Features of LC717A Series

Adhesive Free, Air-gap Available
- Dielectric Materials such as Light Guide Plates are Completely Removed
- Adhesive Process are Taken Away from the Assembly Process
- Mechanical and Electrical Components can be Mounted on Both Sides of PCB

Long Sensor Trace Available
- Long Sensor Traces Provide for a More Effective Design. The Touch Controller can be Placed anywhere on PCB, so that PCB can be Downsized thus Reducing Cost

Proximity
- LC717A Series has the Option of Adjusting Internal Gain of LSI to Incorporate Proximity Sensing

APPLICATION NOTE

Wide Range Operational Temperature
- High Temperature Operation Available

No Extra Components Necessary
- No Extra Components for Sensing, such as Resistance or Capacitance

High Noise Immunity
- IEC61000−4−6 (Level 3) is Certified

Touch ON/OFF Judgment Possible without a Program
- Nonvolatile Memory is Not Built-in. It is Unnecessary for Developers to Develop Touch ON/OFF Determination Process

SELECTION GUIDE FOR LC717A SERIES

LC717A series are designed for the customers to use easily and introduce into their applications quickly. All necessary functions for determining ON and OFF switching are built in one chip. Customers do not need to create any software programs to determine switching. The table below shows the comparison between LC717A series.

Table 1. COMPARISON BETWEEN LC717A SERIES

<table>
<thead>
<tr>
<th>Product Name</th>
<th>LC717A00AR (AJ)</th>
<th>LC717A10AR (AJ/PJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Sensor Inputs</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>Touch-ON Output Terminal Availability</td>
<td>Yes</td>
<td>No (Yes, when I2C/SPI Communication is Available)</td>
</tr>
<tr>
<td>Touch-ON Interrupt is Availability</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Key Features</td>
<td>– To Exchange Mechanical Switches. – To Reduce Design Resources during Introducing Products.</td>
<td>– More than 9 Inputs are Necessary. – To Reduce Current Consumption.</td>
</tr>
</tbody>
</table>
Touch-ON Output Terminal
The ON/OFF judgment result is outputted from Sensing-Output terminal (POUT0 to POUT7) of LC717A00AR/AJ. (The judgment result can also be read at I²C or SPI.) When the ON/OFF status from mechanical-switch is notified to the microcontroller using High (signal of power-supply-voltage level)/Low (signal of GND level), it is possible to replace mechanical-switch with touch-switch. If Sensing-Output function is used, it is not necessary to change the firmware of your products which use mechanical-switch. In such a case, the design resource of software can be reduced greatly. ON/OFF judging by LSI is possible for not only LC717A00AR/AJ but also LC717A10AR/AJ/PJ. In case of LC717A10AR/AJ/PJ, the judgment result can be read only from the register of LSI by I²C or SPI Interface.

Touch-On Interrupt
This function notifies a microcontroller that the touch judgment result is set to “ON”. For example, if you use this function, it is possible to change the state of microcontroller by Interrupt. When the touch judgment result has been “OFF” for a long time, the state of microcontroller can be changed to Sleep-Mode. When the touch judgment result changes to “ON”, the microcontroller can be waked up by touch-on interrupt By carrying out such control, power consumption of your products may be lower.

LC717A SERIES TUTORIAL

Using LC717A10ARGPGEVB and a microcontroller, we can operate touch switch easily.

LC717A10ARGPGEVB is the evaluation board which changed LC717A10AR into 2.54 mm pin pitch and anyone can purchase.

Figure 1. LC717A10ARGPGEVB

Step 1: Making a Switch Pattern
You can make a switch pattern from copper or an aluminum tape with reference to design rule. Since it is handmade, it is OK to have ambiguous pattern size.

In this example, It is made from a copper tape on 2mm-thick acrylics.

Figure 2.
Step 2: Making a Circuit

Figure 3.

Figure 4.

Figure 5.

Please fix handmade Touch Switch to an insulator, you can use with double-stick tape etc. With no insulator, operation is not stabilized.
Step 3: Write Microcontroller Program

```c
void main(void)
{
    // Since this is a sample program, the fail-safe for improving reliability is not contained.
    // Please add the code for fail-safe, as needed.
    //-------------------------------------------------------------
    // Initialize your microcontroller.
    //-------------------------------------------------------------
    InitializeMicro();
    //-------------------------------------------------------------
    // Initialize SPI interface (Unnecessary in I2C)
    //-------------------------------------------------------------
    Wait_for_50msec(); // wait 50 ms
    nCS = 1; // nCS -> High
    Wait_for_1msec(); // wait 1 ms
    nCS = 0; // nCS -> Low
    Wait_for_1msec(); // wait 1 ms
    nCS = 1; // nCS -> High
    Wait_for_50msec(); // wait 50 ms
    //-------------------------------------------------------------
    // Confirm that the calibration is complete
    //-------------------------------------------------------------
    for (;;){
        if(( SpiByteRead( 0x2F ) & 0x86 ) == 0x00 ){ break; }
    }
    // Wait WriteReq, ParaCh and StaCal bit of Control 1 Register are zero.
    //-------------------------------------------------------------
    // Setting Parameters
    //-------------------------------------------------------------
    SpiByteWrite( 0x00, 0x00 ); // Write 0x00 in UseChannel 1 Register
    SpiByteWrite( 0x01, 0x80 ); // Write 0x80 in UseChannel 2 Register
    SpiByteWrite( 0x09, 0x55 ); // Write 0x55 in Cin14/Cin15 2nd Gain Register
    // Please increase the GAIN, when sensitivity is low.
    SpiByteWrite( 0x19, 0x0A ); // Write 0x0A in Cin15 Threshold Register
    SpiByteWrite( 0x30, 0x80 ); // Write 0x80 in Average Count Register
    SpiByteWrite( 0x31, 0x0C ); // Write 0x0C in Filter Parameter Register
    //-------------------------------------------------------------
    // Renewal of parameters
    //-------------------------------------------------------------
    SpiByteWrite( 0x2F, 0x8F ); // Write 0x8F in Control 1 Register
    //-------------------------------------------------------------
    // Confirm that the calibration is complete
    //-------------------------------------------------------------
    for (;;){
        if(( SpiByteRead( 0x2F ) & 0x86 ) == 0x00 ){ break; }
    }
    // Wait WriteReq, ParaCh and StaCal bit of Control 1 Register are zero.
    //-------------------------------------------------------------
    // Read the state of Cin15 & LED ON/OFF Control
    //-------------------------------------------------------------
    for (;;){ //main loop
        if( (SpiByteRead( 0x2B ) & 0x80) == 0x80 ){ // Check the state of Cin15 of Result Data 2 Register
            LED(ON); // LED is turned ON if the state of Cin15 is a touch.
        } else{
            LED(OFF); // LED is turned OFF if the state of Cin15 is a no touch.
        }
        Wait_for_5msec(); // Insert waiting time(e.g., 5msec)
    }
}
```
Step 4: Verify Operation

1. Turn on a power supply (VDD = 2.6 V to 5.5 V)
2. Push the Reset button on the LC717A10ARGPGEVB
3. Reset the user’s microcontroller
4. A touch of a switch will shine LED.

Operation may not be stabilized for handmade switch. In that case, please perform reset operation.
PCB’s touch switch does not have a stability problem.
DESIGN SUPPORT SOFTWARE

We have prepared design support software on our WEB site. Software can be found by visiting onsemi.com and searching part number LC717A00AR/LC717A00AJ. Software will be located under ‘Software’ tab.

Design support software is used for the following purposes.

1. The real-time monitor of Data Register
2. Parameter setup support of various internal registers
3. Adjustment support of Gain Register
4. The output to the file of the set-up register value (development support of microcomputer firmware)

Please be sure to use this software for a setup of an internal register and gain adjustment.
PRINCIPLE OF OPERATION

Capacitive touch switch is a sensor which detects the change of capacitance (line of electric force) between sensor driver pin (Cdrv) and sensor input pin (CinX). The following diagram shows operation principles using lines of electric force. Cref represents reference capacitance input pin. When you put your finger closer to sensor input pin (CinX), the lines of power force reduces and capacitance changes. The switch turns on or off at the judgment threshold of capacitance.

The following shows the basic principle of CV (capacitance-voltage) conversion by “Differential capacitance detection (Mutual capacitance type)” in this LSI.

First, we consider a model of the change in capacitance when the finger touches the sensor. Figure 10 shows a model of the capacitance switch with no touch. Meanwhile, Figure 11 shows the model when touching. The model shows that lines of electric force between parallel plates are shielded by the conductor which is grounded.

Figure 9.

Figure 10.

Figure 11.
Next describes the behavior of the CV amplifier to realize the CV conversion. This CV amplifier realizes the CV conversion through a state change of two-phase (Phase1, Phase2) that are synchronized to Cdrv signal. Figure 12 and Figure 13 show the circuits of CV amplifier when the finger is not touching the switch. Since switch capacitance C1 does not change (C1 = C), reallocation of charge among C1, C2 and Cf does not occur between in Phase1 and in Phase2. As a result, amplifier output is also unchanged, it remains zero (Vf = 0).

Figure 12.

Figure 14 and Figure 15 show the circuits of CV amplifier when the finger is touching the switch. Since a part of the lines of electric force are absorbed by the finger, switch capacitance C1 reduces (C1 = C − ΔC).

Figure 14.

Because of this change, reallocation of charge among C1, C2 and Cf occurs between in Phase1 and in Phase2. As a result, amplifier output reduces (Vf = (ΔC / Cf) * VDD).

Figure 15.

This LSI incorporates differential-input CV amplifier whereby high sensitivity and noise immunity (in-phase noise immunity) are balanced. The descriptions on (1) High sensitivity and (2) Noise immunity (in-phase noise) are given below.

1) High Sensitivity

One possible cause of decrease in sensitivity is the influence of parasitic capacitor for GND. Sensitivity and parasitic capacitance are in inverse relation. In the electrostatic capacitance detection circuit, CV AMP is integrated. When electrostatic capacitance is measured, the 2 input pins of CV AMP, CinX and Cref are virtually-shorted at the potential of 0.5 VDD. In other words, the potential of the input of CV AMP is constantly 0.5 VDD, which cancels the influence of parasitic capacitor for GND wherein parasitic capacitance is apparently zero.
2) Noise (In-phase Noise) Immunity

Error detection likely occurs as the noise level increases due to external cause when without touch. Our LSI incorporates differential-input CV amplifier in electrostatic capacitance detection circuit. When external noise gets into 2 differential input pins (CinX, Cref), the noise is suppressed by in-phase noise rejection function of the CV AMP (in-phase noise rejection ratio: CMRR). As a result, output noise is reduced.
We introduce design rule for the “tile” (unit switch pattern), which is for LC717A series. The design rule (to be described later) leads to ideal tile size, which depends on both “the thickness of surface panel” (e.g. acrylic board) and “the distance from surface panel to PCB” (air gap distance). When you follow this design rule, signal-to-noise-ratio of the signal from touch switch should be greatly improved.

With the combination of multiple tiles, it is possible to design the touch switch of various form (e.g. array, slider and wheel).

*In the case of the switch pattern which cannot be made from a design rule, please contact us.
Design Rule for Single-Switch
(Design Rule for Using One Cin for One Switch)

In case that one switch consists of one Cin, the size of the tile is shown in Table 2. This tile size in Table 2 is a value estimated from our experimental result. Depending on the material which is currently used in your products, either change of gain register value or adjustment of tile size may be needed.

Table 2. TILE SIZE

<table>
<thead>
<tr>
<th>Thickness of Surface Panel (mm)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>2</th>
<th>3</th>
<th>2</th>
<th>3</th>
<th>2</th>
<th>3</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air-gap (mm)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.5</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>1.5</td>
<td>1.5</td>
<td>2</td>
</tr>
<tr>
<td>A: Fixed Cin Width (mm)</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>B: Minimum Cdrv Width (mm)</td>
<td>2</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>C: Fixed Cin–Cdrv Distance (mm)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D: Fixed Cdrv–GND Distance (mm)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity Value between Cin–Cdrv (pF)</td>
<td>0.50</td>
<td>0.63</td>
<td>0.81</td>
<td>0.81</td>
<td>0.63</td>
<td>0.72</td>
<td>0.72</td>
<td>0.81</td>
<td>0.81</td>
<td>0.97</td>
<td>0.97</td>
</tr>
</tbody>
</table>

1. It is a value when “Cin width = 13 mm” is not securable on the condition of “Thickness of surface panel = 3 mm” and “air gap = 2 mm”. Signal to Noise ratio may get a little worse.
2. The surface panel used in our experiment is acrylic board.
3. The thickness of PCB used in our experiment is 1.6 mm. If the back of a tile has a GND pattern, sensitivity of touch switch may fall. In such a case, adjustment such as expanding Cin width a little (about 0.5 mm to 1.0 mm) is needed.
4. This Table is the size of sensor-pattern, which is adjusted so that the value of Cin Data Register might be about 00010100b when 1st Gain is set to 0000b and 2nd Gain is set to 0100b.
5. Wider Cdrv has good SNR.

Actual Touch Detection Area

LC717A series detects a touch by interrupting the electrical flux line between Cin and Cdrv.

For this reason, if the finger is touching both Cdrv and Cin, Touch detection is enabled.

*It is not necessary to cover all Cin with a finger for touch detection.*
Design Rule for Single-Matrix (Design Rule for Using Two Cin for One Switch)

In case that one switch consists of two Cins and switches are arranged as matrix structure, the tile size is shown in Table 3. In this case, the total number of switches is greater than that of Cins. In order to realize 4x4 switch-matrix which consists of 16 switches, 8 (= 4 + 4) Cins are required.

The tile size in Table 3 is a value estimated from our experimental result. Depending on the material which is currently used in your products, either change of the gain register value or adjustment of tile size may be needed.

Table 3. TILE SIZE

<table>
<thead>
<tr>
<th>Thickness of Surface Panel (mm)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>2</th>
<th>3</th>
<th>2</th>
<th>3</th>
<th>2</th>
<th>3</th>
<th>3</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air-gap (mm)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.5</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>1.5</td>
<td>1.5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>A: Fixed Cin Width (mm)</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>B: Minimum Cdrv Width (mm) (Note 11)</td>
<td>2</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>10</td>
<td>10</td>
<td>13</td>
<td>10</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>C: Fixed Cin−Cdrv Distance (mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D: Fixed Cdrv−GND Distance (mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E: Fixed Cdrv Width between Cin−Cin (mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Capacity Value between Cin−Cdrv (pF)</td>
<td>0.50</td>
<td>0.63</td>
<td>0.81</td>
<td>0.81</td>
<td>0.63</td>
<td>0.72</td>
<td>0.72</td>
<td>0.81</td>
<td>0.81</td>
<td>0.97</td>
<td>0.97</td>
<td>1.03</td>
</tr>
</tbody>
</table>

6. It is a value when “Cin width = 13 mm” is not securable on the condition of “Thickness of surface panel = 3 mm” and “air gap = 1.5 mm”. Signal-to-noise ratio may get a little worse.
7. It is a value when “Cin width = 13 mm” is not securable on the condition of “Thickness of surface panel = 2 mm” and “air gap = 2 mm”. Signal-to-noise ratio may get a little worse.
8. The surface panel used in our experiment is acrylic board.
9. The thickness of PCB used in our experiment is 1.6 mm. If the back of a tile has a GND pattern, sensitivity of touch switch may fall. In such a case, adjustment of expanding Cin width a little (about 0.5 mm to 1.0 mm) is needed.
10. This table is the size of sensor-pattern, which is adjusted so that the value of Cin Data Register might be about 00010100b when 1st Gain is set to 0000b and 2nd Gain is set to 0100b.
11. Wider Cdrv has good SNR.
**Matrix Switch**

You can use more switches by combining the input PAD. If you set the 4×4 matrix, you can use 16 switches. (LC717A10 supports up to 64 switches)

![Matrix Switch Diagram]

**NOTE:** You can use 16 switches, but you can’t activate them simultaneously. Simultaneous activation leads to "ghost" reaction.

The ghost reaction is a phenomenon where the LSI cannot determine which switch to turn ON.

e.g.) Even when Cin1,3,4,6 are ON, LC717A series cannot determine the touch point between A and D or B and C. Normally, when 4 points are turned on, MCU ignores and the operation continues.

**Conditions which are not Part of Design Rule**

The dielectric constant of acryl is about 3 to 4 times the air layer.

You can calculate in simple using this character. Example computation is shown below.

In case you make the switch pattern of 1 mm-air-gap and 7 mm-cover (acryl), This condition does not exist in a design rule.

![Diagram of Design Rule]

**Table 4. TILE SIZE**

<table>
<thead>
<tr>
<th>Thickness of Surface Panel (mm)</th>
<th>2</th>
<th>3</th>
<th>2</th>
<th>3</th>
<th>2</th>
<th>3</th>
<th>2</th>
<th>3</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air-gap (mm)</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Recommended Switch Pattern</td>
<td>PA</td>
<td>PA</td>
<td>PA</td>
<td>PA</td>
<td>PB</td>
<td>PB</td>
<td>PB</td>
<td>PB</td>
<td>PB</td>
<td>PB</td>
</tr>
</tbody>
</table>

Recommended Switch Pattern “PA” (Cin–Cdrv Capacity is 1.22 pF). This pattern can be adapted for the air-gap from 3 mm to 4 mm.

A (Cin Width): 8 mm
B (Cdrv Width): 10 mm or more
(If it is possible, please extend width as much as possible)
C (Cdrv–Cin Distance): 1 mm
D (Cdrv–GND Distance): 1 mm

**NOTE:** The thickness of PCB used in our experiment is 1.6 mm. If the back of a tile has a GND pattern, sensitivity of touch switch may fall. In such a case, adjustment of expanding Cin width a little (about 0.5 mm to 1.0 mm) is needed.

![Diagram of Design Case]
Recommended Switch Pattern “PB” (Cin−Cdrv Capacity is 4.13 pF). This pattern can be adapted for the air-gap from 5 mm to 8 mm.

A (Cin Width): 4 mm  
B (Cdrv Width): 7 mm or more  
         (Please extend width as much as possible)  
C (Cdrv−Cin Distance): 1 mm  
D (Cdrv−GND Distance): 1 mm  
E (Cdrv Width between Cin−Cin): 1 mm  

In case an air-gap is thick, separation with an adjacent switch becomes difficult.  
In that case, you read the Data Register currently used as Cin and recognize Cin of the largest data as a touch-ON.  

NOTE: The thickness of PCB used in our experiment is 1.6 mm. If the back of a tile has a GND pattern, sensitivity of touch switch may fall. In such a case, adjustment of expanding Cin width a little (about 0.5 mm) is needed.

Notes on Tile Arrangement  
When Cin to Cin and Cin to PCB-end distance is short, you may not be able to arrange the previously-mentioned tiles on PCB. We explain the solution to this problem below.

Tile Arrangement when Using Overlapped Cdrv Pattern  
The Cdrv section of tiles can be overlapped. The distance between tiles can be reduced by using overlapped Cdrv pattern. By doing this, It is possible for you to use this touch-switch for more applications.

The Maximum Number of a Tile Connectable with Cin(Cref)  
The number of Tiles connectable with one Cin is determined by the total of the capacity between Cin and Cdrv. Capacity between Cin and Cdrv permissible in one Cin is 8 pF.  
For example, when the capacity between Cin and Cdrv of a Tile is 1 pF, you can connect 8 Tiles at the maximum.  
In case you tie three 1 pF Tiles to one Cin.

The Setting Method of Static OffCal CDAC Base Register  
The value set up by “Static OffCal CDAC Base Register”, It is a value of reference capacity when carrying out a static offset calibration, this reference capacity value is compared with the capacity value between Cin (or Cref)−Cdrv(s) of a sensor pattern, and the measurement condition used as the standard of touch detection measurement is determined.
When determining the above-mentioned measurement condition, the dynamic range of OPAmpl inside LSI is determined. The dynamic range of OPAmpl becomes larger as the capacity value between Cin−Cdrv of reference capacity and a sensor pattern becomes near. Since the characteristic of touch detection will improve if the dynamic range of OPAmpl becomes larger, it recommends that “Static OffCal CDAC Base Register” carries out the optimal setup to the capacity value between Cin−Cdrv.

The optimal preset value of “Static OffCal CDAC Base Register” changes with capacity (when two or more sensor patterns are connected to one Cin, it is total capacity value) between Cin−Cdrv.

Please set the following as reference.

- Capacity Value of Cin (Cref)−Cdrv = greater than 2 pF and under 8 pF: 0x80 (4pF)
- Capacity Value of Cin (Cref)−Cdrv = greater than 1 pF and under 2 pF: 0x40 (2pF)
- Capacity Value of Cin (Cref)−Cdrv = under 1 pF: 0x20 (1pF)

However, when the sensor pattern with which a size is different for every Cin is being used, please consider the above to the capacity value between largest Cin−Cdrv.

For example, when a 1.5 pF sensor pattern and a 5 pF sensor pattern are being used, please set up 0x80.

We have the software for finding the capacitance of sensor pattern between Cin (Cref) and Cdrv pins. You can download the software from our web site.

Moreover, when determining a register value using our design support software, you do not need to be conscious about the setting method of Static OffCal CDAC Bass Register.

Design Method for Cref Pattern

LC717A series needs sensor pattern connected to Cin and also reference pattern connected to Cref. With Cref pattern, you can use the same tile as used with Cin.

If you arrange Cref on the top layer of board, the electrical flux line between Cref and Cdrv may be intercepted when a surface panel is touched, and the reference capacity may be altered.

A solution to the above-mentioned problem, Cref pattern is arranged on the bottom layer, and top layer except over Cref is covered with GND. In such a case, there is no electrical flux lines between Cref and Cdrv (in others words, on the front side of the board). Since the capacitance does not change when Cref is touched, the value of measured data does not change.

In addition, since Cref pattern is not covered with GND on top layer, Cref receives the same amount of noise as Cin from front side. So, it is possible for the internal circuit of LSI to cancel these noises as common mode noise.

However, please do not arrange noise source such as a switch power supply near Cref pattern, because Cref is influenced by the noise from the back side of the board.

In case that you can’t arrange Cref pattern without influence from noise source, or in case that you use single layer board, please connect the chip capacitor, which has almost the same capacity value as that of the tile between Cref and Cdrv, near the LSI. To learn more about chip capacitor, please refer to “Design Rule for Unit Switch Pattern”.

Design Rule (Other than Tile)

In producing the PCB, design rules other than Tile are explained.

Common Design Rule

Table 5 shows common design rule about wiring of Cin, Cdrv and so on.
### Table 5. COMMON DESIGN RULE

<table>
<thead>
<tr>
<th>Item</th>
<th>Design Rule</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line width of Cin (or Cref or Cdrv)</td>
<td>0.2 mm wide or smaller</td>
<td>Touch detection result is susceptible to noise signals if line width is wide.</td>
</tr>
<tr>
<td>Distance of the Line between Cin–Cin (or Cref)</td>
<td>0.2 mm or greater</td>
<td>If this distance is too short, sensitivity of touch switch may fall.</td>
</tr>
<tr>
<td>Distance of the Line between Cin (or Cref)–GND (or DC signal)</td>
<td>(Recommended value is 0.5 mm or greater)</td>
<td></td>
</tr>
<tr>
<td>Side-by-side arrangement of Cin (or Cref) and other signal line</td>
<td>Unfavorable</td>
<td>Other signal line means lines other than Cin, Cref, GND or DC signal.</td>
</tr>
<tr>
<td></td>
<td>(Both on the front side of PCB and on the back side of PCB). if you have to make this arrangement reluctantly, insert the GND line with more than 1mm width between Cin (or Cref) and other signal line.</td>
<td>Other signal line serves as a noise source, which results in malfunction or degradation of the characteristic.</td>
</tr>
<tr>
<td>Thickness of PCB</td>
<td>Recommended value is 1.0 mm or greater</td>
<td>If there is GND on the back side of the tile and if PCB is too thin, sensitivity of touch switch may fall greatly. If there is no GND on the back side of the tile, touch detection result is susceptible to noise signals from the back side of PCB. Please be careful.</td>
</tr>
</tbody>
</table>

![Diagram of design rule](image)

**Figure 21.**

**Design Rule (for 1-layer PCB)**

### Table 6. DESIGN RULE FOR 1-LAYER PCB

<table>
<thead>
<tr>
<th>Item</th>
<th>Design Rule</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance of the line between Cdrv–Cin</td>
<td>15 mm or greater, and insert GND between lines</td>
<td>If you arrange Cdrv and Cin side by side, undesirable touch sensor area may be formed between these lines.</td>
</tr>
</tbody>
</table>

![Diagram of design rule](image)

**Figure 22.**
Design Rule (for 2-layer PCB)

Table 7. DESIGN RULE FOR 2-LAYER PCB

<table>
<thead>
<tr>
<th>Item</th>
<th>Design Rule</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance of the line between Cdrv–Cin (or Cref)</td>
<td>5 mm or greater</td>
<td>The line of Cdrv/Cin/Cref should be wired on the back side of PCB.</td>
</tr>
<tr>
<td>Back side of Tile</td>
<td>Please do not arrange any patterns other than GND on the back side of the Cin pattern in the tile.</td>
<td>If the line other than GND is arranged on the back side of the Cin pattern, the erroneous touch decision may occur.</td>
</tr>
<tr>
<td></td>
<td>The thickness of PCB recommends 1 mm or greater.</td>
<td></td>
</tr>
</tbody>
</table>

Figure 23.

Design Rule (for Multi-layer PCB)

In producing multi-layer PCB, the following design rules are added in addition to “Design Rule (for 2-layer PCB)”.

Table 8. ADDITIONAL DESIGN RULE

<table>
<thead>
<tr>
<th>Item</th>
<th>Design Rule</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wiring position of Cin, Cref or Cdrv</td>
<td>Please wire on the bottom layer as mush as possible.</td>
<td>This makes it possible for you to debug easily if there is a problem in wiring. However, if the environment around the outer layer is very bad touch detection result is susceptible to noise signals, you may wire Cin (or Cref or Cdrv) on the inner layer.</td>
</tr>
<tr>
<td>Wiring on the inner layer</td>
<td>Please do not arrange the ground plane either on the inner layer under tile part (between red dashed lines), or on the inner layer over Cin (or Cref or Cdrv) wiring part (between blue dashed lines). In addition, please do not arrange other wiring on the inner layer under Cin (or Cref) pattern in the tile (between green dashed lines).</td>
<td>This results in remarkable deterioration of sensitivity of touch switch. If there is other wiring on the inner layer under Cin (or Cref) pattern of the tile, erroneous touch switch decisions may occur.</td>
</tr>
<tr>
<td>Side-by-side arrangement of Cin (or Cref) and other signal line</td>
<td>If you can’t avoid this arrangement for some reason, please wire other signal line on a layer with a distance as long as possible from bottom layer, where there is either wiring of Cin or wiring of Cref.</td>
<td>This results in either deterioration of sensitivity or erroneous touch decisions of touch switch.</td>
</tr>
</tbody>
</table>

Figure 24.
Influence of Parasitic Capacitance

The sensitivity of a sensor falls as the parasitic capacitance between Cin–GND (or between Cin–Cin*) increases. The following measure is mentioned in order to prevent the fall of sensitivity.

1. Distance between Cin–GND (or between Cin–Cin) is Lengthened.
2. Wiring Distance of Cin is Shortened.

*Cin is being fixed to GND (VSS) except the time of measurement. Therefore, the capacity between Cin–GND and the capacity between Cin–Cin become the same meaning.

When the above-mentioned measures are difficult, respond by setting up a higher gain. In this case, S/N of a sensor gets worse. In the case where touch switch is placed in a severe noise environment, cautions are required.

Example: 2-layer PCB (thickness = 1.6 mm), Relative Permittivity = 4.3, Cin width = 0.2 mm, Cin–GND distance = 0.2 mm. When designed by the above-mentioned set up, when 10 cm wiring is lengthened, sensitivity will fall about 10%. (The following figure circuit pattern)

In the case of LC717A series, the max wiring length of Cin is 500 mm. (Recommendation is 300 mm or less.)

When wiring of Cin is long, Please extend the distance between Cin and GND (distance between Cin and Cin is included) as much as possible.

Influences when Backside is All GND

There are some electrical flux lines between Cin and Cdrv that are terminated to the back side of all GND. Therefore, if the distance of Cin and back side of all GND is small, touch detection sensitivity falls.

However, we recommend back side all GND. This reason is for suppressing the influence of an exogenous noise.

The following graphs show the relation between Tile(Cin) – allGND distance and touch sensitivity.

In the case the distance of Tile(Cin) and all GND is small, touch sensitivity falls.

This graph references data when Cin width is 8 mm and PCB conductivity is 4.3. Results may differ by pattern.
In the case it is expected that sensitivity falls by a thin PCB or long Cin wiring, we recommend making trial PCB to check sensitivity of different Cin sizes. You can find optimal Cin size by trial production PCB.

**Figure 26.**

**Figure 27.**

**Large-size Switch PCB Pattern**

When using a matrix structure switch, or using large-sized switch, the capacity value between Cin–Cdrv of the sensor pattern connected to the Capacitance sensor input terminal (Cin) becomes large. In this case, please design the capacity value between Cin–Cdrv to one of Cin to be set to 8 pF or less that specified in the input offset capacitance adjustment range CoffRANGE in the datasheet.

In a similar case, as for the sensor pattern (or chip capacitor) connected to Cref, the capacity value between Cref–Cdrv should be set to 8 pF or less.

If the capacity value between Cin (or Cref)–Cdrv exceeds 8 pF, touch detection may be impossible. Please be careful.

**Pattern Using Single Cin Channel**

When you make the switch area large, you create a switch arranged with multiple Tiles (same Cin channel).

However, just simply arrange the Tiles, there is a large difference in sensitivity of the switches from the middle to the end.
Therefore, by increasing the distance between Tile to Tile, it adjusts so that as two or more Cins as possible may not be simultaneously touched.

The standard distance between Tile to Tile is the width of the finger, from Tile end to second Tile end. (about 7 mm)

Pattern Using any Cin Channel

When there are any unused Cin channel, 2 or more Cin are arranged alternately, so it create stable touch operation.

Example using 2 Cins

Example using 4 Cins

In this case, the arrangement has a distance of the same Cin channels larger than the construction of a single Cin channel. Therefore, there is less unevenness of touch sensitivity.

It is also possible to arrange LED in the center of switch.

NOTE: Section “Arrangement of parts: LEDs, wiring, etc" will describe the correct manner of adding an LED to center of switch.

Arrangement of Parts: LEDs, Wiring, etc...

It is possible to arrange parts, such as LED and wiring, to the Cdrv section of a sensor pattern. However, since arrangement of LED into Cin causes issues, such as sensitivity, it is not recommend.

It is possible to use PWM (Pulse Width Modulation) for the brilliance control of LED. The frequency of PWM is recommended to be 10 kHz or less. The wiring for Cdrv allows a DC signal or AC signal of 10 kHz or less.

1. When you make arranged LED drive with a transistor, please arrange in parallel with resistance (10 kΩ grade) so that the collector side of a transistor does not become floating (see Figure 29). Moreover, since PWM may becomes a noise source when adjusting the luminosity of LED using PWM, please fully check that it is satisfactory in your noise examination.

2. It recommends connecting the current-limiting resistor for driving LED to the position shown by the Figure 28.
LC717A00 Pout terminal outputs up to 8 mA per output (where the duty is 50%). Make sure that the total current is 40 mA at a maximum in the LSI (where the duty is 25%). If you need more output current, please add transistor.

How to Make Non-square Switches Using Tiles

**A Rectangular Switch**

- Cin
- Cdrv
- switch printed on the cover

*Don’t make Cin into a rectangle.*

A rectangular switch is printed on a square tile.

Cin is arranged at about 7 mm intervals.

**A Round Switch**

- Cin
- Cdrv
- switch printed on the cover

*Don’t make Cin and Cdrv into a circle.*

A round switch is printed on a square tile.

**A Small Switch**

- Cin
- Cdrv
- switch printed on the cover

*Don’t make Cin and Cdrv small like the printed switch.*

3. In case you want to shine LED in the center of a switch, you arrange Cin below a center. Even if you touch a center(LED), it operates satisfactorily, because LC717A series detects a touch by interrupting the electrical flux line between Cin and Cdrv. It is not necessary to cover all Cin with a finger for touch detection.
Water-proof PCB Pattern

Waterdrops of spray or rain do not affect its functionality. Besides, water repellent finish or extra water drainage with such as inclining touch panel part will improve its robustness against water. However, it cannot function properly with touch panel fully covered by water or liquid.

How Waterdrops may Affect Touch Sensor Functionality

With no impact of water on the panel, lines of electric force between Cdrv and Cin are absorbed by the finger when it is approaching. This is because the human body behaves like GND because of its great amount of mass.

LSI identifies touch ON/OFF with picking up variation of lines of electric force (capacitance) between Cin and Cdrv.

Just some water drops between Cin–Cdrv should not affect lines of electric force as water drops has much less mass than human body. Hence, mis-judge should not occur just with some water drops.

However, as the water drops are too much in quantity and reaching out to any surrounding GND’s, it causes very strong electrical connectivity between GND and water, which simulates human body touches. This model may vary existing electric force lines, which may cause a mis-judge.

A counter-measure to this risk is to use sensor patterns which prevent electrical connectivity between water and GND. Hereunder a pattern is shown as an example.

To cover by Cdrv all over the part subject to water.

If replace all the GND of touch sensor face by Cdrv as shown below, there is no electrical connection between water and GND.

On the other hand, even with a case where mis-judge may be caused as water drop becomes “huge”, it can be corrected by firmware design at Microcontroller side.

Double touches at a same time to be disabled. Upper microcontroller can cancel touch sensing by firmware when tow or more switches sense a value change, by identifying it as a disturbance other then a human finger. Large amount of water/liquid may bridge neighboring switches. When a switch encounters a large amount of liquid, touch sensor can possibly consider this as plural switches. Thus mis-judge can be avoided by disabling multi-touch at same time. In the case of an individual switch without neighboring switches, unused Cin can be used as dummy switches. These dummy switches can be placed around an individual switch, this will identify water or any electric conductor that covers the switches, this will enable design algorithm to avoid mis-judge.

We do not guarantee the LSI operation under water. Please refrain from using this LSI under water.

For example, an underwater camera etc.
Pattern for Self Check

We introduce the self check pattern, which is used to check whether there is a short of a sensor signal (Cin, Cref or Cdrv) and/or whether there is poor sensitivity of sensor signals. To do this “Self Check Test” has been made.

Pattern for Self Check

Whenever you use the tile in design rule, please arrange 10 mm square TEST PAD at the back of Tile, as shown in the figure below. Insert space with 1mm width between 10 mm square TEST PAD and GND. TEST PAD is connected to the I/O port of microcontroller. You do not have to use a perfect square TEST PAD because of convenient wiring.

If you use tile larger then design rule, full Cin must be over TEST PAD and partial Cdrv must be over TEST PAD as shown in figure below. Insert space with 1 mm width between TEST PAD and GND.

Principle of “Self Check Test”

If you can change the output to TEST PAD between Hi-Z and GND (VSS) via microcontroller, then you can make artificial finger touches. (Hi-Z = “non-touch”, GND = “touch”)

If you want to do “Self Check Test”, you have to make the above-mentioned pattern, and wire the line to the I/O port of microcontroller to change output to TEST PAD.

NOTE: With the exception of being in “Self Check Test”, the output to TEST PAD must be fixed to GND.

Procedure for “Self Check Test”

1. Microcontroller sets the output to TEST PAD to GND and then resets LC717A series.
2. Microcontroller sets the output to TEST PAD to Hi-Z. The value of Cin Data Register turns into a negative value. In a short time, Cin Data Register value returns to about zero automatically by dynamic offset calibration. (for checking of calibration operation in LSI)
3. Microcontroller sets the output to TEST PAD to GND. The value of Cin Data Register turns into positive value, and the touch result of each channel is usually set to ON. (for checking of touch operation). At this time, Poor sensitivity can be checked by reading the value of Cin Data Register.

NOTE: In case that you use a big tile, the value of Cin Data Register may be saturated during the “Self Check Test”. In this case, please set lower gain so that value of Cin Data Register is not saturated, then perform the “Self Check Test” again.

Substitution of Finger with a Stylus

Any conductive object will detect a touch. However if the area of contact is as small as fine needle, sensitivity drops because the lines of electric force which extend from Cdrv pin to Cin pin are too weak. If you wish to use metallic stylus as pointer, you must take this into consideration for setting sensitivity.

A Touch Switch Made from ITO

LC717A series supports the ITO (Indium Tin Oxide). Compared to PCB, the resistance generated from wiring in ITO is very large and it is hard for the LSI to operate properly. Hence sensitivity gets degraded. This is not confined to our LSI alone, but applicable to any LSI in general. Hence, make sure to keep the layout of ITO as short as possible.
**HOW TO SUPPRESS THE INFLUENCE OF A NOISE**

### I2C, SPI Interface Communication

We recommend verification of data (read/write) for communication fault detection. (However, since Control 1 Register and Control 2 Register change a value automatically, it cannot verify.) Moreover, if the communication fault by a noise is anxious, we recommend using SPI interface.

According to our noise test (pull-up resistor = 3.3 kΩ, VDD = 3.3 V, noise amplitude = 9.0 Vpp, noise frequency = 1~75 MHz),

- Noise Immunity with the use of I2C Interface is 35 MHz or Lower
- Noise Immunity with the use of SPI Interface is 75 MHz or Lower

(judged by the presence of error operation when the sensor is touched).

In a noise, I2C is weaker than SPI. It is because impedance of I2C is higher than SPI.

<table>
<thead>
<tr>
<th>Terminal</th>
<th>Current-Limiting Resistor (max resistance value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cin</td>
<td>10kΩ (1kΩ or less recommended)</td>
</tr>
<tr>
<td>Cref</td>
<td>10kΩ (1kΩ or less recommended)</td>
</tr>
<tr>
<td>Cdrv</td>
<td>1kΩ</td>
</tr>
</tbody>
</table>

**NOTE:** Even if it performs the above-mentioned measures, when ESD tolerance is not improved, it is considered a cause except LC717A series. The cause may be a I2C/SPI communication fault by the impression noise. Keep in mind with I2C the tolerance over an exogenous noise is weak, due to high impedance of (pull-up resistor) of the communication line. Moreover, the noise impression to a nRST (reset) terminal is also considered.

### ESD (Electro-Static Discharge)

The touch sensor is completely insulated from the human body. For this reason, Surge does not enter directly from a human body like a mechanical switch. LC717A series can pass IEC61000−4−2 Level 4 (Contact; 8 kV, Air; 15 kV) easily.

Moreover, when ESD tolerance becomes a problem, arranging the resistance for the following surge current restrictions in series on Cin, Cref, and Cdrv lines will help improve ESD tolerance. Please attach current-limiting resistors near the LC717A series.

### EMI (Electromagnetic Interference)

If the antenna of radio is brought close to a switch pattern, noise sound can be heard from radio. This is caused by a 143 kHz (typ) rectangular wave that is outputted from the Cdrv terminal. The rectangular wave of Cdrv contains 143 kHz fundamental waves and many harmonics which is an odd multiple of 143 kHz.

When the above-mentioned harmonics become a problem as EMI (electromagnetic interference), it is possible to reduce harmonics by adding a CR low pass filter to Cdrv.
Recommended values of CR Filter: Resistance (R) = 1 kΩ, Capacitance (C) = 500 pF or less. However, the parasitic capacitance value between Cdrv−GND of a sensor pattern is also included in 500 pF of C.

The parasitic capacitance value between Cdrv−GND of a sensor pattern can be calculated by the same method as calculating parallel monotonous capacitor capacity.

**Example:**
Thickness of the Two-layer Board: 1.6 mm
Gross Area of Cdrv (of a sensor pattern): 25 cm²
Non-dielectric Constant of a Substrate: 4.3

\[
C_{\text{Cdrv-GND}} = \varepsilon \cdot \varepsilon_0 \frac{S}{d} = 
\]
\[
= 4.3 \times 8.854 \times 10^{-12} \times \frac{25 \text{ cm}^2}{1.6 \text{ mm}} = 
\]
\[
= 60 \text{ pF}
\]

From the above-mentioned calculation, capacity to be added becomes less than 440 pF (= 500 pF – 60 pF) between Cdrv – GND.

In case there is already R (1 kΩ) for ESD, R (1 kΩ) for EMI is unnecessary.

In case of quadratic filter, recommended values are R = 500 Ω and C = 330 pF or less.

**EMS (Electromagnetic Susceptibility)**

*LC717A series can pass IEC61000-4-6 (Level 3) easily using the recommendation switch pattern.* Therefore, LC717A series can be used in noisy environments. (Microwave oven, IH cooker, etc.) However we would request for detailed environment testing (prototype & validation). Moreover, when an insurmountable amount of noise is inputted, touch detection sensitivity falls automatically. This prevents an incorrect touch and operates as a fail-safe function.

We perform evaluation based on IEC61000-4-6 (Level 3).

**TEST STATUS:**
Test Method: IEC61000-4-6:2008
Frequency Range: 150 kHz–80 MHz
Power Supply: 2.6 V, 5.5 V
Temperature: 21°C
Humidity: 35%
Test Room: Shielded Room

Test Level: 10 emf(V)
Model Name: Our Reference Board

![Image showing the LC717A Series and parasitic capacitance](image-url)
Based on the standard of IEC61000−4−6, The common mode noise of a power supply should be 10 Vpp or less.

NOTE: The switch pattern of LC717A00ARGEVK is made from the old design rule. Therefore, it may not pass to IEC61000−4−6 (Level 3). When you begin to design PCB for LC717A series, please use the newest design rule in this application note.

IMPORTANT NOTES

nRST Pin

In order to use POR(power on reset), you need to fix nRST pin to VDD. (Do not set nRST to open.) However, the characteristics of power-on waveform has to follow as defined in specification.

If supply to VDD is unstable or waveform at power supply cannot meet specification, you can either control nRST pin from GPIO in the MCU or use external power-on reset circuit (capacitor + resistor + diode).

Caution: Capacitance and resistance should be defined in such a way to enable reset for 10 μs (approx.) after power supply is stabilized.

If high reliability is required, we do not recommend using POR for LC717A series. Moreover, in order to prevent malfunction by a noise, we recommend attaching the capacitor for noise rejection between nRST and GND.

During reset, each pin of this LSI becomes Hi-Z. For this reason, due to external effects: such as noise, if intermediate electric potential across input, the current will flow. If this is a normal reset period and is only temporary, it will cause no problem. However, do not set the reset pin (nRST) to low for a longer period then it takes to energize VDD.

Environmental Calibration

LC717A series are maintenance-free. The calibration function is integrated to support the aging of sensor board and the change of temperature.

IEC 60730−1/IEC 60335−1 Self Test Library

LC717A Series is ASSP (Application Specific Standard Product) made only for the touch switch. Therefore, only LC717A device is not the target of IEC 60730−1/IEC 60335−1. However, your set which uses LC717A series might be the target of IEC 60730−1/IEC 60335−1.

We have prepared Self Test Library (STL: Self Test Library) of LC717A10 for your set to pass IEC 60730−1/IEC 60335−1.

Please contact us, if required.
Unlike tactile switch or resistor-type touch sensor, electrostatic capacitance touch sensor has no mechanical operation parts. Hence it is free of breakdown and has a long life without need of maintenance. However, if there is an air gap between surface and a board, the dust can possibly be an issue.

Even if you supply VDD in state which put the finger on Touch Switch, LC717A series do not malfunction. That is, in other words, the touch is not detected until you release the finger from the touch switch, but you release your finger from the touch switch once, then subsequent touch detection will work correctly.

**In order to prevent malfunction of dynamic offset calibration, the un-touching noise level of Data Register always needs to be 2 or less.**

When operating time is long (for example, it continues operating for 24 hours), We recommend initialization (Static offset calibration & Changing parameters@Control 1 Register) of LC717A series periodically for a fail-safe.

**Calibration error**

It occurs when the capacitance value of switch pattern exceeds the effective value of LSI internal compensation capacitance.

It is necessary to re-design a switch pattern if calibration error occurs under customer’s environmental testing (with practical temperature and humidity).

**Suitable Surface Covers LC717A Series can Use**

Any insulator (volume resistivity > 1 MΩ·m*) will do, such as PVC, acrylic and glass. However, the insulator should not be coated with metallic or carbon which conducts electricity.

Moreover, the thickness of a cover must be 1 mm or more (use glass, acrylic, plastic, etc.). If the sensor is not covered or the cover is thin, capacitance detection works differently.

*This is resistivity, not resistance.

Line of electric force without cover Finger becomes a dielectrics and the electric force increases. (As a result, touch sensor malfunctions.)

- Line of electric force with cover Finger becomes a shield and the electric force decreases.

**Touch ON Automatic Cancellation Function**

LC717A00AR (AJ) has Touch ON automatic cancellation function. This is a fail-safe function to avoid external touch-on, this includes any non-finger touches. With the default setting a touch after 10 seconds will set auto-off function. You can set auto-off time by Touch ON Count Lower/Higher Register.

It is recommended to set the auto-off time as short as possible, although it is all depends on the features of customers’ products.

**LC717A10AR (AJ/PJ) does not have Touch ON automatic cancellation function. Therefore, you need to implement the auto touch-off function to the firmware of microcontroller for a fail-safe.**

**Unused Cin Pin**

When the LSI is implemented to the application, set the unused pins to open. By disabling the unused channels by Use Channel Register, you can shorten the measurement time. See “Use Channel Register” for further details.

**Initialization of SPI Interface**

After power supply and reset, I²C is selected as interface. Then after the falling edge (not level) of nCS pin is detected, SPI is selected. Hence if input signal to SCK/SI while nCS pin is high and if signal is applicable to I²C then communication is established by false. This will lead to error operation.

When you use SPI, please be sure to perform proper initialization. At first, check that INTOUT terminal is set to Low after reset. After that, please move nCS terminal in order of High → Low (1 μs or more) → High. In case this initialization is not performed, INTOUT which reports the end of initialization may not be set to High.

In case that INTOUT is not used, Please move nCS terminal in order of High → Low (1 μs or more) → High after waiting 20 ms or more from reset of LSI. Begin SPI communication after waiting 1.5 ms or more.

Moreover, while you are not communicating, please always set nCS terminal to High level. Return the nCS terminal to High level as soon as possible after the SPI communication.
### Appendix:

**SPI MODE 0 (Data Write)**

<table>
<thead>
<tr>
<th>nCS</th>
<th>SCK</th>
<th>SI</th>
<th>SO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hi−Z</td>
</tr>
</tbody>
</table>

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Register Address(N)</td>
<td>Data written to Register Address(N)</td>
<td>Data written to Register Address(N+1)</td>
<td>Hi−Z</td>
</tr>
</tbody>
</table>

**SPI MODE 0 (Data Read)**

<table>
<thead>
<tr>
<th>nCS</th>
<th>SCK</th>
<th>SI</th>
<th>SO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hi−Z</td>
</tr>
</tbody>
</table>

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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</tr>
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<tbody>
<tr>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Register Address(N)</td>
<td></td>
<td>Data read from Register Address(N)</td>
<td>Data read from Register Address(N+1)</td>
</tr>
</tbody>
</table>

**SPI MODE 3 (Data Write)**

<table>
<thead>
<tr>
<th>nCS</th>
<th>SCK</th>
<th>SI</th>
<th>SO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hi−Z</td>
</tr>
</tbody>
</table>

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Register Address(N)</td>
<td>Data written to Register Address(N)</td>
<td>Data written to Register Address(N+1)</td>
<td>Hi−Z</td>
</tr>
</tbody>
</table>

**SPI MODE 3 (Data Read)**

<table>
<thead>
<tr>
<th>nCS</th>
<th>SCK</th>
<th>SI</th>
<th>SO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hi−Z</td>
</tr>
</tbody>
</table>

<p>| | | | |</p>
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<thead>
<tr>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Register Address(N)</td>
<td></td>
<td>Data read from Register Address(N)</td>
<td>Data read from Register Address(N+1)</td>
</tr>
</tbody>
</table>
Setting Method of Sensitivity

The following must be done to adjust the sensitivity. This is very important for noise tolerance.

Step1: Average Count Register value is set to 0x80. Filter Parameter Register value is set to 0x0C.

Step2: Cin Threshold Register value is set to 10 (0x0A).

Step3: Check the Data Register value when a switch is touched with a finger.

Step4: Adjust Gain Register so that checked Data Register value is set to about 20 (0x14) to 25 (0x19).

By this setup, LC717A series can pass IEC61000−4−6 (Level 3).

NOTE: Sensitivity changes with the size of a finger, or amounts of moisture of the skin. We recommend carrying out sensitivity adjustment using various fingers with varied age and gender.

In order to prevent malfunction of dynamic offset calibration, when switch is not being touched, the noise level needs to be always 2 or less.

Mobile Devices which Use a Battery

The touch sensitivity that uses a battery falls compared to those that use an AC power supply. While a battery is being used the mobile device becomes a floating field to GND. For this reason, adjust sensitivity accordingly. Since using a battery floats to GND, we do not recommend the use of a battery with the following conditions.

1. The size of PCB is 80 cm² (e.g., 8×10 cm) or less.
2. PCB with extremely little metal pattern.

Touch-off Judging Threshold

The threshold decided by Cin Threshold Register is a touch-on judging threshold. A touch-off judging threshold is determined in the TOFFTH bit of Measurement Mode Register. You can select from 3/4 and 1/2 value detection peaks, we recommend 1/2 peak detection value. In the case touch judgement is OFF in spite of detecting a value greater then threshold specified by Cin Threshold Register, possible cause for this is the setting of Register “Measurement Mode Register”.

Initialization Time of LC717A Series

When powered and internally reset, the interruption signal is issued from INTOUT part to notify that touch sensor is ready. After issuing the interruption signal, communication becomes feasible from MCU via I²C/SPI.
*1: In a worst case situation re-calibration occurs according to an inferior noise environment. Recalibration will not be performed in a usual usage environment. For this reason, a prolonged calibration as shown in a worst case is not performed.
CHARACTERISTICS OF LC717A SERIES

Variation Width of Cdrv Maximum Oscillation
Cdrv signal is generated in the internal RC oscillator. The variation of oscillation frequency by RC oscillator is ±30% (including temperature and power supply voltage). Therefore the variation of Cdrv signal is:
- 100 kHz (min) ~ 143 kHz (typ) ~ 186 kHz (max).

Caution: This value is the maximum oscillation of Cdrv. Cdrv does not always have a fixed frequency.

Variation Width of Measurement Interval Time
Interval Mode: the timing of measurement is determined by LSI’s internal timer.
Short Interval Time (Mainly Interval with Touch): set by Short Interval Time Register
Long Interval Time (Mainly Interval without Touch): set by Long Interval Time Register

Since the timings are determined by internal RC oscillator, fluctuation can occur as follows:
- Short Interval Time: ±60%
- Long Interval Time: ±60%

*When variation in Interval time is a problem, carry out the following fine tuning instructions.
1. Monitor Cdrv signal or INTOUT signal from the microcontroller.
   In case of Cdrv:
   During measurement, the microcontroller measures the time (fixed Low) the Cdrv signal is not being outputted.
   In case of INTOUT (LC717A10 only):
   After setting INTMD1 = 0 and INTMD2 = 1 (Measurement Mode 1 Register) and starting measurement, the microcontroller measures the High Period (interval time) of the INTOUT signal.
   2. Tune the value of either Long Interval or Short Interval time Register finely to get the best possible interval time.

Sleep Mode: This is determined by the timing of Wakeup processing by MCU.
During sleep mode, the timing of measurement is dependent of MCU. However this all depends on MCU performance.

Range of Gain Variations in the Amplifier
(1st Stage Charge Amplifier and 2nd Stage Amplifier)
The variation is attributed to that of Cin detection sensitivity and it is approximately ±5%.

Testing is done before shipping, but we cannot check in the order of 1fF. Alternative measurement ratings are provided as follows: (See “Cin detection sensitivity” for electric characteristics)
Cin detection sensitivity: Min: 0.04 (LSB/fF) / Max: 0.12 (LSB/fF)

Influence of the Power Supply Voltage and Temperature
The following figures show power supply voltages & the temperature characteristics of the LC717A series. There is no significant sensitivity variation by VDD and temperature.

As you know, capacitance C is defined by following formula.
\[ C = \frac{\varepsilon S}{d} \] (eq. 2)

In addition to the PCB substrate and the film substrate, characteristics such as temperature, humidity for the surface material of the product and adhesive etc. significantly affect
to these parameters. The effect of single LSI is negligible compared to these effects.

With the LC717A00, process correction is performed in the LSI automatically, normally parameter variation is not an issue. However, if LSI can not correct, then there will be errors. If such errors occur during evaluation, you may need to change the material to minimize the effects of temperature, or moisture-proof treatment such as a cover that is not affected by humidity changes.

**Range of Usage Temperature**

Operating temperature range is between −40°C and +105°C. +105°C can be used to set high temperature conditions.

**APPLICATIONS**

**LC717A00AR/AJ Connection Configuration Example**

**I²C Compatible Bus Connection Configuration**

In this configuration, the LC717A00AR/AJ is connected to the microcontroller through an I²C compatible bus and communicates switch status by the bus.

**Figure 33. Configuration Example**

Notes:

1. The Least significant bit of slave address is decided by the SA pin status. If it connects to VDD, the LSB is “1”. If it connects to VSS, the LSB is “0”.
2. When the interface is used as I²C compatible bus, fix nCS pin to VDD.
1. Inserting a high-valued capacitor and a low-valued capacitor in parallel between VDD and VSS, is recommended. In this case, the small-valued capacitor should be at least 0.1 µF, and is mounted near the LSI.

2. Fix the GAIN and SA pin to VDD or VSS.

Notes:
- Inserting a high-valued capacitor and a low-valued capacitor in parallel between VDD and VSS, is recommended.
- In this case, the small-valued capacitor should be at least 0.1 µF, and is mounted near the LSI.

Figure 34. Circuit Example
SPI Connection Configuration

In this configuration, the LC717A00AR/AJ is connected to the microcontroller through the SPI and communicates switch status.

![Figure 35. Configuration Example](image)

Notes:
1) Inserting a high-valued capacitor and a low-valued capacitor in parallel between VDD and VSS is recommended. In this case, the small-valued capacitor should be at least 0.1 μF, and is mounted near the LSI.
2) Fix the GAIN and SA pin to to VDD or VSS.

![Figure 36. Circuit Example](image)
In the Case you Connect Pout Terminal to a Microcontroller

In this configuration, Pout0 to 7 in the LC717A00AR/AJ are connected to GPIO in the microcontroller.

Figure 37. Configuration Example

R-2R Resistor Ladder Connection Configuration

In this configuration, Pout0 to 7 in the LC717A00AR/AJ are connected to ADC input in the microcontroller through the resistors as shown below.

The input voltage to the microcontroller defined by the combination of switch of ON/OFF is definitive. Therefore, the microcontroller can judge ON/OFF by the input voltage to ADC.

Figure 38. Configuration Example
LC717A10AR/AJ/PJ Connection Configuration Example

I2C Compatible Bus Connection Configuration

Notes:
1. Choose the slave address by SA0 and SA1.
2. When the interface is used as I2C compatible bus, fix nCS pin to VDD.

Figure 39. Configuration Example

Notes:
1. Inserting a high-valued capacitor and a low-valued capacitor in parallel between VDD and VSS, is recommended. In this case, the small-valued capacitor should be at least 0.1 μF, and is mounted near the LSI.
2. Fix the SA0 and SA1 pin to VDD or VSS.

Figure 40. Circuit Example
SPI Connection Configuration

**Figure 41. Configuration Example**

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<th>SW1</th>
<th>SW2</th>
<th>SW3</th>
<th>SW4</th>
<th>SW5</th>
<th>SW6</th>
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<th>SW12</th>
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</tbody>
</table>
```

**Figure 42. Circuit Example**

Note 1. Inserting a high-valued capacitor and a low-valued capacitor in parallel between $V_{DD}$ and $V_{SS}$ is recommended. In this case, the small-valued capacitor should be at least 0.1 μF, and is mounted near the LSI.
Reference Dimensional Drawing for Foot Patterns

VCT28:

SSOP30: