AN4038
Application note

Guidelines to optimize proximity detection with STM8TL5xxx capacitive sensors

Introduction

The STM8TL5xxx is a microcontroller group targeting touch sensing applications. It offers a high performance capacitive sensing engine which uses the projected Proxsense^{TM} acquisition principle. Outstanding STM8TL5xxx performances allow long range proximity detections. This is a key feature for many end-applications such as personal navigation devices (PNDs) or stove tops which are equipped with backlighting that switches on when a user is detected. Proximity detectors are also implemented in white goods, automotive devices, palm tops, and on any type of kitchen or office appliance where the display needs to be turned on to allow some parameters to be adjusted by the user.

One of the key features of capacitive sensors versus conventional proximity detectors (such as infrared light sensors), is the low power scheme, µA versus mA. Such a low power scheme is a fundamental characteristic of power sensitive applications.

The events described in this document exist in all capacitive sensing implementations. Because of the high sensitivity required by proximity detection, their impact seems amplified compared to touch sensors and therefore must be considered with great care.

Every application has specific proximity detection requirements. The design of the proximity sensing electrode is the result of the sensing requirements of the application and of a careful analysis of what the sensor environment can become in the lifetime of the application. The purpose of this application note is to provide designer guidelines on how to construct proximity electrodes.

The information provided in this application note is based on tests performed using an STM8TL53xx device, but the information extracted is common for the whole STM8TL5xxx product group (see *Table 1*). The absolute performance values, such as detection distance, depends on the environmental test: STM8TL5x sensitivity setting and approach speed.

Table 1. Applicable products

Type	Part numbers
Microcontrollers	STM8TL52F4, STM8TL52G4, STM8TL53C4, STM8TL53F4, STM8TL53G4

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1 Main factors influencing proximity sensitivity

To design a proximity sensor system using an STM8TL5xxx device, the following parameters must be considered:

STM8TL5xxx setting

- Whatever the sensor design of an application, the detection distance can be fine tuned thanks to the STM8TL5xxx sensitivity. Sensitivity is determined by three parameters: the sampling capacitance (C_S), the target reference, and the detection threshold. The C_S is a capacitor used to accumulate charge from the parasitic capacitor created by the sensor electrodes. The target reference is the gain and the detection threshold defines the detection trigger level. The higher the sensitivity is, the better the detection distance is, but the noise on the acquisition signal increases. When the noise increases, the threshold should be increased to filter the noise. However, this effectively decreases the sensitivity. A compromise must be defined between the detection range and the noise immunity.
- The approach speed is one of the constraints of a proximity application. STM8TL5xxx devices are able to compensate environmental change (temperature, V_{DD} variation) thanks to the environment control system (ECS) feature. The response time of the ECS should be in line with the desired approach speed. The lower the approach speed is, the slower the compensation is.

Electrode design

- The detection distance and detection area of a system are determined by the sensor design which is influenced by both the sensor size and shape. Generally, increasing the sensor size, increases the proximity detection distance. The electrode is built with two electrodes. The length, the width, and the spacing between the two electrodes are the three parameters that define the sensor and influence the detection distance.
- Coupling with ground strongly influences the sensitivity of the proximity sensor system. Ground plane or ground surrounding are not recommended. The nearer the ground is from the proximity sensor, the lower the sensitivity is. But, the surrounding ground can have a beneficial effect on the directivity. The directivity can be an important parameter and can be improved by the electrode shape and the surrounding ground. In addition, the mechanical environment around the sensor can significantly modify the detection area and distance.

Front panel

- Front panel materials and thickness modify the detection distance and the projected capacitance. The better the dielectric value is, the better the sensitivity of the sensors is.

Environmental variation

- Variation in the power supply level can disrupt the sensor measurement and cause unwanted proximity detection.
- Temperature and humidity variations modify the electrical field of the sensor and affect the proximity detection range.
- Designers with applications which are influenced by one of these parameters and which are susceptible to large variation should consider and evaluate the impact on the proximity sensing solution. The system should guarantee the stability of the detection to avoid any false detection.

Special care should be taken of the above factors to ensure stability of the systems. Excessive increase of a sensor's sensitivity can cause an unstable system and trigger unwanted proximity detection.

2 Test setup overview

All information provided in this application note is based on tests performed using different hardware boards.

2.1 Sensor performance measurements

The sensor performance measurements presented below were made using very basic sensors. These sensors were designed so that only one parameter was changed in each test series (length, width, clearance gap, etc). In this way, the influence of the 'control' parameter was clearly evaluated.

The sensors used for the tests are shown in *Figure 1*, *Figure 2*, *Figure 3*, and *Figure 4*. During testing, the sensors were connected to an STM8TL5xxx controller board: MCD10-016.

Figure 1. Sensor board - Tx/Rx electrode spacing test

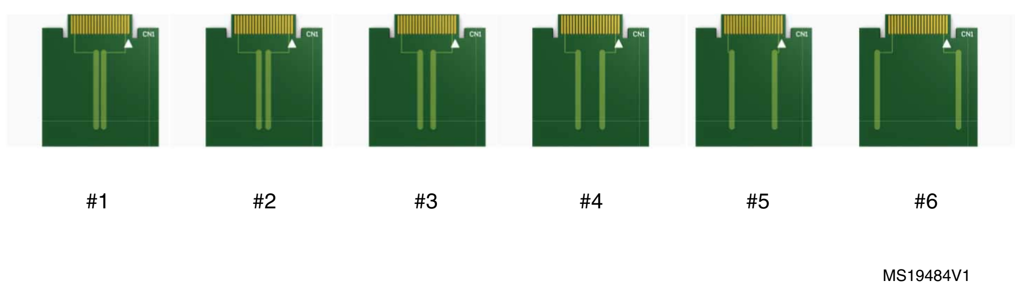


Figure 2. Sensor board - Tx/Rx electrode length test

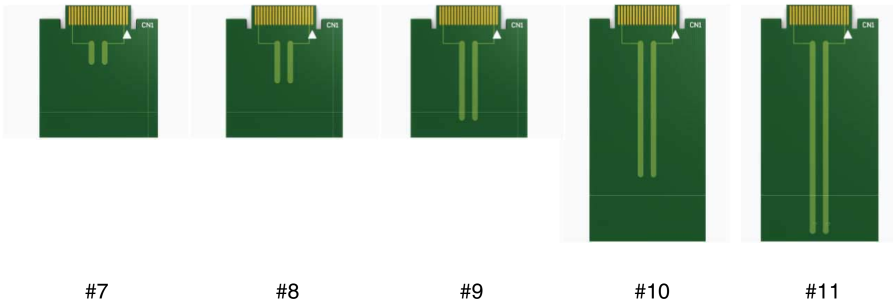


Figure 3. Sensor board - Tx/Rx electrode width test

Figure 4. Sensor board - Tx/Rx electrode ground surrounding test

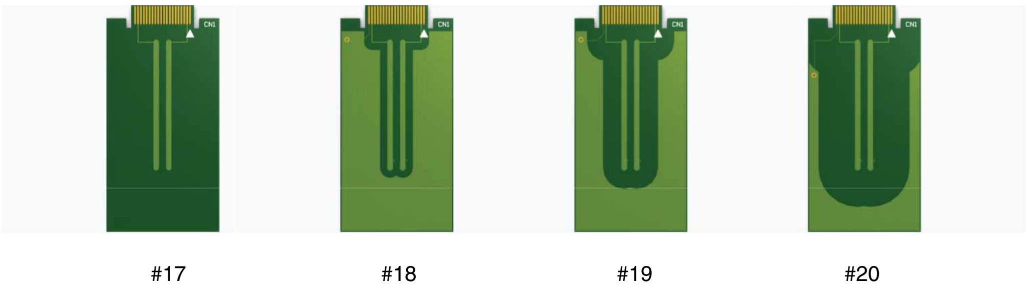


Table 2 summarizes the sensor board characteristics.

Table 2. Sensor board characteristics

Sensor board	Electrode spacing (mm)	Electrode length (mm)	Electrode width (mm)
#1	**0.5**	20	1.5
#2	**1**	20	1.5
#3	**2**	20	1.5
#4	**5**	20	1.5
#5	**10**	20	1.5
#6	**20**	20	1.5
#7	2	**5**	1.5
#8	2	**10**	1.5
#9	2	**20**	1.5
#10/#17/#18/ #19/#20	2	**35**	1.5
#11	2	**50**	1.5
#12	2	20	**0.21**
#13	2	20	**1**
#14	2	20	**1.5**
#15	2	20	**3**
#16	2	20	**5**

Table 3. Sensor board with ground surrounding characteristics

Sensor board	#17	#18	#19	#20
Surrounding distance (mm)	No ground surrounding	2	5	10

2.2 Test environment description

The detection distance measurements were performed automatically using a three-axes table. The table simulated the approach of a finger or hand and guaranteed high precision and repeatability of the measurement. The finger was simulated by a conductive pen (diameter 10 mm) and the hand with a copper plate (80 mm x 80 mm). The approach speed used for the detection distance was 60 mm/second.

The default parameters for measurements of the STM8TL5xxx were:

- C_S (sampling capacitor) = 0 (register value)
- Target reference value = 1000
- Threshold = 30

The front panel, which was used with all sensors, was made of acrylic material with a 1.5 mm thickness. It was glued to the sensor board with a 100 µm of pressure sensitive adhesive.

The noise graphs in this application note are expressed by the standard deviation. The standard deviation (see *Equation 1*) is used to measure the dispersion or variability that exists from the mean (average) value.

Equation 1: Standard deviation

$$\sigma = \sqrt{\sum_{i=0}^{n-1} \frac{(X_i - \bar{X})^2}{n-1}}$$

Where $\bar{X}$ is the mean of the sampled values. The standard deviation was calculated using 5000 samples.

The firmware test developed for the detection distance measurements is based on the STM8TL5x_STMTouch_Lib_V0.1.0.

3 STM8TL5xxx sensitivity setting

STM8TL5xxx sensitivity can be configured and is defined by the following three parameters:

- C_S sampling capacitor(*Section 3.1*)
- Target reference (*Section 3.2*)
- Detection threshold (*Section 3.3*)

3.1 C_S capacitor

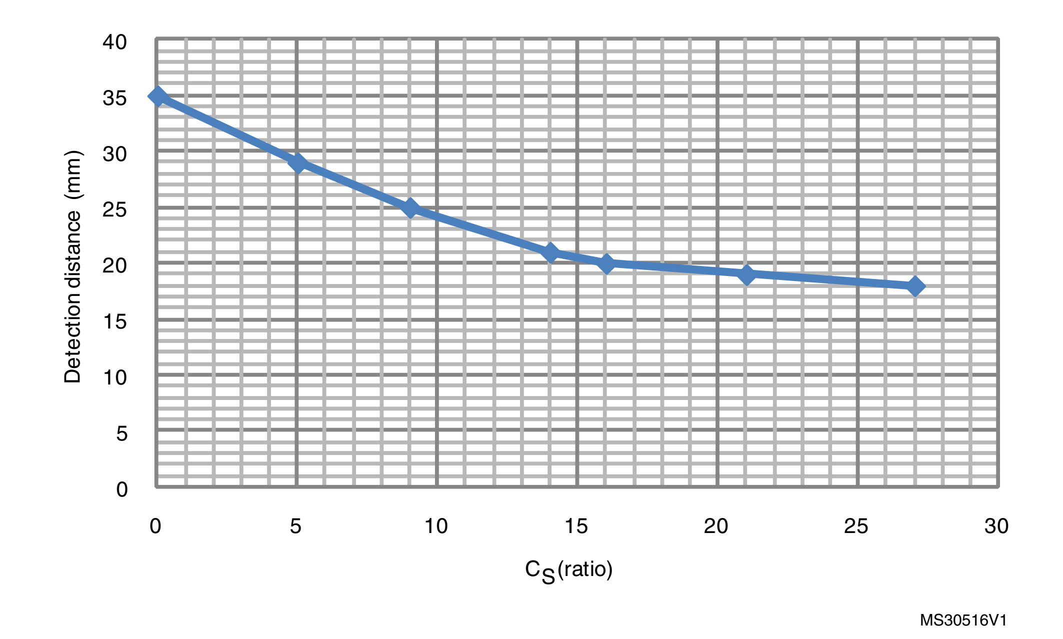
The C_S capacitor is used to accumulate charge from the capacitor created by the sensor. It is implemented on-chip. The C_S capacitor value is selected by choosing a ratio from a constant capacitor. *Table 4* shows the chosen ratios versus the C_S register values. The higher the ratio is, the higher the C_S capacitance is.

Table 4. C_S equivalent ratio

C_S	0	1	2	8	3	4	5	9	6	10	16	11	7	12	17	13	18	19	14	24	15	20	25	21	26	22	27	23	28	29	30	31
Ratio	2	3	4	5	6	7	9	9	12	12	14	15	16	21	21	27	28	35	36	36	48	49	54	63	72	84	90	112	126	162	216	288

The C_S capacitor value influences the detection distance and the noise on the measured signal with a fixed detection threshold. This influence is illustrated in *Figure 5*.

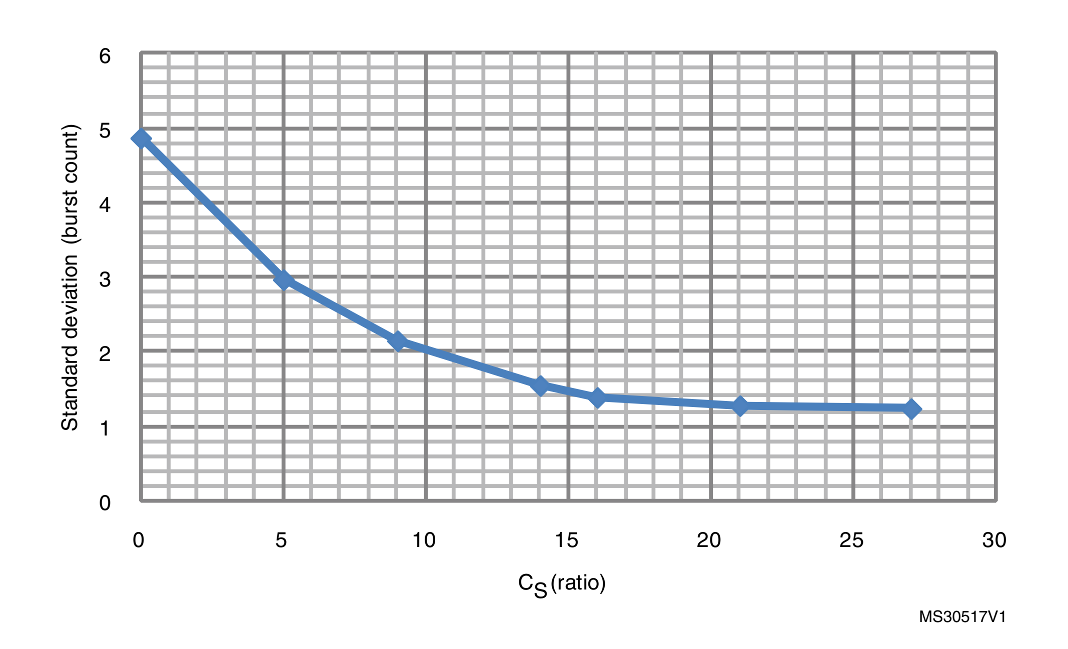
Figure 5. Detection distance versus C_S capacitor with fixed detection threshold



Note: The detection threshold value is fixed at 30 regardless of the target reference.

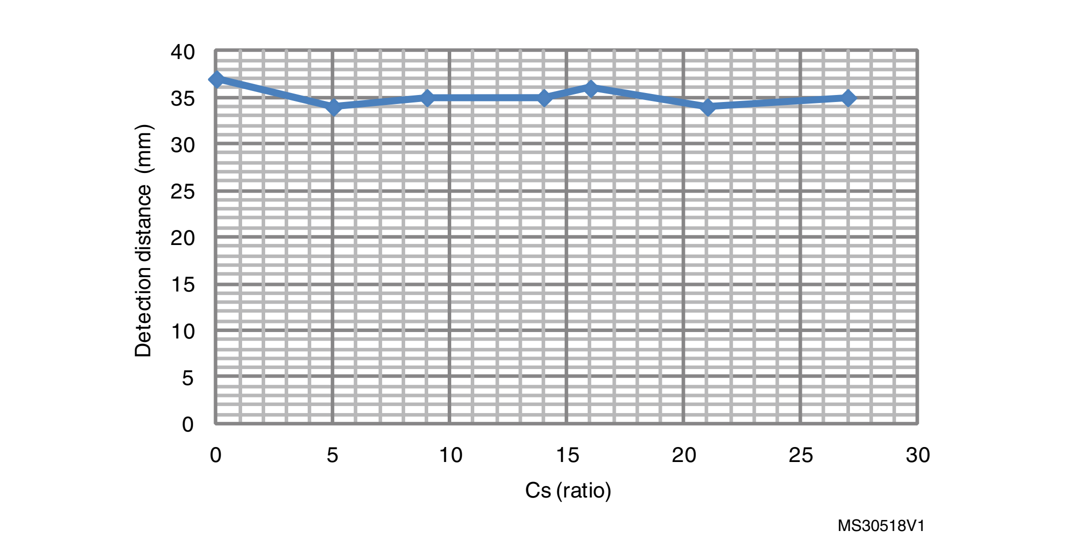
The higher the C_S capacitor is, the lower the detection distance is. However, as shown in *Figure 6*, the higher the C_S capacitor is, the lower the noise is.

Figure 6. Noise versus C_S capacitor



When the detection threshold (D_{th}) is adjusted regarding the noise level (see *Section 3.3: Detection threshold*), it is not influenced by the C_S capacitor value. *Figure 7* shows the detection distance versus the C_S capacitor with the best detection threshold value. This test was performed using sensor #10 (see *Figure 2*).

Figure 7. Detection distance versus C_S capacitor with best detection threshold

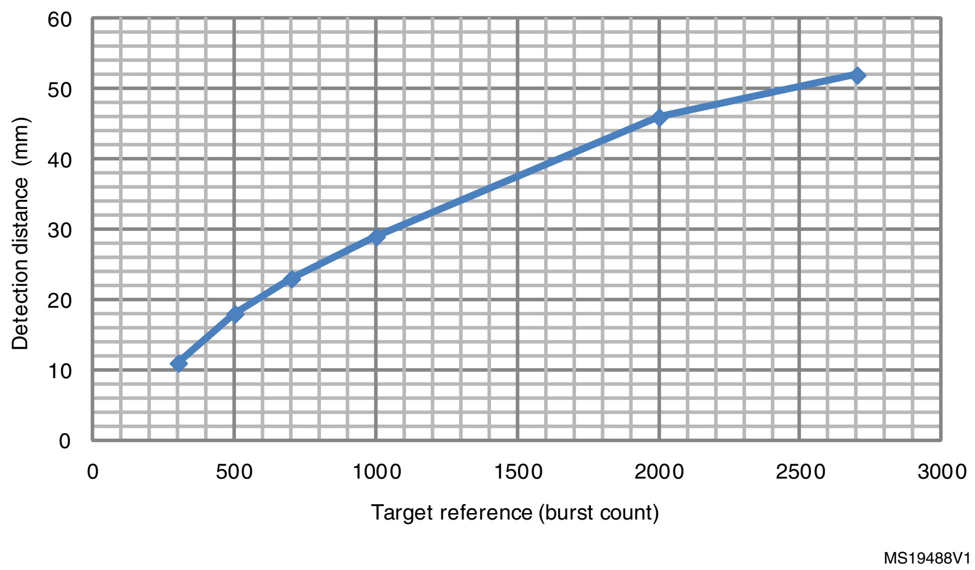


With an optimized detection threshold, the C_S value has no effect on the detection distance.

3.2 Target reference

The target reference determines the gain of the system. The influence of the target reference on the detection distance is illustrated in *Figure 8*. This test was performed with a fixed detection threshold value using sensor #10 (see *Figure 2*).

Figure 8. Detection distance versus target reference with fixed detection threshold

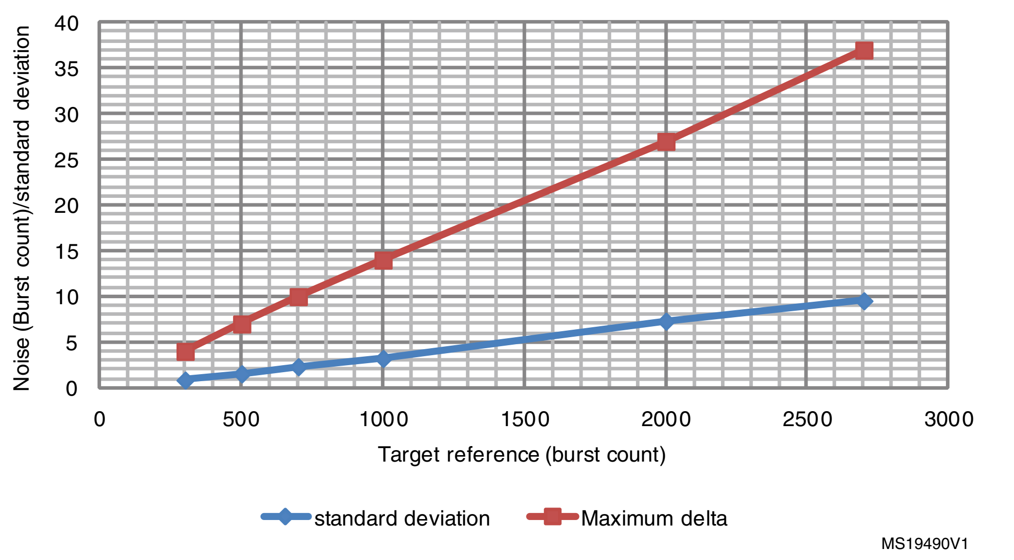


Note: The detection threshold value is fixed at 30 regardless of the target reference.

The higher the target reference is, the better the detection distance is. Increasing the target reference, also increases the acquisition time as more charge transfer cycles are required.

The choice of sensitivity directly influences noise on the acquisition signal. Noise increases when sensitivity increases. *Figure 9* shows the influence of the target reference on the noise standard deviation and on the maximum noise delta variation (signal - reference). This test was performed using sensor #10 (see *Figure 2*).

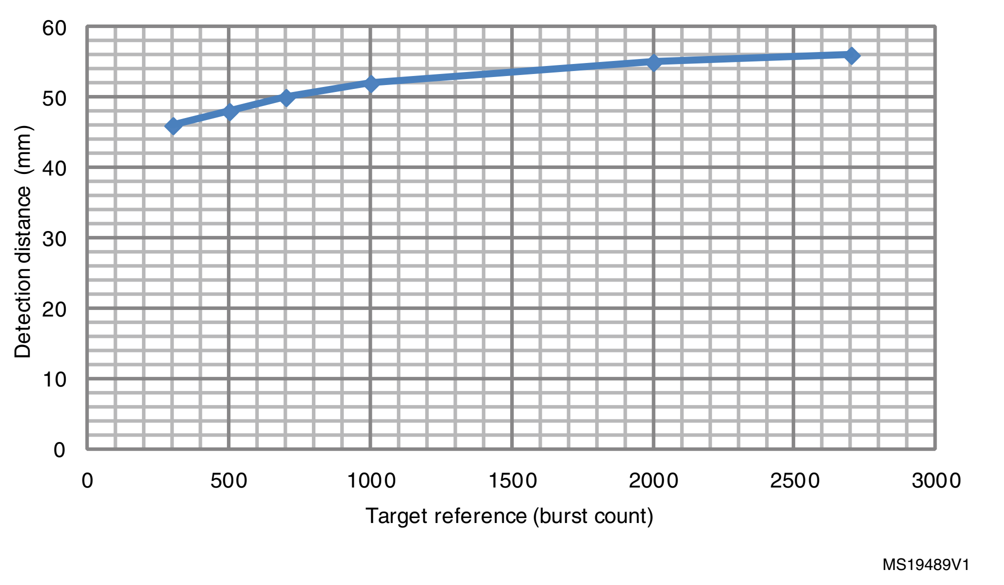
Figure 9. Noise versus target reference



To avoid any false proximity detection and to guarantee system stability, the detection threshold value (see *Section 3.3: Detection threshold*) must be set to filter out noise on the acquisition signal.

Figure 10 shows the test for detection distance versus the target reference with the best detection threshold value (see how to select the best threshold in *Section 3.3: Detection threshold*). This test was performed using sensor #10 (see *Figure 2*).

Figure 10. Detection distance versus target reference with best detection threshold



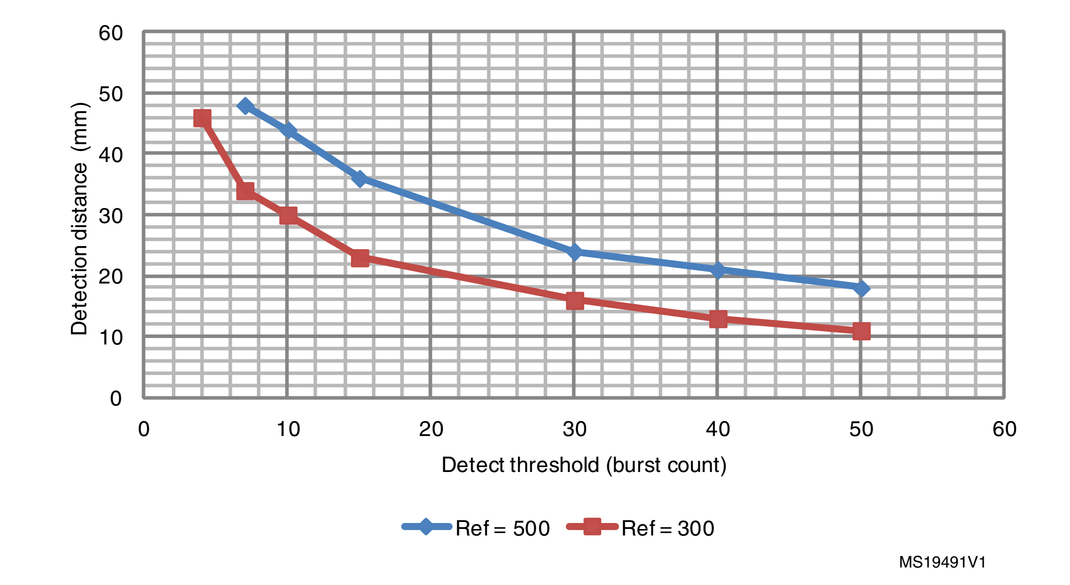
With an optimum detection threshold setup, the detection distance increases slowly when the target reference increases significantly.

3.3 Detection threshold

The detection threshold (D_{th}) is the minimum value between the reference and the current signal necessary to report a proximity detection. The D_{th} directly influences the detection distance of the system. The lower D_{th} is, the higher the detection distance is.

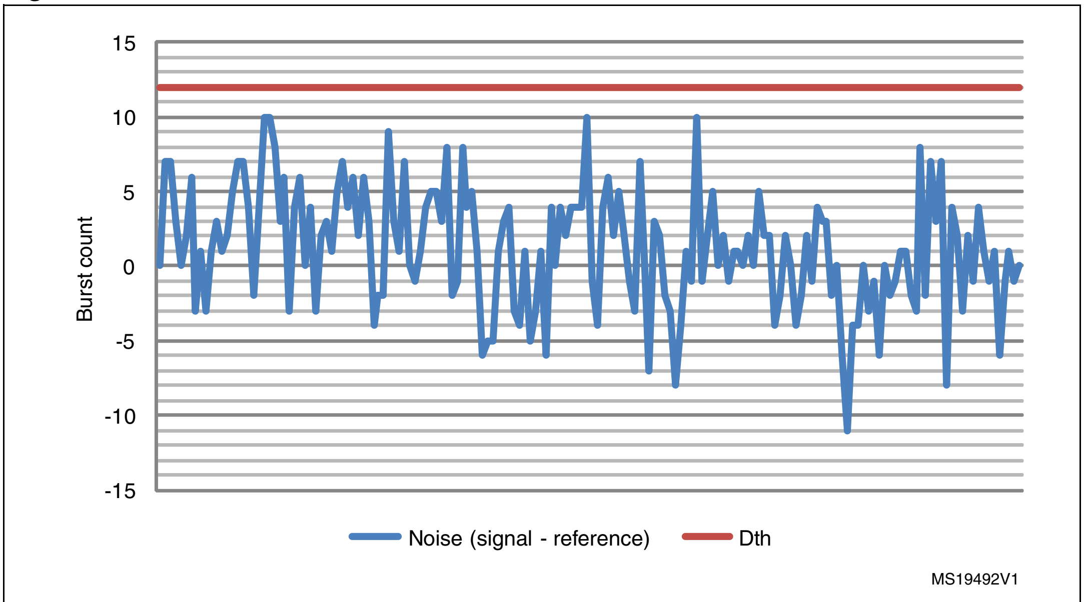
Figure 11 shows the detection distance versus the D_{th}. This test was performed using sensor #10 (see *Figure 2*).

Figure 11. Detection distance versus detection threshold



The D_{th} value should be set higher than the noise amplitude to filter environmental noise signals and to guarantee the stability of the system. *Figure 12* shows the D_{th} versus noise. This test was performed using sensor #10 (see *Figure 2*).

Figure 12. Detection threshold versus noise



The choice of the D_{th} is a compromise between the immunity of the system (to avoid false detection caused by environmental noise) and the application targeted detection distance. The best practice to define the D_{th} is to use the noise standard variation as shown in the following expression:

$$D_{th} > 4 * Noise_{std\_deviation}$$

Table 5 shows the maximum detection distances with the best detection threshold values. The best detection thresholds have been defined using the above expression with different target references. These measurements were performed using sensor #10 (see *Figure 2*).

Table 5. Best detection range versus target reference

Target reference (burst count)	Detection threshold (burst count)	Maximum detection distance (mm)	Noise standard deviation
2700	40	56	9,54
2000	30	55	7,31
1000	15	52	3,22
700	10	50	2,32
500	7	48	1,54
300	4	46	0,85

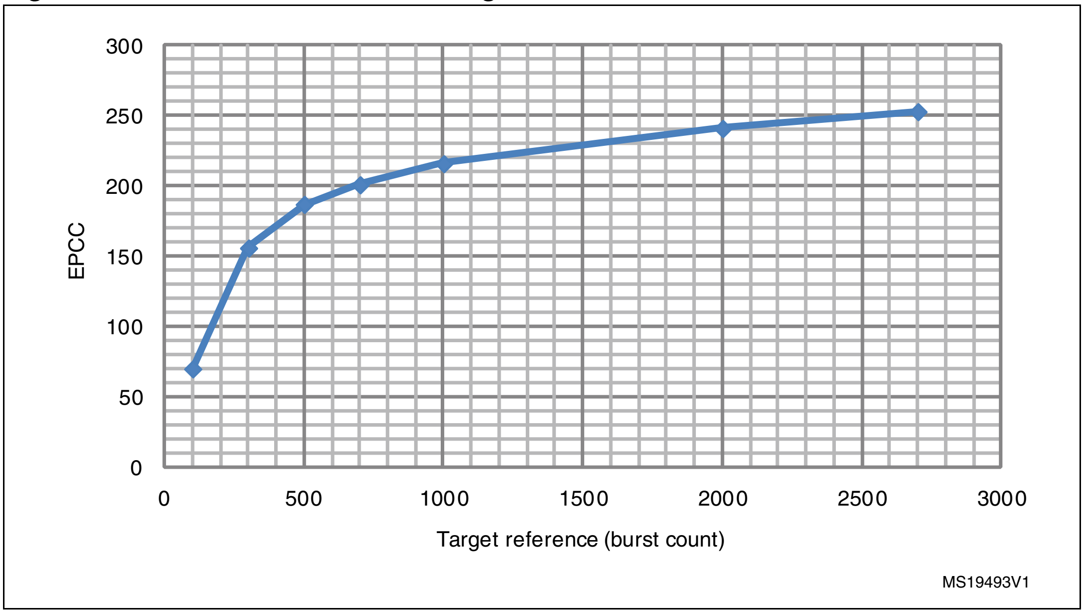
3.4 Electrode parasitic capacitance compensation (EPCC)

The EPCC compensates part of the projected capacitance to achieve the target reference value. The target reference is the gain defined by the ratio:

$$C_S / (C_X - C_{EPPC})$$

Figure 13 shows the EPCC variation versus the target reference. This test was performed using sensor #10 (see *Figure 2*).

Figure 13. EPCC variation versus target reference



At a fixed C_S capacitance, the higher the selected target reference value is, the higher the C_{EPPC} value is to compensate the C_X capacitance.

To guarantee optimum system performance, it is recommended to check that the EPCC value, after calibration, is in the range 20 < EPCC < 230. This ensures a sufficient operating margin to adapt the system to environmental or mechanical changes.

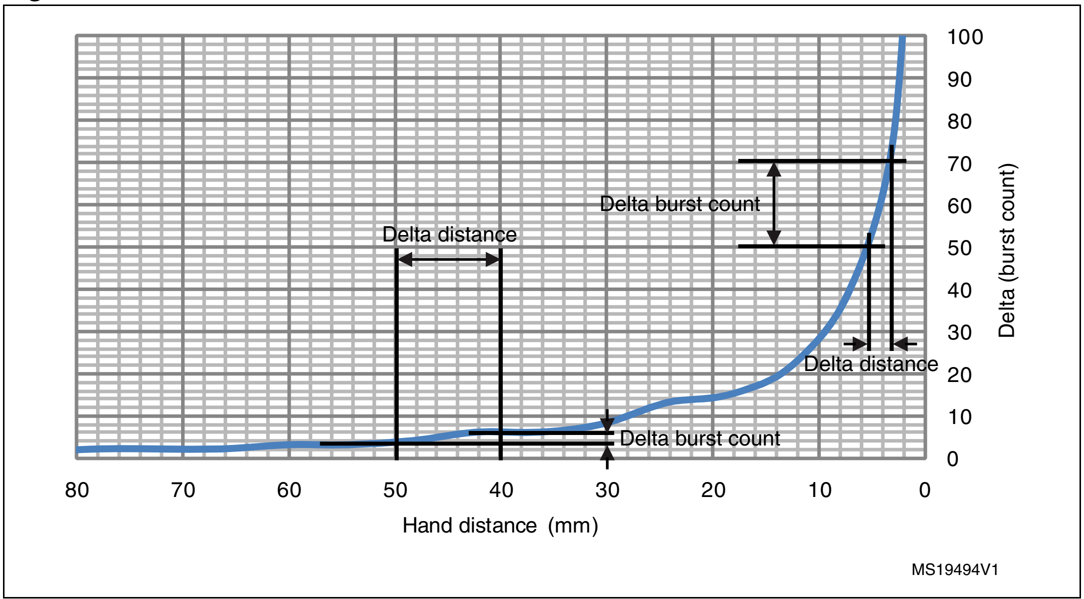
3.5 Approach speed and environmental change

The STM8TL5xxx can compensate environmental change thanks to the ECS (environment control system) feature. Power supply voltage, temperature, and air humidity variation may induce a slow variation of the acquisition signal.

The ECS mechanism forces the reference to follow slow evolutions of the signal. It is based on a infinite response digital low pass filter. The sampling frequency of the low pass filter is programmable. The low pass filter uses a coefficient ‘K’. The higher K is, the faster the response is.

Figure 14 shows the delta signal variation (current measurement - reference) versus distance between a hand and an electrode. This measurement was performed with electrode #10 (refer to *Figure 2*) with a target reference of 300 burst counts.

Figure 14. Delta burst count versus hand distance



A hand moving at a constant speed causes a higher delta variation (larger projected capacitance variation) nearer the sensor plate than when it is far from it.

Depending on the desired approach speed for the proximity system, the ECS can compensate part of the variation induced by the approach of a hand/finger. This occurs mainly when the hand/finger is far from the electrode and has entered the electrode field. In this case, the detection distance can be reduced by the ECS feature. In most applications, the default ECS K factor is fine, but for slow speed approach detection needs, the K factor can be increased to slow down the ECS.

4 Proximity sensor design

Each application has specific proximity detection requirements. The design of the sensing electrode is the result of the sensing requirements of the application and of a careful analysis of what the sensor environment is over the lifetime of the application. The sensor is built with two electrode plates. The two electrode plates create a projected capacitance.

The projected capacitance is defined in *Equation 2* and illustrated in *Figure 15*.

Equation 2:

$$C = (\varepsilon_d \times A) / d$$

where

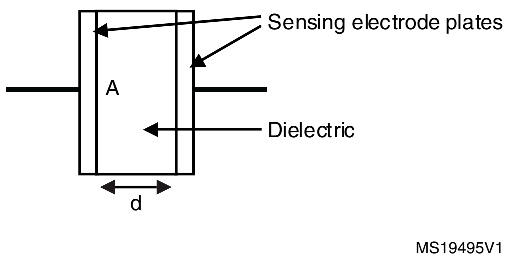
C = capacitance in farad (F)

ε_d = permittivity of the dielectric

A = cross sectional area of the sensing electrodes in square meters (m^2)

d = distance between sensing electrodes in meters (m)

Figure 15. Illustration of the theoretical projected capacitance equation



4.1 Tx/Rx electrode spacing influence

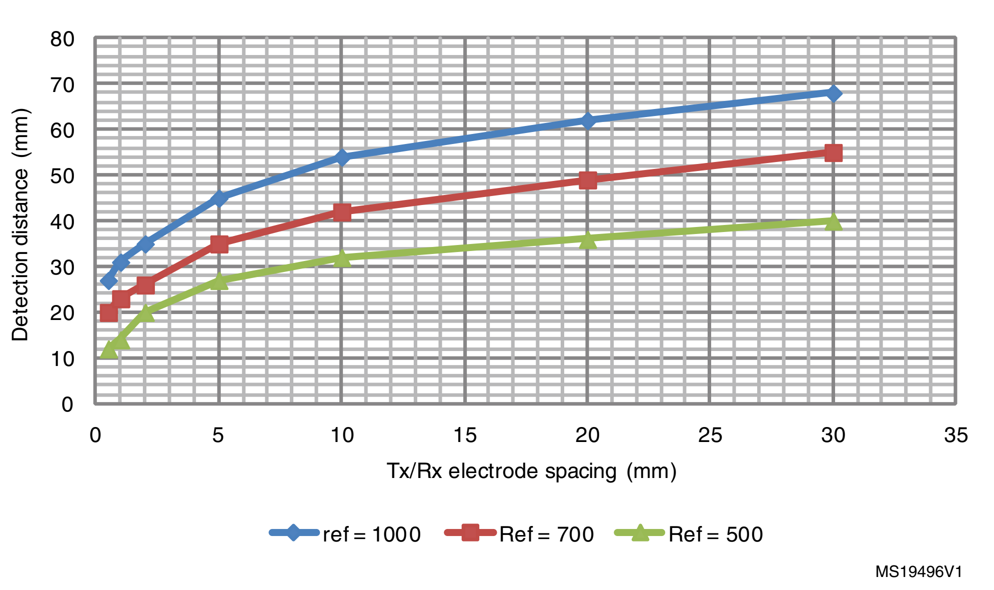
The spacing between the Tx/Rx plates significantly impacts the detection distance. The Tx/Rx electrode spacing also directly influences the projected capacitance and its area field.

Theoretically, increasing the spacing between the two electrodes influences the projected capacitance and causes two important effects:

- It increases the projected capacitance field area and decreases the projected capacitance value. In this case, the influence induced by the hand or finger on the projected capacitance value is higher. The sensitivity of the sensor is improved and consequently the detection distance and area is increased.
- It also increases the noise on the acquisition signal. The lower the projected capacitance is, the higher the noise is.

Figure 16 shows the influence of the electrode spacing on the detection distance.

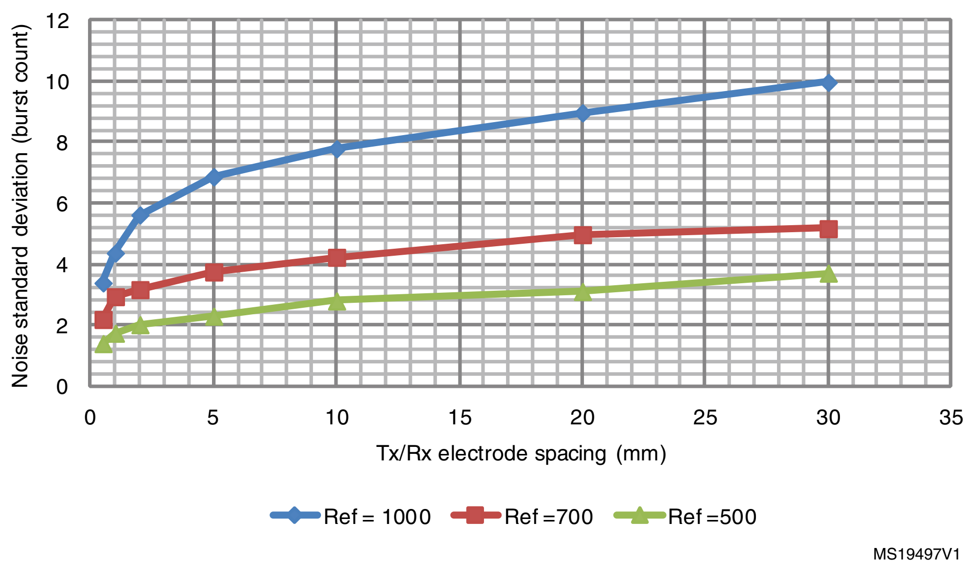
Figure 16. Detection distance versus Tx/Rx electrode spacing



The closer the Tx/Rx electrodes are, the lower the detection distance is, which occurs mainly when the electrodes spacing is < 2 mm.

Figure 17 shows the influence of the electrode spacing on the standard deviation of the noise.

Figure 17. Noise standard deviation versus Tx/Rx electrode spacing



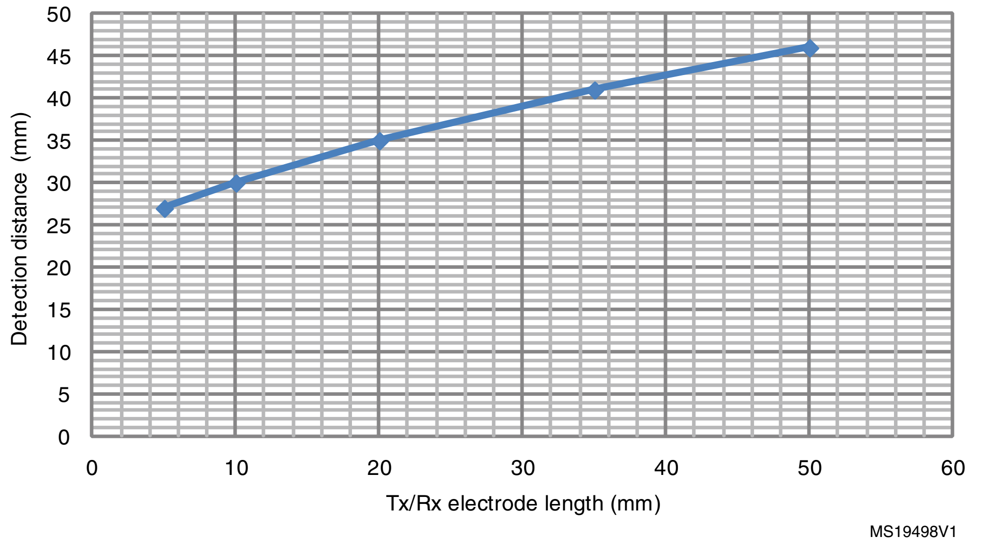
The noise is proportional to the sensitivity and with an electrode spacing greater than 2 mm, the noise increases slowly.

In conclusion, the largest electrode spacing increases sensitivity to the detriment of the noise. Increased noise requires that the detection threshold is adjusted to filter out noise and guarantee system stability. Therefore, a compromise is necessary between detection range and system noise immunity. If the Tx/Rx electrodes are too close, the detection distance is drastically decreased, especially when the spacing is less than 2 mm. Care should be taken not to space the electrodes too far apart as this can create a projected capacitance which is too small to be measured. In this case, the STM8TL5xxx cannot compensate with the EPCC to target the reference. The EPCC is out of the recommended range (see *Section 3.4: Electrode parasitic capacitance compensation (EPCC)* and can cause an unstable proximity system. To summarize, increasing the electrode spacing increases the detection area as long as the EPCC remains in the recommended range.

4.2 Tx/Rx electrode length influence

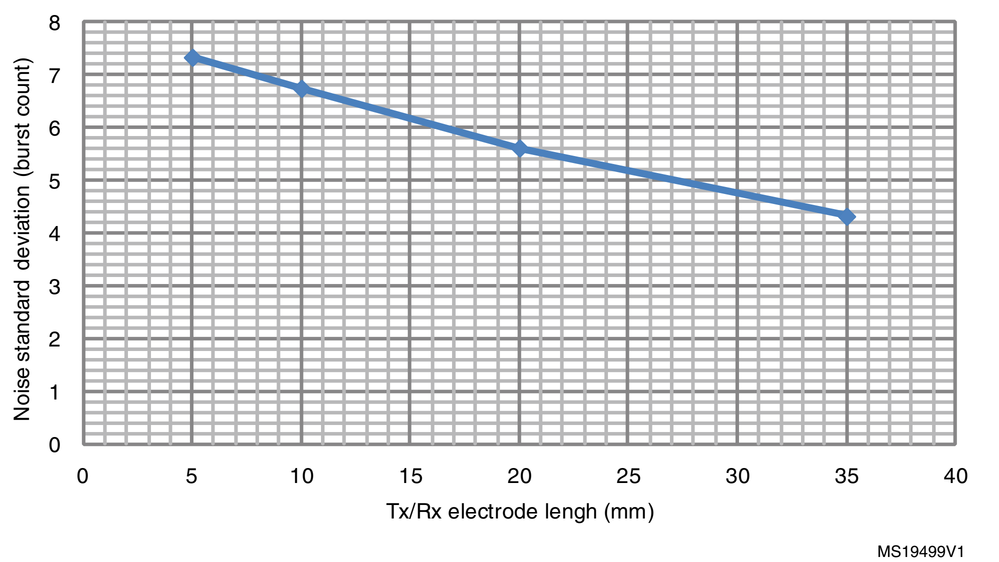
The Tx/Rx electrode length influences the proximity detection distance. The longer the Tx/Rx plate length, the higher the detection distance is. *Figure 18* shows the influence of the Tx/Rx electrode length on the detection range.

Figure 18. Detection range versus Tx/Rx electrode length



In addition, the projected capacitance between the Tx and Rx electrode increases when the Rx/Tx electrode length increases. Regarding the projected capacitance equation (see *Equation 2* and *Figure 15*), the higher the front area of the two electrodes is, the higher the capacitance is. When the projected capacitance increases the noise on the acquisition signal decreases. *Figure 19* shows the influence of the Tx/Rx electrode length on the noise standard deviation.

Figure 19. Noise standard deviation versus Tx/Rx electrode length

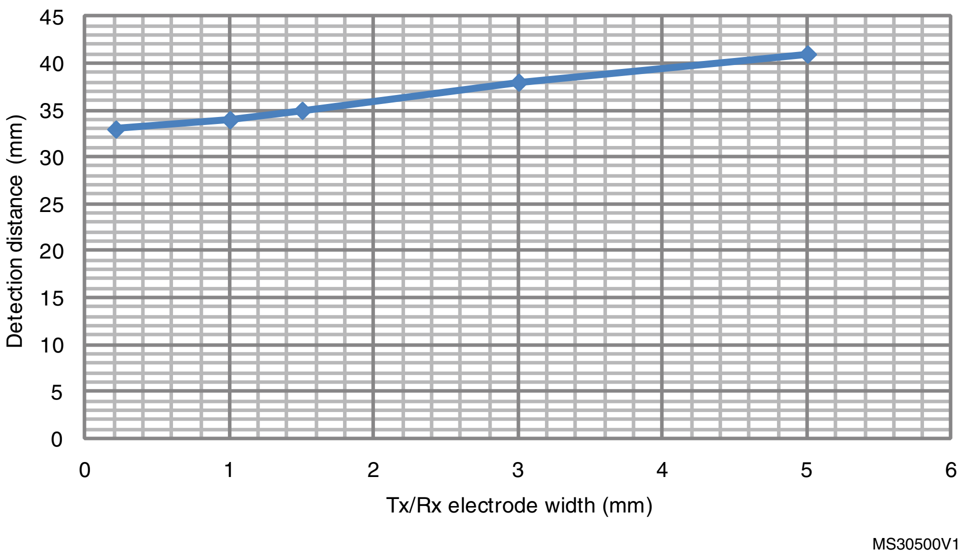


In conclusion, increasing the length of the proximity sensor, significantly increases detection distance and decreases noise. It is the best compromise in term of detection distance and noise immunity. To increase the detection distance of the proximity sensor system, it is recommended to increase length of the Tx/Rx electrodes first before increasing the spacing between the Tx/Rx electrodes or the electrode width.

4.3 Tx/Rx electrode width influence

The plate width also influences the detection distance. *Figure 20* shows the variation of the detection distance versus electrode width.

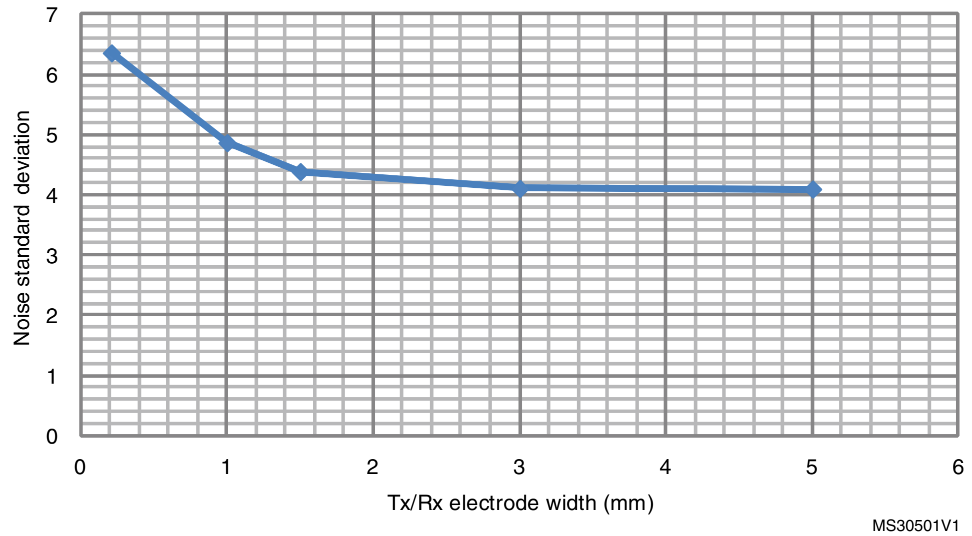
Figure 20. Detection range versus Tx/Rx electrode width



The width of the Tx/Rx electrodes have a low impact on the detection distance. When the Rx/Tx electrode width is greater than 1.5 mm, the detection distance increases very slowly compared to that of the width. When the width is less than 1.5 mm, the detection distance variation is very low.

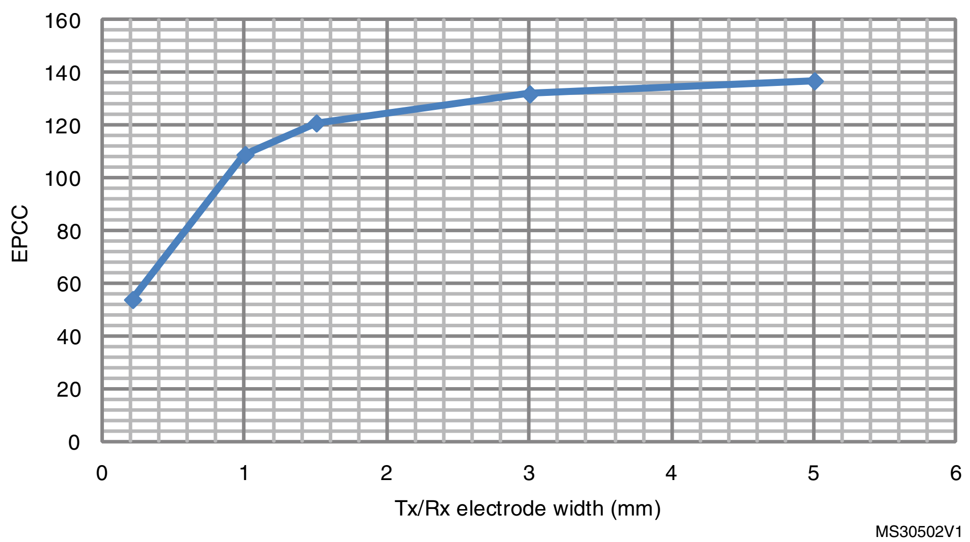
Noise decreases when the electrode width increases as shown in *Figure 21*. The noise standard deviation increases significantly when the TX/Rx electrode width is lower than 1.5 mm, but it is almost stable when Tx/Rx value is greater than 1.5 mm.

Figure 21. Noise standard deviation versus Tx/Rx electrode width



The significant noise variation when the Tx/Rx electrode width is lower than 1.5 mm is explained by the variation of the projected capacitance (see *Figure 22*). The smaller the EPCC compensation is, the lower the projected capacitance is and the higher the noise is.

Figure 22. EPCC versus Tx/Rx electrode width

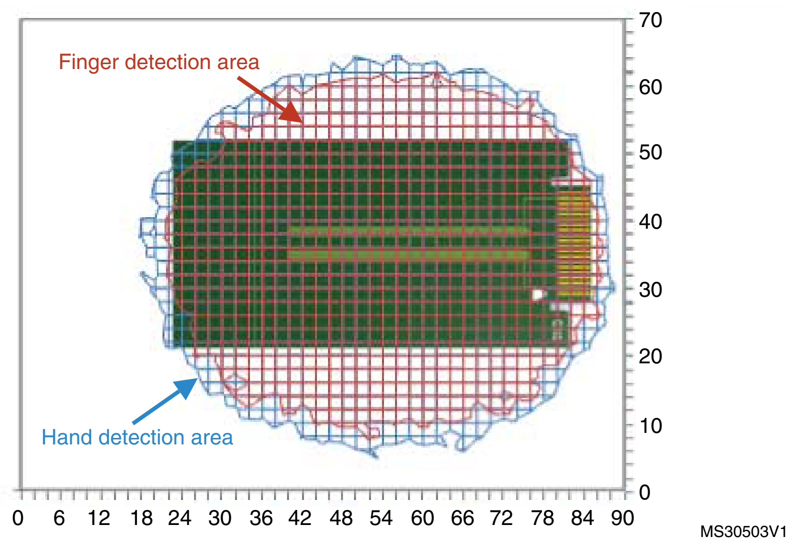


In conclusion, it is recommended to design sensors with an electrode width greater than 1.5 mm. This guarantees an acceptable proximity detection distance and ensures the best noise immunity. As electrode width has only a small effect on the detection distance, it is recommended to increase first electrode length or electrode spacing to improve the detection distance.

4.4 Electrode size and shape

The sensor size and shape define the detection area. The size of the sensor should be defined to be in line with the size of the object to be detected. With a capacitive projected technology, the size of the object to be detected has a small influence on the detection area. The detection area is defined by the projected capacitance field which is determined by two electrodes designs. *Figure 23* shows the detection area with a hand compared to a finger approach.

Figure 23. Hand versus finger detection area



Generally, we can consider that the object size does not influence the detection area if its size is in the same range or greater than the electrode field.

On the other hand, if the size of the object to be detected is smaller than the electrode size, the detection range is lower. In fact, if the object covers only a part of the projected capacitance field, its influence is smaller. In this case, the variation on the acquisition signal is lower and the detection range is less than with a higher triggered object (see *Table 6*).

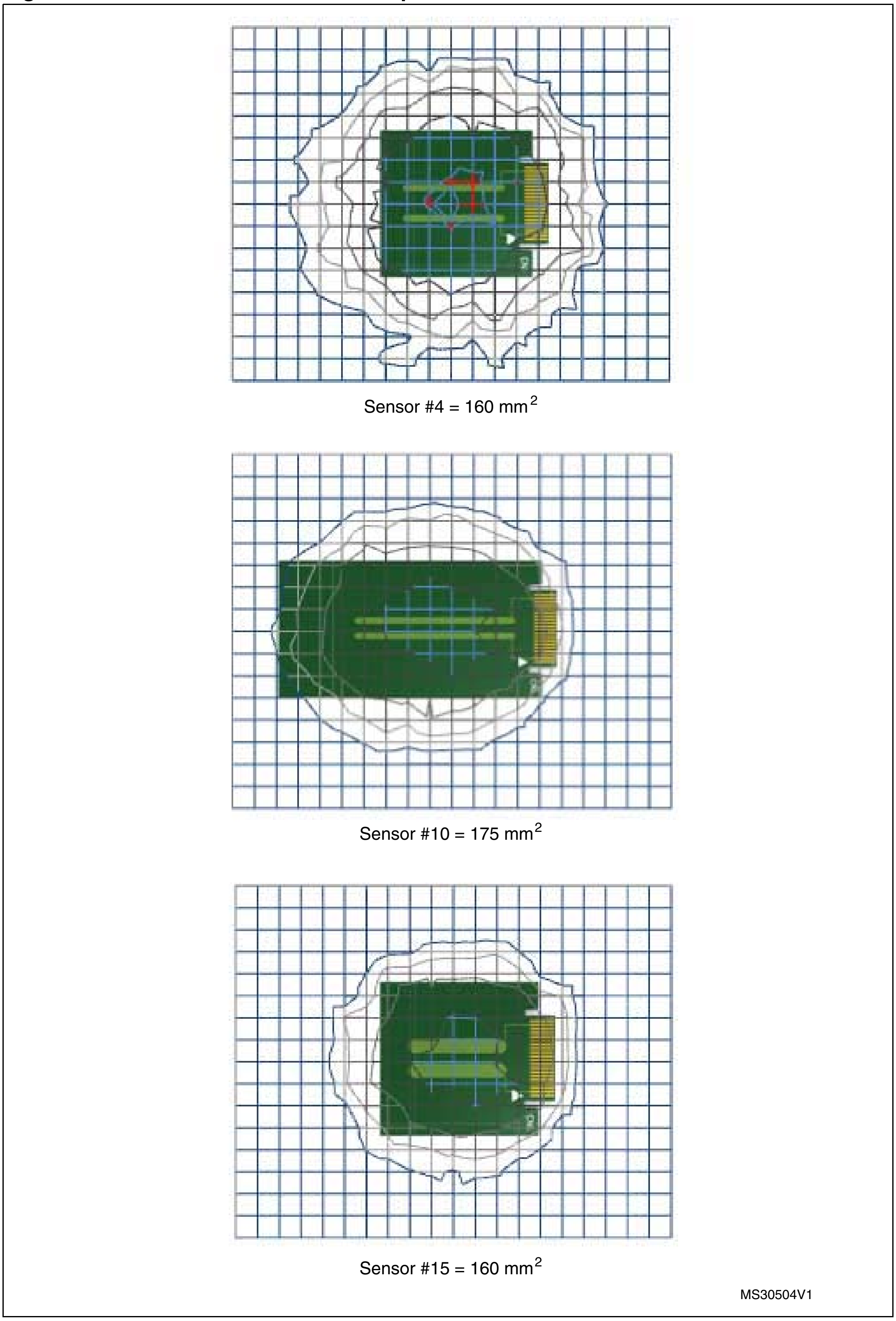
Table 6. Detection range versus hand or finger approach

Object	Detection range (mm)
Hand	36
Finger	26

In conclusion, the size of the object to be detected (e.g. a hand or a finger) has very little influence on the detection area (*Figure 23*) but, it does influence detection distance (*Table 6*).

The shape of the sensor influences the proximity detection area (see *Figure 24*) which compares three electrodes of equivalent size but different shape.

Figure 24. Detection area versus shape



The field generated by each electrode is centred in the middle of the two plates, Tx and Rx. The detection area of the rectangular electrode (sensor #4) is ostensibly the same as the square sensor (sensor #15) but, the width of the detection area for the long electrode (sensor #10) is lower. It appears that the lower the spacing is between electrode plates, the lower the detection distance is outside the electrode. Electrode spacing can thus improve the directivity of the electrode. The smaller the Tx/Rx electrode spacing is, the better the directivity is.

4.5 Ground coupling

To improve sensor sensitivity, care should be taken concerning the ground plane on the back of the electrode or ground surrounding. If the ground plane is too close to the sensor, it significantly reduces the detection distance. *Figure 25* shows the influence of the ground plane on the projected capacitance. The ground plane or ground surrounding decreases the electric field between the Tx/Rx electrodes. The electric field takes the shortest path to ground. As shown in *Figure 25*, the presence of the ground plane flattens the field and shortens the detection range.

Figure 25. Influence of ground plane on projected capacitance

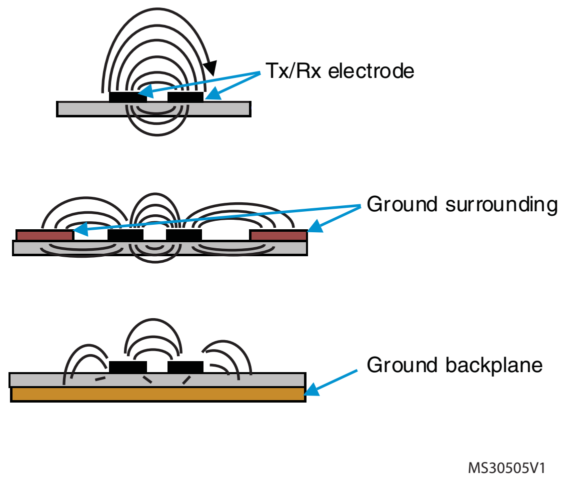
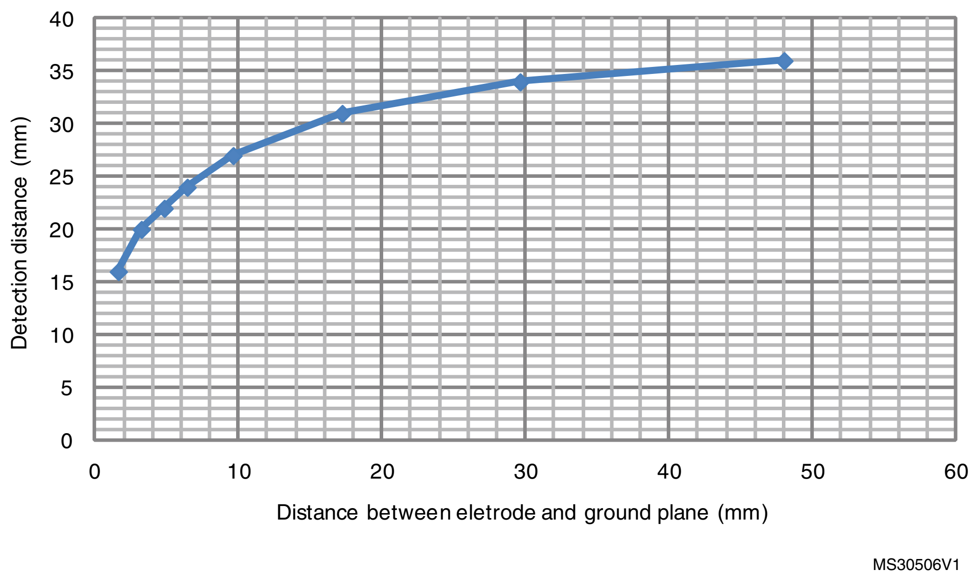


Figure 26 shows the measured detection distance versus the distance between the ground backplane and the sensor for a dielectric epoxy material (FR4). This test was performed using sensor #3 (see *Figure 1*).

Figure 26. Detection distance versus distance between ground plane and electrode for dielectric material (FR4)



Detection distance significantly decreases for an FR4 dielectric thickness less than 10 mm. For an FR4 dielectric thickness above 10 mm to maximum thickness, the increase of the proximity detection distance levels off.

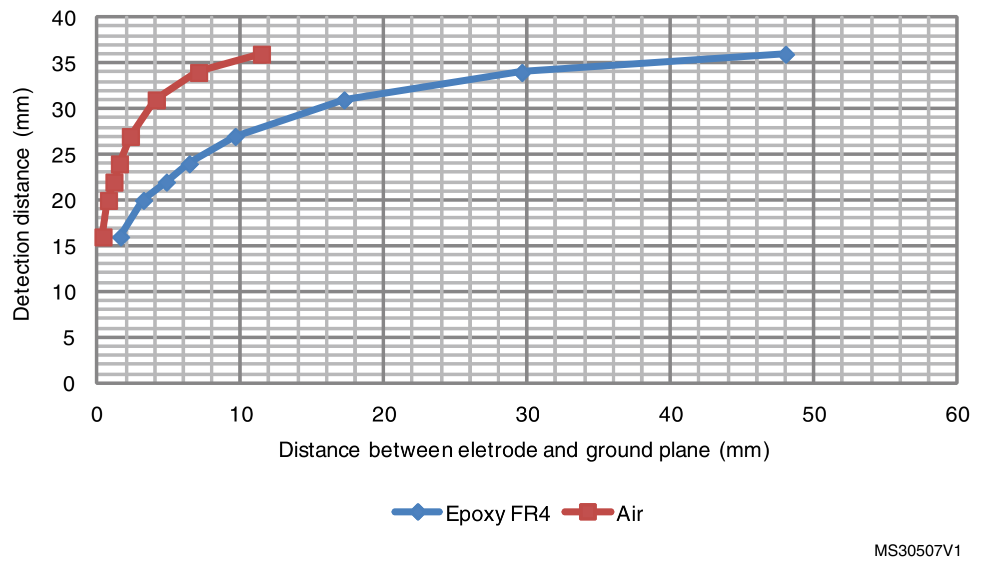
With regard to the dielectric epsilon factor (permittivity), at the same dielectric thickness, the lower the dielectric epsilon is, the greater the proximity detection distance is.

The permittivity (dielectric constant) for:

- FR4 is 4.2
- Air is around 1

Figure 27 shows the theoretical detection distance versus the distance between the ground backplane and the sensor for two dielectric materials: air and FR4.

Figure 27. Detection distance versus distance between ground backplane and electrode for two dielectric materials (air and FR4)



It is strongly advised never to put ground planes behind the sensor and to keep a clearance distance between it and any ground object with an air thickness greater than 2 mm. For air thicknesses under 2 mm, the ground backplane strongly decreases detection range.

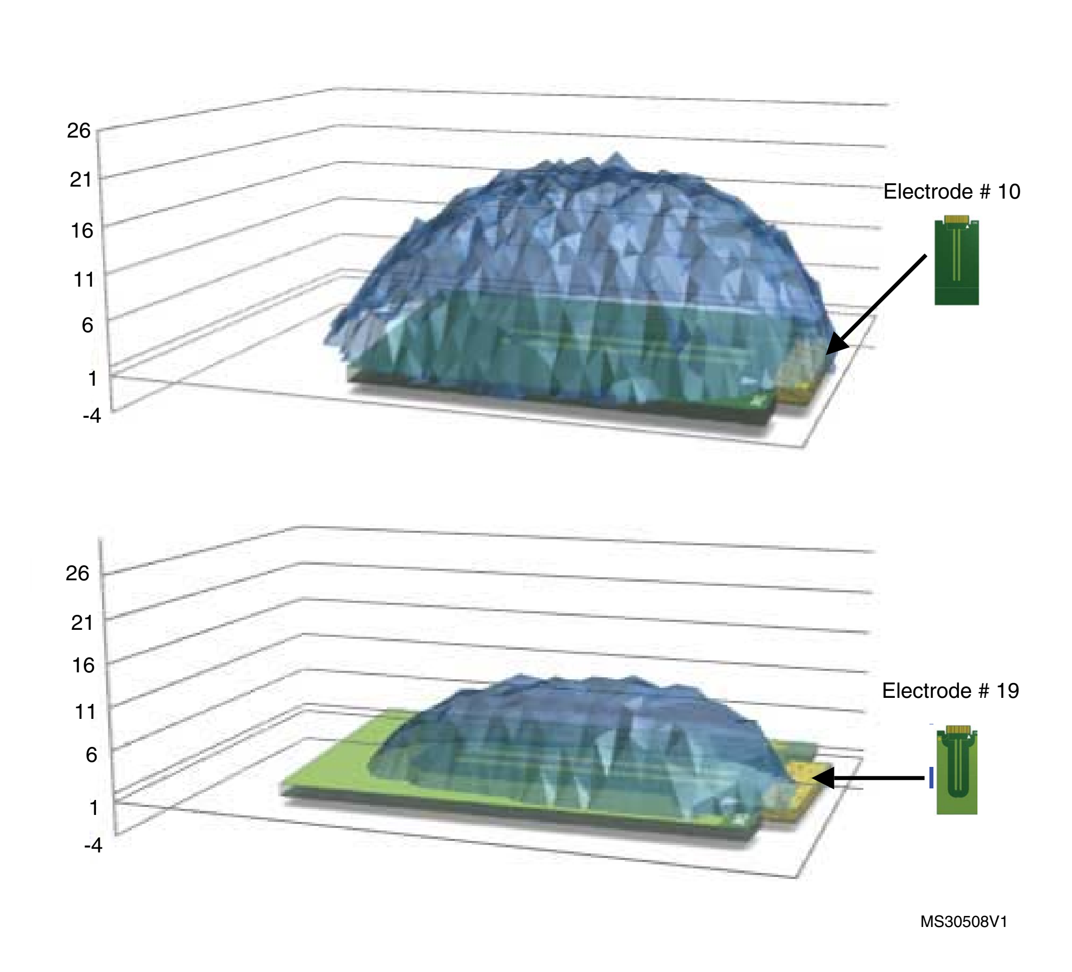
The closer the surrounding ground is to the electrode plates, the lower the sensitivity is. *Table 7* shows that at a surrounding clearance of 2 mm, the detection distance is drastically reduced.

Table 7. Detection range versus electrode ground surrounding

Surrounding clearance (mm)	Detection distance (mm)
2	11
5	15
10	23
No ground	42

In addition, the ground surrounding reduces the electrode detection area significantly. *Figure 28* shows the detection area and detection ranges obtained with a finger using the same electrode with and without ground surrounding.

Figure 28. Detection area and detection distance versus ground surrounding



Surrounding the electrode plate can improve the directivity of the proximity detection, but clearly reduces the detection range.

In conclusion, a ground backplane or ground surrounding close to the sensor plates drastically reduces the detection distance. It is strongly advised to keep the ground backplane or ground surrounding at a distance from the sensor. This helps maintain proximity sensitivity of the application.

5 Front Panel

The front panel material and thickness influence the projected capacitance field. Each material type is defined with a dielectric constant, known as epsilon (ε_r). The higher ε_r is, the easier the field can pass through material.

For example (see *Figure 29*), if the proximity distance without any panel is t_{air0}, it becomes t_{air1} when a panel is inserted between the sensor and the hand. t_{air1} is the distance between the hand and the front panel, and T_{total} is the total distance between the hand and the sensor. t_{air1} is lower than t_{air0} but the T_{total} is higher than t_{air0}.

Figure 29. Influence of panel on detection distance

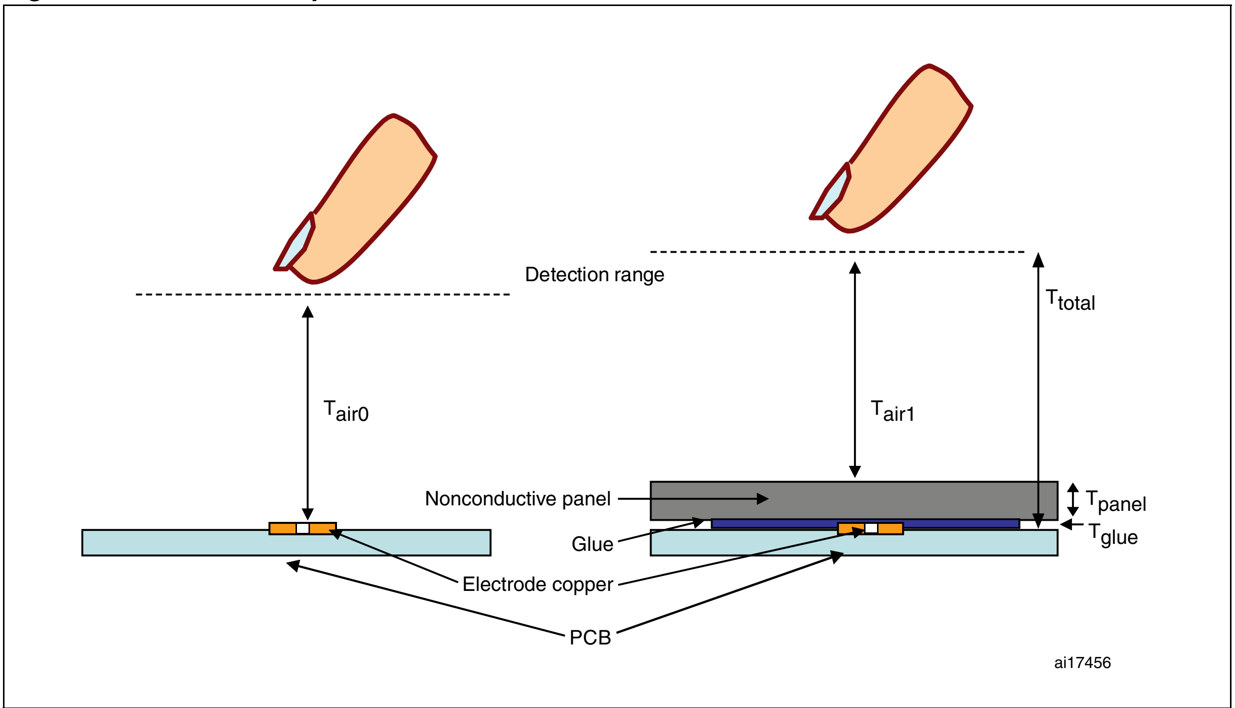
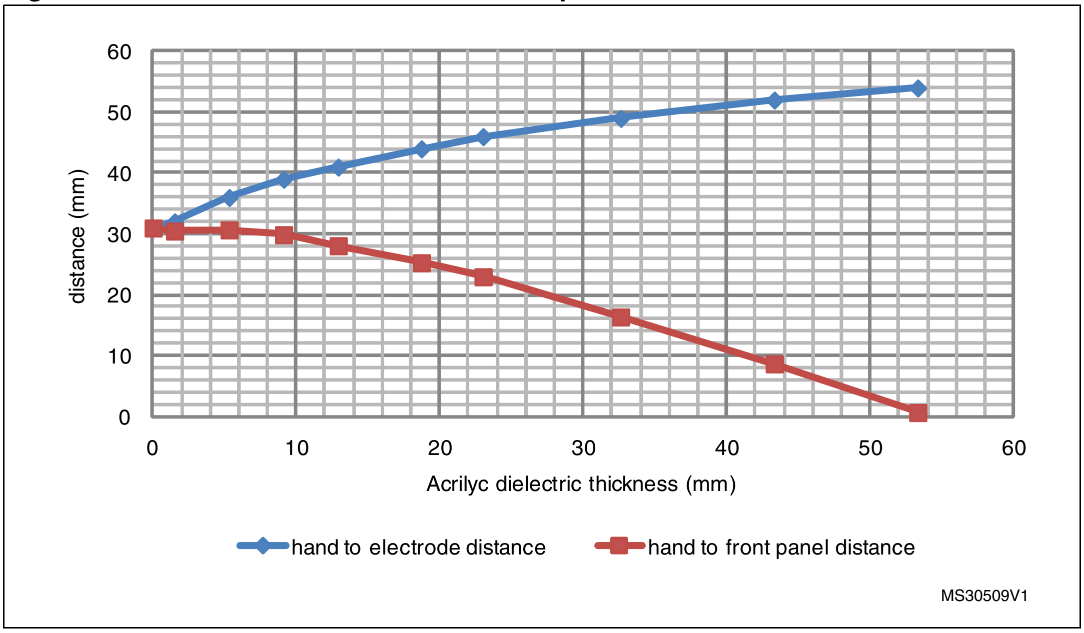


Figure 30 shows a comparison of the distance between a hand and the sensor and a hand and the front panel. This test was performed with an acrylic front panel material.

Figure 30. Detection distance versus front panel thickness



Note: Measurements performed with sensor board #3 (see *Figure 1*).

The thicker the front panel is, the greater the total detection distance is between the hand and the electrode, but the distance between the hand and the front panel decreases.

An electrode with a thin front panel glued onto it compared to an electrode without a front panel does not significantly influence detection range. The front panel only increases the projected capacitance.

6 Environmental variation

6.1 Power supply variation influence

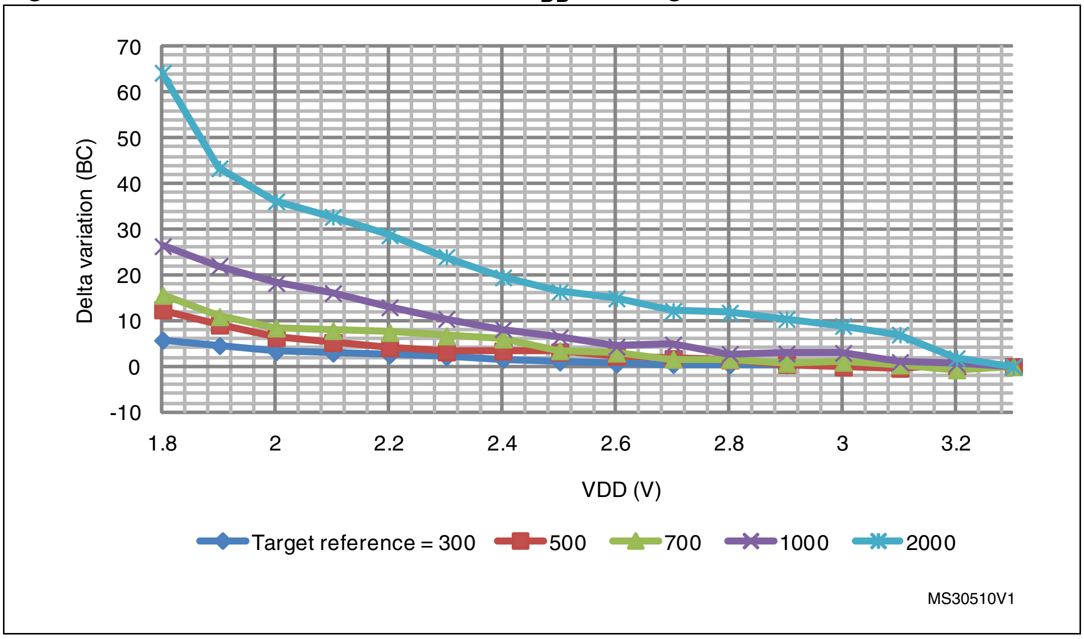
The stability of the device power supply is critical to provide a precise and repeatable capacitance measurement. Consequently, a linear regulator is embedded into STM8TL5xxx devices to provide the best power supply noise rejection possible.

Even with the embedded regulator, variations of the power supply voltage may have an impact on the measured signal, especially in proximity configurations with a large acquisition gain and small sensitivity threshold.

A variation of the power supply voltage (ΔV) induces a variation of the signal burst count (ΔBC). This variation depends on the sensitivity: a high sensitivity (high target reference) increases the effect of the power supply variation and can lead to an unstable proximity detection.

Figure 31 shows the burst count signal variation with V_{DD} variation from 1.8 V to 3.3 V with different target references. For this test, the system was calibrated at V_{DD} = 3.3 V.

Figure 31. Burst count variation versus V_{DD} and target reference

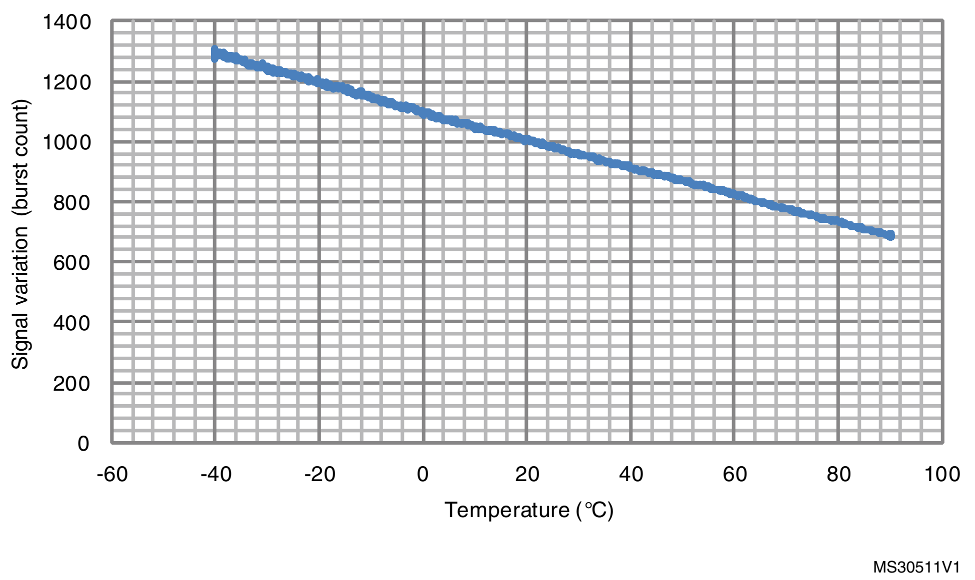


6.2 Temperature and humidity variation influence

6.2.1 Temperature influence

A variation of the temperature induces a variation of the measured signal. STM8TL5xxx devices compensate this by slowly tracking environmental changes thanks to the ECS (environment control system). *Figure 32* shows the acquisition signal variation versus temperature.

Figure 32. Acquisition signal variation versus temperature

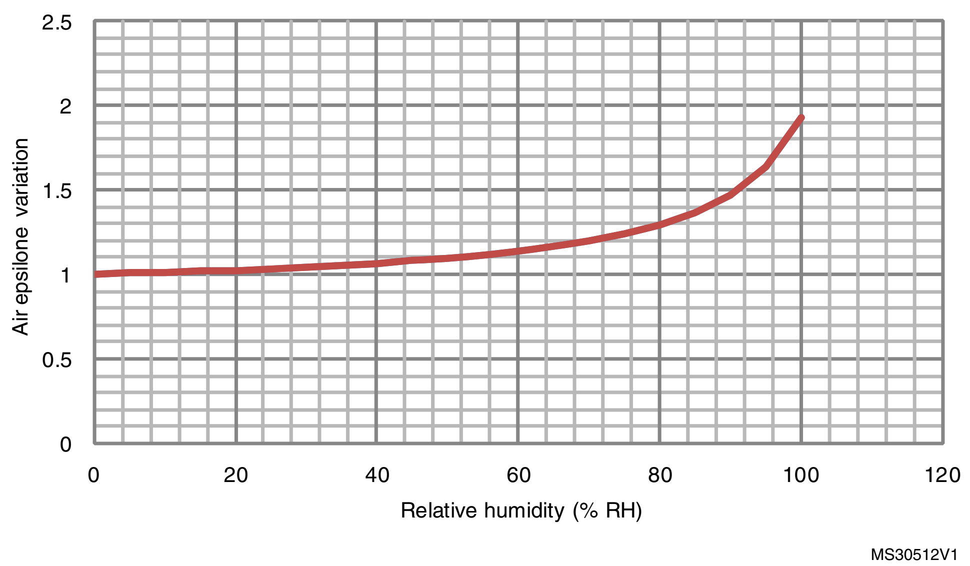


A variation of the temperature (ΔT) induces a variation of the signal burst count (ΔBC). This ΔBC variation depends on the device sensitivity. The higher the sensitivity is, the higher the burst count variation with temperature variation is. The ECS is able to compensate slow temperature variations but, an application subjected to fast and brutal temperature variation may give unstable proximity detections. Therefore, careful attention should be taken to avoid abrupt changes in temperature. Note that the decrease of the reference decreases the sensitivity. However, sensitivity can be compensated by the EPCC which is directly managed by the STM8TL5x STMTouch library.

6.2.2 Humidity influence

Humidity influences the detection range of the proximity system. Effectively, the dielectric constant, known as epsilon (ε_r) of the air varies with humidity. *Figure 33* shows the air permittivity variation versus relative humidity.

Figure 33. Air permittivity variation versus relative humidity



This situation is already describe in *Section 5: Front Panel*. The higher ε_r is, the easier it is for an electrical field to pass through materials. If the relative humidity increases, the detection range increases. Humidity variation is significant only with a relative humidity greater than 70 %.

7 Conclusion

This proximity sensor guideline gives some indications of the parameters to consider when developing a proximity application.

Results from the tests presented in this application note, advise designers to find the best compromise between sensitivity, stability, and noise immunity.

7.1 Practical example

An example is given below of how to design two electrodes which have a size constraint.

- Electrode #1, size constraint = 50 mm^2
- Electrode #2, size constraint = 300 mm^2

In accordance with the recommendations given in this application note, to obtain the best detection range and the least noise amplitude, the following parameters for *Electrode #1* and *Electrode #2* are proposed.

Electrode #1

- Because of its small size, increase the spacing between the Tx/Rx electrodes as much as possible. This should improve detection distance and increase noise. The best compromise is to favor the best detection distance. Take care not to space the electrodes too far apart as this can create a projected capacitance which is too small. If this happens, STM8TL5xxx devices are not be able to compensate part of the projected capacitance with the EPCC to achieve the target reference. Consequently, the EPCC will be out of the recommended range (see *Section 3.4: Electrode parasitic capacitance compensation (EPCC)* and can lead to an unstable proximity system. Electrode spacing selected: 4 mm.
- Increase the Rx/Tx electrode length to improve the detection distance and decrease the noise by increasing the projected capacitance. Electrode length selected: 7mm
- Chose an electrode width which does not penalize the detection distance and does not increase noise. Electrode width selected: 1.5 mm.
- Reduce the target reference as much as possible to reduce noise, but check the EPCC value is in the recommended range. The target reference selected is 1000 and the threshold setup is in accordance with the noise standard deviation recommendation.

Electrode #2

- With a big electrode, increase the Rx/Tx length to improve detection distance and reduce noise. Electrode length selected: 35 mm
- Increase the spacing between the Tx and Rx electrodes to improve the detection range. Note that increasing the spacing increases noise: always give preference to increasing electrode length before electrode spacing. Electrode spacing selected: 5 mm.
- Chose an electrode width which does not penalize the detection distance or increase noise. Electrode width selected: 1.5 mm.

Figure 34 shows the parameters chosen for electrodes #1 and #2.

Figure 34. Two electrode designs

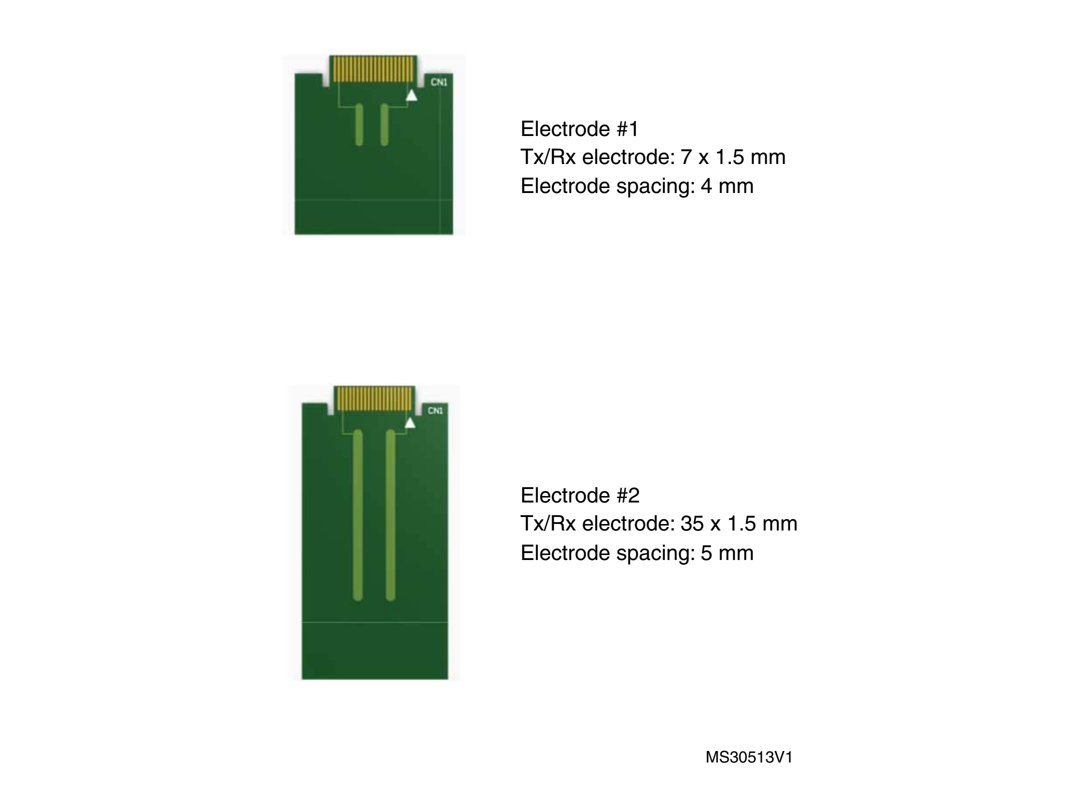


Table 8. Sensor parameter results

Characteristic	Electrode #1	Electrode #2
Detection distance (mm)	29	63
Noise standard deviation	5.70	5.25
Noise maximum delta (burst count)	19	17
Target reference (burst count)	700	1000
Detection threshold (burst count)	25	25
EPCC	20	137

7.2 Influential parameters summary

Table 9 summarizes the main parameters influencing detection distance and noise.

Table 9. influential parameters summary

Parameter	Detection distance	Noise	Minimum interval recommended
Increasing C_S capacitor	--	++	
Increasing target reference	+++	--	≥300
Decreasing detection threshold	++	0	≥4 * noise standard deviation
Spacing between Tx and Rx electrode	+++	--	≥2 mm
Increasing Tx/Rx length	++	++	
Increasing Tx/Rx width	+	+	≥1.5 mm
Decreasing distance between ground plane and sensor	---	-	
Decreasing distance between ground surrounding and sensor	---	-	≥2 mm(with air as dielectric)

In conclusion, many considerations need to be take into account including application constraints, environmental change, board design constraints, and power supply.

Generally, the best thing to do is to develop a prototyping proximity board to fine-tune the different parameters of the application and come to a reliable solution in terms of sensitivity and stability.

8 Revision history

Table 10. Document revision history

Date	Revision	Changes
31-May-2012	1	Initial release.