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LC717A00AJ

CMOS LSI

Capacitance-Digital-Converter LSI for Electrostatic Capacitive Touch Sensors

Overview

The LC717A00AJ is a high-performance, low-cost capacitance-digital-converter LSI for electrostatic capacitive touch sensor, especially focused on usability. It has 8 channels capacitance-sensor input. The built-in logic circuit can detect the state (ON/OFF) of each input and output the result. This makes it ideal for various switch applications.

The calibration function is automatically performed by the built-in logic circuit during power activation or whenever there are environmental changes. In addition, since initial settings of parameters, such as gain, are configured, LC717A00AJ can operate as stand-alone when the recommended switch pattern is applied.

Also, since LC717A00AJ has a serial interface compatible with I²C and SPI bus, parameters can be adjusted using external devices whenever necessary. Moreover, outputs of the 8-input capacitance data can be detected and measured as 8-bit data.

Features

- Detection system: Differential capacitance detection (Mutual capacitance type)
- Input capacitance resolution: Can detect capacitance changes in the femto Farad order
- Measurement interval (8 differential inputs): 18ms (Typ) (at initial configuration),
3ms (Typ) (at minimum interval configuration)
- External components for measurement: Not required
- Current consumption: 320μA (Typ) (V_{DD} = 2.8V), 740μA (Typ) (V_{DD} = 5.5V)
- Supply voltage: 2.6V to 5.5V
- Detection operations: Switch
- Packages: SSOP30
- Interface: I²C * compatible bus or SPI selectable.

* I²C Bus is a trademark of Philips Corporation.

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Specifications

Absolute Maximum Ratings at Ta = +25°C

| Parameter | Symbol | Ratings (V _{SS} = 0V) | Unit | Remarks |
|----------------------|------------------|--------------------------------|------|--|
| Supply voltage | V _{DD} | -0.3 to +6.5 | V | |
| Input voltage | V _{IN} | -0.3 to V _{DD} +0.3 | V | *1 |
| Output voltage | V _{OUT} | -0.3 to V _{DD} +0.3 | V | *2 |
| Power dissipation | Pd max | 160 | mW | Ta = +105°C, Mounted on a substrate *3 |
| Peak output current | I _{OP} | ±8 | mA | per terminal, 50% Duty ratio *2 |
| Total output current | I _{OA} | ±40 | mA | Output total value of LSI, 25% Duty ratio |
| Storage temperature | Tstg | -55 to +125 | °C | |

*1) Apply to Cin0 to 7, Cref, nRST, SCL, SDA, SA, SCK, SI, nCS, GAIN

*2) Apply to Cdrv, Pout0 to 7, SDA, SO, ERROR, INTOUT

*3) Single-layer glass epoxy board (76.1×114.3×1.6t mm)

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

Recommended Operating Conditions

| Parameter | Symbol | Conditions | min | typ | max | Unit | Remarks |
|--------------------------|-----------------|------------|-----|-----|-----|------|---------|
| Operating supply voltage | V _{DD} | | 2.6 | | 5.5 | V | |
| Supply ripple + noise | Vpp | | | | ±20 | mV | *1 |
| Operating temperature | Topr | | -40 | 25 | 105 | °C | |

*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 0.1μF, and is mounted near the LSI.

Electrical Characteristics at V_{SS} = 0V, V_{DD} = 2.6 to 5.5V, Ta = -40 to +105°C

* Unless otherwise specified, the Cdrv drive frequency is f_{CDRV} = 143kHz.

* Not tested at low temperature before shipment.

| Parameter | Symbol | Conditions | min | typ | max | Unit | Remarks |
|--|-----------------------|---|--------------------|------|--------------------|--------|---------|
| Capacitance detection resolution | N | | | | 8 | bit | |
| Output noise RMS | N _{RMS} | minimum gain setting | | | ±1.0 | LSB | *1 *3 |
| Input offset capacitance adjustment range | Coff _{RANGE} | | | ±8.0 | | pF | *1 *3 |
| Input offset capacitance adjustment resolution | Coff _{RESO} | | | 8 | | bit | |
| Cin offset drift | Cin _{DRIFT} | minimum gain setting | | | ±8 | LSB | *1 |
| Cin detection sensitivity | Cin _{SENSE} | minimum gain setting | 0.04 | | 0.12 | LSB/FF | *2 |
| Cin pin leak current | I _{Cin} | Cin = Hi-Z | | ±25 | ±500 | nA | |
| Cin allowable parasitic input capacitance | Cin _{SUB} | Cin against V _{SS} | | | 30 | pF | *1 *3 |
| Cdrv drive frequency | f _{CDRV} | | 100 | 143 | 186 | kHz | |
| Cdrv pin leak current | I _{CDRV} | Cdrv = Hi-Z | | ±25 | ±500 | nA | |
| nRST minimum pulse width | t _{NRST} | | 1 | | | μs | *1 |
| Power-on reset time | t _{POR} | | | | 20 | ms | *1 |
| Power-on reset operation condition: Hold time | t _{POROP} | | 10 | | | ms | *1 |
| Power-on reset operation condition: Input voltage | V _{POROP} | | | | 0.1 | V | *1 |
| Power-on reset operation condition: Power supply rise rate | t _{VDD} | 0V to V _{DD} | 1 | | | V/ms | *1 |
| Pin input voltage | V _{IH} | High input | 0.8V _{DD} | | | V | *1 *4 |
| | V _{IL} | Low input | | | 0.2V _{DD} | | |
| Pin output voltage | V _{OH} | High output (I _{OH} = +3mA) | 0.8V _{DD} | | | V | *5 |
| | V _{OL} | Low output (I _{OL} = -3mA) | | | 0.2V _{DD} | | |

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| Parameter | Symbol | Conditions | min | typ | max | Unit | Remarks |
|----------------------|---------------|---|-----|-----|---------|---------|---------|
| SDA pin leak current | $V_{OL} I^2C$ | SDA Low output ($I_{OL} = -3mA$) | | | 0.4 | V | |
| Pin leak current | I_{LEAK} | | | | ± 1 | μA | *6 |
| Current consumption | I_{DD} | When stand-alone configuration and non-touch $V_{DD} = 2.8V$ | | 320 | 390 | μA | *1 *3 |
| | | when stand-alone configuration and non-touch $V_{DD} = 5.5V$ | | 740 | 900 | | |
| | I_{STBY} | During Sleep process | | | 1 | μA | *3 |

- *1) Design-guaranteed values (not tested before shipment)
- *2) Measurements conducted using the test mode in the LSI
- *3) $T_a = +25^{\circ}C$
- *4) Apply to nRST, SCL, SDA, SA, SCK, SI, nCS, GAIN
- *5) Apply to Cdrv, Pout0 to 7, SO, ERROR, INTOUT
- *6) Apply to nRST, SCL, SDA, SA, SCK, SI, nCS, GAIN

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I²C Compatible Bus Timing Characteristics at V_{SS} = 0, V_{DD} = 2.6 to 5.5V, Ta = -40 to +105°C

*Not tested at low temperature before shipment

| Parameter | Symbol | Pin Name | Conditions | min | typ | max | Unit | Remarks |
|-------------------------------------|---------------------------------|------------|------------|-----|-----|-----|------|---------|
| SCL clock frequency | f _{SCL} | SCL | | | | 400 | kHz | |
| START condition hold time | t _{HD;STA} | SCL SDA | | 0.6 | | | μs | |
| SCL clock low period | t _{LOW} | SCL | | 1.3 | | | μs | |
| SCL clock high period | t _{HIGH} | SCL | | 0.6 | | | μs | |
| Repeated START condition setup time | t _{SU;STA} | SCL SDA | | 0.6 | | | μs | *1 |
| Data hold time | t _{HD;DAT} | SCL SDA | | 0 | | 0.9 | μs | |
| Data setup time | t _{SU;DAT} | SCL SDA | | 100 | | | μs | *1 |
| SDA, SCL rise/fall time | t _r / t _f | SCL SDA | | | | 300 | μs | *1 |
| STOP condition setup time | t _{SU;STO} | SCL SDA | | 0.6 | | | μs | |
| STOP-to-START bus release time | t _{BUF} | SCL SDA | | 1.3 | | | μs | *1 |

*1) Design-guaranteed values (not tested before shipment)

SPI Bus Timing Characteristics at V_{SS} = 0, V_{DD} = 2.6 to 5.5V, Ta = -40 to +105°C

*Not tested at low temperature before shipment

| Parameter | Symbol | Pin Name | Conditions | min | typ | max | Unit | Remarks |
|--|---------------------------------|------------------|------------|-----|-----|-----|------|---------|
| SCK clock frequency | f _{SCK} | SCK | | | | 5 | MHz | |
| SCK clock Low time | t _{LOW} | SCK | | 90 | | | ns | *1 |
| SCK clock High time | t _{HIGH} | SCK | | 90 | | | ns | *1 |
| Input signal rise/fall time | t _r / t _f | nCS SCK SI | | | | 300 | ns | *1 |
| nCS setup time | t _{SU;nCS} | nCS SCK | | 90 | | | ns | *1 |
| SCK clock setup time | t _{SU;SCK} | nCS SCK | | 90 | | | ns | *1 |
| Data setup time | t _{SU;SI} | SCK SI | | 20 | | | ns | *1 |
| Data hold time | t _{HD;SI} | SCK SI | | 30 | | | ns | *1 |
| nCS hold time | t _{HD;nCS} | nCS SCK | | 90 | | | ns | *1 |
| SCK clock hold time | t _{HD;SCK} | nCS SCK | | 90 | | | ns | *1 |
| nCS standby pulse width | t _{CPH} | nCS | | 90 | | | ns | *1 |
| Output high impedance time from nCS | t _{CHZ} | nCS SO | | | | 80 | ns | *1 |
| Output data determination time | t _v | SCK SO | | | | 80 | ns | *1 |
| Output data hold time | t _{HD;SO} | SCK SO | | 0 | | | ns | *1 |
| Output low impedance time from SCK clock | t _{CLZ} | SCK SO | | 0 | | | ns | *1 |

*1) Design-guaranteed values (not tested before shipment)

Power-on Reset (POR)

When power is turned on, power-on reset is enabled inside the LSI and its state is released after a certain power-on reset time, t_{POR} . Power-on reset operation condition: Power supply rise rate t_{VDD} must be at least 1V/ms.

Since INTOUT pin changes from “High” to “Low” at the same time as the released of power-on reset state, it is possible to verify the t_{POR} externally.

During power-on reset state, Cin, Cref and Pout are unknown.

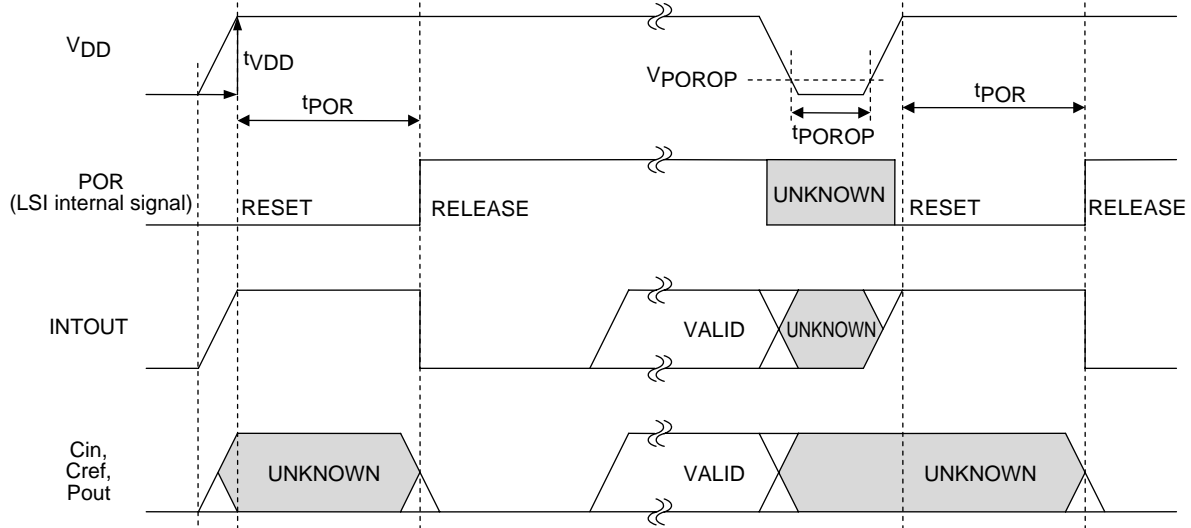


fig.1

I²C Compatible Bus Data Timing

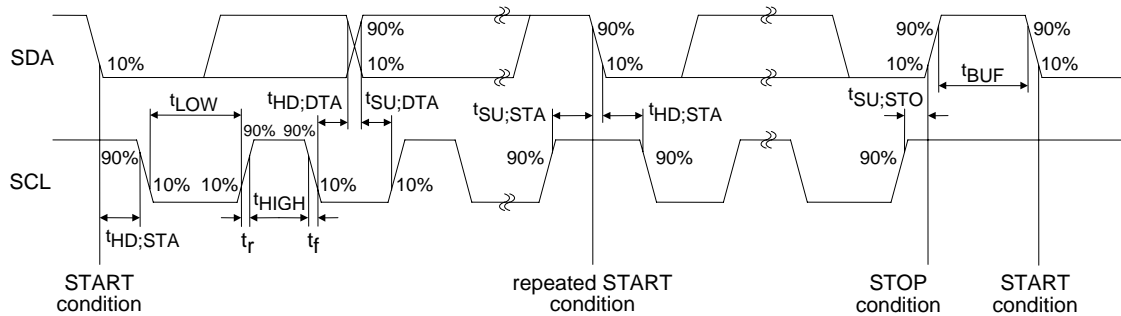


fig.2

I²C Compatible Bus Communication Formats

- Write format (data can be written into sequentially incremented addresses)

| | | | | | | | | | | |
|-------|---------------|---------|-----|----------------------|-------|--------------------------------------|-------|--|-------|------|
| START | Slave Address | Write=L | ACK | Register Address (N) | ACK | Data written to Register Address (N) | ACK | Data written to Register Address (N+1) | ACK | STOP |
| | | Slave | | | Slave | | Slave | | Slave | |

fig.3

- Read format (data can be read from sequentially incremented addresses)

| | | | | | | | | | | |
|---------|---------------|---------|-----|-------------------------------------|--------|---------------------------------------|--------|---------------------------------------|--------|------|
| START | Slave Address | Write=L | ACK | Register Address (N) | ACK | | | | | |
| | | Slave | | | Slave | | | | | |
| RESTART | Slave Address | Read=H | ACK | Data read from Register Address (N) | ACK | Data read from Register Address (N+1) | ACK | Data read from Register Address (N+2) | NACK | STOP |
| | | Slave | | | Master | | Master | | Master | |

fig.4

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I²C Compatible Bus Slave Address

Selection of two kinds of addresses is possible through the SA terminal.

| SA pin input | 7bit Slave Address | Binary Notation | 8bit Slave Address |
|--------------|--------------------|-------------------|--------------------|
| Low | 0x16 | 00101100b (Write) | 0x2C |
| | | 00101101b (Read) | 0x2D |
| High | 0x17 | 00101110b (Write) | 0x2E |
| | | 00101111b (Read) | 0x2F |

SPI Data Timing (SPI Mode 0 / Mode 3)

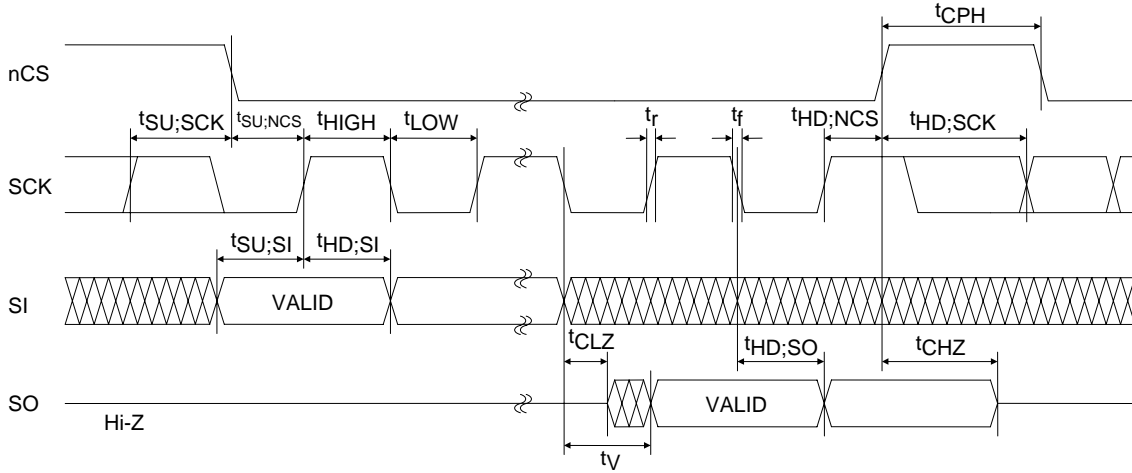


fig.5

SPI Communication Formats (Example of Mode 0)

- Write format (data can be written into sequentially incremented addresses while holding nCS = L)

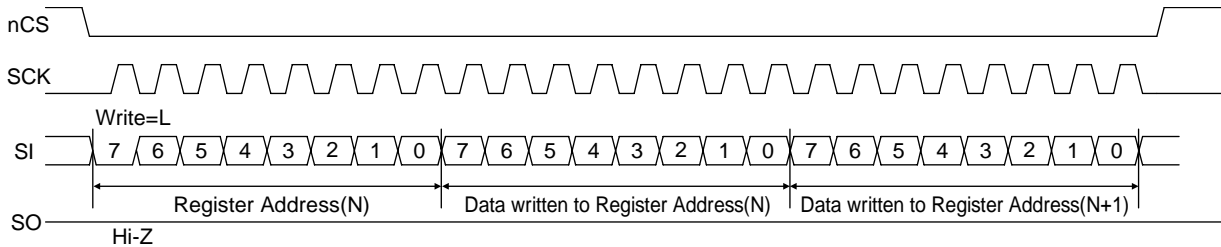


fig.6

- Read format (data can be read from sequentially incremented addresses while holding nCS = L)

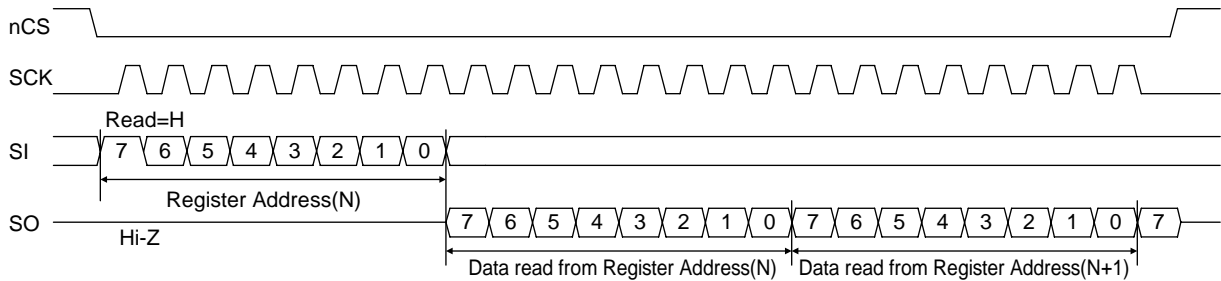


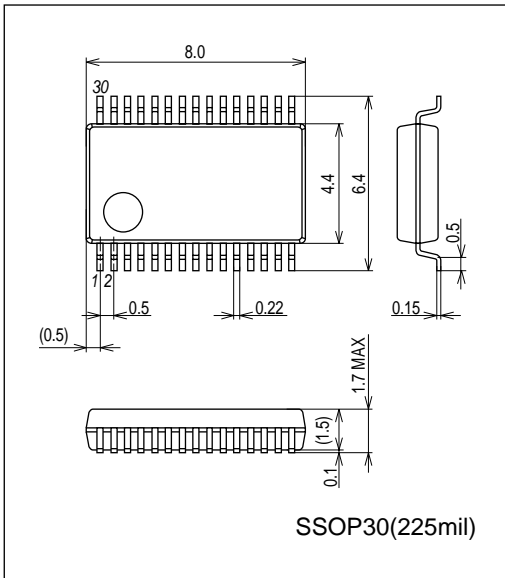
fig.7

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Package Dimensions [LC717A00AJ]

unit : mm (typ)

3421



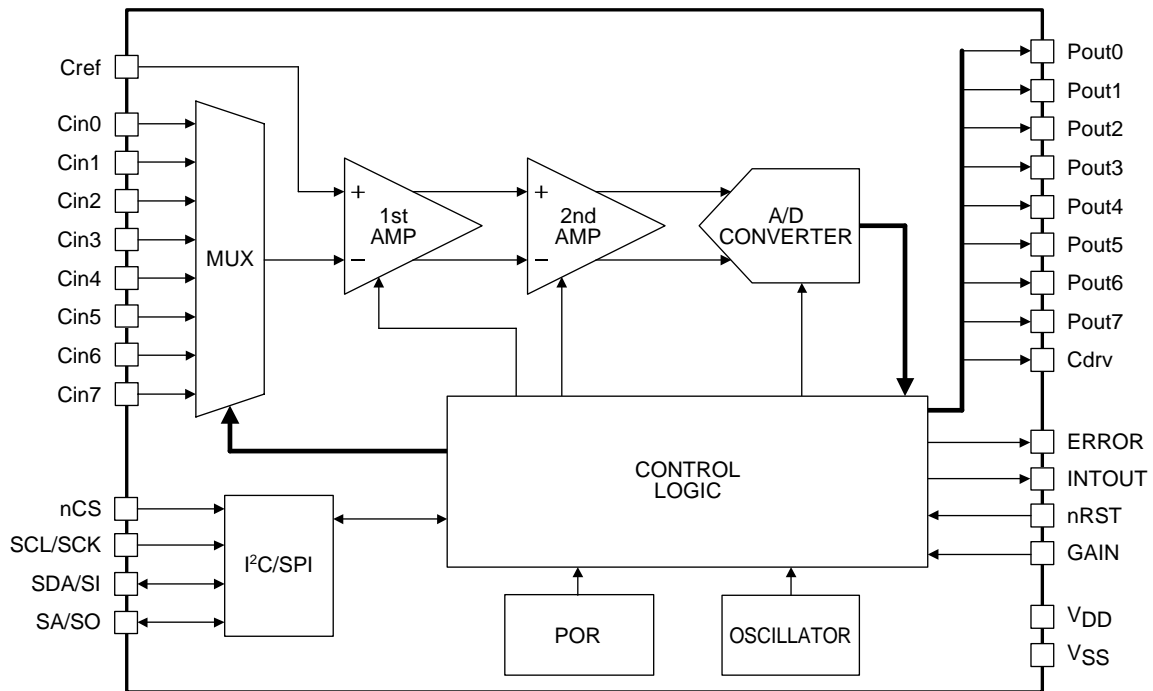
Pin Assignment

| Pin No. | Pin Name | Pin No. | Pin Name |
|---------|-----------------|---------|----------------|
| 1 | V _{DD} | 16 | Cref |
| 2 | V _{SS} | 17 | ERROR |
| 3 | Non Connect *1 | 18 | Cdrv |
| 4 | Cin4 | 19 | INTOUT |
| 5 | Cin5 | 20 | GAIN |
| 6 | Cin6 | 21 | SCL/SCK |
| 7 | Cin7 | 22 | SDA/SI |
| 8 | Pout0 | 23 | SA/SO |
| 9 | Pout1 | 24 | nCS |
| 10 | Pout2 | 25 | nRST |
| 11 | Pout3 | 26 | Non Connect *1 |
| 12 | Pout4 | 27 | Cin0 |
| 13 | Pout5 | 28 | Cin1 |
| 14 | Pout6 | 29 | Cin2 |
| 15 | Pout7 | 30 | Cin3 |

*1) connect to GND when mounted

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Block Diagram



LC717A00AJ is capacitance-digital-converter LSI capable of detecting changes in capacitance in the femto Farad order. It consists of an oscillation circuit that generates the system clock, a power-on reset circuit that resets the system when the power is turned on, a multiplexer that selects the input channels, a two-stage amplifier that detects the changes in the capacitance and outputs analog-amplitude values, a A/D converter that converts the analog-amplitude values into digital data, and a control logic that controls the entire chip. Also, it has an I²C compatible bus or SPI that enables serial communication with external devices as necessary.

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Pin Functions

| Pin Name | I/O | Pin Functions | Pin Type |
|-----------------|-----|---|----------|
| Cin0 | I/O | Capacitance sensor input | |
| Cin1 | I/O | Capacitance sensor input | |
| Cin2 | I/O | Capacitance sensor input | |
| Cin3 | I/O | Capacitance sensor input | |
| Cin4 | I/O | Capacitance sensor input | |
| Cin5 | I/O | Capacitance sensor input | |
| Cin6 | I/O | Capacitance sensor input | |
| Cin7 | I/O | Capacitance sensor input | |
| Cref | I/O | Reference capacitance input | |
| Pout0 | O | Cin0 judgment result output | |
| Pout1 | O | Cin1 judgment result output | |
| Pout2 | O | Cin2 judgment result output | |
| Pout3 | O | Cin3 judgment result output | |
| Pout4 | O | Cin4 judgment result output | |
| Pout5 | O | Cin5 judgment result output | |
| Pout6 | O | Cin6 judgment result output | |
| Pout7 | O | Cin7 judgment result output | |
| ERROR | O | Error occurrence status output | |
| Cdrv | O | Output for capacitance sensors drive | |
| INTOUT | O | Interrupt output | |
| SCL/SCK | I | Clock input (I ² C) / Clock input (SPI) | |
| GAIN | I | Selection pin of the initial value of gain of the 2nd-amplifier | |
| nCS | I | Interface selection / Chip select inverting input (SPI) | |
| nRST | I | External reset signal inverting input | |
| SDA/SI | I/O | Data input and output (I ² C) / Data input (SPI) | |
| SA/SO | I/O | Slave address selection (I ² C) / Data output (SPI) | |
| V _{DD} | | Power supply (2.6V to 5.5V) *1 | |
| V _{SS} | | Ground (Earth) *1 *2 | |

*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 0.1μF, and is mounted near the LSI.

*2) When V_{SS} terminal is not grounded in battery-powered mobile equipment, detection sensitivity may be degraded.

Details of Pin Functions

●Cin0 to Cin7

These are the capacitance-sensor-input pins. These pins are used by connecting them to the touch switch pattern. Cin and the Cdrv wire patterns should be close to each other. By doing so, Cdrv and Cin patterns are capacitively coupled. Therefore, LSI can detect capacitance change near each pattern as 8bit digital data.

However, if the shape of each pattern or the capacitively coupled value of Cdrv is not appropriate, it may not be able to detect the capacitance change correctly.

In this LSI, there is a two-stage amplifier that detects the changes in the capacitance and outputs analog-amplitude values. Cin0 to Cin7 are connected to the inverting input of the 1st amplifier.

During measurement process, channels other than the one being measured are all in “Low” condition.

Leave the unused terminals open.

●Cref

It is the reference-capacitance-input pin. It is used by connecting to the wire pattern like Cin pins or is used by connecting any capacitance between this pin and Cdrv pin.

In this LSI, there is a two-stage amplifier that detects the changes in the capacitance and outputs analog-amplitude values. Cref is connected to the non-inverting input of the 1st amplifier.

Due to the parasitic capacitance generated in the wire connections of Cin pins and their patterns, as well as the one generated between the wire patterns of Cin and Cdrv pins, Cref may not detect capacitance change of each Cin pin accurately. In this case, connect an appropriate capacitance between Cref and Cdrv to detect capacitance change accurately.

However, if the difference between the parasitic capacitance of each Cin pin is extremely large, it may not detect capacitance change in each Cin pin correctly.

●Pout0 to Pout7

These are the detection-result-output pins. The capacitance detection results of Cin0 to Cin7 are compared with the threshold of the LSI. The pin outputs a “High” or a “Low” depending on the result.

●ERROR

It is the error-occurrence-status-output pin.

It outputs “Low” during normal operation. If there is a calibration error or a system error, it outputs “High” to indicate that an error occurred.

●Cdrv

It is the output pin for capacitance sensors drive. It outputs the pulse voltage which is needed to detect capacitance at Cin0 to Cin7.

Cdrv and Cin wire patterns should be close to each other so that they are capacitively coupled.

●INTOUT

It is the interrupt-output pin. It outputs “High” when a measurement process is completed.

Connect to a main microcomputer if necessary, and use as interrupt signal.

Leave the terminal open if not in used.

●SCL/SCK

Clock input (I²C) / Clock input (SPI)

It is the clock input pin of the I²C compatible bus or the SPI depending on the mode of operation.

If interface is not to be used, fix the pin to “High”. However, even if interface is not to be used, providing a communication terminal on board is still recommended.

●GAIN

In this LSI, there is a two-stage amplifier that detects the changes in the capacitance and outputs analog-amplitude values. It is the selection pin of the initial value of gain of the 2nd amplifier.

Even if this LSI is used alone, gain setting can still be selected through this terminal. At initialization of the LSI, it is set to 7-times higher than the minimum setting when GAIN pin is “Low”, and is set to 14-times higher than the minimum setting when GAIN pin is “High”.

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- nCS

Interface selection / Chip-select-inverting input (SPI)

Selection of I²C compatible bus mode or SPI mode is through this terminal. After initialization, the LSI is automatically in I²C compatible bus mode. To continually use I²C compatible bus mode, fix nCS pin to “High”. To switch to SPI mode after LSI initialization, change the nCS input “High” → “Low”. The nCS pin is used as the chip-select-inverting input pin of SPI, and SPI mode is kept until LSI is again initialized.

If interface is not to be used, fix the pin to “High”.

- nRST

It is the external-reset-signal-inverting-input pin. When nRST pin is “Low”, LSI is in the reset state.

Each pin (Cin0 to 7, Cref, Pout,0 to 7, ERROR) is “Hi-Z” during reset state.

- SDA/SI

Data input and output (I²C) / Data input (SPI)

It is the data input and output pin of the I²C compatible bus or the data input pin of the SPI depending on the mode of operation.

If interface is not to be used, fix the pin to “High”. However, even if interface is not to be used, providing a communication terminal on board is still recommended.

- SA/SO

Slave address selection (I²C) / Data output (SPI)

It is the slave address selection pin of the I²C compatible bus or the data output pin of the SPI depending on the mode of operation.

If interface is not to be used, fix the pin to “High”. However, even if interface is not to be used, providing a communication terminal on board is still recommended.

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Direct +86 (21) 6401-6692

Email amall@ameya360.com

QQ 800077892

Skype [ameyasales1](#) [ameyasales2](#)

➤ Customer Service :

Email service@ameya360.com

➤ Partnership :

Tel +86 (21) 64016692-8333

Email mkt@ameya360.com