## Capacitive Controller ICs

## Capacitive Switch Controller IC

## BU21170MUV

## General Description

BU21170MUV is a capacitive sensor controller for switch operation.
BU21170MUV has five sensors and provides the simple switch function by each sensor.
If external noise and temperature drift are detected, the automatic self-calibration is operated.
Include LED controller with PWM function.

## Features

- 5 capacitive sensor ports.
- Automatic self-calibration.
- Continued touch detection.
- LED controller with PWM function.
- Inform the detected result of switch operation by interrupt.
- 2-wire serial bus interface.
- Single power supply.
- Built-in Power-On-Reset and Oscillator.


## Applications

- Information appliance as printer.
- AV appliance as digital TV and HDD recorder.
- Notebook PC.


## Key Specifications

- Power Supply Voltage Range:
3.0 V to 5.5 V
- Operating Temperature Range
$-25^{\circ} \mathrm{C}$ to $+85^{\circ} \mathrm{C}$
■ Operating Current: $\quad 3.5 \mathrm{~mA}$ (Typ without load)
- Scan Rate: $14.8 \mathrm{msec}(\mathrm{Typ})$

Package
VQFN020V4040

W(Typ) x D(Typ) x H(Max)
$4.00 \mathrm{~mm} \times 4.00 \mathrm{~mm} \times 1.00 \mathrm{~mm}$


## Typical Application Circuit



Figure 1. Typical Application Circuit

## Pin Configuration



Figure 2. Pin Configuration

Pin Descriptions

| Pin <br> No. | Pin <br> Name | Type | Function | Note | Power | Initial <br> Condition | I/O <br> Equivalent <br> Circuit |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| 1 | SIN1 | Ain | Capacitive touch sensor 1 |  | AVDD | Hi-Z | Figure 3 |
| 2 | SIN0 | Ain | Capacitive touch sensor 0 |  | AVDD | Hi-Z | Figure 3 |
| 3 | AVDD | Power | LDO output for analog blocks |  | - | - | - |
| 4 | VDD | Power | Power |  | - | - | - |
| 5 | DVDD | Power | LDO output for digital blocks |  | - | - | - |
| 6 | VSS | Ground | Ground |  | - | - | - |
| 7 | TEST | In | Test input | Fixed 'L' at the normal operation | VDD | - | Figure 4 |
| 8 | SCL | InOut | Host I/F : SCL |  | VDD | Hi-Z | Figure 4 |
| 9 | SDA | InOut | Host I/F : SDA |  | VDD | Hi-Z | Figure 4 |
| 10 | INT | Out | Interrupt output | VDD | 'L' | Figure 5 |  |
| 11 | ADR | In | Select slave address input | 'H':0x4D , 'L':0x4C | VDD | - | Figure 4 |
| 12 | LED0 | Out | LED control with PWM output 0 | Active High | VDD | Hi-Z | Figure 5 |
| 13 | LED1 | Out | LED control with PWM output 1 | Active High | VDD | Hi-Z | Figure 5 |
| 14 | LED2 | Out | LED control with PWM output 2 | Active High | VDD | Hi-Z | Figure 5 |
| 15 | LED3 | Out | LED control with PWM output 3 | Active High | VDD | Hi-Z | Figure 5 |
| 16 | LED4 | Out | LED control with PWM output 4 | Active High | VDD | Hi-Z | Figure 5 |
| 17 | N.C. | - | - | - | - | - |  |
| 18 | SIN4 | Ain | Capacitive touch sensor 4 |  | AVDD | Hi-Z | Figure 3 |
| 19 | SIN3 | Ain | Capacitive touch sensor 3 |  | AVDD | Hi-Z | Figure 3 |
| 20 | SIN2 | Ain | Capacitive touch sensor 2 |  | AVDD | Hi-Z | Figure 3 |

## I/O Equivalent Circuits



Figure 3. I/O Equivalent Circuit (a)


Figure 4. I/O Equivalent Circuit (b)


Figure 5. I/O Equivalent Circuit (c)

## Block Diagram



Figure 6. Block Diagram

## Block Descriptions

Sensor AFE, C/V Converter
Convert from capacitance to voltage following the order of sensors.
A/D
Convert from voltage to the detected result the digital value.
LDO28
2.73 V output LDO for Sensor AFE, C/V Converter and A/D.

LDO15
1.5 V output LDO for OSC and digital blocks.

OSC
Ring oscillator as the system clock.
POR
Power-On-Reset monitoring VDD as the system reset.
MPU
Based on the detection result, detect switch operations (Touch/Release/Hold) and run Auto-calibration. Inform by the INT port to the host about that the switch operations are detected.
LED ports are controlled by the commands from the host.
HOST I/F
2-wire serial bus interface compatible with $I^{2} C$ protocol. Slave address is selectable by pin ADR.
AFE CNT
Sequencer of Sensor AFE, C/V converter and A/D.
PWM CNT
PWM timers for the LED ports.
LEDDRV
LED port drivers.
WDTR
Watchdog timer Timeout Reset. It releases the system reset after 0.6 sec from that MPU cannot clear WDTR.
(If MPU cannot clear WDTR, MPU is hung up.)
PROM
Program ROM for the included MPU.
WRAM
Work RAM for the included MPU.

Absolute Maximum Ratings $\left(\mathrm{Ta}=25^{\circ} \mathrm{C}\right)$

| Parameter | Symbol | Rating | Unit |
| :--- | :---: | :---: | :---: |
| Power Supply Voltage | $\mathrm{V}_{\mathrm{DD}}$ | -0.5 to 7.0 | V |
| Input Voltage | $\mathrm{V}_{\mathrm{IN}}$ | -0.3 to $\mathrm{V}_{\mathrm{DD}}+0.7$ | V |
| Power Dissipation ${ }^{\text {(Note 1) }}$ | Pd | 0.55 | W |
| Operating Temperature Range | Topr | -25 to +85 | ${ }^{\circ} \mathrm{C}$ |
| Storage Temperature Range | Tstg | -55 to +125 | ${ }^{\circ} \mathrm{C}$ |
| Maximum Junction Temperature | $\mathrm{T}_{\mathrm{jmax}}$ | 125 | ${ }^{\circ} \mathrm{C}$ |

(Note 1) Mounted on $74.2 \mathrm{~mm} \times 74.2 \mathrm{~mm} \times 1.6 \mathrm{~mm}$ glass epoxy 1 layer board (Copper foil area : $10.29 \mathrm{~mm}{ }^{2}$ ). Reduce 5.5 mW per $1^{\circ} \mathrm{C}$ above $25^{\circ} \mathrm{C}$
Caution: Operating the IC over the absolute maximum ratings may damage the IC. The damage can either be a short circuit between pins or an open circuit between pins and the internal circuitry. Therefore, it is important to consider circuit protection measures, such as adding a fuse, in case the IC is operated over the absolute maximum ratings.

## Recommended Operating Conditions

| Parameter | Symbol | Min | Typ | Max | Unit |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Power Supply Voltage | $\mathrm{V}_{\mathrm{DD}}$ | 3.0 | 3.3 | 5.5 | V |

## Electrical Characteristics

| Parameter | Symbol | Min | Typ | Max | Unit | Condition |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Input High voltage | $\mathrm{V}_{\mathrm{IH}}$ | $V_{\text {DD }} \times 0.7$ | - | $V_{D D}+0.3$ | V |  |
| Input Low voltage | $\mathrm{V}_{\mathrm{IL}}$ | $\mathrm{V}_{\text {Ss }}-0.3$ | - | $V_{\text {DD }} \times 0.3$ | V |  |
| Output High voltage | Vor | $V_{\text {DD }}-0.5$ | - | $V_{D D}$ | V | $\mathrm{IOH}=-4 \mathrm{~mA}$ |
| Output Low voltage | Vol | $\mathrm{V}_{\mathrm{ss}}$ | - | $\mathrm{V}_{\text {ss }}+0.5$ | V | $\mathrm{loL}=4 \mathrm{~mA}$ |
| Oscillator clock frequency | fosc | 45 | 50 | 55 | MHz |  |
| DVDD LDO output voltage | V ${ }_{\text {dvd }}$ | 1.35 | 1.50 | 1.65 | V |  |
| AVDD LDO output voltage | $\mathrm{V}_{\text {AVDD }}$ | 2.63 | 2.73 | 2.83 | V |  |
| Power-on-reset release voltage |  | 2.25 | - | 2.55 | V |  |
| Power-on-reset detect voltage |  | 2.10 | - | 2.40 | V |  |
| Operating Current | IDD | - | 3.5 | - | mA | Without load of sensors. |

## Register Map

(OSC $=50 \mathrm{MHz}$, unless otherwise noted)
No accessing to the reserved areas is allowed.


## 【0x00－0x04 ：Sensor Data】

Name：$\quad$ SIN＿DATA
Address： $0 \times 00-0 \times 04$
Description：This registers shows 8bit ADC value of each sensor．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0x00 | SD＿SINO［7：0］ |  |  |  |  |  |  |  |
| $0 \times 01$ | SD＿SIN1［7：0］ |  |  |  |  |  |  |  |
| 0x02 | SD＿SIN2［7：0］ |  |  |  |  |  |  |  |
| $0 \times 03$ | SD＿SIN3［7：0］ |  |  |  |  |  |  |  |
| 0x04 | SD＿SIN4［7：0］ |  |  |  |  |  |  |  |
| R／W | R | R | R | R | R | R | R | R |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

【 $0 \times 0 \mathrm{E}$ ：State of the peripheral PWM timer】
Name：STATE＿PWM

Address：0x0E
Description：$\quad 1$ ：The PWM timer is running．PWM state is on＇RISE＇，＇FALL＇，＇ON＇or＇OFF＇．
0 ：The PWM timer is not running．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0x0E | - | - | - | - | PWM3 | PWM2 | PWM1 | PWM0 |
| R／W | - | - | - | - | $R$ | $R$ | R | R |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 【0x0F ：State of the PWM sequence】

Name：CONT＿PWM
Address：0x0F
Description：$\quad 1$ ：PWM timer is running and not received stop command．
0 ：PWM timer is running and received stop command．Or PWM timer is stopped．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0x0F | - | - | - | - | PWM3 | PWM2 | PWM1 | PWM0 |
| R／W | - | - | - | - | $R$ | $R$ | R | R |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 【0x10 : Interrupt factor】 <br> Name:

INTERRUPT
Address: $0 \times 10$
Description: This register shows the interrupt factors. Port INT outputs this register's OR operation.

## INI : Initialization finish :

This register is set to ' 1 ' when initialization is complete after power-on-sequence or watch dog timer reset. This register is cleared by setting ' 0 ' to the bit INI that is included the 'Clear interrupt' registers (Address 0xF0).

## CAL : Software-calibration finish :

This register is set to ' 1 ' when software calibration is complete. This register is cleared by setting ' 0 ' to the bit CAL that is included the 'Clear interrupt' registers (Address 0xF0).

ERCAL: Self-re-calibration finish :
This register is set to ' 1 ' when self-re-calibration is complete. Self-re-calibration runs automatically after the detection that IC should be re-calibration. This register is cleared by setting ' 0 ' to the bit ERCAL that is included the 'Clear interrupt' registers (Address 0xF0).

PWM : PWM continuous flashing of LED finish:
This register is set to ' 1 ' when LED's PWM drive has finished. This register is cleared by clearing every bit of the 'Interrupt of PWM continuous flashing' register.

## PERCAL : Periodic calibration finish :

This register is set to ' 1 ' when periodic calibration is complete. This register is cleared by setting ' 0 ' to the bit PERCAL that is included the 'Clear interrupt' registers (Address 0xF0).

## ONDET : Detection of switch-on :

This register is set to ' 1 ' when it detects a switch operation is considered to be On. This register is cleared by clearing every bit of the 'Detection Switch-On' register.

## OFFDET : Detection of switch-off :

This register is set to ' 1 ' when it detects a switch operation is considered to be Off. This register is cleared by clearing every bit of the 'Detection Switch-Off' register.

## CONTDET : Detection of continued touch :

This register is set to ' 1 ' when it detects a continued touch switch operation. This register is cleared by clearing every bit of the 'Detection continuous touch' register.

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0x10 | CONTDET | OFFDET | ONDET | PERCAL | PWM | ERCAL | CAL | INI |
| R/W | $R$ | $R$ | $R$ | $R$ | $R$ | $R$ | $R$ | $R$ |
| Initial val. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 【0x11 ：Detection Switch－On】

Name：DETECT＿ON
Address：0x11
Description：This register indicates the change to ON from OFF of each switch．
If the mask for the ON operation included in the sensor settings is enabled，this register is disabled． Logical OR of this register is ONDET included＇Interrupt factor＇register．
1 ：Detect On． 0 ：Not detect On．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathbf{0 x 1 1}$ | - | - | - | ON＿SW4 | ON＿SW3 | ON＿SW2 | ON＿SW1 | ON＿SW0 |
| R／W | - | - | - | $R$ | $R$ | $R$ | $R$ | $R$ |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

【0x12 ：Detection Switch－Off】
Name：DETECT＿OFF
Address： $0 \times 12$
Description：This register indicates the change to OFF from ON of each switch．
If the mask for the OFF operation included in the sensor settings is enabled，this register is disabled． Logical OR of this register is OFFDET included＇Interrupt factor＇register．
1 ：Detect Off． 0 ：Not detect Off．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathbf{0 x 1 2}$ | - | - | - | OFF＿SW4 | OFF＿SW3 | OFF＿SW2 | OFF＿SW1 | OFF＿SW0 |
| R／W | - | - | - | $R$ | $R$ | $R$ | $R$ | $R$ |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 【0x13 ：Detection continuous touch】

Name： DETECT＿CONT
Address： $0 \times 13$
Description：This register indicates the detection of continuous touch of each switch．
If the mask for the continuous touch operation included in the sensor settings is enabled，this register is disabled．
Logical OR of this register is CONTDET included＇Interrupt factor＇register．
1 ：Detect Continuous touch． 0 ：Not detect Continuous touch．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0x13 | - | - | - | CONT＿SW4 | CONT＿SW3 | CONT＿SW2 | CONT＿SW1 | CONT＿SW0 |
| R／W | - | - | - | $R$ | $R$ | $R$ | $R$ | R |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 【0×14 ：Interrupt of PWM continuous flashing】

Name：DETECT＿PWM＿FINISH
Address：0x14
Description：This register indicates the end of the each LED PWM drive．And in the case that the PWM function is stopped by the writing 0 to the PWM operation register（ $0 x F C$ ），this register is set to 1 ．
Logical OR of this register is PWM included＇Interrupt factor＇register．
1 ：Finished LED PWM drive． 0 ：Clear．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0x14 | - | - | - | - | PWM3 | PWM2 | PWM1 | PWM0 |
| R／W | - | - | - | - | $R$ | $R$ | R | R |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 【0x1B ：State of interrupt from the peripherals】

Name：STATE＿INT
Address：0x1B
Description：This register shows the peripheral which issues an interrupt to MPU． 1 ：Interrupt is． 0 ：Interrupt is not．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0x1B | PWM3 | PWM2 | PWM1 | PWM0 | WDT | - | AFE | I2C |
| R／W | R | R | R | R | R | - | R | R |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 【0×1C ：State of IC】

## Name：STATE

Address：0x1C
Description：This register indicates the state of IC．
Indicates whether the IC is in calibration or not．
1 ：In calibration． 0 ：Not in calibration
The required time for calibration．：About 140 msec ．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0x1C | - | - | - | - | - | - | - | CALIB |
| R／W | - | - | - | - | - | - | - | R |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 【0x1D ：Sensor State】

Name：$\quad$ STATE＿SIN
Address：0x1D
Description：This register indicates the state of each sensor
1 ：Switch－on．（Register＇SIN＿DATA＇＞Register＇TH＿ON＇）
0 ：Switch－off．（Register＇SIN＿DATA＇＜Register＇TH＿OFF＇）

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0x1D | - | - | - | SIN4 | SIN3 | SIN2 | SIN1 | SIN0 |
| R／W | - | - | - | R | R | R | R | R |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

【0×1E：Read register for operation check of IC】
Name：RACT
Address：0x1E
Description：This register is a read register for operational check of the IC．The value written to the write register for operation check（Address is $0 x F E$ ）is copied to this register．If the write value and the read value are equal， MPU and I／F are operating normally．
The required time to copy to this register from the write register for operation check ：About 20usec．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0x1E |  |  |  |  |  |  |  |  |  |
| R／W | R | R | R | R | R （7：0］ | R | R | R | R |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |

【0x85，0x8A：Software Reset】
Name：SOFTRESET
Address： $0 \times 85,0 \times 8 \mathrm{~A}$
Description：These registers are used for hardware reset．If the $0 \times 85$ register＇s value is $0 \times 55$ and the $0 \times 8 \mathrm{~A}$ is $0 \times A A$ ， then a hardware reset will be done．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0x85 | SRST［7：0］ |  |  |  |  |  |  |  |
| 0x8A |  |  |  |  |  |  |  |  |
| R／W | R／W | R／W | R／W | R／WST［15：8］ | R／W | R／W | R／W | R／W |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 【0xC0－0xCE ：Sensor Settings】

## Name：SIN＿CFG <br> Address：$\quad 0 x C \overline{0}-0 \times C E$

Description：These registers are for setting of each SIN sensor．
The settings are the thresholds（from On to Off，and from Off to On），the gain and the mask function of the each switch operation（On／Off／Continuous touch）．

GAIN＿SIN＊［3：0］：Setting for the gain ：
This register is for setting the gain of AFE．The smaller the value of this register is，the higher the gain is． Adjustment range ： $0 \times 1 \leq$ GAIN＿SIN $\leq 0 x F$
The sensor which setting value is 0 has no switch function
ON＿TH＿SIN＊［7：0］：The threshold from Off to On ：
This register is the threshold from Off to On．This value is compared to the register SIN＿DATA．If the value of this register is larger than SIN＿DATA，the On operation is detected．

OFF＿TH＿SIN＊［7：0］：The threshold from On to Off ：
This register is the threshold from On to Off．This value is compared to the register SIN＿DATA．If the value of this register is smaller than SIN＿DATA，the Off operation is detected．

Adjustment range ：0x00＜OFF＿SIN＊＜ON＿SIN＊＜0xFF
The sensor which setting value is out of this range is unusable for switch operation．
MSK＿ON＿SIN＊，MSK＿OFF＿SIN＊，MSK＿CONT＿SIN＊：Mask for the switch operation ：
This register is the mask function of the each switch operation（On／Off／Continuous touch）． If the mask function is enabled，the register for detection of switch operation is disabled．
1 ：Mask function is enable． 0 ：Mask function is disable（default）．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0xC0 | － | MSK＿CONT＿SINO | MSK＿OFF＿SINO | MSK＿ON＿SINO | GAIN＿SIN0［3：0］ |  |  |  |
| 0xC1 | ON＿TH＿SIN0［7：0］ |  |  |  |  |  |  |  |
| 0xC2 | OFF＿TH＿SINO［7：0］ |  |  |  |  |  |  |  |
| 0xC3 | － | MSK＿CONT＿SIN1 | MSK＿OFF＿SIN1 | MSK＿ON＿SIN1 | GAIN＿SIN1［3：0］ |  |  |  |
| 0xC4 | ON＿TH＿SIN1［7：0］ |  |  |  |  |  |  |  |
| 0xC5 | OFF＿TH＿SIN1［7：0］ |  |  |  |  |  |  |  |
| 0xC6 | － | MSK＿CONT＿SIN2 | MSK＿OFF＿SIN2 | MSK＿ON＿SIN2 | GAIN＿SIN2［3：0］ |  |  |  |
| 0xC7 | ON＿TH＿SIN2［7：0］ |  |  |  |  |  |  |  |
| 0xC8 | OFF＿TH＿SIN2［7：0］ |  |  |  |  |  |  |  |
| 0xC9 | － | MSK＿CONT＿SIN3 | MSK＿OFF＿SIN3 | MSK＿ON＿SIN3 | GAIN＿SIN3［3：0］ |  |  |  |
| 0xCA | ON＿TH＿SIN3［7：0］ |  |  |  |  |  |  |  |
| 0xCB | OFF＿TH＿SIN3［7：0］ |  |  |  |  |  |  |  |
| 0xCC | － | MSK＿CONT＿SIN4 | MSK＿OFF＿SIN4 | MSK＿ON＿SIN4 | GAIN＿SIN4［3：0］ |  |  |  |
| 0xCD | ON＿TH＿SIN4［7：0］ |  |  |  |  |  |  |  |
| 0xCE | OFF＿TH＿SIN4［7：0］ |  |  |  |  |  |  |  |
| R／W | R／W | R／W | R／W | R／W | R／W | R／W | R／W | R／W |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 【0xCF ：Monitor activity of the sensor】

Name：MONI＿ACT
Address： $0 \times C F$
Description：This register is used to select whether to monitor the register ACT（scan enable bit at the address 0xFF）． The monitor＇s purpose is to prevent erroneous stop of detection of the AFE．
If the state that the AFE scan is stopped in the case that the monitor function is enabled is detected，the AFE scan will be self－restarted．
Monitor function is executed about 300 msec ．
1 ：Monitor function is enabled． 0 ：Monitor function is disabled（default）．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0xCF | - | - | - | - | - | - | - | MONI＿ACT |
| R／W | - | - | - | - | - | - | - | R／W |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 【0xD0 ：Configuration continuous touch】

Name：CONTTIMES
Address：0xD0
Description：CONTSEL ：This register is to select the interrupt frequency by detection continuous touch．
1 ：Every continuous touch period．
0 ：First detect only．
CONT［5：0］：Continuous touch period is about $0.1[\mathrm{sec}] \times$ CONT．
If the setting value is $0 \times 0$ ，continuous touch function is disable． （ $0.1 \mathrm{sec} \leq$ Continuous touch period $\leq 6.3 \mathrm{sec}$ ）

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0xD0 | CONTSEL | - | CONT［5：0］ |  |  |  |  |  |  |  |
| R／W | R／W | - | R／W | R／W | R／W | R／W | R／W | R／W |  |  |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |  |

## 【0xD1 ：Configuration oversampling】

## Name：OSTIMES

Address：0xD1
Description：OST［3：0］：This register is the number of times of oversampling for canceling chattering to the＇ON＇or＇OFF＇ operation．If the continuance of the＇ON＇or＇OFF＇operations is lower than this register，the operations are ignored．If this register value is＇ 0 ＇，the number of times of oversampling is＇ 1 ＇． Sampling rate：About 14.8 msec ．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0xD1 | OST［3：0］ |  |  |  |  |  |  |  |
| R／W | R／W | R／W | R／W | R／W | - | - | - | - |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | - | - |

【0xDF ：Mask interrupt】
Name：MASK＿INTERRUPT
Address：0xDF
Description：This register is for mask to the interrupt factor．The masked interrupt factor is not shown on the register ＇Interrupt factor（address 0x10）＇，so it does not affect to output port INT．
1 ：Masked 0 ：Unmasked（default）
MSK＿CAL ：Mask for Software－calibration finish ：
This bit does mask to the interrupt of Software－calibration finish（the bit CAL in the register＇Interrupt factor＇ （address 0x10））．

## MSK＿ERCAL ：Mask for Self－calibration finish ：

This bit does mask to the interrupt of Self－calibration finish（the bit ERCAL in the register＇Interrupt factor＇ （address $0 \times 10$ ））．

MSK＿PERCAL ：Mask for Periodic calibration finish ：
This bit does mask to the interrupt of Periodic calibration finish（the bit PERCAL in the register＇Interrupt factor＇（address $0 \times 10$ ））．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathbf{0 x D F}$ | - | - | - | MSK＿PERCAL | - | MSK＿ERCAL | MSK＿CAL | - |
| R／W | - | - | - | R／W | - | R／W | R／W | - |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

【0xE0-0xEB : Configuration of PWM】

## Name: <br> PWM_CFG

Address: 0xEO - 0xEB
Description: $\quad$ Each of the 4 PWM timers (PWM-0/1/2/3) has 5 parameters.
When the register for PWM operation ( 0 xFC ) is changed from 0 to 1 , these setting will be enabled.
I. RIS_PWM* : Rising Time Adjustment range : $0 \times 0 \leq$ RIS_PWM $\leq 0 \times F$

Rising Time $=$ About $317 \mathrm{msec} \times$ RIS_PWM ${ }^{*}(0 \leq$ Rising Time $\leq 4755$ [ msec ])
II. FAL_PWM* : Falling Time Adjustment range : $0 \times 0 \leq F A L \_P W M \leq 0 x F$

Falling Time $=$ About $317 \mathrm{msec} \times$ FAL_PWM* $(0 \leq$ Falling Time $\leq 4755$ [msec])
III. ON_PWM* : Lights-On Time. Adjustment range : $0 \times 1 \leq$ RIS_PWM $\leq 0 x F$.

Lights-On Time $=$ About $300 \mathrm{msec} \times$ ON_PWM* $(300 \leq$ Lights-On Time $\leq 4500$ [msec])
If the setting value is $0 \times 0$, the PWM timer continues to lighting. In the case of continuous lighting, the way how to turn off the light is to change the value of the register for PWM operation (0xFC) from 1 to 0 .
IV. OFF_PWM ${ }^{*}$ : Lights-Off Time. Adjustment range : $0 \times 0 \leq$ OFF_PWM $\leq 0 x F$ Lights-Off Time $=$ About $300 \mathrm{msec} \times$ OFF_PWM ${ }^{*}(0 \leq$ Lights-Off Time $\leq 4500$ [msec])
V. REP_PWM* : Repeat Count.

In the case that the setting value is $0 \times 0$ or $0 \times 1$, non repeat.
In the case that the setting value is $0 x F$, unlimited repeat.
In the case that the setting value is from $0 \times 2$ to $0 x E$, repeat as many times as the setting value.
When the PWM function is finished, the bit PWM which is included in 'Interrupt factor' register (0x10) will be set to 1 and the level of the port INT will be High-Level. The bit PWM which is included in 'Interrupt factor' register is cleared by the writing 0 to the bit PWM which is included in 'Interrupt clear' register. And FAL_PWM is applied in the falling time.


Figure 7. PWM waveform

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0xE0 | FAL_PWM0[3:0] |  |  |  | RIS_PWMO[3:0] |  |  |  |
| 0xE1 | OFF_PWM0[3:0] |  |  |  | ON_PWM0[3:0] |  |  |  |
| 0xE2 | - | - | - | - | REP_PWM0[3:0] |  |  |  |
| 0xE3 | FAL_PWM1[3:0] |  |  |  |  | RIS | [3:0] |  |
| 0xE4 | OFF_PWM1[3:0] |  |  |  | ON_PWM1[3:0] |  |  |  |
| 0xE5 |  |  |  |  | REP_PWM1[3:0] |  |  |  |
| 0xE6 | FAL_PWM2[3:0] |  |  |  |  | RIS | [3:0] |  |
| 0xE7 | OFF_PWM2[3:0] |  |  |  | ON_PWM2[3:0] |  |  |  |
| 0xE8 |  |  |  |  | REP_PWM2[3:0] |  |  |  |
| 0xE9 | FAL_PWM3[3:0] |  |  |  |  | RIS | [3:0] |  |
| 0xEA | OFF_PWM3[3:0] |  |  |  | ON_PWM3[3:0] |  |  |  |
| 0xEB |  |  |  |  | REP_PWM3[3:0] |  |  |  |
| R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W |
| Initial val. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

[ 0xEC : Mask Interrupt of PWM continuous flashing]

| Name: | MASK_PWM_FINISH |
| :--- | :--- |
| Address: | OxEC |
| Description: | This register is the mask function for the interrupt of the end of the each LED PWM drive. |
|  | $1:$ Masked $0:$ Unmasked (default) |


|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0xEC | - | - | - | - | MSK_PWM3 | MSK_PWM2 | MSK_PWM1 | MSK_PWM0 |
| R/W | - | - | - | - | R/W | R/W | R/W | R/W |
| Initial val. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

【0xED－0xEE ：LED－PWM assign】
Name：PWM＿ASSIGN
Address： $0 x E D-0 x E E$
Description：These registers are used to set any PWM setting from the four settings to each LED port．
$0 \times 0$ ：Assign PWM－0
0x1 ：Assign PWM－1
$0 \times 2$ ：Assign PWM－2
0x3 ：Assign PWM－3
These registers value is set by writing＇ 1 ＇to the Switch PWM assign register（Address $=0 \times F 9$ ）．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0xED | PWMA＿LED3［1：0］ | PWMA＿LED2［1：0］ | PWMA＿LED1［1：0］ | PWMA＿LED0［1：0］ |  |  |  |  |
| 0xEE | - | - | - | - | - | - | PWMA＿LED4［1：0］ |  |
| R／W | R／W | R／W | R／W | R／W | R／W | R／W | R／W | R／W |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 【0xEF ：LED calibration】

Name：LED＿CALIB
Address：0xEF
Description：This register is used to select whether to perform the calibration．The calibration is done by writing to any LED port or by periodic calibration．

## LEDCAL ：Self－calibration enable bit at controlled for LED／PWM ：

This register is used to select whether to perform the self－calibration when the corresponding registers for LED／PWM control are written．The corresponding registers＇addresses are from 0xF9 to 0xFC．
1 ：Not perform the self－calibration． 0 ：Perform the self－calibration（default）．

## PERCAL ：Periodical calibration ：

This register is used to select whether to perform the periodical calibration．
1 ：Not perform the periodical calibration． 0 ：Perform the periodical calibration（default）．

## PERCALCOND ：Condition of the periodical calibration ：

This register is used to select the condition to perform the periodical calibration．
1 ：Always． 0 ：At any LED port is lighting（default）．
PWMCAL ：Condition of the periodical calibration when the PWM function is active ：
This register is used to select whether to perform the periodical calibration in the case that the periodical calibration is enable．
1 ：Perform the periodical calibration regardless of the condition of the LED port assigned to PWM function．
0 ：Perform the periodical calibration only the LED port assigned to PWM function is set to inactive（default）．

| Conditions |  |  | Periodical Calibration |
| :---: | :---: | :---: | :---: |
| State of the LED port assigned to PWM function | bit state |  |  |
|  | PERCAL | PWMCAL |  |
| With flashing by PWM drive． | 0 | 0 | Not performed |
|  |  | 1 | Performed |
|  | 1 | 0 | Not performed |
|  |  | 1 |  |
| Without flashing by PWM drive． | 0 | 0 | Performed |
|  |  | 1 |  |
|  | 1 | 0 | Not performed |
|  |  | 1 |  |

PERIOD［7：4］：Interval of the periodical calibration ：
This register is used to set the interval of the periodical calibration．
The interval of the periodical calibration $=$ About 5 seconds $\times($ PERIOD +1$)$
（ 5 seconds $\leq$ Interval time $\leq 80$ seconds）

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0xEF | PERIOD［3：0］ |  |  |  | PWMCAL | PERCALCOND | PERCAL | LEDCAL |
| R／W | R／W | R／W | R／W | R／W | R／W | R／W | R／W | R／W |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 【0xF0 ：Clear Interrupt】

Name：CLR＿INTERRUPT
Address：0xFO
Description：Clear Interrupt Register．
INI ：Clear Interrupt of Initialization finish ：
Clear the INI interrupt by writing＇ 0 ＇to this register．If the written value is＇ 1 ＇，the operation is not valid．

## CAL ：Clear Interrupt of Software－calibration finish ：

Clear the CAL interrupt by writing＇ 0 ＇to this register．If the written value is＇ 1 ＇，the operation is not valid．
ERCAL ：Clear Interrupt of Self－calibration finish ：
Clear the ERCAL interrupt by writing＇ 0 ＇to this register．If the written value is＇ 1 ＇，the operation is not valid．
PERCAL ：Clear Interrupt of Periodic calibration finish ：
Clear the PERCAL interrupt by writing＇ 0 ＇to this register．If the written value is＇ 1 ＇，the operation is not valid．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0xF0 | - | - | - | PERCAL | - | ERCAL | CAL | INI |
| R／W | - | - | - | R／W | - | R／W | R／W | R／W |
| Initial val． | - | - | - | 0 | - | 0 | 0 | 0 |

## 【0xF1：Clear Switch－On】

Name：CLR＿DETECT＿ON
Address：0xF1
Description：DETECT＿ON Clear Register．Clear the DETECT＿ON by writing＇ 0 ＇in these registers．If the written value is＇ 1 ＇，the operation is not valid．
1 ：Invalid． 0 ：Clear．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0xF1 | - | - | - | ON＿SW4 | ON＿SW3 | ON＿SW2 | ON＿SW1 | ON＿SW0 |
| R／W | - | - | - | R／W | R／W | R／W | R／W | R／W |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 【0xF2 ：Clear Switch－Off】

Name：CLR＿DETECT＿OFF
Address： $0 \times F 2$
Description：DETECT＿OFF Clear Register．Clear the DETECT＿OFF by writing＇ 0 ＇in these registers．If the written value is＇$\overline{1}$＇，the operation is not valid．
1 ：Invalid． 0 ：Clear．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0xF2 | - | - | - | OFF＿SW4 | OFF＿SW3 | OFF＿SW2 | OFF＿SW1 | OFF＿SW0 |
| R／W | - | - | - | R／W | R／W | R／W | R／W | R／W |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

【0xF3：Clear continuous touch】
Name：CLR＿DETECT＿CONT
Address：0xF3
Description：DETECT＿CONT Clear Register．Clear the DETECT＿CONT by writing＇ 0 ＇to these registers．If the written value is＇ 1 ＇，the operation is not valid．
1 ：Invalid． 0 ：Clear．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0xF3 | - | - | - | CONT＿SW4 | CONT＿SW3 | CONT＿SW2 | CONT＿SW1 | CONT＿SW0 |
| R／W | R／W | R／W | R／W | R／W | R／W | R／W | R／W | R／W |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 【0xF4 ：Clear Interrupt of PWM continuous flashing】

Name：CLR＿DETECT＿PWM＿FINISH
Address：0xF4
Description：DETECT＿PWM＿FINISH Clear Register．Clear the DETECT＿PWM＿FINISH by writing＇ 0 ＇to these registers． If the written value is＇ 1 ＇，the operation is not valid．
1 ：Invalid． 0 ：Clear．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0xF4 | - | - | - | - | PWM3 | PWM2 | PWM1 | PWM0 |
| R／W | - | - | - | - | R／W | R／W | R／W | R／W |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

【0xF9 ：Switch PWM assign】
Name：PWM＿SWITCH
Address：0xF9
Description：CFG ：Switch PWM assign ：
If the written value is＇ 1 ＇，the PWM configurations（Address from 0xED to $0 x E E$ ）are valid．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0xF9 | - | - | - | - | - | - | - | CFG |
| R／W | - | - | - | - | - | - | - | R／W |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

【0xFA ：Control LED port】

| Name： | LED＿CNT |
| :--- | :--- |
| Address： | OxFA |
| Description： | This register is used to control each LED port． |
|  |  |
|  | $1:$ Always On（High drive） 0 ：Always Off（Low drive） |


|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0xFA | - | - | - | LED4＿EN | LED3＿EN | LED2＿EN | LED1＿EN | LED0＿EN |
| R／W | - | - | - | R／W | R／W | R／W | R／W | R／W |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 【0xFB ：Select PWM】

```
Name: PWM_SELECT
Address: 0xFB
Description: This register is used to select whether PWM function for each LED port.
                                1: Use PWM function. 0: Not use PWM function (default).
```

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0xFB | - | - | - | PWMS＿LED4 | PWMS＿LED3 | PWMS＿LED2 | PWMS＿LED1 | PWMS＿LED0 |
| R／W | - | - | - | RW | R／W | R／W | R／W | R／W |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

【0xFC ：Control PWM function】

| Name： | PWM＿CNT |
| :--- | :--- |
| Address： | 0xFC |
| Description： | This register is used to control PWM function． |

By writing＇ 1 ＇to the register which value is＇ 0 ＇，the PWM function is started．
By writing＇ 0 ＇to the register which value is＇ 1 ＇，the PWM function is stopped．
In the case that the PWM function is finished by reaching repeat number，set＇ 0 ＇to this register for the next operation of PWM function．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0xFC | - | - | - | - | PWM3＿EN | PWM2＿EN | PWM1＿EN | PWM0＿EN |
| R／W | - | - | - | - | R／W | R／W | R／W | R／W |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 【0xFE ：Write register for operation check of IC】

## Name：WACT <br> Address：0xFE

Description：This register is a write register for operational check of the IC．This register＇s value is copied to the read register for operation check（Address is $0 \times 1 \mathrm{E}$ ）．If the write value and the read value are equal，MPU and I／F are operating normally．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0xFE | WACT［7：0］ |  |  |  |  |  |  |  |  | R／W |
| R／W | R／W | R／W | R／W | R／W | R／W | R／W | R／W |  |  |  |
| Initial val． | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |  |  |

## 【0xFF ：AFE Control】

Name：CNT
Address：0xFF
Description：This register is for controlling AFE．

## ACT ：Scan Enable ：

This bit is the scan enable for AFE．
1 ：Scan Enable． 0 ：Scan Disable．

## CAL ：Act Soft－calibration ：

The calibration is operated by setting＇ 1 ＇．

## CFG ：Enable Configuration Value ：

Writing＇ 1 ＇to this bit，the value of Sensor configuration（address from 0xC0 to 0xD1），Mask Configuration （address 0xDF），Mask Interrupt of PWM continuous flashing（address＝0xEC），LED calibration（address＝ $0 x E F$ ），FRCRLS and CALOVF are effective to the IC＇s operation．

## CALMOD ：Select Software－calibration mode ：

0 ：All sensors are the targets for soft－calibration．If some sensor has the value more than the threshold for ＇OFF＇to＇ON＇，the sensors are changed to＇OFF＇，and DETECT＿OFF register is enabled（default）．
1：The sensors with the value more than the threshold for＇OFF＇to＇ON＇are not calibrated．

## CALOVF ：Select Self－calibration mode detected overflow

When the periodic calibration is active，it selects whether to activate self－calibration or not to activate in the case that the sensor values are over the dynamic range of included ADC．
0 ：Deactivate self－calibration（default）．1：Activate self－calibration
FRCRLS ：Select Force OFF at continuous touch ：
When the continuous touch is active，select whether to activate force OFF or not in the case that the max value after detect continuous touch minus the current sensor value is more than the threshold for＇OFF＇to ＇ON＇．
0 ：Deactivate force OFF（default）．1：Activate force OFF．
By force OFF is performed，the continuous touch sensor is changed to OFF，and DETECT＿OFF register is enabled．

|  | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0xFF | FRCRLS | CALOVF | - | CALMOD | - | CFG | CAL | ACT |
| R／W | R／W | R／W | - | R／W | - | R／W | R／W | R／W |
| Initial val． | 0 | 0 | - | 0 | - | 0 | 0 | 0 |

## Timing Charts

## Host interface

2-wire serial bus.
Compatible with I ${ }^{2} \mathrm{C}$ protocol.
Support slave mode only.
7-bit Slave Address = 0x4C (in the case of ADR = 'L'), 0x4D (in the case of ADR = 'H').
Standard-mode (data transfer rate of $100 \mathrm{kbit} / \mathrm{s}$ ), Fast-mode (data transfer rate of $400 \mathrm{kbit} / \mathrm{s}$ ).
Supports sequential read.

SDA

SCL


Figure 8. 2-wire serial bus data format


Figure 9. 2-wire serial bus data timing chart

| Parameter | Symbol | Standard-mode |  | Fast-mode |  | Unit |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | MIN | MAX | MIN | MAX |  |
| SCL clock frequency | fsCL | 0 | 100 | 0 | 400 | kHz |
| Hold time (repeated) START condition | $\mathrm{t}_{\text {HD; }}$ STA | 4.0 | - | 0.6 | - | usec |
| LOW period of the SCL clock | tLow | 4.7 | - | 1.3 | - | usec |
| HIGH period of the SCL clock | $\mathrm{t}_{\text {HIGH }}$ | 4.0 | - | 0.6 | - | usec |
| Data hold time | $\mathrm{t}_{\mathrm{HD} ; \mathrm{DAT}}$ | 0.1 | 3.45 | 0.1 | 0.9 | usec |
| Data set-up time | $\mathrm{t}_{\text {SU; }{ }_{\text {DAT }}}$ | 0.25 | - | 0.1 | - | usec |
| Set-up time for a repeated START condition | $\mathrm{t}_{\text {SU;STA }}$ | 4.7 | - | 0.6 | - | usec |
| Set-up time for STOP condition | $\mathrm{tsu}_{\text {jsto }}$ | 4.0 | - | 0.6 | - | usec |
| Bus free time between STOP and START condition | $\mathrm{t}_{\text {BUF }}$ | 4.7 | - | 1.3 | - | usec |

[^0]
## - Byte Write



SA: Slave Address<br>RA: Register Address<br>RD : Read Data<br>WD : Write Data

- Random Read



## - Sequential Read



Figure 10. 2-wire serial bus protocol

## Scan Rate

After scan each sensor in time series, MPU convert to the switch operations from the detected results. One scan rate is about 14.8 msec at typical.


Figure 11. Timing chart of scan rate

## Power on sequence

Power supply pin is VDD only. AVDD and DVDD are supplied by each LDO included this IC, so that have no priority about power on sequence. When VDD reaches to the effective voltage, power-on-reset which initializes the digital block is released.
Power-on-reset is monitoring VDD, so it needs that decoupling capacitor's value is suitable for VDD rising time. (DVDD's rising time < VDD's rising time.)
Figure 12. Arrangement of external decoupling capacitors
Recommended value of external capacitors

| $\mathrm{C}_{1}$ | 0.1 uF | VDD decoupling capacitor |
| :--- | :--- | :--- |
| $\mathrm{C}_{2}$ | 1.0 uF | DVDD decoupling capacitor |
| $\mathrm{C}_{3}$ | 2.2 uF | AVDD decoupling capacitor |



Figure 13. Timing chart of power on sequence

When power-on-reset is released, MPU starts initial sequence. Inform by the INT port to the host that the initialization has been completed. After verify that the initialization has been completed, the host will need to resend the command to this IC.
In the case that WDTR is released as well, MPU starts initial sequence. If WDTR has released, all registers of this IC have been initialized. So the host will need to resend the command to this IC.


Figure 14. Timing chart of initialization

Initialize operation
This IC is initialized and all registers are cleared by Power-on reset, WDT time-out reset, and Software reset command When initialization is complete, the register INI is set to ' 1 ' and I/O port INT is set to ' H ',
After the IC is initialized, write the configuration values to registers. After setting configuration values, the next action is sensor calibration. Set ' 1 ' to the registers ACT, CFG and CAL on Address 0xFF, so calibration sequence is performed.

IC's initialization after hardware reset
Power-on-reset
WDTR (Watchdog timer timeout reset)
Software reset command
The above actions act hardware reset to the IC. Hardware reset clear the all registers to the default value and initialize MPU. After hardware reset, MPU runs the initial sequence of firmware on Program ROM


Figure 15. Initialization routine after hardware reset


Figure 16. Configuration sequence including clear interrupts

## Calibration

## Self-calibration

Self-calibration is performed by this IC automatically. It is performed in the following cases.

1. Detect drift condition :

When the IC detects the drift condition, the IC acts self-calibration. When calibration is complete, the interrupt factor register CAL is set to ' 1 ' and I/O port INT is set to ' H '. When there is the sensor with the sensor value more than the threshold for 'Off to On', IC does not detect drift condition. The interrupt factor register CAL is maskable by the mask interrupt register CAL. The interrupt factor register CAL is cleared by writing ' 1 ' to the interrupt clear register CAL.
2. Detect noise :

When the IC detects the noise, the IC changes the scan rate to not synchronize with the noise, and the IC acts self-calibration. When calibration is complete, the Interrupt factor register CAL is set to ' 1 ' and I/O port INT is set to ' H '. The interrupt factor register CAL is maskable by the mask interrupt register CAL. The interrupt factor register CAL is cleared by writing ' 1 ' to the interrupt clear register CAL.
3. Detect incorrect operation :

When the finger is on the sensor at the calibration, the sensor base state is with the finger. Without the finger, the sensor value is under the base state value. This abnormal condition is defined to incorrect operation. Detected incorrect operation, the IC acts self-calibration. The interrupt factor register CAL is maskable by the mask interrupt register CAL. The interrupt factor register CAL is cleared by writing ' 1 ' to the interrupt clear register CAL.

## Software-calibration

Software-calibration is performed by the command from the host.

1. Write ' 1 ' to the Act Software-calibration bit.
2. Finishing the calibration, the Software-calibration finish bit (CAL on Address $0 \times 10$ ) is set to ' 1 ' and I/O port INT is set to ' H '. For next calibration, clear the interrupt.

When the sensor setting value is changed, it is necessary to execute a soft calibration. It is necessary for changing the value of the sensor setting that the scan is disabled.

In the act of calibration, sensor values are not changed. So the switching operations are invalid.
If the software-calibration is released at sensing sensors, IC acts calibration at next sensing sensors.

LED calibration
When the register for LED/PWM drivers operation (address area from 0xF9 to 0xFC) is written, this IC is selectable whether to perform self-calibration. Selecting whether to perform the LED calibration is defined by the configuration for calibration register (LEDCAL on Address 0xEF).

If there is the writing to the register for LED/PWM drivers operation (address area from 0xF9 to 0xFC), when the finger on the sensors. Incorrect operation will be detected at the finger leaving, and so IC will act self-calibration.

## Periodical calibration

The periodical calibration is to perform self-calibration periodically. This IC is selectable whether to perform periodical calibration. Selecting whether to perform the periodical calibration is defined by the configuration for calibration register (PERCAL on Address0xEF).
The sensor with the finger is not calibrated by the periodical calibration.
Whenever periodical calibration is complete, the interrupt factor register PERCAL is set to ' 1 ' and I/O port INT is set to 'H'. The interrupt factor register PERCAL is maskable by the mask interrupt register PERCAL. The interrupt factor register CAL is cleared by writing ' 1 ' to the interrupt clear register PERCAL.

Interrupt when multi calibration factor occurs
The calibration of the four factors to carry out the calibration is different respectively. Therefore, state the calibration of another is started during the conduct of certain calibration, the conflict occurs
If the calibration different conditions occur in the middle of the calibration, calibration being performed to stop, a new calibration is carried out from the beginning.
The interrupt by finishing the first factor's calibration is set, and the interrupt by the new factor's calibration is set too.


Interrupt of each factor is output

Figure 17. Interrupt when multi calibration factor occurs

## Switch operation

Every sensor is used for simple switch. Each switch has the registers of detected Touch/Release/Hold operations. Every switch supports to multi-detect Touch/Release/Hold. Unused switches are maskable.


Figure 18. Interrupt of switch operation (1)


Figure 19. Interrupt of switch operation (2)

## Interrupt of PWM continuous flashing

When PWM configuration is set to not always lights, PWM drive repeat as many times as the setting value. The interrupt is released at finishing PWM drive.
In the case that PWM always lights, the way to turn PWM off is to write ' 0 ' to the Control PWM function register which value is ' 1 ', and the interrupt is released at finishing PWM drive. However, if you restart the PWM timer before the PWM timer will not finish, the interrupt is not released.


Figure 20. Interrupt of PWM drive

## Operational Notes

1. Reverse Connection of Power Supply

Connecting the power supply in reverse polarity can damage the IC. Take precautions against reverse polarity when connecting the power supply, such as mounting an external diode between the power supply and the IC's power supply terminals.

## 2. Power Supply Lines

Design the PCB layout pattern to provide low impedance supply lines. Separate the ground and supply lines of the digital and analog blocks to prevent noise in the ground and supply lines of the digital block from affecting the analog block. Furthermore, connect a capacitor to ground at all power supply pins. Consider the effect of temperature and aging on the capacitance value when using electrolytic capacitors.
3. Ground Voltage

Ensure that no pins are at a voltage below that of the ground pin at any time, even during transient condition.
4. Ground Wiring Pattern

When using both small-signal and large-current ground traces, the two ground traces should be routed separately but connected to a single ground at the reference point of the application board to avoid fluctuations in the small-signal ground caused by large currents. Also ensure that the ground traces of external components do not cause variations on the ground voltage. The ground lines must be as short and thick as possible to reduce line impedance.

## 5. Thermal Consideration

Should by any chance the power dissipation rating be exceeded the rise in temperature of the chip may result in deterioration of the properties of the chip. The absolute maximum rating of the Pd stated in this specification is when the IC is mounted on $74.2 \mathrm{~mm} \times 74.2 \mathrm{~mm} \times 1.6 \mathrm{~mm}$ glass epoxy 1 layer board (Copper foil area : $10.29 \mathrm{~mm}^{2}$ ). In case of exceeding this absolute maximum rating, increase the board size and copper area to prevent exceeding the Pd rating.

## 6. Recommended Operating Conditions

These conditions represent a range within which the expected characteristics of the IC can be approximately obtained. The electrical characteristics are guaranteed under the conditions of each parameter.
7. Rush Current

When power is first supplied to the IC, it is possible that the internal logic may be unstable and inrush current may flow instantaneously due to the internal powering sequence and delays, especially if the IC has more than one power supply. Therefore, give special consideration to power coupling capacitance, power wiring, width of ground wiring, and routing of connections.
8. Operation Under Strong Electromagnetic Field

Operating the IC in the presence of a strong electromagnetic field may cause the IC to malfunction.
9. Testing on Application Boards

When testing the IC on an application board, connecting a capacitor directly to a low-impedance output pin may subject the IC to stress. Always discharge capacitors completely after each process or step. The IC's power supply should always be turned off completely before connecting or removing it from the test setup during the inspection process. To prevent damage from static discharge, ground the IC during assembly and use similar precautions during transport and storage.
10. Inter-pin Short and Mounting Errors

Ensure that the direction and position are correct when mounting the IC on the PCB. Incorrect mounting may result in damaging the IC. Avoid nearby pins being shorted to each other especially to ground, power supply and output pin. Inter-pin shorts could be due to many reasons such as metal particles, water droplets (in very humid environment) and unintentional solder bridge deposited in between pins during assembly to name a few.

## 11. Unused Input Terminals

Input terminals of an IC are often connected to the gate of a MOS transistor. The gate has extremely high impedance and extremely low capacitance. If left unconnected, the electric field from the outside can easily charge it. The small charge acquired in this way is enough to produce a significant effect on the conduction through the transistor and cause unexpected operation of the IC. So unless otherwise specified, unused input terminals should be connected to the power supply or ground line.
12. Regarding the Input Pin of the IC

In the construction of this IC, P-N junctions are inevitably formed creating parasitic diodes or transistors. The operation of these parasitic elements can result in mutual interference among circuits, operational faults, or physical damage. Therefore, conditions which cause these parasitic elements to operate, such as applying a voltage to an input pin lower than the ground voltage should be avoided. Furthermore, do not apply a voltage to the input terminals when no power supply voltage is applied to the IC. Even if the power supply voltage is applied, make sure that the input terminals have voltages within the values specified in the electrical characteristics of this IC.
13. Ceramic Capacitor

When using a ceramic capacitor, determine the dielectric constant considering the change of capacitance with temperature and the decrease in nominal capacitance due to DC bias and others.
14. Area of Safe Operation (ASO)

Operate the IC such that the output voltage, output current, and power dissipation are all within the Area of Safe Operation (ASO).

## Ordering Information



## Marking Diagram

VQFNO20V4040 (TOP VIEW)


Physical Dimension, Tape and Reel Information

| Package Name | VQFN020V4040 |
| :--- | :--- |



## Revision History

| Date | Revision | Changes |
| :---: | :---: | :---: |
| 31.Oct. 2013 | 001 | New Release |
| 14.Jul. 2016 | 002 | P3 Figure 6. Block Diagram <br> Correct wiring error to the block PoR. <br> P7 Correct clerical error <br> (old) couth <br> (new) touch <br> P7 Correct clerical error <br> (old) 'Detection continued touch' <br> (new) 'Detection continuous touch' <br> P13 Correct clerical error (old) the periodical : (new) the periodical calibration : <br> P13 Correct clerical error (old) the periodical when (new) the periodical calibration when <br> P14 Correct clerical error (old) Clear the INI interrupt (new) Clear the PERCAL interrupt <br> P19 Correct clerical error (old) the initialization ha completed, (new) the initialization has been completed, <br> P20 Correct clerical error in Figure 15. (old) Resister (new) Register |

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[h] Use of the Products in places subject to dew condensation
4. The Products are not subject to radiation-proof design.
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8. Confirm that operation temperature is within the specified range described in the product specification.
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For details, please refer to ROHM Mounting specification

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105318, г.Москва, ул.Щербаковская д.3, офис 1107, 1118, ДЦ «Щербаковский»
Телефон: +7 495 668-12-70 (многоканальный)
Факс: +7 495 668-12-70 (доб.304)
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moschip.ru
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[^0]:    * It is necessary that interval time for writing to register which address is from 0xF0 to 0xFF is more than 650usec.

