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Preface

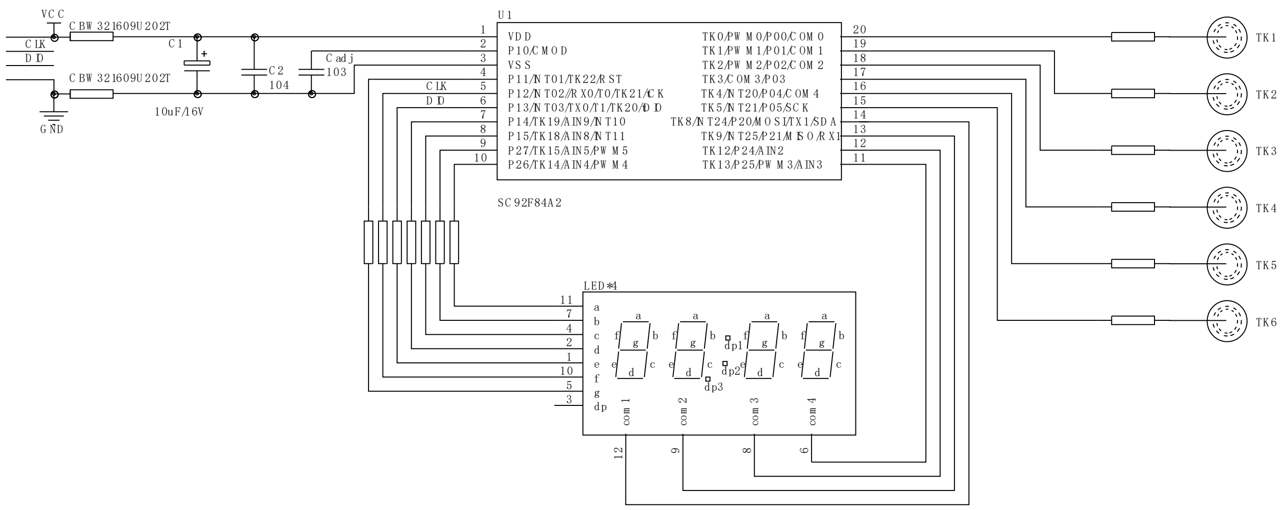
Overview

This manual is a technical manual of PCB Layout design for Touchkey MCU application provided by SinOne, aiming at better applying the touchkey performance when designing PCB for touchkey MCU and improving the system stability. The design points of this technical manual include PCB design for General Plan of Touchkey MCU and PCB design points of several touchkey plans, etc.

The touchkey architecture of SinOne MCU is divided into high-sensitivity touchkey mode and high-reliability touchkey mode; double-module touchkey is built in partial models (for details, see the specifications); for specific differences, please see related application guidelines: SinOne SC95F Series TouchKey MCU Application Guidelines or SinOne SC92F_93F Series TouchKey MCU Application Guidelines; in this manual, we mainly introduce the PCB Layout design related to touchkey MCU.

1. PCB Design Points for General Plan of Touchkey MCU

1.1 Application Circuit of SinOne Touchkey MCU



Notes:

1. The capacitance of Cadj shall adapt to the touchkey mode:
    a) 473 polyester capacitor is recommended for high-reliability touchkey mode;
    b) 103 capacitor is recommended for high-sensitivity touchkey mode;
2. The matched resistance on TK pins ranges from 510Ω to 5.6K with the recommended value of 510R
3. Two channels of magnetic beads at the power supply inlet (CBW321609U202T: 600Ω@100MHz) can be reserved for self-selection; Under special circumstances, if the products fail to pass 10V dynamic CS test, magnetic beads can be added for improvement.

1.2 Requirements for Overall Layout

1.2.1 Positions of Chips and Matched Resistance

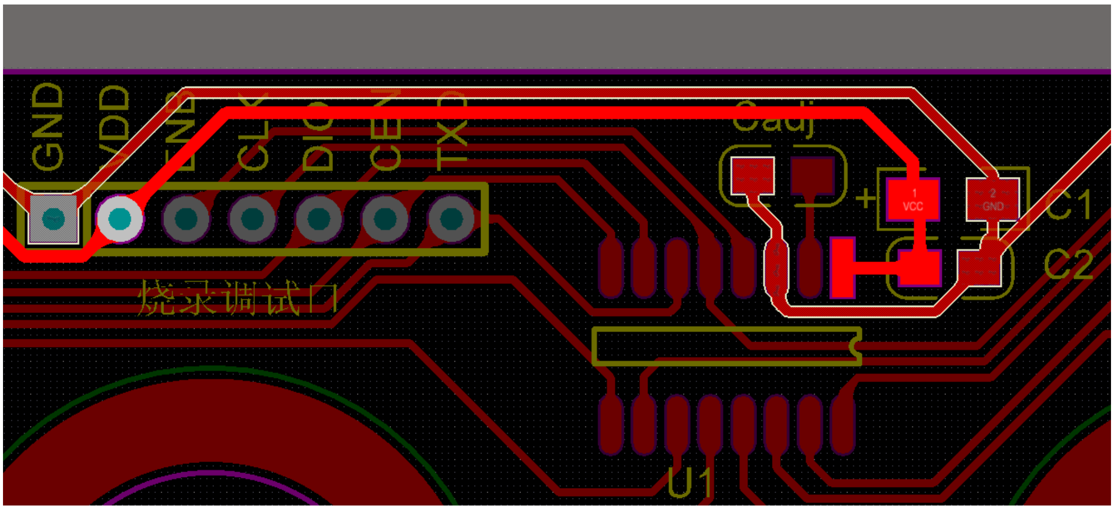
1. Try to place the touchkey MCU in the center of multiple touch keys upon layout;
2. The recommended value of the matched resistance is 510R, and it shall be placed as close to the touch chip as possible;
3. The reference capacitor Cadj is connected between CMOD and VSS pins of MCU. As the charge and discharge capacitance of touch induction circuit, it is the essential device to realize the touch function and ensure the normal work of the touch circuit. The Cadj capacitance ranges from 472 to 104 **with 103 capacitor recommended for high sensitivity and 473 polyester capacitor recommended for high reliability mode**. It is recommended to use the capacitor with a small temperature coefficient and high precision so as not to cause inconsistent sensitivity or change with temperature. In general, it is suggested to use the polyester capacitor with 5% precision for plug-in capacitors. For chip capacitors, NPO or X7R capacitors with no less than 10% precision is advised.
4. Cadj capacitor shall be as close to the chip pin as possible.

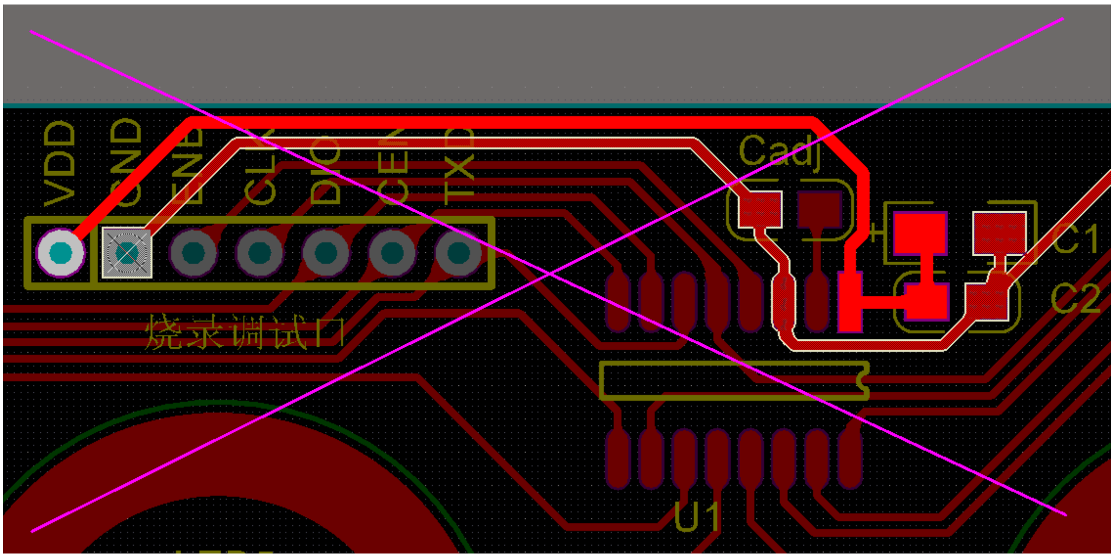
1.2.2 Power Supply Circuit

1. The power cord and ground wire shall be firstly conducted with the capacitor filter (electrolytic capacitor + 104 ceramic capacitor) before being connected to MCU VDD and VSS pins; the electrolytic capacitor can also be changed into tantalum capacitor with the capacitance value of not less than 10uF;
2. 104 capacitors shall be laid out close to MCU VDD and VSS pins;
3. The power supply of power load and MCU control shall be set up separately and the former shall be charged before the 104 capacitor.

Refer to the following figure for the cabling mode of VDD and VSS:

U1 is for touchkey IC, and two highlighted cables are connected to U1 VDD and U1 VSS respectively, which have passed through C1 (10uF tantalum capacitor) and C2 (104 chip capacitor) successively, and then connected to U1 VDD and VSS pins.





1.2.3 Sensor Pad

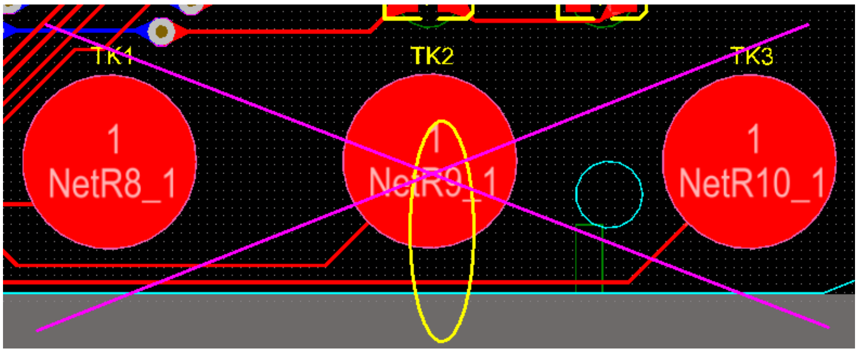
1. According to different application requirements, the Sensor Pad is usually made of PCB copper foils, flat spring, conductive cotton, conductive rubber, ITO glass layer, etc. It is recommended to use the spring as the induction medium;

2. If PCB copper foil-type induction keys are used, solder mask ink shall be applied to the copper foil of the sensor pad with no copper being exposed; the shape of the sensor pad shall be regular and symmetrical as far as possible. It is recommended to use the round or oval sensor pad with the diameter between 8 mm and 15mm and key clearance of more than 5mm;
3. For the copper foil-type induction keys, it is required that the vertical distance between the copper foil on the sensor pad and the touch panel shall be no more than 3mm; otherwise the touch sensitivity will be reduced. **For the project with the distance more than 3mm, please contact SinOne engineer;**
4. For the spring-type induction keys, try to make sure that the distance between the spring key and the panel is consistent and there is no gap between the top of the spring and the touch panel.

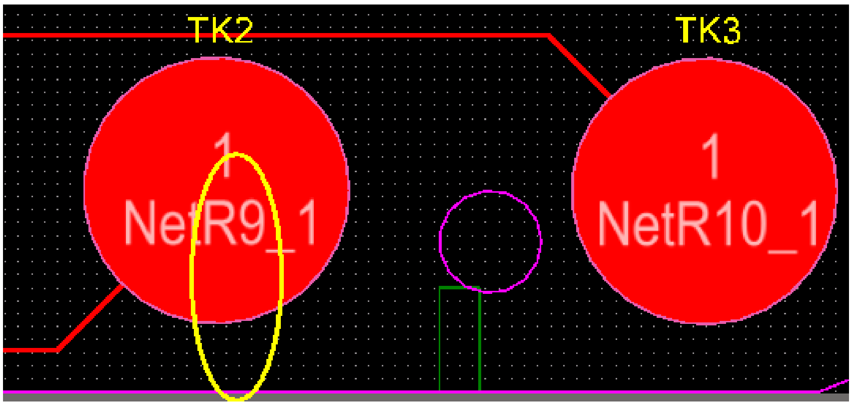
1.3 Cabling Requirements

1. The routing of TK channel shall be as thin as possible with the recommended cable width of 0.3mm; **if the cable width of the touch network is more than 0.5mm due to process limitations, please contact SinOne engineer; do not use cable holes and jumpers on the same cable; if it is required to use, no more than 2 are advised;**
2. The routing of TK channel and sensor pad shall be far away from other network components, high current and high-frequency signal sources (IIC, SPI, RF and other high-frequency signals) as well as digital tubes;
3. If multiple TK channels are drawn from PCB, the length of each TK channels shall be consistent where the layout allows (IC can be placed in the center of multiple TK channels upon layout);
4. As far as possible, the distance between the routes of different TK channels shall be more than twice the cable width, and the distance between the sensor pads of different TK channels shall be as large as possible, otherwise, the interference of adjacent keys will be increased and thus affect the touchkey performance;

5. In practice, upon touching a single sensor pad, avoid the routes of other TK channels where your fingers are most easily covered to minimize the influence between TK channels. As shown below, the yellow oval represents the finger, when TK2 is touched, the routing of TK3 channel will also be affected by the finger:

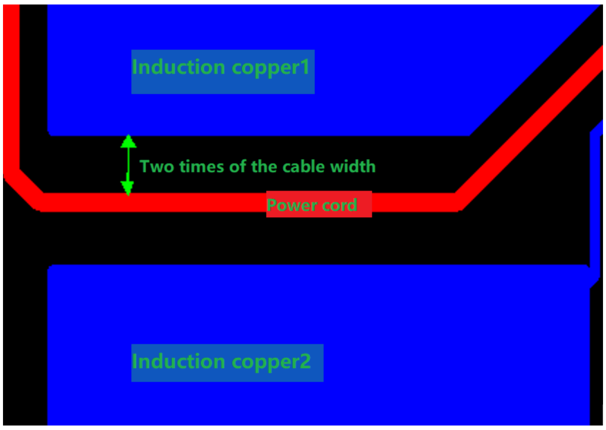


By routing TK3 over TK2, TK3 will be less impacted when TK2 is touched by the finger, as shown in the figure below:



6. It is strongly recommended not to place non-TK network components and cables on the projection plane of the induction keys; for copper-foil induction keys, solder mask ink shall be applied with no copper being exposed;

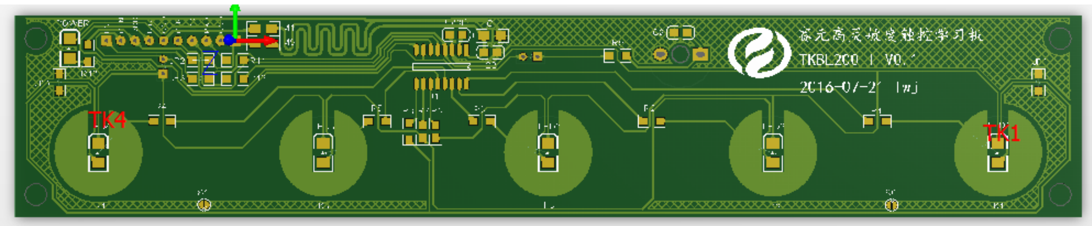
7. The front and back sides of TK channel network shall avoid cable jumper or routing passing through other network as far as possible. If it can not be avoided, the vertical routing of front and back sides shall be adopted to minimize the interference, or the routing width of different networks on the front and back sides shall be more than 2 times of the cable width by referring to the mode shown below:



1.4 Copper Coating Requirements

1. GND copper coating can enhance the anti-interference performance of PCBA. It is recommended to use grid-type copper coating with the effective area of copper sheet shall be less than 40%; (the layout mode of proximity sensing application is special, please refer to 2.2 Capacitive Proximity Sensor Coil for details)
2. The network of GND copper coating shall be led out from the GND behind the filter capacitor 104 so as to shield the interference signal to the maximum extent;
3. The TK channel around the sensor pad with the least touchkey network shall be coated with GND copper, and the distance between GND copper coating and the sensor pad of this TK channel or the edge of the projection surface of the touchkey shall be not less than 3mm and 3mm is preferred.

As shown in the figure below, there is only 1 TK channel on the right around TK 4 at the leftmost end, and the number of the touchkey networks around TK4 is the least. According to requirement 3, GND copper coating shall be performed around the sensor pad of TK4. The same procedure shall be done for TK1 on the right and one TK channel on the left.

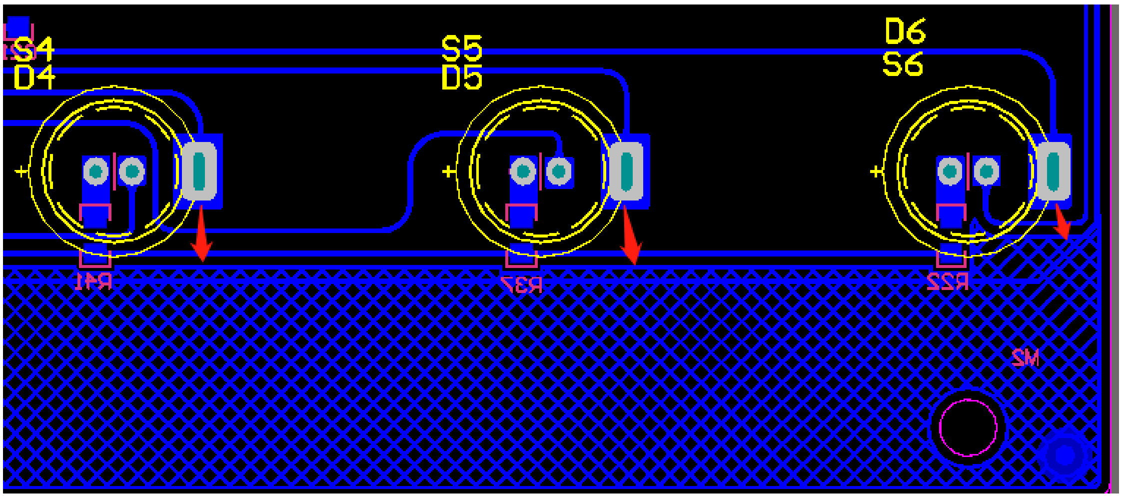


When applying copper coating to the GND network around the sensor pad, pay attention to:

1) Avoid to form a closed loop with the copper sheet of GND network;

2) Only apply copper coating around the sensor pad of GND. Do not apply near the routing of all TK channels, otherwise it will reduce the sensitivity of the touchkey.

4. Except for Article 3, other touchkey networks shall be far away from GND network as far as possible;
5. For double-sided PCB, it is necessary to avoid applying copper coating for GND network on the TK channel routing and the back of sensor pad so as to not affect the sensitivity.
6. If the commissioning interface is needed to be led out, the lead spacing between SCK and SDA routing and the routing port shall be at least twice the cable width as far as possible; do not route parallelly; if it is unavoidable, separate two cables with a ground cable to ensure that the data collection works normally upon debugging by using Touch Key Tool. If no data is uploaded during the process of data collection, it is able to connect 101 capacitor to the ground in SCK of MCU terminal (as close as possible to IC pin).
7. Connect the resistor in series to PAD on each TK channel. Try not to apply copper coating near the touchkey routes and PAD (reduce the capacitance to the ground), and refer to the following figure for layout and routing. Try to keep a certain spacing between the touchkey PAD and the copper coating (>=3mm)



1.5 Selection of Touch Panel Materials

1. The material of the touch panel shall be insulated or non-conductive, and conductive materials containing metals or carbons shall be avoided;
2. The thicker the touch panel is, the smaller the touch sensitivity will be and the lower the signal-to-noise ratio will be. When acrylic materials are used, the recommended thickness is 1.5-3mm;
3. If the dielectric constant of the materials of the touch panel is too small, the sensitivity of the touch key will become poor; if the dielectric constant is too large, the touch key is prone to be misoperated.

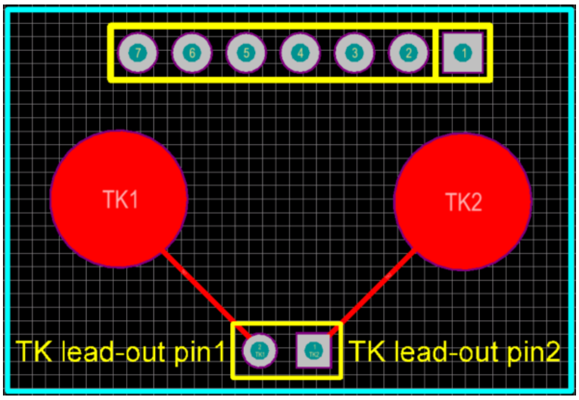
2. PCB Design Points of Several Touch Plans

2.1 Display with Touchkey Sensor Pad

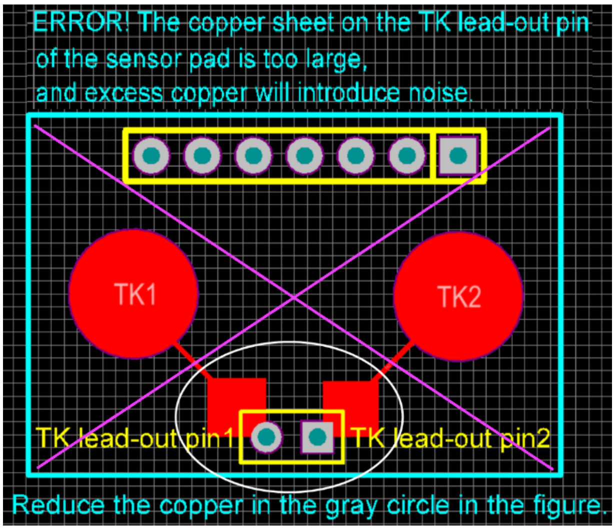
In the digital tube display or LCD, place a metal sensor pad and lead the sensor pad out through the pins to make the display with the touchkey sensor pad. By installing such display on the mainboard of SinOne touchkey MCU, connecting the lead-out pin of the sensor pad to the touch pin of MCU and connecting SEG and COM ports of the display to the I/O ports of touchkey MCU can produce the display scheme with touch functions.

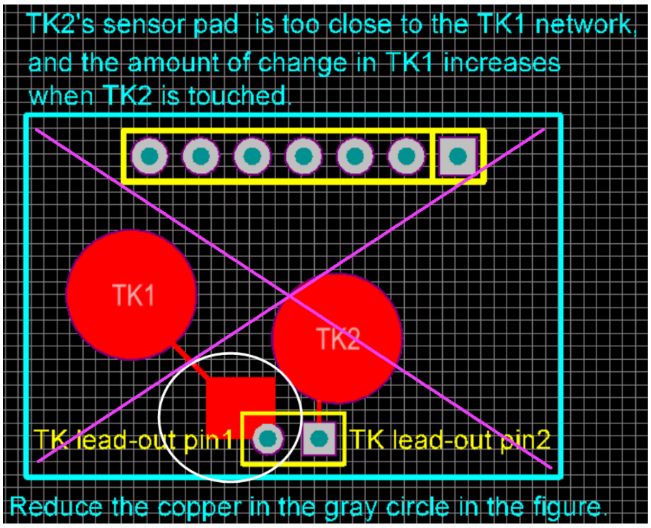
2.1.1 Routing Requirements for Display with Touchkey Sensor Pad

1. The following figure shows the routing diagram for the display sensor pad with touch sensor pad, the red part is the touch sensor pad TK1 and TK2 in the display, which are led to TK lead-out pin 1 and 2 respectively through cable routing:



2. The copper sheet on the lead-out pin of the sensor pad shall be as little as possible to avoid excessive noise, and contact between TK channels shall also be minimized. The user shall strictly follow 1.3 Routing Requirements to conduct the layout of the internal routing for the digital display. Below is a diagram of error that shall be avoided by the user when designing digital displays.



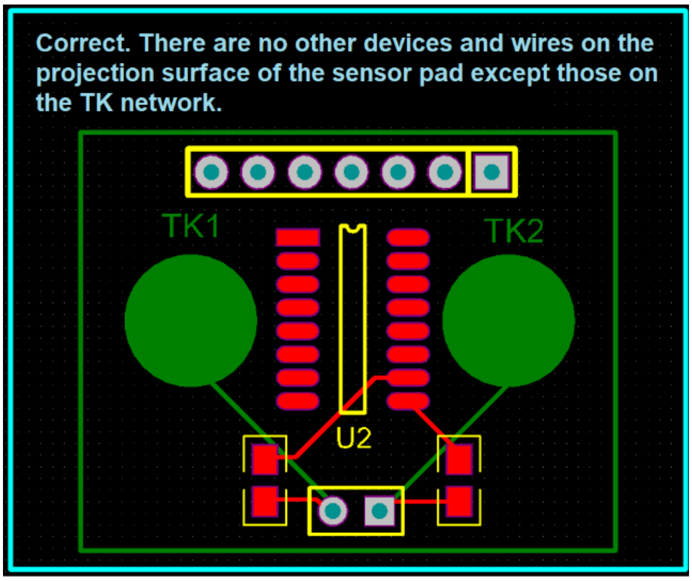


3. In general, internal routing of the display is completed by the manufacturer, therefore, the user shall communicate with the manufacturer about the routing precautions before sample making. It is suggested to provide this layout instructions to the display manufacturer.

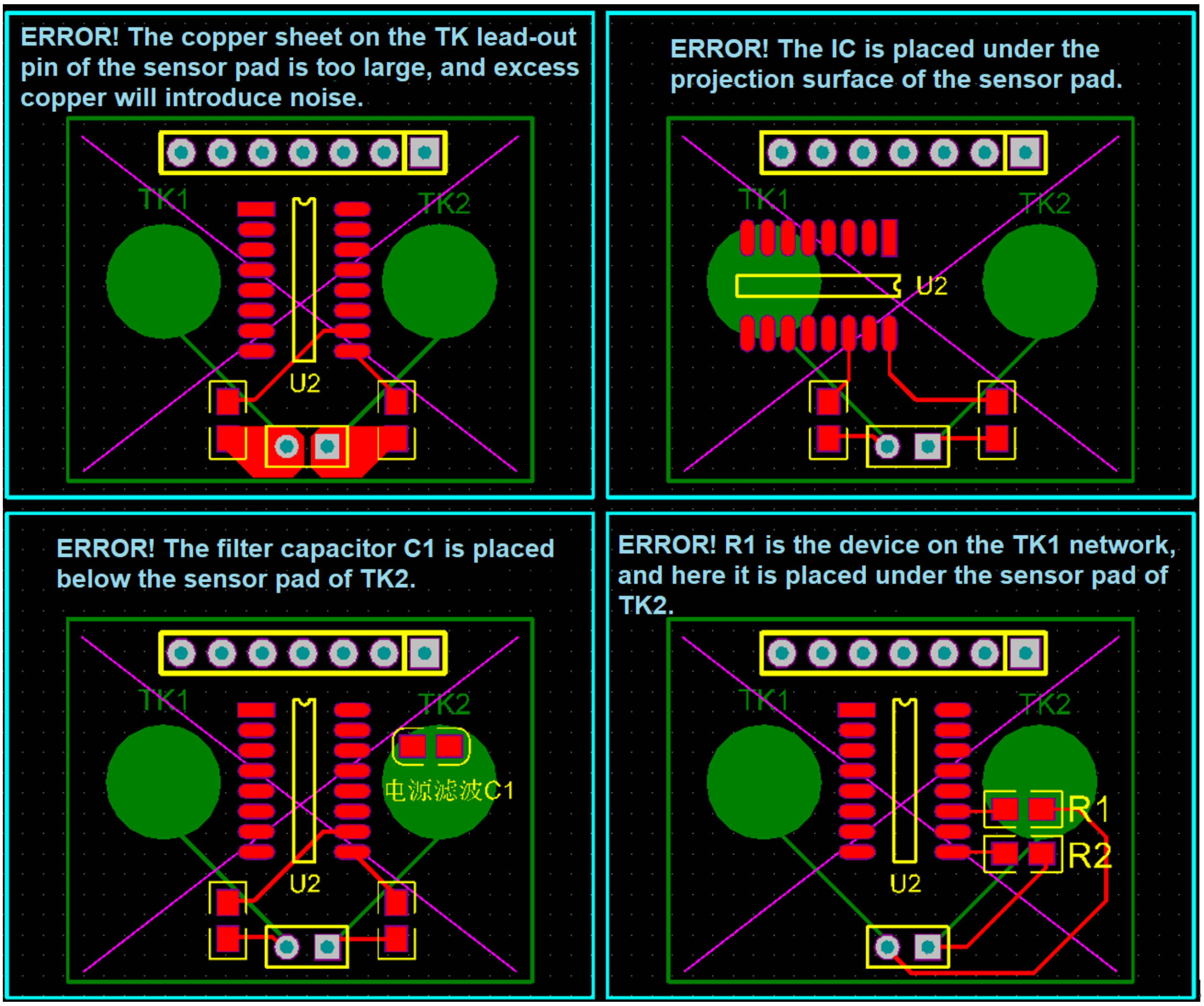
2.1.2 Mainboard Circuit Routing Requirements for the Display with Touchkey Sensor Pad

After the display is made, assemble it on a PCB welded with SinOne touchkey MCU, which is called as the "Mainboard" of PCB. There are touchkey MCU, power control and other components on the mainboard. To guarantee the performance of the touch keys, non-TK channel components and routing shall be avoided within the scope of projection surface of the built-in sensor pad of the display, that is to say, after the display is installed on the mainboard, do not place non-TK channel components and routing within the scope of the projection surface of the sensor pad corresponding to the mainboard. Touch key MCU shall not be placed under the projection surface of the sensor pad.

Below is the proper routing diagram for the mainboard, U2 is touchkey IC, and the green parts represent the projection of the sensor pad on the display.



The following figures are four **incorrect routing diagrams**, which shall be avoided upon layout by the user:



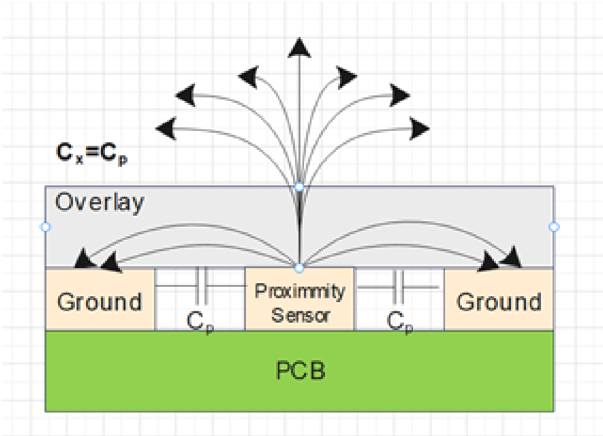
2.2 Capacitive Proximity Sensor Coil

Please note that the capacitive proximity sensor technology is only available for **high-sensitivity touchkey applications** currently.

2.2.1 Simple Principle of Capacitive Proximity Sensor

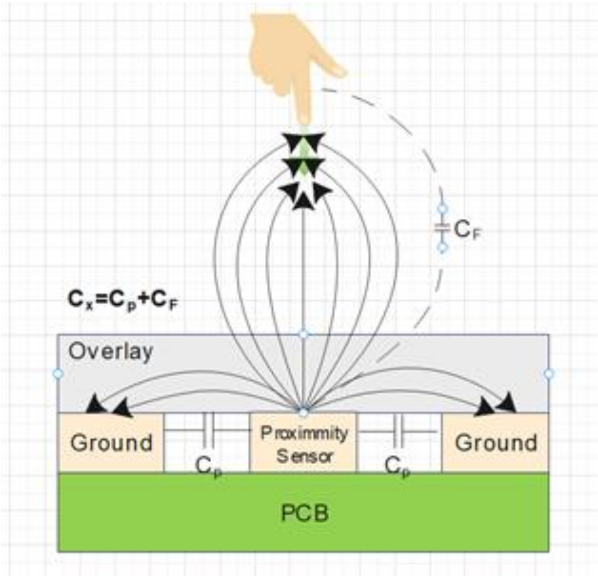
Capacitive proximity sensor technology is to measure the change in capacitance of a target as it closes to the sensor. The target can be a human body or any conductive object. The capacitive proximity sensor can use the conductive objects as the sensor (usually copper, tin, etc.) and usually located on the PCB.

When a capacitive proximity sensor is excited by a voltage source, an electric field will be generated surrounding the sensor. A small amount of the electric field lines are coupled to the ground nearby, while the majority of the field lines are projected to the space nearby.



Electric Field of Proximity Sensor

When an object is close to the proximity sensor, some fields lines will be coupled with the target and form a capacitance. The change in capacitance is measured by the capacitor circuit to detect the approaching target.



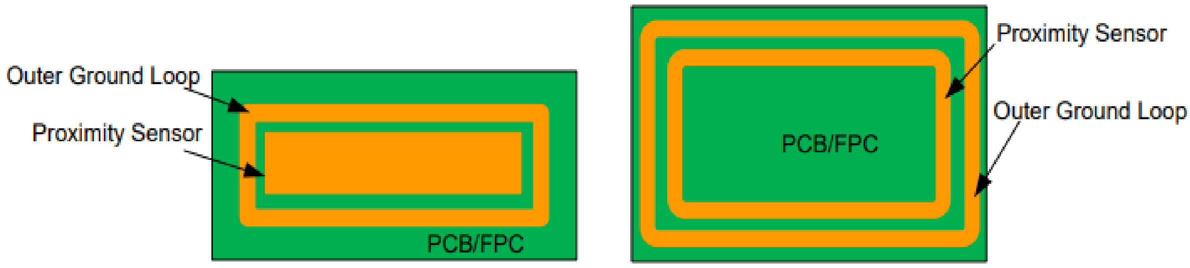
Electric Fields of Proximity Sensor (with hand approaching)

To guarantee the performance of the proximity sensor channel at a long distance, the parasitic capacitance C_P on the sensor channel shall be reduced. It is recommended to use a closed loop with a cable width of 2-3mm as the sensor coil of proximity sensor TK channel. The area of the sensor coil shall be as large as possible.

2.2.2 Layout Design for Capacitive Proximity Sensor

Achieving the capacitive proximity sensor is a challenge in practical application, because the proximity sensor distance depends on various factors such as sensor layout, the presence of noise and the floating or grounded conductive objects, etc.

The structure of the proximity sensor depends on the applications and the desired proximity scope. In the control application of the close proximity sensor (the maximum proximity distance is 3CM), a sensor with a small area and solid filled shape is required to obtain the proximity distance; for the application requiring a larger proximity distance, a larger sensor loop around the device is used to obtain a larger proximity distance.



Building of Proximity Sensor on PCB/FPC

Note: In the diagram, Outer Ground Loop is to enhance the resistance to ESD events. Do not add it if no ESD is required. After adding Outer Ground Loop, it is required to test and balance the proximity range, noise resistance and ESD performance.

Constructions of common proximity sensor:

(1) Copper cabling on PCB or FPC: Regular circular or square PCB or FPC routing can be used for the proximity sensor.

2.2.3 Selection for Coil Specifications of Capacitive Proximity Sensor

The size of the proximity sensor depends on factors such as the desired proximity sensing distance, the presence of a noise source and the suspended or grounded conductive objects. The noise sources and the suspended or grounded conductive objects may reduce the signal-to-noise ratio (SNR: the ratio of the signal strength to the noise strength) and the proximity sensing distance.

The relationship between the distance given by SinOne and the specification of the coil is as follows:

Assume that the proximity sensor coil is a regular circular loop (diameter D1) or a square loop (diagonal distance D2)

The proximity sensing distance is about 1.5 times of the sensing distance of D1/D2.

However, due to the complex environment of the terminal system, the sensor in the same size may obtain different proximity sensing distance.

It is recommended to perform the environment measurement with a minimum loop diameter that is close to the desired proximity sensing distance (in the case of a circular loop) or diagonal (in the case of a square loop). If the desired proximity sensing distance is not achieved, it is recommended to gradually increase the sensor loop diameter or diagonal until the desired proximity sensing distance is obtained.

2.2.4 Layout Design Points of Capacitive Proximity Sensor

Category	Details	Suggestions/Remark
Proximity	Shape of proximity sensor coil	• Copper sheet loop of hollow circular or square (bending edge)

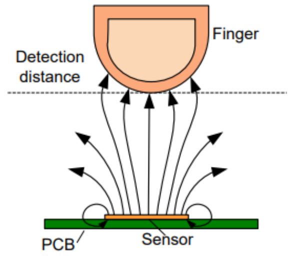
Sensor Coil		coil on PCB/FPC (The sensing distance is required to be larger than 3cm) • Solid-filled circular or square (The sensing distance is required to be less than 3cm)
	Routing width of proximity sensor coil	1.5mm-5mm (2-3mm is recommended)
	Distance between the proximity sensor loop and the ground loop **(It is required to be paid attention to for ESD required; otherwise, ignore it)**	1mm-2mm
	Routing width of ground loop **(It is required to be paid attention to for ESD required; otherwise, ignore it)**	1.5mm
	Loop diameter or diagonal length of proximity sensor	Convert according to the principle of the required sensing distance being 1.5 times of the diameter or diagonal length of the coil loop, and appropriately increase the coil size to leave a margin
Layout and Routing	Routing width	Less than 0.25mm(10mil)
	Routing Layout	Route as close to the side of the proximity sensor coil as possible (it is recommended that no cable is routed in the coil/there is no component in the coil to obtain the most appropriate sensing distance; otherwise, it may reduce the distance. The specific influence shall be subject to the actual environment measurement). If non-TK cables are routed through TK cables, make sure that they are intersected with each other vertically or spaced at least 2mm apart from TK cables **(No clock, data or periodic signal cables can be routed in parallel to the signal routing of the proximity sensor coil. These signal cables shall be routed as perpendicular to the signal routing of the proximity sensor coil as possible or routed in other areas of the PCB. If the clock, data or any periodic signal cables really need to be routed parallel to the sensor signal cables, they shall be routed on different layers and not be overlapped, and the length of the parallel portion of the signal cables shall be shortened as much as possible)**
	Routing holes and connection position of the proximity sensing coil signal	Reduce the routing length as much as possible, make the holes be close to the coil edge, and connect the routing of the proximity sensor signal to the proximity sensor coil vertically
	Placement of series resistance	The series resistance is recommended to be 510ohms. Place the series resistor be close to the TK pin corresponding to the chip IC so as to achieve noise suppression.
	Ground/shielding copper cladding	It is not recommended to apply the ground copper cladding, with the purpose of reducing the parasitic capacitance CP and improve the sensitivity
Coating Layer	Thickness and material of coating layer	Evaluate the thickness and materials of the coating layer according to the PCB layout and application environment and

		require to use non-conductive materials (such as glass, ABS, etc.).

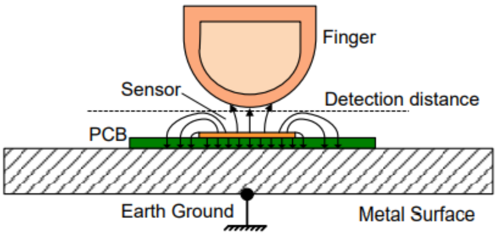
2.2.5 Notes for Application Environment of Capacitive Proximity Sensor

Do not place metal objects near the proximity sensor coil or close to the ground, otherwise, it will reduce the sensitivity and the sensing distance.

Because partial electric field may be captured by the metal or ground, it is required to increase the parasitic capacitance CP and thus reduce the capacitance generated by the finger and shorten the sensing distance.



Electric Field of Single Sensor



Electric Field of Single Sensor (ground or metal exists)

2.3 Sensor Pad of Wheel/Slider

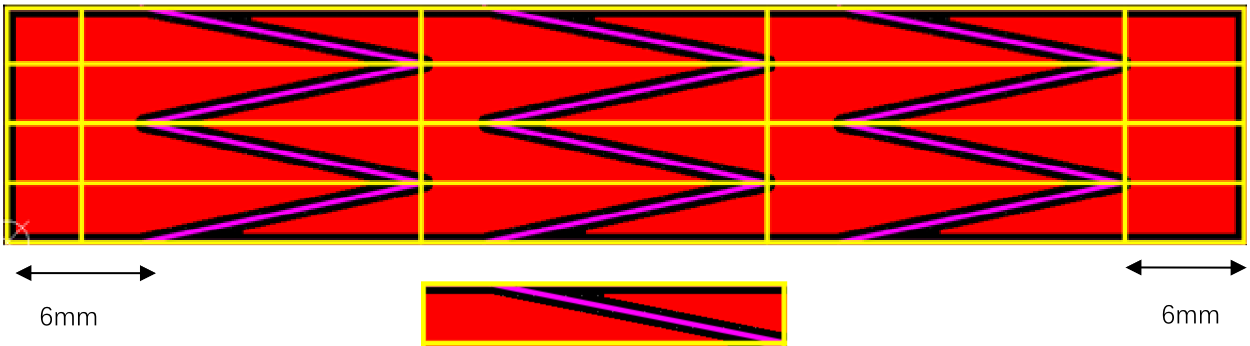
Please note that the capacitive proximity sensor technology is only available for **high-sensitivity touchkey applications** currently.

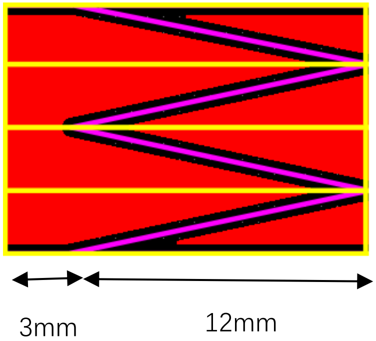
The wheel/slider is to detect the position touched by the finger in a one-dimensional direction. The effect of the sliding touch depends largely on the PCB design. The wheel/slider is based on the exact capacitance change ratio of each sensor channel to determine the finger position.

The sensor pad of the wheel/slider shall be arranged in the mode of interactive sawtooth on the PCB. To guarantee the effect, the width of the sensor pad shall be in the width of a finger (5mm-15mm) and the spacing between the sensor pads shall be more than 0.5mm. In principle, there shall be no components at the bottom of the sensor pad and parallel routing around the sensor pad shall be prohibited, especially for high-frequency signal cables. No TK routing for the wheel/slider can pass through the sensor pad area of other wheel/slider, and the cable of the sensor pad shall be led out at the edge to reduce the length of the routing.

2.3.1 PCB Design of Slider Sensor Pad

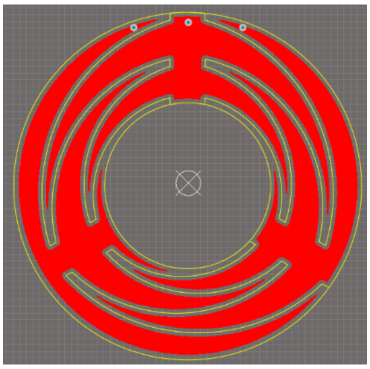
For the slider with total length of less than 50mm, it is recommended to use 4 TK channel for design. For the total length of the slider being increased by 10mm to 20mm, it is recommended to add one TK channel with each sawtooth being engaged; however, a transition area shall be reserved between the front and back of the sawtooth, as shown in the figure, if the length of the sawtooth is 12mm, the transition area shall be a quarter of the length, which is 3mm. A large transition area shall be reserved at the front and end of the slider, generally, half of the length of the sawtooth shall be taken, which is 6mm, for the purpose of obtaining the maximum and minimum values.



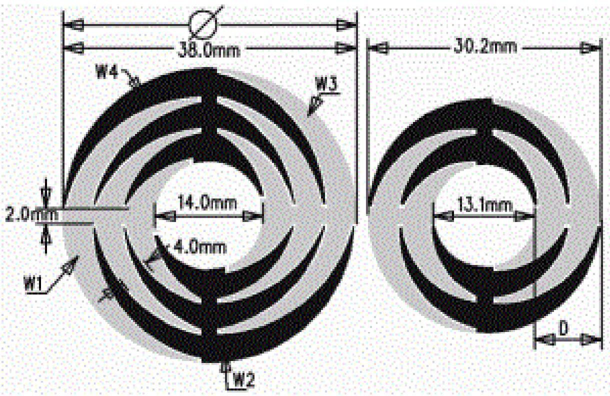


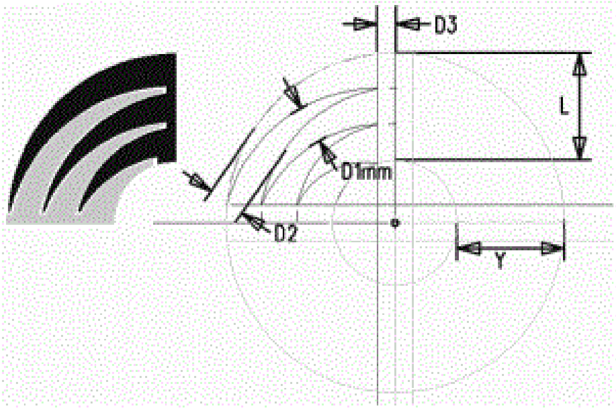
2.3.2 PCB Design of Wheel Sensor Pad

The wheel sensor pad is made by circular interactive sawtooth with the shape of each sensor pad remaining symmetrical. In practical application, the wheel PCB package provided by SinOne can be directly used to scale up and down in the same proportion. In the PCB design, the central transition area of each sensor pad be more than 2mm, and the number of the channels can be roughly rounded as the diameter of the outer ring (in mm) divided by 10 (not such strict in practical application), but the minimum number of TK channel shall be 3.



Design Method (as shown in the figure, the example is 4-channel wheel): First, draw the inner and outer circle of the wheel at the Drill Drawing layer according to the wheel's structure and size, then draw a frame line of half of the wheel channel after dividing the ring L into three equal parts, where D1=D2=4mm, and D1, D2 and the width of the ring are proportional to Y: D/Y=1/3, D3=1mm. After completing the border line, copy and paste the border line and rotate it for 3 times to get a symmetrical wheel and finally fill in the copper sheet.





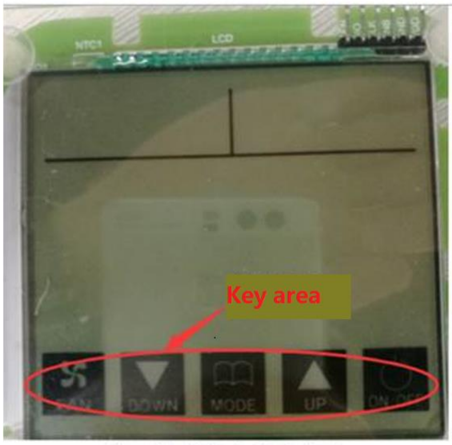
2.4 Design Instructions for LCD Screen with Touchkey

2.4.1 LCD Screen with Touchkey

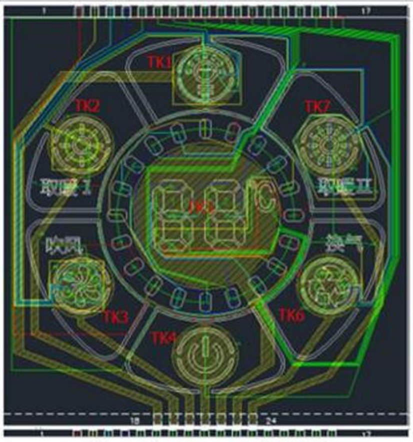
1. The LCD display is generally composed of two layers of glass and filled with liquid crystal in the middle. ITO is carved on the upper and lower glass at the display place to form two positive and negative plates (SEG and COM), which will be connected the packaged pins through ITO as the lead;
2. In general, the routing of the touch keys and touch channels is made of ITO. Sometimes, in order to reduce the routing impedance of the touch keys, the silver paste routing is applied to replace ITO routing on the touch keys, and the maximum routing impedance of the touch key is required to be no more than 1.5KΩ;
3. The ITO coating of touch LCK screen is divided into two layers and three layers; for two-layer ITO, the touch sensor PAD shares one layer with SEG or COM; for three-layer ITO, the touch sensor PAD is along on the top layer.

2.4.2 Three Common LCD Screen with Touchkey

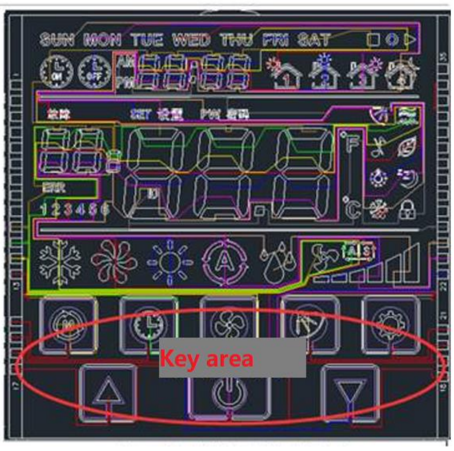
- Screen 1 (preferred): The display is completely separated with the keys, no key section is showed, a layer of black material is coated on the outside of the bottom glass to indicate the position of the key, and the keys are coated with ITO as the PAD of the touch sensor:
  - The routing of the touch keys on such screen is short, and the impedance of the touch key on the routing is usually within 1KΩ, which is easy to realize stable and effective touch control; therefore, it is strongly recommended.
- Screen 2: There are keys in the display area, through which the position of the keys can be indicated. This kind of the LCD screen has three layers of ITO, with the keys on the top layer;
  - Because the keys of such screen are distributed within the whole screen, the routing length of the touchkey channel differs significantly, and the maximum impedance is more than 5KΩ, as shown in the middle figure below. To reduce the impedance, it is required to lead the touchkey cables out to the upper and lower sides of LCD screen.
- Screen 3: The key area has a display, through which the position of the keys is indicated. This kind of LCD screen has two layers of ITO, with the keys and displayed SEG or COM sharing one;
  - As the following figure shown on the right, for this kind of screen, the cables are led out from the left and right sides of the LCD screen; because the spacing between the upper and lower rows of TK is too small, which has limited the width of the TK routing and resulted in too large impedance, it is required to lead the cable out downwards so as to increase the width of TK routing and reduce the impedance.



The first kind:The key area is separated from the display area.



The second kind: The key area is inside the display area.



The third kind: The display area is inside the key area.

2.4.3 Notes for LCD Touchkey Screen Design

1. Where there is a display around the keys, the switch of display will generate a high noise to TK. To reduce such noise and increase the amount of change and thus make the signal-to-noise ratio in normal range, LCD screen shall be designed to display the area as small as possible and make the area of the touch sensor as large as possible.
2. Screen 1 features simple operations and good anti-interference performance, which is recommended for users to choose;
3. For Screen 2 and Screen 3, due to complex routing, to guarantee the touch effects and performance, the following conditions shall be satisfied:
   1) TK routing impedance is lower than 1.5 KΩ
   2) The area of the touch sensor PAD is not less than 1.5 times of the displayed area.

2.5 Instructions for Spring Touch Scheme – General

This scheme is general with the minimum requirements on layout compared with others. For layout and routing, refer to 1.2 Requirements for Overall Layer.

3. Version Change History

Version	Change History	Date
V1.0	Initial version	Dec. 2022

Statement