFP64 / WLCSP64 | | | |
| Part numbers | | | STM32L152CC | | | STM32L151UC | | | STM32L151RC<br>STM32L152RC<br>STM32L162RC | | | |
| Analog I/O group | Gx_IOy | GPIO | Pin | Number of available pins | Usage | WLCSP ball | Number of available pins | Usage | LQFP pin | WLCSP ball | Number of available pins | Usage |
| Group 8 | G8_IO1 | PC0 | - | 0 | Cannot be used for touch sensing | E6 | 4 | 3 channels with 1 sampling capacitor | 8 | E8 | 4 | 3 channels with 1 sampling capacitor |
| | G8_IO2 | PC1 | - | | | E5 | | | 9 | F8 | | |
| | G8_IO3 | PC2 | - | | | G7 | | | 10 | D6 | | |
| | G8_IO4 | PC3 | - | | | G6 | | | 11 | F7 | | |
| Group 9 | G9_IO1 | PC4 | - | 0 | | F4 | 2 | 1 channel with 1 sampling capacitor | 24 | H6 | 2 | 1 channel with 1 sampling capacitor |
| | G9_IO2 | PC5 | - | | | J4 | | | 25 | H5 | | |
| | G9_IO3 | PF13 | - | | | - | | | - | - | | |
| | G9_IO4 | PF14 | - | | | - | | | - | - | | |
| Group 10 | G10_IO1 | PC6 | - | 0 | | F1 | 4 | 3 channels with 1 sampling capacitor | 37 | E1 | 4 | 3 channels with 1 sampling capacitor |
| | G10_IO2 | PC7 | - | | | E1 | | | 38 | E2 | | |
| | G10_IO3 | PC8 | - | | | D1 | | | 39 | E3 | | |
| | G10_IO4 | PC9 | - | | | E2 | | | 40 | D1 | | |
| Group11 | G11_IO1 | PF6 | - | 0 | | - | 0 | Cannot be used for touch sensing | - | - | 0 | Cannot be used for touch sensing |
| | G11_IO2 | PF7 | - | | | - | | | - | - | | |
| | G11_IO3 | PF8 | - | | | - | | | - | - | | |
| | G11_IO4 | PF9 | - | | | - | | | - | - | | |
| | G11_IO5 | PF10 | - | | | - | | | - | - | | |

**Table 70. Available touch sensing channels for STM32L1 Series 256K (table 1/2) (continued)**

| Subfamily | | | STM32L1 Series 256K | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Packages | | | LQFP48 or UFQFPN48 | | | WLCSP63 | | | LQFP64 / WLCSP64 | | | |
| Part numbers | | | STM32L152CC | | | STM32L151UC | | | STM32L151RC<br>STM32L152RC<br>STM32L162RC | | | |
| Analog I/O group | Gx_IOy | GPIO | Pin | Number of available pins | Usage | WLCSP ball | Number of available pins | Usage | LQFP pin | WLCSP ball | Number of available pins | Usage |
| Maximum number of channels | | | 16 channels with 7 sampling capacitors | | | 23 channels with 10 sampling capacitors | | | 23 channels with 10 sampling capacitors | | | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.
2. This GPIO can only be configured as sampling capacitor I/O when using HW acquisition mode and as channel I/O when using SW acquisition mode.

**Table 71. Available touch sensing channels for STM32L1 Series 256K (table 2/2)**

| Subfamily | | | STM32L1 Series 256K | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Packages | | | LQFP100 / UFBGA100 | | | | UFBGA132 | | | LQFP144 | | |
| Part numbers | | | STM32L151VC<br>STM32L152VC<br>STM32L162VC | | | | STM32L151QC<br>STM32L152QC<br>STM32L162QC | | | STM32L151ZC<br>STM32L152ZC<br>STM32L162ZC | | |
| Analog I/O group | Gx_IOy | GPIO | LQFP pin | BGA ball | Number of available pins | Usage | BGA ball | Number of available pins | Usage | LQFP pin | Number of available pins | Usage |
| Group 1 | G1_IO1 | PA0 | 23 | L2 | 4 | 3 channels with 1 sampling capacitor | L2 | 4 | 3 channels with 1 sampling capacitor | 34 | 4 | 3 channels with 1 sampling capacitor |
| | G1_IO2 | PA1 | 24 | M2 | | | M2 | | | 35 | | |
| | G1_IO3 | PA2 | 25 | K3 | | | K3 | | | 36 | | |
| | G1_IO4 | PA3(1) | 26 | L3 | | | L3 | | | 37 | | |
| Group 2 | G2_IO1 | PA6 | 31 | L4 | 2 | 1 channel with 1 sampling capacitor | L4 | 4(2) | 3 channels with 1 sampling capacitor | 42 | 4(2) | 3 channels with 1 sampling capacitor |
| | G2_IO2 | PA7 | 32 | M4 | | | J5 | | | 43 | | |
| | G2_IO3 | PF15 | - | - | | | J9 | | | 55 | | |
| | G2_IO4 | PG0(3) | - | - | | | H9 | | | 56 | | |
| | G2_IO5 | PG1(3) | - | - | | | G9 | | | 57 | | |
| Group 3 | G3_IO1 | PB0(1) | 35 | M5 | 3 | 2 channels with 1 sampling capacitor | M5 | 5 | 4 channels with 1 sampling capacitor | 46 | 5 | 4 channels with 1 sampling capacitor |
| | G3_IO2 | PB1 | 36 | M6 | | | M6 | | | 47 | | |
| | G3_IO3 | PB2 | 37 | L6 | | | L6 | | | 48 | | |
| | G3_IO4 | PF11 | - | - | | | K6 | | | 49 | | |
| | G3_IO5 | PF12 | - | - | | | J7 | | | 50 | | |
| Group 4 | G4_IO1 | PA8 | 67 | D11 | 3 | 2 channels with 1 sampling capacitor | D11 | 3 | 2 channels with 1 sampling capacitor | 100 | 3 | 2 channels with 1 sampling capacitor |
| | G4_IO2 | PA9 | 68 | D10 | | | D10 | | | 101 | | |
| | G4_IO3 | PA10 | 69 | C12 | | | C12 | | | 102 | | |

Table 71. Available touch sensing channels for STM32L1 Series 256K (table 2/2) (continued)

| Subfamily | | | STM32L1 Series 256K | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Packages | | | LQFP100 / UFBGA100 | | | | UFBGA132 | | | LQFP144 | | |
| Part numbers | | | STM32L151VC STM32L152VC STM32L162VC | | | | STM32L151QC STM32L152QC STM32L162QC | | | STM32L151ZC STM32L152ZC STM32L162ZC | | |
| Analog I/O group | Gx_IOy | GPIO | LQFP pin | BGA ball | Number of available pins | Usage | BGA ball | Number of available pins | Usage | LQFP pin | Number of available pins | Usage |
| Group 5 | G5_IO1 | PA13 | 72 | A11 | 3 | 2 channels with 1 sampling capacitor | A11 | 3 | 2 channels with 1 sampling capacitor | 105 | 3 | 2 channels with 1 sampling capacitor |
| | G5_IO2 | PA14 | 76 | A10 | | | A10 | | | 109 | | |
| | G5_IO3 | PA15 | 77 | A9 | | | A9 | | | 110 | | |
| Group 6 | G6_IO1 | PB4 | 90 | A7 | 4 | 3 channels with 1 sampling capacitor | A7 | 4 | 3 channels with 1 sampling capacitor | 134 | 4 | 3 channels with 1 sampling capacitor |
| | G6_IO2 | PB5 | 91 | C5 | | | C5 | | | 135 | | |
| | G6_IO3 | PB6 | 92 | B5 | | | B5 | | | 136 | | |
| | G6_IO4 | PB7 | 93 | B4 | | | B4 | | | 137 | | |
| Group 7 | G7_IO1 | PB12 | 51 | L12 | 4 | 3 channels with 1 sampling capacitor | L12 | 5(2) | 4 channels with 1 sampling capacitor | 73 | 5(2) | 4 channels with 1 sampling capacitor |
| | G7_IO2 | PB13 | 52 | K12 | | | K12 | | | 74 | | |
| | G7_IO3 | PB14 | 53 | K11 | | | K11 | | | 75 | | |
| | G7_IO4 | PB15 | 54 | K10 | | | K10 | | | 76 | | |
| | G7_IO5 | PG2(3) | - | - | | | G10 | | | 87 | | |
| | G7_IO6 | PG3(3) | - | - | | | F9 | | | 88 | | |
| | G7_IO7 | PG4(3) | - | - | | | F10 | | | 89 | | |
| Group 8 | G8_IO1 | PC0 | 15 | H1 | 4 | 3 channels with 1 sampling capacitor | H1 | 4 | 3 channels with 1 sampling capacitor | 26 | 4 | 3 channels with 1 sampling capacitor |
| | G8_IO2 | PC1 | 16 | J2 | | | J2 | | | 27 | | |
| | G8_IO3 | PC2 | 17 | J3 | | | J3 | | | 28 | | |
| | G8_IO4 | PC3 | 18 | K2 | | | K2(3) | | | 29(3) | | |

**Table 71. Available touch sensing channels for STM32L1 Series 256K (table 2/2) (continued)**

| Subfamily | | | STM32L1 Series 256K | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Packages | | | LQFP100 / UFBGA100 | | | | UFBGA132 | | | LQFP144 | | |
| Part numbers | | | STM32L151VC<br>STM32L152VC<br>STM32L162VC | | | | STM32L151QC<br>STM32L152QC<br>STM32L162QC | | | STM32L151ZC<br>STM32L152ZC<br>STM32L162ZC | | |
| Analog I/O group | Gx_IOy | GPIO | LQFP pin | BGA ball | Number of available pins | Usage | BGA ball | Number of available pins | Usage | LQFP pin | Number of available pins | Usage |
| Group 9 | G9_IO1 | PC4 | 33 | K5 | 2 | 1 channel with 1 sampling capacitor | K5 | 4 | 3 channels with 1 sampling capacitor | 44 | 4 | 3 channels with 1 sampling capacitor |
| | G9_IO2 | PC5 | 34 | L5 | | | L5 | | | 45 | | |
| | G9_IO3 | PF13 | - | - | | | K7 | | | 53 | | |
| | G9_IO4 | PF14 | - | - | | | J8 | | | 54 | | |
| Group 10 | G10_IO1 | PC6 | 63 | E12 | 4 | 3 channels with 1 sampling capacitor | E12 | 4 | 3 channels with 1 sampling capacitor | 96 | 4 | 3 channels with 1 sampling capacitor |
| | G10_IO2 | PC7 | 64 | E11 | | | E11 | | | 97 | | |
| | G10_IO3 | PC8 | 65 | E10 | | | E10 | | | 98 | | |
| | G10_IO4 | PC9 | 66 | D12 | | | D12 | | | 99 | | |
| Group11 | G11_IO1 | PF6 | - | - | 0 | Cannot be used for touch sensing | G3 | 4 | 3 channels with 1 sampling capacitor | 18 | 5 | 4 channels with 1 sampling capacitor |
| | G11_IO2 | PF7 | - | - | | | G4 | | | 19 | | |
| | G11_IO3 | PF8 | - | - | | | H4 | | | 20 | | |
| | G11_IO4 | PF9 | - | - | | | J6 | | | 21 | | |
| | G11_IO5 | PF10 | - | - | | | - | | | 22 | | |
| Maximum number of channels | | | 23 channels with 10 sampling capacitors | | | | 33 channels with 11 sampling capacitors | | | 34 channels with 11 sampling capacitors | | |

1. This GPIO offers a reduced touch sensing sensitivity. It is thus recommended to use it as sampling capacitor I/O.
2. Not all the pins are available simultaneously on this group.
3. This GPIO can only be configured as sampling capacitor I/O when using HW acquisition mode and as channel I/O when using SW acquisition mode.

**Table 72. Available touch sensing channels for STM32L15x 32K to 128K**

| Subfamily | | | STM32L15x 32K to 128K | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Packages | | | LQFP48 / VFQFPN48 | | | LQFP64 / BGA64 | | | | LQFP100 / BGA100 | | | |
| Part numbers | | | STM32L151C6<br>STM32L151C8<br>STM32L151CB<br>STM32L152C6<br>STM32L152C8<br>STM32L152CB | | | STM32L151R6<br>STM32L151R8<br>STM32L151RB<br>STM32L152R6<br>STM32L152R8<br>STM32L152RB | | | | STM32L151V8<br>STM32L151VB<br>STM32L152V8<br>STM32L152VB | | | |
| Analog I/O group | Gx_IOy | GPIO | Pin | Number of available pins | Usage | LQFP pin | BGA ball | Number of available pins | Usage | LQFP pin | BGA ball | Number of available pins | Usage |
| Group 1 | G1_IO1 | PA0 | 10 | 4 | 3 channels with 1 sampling capacitor | 14 | G2 | 4 | 3 channels with 1 sampling capacitor | 23 | L2 | 4 | 3 channels with 1 sampling capacitor |
| | G1_IO2 | PA1 | 11 | | | 15 | H2 | | | 24 | M2 | | |
| | G1_IO3 | PA2 | 12 | | | 16 | F3 | | | 25 | K3 | | |
| | G1_IO4 | PA3 | 13 | | | 17 | G3 | | | 26 | L3 | | |
| Group 2 | G2_IO1 | PA6 | 16 | 2 | 1 channel with 1 sampling capacitor | 22 | G4 | 2 | 1 channel with 1 sampling capacitor | 31 | L4 | 2 | 1 channel with 1 sampling capacitor |
| | G2_IO2 | PA7 | 17 | | | 23 | H4 | | | 32 | M4 | | |
| Group 3 | G3_IO1 | PB0 | 18 | 2 | 1 channel with 1 sampling capacitor | 26 | F5 | 2 | 1 channel with 1 sampling capacitor | 35 | M5 | 2 | 1 channel with 1 sampling capacitor |
| | G3_IO2 | PB1 | 19 | | | 27 | G5 | | | 36 | M6 | | |
| Group 4 | G4_IO1 | PA8 | 29 | 3 | 2 channels with 1 sampling capacitor | 41 | D7 | 3 | 2 channels with 1 sampling capacitor | 67 | D11 | 3 | 2 channels with 1 sampling capacitor |
| | G4_IO2 | PA9 | 30 | | | 42 | C7 | | | 68 | D10 | | |
| | G4_IO3 | PA10 | 31 | | | 43 | C6 | | | 69 | C12 | | |
| Group 5 | G5_IO1 | PA13 | 34 | 3 | 2 channels with 1 sampling capacitor | 46 | A8 | 3 | 2 channels with 1 sampling capacitor | 72 | A11 | 3 | 2 channels with 1 sampling capacitor |
| | G5_IO2 | PA14 | 37 | | | 49 | A7 | | | 76 | A10 | | |
| | G5_IO3 | PA15 | 38 | | | 50 | A6 | | | 77 | A9 | | |

Table 72. Available touch sensing channels for STM32L15x 32K to 128K (continued)

| Subfamily | | | STM32L15x 32K to 128K | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Packages | | | LQFP48 / VFQFPN48 | | | LQFP64 / BGA64 | | | | LQFP100 / BGA100 | | | |
| Part numbers | | | STM32L151C6<br>STM32L151C8<br>STM32L151CB<br>STM32L152C6<br>STM32L152C8<br>STM32L152CB | | | STM32L151R6<br>STM32L151R8<br>STM32L151RB<br>STM32L152R6<br>STM32L152R8<br>STM32L152RB | | | | STM32L151V8<br>STM32L151VB<br>STM32L152V8<br>STM32L152VB | | | |
| Analog I/O group | Gx_IOy | GPIO | Pin | Number of available pins | Usage | LQFP pin | BGA ball | Number of available pins | Usage | LQFP pin | BGA ball | Number of available pins | Usage |
| Group 6 | G6_IO1 | PB4 | 40 | 2 | 1 channel with 1 sampling capacitor | 56 | A4 | 2 | 1 channel with 1 sampling capacitor | 90 | A7 | 2 | 1 channel with 1 sampling capacitor |
| | G6_IO2 | PB5 | 41 | | | 57 | C4 | | | 91 | C5 | | |
| Group 7 | G7_IO1 | PB12 | 25 | 4 | 3 channels with 1 sampling capacitor | 33 | H8 | 4 | 3 channels with 1 sampling capacitor | 51 | L12 | 4 | 3 channels with 1 sampling capacitor |
| | G7_IO2 | PB13 | 26 | | | 34 | G8 | | | 52 | K12 | | |
| | G7_IO3 | PB14 | 27 | | | 35 | F8 | | | 53 | K11 | | |
| | G7_IO4 | PB15 | 28 | | | 36 | F7 | | | 54 | K10 | | |

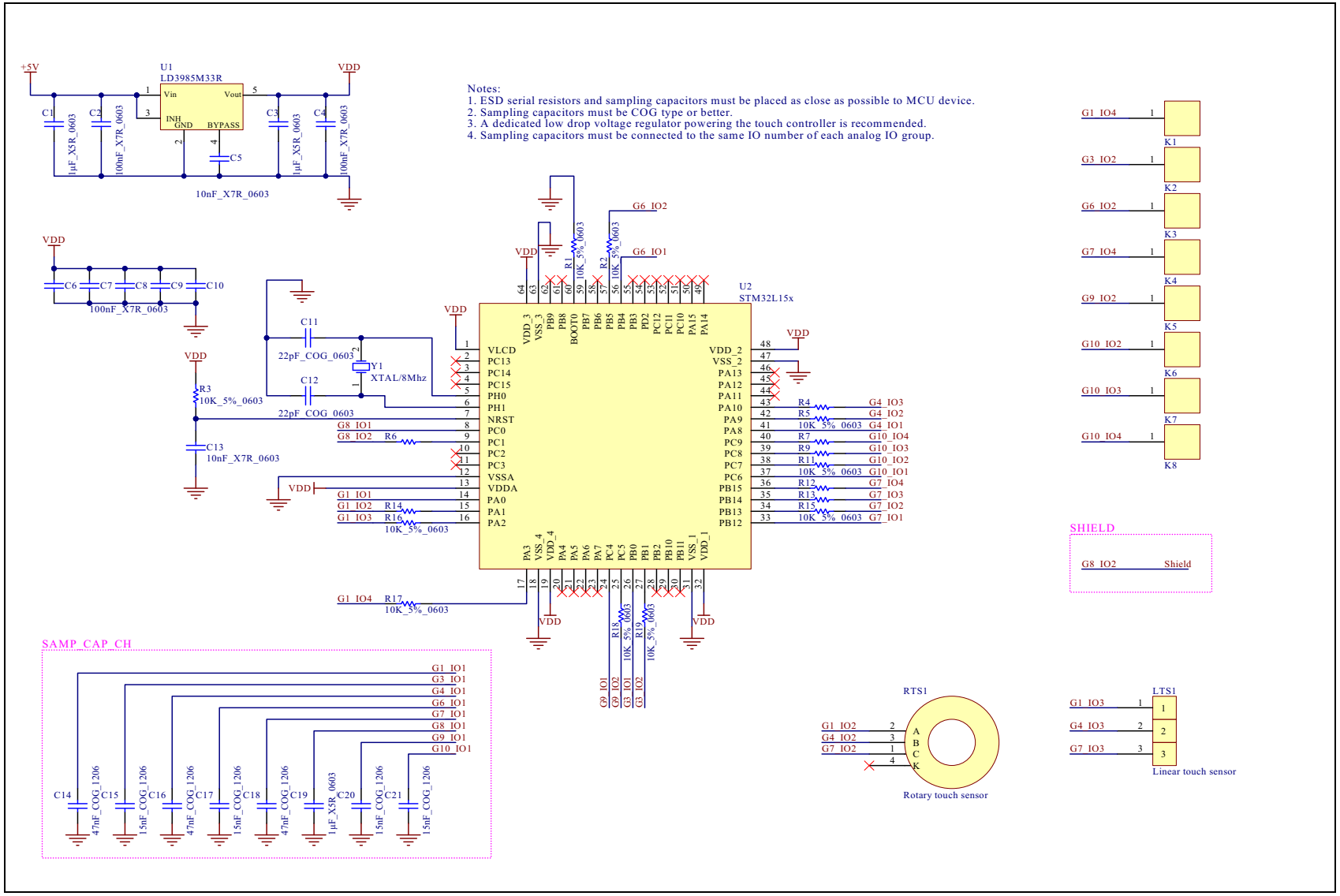
**Table 72. Available touch sensing channels for STM32L15x 32K to 128K (continued)**

| Subfamily | | | STM32L15x 32K to 128K | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Packages | | | LQFP48 / VFQFPN48 | | | LQFP64 / BGA64 | | | | LQFP100 / BGA100 | | | | |
| Part numbers | | | STM32L151C6<br>STM32L151C8<br>STM32L151CB<br>STM32L152C6<br>STM32L152C8<br>STM32L152CB | | | STM32L151R6<br>STM32L151R8<br>STM32L151RB<br>STM32L152R6<br>STM32L152R8<br>STM32L152RB | | | | STM32L151V8<br>STM32L151VB<br>STM32L152V8<br>STM32L152VB | | | | |
| Analog I/O group | Gx_IOy | GPIO | Pin | Number of available pins | Usage | LQFP pin | BGA ball | Number of available pins | Usage | LQFP pin | BGA ball | Number of available pins | Usage | |
| Group 8 | G8_IO1 | PC0 | - | 0 | Cannot be used for touch sensing | 8 | E3 | 4/3 | 3/2 channels with 1 sampling capacitor | 15 | H1 | 4 | 3 channels with 1 sampling capacitor | |
| | G8_IO2 | PC1 | - | | | 9 | E2 | | | 16 | J2 | | | |
| | G8_IO3 | PC2 | - | | | 10 | F2 | | | 17 | J3 | | | |
| | G8_IO4 | PC3 | - | | | 11 | - | | | 18 | K2 | | | |
| Group 9 | G9_IO1 | PC4 | - | 0 | | 24 | H5 | 2 | 1 channel with 1 sampling capacitor | 33 | K5 | 2 | 1 channel with 1 sampling capacitor | |
| | G9_IO2 | PC5 | - | | | 25 | H6 | | | 34 | L5 | | | |
| Group 10 | G10_IO1 | PC6 | - | 0 | | 37 | F6 | 4 | 3 channels with 1 sampling capacitor | 63 | E12 | 4 | 3 channels with 1 sampling capacitor | |
| | G10_IO2 | PC7 | - | | | 38 | E7 | | | 64 | E11 | | | |
| | G10_IO3 | PC8 | - | | | 39 | E8 | | | 65 | E10 | | | |
| | G10_IO4 | PC9 | - | | | 40 | D8 | | | 66 | D12 | | | |
| Maximum number of channels | | | 13 channels with 7 sampling capacitors | | | 20/19 channels with 10 sampling capacitors | | | | 20 channels with 10 sampling capacitors | | | | |

## 4.7 Hardware implementation example

*Figure 21* shows an example of hardware implementation on STM32L1 Series microcontrollers.

## Figure 21. STM32L1 Series hardware implementation example



# 5 Getting started

## 5.1 Create your application

Start with an application example present in the STM32Cube package of the device you intend to use. Take an example that is close in term of number of channels/sensors with your target application. Copy and paste the example in the same parent folder and rename it according your target application. Then modify the files as described below.

The following sections describe the necessary steps to create a new application project.

### 5.1.1 Toolchain compiler preprocessor section

The device that you intend to use must be written in the **toolchain compiler preprocessor section** of your project.

These defines are the same as those used by the STM32Cube. Please see the stm<xxx>.h map file to have the list of the microcontrollers definition.

*Note: The hardware acquisition mode is selected per default for the STM32L1 Series microcontrollers with a minimum of 384 K of Flash. If you want to use the software acquisition mode you must add the following constant in the toolchain compiler preprocessor:*

- TSLPRM_STM32L1XX_SW_ACQ

### 5.1.2 The tsl_conf.h file

The **tsl_conf.h** file contains all the STMTouch touch sensing library parameters. The following edits must be done:

1. Change the number of channels, banks, sensors according your application.
2. Change the common parameters: thresholds, debounce, ECS, DTO, etc.
3. Change the parameters specific to the device.

### 5.1.3 The main file

The **main.c** and **main.h** files contain the application code itself (LEDs and LCD management, etc.) and the call to the STMTouch touch sensing library initialization and action functions.

### 5.1.4 The tsl_user file

The **tsl_user.c** and **tsl_user.h** files contain the STMTouch touch sensing library configuration (definition of channels, banks, sensors, etc.) and the STMTouch touch sensing library initialization (**TSL_user_Init**) and action (**TSL_user_Action**) functions.

Create the channels variables using the structures (**mandatory**):

- TSL_ChannelSrc_T
- TSL_ChannelDest_T
- TSL_ChannelData_T

Create the Banks variables using the structures (**mandatory**):

- TSL_Bank_T

Create the touchkeys variables using the structures (optional):

- TSL_TouchKeyData_T
- TSL_TouchKeyParam_T
- TSL_State_T
- TSL_TouchKeyMethods_T
- TSL_TouchKeyB_T
- TSL_TouchKey_T

Create the linear and rotary touch sensors variables using the structures (optional):

- TSL_LinRotData_T
- TSL_LinRotParam_T
- TSL_State_T
- TSL_LinRotMethods_T
- TSL_LinRotB_T
- TSL_LinRot_T

Create the generic sensors (objects) variables using the structures (**mandatory**):

- TSL_Object_T
- TSL_ObjectGroup_T

The **TSL_user_Init()** function contains the initialization of the STMTouch touch sensing library. Modify this function to take into account your bank array name and object groups names.

The **TSL_user_Exec()** function contains the main state machine. Modify it also if you have several object groups to process or to change the ECS period, etc.

## 5.2 Debug with STM Studio

The STM Studio software is very useful to observe variables of the STMTouch touch sensing library. Its powerful features allow a better understanding of how the sensors behave and to find the better parameters to apply.

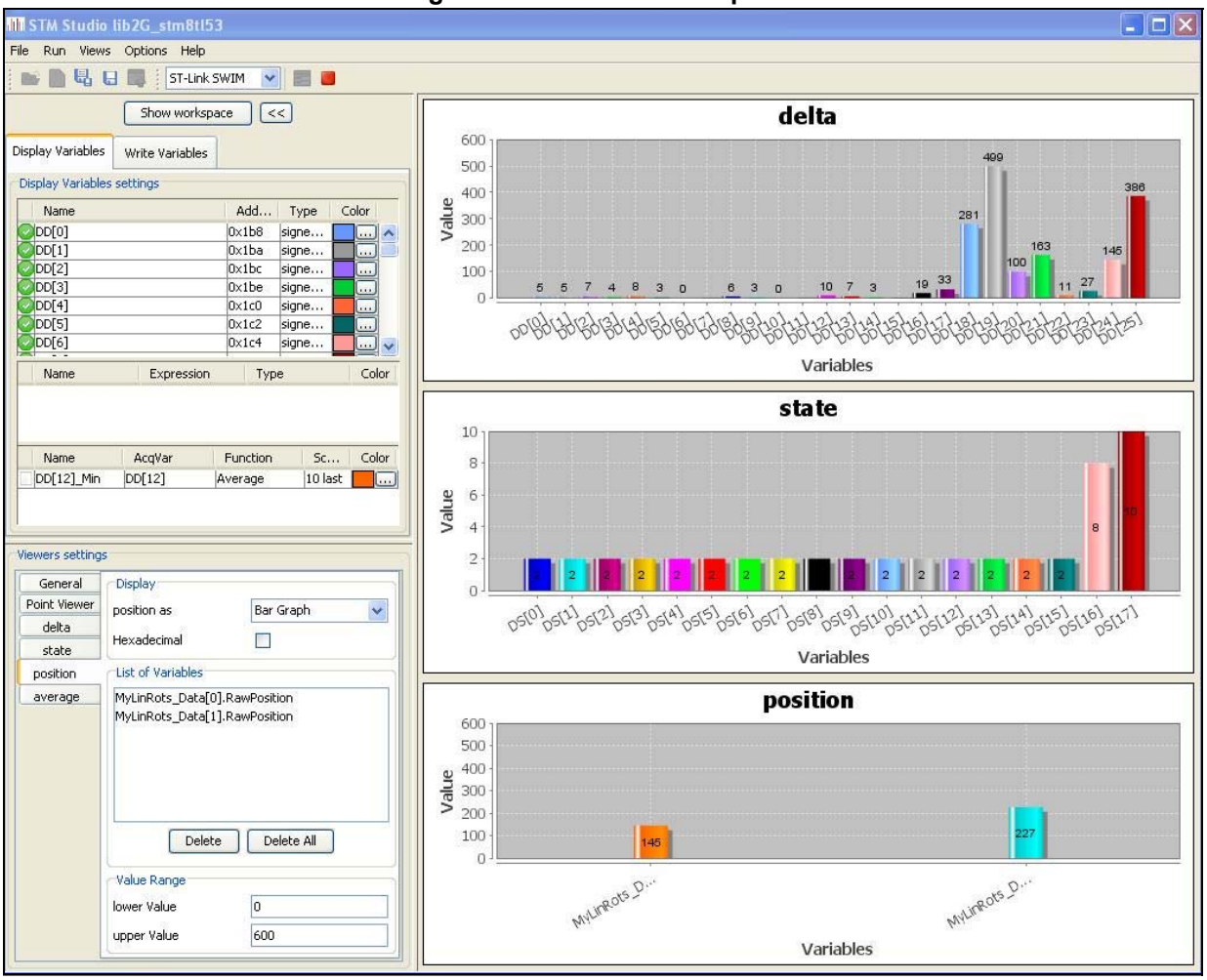
This section does not intend to explain how to use this tool, but give some advice to better understand and debug user's application.

This is a non-exhaustive list of the STMTouch touch sensing library variables to observe:

- The **channels measure**, **reference** and **delta**. These variables are present inside the **TSL_ChannelData_T** structure. This is useful to adjust the **thresholds** parameters.
- The **sensors state** present in the **TSL_TouchKeyData_T** and **TSL_LinRotData_T** structures. This is useful to adjust the **Debounce**, **ECS** and **DTO** parameters.
- The linear and rotary touch sensors **position** in the **TSL_LinRotData_T** structure.

The following snapshot is an example of data visualization on STM Studio:

**Figure 22. STM Studio snapshot**



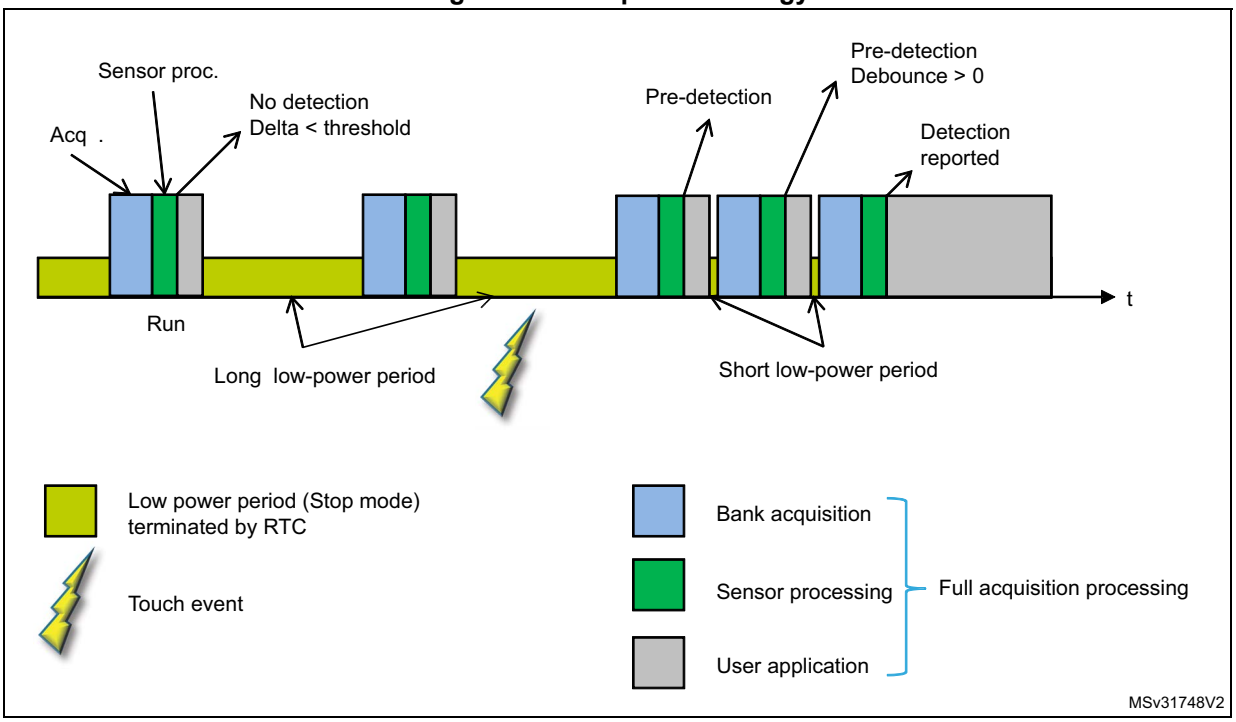

## 5.3 Low-power strategy

The following figure shows the acquisition sequencing for a single bank acquisition to optimize the power consumption of the device.

To reduce the power consumption, the acquisitions are sequenced with a long delay in between. During this delay, the MPU can be in low-power mode (i.e. Stop mode). This delay can be shortened or even removed between two consecutive acquisitions when the delta becomes greater than a detection threshold (proximity or touch). The long delay is restored if all the sensors return in RELEASE state.

For optimum power consumption, the acquisition must be performed with the MCU in Sleep or Low-power sleep mode and with the optimum TSC peripheral clock frequency (not too low or too high). The sensor processing must be performed at the highest possible frequency in order to minimize the processing duration. The user application processing must be done at the optimum CPU frequency to offer the best trend between task duration and power consumption.

Figure 23. Low-power strategy




This approach allows power consumption saving without increasing the response time. The maximum response time is obtained when a touch occurs during the sensor processing. It can be expressed as followed:

Max Response Time = long low-power period + (n) x short low-power period + (n+2) x full acquisition processing - bank acquisition

with n being the debounce value.

## 5.4 Tips and tricks

### 5.4.1 Recommendations to increase the noise immunity on the PCB

To ensure a correct operation in noisy environment, the floating nets must be avoided (tracks, copper elements, conductive frames, etc.).

As a consequence:

- All unused touch controller I/Os must be either configured to output push-pull low or externally tied to GND.
- The parameter TSLPRM_TSC_IODEF must also be configured to the output push-pull low state.
- We recommend to drive the sampling capacitor common node using a standard I/O of the touch controller configured in output push-pull low mode.
- It may also be required to add a capacitor-input filter (pi filter) on each channel line.

### 5.4.2 Bank definition

For optimum sensitivity and position reporting, all the channels composing a linear or a rotary touch sensor must be acquired **simultaneously**. This means that all the channels must belong to the **same bank**.

*Note: The library allows the definition of a linear or a rotary touch sensor with channels belonging to different banks. A such configuration induces a **loss of sensitivity** and a **higher noise level**. Moreover, depending on the acquisition time, it is also possible to observe a position change when removing the finger from the sensor.*

### 5.4.3 Channel assignment

It is recommended to assign GPIOs offering the same sensitivity level to all the channels composing a linear or a rotary touch sensor. Moreover, it is not recommended to use GPIOs offering a reduced sensitivity.

### 5.4.4 IO Default state parameter

For optimum acquisition noise level, it is recommended to set the **TSLPRM_TSC_IODEF**

or **TSLPRM_IODEF** parameter to **output push-pull low**.

However, if your application is using a linear or a rotary touch sensor with channels belonging to different banks, this parameter must be set to **input floating**. This ensures optimum sensitivity.

## 5.5 Related documents

[1] MISRA C 2004 Guidelines for the use of the C language in critical systems.

[2] *Design with surface sensors for touch sensing applications on MCUs* (AN4312)

[3] *Improve conducted noise robustness for touch sensing applications on STM32 MCUs* (AN4299)

[4] Tuning a touch sensing application on MCUs (AN4316)

# 6 Revision history

Table 73. Document revision history

| Date | Revision | Changes |
|---|---|---|
| 05-Jan-2016 | 1 | Initial release. |
| 29-Feb-2016 | 2 | Updated *Section 2.4.3: Acquisition and processing layers*.<br>Removed former *Section 2.7: Zone*. |
| 19-May-2016 | 3 | Updated document title.<br>Updated *Section : Introduction*.<br>Updated line TSC_G3_IO4 in *Table 41: Available touch sensing channels for STM32F334x4/x6/x8*. |
| 24-Nov-2016 | 4 | Updated *Section 5.5: Related documents*. |
| 26-Sep-2017 | 5 | Added STM32L083 and STM32L082 lines in *Section 3.7.2*.<br>Added STM32L496 and STM32L4A6 lines in *Section 3.8.2*. |
| 14-Mar-2018 | 6 | Updated *Section 2.9.4: Electrodes placement* including *Figure 8: Electrodes designs*, *Figure 9: Positions 0 and 255*, and *Table 3: Supported linear and rotary touch sensors*. |
| 26-Sep-2018 | 7 | Added *Section 2.18: Sensors acquisition timings* and *Section 2.19: Error management*.<br>Updated:<br>– *Section 2.12: Environment change system (ECS)*<br>– *Section 2.12.4: Usage example*<br>– *Section 5.1.4: The tsl_user file* |
| 23-Oct-2019 | 8 | Updated:<br>– *Introduction*<br>– *Section 2.1.1: Supported microcontrollers*<br>– *Section 2.18.3: Acquisition timing using touchkey, linear and rotary sensors* |