

PCA2131

Nano-power highly accurate RTC with integrated quartz crystal for automotive applications

Rev. 2.0 — 5 October 2023

Product data sheet



1 General description

The PCA2131 is a CMOS Real Time Clock (RTC) and calendar with an integrated Temperature Compensated Crystal (Xtal) Oscillator (TCXO) and a 32.768 kHz quartz crystal optimized for very high accuracy and ultra low power consumption. The PCA2131 has a selectable I²C-bus or SPI-bus, a backup battery switch-over circuit, a programmable watchdog function, four timestamps function, and many other features.

For a selection of NXP Real-Time Clocks, see [Section 15.1](#).

2 Features and benefits

- AEC-Q100 compliant version: PCA2131TF/Q900 for automotive applications
- Operating temperature range from -40 °C to +105 °C
- Temperature Compensated Crystal Oscillator (TCXO) with trimmed integrated capacitors
- Clock operational up to 125 °C
- Ultra low supply current: typical 106 nA at V_{DD} = 3.3 V
- Temperature compensated RTC, typical accuracy ±3 ppm from -40 °C to +85 °C; ±8 ppm from +85 °C to +105 °C
- Integration of a 32.768 kHz quartz crystal and oscillator in the same package
- Provides year, month, day, weekday, hours, minutes, seconds and 1/100 seconds
- Provides leap year correction
- Timestamp function
 - with interrupt capability
 - detection of four different events on four input pins (for example, for tamper detection)
- 2-line bidirectional 400 kHz Fast-mode I²C-bus interface
- 4-line SPI-bus with separate data input and output (maximum speed 6.5 Mbit/s)
- Battery backup input pin and switch-over circuitry
- Battery backed output voltage
- Battery low detection function
- Power-On Reset (POR)
- Power-On Reset Override (PORO) function
- Software reset function
- Two interrupt outputs (open-drain)
- Programmable 1 second or 1 minute interrupt
- Programmable watchdog timer with interrupt
- Programmable alarm function with interrupt capability
- Programmable square output
- Clock operating voltage: 1.2 V to 5.5 V



3 Applications

- Electronic metering for electricity, water, and gas
- Precision timekeeping
- Access to accurate time of the day
- GPS equipment to reduce time to first fix
- Applications that require an accurate process timing
- Products with long automated unattended operation time

4 Ordering information

Table 1. Ordering information

| Type number | Topside marking | Package | | |
|----------------|-----------------|---------|---|-----------|
| | | Name | Description | Version |
| PCA2131TF/Q900 | A31 | HLSON16 | thermal enhanced low profile small outline; no leads, 16 terminals, 0.125 dimple wettable flank, 0.5 mm pitch, 4.5 mm x 3.5 mm x 1.45 mm body | SOT1992-1 |

4.1 Ordering options

Table 2. Ordering options

| Product type number | Orderable part number | Package | Packing method | Minimum Order Quantity | Temperature |
|---------------------|-----------------------|---------|----------------|------------------------|--------------------------------------|
| PCA2131TF/Q900 | PCA2131TF/Q900Y | HLSON16 | REEL 13" Q1 DP | 4000 | T _{amb} = -40 °C to +105 °C |

5 Block diagram

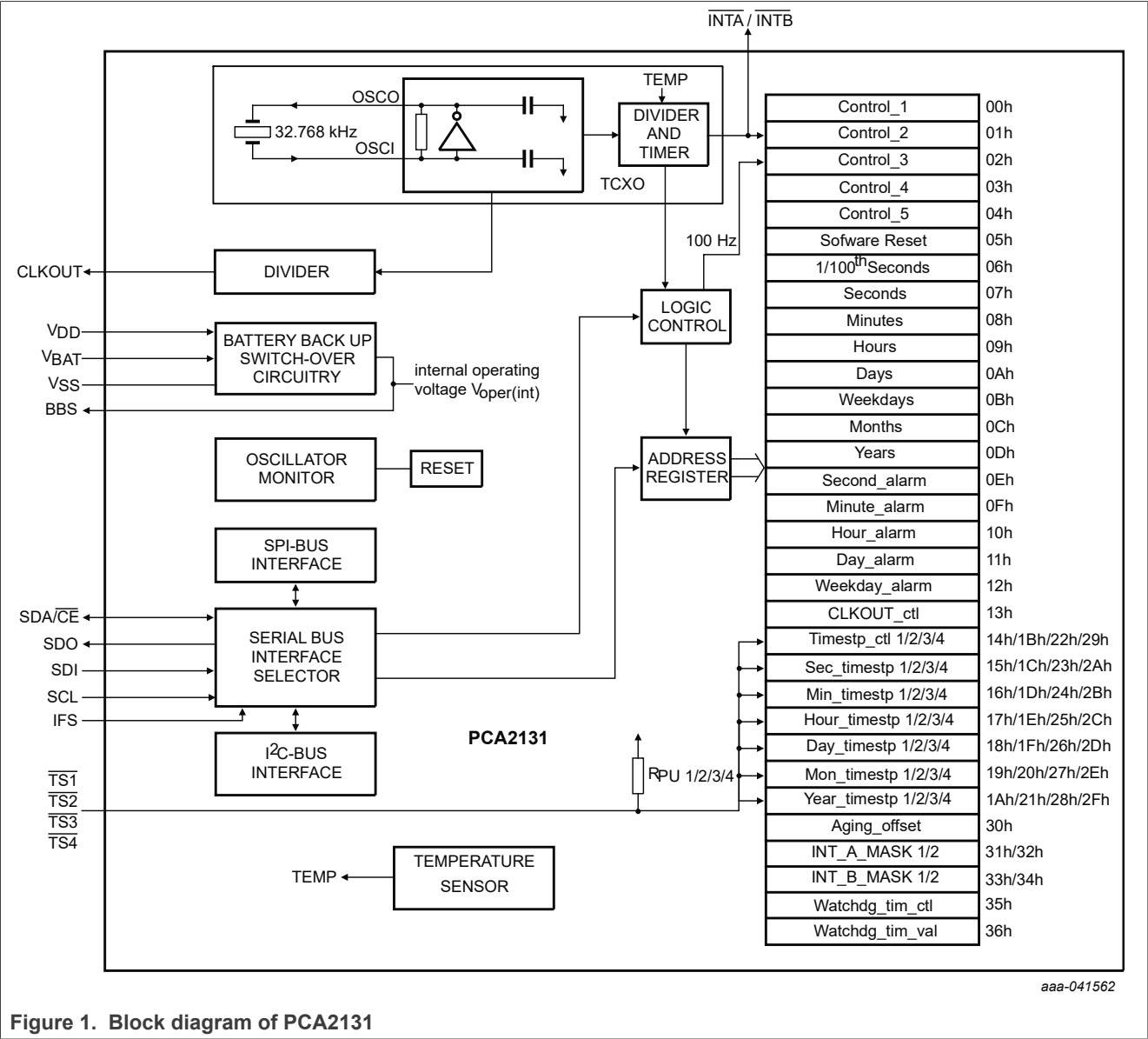


Figure 1. Block diagram of PCA2131

6 Pinning information

6.1 Pinning

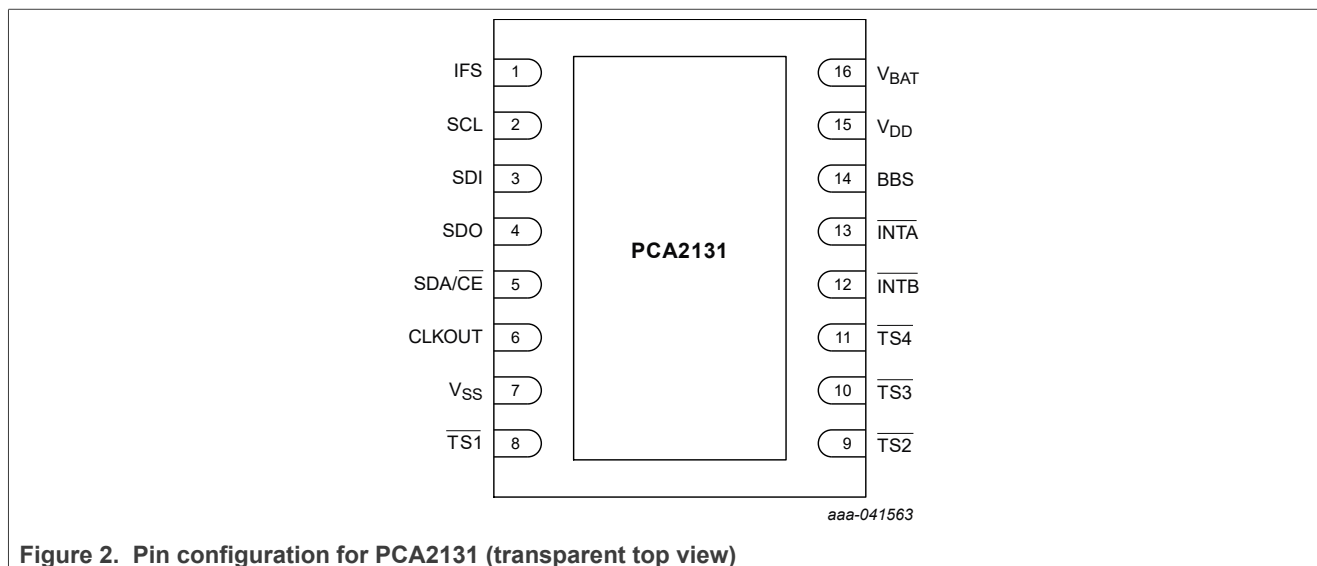


Figure 2. Pin configuration for PCA2131 (transparent top view)

6.2 Pin description

Table 3. Pin description

Input or input/output pins must always be at a defined level (V_{SS} or V_{DD}) unless otherwise specified.

| Symbol | Pin | Description |
|---------------------|--------------|---|
| SCL | 2 | combined serial clock input for both I ² C-bus and SPI-bus |
| SDI | 3 | serial data input for SPI-bus connect to pin V_{SS} if I ² C-bus is selected |
| SDO | 4 | serial data output for SPI-bus, push-pull leave open or connect to pin V_{SS} if I ² C-bus is selected |
| SDA/CE | 5 | combined serial data input and output for the I ² C-bus and chip enable input (active LOW) for the SPI-bus |
| IFS | 1 | interface selector input connect to pin V_{SS} to select the SPI-bus connect to pin V_{DD} to select the I ² C-bus |
| TS1, TS2, TS3, TS4, | 8, 9, 10, 11 | timestamp input (active LOW) with 500 k Ω internal pull-up resistor (R_{PU}) |
| CLKOUT | 6 | clock output (push-pull) |
| V_{SS} | 7 | ground supply voltage |
| INTB | 12 | interrupt B output (open-drain; active LOW) |
| INTA | 13 | interrupt A output (open-drain; active LOW) |
| BBS | 14 | output voltage (battery backed) |

Table 3. Pin description...continued
Input or input/output pins must always be at a defined level (V_{SS} or V_{DD}) unless otherwise specified.

| Symbol | Pin | Description |
|-------------|-----|---|
| V_{BAT} | 16 | battery supply voltage (backup) connect to V_{SS} if battery switch-over is not used |
| V_{DD} | 15 | supply voltage |
| Exposed Pad | | Tie to V_{SS} (preferred) ^[1] or leave floating |

[1] This protects against signal feedback to the oscillator if routed close to the part.

7 Functional description

The PCA2131 is a Real Time Clock (RTC) and calendar with an on-chip Temperature Compensated Crystal (Xtal) Oscillator (TCXO) and a 32.768 kHz quartz crystal integrated into the same package.

Address and data are transferred by a selectable 400 kHz Fast-mode I²C-bus or a 4-line SPI-bus with separate data input and output (see [Section 7.16](#)). The maximum speed of the SPI-bus is 6.5 Mbit/s.

The PCA2131 has a backup battery input pin and backup battery switch-over circuit which monitors the main power supply. The backup battery switch-over circuit automatically switches to the backup battery when a power failure condition is detected (see [Section 7.5.1](#)). Accurate timekeeping is maintained even when the main power supply is interrupted.

A battery low detection circuit monitors the status of the battery (see [Section 7.5.2](#)). When the battery voltage drops below a certain threshold value, a flag is set to indicate that the battery must be replaced soon. This ensures the integrity of the data during periods of battery backup.

7.1 Register overview

The PCA2131 contains an auto-incrementing address register: the built-in address register will increment automatically after each read or write of a data byte up to the register 36h. After register 36h, the auto-incrementing will wrap around to address 00h (see [Figure 3](#)).

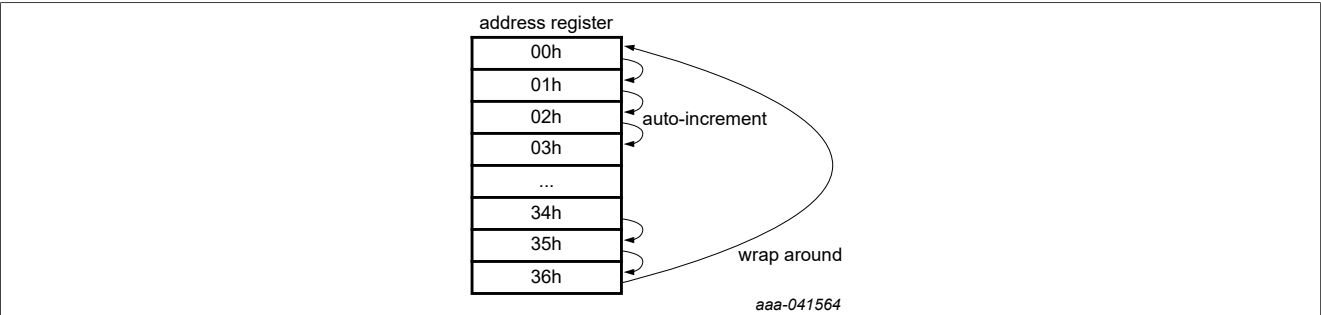


Figure 3. Handling address registers

- The first five registers (memory address 00h, 01h, 02h, 03h and 04h) are used as control registers (see [Section 7.2](#)).
- The register at address 05h is for software reset.
- The memory addresses 06h through to 0Dh are used as counters for the clock function (1/100 seconds up to years). The date is automatically adjusted for months with fewer than 31 days, including corrections for leap years. The clock can operate in 12-hour mode with an AM/PM indication or in 24-hour mode (see [Section 7.9](#)).

- The registers at addresses 0Eh through 12h define the alarm function. It can be selected that an interrupt is generated when an alarm event occurs (see [Section 7.10](#)).
- The register at address 13h defines the temperature measurement period and the clock out mode. The temperature measurement can be selected from every 32 minutes (default) down to every 4minutes (see [Table 17](#)). CLKOUT frequencies of 32.768 kHz (default) down to 1 Hz for use as system clock, microcontroller clock, and so on, can be chosen (see [Table 18](#)).
- The registers at addresses 14h to 2Fh are used for the timestamp function. When the trigger event happens, the actual time is saved in the timestamp registers (see [Section 7.12](#)).
- The register at address 30h is used for the correction of the crystal aging effect (see [Section 7.4.1](#)).
- The registers at addresses 31h to 34h are used for interrupt configuration.
- The registers at addresses 35h and 36h are used for the watchdog timer functions. The watchdog timer has four selectable source clocks allowing for timer periods from less than 20 ms to greater than 4 hours (see [Table 59](#)). An interrupt is generated when the watchdog times out.
- The registers 100th Seconds, Seconds, Minutes, Hours, Days, Months, and Years are all coded in Binary Coded Decimal (BCD) format to simplify application use. Other registers are either bit-wise or standard binary.

When one of the RTC registers is written or read, the content of all counters is temporarily frozen, all registers hold their state during SPI or I2C transactions. The time stamp registers would update as soon as the bus transaction completes. This prevents a faulty writing or reading of the clock and calendar during a carry condition (see [Section 7.9.9](#)).

Table 4. Register overview

Bit positions labeled as *T* are unused and return 0 when read. Bits labeled as *X* are undefined at power-on and unchanged by subsequent resets.

| Address | Register name | Bit | | | | | | | | Reset value | Reference |
|-------------------------|---------------|------------------------|------------------------|--------------------------------------|--------------------------------------|----------|------------------------|-----------|--------------------------|--------------------------|--------------------------|
| | | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |
| Control registers | | | | | | | | | | | |
| 00h | Control_1 | EXT_TEST | TC_DIS | STOP | 100TH_S_DIS | POR_OVRD | 12_24 | MI | SI | 0000 1000 | Table 5 |
| 01h | Control_2 | MSF | WDTF | T | AF | T | T | AIE | T | 0000 0000 | Table 7 |
| 02h | Control_3 | PWRMNG[2:0] | | | BTSE | BF | BLF | BIE | BLIE | 1110 0000 | Table 9 |
| 03h | Control_4 | TSF1 | TSF2 | TSF3 | TSF4 | T | T | T | T | 0000 0000 | Table 11 |
| 04h | Control_5 | TSIE1 | TSIE2 | TSIE3 | TSIE4 | T | T | T | T | 0000 0000 | Table 13 |
| Software Reset | | | | | | | | | | | |
| 05h | SR_Reset | CPR | 0 | 1 | 0 | SR | 1 | 0 | CTS | 0010 0100 | Table 24 |
| Time and date registers | | | | | | | | | | | |
| 06h | 100th_Seconds | 100TH_SECONDS(0 to 99) | | | | | | | | 0000 0000 | Table 25 |
| 07h | Seconds | OSF | SECONDS (0 to 59) | | | | | | 1000 0000 | Table 28 | |
| 08h | Minutes | - | MINUTES (0 to 59) | | | | | | 0000 0000 | Table 31 | |
| 09h | Hours | - | - | AMPM | HOURS (1 to 12) in 12-hour mode | | | | 0000 0000 | Table 33 | |
| | | | | HOURS (0 to 23) in 24-hour mode | | | | 0000 0000 | | | |
| 0Ah | Days | - | - | DAYS (1 to 31) | | | | 0000 0001 | Table 35 | | |
| 0Bh | Weekdays | - | - | - | - | - | WEEKDAYS (0 to 6) | | 0000 0001 | Table 37 | |
| 0Ch | Months | - | - | - | MONTHS (1 to 12) | | | | 0000 0001 | Table 40 | |
| 0Dh | Years | YEARS (0 to 99) | | | | | | | | 0000 0001 | Table 43 |
| Alarm registers | | | | | | | | | | | |
| 0Eh | Second_alarm | AE_S | SECOND_ALARM (0 to 59) | | | | | | 1000 0000 | Table 45 | |
| 0Fh | Minute_alarm | AE_M | MINUTE_ALARM (0 to 59) | | | | | | 1000 0000 | Table 47 | |
| 10h | Hour_alarm | AE_H | - | AMPM | HOUR_ALARM (1 to 12) in 12-hour mode | | | | 1000 0000 | Table 49 | |
| | | | | HOUR_ALARM (0 to 23) in 24-hour mode | | | | 1000 0000 | | | |
| 11h | Day_alarm | AE_D | - | DAY_ALARM (1 to 31) | | | | 1000 0000 | Table 51 | | |
| 12h | Weekday_alarm | AE_W | - | - | - | - | WEEKDAY_ALARM (0 to 6) | | 1000 0000 | Table 53 | |
| CLKOUT control register | | | | | | | | | | | |

Table 4. Register overview...continued

Bit positions labeled as *T* are unused and return 0 when read. Bits labeled as *X* are undefined at power-on and unchanged by subsequent resets.

| Address | Register name | Bit | | | | | | | | Reset value | Reference |
|----------------------|-----------------|--------------------------|----------------------------|--|--|---|----------|-----------|--------------------------|--------------------------|--------------------------|
| | | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |
| 13h | CLKOUT_ctl | TCR[1:0] | | OTPR | - | - | COF[2:0] | | | 00X0 0000 | Table 15 |
| Timestamp1 registers | | | | | | | | | | | |
| 14h | Timestamp_ctl1 | TSM | TSOFF | - | SUBSEC_TIMESTAMP[4:0] | | | | 0000 0000 | Table 64 | |
| 15h | Sec_timestamp1 | - | SECOND_TIMESTAMP (0 to 59) | | | | | | 0000 0000 | Table 66 | |
| 16h | Min_timestamp1 | - | MINUTE_TIMESTAMP (0 to 59) | | | | | | 0000 0000 | Table 68 | |
| 17h | Hour_timestamp1 | - | - | AMPM | HOUR_TIMESTAMP (1 to 12) in 12-hour mode | | | | 0000 0000 | Table 70 | |
| | | | | HOUR_TIMESTAMP (0 to 23) in 24-hour mode | | | | 0000 0000 | | | |
| 18h | Day_timestamp1 | - | - | DAY_TIMESTAMP (1 to 31) | | | | 0000 0000 | Table 72 | | |
| 19h | Mon_timestamp1 | - | - | - | MONTH_TIMESTAMP (1 to 12) | | | | 0000 0000 | Table 74 | |
| 1Ah | Year_timestamp1 | YEAR_TIMESTAMP (0 to 99) | | | | | | 0000 0000 | Table 76 | | |
| Timestamp2 registers | | | | | | | | | | | |
| 1Bh | Timestamp_ctl2 | TSM | TSOFF | - | SUBSEC_TIMESTAMP[4:0] | | | | 0000 0000 | Table 64 | |
| 1Ch | Sec_timestamp2 | - | SECOND_TIMESTAMP (0 to 59) | | | | | | 0000 0000 | Table 66 | |
| 1Dh | Min_timestamp2 | - | MINUTE_TIMESTAMP (0 to 59) | | | | | | 0000 0000 | Table 68 | |
| 1Eh | Hour_timestamp2 | - | - | AMPM | HOUR_TIMESTAMP (1 to 12) in 12-hour mode | | | | 0000 0000 | Table 70 | |
| | | | | HOUR_TIMESTAMP (0 to 23) in 24-hour mode | | | | 0000 0000 | | | |
| 1Fh | Day_timestamp2 | - | - | DAY_TIMESTAMP (1 to 31) | | | | 0000 0000 | Table 72 | | |
| 20h | Mon_timestamp2 | - | - | - | MONTH_TIMESTAMP (1 to 12) | | | | 0000 0000 | Table 74 | |
| 21h | Year_timestamp2 | YEAR_TIMESTAMP (0 to 99) | | | | | | 0000 0000 | Table 76 | | |
| Timestamp3 registers | | | | | | | | | | | |
| 22h | Timestamp_ctl3 | TSM | TSOFF | - | SUBSEC_TIMESTAMP[4:0] | | | | 0000 0000 | Table 64 | |
| 23h | Sec_timestamp3 | - | SECOND_TIMESTAMP (0 to 59) | | | | | | 0000 0000 | Table 66 | |
| 24h | Min_timestamp3 | - | MINUTE_TIMESTAMP (0 to 59) | | | | | | 0000 0000 | Table 68 | |
| 25h | Hour_timestamp3 | - | - | AMPM | HOUR_TIMESTAMP (1 to 12) in 12-hour mode | | | | 0000 0000 | Table 70 | |
| | | | | HOUR_TIMESTAMP (0 to 23) in 24-hour mode | | | | 0000 0000 | | | |
| 26h | Day_timestamp3 | - | - | DAY_TIMESTAMP (1 to 31) | | | | 0000 0000 | Table 72 | | |
| 27h | Mon_timestamp3 | - | - | - | MONTH_TIMESTAMP (1 to 12) | | | | 0000 0000 | Table 74 | |

Nano-power highly accurate RTC with integrated quartz crystal for automotive applications

Table 4. Register overview...continued

Bit positions labeled as *T* are unused and return 0 when read. Bits labeled as *X* are undefined at power-on and unchanged by subsequent resets.

| Address | Register name | Bit | | | | | | | | Reset value | Reference |
|--------------------------|-----------------|------------------------|--------------------------|--|--|---------|--------|---------|-----------|--------------------------|--------------------------|
| | | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |
| 28h | Year_timestp3 | YEAR_TIMESTP (0 to 99) | | | | | | | | 0000 0000 | Table 76 |
| Timestamp4 registers | | | | | | | | | | | |
| 29h | Timestp_ctl4 | TSM | TSOFF | - | SUBSEC_TIMESTP[4:0] | | | | | 0000 0000 | Table 64 |
| 2Ah | Sec_timestp4 | - | SECOND_TIMESTP (0 to 59) | | | | | | | 0000 0000 | Table 66 |
| 2Bh | Min_timestp4 | - | MINUTE_TIMESTP (0 to 59) | | | | | | | 0000 0000 | Table 68 |
| 2Ch | Hour_timestp4 | - | - | AMPM | HOUR_TIMESTP (1 to 12) in 12-hour mode | | | | | 0000 0000 | Table 70 |
| | | | | HOUR_TIMESTP (0 to 23) in 24-hour mode | | | | | 0000 0000 | | |
| 2Dh | Day_timestp4 | - | - | DAY_TIMESTP (1 to 31) | | | | | 0000 0000 | Table 72 | |
| 2Eh | Mon_timestp4 | - | - | - | MONTH_TIMESTP (1 to 12) | | | | | 0000 0000 | Table 74 |
| 2Fh | Year_timestp4 | YEAR_TIMESTP (0 to 99) | | | | | | | | 0000 0000 | Table 76 |
| Aging offset register | | | | | | | | | | | |
| 30h | Aging_offset | - | - | - | - | AO[3:0] | | | | 0000 1000 | Table 19 |
| Interrupt mask registers | | | | | | | | | | | |
| 31h | INT_A_MASK1 | - | - | MIA | SIA | WD_CDA | AIEA | BIEA | BLIEA | 0011 1111 | Table 80 |
| 32h | INT_A_MASK2 | - | - | - | - | TSIE1A | TSIE2A | TSIE3A | TSIE4A | 0000 1111 | Table 80 |
| 33h | INT_B_MASK1 | - | - | MIB | SIB | WD_CDB | AIEB | BIEB | BLIEB | 0011 1111 | Table 82 |
| 34h | INT_B_MASK2 | - | - | - | - | TSIE1B | TSIE2B | TSIE3B | TSIE4B | 0000 1111 | Table 82 |
| Watchdog registers | | | | | | | | | | | |
| 35h | Watchdg_tim_ctl | WD_CD | T | TI_TP | - | - | - | TF[1:0] | | 0000 0011 | Table 55 |
| 36h | Watchdg_tim_val | WATCHDG_TIM_VAL[7:0] | | | | | | | | 0000 0000 | Table 57 |

7.2 Control registers

The first five registers of the PCA2131, with the addresses 00h, 01h, 02h, 03h and 04h, are used as control registers.

7.2.1 Register Control_1

Table 5. Control_1 - control and status register 1 (address 00h) bit allocation

Bits labeled as *T* are unused and return 0 when read.

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|----------|--------|------|-------------|----------|-------|----|----|
| Symbol | EXT_TEST | TC_DIS | STOP | 100TH_S_DIS | POR_OVRD | 12_24 | MI | SI |
| Reset value | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |

Table 6. Control_1 - control and status register 1 (address 00h) bit description

Bits labeled as *T* are unused and return 0 when read.

| Bit | Symbol | Value | Description | Reference |
|-----|-------------|-------|--|--|
| 7 | EXT_TEST | 0 | normal mode | Section 7.14 |
| | | 1 | external clock test mode | |
| 6 | TC_DIS | 0 | Temperature compensation enabled | Section 7.3.1 |
| | | 1 | Temperature compensation disabled | |
| 5 | STOP | 0 | RTC source clock runs | Section 7.15 |
| | | 1 | RTC clock is stopped; RTC divider chain flip-flops are asynchronously set logic 0; CLKOUT output frequencies are still available | |
| 4 | 100TH_S_DIS | 0 | 100th seconds counter enabled | - |
| | | 1 | 100th seconds counter Disabled, register 06h reset to 00h. | - |
| 3 | POR_OVRD | 0 | Power-On Reset Override (PORO) facility disabled; set logic 0 for normal operation | Section 7.7.2 |
| | | 1 | Power-On Reset Override (PORO) sequence reception enabled | |
| 2 | 12_24 | 0 | 24-hour mode selected | Table 34, Table 50, Table 71 |
| | | 1 | 12-hour mode selected | |
| 1 | MI | 0 | minute interrupt disabled | Section 7.13.1 |
| | | 1 | minute interrupt enabled | |
| 0 | SI | 0 | second interrupt disabled | |
| | | 1 | second interrupt enabled | |

7.2.2 Register Control_2

Table 7. Control_2 - control and status register 2 (address 01h) bit allocation

Bits labeled as T are unused and return 0 when read.

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|-----|------|---|----|---|---|-----|---|
| Symbol | MSF | WDTF | T | AF | T | T | AIE | T |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 8. Control_2 - control and status register 2 (address 01h) bit description

Bits labeled as T are unused and return 0 when read.

| Bit | Symbol | Value | Description | Reference |
|-----|--------|-------|--|--------------------------------|
| 7 | MSF | 0 | no minute or second interrupt generated | Section 7.13 |
| | | 1 | flag set when minute or second interrupt generated; flag must be cleared to clear interrupt | |
| 6 | WDTF | 0 | no watchdog timer interrupt generated | Section 7.13.3 |
| | | 1 | flag set when watchdog timer interrupt generated; flag cannot be cleared by command (read-only) | |
| 5 | T | 0 | unused | - |
| 4 | AF | 0 | no alarm interrupt triggered | Section 7.10.6 |
| | | 1 | flag set when alarm triggered; flag must be cleared to clear interrupt | |
| 3:2 | T | 0 | unused | - |
| 1 | AIE | 0 | no interrupt generated from the alarm flag | Section 7.13.4 |
| | | 1 | interrupt generated when alarm flag set | |
| 0 | T | 0 | unused | - |

7.2.3 Register Control_3

Table 9. Control_3 - control and status register 3 (address 02h) bit allocation

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|-------------|---|---|------|----|-----|-----|------|
| Symbol | PWRMNG[2:0] | | | BTSE | BF | BLF | BIE | BLIE |
| Reset value | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |

Table 10. Control_3 - control and status register 3 (address 02h) bit description

| Bit | Symbol | Value | Description | Reference |
|--------|-------------|------------------------------|--|--|
| 7 to 5 | PWRMNG[2:0] | see Table 22 | control of the battery switch-over, battery low detection, and extra power fail detection functions | Section 7.5 |
| 4 | BTSE | 0 | no timestamp when battery switch-over occurs | Section 7.12.4 |
| | | 1 | time-stamped when battery switch-over occurs | |
| 3 | BF | 0 | no battery switch-over interrupt occurred | Section 7.5.1 and Section 7.12.4 |
| | | 1 | flag set when battery switch-over occurs; flag must be cleared to clear interrupt | |
| 2 | BLF | 0 | battery status ok; no battery low interrupt generated | Section 7.5.2 |
| | | 1 | battery status low; flag cannot be cleared by command, flag is automatically cleared when battery is replaced. | |
| 1 | BIE | 0 | no interrupt generated from the battery flag (BF) | Section 7.13.6 |
| | | 1 | interrupt generated when BF is set | |
| 0 | BLIE | 0 | no interrupt generated from battery low flag (BLF) | Section 7.13.7 |
| | | 1 | interrupt generated when BLF is set | |

7.2.4 Register Control_4

Table 11. Control_4 - control and status register 4 (address 03h) bit allocation

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|------|------|------|------|---|---|---|---|
| Symbol | TSF1 | TSF2 | TSF3 | TSF4 | T | T | T | T |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 12. Control_4 - control and status register 4 (address 03h) bit description

| Bit | Symbol | Value | Description | Reference |
|-----|--------|-------|--|--------------------------------|
| 7 | TSF1 | 0 | no timestamp interrupt generated for pin $\overline{\text{TS1}}$ | Section 7.12.1 |
| | | 1 | flag set when $\overline{\text{TS1}}$ input is driven to ground; flag must be cleared to clear interrupt | |
| 6 | TSF2 | 0 | no timestamp interrupt generated when pin $\overline{\text{TS2}}$ | Section 7.12.1 |
| | | 1 | flag set when $\overline{\text{TS2}}$ input is driven to ground; flag must be cleared to clear interrupt | |
| 5 | TSF3 | 0 | no timestamp interrupt generated for pin $\overline{\text{TS3}}$ | Section 7.12.1 |
| | | 1 | flag set when $\overline{\text{TS3}}$ input is driven to ground; flag must be cleared to clear interrupt | |
| 4 | TSF4 | 0 | no timestamp interrupt generated when pin $\overline{\text{TS4}}$ | Section 7.12.1 |
| | | 1 | flag set when $\overline{\text{TS4}}$ input is driven to ground; flag must be cleared to clear interrupt | |
| 3 | T | 0 | Unused | |

Table 12. Control_4 - control and status register 4 (address 03h) bit description...continued

| Bit | Symbol | Value | Description | Reference |
|-----|--------|-------|-------------|-----------|
| 2 | T | 0 | Unused | |
| 1 | T | 0 | Unused | |
| 0 | T | 0 | Unused | |

7.2.5 Register Control_5

Table 13. Control_5 - control and status register 5 (address 04h) bit allocation

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|-------|-------|-------|-------|---|---|---|---|
| Symbol | TSIE1 | TSIE2 | TSIE3 | TSIE4 | T | T | T | T |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 14. Control_5 - control and status register 5 (address 04h) bit description

| Bit | Symbol | Value | Description | Reference |
|--------|--------|-------|--|--------------------------------|
| 7 | TSIE1 | 0 | no interrupt generated from timestamp flag of TS1 | Section 7.13.5 |
| | | 1 | interrupt generated when timestamp flag set of TS1 | |
| 6 | TSIE2 | 0 | no interrupt generated from timestamp flag of TS2 | Section 7.13.5 |
| | | 1 | interrupt generated when timestamp flag set of TS2 | |
| 5 | TSIE3 | 0 | no interrupt generated from timestamp flag of TS3 | Section 7.13.5 |
| | | 1 | interrupt generated when timestamp flag set of TS3 | |
| 4 | TSIE4 | 0 | no interrupt generated from timestamp flag of TS4 | Section 7.13.5 |
| | | 1 | interrupt generated when timestamp flag set of TS4 | |
| 3 to 0 | T | 0 | unused | - |

7.3 Register CLKOUT_ctl

Table 15. CLKOUT_ctl - CLKOUT control register (address 13h) bit allocation

Bits labeled as T are unused and return 0 when read. Bits labeled as X are undefined at power-on and unchanged by subsequent resets.

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|----------|---|------|---|---|----------|---|---|
| Symbol | TCR[1:0] | | OTPR | T | T | COF[2:0] | | |
| Reset value | 0 | 0 | X | 0 | 0 | 0 | 0 | 0 |

Table 16. CLKOUT_ctl - CLKOUT control register (address 13h) bit description*Bits labeled as T are unused and return 0 when read.*

| Bit | Symbol | Value | Description | Reference |
|--------|----------|------------------------------|--------------------------------|-------------------------------|
| 7 to 6 | TCR[1:0] | see Table 17 | temperature measurement period | |
| 5 | OTPR | 0 | no OTP refresh | Section 7.3.2 |
| | | 1 | OTP refresh performed | |
| 4 | T | 0 | unused ^[1] | |
| 3 | T | 0 | unused | |
| 2 to 0 | COF[2:0] | see Table 18 | CLKOUT frequency selection | Section 7.3.3 |

[1] programming this bit to 1 may lead to a decrease of timing accuracy.

7.3.1 Temperature compensated Real Time Clock

The frequency of tuning fork quartz crystal oscillators is temperature-dependent. In the PCA2131, the frequency deviation caused by temperature variation is corrected by adjusting the RTC frequency divider with digital method.

The load capacitance is trimmed to the required value at 25 °C in order to compensate the frequency deviation over process variation.

The frequency accuracy at 25 °C can be evaluated by measuring the frequency of the square wave signal available at the output pin CLKOUT. However, the selection of $f_{CLKOUT} = 32.768$ kHz (default value) can lead to inaccurate measurements. Accurate frequency measurement occurs when $f_{CLKOUT} = 16.384$ kHz or lower is selected (see [Table 18](#)).

The temperature compensated frequency input for the Real Time Clock cannot be observed at the CLKOUT pin but can be evaluated by following these steps.

- Set Second Interrupt, bit SI in register Control_1 to 1
- Set bit TI_TP in register Watchdg_tim_ctl to 1 for a pulsed interrupt signal
- Set bit SIA in register INTA_MASK_1 to 0 to direct the Second Interrupt to pin INTA for a 1 Hz pulse output.

The RTC temperature compensation works by adding or deleting pulses at the 32.768 kHz level. These correction pulses are spaced evenly over a sufficiently long period of time to reach the required resolution and accuracy. Every second corrections with a resolution of about 30.5 ppm (1/32768) can be generated by the temperature compensation engine. If for instance a 10 ppm correction is called for, the correction pulses will be generated approximately once every 3 seconds, for a 50 ppm correction every 0.6 s and so on.

The 1 Hz interrupt output signal can be measured with a counter and by selecting an appropriate gating time the measurement resolution can be set to the desired level. A gating time of 100 s for instance will determine the averaged 1 second period with a resolution of 0.3 ppm.

The feature of temperature compensation can be turned off for ultra low power consumption by first performing a software reset (SR) followed by setting TC_DIS to '1' within 5 seconds.

7.3.1.1 Temperature measurement

The PCA2131 has a temperature sensor circuit used to perform temperature compensation of the clock input to the RTC. The temperature is measured immediately after power-on and then periodically with a period set by the temperature conversion rate TCR[1:0] in the register CLKOUT_ctl. During the first approximately 60 s after start-up the compensation will be inactive, after this period the temperature compensation is active.

Table 17. Temperature measurement period

| TCR[1:0] | | Temperature measurement period |
|----------|-----|--------------------------------|
| 00 | [1] | 32 min |
| 01 | | 16 min |
| 10 | | 8 min |
| 11 | | 4 min |

[1] Default value.

7.3.2 OTP refresh

Each IC is calibrated during production and testing of the device. The calibration parameters are stored on EPROM cells called One Time Programmable (OTP) cells. It is recommended to process an OTP refresh once after the power is up and the oscillator is operating stable. The OTP refresh takes less than 100 ms to complete.

To perform an OTP refresh, bit OTPR has to be cleared (set to logic 0) and then set to logic 1 again.

When read OTPR bit, its state is:

"0" until the OTP read state machine completes copying of the eFuse data into the shadow registers. This could be due to a POR event or to writing a 0 > 1 to the OTPR register bit.

"1" when the OTP read state machine completes copying to the shadow registers from the eFuse instances. During normal operation OTPR must be kept at 1 to prevent higher power usage.

The OTP logic is not reset nor affected by the Software Reset. The OTPR functionality is only reset by the initial digital POR.

During OTP refresh, V_{DD} has to be above 1.8 V, the rising speed to 1.8 V needs to be faster than 2 V/100 ms. After OTP refresh has finished, PCA2131 can operate with V_{DD} as low as 1.2 V.

7.3.3 Clock output

A programmable square wave is available at pin CLKOUT. Operation is controlled by the COF[2:0] control bits in register CLKOUT_ctl. Frequencies of 32.768 kHz (default) down to 1 Hz can be generated for use as system clock, microcontroller clock, charge pump input, or for calibrating the oscillator at 25 °C to determine aging offset. The CLKOUT output is not temperature compensated to prevent jitter due to digital compensation method.

CLKOUT is a push-pull output and is enabled at power-on. When disabled, the output is high-impedance.

Table 18. CLKOUT frequency selection

| COF[2:0] | | CLKOUT frequency (Hz) | Typical duty cycle [1] |
|----------|-----|-----------------------|------------------------|
| 000 | [2] | 32 768 | 60 : 40 to 40 : 60 |
| 001 | | 16 384 | 50 : 50 |
| 010 | | 8 192 | 50 : 50 |
| 011 | | 4 096 | 50 : 50 |
| 100 | | 2 048 | 50 : 50 |
| 101 | | 1 024 | 50 : 50 |
| 110 | | 1 | 50 : 50 |
| 111 | | CLKOUT = high-Z | - |

[1] Duty cycle definition: % HIGH-level time: % LOW-level time.

[2] Default value.

The duty cycle of the selected clock is not controlled, however, due to the nature of the clock generation all but the 32.768 kHz frequencies are 50 : 50.

7.4 Register Aging_offset

Table 19. Aging_offset - crystal aging offset register (address 30h) bit allocation

Bits labeled as T are unused and return 0 when read.

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|---|---|---|---|---------|---|---|---|
| Symbol | T | T | T | T | AO[3:0] | | | |
| Reset value | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |

Table 20. Aging_offset - crystal aging offset register (address 30h) bit description

Bits labeled as T are unused and return 0 when read.

| Bit | Symbol | Value | Description |
|--------|---------|------------------------------|--------------------|
| 7 to 4 | T | 0000 | unused |
| 3 to 0 | AO[3:0] | see Table 21 | aging offset value |

7.4.1 Crystal aging correction

The PCA2131 has an offset register Aging_offset to correct the crystal aging effects ¹.

The accuracy of the frequency of a quartz crystal depends on its aging. The aging offset adds an adjustment, positive or negative, in the temperature compensation circuit which allows correcting the aging effect.

The aging offset bits allow a frequency correction of typically 2 ppm per AO[3:0] value, from -14 ppm to +16 ppm.

Table 21. Frequency correction at 25 °C, typical

| AO[3:0] | | | ppm |
|---------|--------|----------------|-----|
| Decimal | Binary | | |
| 0 | 0000 | | +16 |
| 1 | 0001 | | +14 |
| 2 | 0010 | | +12 |
| 3 | 0011 | | +10 |
| 4 | 0100 | | +8 |
| 5 | 0101 | | +6 |
| 6 | 0110 | | +4 |
| 7 | 0111 | | +2 |
| 8 | 1000 | ^[1] | 0 |
| 9 | 1001 | | -2 |

¹ For further information, refer to the application note [\[1\]](#).

Table 21. Frequency correction at 25 °C, typical...continued

| AO[3:0] | | | ppm |
|---------|--------|--|-----|
| Decimal | Binary | | |
| 10 | 1010 | | -4 |
| 11 | 1011 | | -6 |
| 12 | 1100 | | -8 |
| 13 | 1101 | | -10 |
| 14 | 1110 | | -12 |
| 15 | 1111 | | -14 |

[1] Default value.

7.5 Power management functions

The PCA2131 has two power supplies:

V_{DD} - the main power supply

V_{BAT} - the battery backup supply

Internally, PCA2131 operates with the internal operating voltage $V_{oper(int)}$ which is also available as V_{BBS} on the battery backed output voltage pin, BBS. Depending on the condition of the main power supply and the selected power management function, $V_{oper(int)}$ is either on the potential of V_{DD} or V_{BAT} .

Two power management functions are implemented:

Battery switch-over function - monitors the main power supply V_{DD} and switching to V_{BAT} in case a power fail condition is detected (see [Section 7.5.1](#)).

Battery low detection function - monitors the status of the battery, V_{BAT} (see [Section 7.5.2](#)).

The power management functions are controlled by the control bits PWRMNG[2:0] (see [Table 22](#)) in register Control_3 (see [Table 10](#)):

Table 22. Power management control bit description

| PWRMNG[2:0] | | Function |
|-------------|---------|---|
| 000 | | battery switch-over function is enabled in standard mode; battery low detection function is enabled |
| 001,010 | | battery switch-over function is enabled in standard mode; battery low detection function is disabled |
| 011 | | battery switch-over function is enabled in direct switching mode; battery low detection function is enabled |
| 100,101 | | battery switch-over function is enabled in direct switching mode; battery low detection function is disabled |
| 110,111 | [1] [2] | battery switch-over function is disabled, only one power supply (V_{DD}); battery low detection function is disabled |

[1] Default value.

[2] When the battery switch-over function is disabled, the device works only with the power supply V_{DD} . V_{BAT} must be put to ground and the battery low detection function is disabled.

7.5.1 Battery switch-over function

PCA2131 has a backup battery switch-over circuit which monitors the main power supply V_{DD} . When a power failure condition is detected, it automatically switches to the backup battery.

One of two operation modes can be selected:

Standard mode - the power failure condition happens when:

$$V_{DD} < V_{BAT} \text{ AND } V_{DD} < V_{th(sw)bat}$$

$V_{th(sw)bat}$ is the battery switch threshold voltage. Typical value is 2.5 V. The battery switch-over in standard mode works only for $V_{DD} > 2.5$ V. Applying back-up battery voltage to V_{BAT} without applying V_{DD} supply will not power on the device; only when V_{DD} main power is supplied the device will start operating.

Direct switching mode - the power failure condition happens when $V_{DD} < V_{BAT}$. Direct switching from V_{DD} to V_{BAT} without requiring V_{DD} to drop below $V_{th(sw)bat}$

When a power failure condition occurs and the power supply switches to the battery, the following sequence occurs:

1. The battery switch flag BF (register Control_3) is set to logic 1.
2. An interrupt is generated if the control bit BIE (register Control_3) is enabled (see [Section 7.13.6](#)).
3. If the control bit BTSE (register Control_3) is logic 1, the timestamp 4 registers store the time and date when the battery switch occurred (see [Section 7.12.4](#)).
4. The battery switch flag BF is cleared by command; it must be cleared to clear the interrupt.

The interface and CLKOUT output are disabled in battery backup operation:

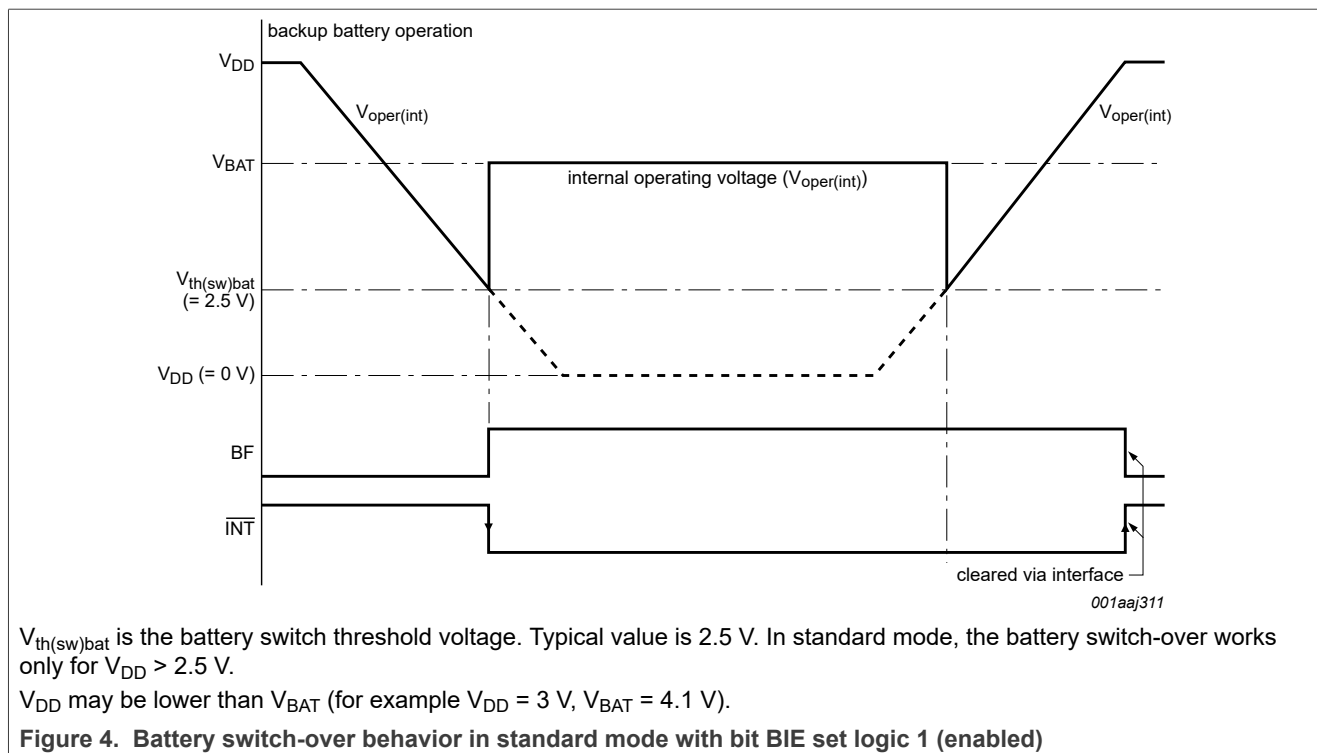
- Interface inputs are not recognized, preventing extraneous data being written to the device
- Interface outputs are high-impedance

For further information about I²C-bus communication and battery backup operation, see [Section 7.16.3](#).

7.5.1.1 Standard mode

If $V_{DD} > V_{BAT}$ OR $V_{DD} > V_{th(sw)bat}$: $V_{oper(int)}$ is at V_{DD} potential.

If $V_{DD} < V_{BAT}$ AND $V_{DD} < V_{th(sw)bat}$: $V_{oper(int)}$ is at V_{BAT} potential.



7.5.1.2 Direct switching mode

If $V_{DD} > V_{BAT}$: $V_{oper(int)}$ is at V_{DD} potential.

If $V_{DD} < V_{BAT}$: $V_{oper(int)}$ is at V_{BAT} potential.

The direct switching mode is useful in systems where V_{DD} is always higher than V_{BAT} . This mode is not recommended if the V_{DD} and V_{BAT} values are similar (for example, $V_{DD} = 3.3 V$, $V_{BAT} \geq 3.0 V$). In direct switching mode, the power consumption is reduced compared to the standard mode because the monitoring of V_{DD} and $V_{th(sw)bat}$ is not performed.

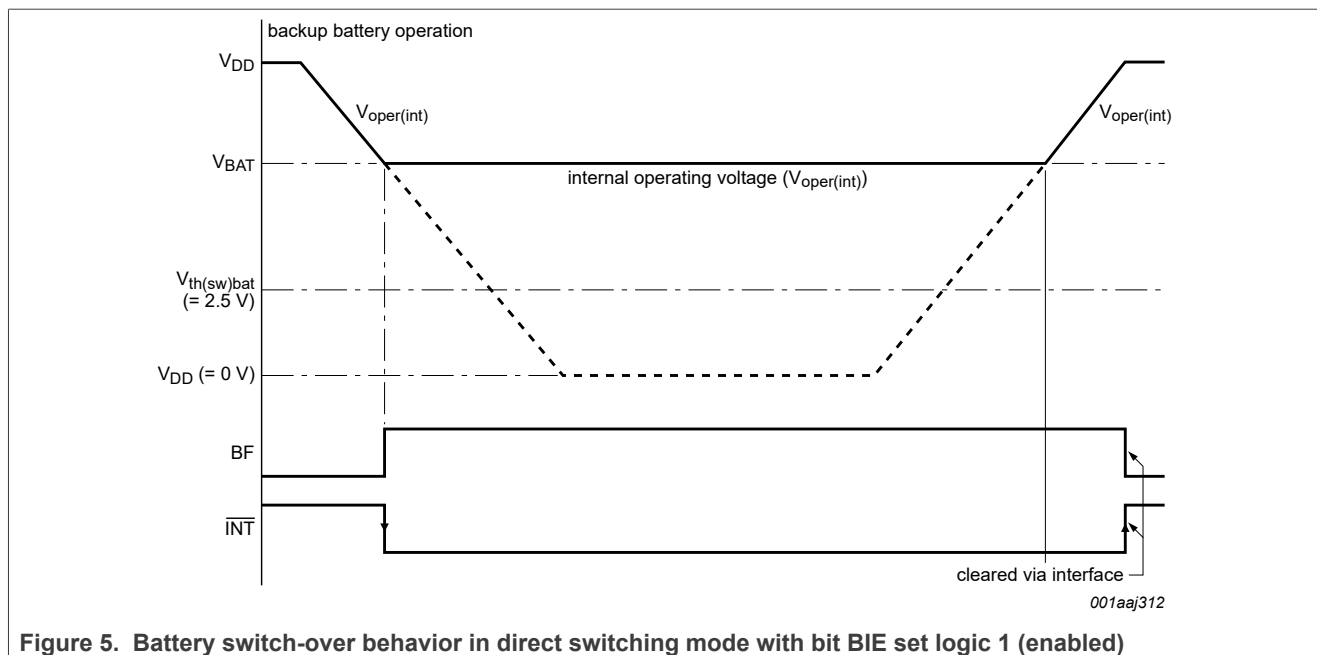


Figure 5. Battery switch-over behavior in direct switching mode with bit BIE set logic 1 (enabled)

7.5.1.3 Battery switch-over disabled: only one power supply (V_{DD})

When the battery switch-over function is disabled:

- The power supply is applied on the V_{DD} pin
- The V_{BAT} pin must be connected to ground
- $V_{oper(int)}$ is at V_{DD} potential
- The battery flag (BF) is always logic 0

7.5.1.4 Battery switch-over architecture

The architecture of the battery switch-over circuit is shown in [Figure 6](#).

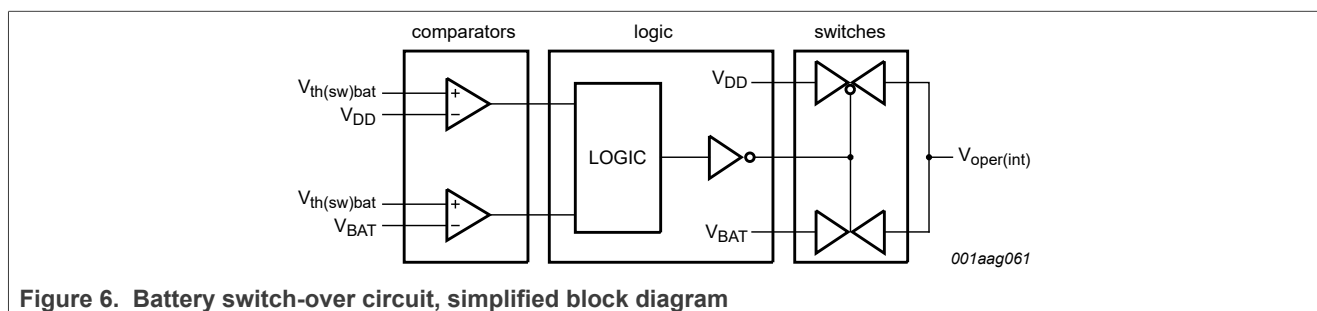


Figure 6. Battery switch-over circuit, simplified block diagram

$V_{oper(int)}$ is at V_{DD} or V_{BAT} potential.

Remark: It has to be assured that there are decoupling capacitors on the pins V_{DD} , V_{BAT} , and BBS.

7.5.2 Battery low detection function

The PCA2131 has a battery low detection circuit which monitors the status of the battery V_{BAT} .

When V_{BAT} drops below the threshold value $V_{th(bat)low}$ (typical 2.5 V), the BLF flag (register Control_3) is set to indicate that the battery is low and that it must be replaced. Monitoring of the battery voltage also occurs during battery operation.

An unreliable battery cannot prevent the supply voltage from dropping below V_{low} (typical 1.2 V) and with that the data integrity gets lost. (For further information about V_{low} see [Section 7.6.](#))

When V_{BAT} drops below the threshold value $V_{th(bat)low}$, the following sequence occurs (see [Figure 7](#)):

1. The battery low flag BLF is set logic 1.
2. An interrupt is generated if the control bit BLIE (register Control_3) is enabled (see [Section 7.13.7](#)).
3. The flag BLF remains logic 1 until the battery is replaced. BLF cannot be cleared by command. It is automatically cleared by the battery low detection circuit when the battery is replaced or when the voltage rises again above the threshold value. This could happen if a super capacitor is used as a backup source and the main power is applied again.

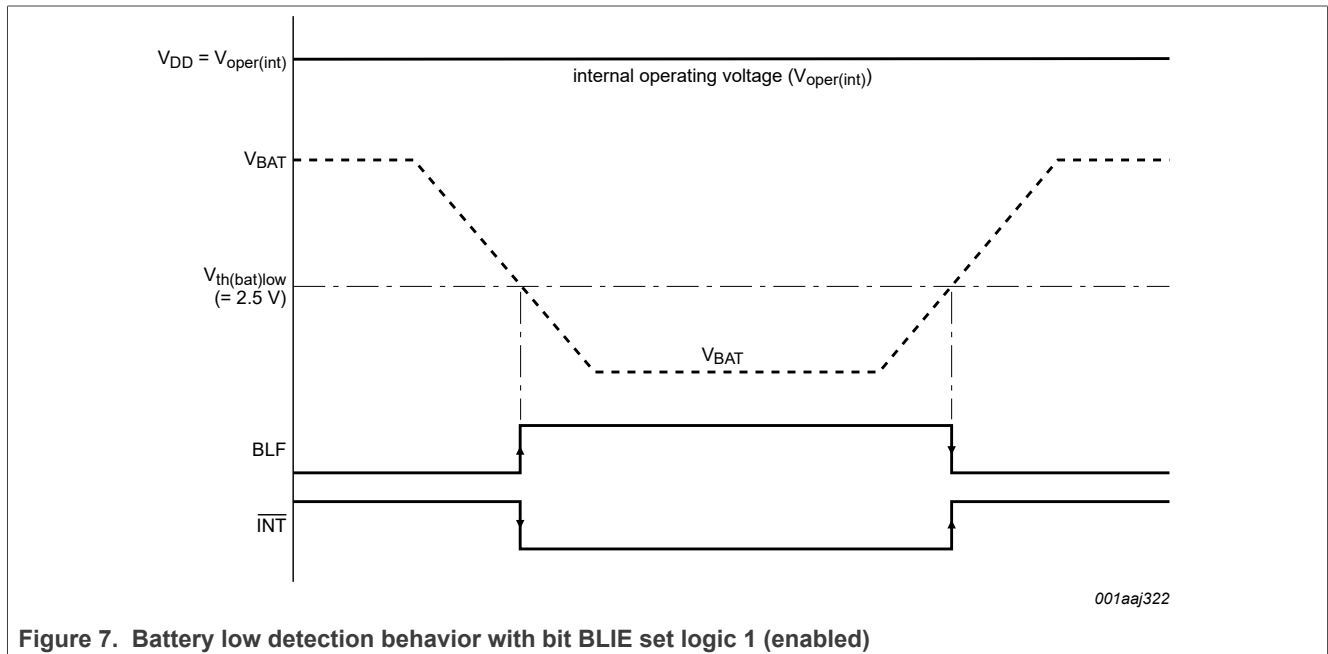


Figure 7. Battery low detection behavior with bit BLIE set logic 1 (enabled)

7.5.3 Battery backup supply

The V_{BBS} voltage on the output pin BBS is at the same potential as the internal operating voltage $V_{oper(int)}$, depending on the selected battery switch-over function mode:

Table 23. Output pin BBS

| Battery switch-over function mode | Conditions | Potential of $V_{oper(int)}$ and V_{BBS} |
|-----------------------------------|---|--|
| standard | $V_{DD} > V_{BAT}$ OR $V_{DD} > V_{th(sw)bat}$ | V_{DD} |
| | $V_{DD} < V_{BAT}$ AND $V_{DD} < V_{th(sw)bat}$ | V_{BAT} |
| direct switching | $V_{DD} > V_{BAT}$ | V_{DD} |
| | $V_{DD} < V_{BAT}$ | V_{BAT} |
| disabled | only V_{DD} available, V_{BAT} must be put to ground | V_{DD} |

The output pin BBS can be used as a supply for external devices with battery backup needs, such as SRAM (see [1]).

7.6 Oscillator stop detection function

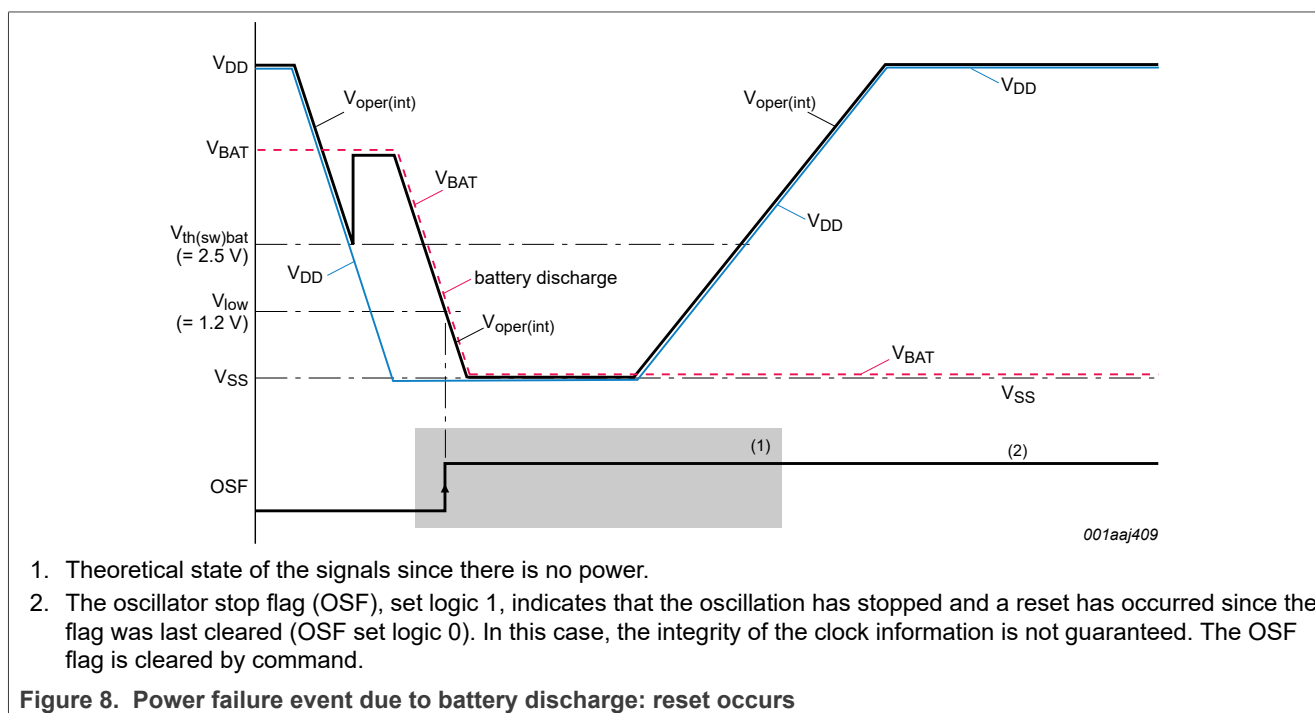
The PCA2131 has an on-chip oscillator detection circuit which indicates the status of the oscillation by monitoring the supply of oscillator: whenever the supply is out of the expected range, a reset occurs and the oscillator stop flag OSF (in register Seconds) is set logic 1.

• Power-on:

1. The oscillator is not running, the chip is in reset (OSF is logic 1).
2. When the oscillator starts running and supply is OK after power-on, the chip exits from reset.
3. The flag OSF is still logic 1 and can be cleared (OSF set logic 0) by command.

• Power supply failure:

1. When the power supply of the chip drops below a certain value (V_{low}), typically 1.2 V, the oscillator supply also fails and a reset occurs.
2. When the power supply returns to normal operation, the oscillator supply is OK again, the chip exits from reset.
3. The flag OSF is still logic 1 and can be cleared (OSF set logic 0) by command.
4. When OSF flag is cleared an OTP refresh should be performed (see [Section 7.3.2](#)).



7.7 Power-On Reset function

The PCA2131 has a Power-On Reset (POR) and a Power-On Reset Override (PORO) function implemented.

7.7.1 Power-On Reset (POR)

The POR is active whenever the oscillator is stopped. The oscillator is considered to be stopped during the time between power-on and stable crystal resonance (see [Figure 9](#)). This time may be in the range of 200 ms to 2 s

depending on temperature and supply voltage. Whenever an internal reset occurs, the oscillator stop flag is set (OSF set logic 1).

The OTP refresh (see [Section 7.3.2](#)) should ideally be executed as the first instruction after start-up and also after a reset due to an oscillator stop.

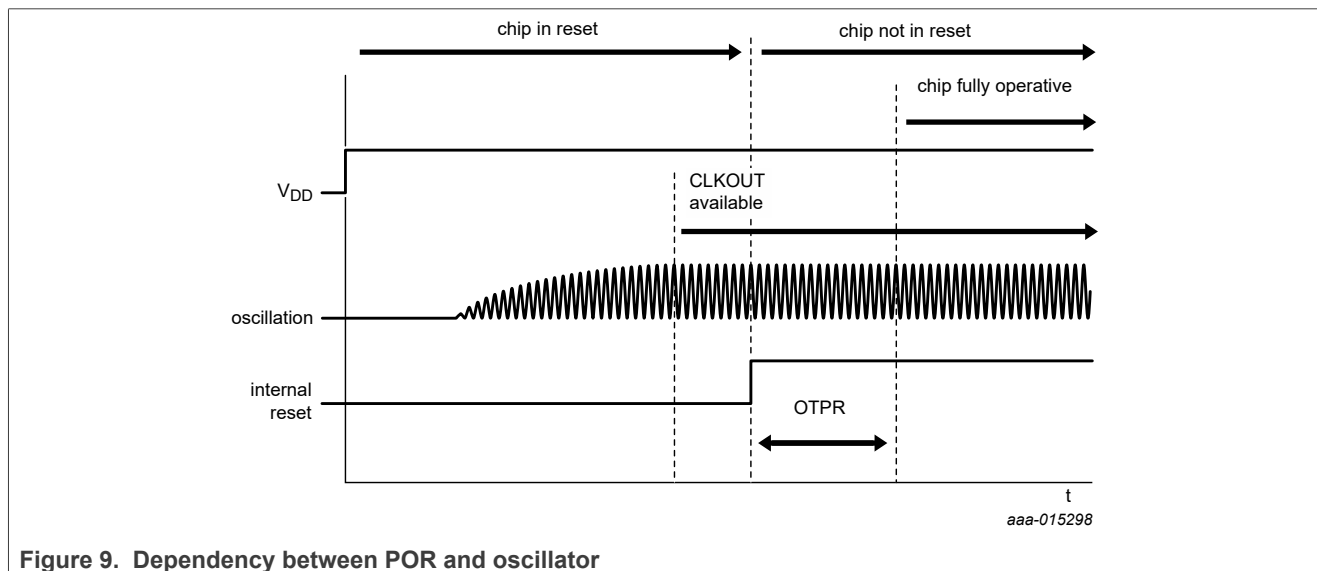


Figure 9. Dependency between POR and oscillator

After POR, the following mode is entered:

- 32.768 kHz CLKOUT active
- Power-On Reset Override (PORO) available to be set
- 24-hour mode is selected
- Battery switch-over function disabled, only one power supply (V_{DD})
- Temperature compensation enabled
- 100th second enabled
- Time 00:00:00.00
- Date 2001.01.01
- Weekday Monday

The register values after power-on are shown in [Table 4](#).

7.7.2 Power-On Reset Override (PORO)

The POR duration is directly related to the crystal oscillator start-up time. Due to the long start-up times experienced by these types of circuits, a mechanism has been built in to disable the POR and therefore speed up the on-board test of the device.

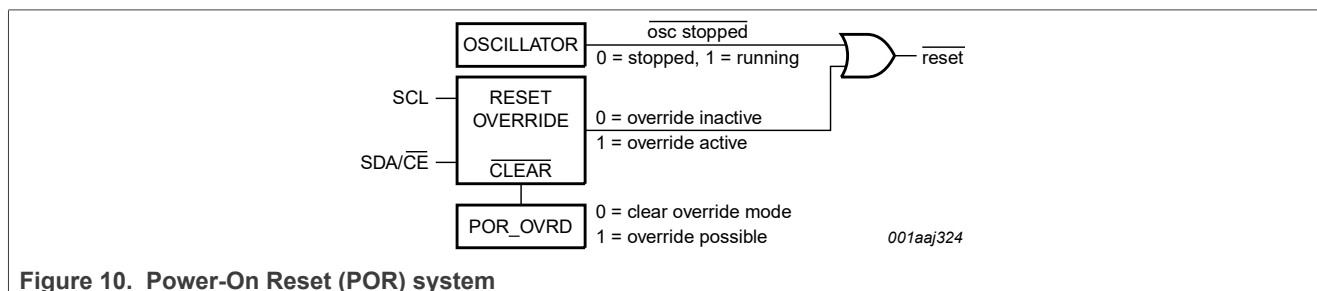
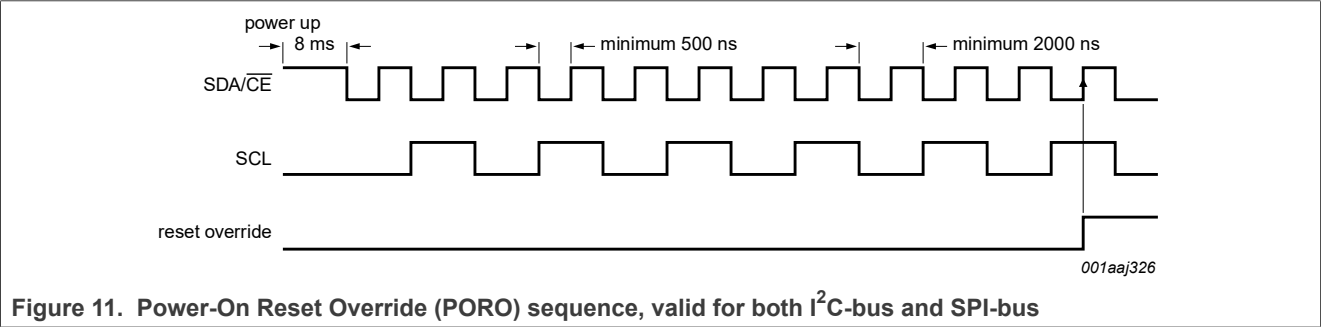


Figure 10. Power-On Reset (POR) system

The setting of the PORO mode requires that POR_OVRD in register Control_1 is set logic 1 and that the signals at the interface pins SDA/CE and SCL are toggled as illustrated in [Figure 11](#). All timings shown are required minimum.



Once the override mode is entered, the device is immediately released from the reset state and the set-up operation can commence.

The PORO mode is cleared by writing logic 0 to POR_OVRD. POR_OVRD must be logic 1 before a re-entry into the override mode is possible. Setting POR_OVRD logic 0 during normal operation has no effect except to prevent accidental entry into the PORO mode.

7.8 Software Reset register

Table 24. Reset - software reset control (address 05h) bit description

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---------|-------------------------------|---|---|---|-------------------------------|---|---|-------------------------------|
| Symbol | CPR | 0 | 1 | 0 | SR | 1 | 0 | CTS |
| Section | Section 7.8.2 | | | | Section 7.8.1 | | | Section 7.8.3 |

To

- trigger a software reset (SR), 0010 1100 (2Ch) must be sent to register Reset (address 05h). A software reset also triggers CPR and CTS
- clear prescaler (CPR), 1010 0100 (A4h) must be sent to register Reset (address 05h)
- clear timestamp (CTS), 0010 0101 (25h) must be sent to register Reset (address 05h)

It is possible to combine CPR and CTS by sending 1010 0101 (A5h).

Read of the SR_RESET register will return a fixed pattern of 00100100;

Remark: Any other value sent to this register is ignored.

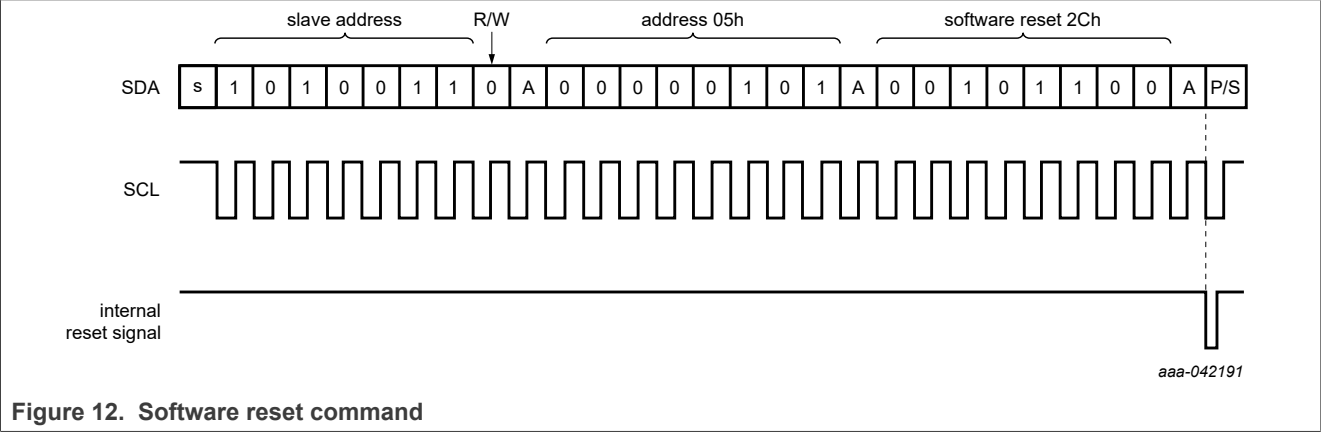
7.8.1 SR - Software reset

A reset is automatically generated at power-on as Power-On Reset as described in [Section 7.7](#). A reset can also be initiated with the software reset command.

After software reset, the following mode is entered:

- 32.768 kHz CLKOUT active
- Power-On Reset Override (PORO) unchanged
- OTP not reloaded, OTPR unchanged.
- 24-hour mode is selected
- Battery switch-over function disabled, only one power supply (V_{DD})
- Temperature compensation enabled

- 100th second enabled
- Time 00:00:00.00
- Date 2001.01.01
- Weekday Monday



7.8.2 CPR: clear prescaler

To set the time for RTC mode, the clear prescaler instruction is needed.
Before sending this instruction, it is mandatory to first set *stop* by the STOP bit.
See STOP definition for an explanation on using this instruction.

7.8.3 CTS: clear timestamp

The timestamp registers (address 14h to 2Fh) can be set to all 0 with this instruction.

7.9 Time and date function

Most of these registers are coded in the Binary Coded Decimal (BCD) format.

7.9.1 Register 100th Seconds

Table 25. 100th Seconds - 100th seconds (address 06h) bit allocation

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|-------------------------|---|---|---|---|---|---|---|
| Symbol | 100TH SECONDS (0 to 99) | | | | | | | |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 26. 100th Seconds - 100th seconds register (address 06h) bit description

| Bit | Symbol | Value | Place value | Description |
|--------|---------------|--------|-------------|------------------------------------|
| 7 to 4 | 100TH SECONDS | 0 to 9 | ten's place | actual seconds coded in BCD format |
| 3 to 0 | | 0 to 9 | unit place | |

Table 27. 100th Seconds coded in BCD format

| Seconds value in decimal | Upper-digit (ten's place) | | | | Digit (unit place) | | | |
|--------------------------|---------------------------|-------|-------|-------|--------------------|-------|-------|-------|
| | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
| 00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 02 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| : | : | : | : | : | : | : | : | : |
| 09 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 10 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| : | : | : | : | : | : | : | : | : |
| 98 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 99 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |

7.9.2 Register Seconds

Table 28. Seconds - seconds and clock integrity register (address 07h) bit allocation

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|-----|-------------------|---|---|---|---|---|---|
| Symbol | OSF | SECONDS (0 to 59) | | | | | | |
| Reset value | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 29. Seconds - seconds and clock integrity register (address 07h) bit description

| Bit | Symbol | Value | Place value | Description |
|--------|---------|--------|-------------|--|
| 7 | OSF | 0 | - | clock integrity is guaranteed |
| | | 1 | - | clock integrity is not guaranteed: oscillator has stopped and chip reset has occurred since flag was last cleared |
| 6 to 4 | SECONDS | 0 to 5 | ten's place | actual seconds coded in BCD format |
| 3 to 0 | | 0 to 9 | unit place | |

Table 30. Seconds coded in BCD format

| Seconds value in decimal | Upper-digit (ten's place) | | | Digit (unit place) | | | |
|--------------------------|---------------------------|-------|-------|--------------------|-------|-------|-------|
| | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
| 00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 01 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 02 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| : | : | : | : | : | : | : | : |
| 09 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 10 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |

Table 30. Seconds coded in BCD format...continued

| Seconds value in decimal | Upper-digit (ten's place) | | | Digit (unit place) | | | |
|--------------------------|---------------------------|-------|-------|--------------------|-------|-------|-------|
| | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
| : | : | : | : | : | : | : | : |
| 58 | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| 59 | 1 | 0 | 1 | 1 | 0 | 0 | 1 |

7.9.3 Register Minutes

Table 31. Minutes - minutes register (address 08h) bit allocation

Bits labeled as *T* are unused and return 0 when read

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|---|-------------------|---|---|---|---|---|---|
| Symbol | T | MINUTES (0 to 59) | | | | | | |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 32. Minutes - minutes register (address 08h) bit description

Bits labeled as *T* are unused and return 0 when read

| Bit | Symbol | Value | Place value | Description |
|--------|---------|--------|-------------|------------------------------------|
| 7 | T | 0 | - | unused |
| 6 to 4 | MINUTES | 0 to 5 | ten's place | actual minutes coded in BCD format |
| 3 to 0 | | 0 to 9 | unit place | |

7.9.4 Register Hours

Table 33. Hours - hours register (address 09h) bit allocation

Bits labeled as *T* are unused and return 0 when read

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|---|---|------|---------------------------------|---|---|---|---|
| Symbol | T | T | AMPM | HOURS (1 to 12) in 12-hour mode | | | | |
| | | | | HOURS (0 to 23) in 24-hour mode | | | | |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 34. Hours - hours register (address 09h) bit description

Bits labeled as *T* are unused and return 0 when read

| Bit | Symbol | Value | Place value | Description |
|-----------------------------|--------|-------|-------------|--------------|
| 7 to 6 | T | 00 | - | unused |
| 12-hour mode ^[1] | | | | |
| 5 | AMPM | 0 | - | indicates AM |
| | | 1 | - | indicates PM |

Nano-power highly accurate RTC with integrated quartz crystal for automotive applications

Table 34. Hours - hours register (address 09h) bit description...continued

Bits labeled as T are unused and return 0 when read

| Bit | Symbol | Value | Place value | Description |
|-----------------------------|--------|--------|-------------|---|
| 4 | HOURS | 0 to 1 | ten's place | actual hours coded in BCD format when in 12-hour mode |
| 3 to 0 | | 0 to 9 | unit place | |
| 24-hour mode ^[1] | | | | |
| 5 to 4 | HOURS | 0 to 2 | ten's place | actual hours coded in BCD format when in 24-hour mode |
| 3 to 0 | | 0 to 9 | unit place | |

[1] Hour mode is set by the bit 12_24 in register Control_1 (see [Table 6](#)).

7.9.5 Register Days

Table 35. Days - days register (address 0Ah) bit allocation

Bits labeled as T are unused and return 0 when read

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|---|---|----------------|---|---|---|---|---|
| Symbol | T | T | DAYS (1 to 31) | | | | | |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 36. Days - days register (address 0Ah) bit description

| Bit | Symbol | Value | Place value | Description |
|--------|---------------------|--------|-------------|--------------------------------|
| 7 to 6 | T | 00 | - | unused |
| 5 to 4 | DAYS ^[1] | 0 to 3 | ten's place | actual day coded in BCD format |
| 3 to 0 | | 0 to 9 | unit place | |

[1] If the year counter contains a value which is exactly divisible by 4, excluding the year 00, the RTC compensates for leap years by adding a 29th day to February. Note that next time the year will roll over to 00 will be year 2100, which is not going to be leap year.

7.9.6 Register Weekdays

Table 37. Weekdays - weekdays register (address 0Bh) bit allocation

Bits labeled as T are unused and return 0 when read

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|---|---|---|---|---|-------------------|---|---|
| Symbol | T | T | T | T | T | WEEKDAYS (0 to 6) | | |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

Table 38. Weekdays - weekdays register (address 0Bh) bit description

Bits labeled as T are unused and return 0 when read

| Bit | Symbol | Value | Description |
|--------|----------|--------|--|
| 7 to 3 | T | 000 | unused |
| 2 to 0 | WEEKDAYS | 0 to 6 | actual weekday value, see Table 39 |

Although the association of the weekdays counter to the actual weekday is arbitrary, the PCA2131 assumes that Sunday is 000 and Monday is 001 for the purpose of determining the increment for calendar weeks.

Table 39. Weekday assignments

| Day ^[1] | Bit | | |
|--------------------|-----|---|---|
| | 2 | 1 | 0 |
| Sunday | 0 | 0 | 0 |
| Monday | 0 | 0 | 1 |
| Tuesday | 0 | 1 | 0 |
| Wednesday | 0 | 1 | 1 |
| Thursday | 1 | 0 | 0 |
| Friday | 1 | 0 | 1 |
| Saturday | 1 | 1 | 0 |

[1] Definition may be reassigned by the user.

7.9.7 Register Months

Table 40. Months - months register (address 0Ch) bit allocation

Bits labeled as T are unused and return 0 when read

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|---|---|---|------------------|---|---|---|---|
| Symbol | T | T | T | MONTHS (1 to 12) | | | | |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

Table 41. Months - months register (address 0Ch) bit description

Bits labeled as T are unused and return 0 when read

| Bit | Symbol | Value | Place value | Description |
|--------|--------|--------|-------------|--|
| 7 to 5 | T | 000 | - | unused |
| 4 | MONTHS | 0 to 1 | ten's place | actual month coded in BCD format, see Table 42 |
| 3 to 0 | | 0 to 9 | unit place | |

Table 42. Month assignments in BCD format

| Month | Upper-digit (ten's place) | Digit (unit place) | | | |
|----------|---------------------------|--------------------|-------|-------|-------|
| | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
| January | 0 | 0 | 0 | 0 | 1 |
| February | 0 | 0 | 0 | 1 | 0 |
| March | 0 | 0 | 0 | 1 | 1 |
| April | 0 | 0 | 1 | 0 | 0 |
| May | 0 | 0 | 1 | 0 | 1 |

Table 42. Month assignments in BCD format...continued

| Month | Upper-digit (ten's place) | Digit (unit place) | | | |
|-----------|---------------------------|--------------------|-------|-------|-------|
| | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
| June | 0 | 0 | 1 | 1 | 0 |
| July | 0 | 0 | 1 | 1 | 1 |
| August | 0 | 1 | 0 | 0 | 0 |
| September | 0 | 1 | 0 | 0 | 1 |
| October | 1 | 0 | 0 | 0 | 0 |
| November | 1 | 0 | 0 | 0 | 1 |
| December | 1 | 0 | 0 | 1 | 0 |

7.9.8 Register Years

Table 43. Years - years register (address 0Dh) bit allocation

Bits labeled as *T* are unused and return 0 when read

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|-----------------|---|---|---|---|---|---|---|
| Symbol | YEARS (0 to 99) | | | | | | | |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

Table 44. Years - years register (address 0Dh) bit description

Bits labeled as *T* are unused and return 0 when read

| Bit | Symbol | Value | Place value | Description |
|--------|--------|--------|-------------|---------------------------------|
| 7 to 4 | YEARS | 0 to 9 | ten's place | actual year coded in BCD format |
| 3 to 0 | | 0 to 9 | unit place | |

7.9.9 Setting and reading the time

[Figure 13](#) shows the data flow and data dependencies starting from the 100 Hz/1 Hz clock tick.

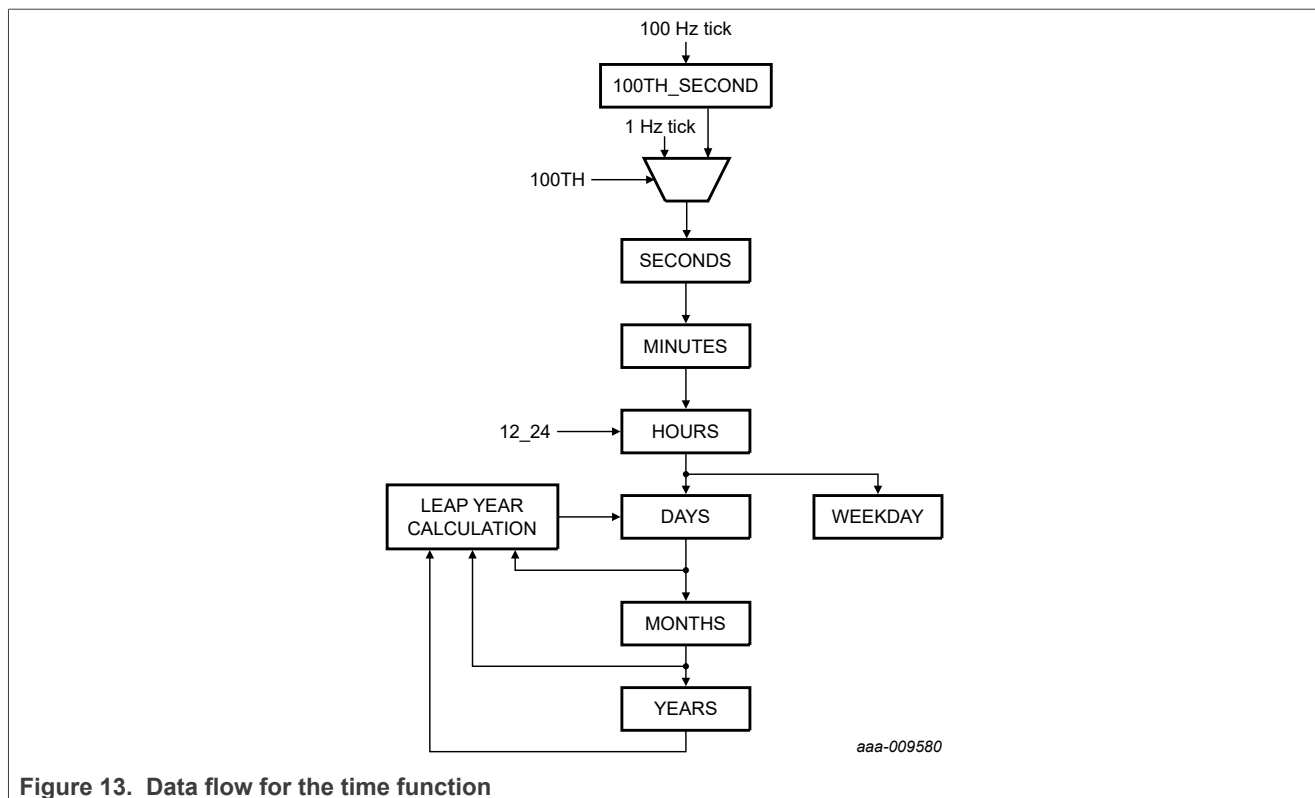


Figure 13. Data flow for the time function

Write access requires setting the STOP bit. The flow for accurately setting the time in RTC mode is:

- start an I2C access at register control_1
- set STOP bit
- set CPR (register SR_RESET, CPR is logic 1)
- address counter rolls over to address 06h
- set time (100th seconds, seconds to years)
- end I2C access
- wait for external time reference to indicate that time counting should start
- start an I2C access at register control_1
- clear STOP bit (time starts counting from now)
- end I2C access

The first increment of the time circuits is between 0 s and 122 ms after STOP is released. See description for STOP bit in [Section 7.15](#)

During read operations, the time counting circuits (memory locations 06h through 0Dh) are blocked. This prevents

- Faulty reading of the clock and calendar during a carry condition
- Incrementing the time registers during the read cycle

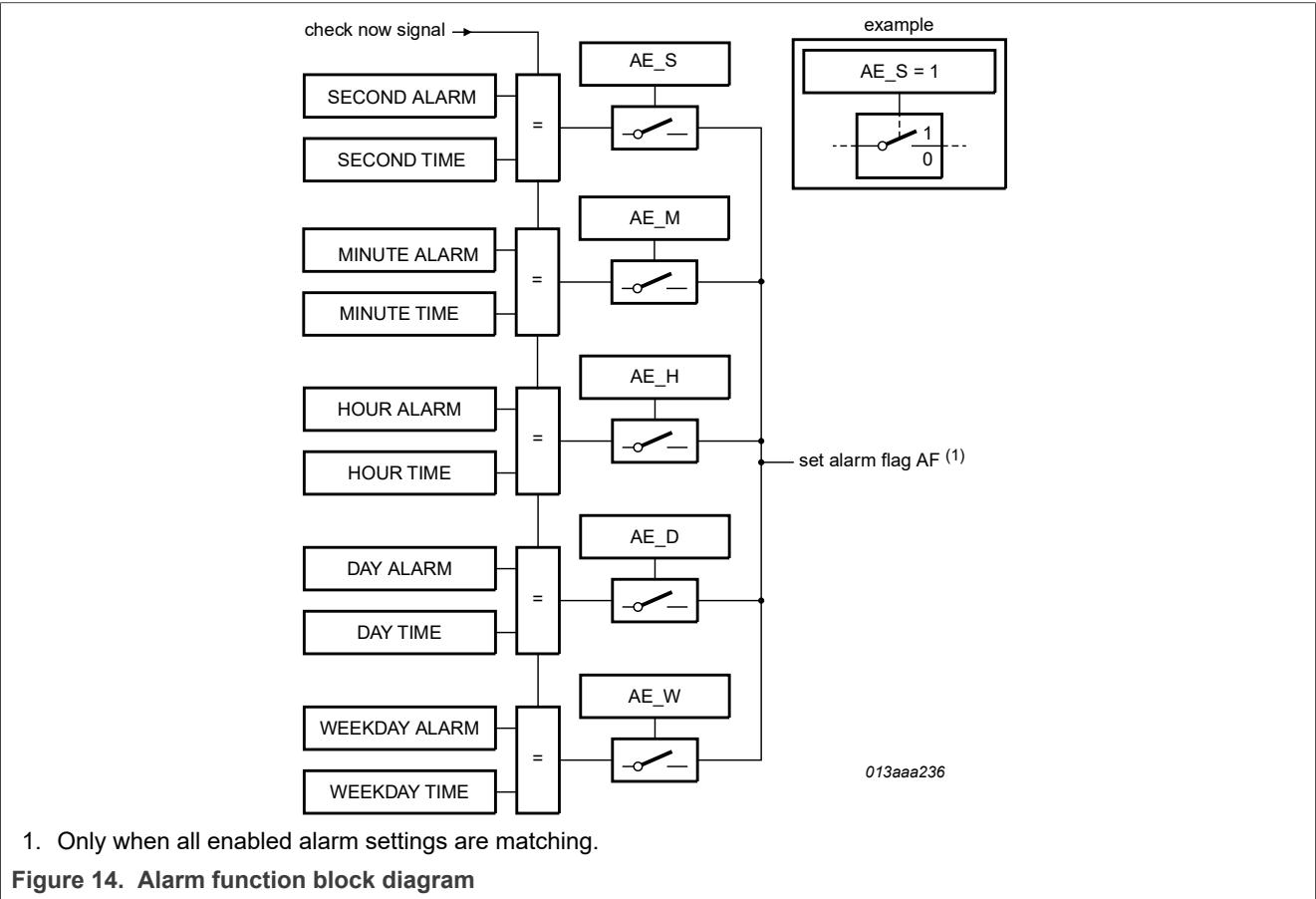
After this read access is completed, the time circuit is released again. Any pending request to increment the time counters that occurred during the read access is serviced.

As a consequence of this method, it is very important to make a read access in one go. That is, reading seconds through to years should be made in one single access. Failing to comply with this method could result in the time becoming corrupted.

As an example, a roll-over may occur between reads thus giving the minutes from one moment and the hours from the next. Therefore it is advised to read all time and date registers in one access.

7.10 Alarm function

When one or more of the alarm bit fields are loaded with a valid second, minute, hour, day, or weekday and its corresponding alarm enable bit (AE_x) is logic 0, then that information is compared with the actual second, minute, hour, day, and weekday (see [Figure 14](#)).



The generation of interrupts from the alarm function is described in [Section 7.13.4](#).

7.10.1 Register Second_alarm

Table 45. Second_alarm - second alarm register (address 0Eh) bit allocation
Bits labeled as X are undefined at power-on and unchanged by subsequent resets.

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|------|------------------------|---|---|---|---|---|---|
| Symbol | AE_S | SECOND_ALARM (0 to 59) | | | | | | |
| Reset value | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 46. Second_alarm - second alarm register (address 0Eh) bit description

| Bit | Symbol | Value | Place value | Description |
|--------|--------------|--------|-------------|--|
| 7 | AE_S | 0 | - | second alarm is enabled |
| | | 1 | - | second alarm is disabled |
| 6 to 4 | SECOND_ALARM | 0 to 5 | ten's place | second alarm information coded in BCD format |
| 3 to 0 | | 0 to 9 | unit place | |

7.10.2 Register Minute_alarm

Table 47. Minute_alarm - minute alarm register (address 0Fh) bit allocation

Bits labeled as X are undefined at power-on and unchanged by subsequent resets.

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|------|------------------------|---|---|---|---|---|---|
| Symbol | AE_M | MINUTE_ALARM (0 to 59) | | | | | | |
| Reset value | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 48. Minute_alarm - minute alarm register (address 0Fh) bit description

Bits labeled as X are undefined at power-on and unchanged by subsequent resets.

| Bit | Symbol | Value | Place value | Description |
|--------|--------------|--------|-------------|--|
| 7 | AE_M | 0 | - | minute alarm is enabled |
| | | 1 | - | minute alarm is disabled |
| 6 to 4 | MINUTE_ALARM | 0 to 5 | ten's place | minute alarm information coded in BCD format |
| 3 to 0 | | 0 to 9 | unit place | |

7.10.3 Register Hour_alarm

Table 49. Hour_alarm - hour alarm register (address 10h) bit allocation

Bits labeled as T are unused and return 0 when read. Bits labeled as X are undefined at power-on and unchanged by subsequent resets.

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|------|---|------|--------------------------------------|---|---|---|---|
| Symbol | AE_H | T | AMPM | HOUR_ALARM (1 to 12) in 12-hour mode | | | | |
| | | | | HOUR_ALARM (0 to 23) in 24-hour mode | | | | |
| Reset value | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 50. Hour_alarm - hour alarm register (address 10h) bit description

Bit positions labeled as - are not implemented and return 0 when read. Bits labeled as X are undefined at power-on and unchanged by subsequent resets.

| Bit | Symbol | Value | Place value | Description |
|-----|--------|-------|-------------|------------------------|
| 7 | AE_H | 0 | - | hour alarm is enabled |
| | | 1 | - | hour alarm is disabled |

Table 50. Hour_alarm - hour alarm register (address 10h) bit description...continued

Bit positions labeled as - are not implemented and return 0 when read. Bits labeled as X are undefined at power-on and unchanged by subsequent resets.

| Bit | Symbol | Value | Place value | Description |
|-----------------------------|------------|--------|-------------|---|
| 6 | T | 0 | - | unused |
| 12-hour mode ^[1] | | | | |
| 5 | AMPM | 0 | - | indicates AM |
| | | 1 | - | indicates PM |
| 4 | HOUR_ALARM | 0 to 1 | ten's place | hour alarm information coded in BCD format when in 12-hour mode |
| 3 to 0 | | 0 to 9 | unit place | |
| 24-hour mode ^[1] | | | | |
| 5 to 4 | HOUR_ALARM | 0 to 2 | ten's place | hour alarm information coded in BCD format when in 24-hour mode |
| 3 to 0 | | 0 to 9 | unit place | |

[1] Hour mode is set by the bit 12_24 in register Control_1.

7.10.4 Register Day_alarm

Table 51. Day_alarm - day alarm register (address 11h) bit allocation

Bit positions labeled as - are not implemented and return 0 when read. Bits labeled as X are undefined at power-on and unchanged by subsequent resets.

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|--------------------|------|---|---------------------|---|---|---|---|---|
| Symbol | AE_D | T | DAY_ALARM (1 to 31) | | | | | |
| Reset value | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 52. Day_alarm - day alarm register (address 11h) bit description

Bits labeled as T are unused and return 0 when read. Bits labeled as X are undefined at power-on and unchanged by subsequent resets.

| Bit | Symbol | Value | Place value | Description |
|--------|-----------|--------|-------------|---|
| 7 | AE_D | 0 | - | day alarm is enabled |
| | | 1 | - | day alarm is disabled |
| 6 | T | 0 | - | unused |
| 5 to 4 | DAY_ALARM | 0 to 3 | ten's place | day alarm information coded in BCD format |
| 3 to 0 | | 0 to 9 | unit place | |

7.10.5 Register Weekday_alarm

Table 53. Weekday_alarm - weekday alarm register (address 12h) bit allocation

Bits labeled as T are unused and return 0 when read. Bits labeled as X are undefined at power-on and unchanged by subsequent resets.

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|------|---|---|---|---|------------------------|---|---|
| Symbol | AE_W | T | T | T | T | WEEKDAY_ALARM (0 to 6) | | |
| Reset value | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 54. Weekday_alarm - weekday alarm register (address 12h) bit description

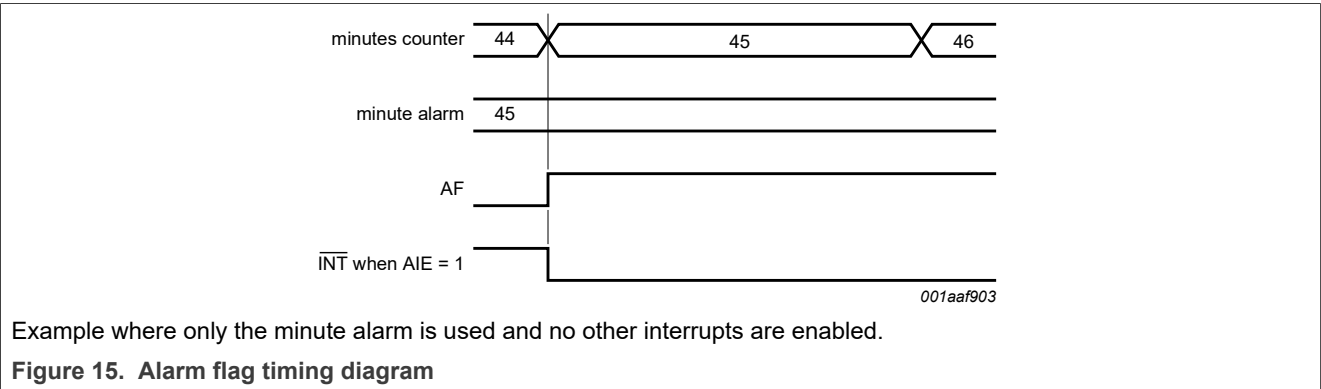
Bit positions labeled as - are not implemented and return 0 when read. Bits labeled as X are undefined at power-on and unchanged by subsequent resets.

| Bit | Symbol | Value | Description |
|--------|---------------|--------|---------------------------|
| 7 | AE_W | 0 | weekday alarm is enabled |
| | | 1 | weekday alarm is disabled |
| 6 to 3 | T | 0 | unused |
| 2 to 0 | WEEKDAY_ALARM | 0 to 6 | weekday alarm information |

7.10.6 Alarm flag

When all enabled comparisons first match, the alarm flag AF (register Control_2) is set. AF remains set until cleared by command. Once AF has been cleared, it will only be set again when the time increments to match the alarm condition once more. For clearing the flags, see [Section 7.11.5](#)

Alarm registers which have their alarm enable bit AE_x at logic 1 are ignored.



7.11 Watchdog timer functions

The PCA2131 has a watchdog timer function. The timer can be switched on and off by using the control bit WD_CD in the register Watchdog_tim_ctl.

The watchdog timer has four selectable source clocks. It can, for example, be used to detect a micro-controller with interrupt and reset capability which is out of control (see [Section 7.11.3](#))

To control the timer function and timer output, the registers Control_2, Watchdog_tim_ctl, and Watchdog_tim_val are used.

7.11.1 Register Watchdg_tim_ctl

Table 55. Watchdg_tim_ctl - watchdog timer control register (address 35h) bit allocation

Bits labeled as T are unused and return 0 when read.

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|-------|---|-------|---|---|---|---------|---|
| Symbol | WD_CD | T | TI_TP | T | T | T | TF[1:0] | |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |

Table 56. Watchdg_tim_ctl - watchdog timer control register (address 35h) bit description

Bits labeled as T are unused and return 0 when read.

| Bit | Symbol | Value | Description |
|--------|---------|-------|--|
| 7 | WD_CD | 0 | watchdog timer interrupt disabled |
| | | 1 | watchdog timer interrupt enabled; the interrupt pin INTA/B is activated when timed out |
| 6 | T | 0 | unused |
| 5 | TI_TP | 0 | the interrupt pin INTA/B is configured to generate a permanent active signal when MSF is set |
| | | 1 | the interrupt pin INTA/B is configured to generate a pulsed signal when MSF flag is set (see Figure 17) |
| 4 to 2 | T | 000 | unused |
| 1 to 0 | TF[1:0] | | timer source clock for watchdog timer |
| | | 00 | 64 Hz |
| | | 01 | 4 Hz |
| | | 10 | $\frac{1}{4}$ Hz |
| | | 11 | $\frac{1}{64}$ Hz |

7.11.2 Register Watchdg_tim_val

Table 57. Watchdg_tim_val - watchdog timer value register (address 36h) bit allocation

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|----------------------|---|---|---|---|---|---|---|
| Symbol | WATCHDG_TIM_VAL[7:0] | | | | | | | |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 58. Watchdg_tim_val - watchdog timer value register (address 36h) bit description

Bits labeled as X are undefined at power-on and unchanged by subsequent resets.

| Bit | Symbol | Value | Description |
|--------|----------------------|----------|--|
| 7 to 0 | WATCHDG_TIM_VAL[7:0] | 00 to FF | timer period in seconds: $TimerPeriod = \frac{(n-1)+/-0.5}{SourceClockFrequency}$ |

Table 58. Watchdg_tim_val - watchdog timer value register (address 36h) bit description

Bits labeled as X are undefined at power-on and unchanged by subsequent resets.

| Bit | Symbol | Value | Description |
|-----|--------|-------|--|
| | | | where n is the timer value (n > 1) Write Only |

Table 59. Programmable watchdog timer

| TF[1:0] | Timer source clock frequency | Units | Minimum timer period (n = 2) | Units | Maximum timer period (n = 255) | Units |
|---------|------------------------------|-------|------------------------------|-------|--------------------------------|-------|
| 00 | 64 | Hz | 15.625 | ms | 3.984 | s |
| 01 | 4 | Hz | 250 | ms | 63.744 | s |
| 10 | $\frac{1}{4}$ | Hz | 4 | s | 1020 | s |
| 11 | $\frac{1}{64}$ | Hz | 64 | s | 16320 | s |

7.11.3 Watchdog timer function

The watchdog timer interrupt function is enabled or disabled by the WD_CD bit of the register Watchdg_tim_ctl (see [Table 56](#)).

The 2 bits TF[1:0] in register Watchdg_tim_ctl determine one of the four source clock frequencies for the watchdog timer: 64 Hz, 4 Hz, $\frac{1}{4}$ Hz or $\frac{1}{64}$ Hz (see [Table 59](#)).

When the watchdog timer function is enabled, the 8-bit timer in register Watchdg_tim_val determines the watchdog timer period (see [Table 59](#)).

The watchdog timer counts down from the software programmed 8-bit binary value n in register Watchdg_tim_val. When the counter reaches 1, the watchdog timer flag WDTF (register Control_2) is set logic 1 and an interrupt is generated. The period accuracy corresponds to n +/- 0.5.

The register Watchdg_tim_val is write only and not readable after set.

The counter does not automatically reload.

When WD_CD is logic 1/0 (watchdog timer interrupt enabled/disabled) and the Micro-controller Unit (MCU) loads a watchdog timer value n:

- the flag WDTF is reset
- $\overline{\text{INTA/B}}$ is cleared
- the watchdog timer starts again

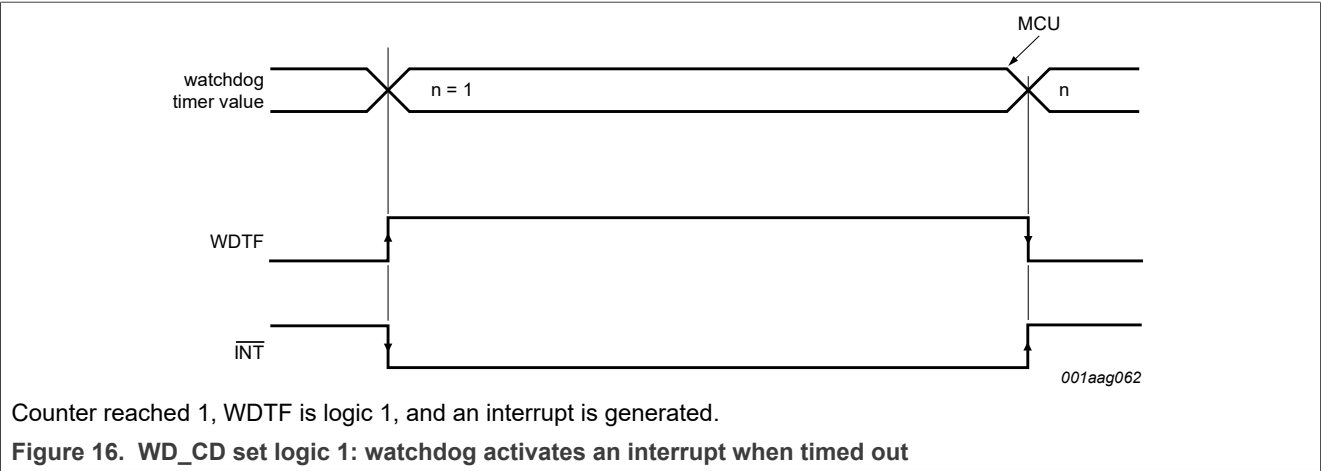
Loading the counter with 0 or 1 will:

- reset the flag WDTF
- clear $\overline{\text{INTA/B}}$
- stop the watchdog timer

Remark: WDTF can be cleared by:

- loading a value in register Watchdg_tim_val
- writing a logic 0 to WDTF

Writing a logic 1 to WDTF has no effect.



- When the watchdog timer counter reaches 1, the watchdog timer flag WDTF is set logic 1
- When a minute or second interrupt occurs, the minute/second flag MSF is set logic 1 (see [Section 7.13.1](#)).

7.11.4 Pre-defined timers: second and minute interrupt

PCA2131 has two pre-defined timers which are used to generate an interrupt either once per second or once per minute (see [Section 7.13.1](#)). The pulse generator for the minute or second interrupt operates from an internal 64 Hz clock. It is independent of the watchdog timer. Each of these timers can be enabled by the bits SI (second interrupt) and MI (minute interrupt) in register Control_1.

7.11.5 Clearing flags

The flags MSF and AF can be cleared by command. To prevent one flag being overwritten while clearing another, a logic AND is performed during the write access. A flag is cleared by writing logic 0 while a flag is not cleared by writing logic 1. Writing logic 1 results in the flag value remaining unchanged.

Two examples are given for clearing the flags. Clearing a flag is made by a write command:

- Bits labeled with - must be written with their previous values
- Bits labeled with T have to be written with logic 0
- WDTF is read only and has to be written with logic 0

Repeatedly rewriting these bits has no influence on the functional behavior.

Table 60. Flag location in register Control_2

| Register | Bit | | | | | | | |
|-----------|-----|------|---|----|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Control_2 | MSF | WDTF | T | AF | T | - | - | T |

Table 61. Example values in register Control_2

| Register | Bit | | | | | | | |
|-----------|-----|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Control_2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |

The following tables show what instruction must be sent to clear the appropriate flag.

Table 62. Example to clear only AF (bit 4)

| Register | Bit | | | | | | | |
|-----------|-----|---|---|---|---|------------------|------------------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Control_2 | 1 | 0 | 1 | 0 | 0 | 0 ^[1] | 0 ^[1] | 0 |

[1] The bits labeled as - have to be rewritten with the previous values.

Table 63. Example to clear only MSF (bit 7)

| Register | Bit | | | | | | | |
|-----------|-----|---|---|---|---|------------------|------------------|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Control_2 | 0 | 0 | 1 | 1 | 0 | 0 ^[1] | 0 ^[1] | 0 |

[1] The bits labeled as - have to be rewritten with the previous values.

7.12 Timestamp function

The PCA2131 has four active LOW timestamp input pins $\overline{TS1}$, $\overline{TS2}$, $\overline{TS3}$ and $\overline{TS4}$, internally pulled with on-chip pull-up resistors to $V_{oper(int)}$. It also has a timestamp detection circuit which can detect the event when inputs on pin $\overline{TS1/2/3/4}$ are driven to ground.

The timestamp function is enabled by default after power-on and it can be switched off by setting the control bit TSOFF (register Timestp_ctl1/2/3/4).

The time recorded in the time stamps, when in 100 Hz disable mode (1 Hz mode), will be at least two 16 Hz clocks behind the timestamp event and no more than 3 clocks behind. If the exact time of the timestamp event is required then subtract 2 subseconds from the timestamp value and the result will have -0 subseconds to +1 subseconds of uncertainty.

A most common application of the timestamp function is described in [1].

See [Section 7.13.5](#) for a description of interrupt generation from the timestamp function.

7.12.1 Timestamp flag

1. When the $\overline{TS1/2/3/4}$ input pin are driven to ground, the following sequence occurs:
 - a. The actual date and time are stored in the timestamp registers.
 - b. The timestamp flag TSF1/2/3/4 flag is set.
 - c. If the TSIE1/2/3/4 bit is active, and corresponding interrupt mask is disabled, an interrupt on the $\overline{INTA/B}$ pin is generated.

The TSF1/2/3/4 and TSF1/2/3/4_2 flags can be cleared by command; clearing the flag clears the interrupt. Once TSF1/2/3/4 is cleared, it will only be set again when $\overline{TS1/2/3/4}$ pin is driven to ground once again.

7.12.2 Timestamp mode

The timestamp function has two different modes selected by the control bit TSM (timestamp mode) in register Timestp_ctl:

- If TSM is logic 0 (default): in subsequent trigger events without clearing the timestamp flags, the last timestamp event is stored
- If TSM is logic 1: in subsequent trigger events without clearing the timestamp flags, the first timestamp event is stored

The timestamp function also depends on the control bit BTSE in register Control_3, see [Section 7.12.4](#).

7.12.3 Timestamp registers

7.12.3.1 Register Timestp_ctl1/2/3/4

Table 64. Timestp_ctl1/2/3/4 - timestamp control register (address 14h/1Bh/22h/29h) bit allocation

Bits labeled as T are unused and return 0 when read

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|-----|-------|---|---------------------|---|---|---|---|
| Symbol | TSM | TSOFF | T | SUBSEC_TIMESTP[4:0] | | | | |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 65. Timestp_ctl1/2/3/4 - timestamp control register (address 14h/1Bh/22h/29h) bit description

Bits labeled as T are unused and return 0 when read

| Bit | Symbol | Value | Description |
|--------|---------------------|-------|---|
| 7 | TSM | 0 | in subsequent events without clearing the timestamp flags, the last event is stored |
| | | 1 | in subsequent events without clearing the timestamp flags, the first event is stored |
| 6 | TSOFF | 0 | timestamp function active |
| | | 1 | timestamp function disabled |
| 5 | - | - | unused |
| 4 to 0 | SUBSEC_TIMESTP[4:0] | | $\frac{1}{16}$ second timestamp information coded in BCD format when 100TH_S_DIS = '1' ^[1] , $\frac{1}{20}$ second timestamp information coded in BCD format when 100TH_S_DIS = '0'; |

[1] The time recorded in the time stamps, when in 100 Hz disable mode (1 Hz mode), will be at least two 16 Hz clocks behind the timestamp event and no more than 3 clocks behind. If the exact time of the timestamp event is required then subtract 2 subseconds from the timestamp value and the result will have -0 subseconds to +1 subseconds of uncertainty.

7.12.3.2 Register Sec_timestp

Table 66. Sec_timestp1/2/3/4 - second timestamp register (address 15h/1Ch/23h/2Ah) bit allocation

Bits labeled as T are unused and return 0 when read

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|---|--------------------------|---|---|---|---|---|---|
| Symbol | T | SECOND_TIMESTP (0 to 59) | | | | | | |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 67. Sec_timestp1/2/3/4 - second timestamp register (address 15h/1Ch/23h/2Ah) bit description

Bits labeled as T are unused and return 0 when read

| Bit | Symbol | Value | Place value | Description |
|--------|----------------|--------|-------------|--|
| 7 | T | 0 | - | unused |
| 6 to 4 | SECOND_TIMESTP | 0 to 5 | ten's place | second timestamp information coded in BCD format |
| 3 to 0 | | 0 to 9 | unit place | |

7.12.3.3 Register Min_timestp

Table 68. Min_timestp1/2/3/4 - minute timestamp register (address 16h/1Dh/24h/2Bh) bit allocation

Bits labeled as T are unused and return 0 when read.

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|---|--------------------------|---|---|---|---|---|---|
| Symbol | T | MINUTE_TIMESTP (0 to 59) | | | | | | |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 69. Min_timestp1/2/3/4 - minute timestamp register (address 16h/1Dh/24h/2Bh) bit description

Bits labeled as T are unused and return 0 when read.

| Bit | Symbol | Value | Place value | Description |
|--------|----------------|--------|-------------|--|
| 7 | T | 0 | - | unused |
| 6 to 4 | MINUTE_TIMESTP | 0 to 5 | ten's place | minute timestamp information coded in BCD format |
| 3 to 0 | | 0 to 9 | unit place | |

7.12.3.4 Register Hour_timestp

Table 70. Hour_timestp1/2/3/4 - hour timestamp register (address 17h/1Eh/25h/2Ch) bit allocation

Bits labeled as T are unused and return 0 when read.

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|---|---|------|--|---|---|---|---|
| Symbol | T | T | AMPM | HOUR_TIMESTP (1 to 12) in 12-hour mode | | | | |
| | | | | HOUR_TIMESTP (0 to 23) in 24-hour mode | | | | |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 71. Hour_timestp1/2/3/4 - hour timestamp register (address 17h/1Eh/25h/2Ch) bit description

Bits labeled as T are unused and return 0 when read.

| Bit | Symbol | Value | Place value | Description |
|-----------------------------|--------|-------|-------------|--------------|
| 7 to 6 | - | - | - | unused |
| 12-hour mode ^[1] | | | | |
| 5 | AMPM | 0 | - | indicates AM |
| | | 1 | - | indicates PM |

Table 71. Hour_timestp1/2/3/4 - hour timestamp register (address 17h/1Eh/25h/2Ch) bit description...continued
 Bits labeled as *T* are unused and return 0 when read.

| Bit | Symbol | Value | Place value | Description |
|-----------------------------|--------------|--------|-------------|---|
| 4 | HOUR_TIMESTP | 0 to 1 | ten's place | hour timestamp information coded in BCD format when in 12-hour mode |
| 3 to 0 | | 0 to 9 | unit place | |
| 24-hour mode ^[1] | | | | |
| 5 to 4 | HOUR_TIMESTP | 0 to 2 | ten's place | hour timestamp information coded in BCD format when in 24-hour mode |
| 3 to 0 | | 0 to 9 | unit place | |

[1] Hour mode is set by the bit 12_24 in register Control_1.

7.12.3.5 Register Day_timestp

Table 72. Day_timestp1/2/3/4 - day timestamp register (address 18h/1Fh/26h/2Dh) bit allocation
 Bits labeled as *T* are unused and return 0 when read.

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|---|---|-----------------------|---|---|---|---|---|
| Symbol | T | T | DAY_TIMESTP (1 to 31) | | | | | |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 73. Day_timestp1/2/3/4 - day timestamp register (address 18h/1Fh/26h/2Dh) bit description
 Bits labeled as *T* are unused and return 0 when read.

| Bit | Symbol | Value | Place value | Description |
|--------|-------------|--------|-------------|---|
| 7 to 6 | T | 00 | - | unused |
| 5 to 4 | DAY_TIMESTP | 0 to 3 | ten's place | day timestamp information coded in BCD format |
| 3 to 0 | | 0 to 9 | unit place | |

7.12.3.6 Register Mon_timestp

Table 74. Mon_timestp1/2/3/4 - month timestamp register (address 19h/20h/27h/2Eh) bit allocation
 Bits labeled as *T* are unused and return 0 when read.

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|---|---|---|-------------------------|---|---|---|---|
| Symbol | T | T | T | MONTH_TIMESTP (1 to 12) | | | | |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 75. Mon_timestp1/2/3/4 - month timestamp register (address 19h/20h/27h/2Eh) bit description
 Bits labeled as *T* are unused and return 0 when read.

| Bit | Symbol | Value | Place value | Description |
|--------|---------------|--------|-------------|---|
| 7 to 5 | T | 000 | - | unused |
| 4 | MONTH_TIMESTP | 0 to 1 | ten's place | month timestamp information coded in BCD format |

Table 75. Mon_timestp1/2/3/4 - month timestamp register (address 19h/20h/27h/2Eh) bit description...continued
 Bits labeled as *T* are unused and return 0 when read.

| Bit | Symbol | Value | Place value | Description |
|--------|--------|--------|-------------|-------------|
| 3 to 0 | | 0 to 9 | unit place | |

7.12.3.7 Register Year_timestp

Table 76. Year_timestp1/2/3/4 - year timestamp register (address 1Ah/21h/28h/2Fh) bit allocation

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|------------------------|---|---|---|---|---|---|---|
| Symbol | YEAR_TIMESTP (0 to 99) | | | | | | | |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

Table 77. Year_timestp1/2/3/4 - year timestamp register (address 1Ah/21h/28h/2Fh) bit description

| Bit | Symbol | Value | Place value | Description |
|--------|--------------|--------|-------------|--|
| 7 to 4 | YEAR_TIMESTP | 0 to 9 | ten's place | year timestamp information coded in BCD format |
| 3 to 0 | | 0 to 9 | unit place | |

7.12.4 Dependency between Battery switch-over and timestamp

The timestamp function depends on the control bit BTSE in register Control_3:

Table 78. Battery switch-over and timestamp

| BTSE | BF | | Description |
|------|----|-----|---|
| 0 | - | [1] | the battery switch-over does not affect the timestamp registers |
| 1 | | | If a battery switch-over event occurs: |
| | 0 | [1] | the timestamp 4 group registers store the time and date when the switch-over occurs; after this event occurred BF is set logic 1 |
| | 1 | | the timestamp 4 group registers are not modified; in this condition subsequent battery switch-over events or falling edges on pin TS4 are not registered |

[1] Default value.

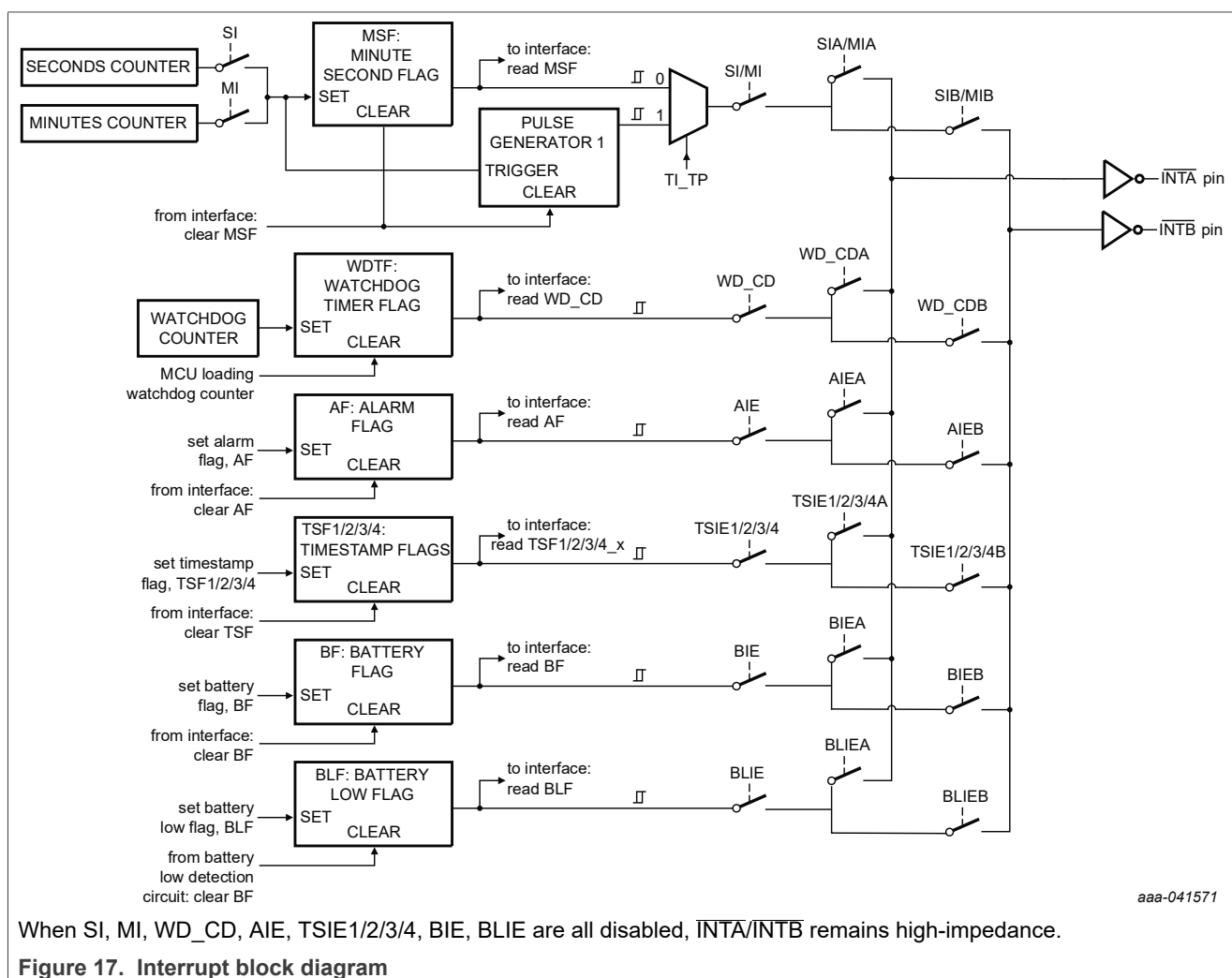
7.13 Interrupt output, INTA/INTB

PCA2131 has two interrupt output pins $\overline{\text{INTA}}$ and $\overline{\text{INTB}}$ which are open-drain, active LOW (requiring a pull-up resistor if used). Interrupts may be sourced from different places:

- second or minute timer
- watchdog timer
- alarm
- timestamp1/2/3/4
- battery switch-over
- battery low detection

The control bit TI_TP (register Watchdog_tim_ctl) is used to configure whether the interrupts generated from the second/minute timer (flag MSF in register Control_2) are pulsed signals or a permanently active signal. All the other interrupt sources generate a permanently active interrupt signal which follows the status of the corresponding flags. When the interrupt sources are all disabled, INTA/B remains high-impedance.

- The flags MSF, AF, TSFx, and BF can be cleared by command.
- The flag WDTF is read only. How it can be cleared is explained in [Section 7.11.5](#).
- The flag BLF is read only. It is cleared automatically from the battery low detection circuit when the battery is replaced.



7.13.1 Minute and second interrupts

Minute and second interrupts are generated by predefined timers. The timers can be enabled independently from one another by the bits MI and SI in register Control_1. However, a minute interrupt enabled on top of a second interrupt cannot be distinguishable since it occurs at the same time.

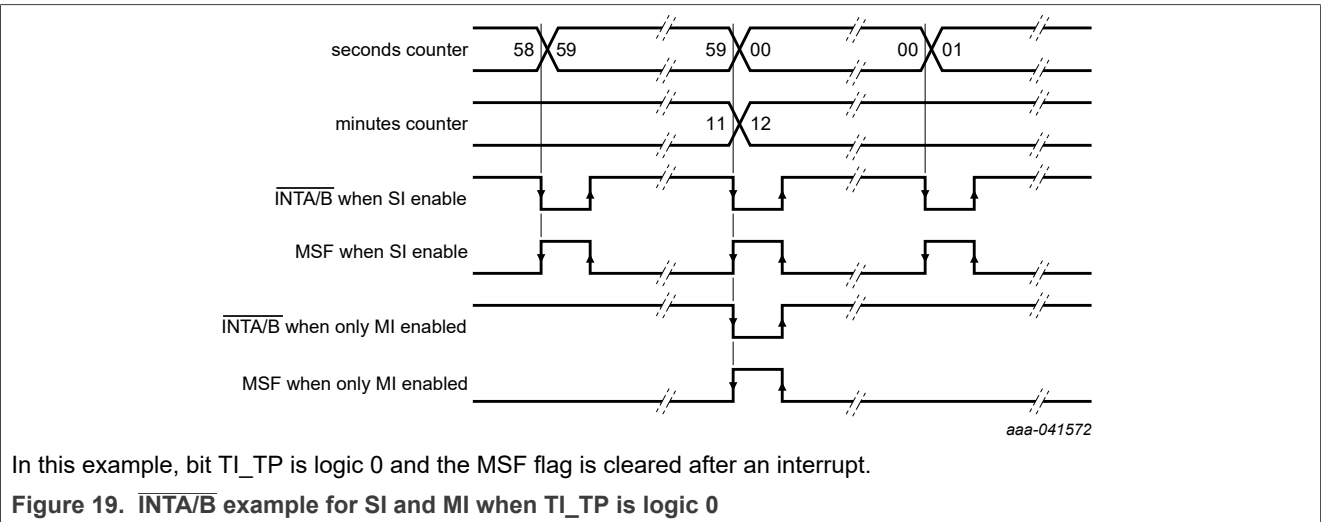
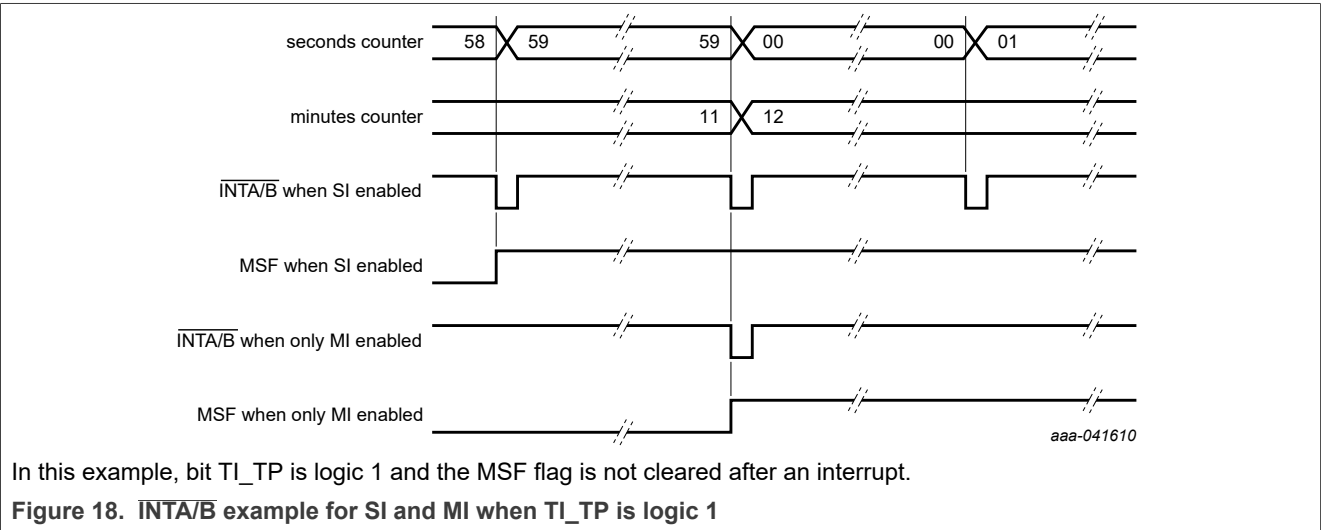
The minute/second flag MSF (register Control_2) is set logic 1 when either the seconds or the minutes counter increments according to the enabled interrupt (see [Table 79](#)). The MSF flag can be cleared by command.

Table 79. Effect of bits MI and SI on pin INTA/B and bit MSF

| MI | SI | Result on INTA/B | Result on MSF |
|----|----|------------------------------|--|
| 0 | 0 | no interrupt generated | MSF never set |
| 1 | 0 | an interrupt once per minute | MSF set when minutes counter increments |
| 0 | 1 | an interrupt once per second | MSF set when seconds counter increments |
| 1 | 1 | an interrupt once per second | MSF set when seconds counter increments |

When MSF is set logic 1:

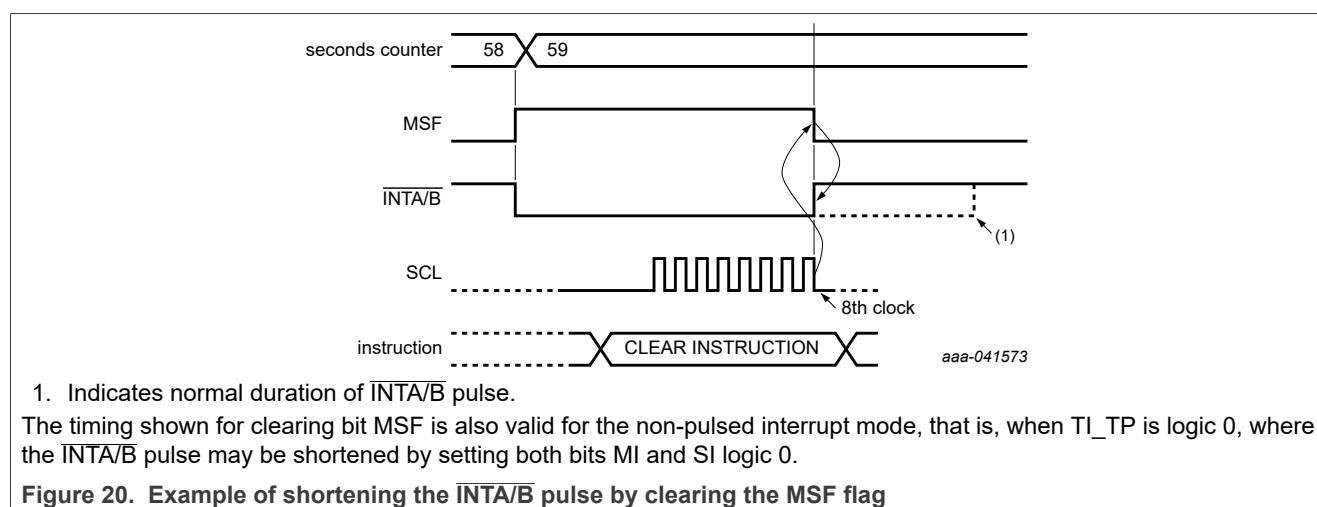
- If TI_TP is logic 1, the interrupt is generated as a pulsed signal if not masked.
- If TI_TP is logic 0, the interrupt is permanently active signal that remains until MSF is cleared.



The pulse generator for the minute/second interrupt operates from an internal 64 Hz clock and generates a pulse of $\frac{1}{64}$ seconds in duration.

7.13.2 $\overline{\text{INTA/B}}$ pulse shortening

If the MSF flag (register Control_2) is cleared before the end of the $\overline{\text{INTA/B}}$ pulse, then the $\overline{\text{INTA/B}}$ pulse is shortened. This allows the source of a system interrupt to be cleared immediately when it is serviced, that is, the system does not have to wait for the completion of the pulse before continuing; see Figure 20. Instructions for clearing the bit MSF can be found in Section 7.11.5.



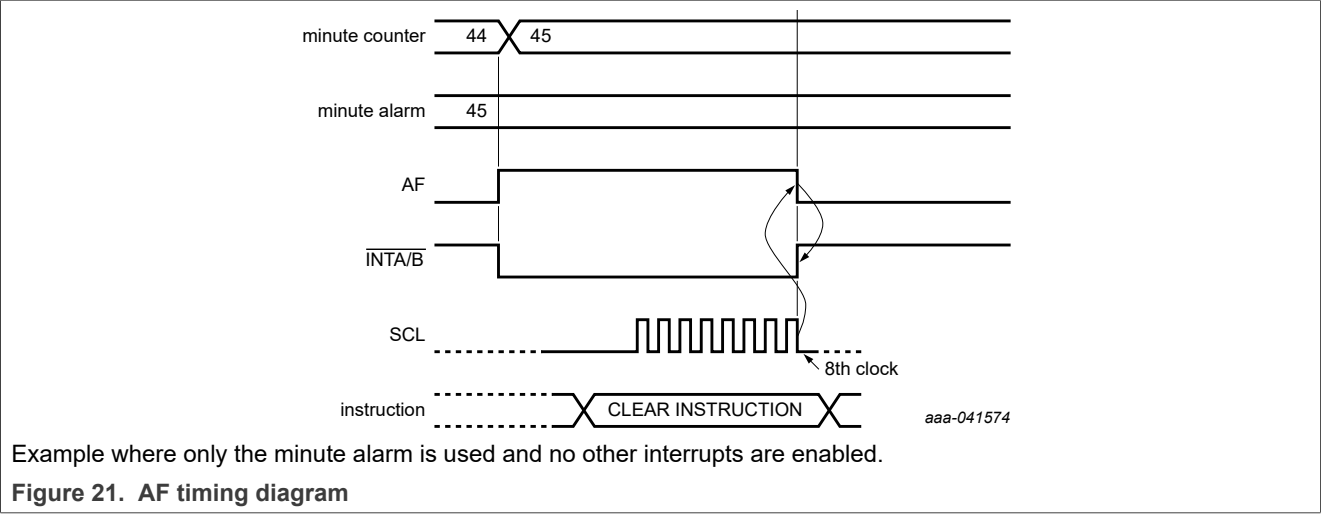
7.13.3 Watchdog timer interrupts

The generation of interrupts from the watchdog timer is controlled using the WD_CD bit (register Watchdg_tim_ctl). The interrupt is generated as an active signal which follows the status of the watchdog timer flag WDTF (register Control_2) if not masked. No pulse generation is possible for watchdog timer interrupts.

The interrupt is cleared when the flag WDTF is reset. Instructions for clearing it can be found in Section 7.11.5.

7.13.4 Alarm interrupts

Generation of interrupts from the alarm function is controlled by the bit AIE (register Control_2). If AIE is enabled, the $\overline{\text{INTA/B}}$ pin follows the status of bit AF (register Control_2) if not masked. Clearing AF immediately clears $\overline{\text{INTA/B}}$. No pulse generation is possible for alarm interrupts.



7.13.5 Timestamp interrupts

Interrupt generation from the timestamp function is controlled using the TSIE1-4 bit (register Control_5). If TSIE1-4 is enabled, the INTA/B pin follows the status of the flags TSF1/2/3/4, if not masked. Clearing the flags TSF_x immediately clears INTA/B. No pulse generation is possible for timestamp interrupts.

7.13.6 Battery switch-over interrupts

Generation of interrupts from the battery switch-over is controlled by the BIE bit (register Control_3). If BIE is enabled, the INTA/B pin follows the status of bit BF in register Control_3 if not masked(see Table 78). Clearing BF immediately clears INTA/B. No pulse generation is possible for battery switch-over interrupts.

7.13.7 Battery low detection interrupts

Generation of interrupts from the battery low detection is controlled by the BLIE bit (register Control_3). If BLIE is enabled, the INTA/B pin follows the status of bit BLF (register Control_3) if not masked. The interrupt is cleared when the battery is replaced (BLF is logic 0) or when bit BLIE is disabled (BLIE is logic 0). BLF is read only and therefore cannot be cleared by command.

7.13.8 Interrupt masks

Table 80. INT_A/B_MASK1 - interrupt mask 1 register (address 31h/33h) bit allocation

Bits labeled as T are unused and return 0 when read.

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|---------------|---|---|---|---|---|---|---|
| Symbol | INT_A/B_MASK1 | | | | | | | |
| Reset value | - | - | 1 | 1 | 1 | 1 | 1 | 1 |

Table 81. INT_A/B_MASK1 - interrupt mask 1 register (address 31h/33h) bit description

Bits labeled as T are unused and return 0 when read.

| Bit | Symbol | Value | Description |
|--------|--------|-------|-------------|
| 7 to 6 | T | 00 | unused |

Table 81. INT_A/B_MASK1 - interrupt mask 1 register (address 31h/33h) bit description...continued

Bits labeled as T are unused and return 0 when read.

| Bit | Symbol | Value | Description |
|-----|----------|-------|---------------------------------|
| 5 | MIA/B | 1 | minute interrupt mask |
| 4 | SIA/B | 1 | second interrupt mask |
| 3 | WD_CDA/B | 1 | watchdog interrupt mask |
| 2 | AIEA/B | 1 | alarm interrupt mask |
| 1 | BIEA/B | 1 | battery flag interrupt mask |
| 0 | BLIEA/B | 1 | battery low flag interrupt mask |

Table 82. INT_A/B_MASK2 - interrupt mask 2 register (address 32h/34h) bit allocation

Bits labeled as T are unused and return 0 when read.

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|---------------|---|---|---|---|---|---|---|
| Symbol | INT_A/B_MASK2 | | | | | | | |
| Reset value | T | T | T | T | 1 | 1 | 1 | 1 |

Table 83. INT_A/B_MASK2 - interrupt mask 2 register (address 32h/34h) bit description

Bits labeled as T are unused and return 0 when read.

| Bit | Symbol | Value | Description |
|--------|----------|-------|-----------------------------|
| 7 to 4 | T | 0000 | unused |
| 3 | TSIE1A/B | 1 | time stamp 1 interrupt mask |
| 2 | TSIE2A/B | 1 | time stamp 2 interrupt mask |
| 1 | TSIE3A/B | 1 | time stamp 3 interrupt mask |
| 0 | TSIE4A/B | 1 | time stamp 4 interrupt mask |

The registers at addresses 31h to 32h are used to configure interrupt source for $\overline{\text{INTA}}$ pin, and the registers at addresses 33h to 34h are for $\overline{\text{INTB}}$ pin.

All of above interrupts could be masked from either $\overline{\text{INTA}}$ or $\overline{\text{INTB}}$, with corresponding bit set to '1', as shown in [Figure 17](#).

7.14 External clock test mode

A test mode is available which allows on-board testing. In this mode, it is possible to set up test conditions and control the operation of the RTC.

The test mode is entered by setting bits COF[2:0] logic 111 (register CLKOUT_ctl) and bit EXT_TEST logic 1 (register Control_1). Then pin CLKOUT becomes an input. The test mode replaces the internal clock signal (8192 Hz) with the signal applied to pin CLKOUT. Every 8192 positive edges applied to pin CLKOUT generate an increment of one second.

The signal applied to pin CLKOUT should have a minimum pulse width of 300 ns and a minimum period of 1 000 ns. The internal clock, now sourced from CLKOUT, is divided down by a divider chain called prescaler. The

prescaler can be set into a known state by using bit STOP and CPR. When bit STOP and CPR are logic 1, the prescaler is reset to 0. STOP and CPR must be cleared before the prescaler can operate again.

From a stop condition, the first 1 second increment will take place after 8192 positive edges on pin CLKOUT. Thereafter, every 8192 positive edges cause a 1 second increment. In 100 Hz mode, the first 100th of a second increment will take place after 80 pulses on pin CLKOUT, and the first 1 second increment will take place after 8176 pulses on pin CLKOUT. Thereafter, every 8192 pulses cause a 1 second increment. The 100 Hz clock is generated from a dithered state machine which runs on the 256 Hz clock, so the number of pulses for each subsequent 100ths change is not constant. After the first 1 second increment the 25-bit dither pattern proceeds as follows from left to right: 1101010101101010110101010

Where 1 == 96 CLKOUT pulses, and 0 == 64 CLKOUT pulses. This pattern repeats 4 times every second. In the first second, after 80 clock pulses trigger the first 100th, the left pattern is 101010101101010110101010, 1101010101101010110101010, 1101010101101010110101010, 1101010101101010110101010, which means 96 pulses for 100ths == 2, then 64 pulses for 100ths == 3, 96 for 100ths == 4, and so on.

Remark: Entry into test mode is not synchronized to the internal 8192 Hz clock. When entering the test mode, no assumption as to the state of the prescaler can be made.

Operating example:

1. Set CLKOUT = high-Z (register CLKOUT_ctl, COF[2:0] = 111).
2. Set EXT_TEST test mode (register Control_1, EXT_TEST is logic 1).
3. Set bit STOP (register Control_1, STOP is logic 1).
4. Set bit CPR (register SR_RESET, CPR is logic 1).
5. Set time registers to desired value.
6. Clear STOP (register Control_1, STOP is logic 0).
7. Apply 8192 clock pulses to CLKOUT.
8. Read time registers to see the first change.
9. Apply 8192 clock pulses to CLKOUT.
10. Read time registers to see the second change.

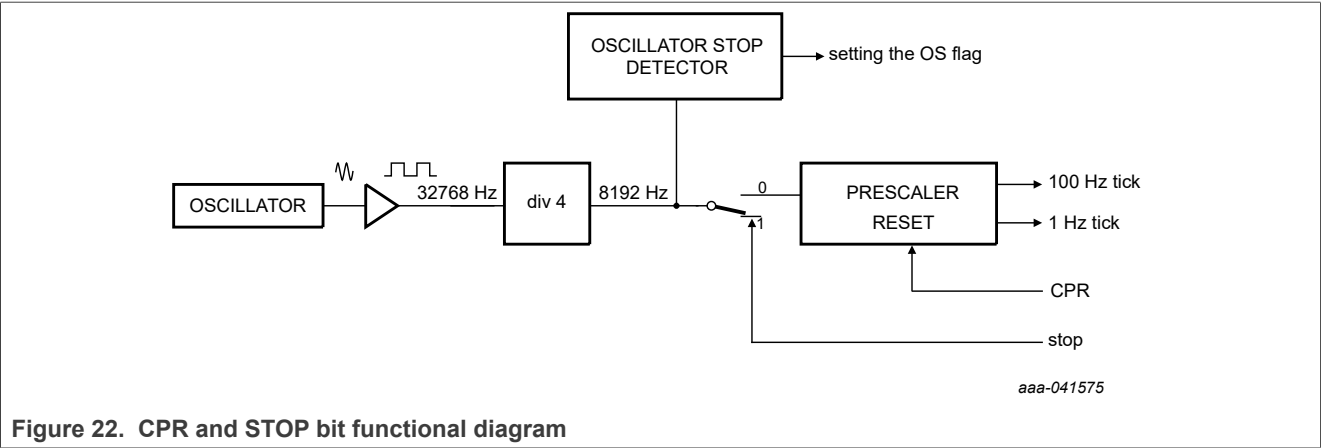
Repeat 7 and 8 for additional increments.

Operating example (100 Hz mode):

1. Set CLKOUT = high-Z (register CLKOUT_ctl, COF[2:0] = 111).
2. Set EXT_TEST test mode (register Control_1, EXT_TEST is logic 1).
3. Set bit STOP (register Control_1, STOP is logic 1).
4. Set bit CPR (register SR_RESET, CPR is logic 1).
5. Set time registers to desired value.
6. Clear STOP (register Control_1, STOP is logic 0).
7. Apply 80 clock pulses to CLKOUT.
8. Read hundredths registers to see the first change.
9. Apply 8096 clock pulses to CLKOUT (8096 + 80 = 8176 total pulses).
10. Read seconds registers to see the first change.
11. Apply the number of pulses needed for the current dither value.
12. Read the hundredths register to see subsequent changes.
13. Read the seconds register every 8192 pulses to see subsequent changes.

7.15 STOP bit function

The STOP bit stops the time from counting in both RTC mode and external clock test mode. STOP must be set to unlock the time and date registers to set the time.

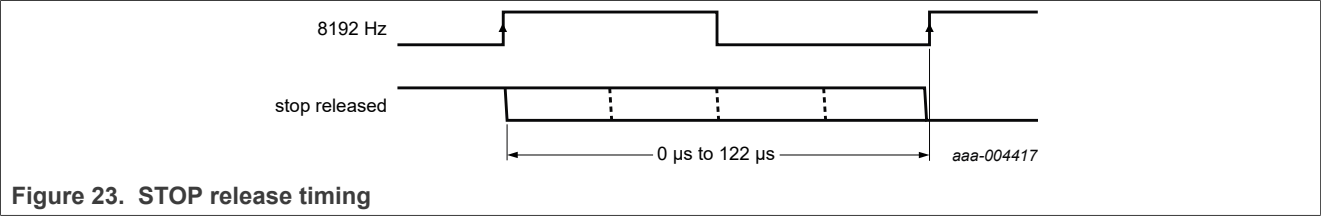


The *stop* signal blocks the 8.192 kHz clock from generating system clocks and freezes the time. In this state, the prescaler can be cleared with the CPR command in the Resets register.

Remark: The CLKOUT output of clock frequencies is not affected.

The time circuits can then be set and do not increment until the STOP bit is released. There is a slight chance that STOP is set during a carry over of multiple time registers, which may have been executed incomplete. Therefore time must be set before clearing STOP to maintain time integrity.

The *stop* acts on the 8.192 kHz signal. Because the I²C-bus or TS pin input is asynchronous to the crystal oscillator, the accuracy of restarting the time circuits is between zero and one 8.192 kHz cycle (see [Figure 23](#)).



The first increment of the time circuits is between 0 s and 122 μs after STOP is released.

7.16 Interfaces

The PCA2131 has an I²C-bus or SPI-bus interface using the same pins. The selection is done using the interface selection pin IFS (see [Table 84](#)).

Table 84. Interface selection input pin IFS

| Pin | Connection | Bus interface | Reference |
|-----|-----------------|----------------------|--------------------------------|
| IFS | V _{SS} | SPI-bus | Section 7.16.1 |
| | V _{DD} | I ² C-bus | Section 7.16.2 |

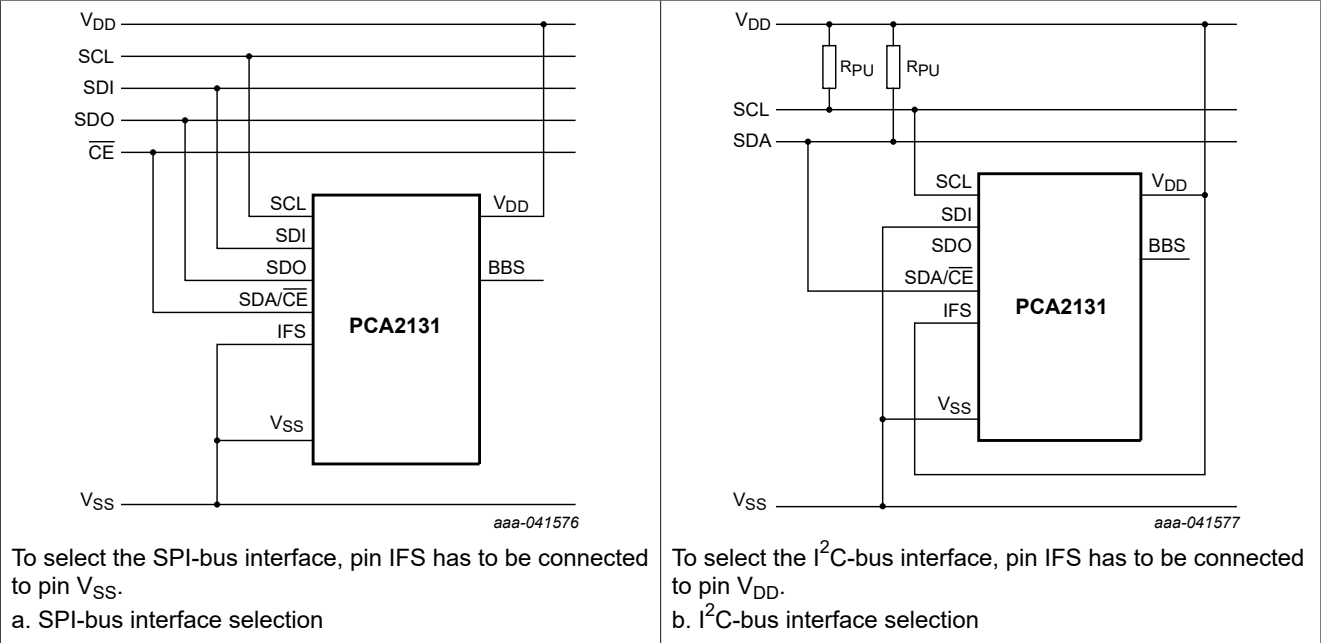


Figure 24. Interface selection

7.16.1 SPI-bus interface

Data transfer to and from the device is made by a 4-line SPI-bus (see [Table 85](#)). The data lines for input and output are split. The SPI-bus is initialized whenever the chip enable line pin SDA/CE is inactive.

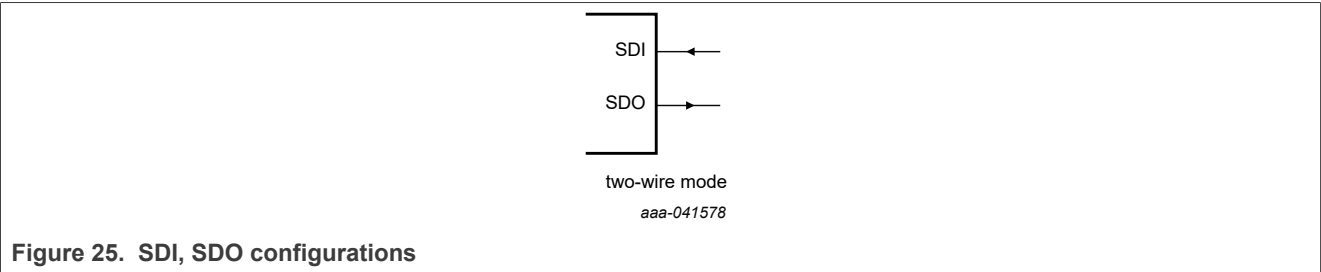


Figure 25. SDI, SDO configurations

Table 85. Serial interface

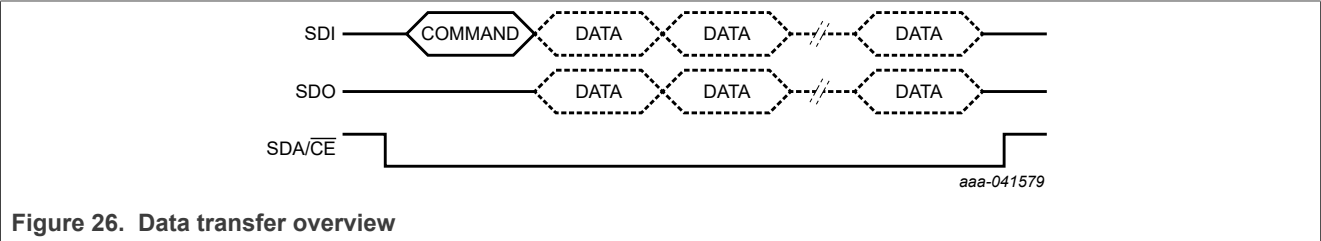
| Symbol | Function | | Description |
|--------|----------------------------------|-----|--|
| SDA/CE | chip enable input; active LOW | [1] | when HIGH, the interface is reset; input may be higher than V _{DD} |
| SCL | serial clock input | | when SDA/CE is HIGH, input may float; input may be higher than V _{DD} |
| SDI | serial data input | | when SDA/CE is HIGH, input may float; input may be higher than V _{DD} ; input data is sampled on the rising edge of SCL |
| SDO | serial data output | | push-pull output; drives from V _{SS} to V _{oper(int)} (V _{BBS}); output data is changed on the falling edge of SCL |

[1] The chip enable must not be wired permanently LOW.

7.16.1.1 Data transmission

The chip enable signal is used to identify the transmitted data. Each data transfer is a whole byte, with the Most Significant Bit (MSB) sent first.

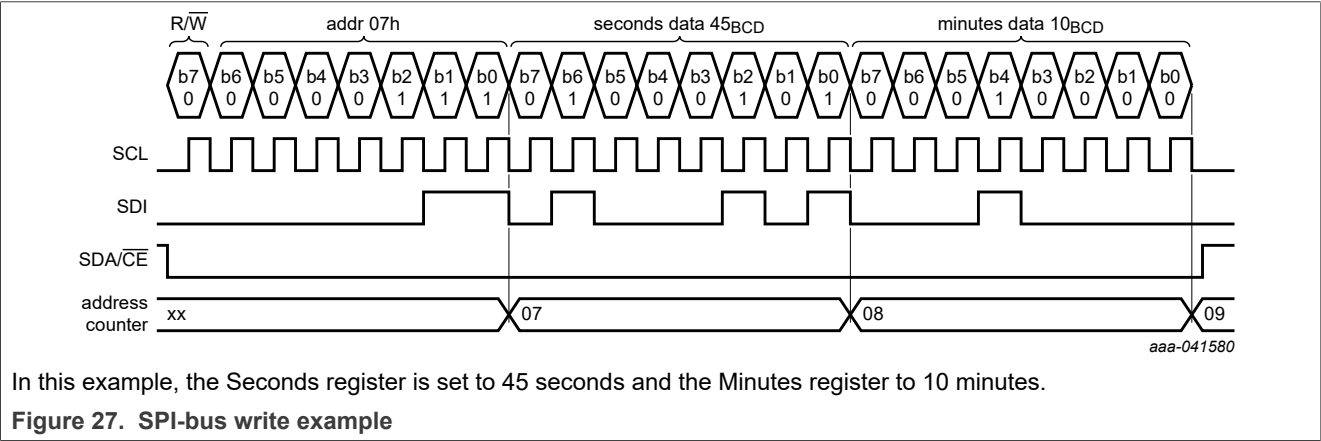
The transmission is controlled by the active LOW chip enable signal SDA/CE. The first byte transmitted is the command byte. Subsequent bytes are either data to be written or data to be read (see Figure 26).

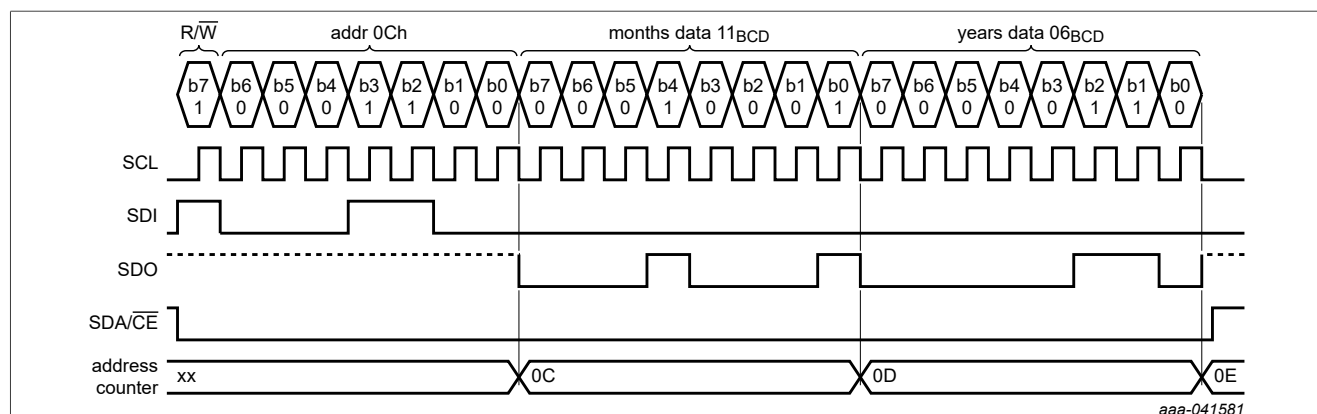


The command byte defines the address of the first register to be accessed and the read/write mode. The address counter will auto increment after every access and will reset to zero after the last valid register is accessed. The R/\overline{W} bit defines if the following bytes are read or write information.

Table 86. Command byte definition

| Bit | Symbol | Value | Description |
|--------|-------------------|------------|------------------------------|
| 7 | R/ \overline{W} | | data read or write selection |
| | | 0 | write data |
| | | 1 | read data |
| 6 to 0 | RA | 00h to 36h | register address |





In this example, the registers Months and Years are read. The pins SDI and SDO are not connected together. For this configuration, it is important that pin SDI is never left floating. It must always be driven either HIGH or LOW. If pin SDI is left open, high I_{DD} currents may result.

Figure 28. SPI-bus read example

7.16.2 I²C-bus interface

The I²C-bus is for bidirectional, two-line communication between different ICs or modules. The two lines are a Serial Data line (SDA) and a Serial CLock line (SCL). Both lines are connected to a positive supply by a pull-up resistor. Data transfer is initiated only when the bus is not busy.

7.16.2.1 Bit transfer

One data bit is transferred during each clock pulse. The data on the SDA line remains stable during the HIGH period of the clock pulse as changes in the data line at this time are interpreted as control signals (see [Figure 29](#)).

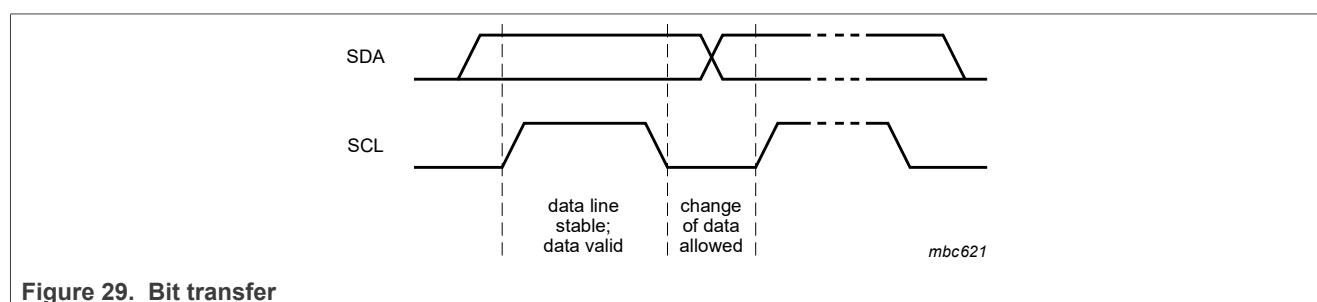
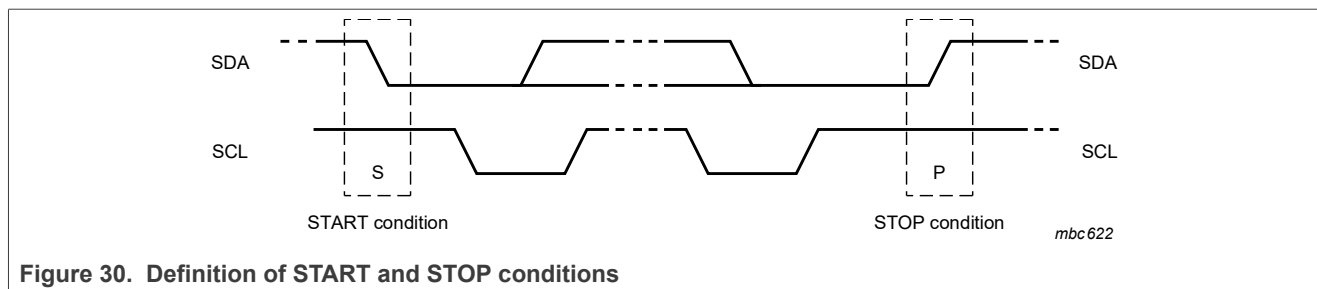


Figure 29. Bit transfer

7.16.2.2 START and STOP conditions

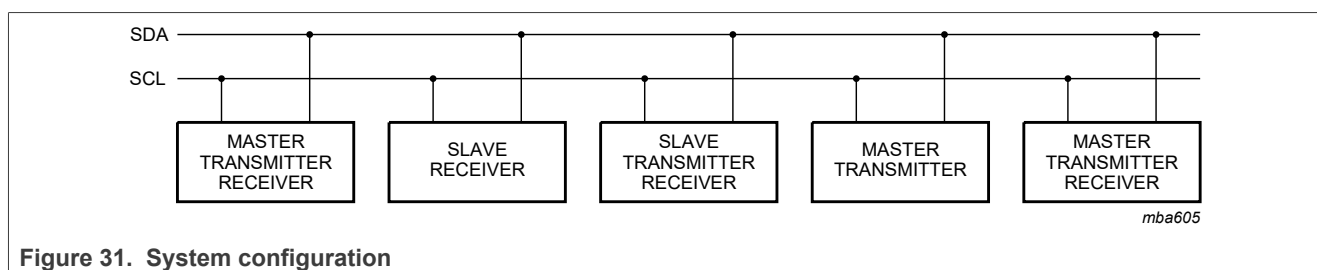
Both data and clock lines remain HIGH when the bus is not busy. A HIGH-to-LOW transition of the data line, while the clock is HIGH, is defined as the START condition S. A LOW-to-HIGH transition of the data line while the clock is HIGH is defined as the STOP condition P (see [Figure 30](#)).



7.16.2.3 System configuration

A device generating a message is a transmitter; a device receiving a message is the receiver. The device that controls the message is the master; and the devices which are controlled by the master are the slaves.

The PCA2131 can act as a slave transmitter and a slave receiver.

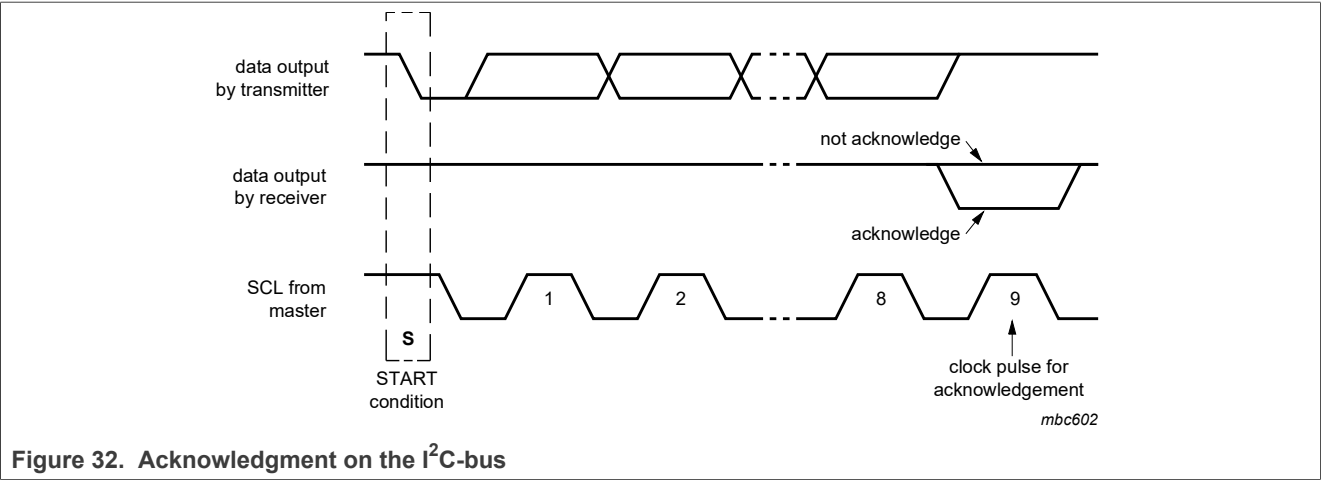


7.16.2.4 Acknowledge

The number of data bytes transferred between the START and STOP conditions from transmitter to receiver is unlimited. Each byte of 8 bits is followed by an acknowledge cycle.

- A slave receiver which is addressed must generate an acknowledge after the reception of each byte.
- Also a master receiver must generate an acknowledge after the reception of each byte that has been clocked out of the slave transmitter.
- The device that acknowledges must pull-down the SDA line during the acknowledge clock pulse, so that the SDA line is stable LOW during the HIGH period of the acknowledge related clock pulse (set-up and hold times must be considered).
- A master receiver must signal an end of data to the transmitter by not generating an acknowledge on the last byte that has been clocked out of the slave. In this event, the transmitter must leave the data line HIGH to enable the master to generate a STOP condition.

Acknowledgment on the I²C-bus is illustrated in [Figure 32](#).



7.16.2.5 I²C-bus protocol

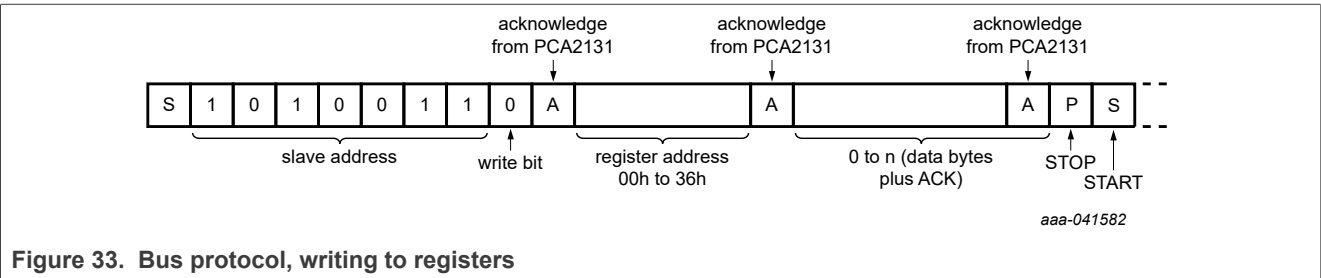
After a start condition, a valid hardware address has to be sent to a PCA2131 device. The appropriate I²C-bus slave address is 1010 011. The entire I²C-bus slave address byte is shown in [Table 87](#).

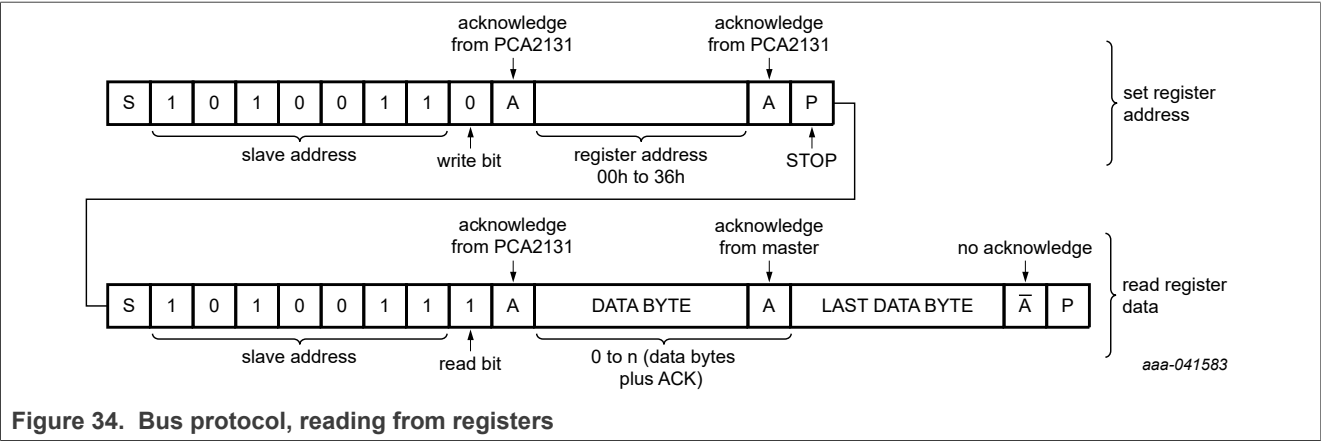
Table 87. I²C slave address byte

| Slave address | | | | | | | | |
|---------------|-----|---|---|---|---|---|---|-----|
| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| | MSB | | | | | | | LSB |
| | 1 | 0 | 1 | 0 | 0 | 1 | 1 | R/W |

The R/W bit defines the direction of the following single or multiple byte data transfer (read is logic 1, write is logic 0).

For the format and the timing of the START condition (S), the STOP condition (P), and the acknowledge (A) refer to the I²C-bus specification [\[3\]](#) and the characteristics table ([Table 92](#)). In the write mode, a data transfer is terminated by sending a STOP condition.





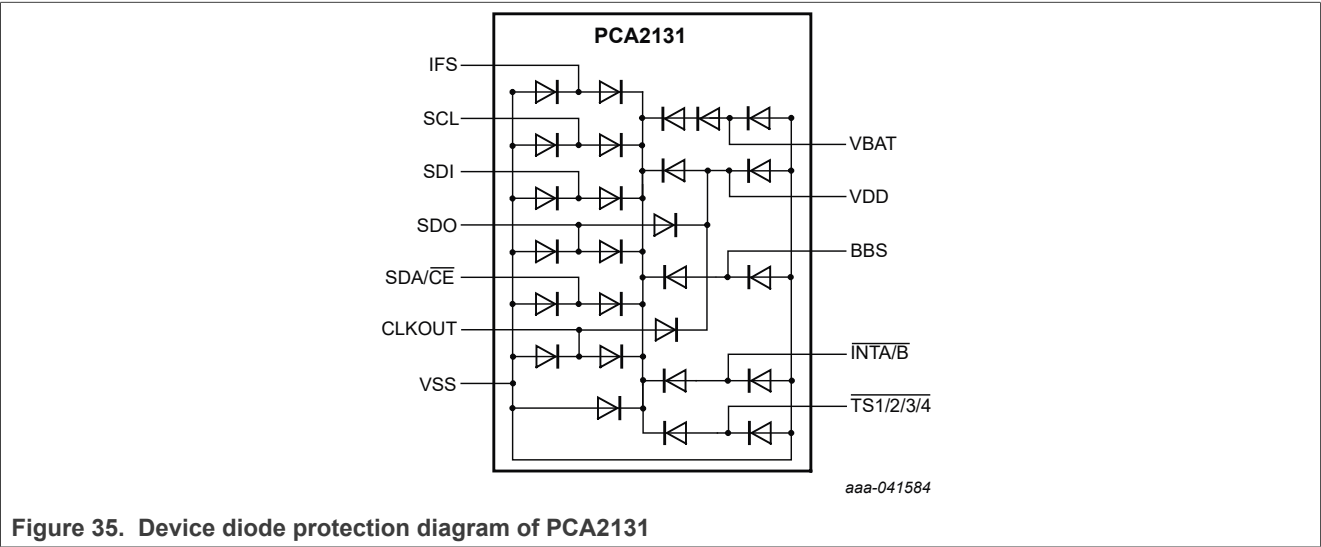
7.16.3 Bus communication and battery backup operation

To save power during battery backup operation (see [Section 7.5.1](#)), the bus interfaces are inactive. Therefore the communication via I²C- or SPI-bus should be terminated before the supply of the PCA2131 is switched from V_{DD} to V_{BAT}.

With I2C interface, PCA2131 will terminate transaction before switching from V_{DD} to V_{BAT}, with SPI interface, PCA2131 will corrupt SPI write and read data when battery switchover occurs.

Remark: If the I²C-bus communication was terminated uncontrolled, the I²C-bus has to be reinitialized by sending a STOP followed by a START after the device switched back from battery backup operation to V_{DD} supply operation.

7.17 Internal circuitry



7.18 Safety notes

CAUTION



This device is sensitive to ElectroStatic Discharge (ESD). Observe precautions for handling electrostatic sensitive devices.

Such precautions are described in the *ANSI/ESD S20.20*, *IEC/ST 61340-5*, *JESD625-A* or equivalent standards.

8 Limiting values

Table 88. Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134).

| Symbol | Parameter | Conditions | | Min | Max | Unit |
|------------------|---------------------------------|------------------|-----|------|--------|------|
| V _{DD} | supply voltage | | | -0.5 | +6.5 | V |
| I _{DD} | supply current | | | -50 | +50 | mA |
| V _i | input voltage | | | -0.5 | +6.5 | V |
| I _I | input current | | | -10 | +10 | mA |
| V _O | output voltage | | | -0.5 | +6.5 | V |
| I _O | output current | | | -10 | +10 | mA |
| | | at pin SDA/CE | | -10 | +20 | mA |
| V _{BAT} | battery supply voltage | | | -0.5 | +6.5 | V |
| P _{tot} | total power dissipation | | | - | 300 | mW |
| V _{ESD} | electrostatic discharge voltage | HBM | [1] | - | ±2 000 | V |
| | | CDM | [2] | - | ±500 | V |
| I _{Iu} | latch-up current | | [3] | - | 1 00 | mA |
| T _{stg} | storage temperature | | [4] | -55 | +125 | °C |
| T _{amb} | ambient temperature | operating device | | -40 | +125 | °C |

[1] Pass level; Human Body Model (HBM) according to AEC Q100-002.

[2] Pass level (750 V for corner pins); Charged-Device Model (CDM), according to AEC Q100-011.

[3] Pass level; latch-up testing according to AEC Q100-004 at maximum ambient temperature (T_{amb(max)}).

[4] According to the store and transport requirements (see [4]) the devices have to be stored at a temperature of +8 °C to +45 °C and a humidity of 25 % to 75 %.

Note: The PCA2131 part is not guaranteed (nor characterized) above the operating range as denoted in the data sheet. NXP recommends not to bias the PCA2131 device during reflow (e.g. if utilizing a 'coin' type battery in the assembly). If customer so chooses to use this assembly method, there must be the allowance for a full \Q0 V' level Power supply \Qreset' to re-enable the device. Without a proper POR, the device may remain in an indeterminate state.

9 Static characteristics

Table 89. Static characteristics

$V_{DD} = 1.2\text{ V to }5.5\text{ V}$; $V_{SS} = 0\text{ V}$; $T_{amb} = -40\text{ °C to }+105\text{ °C}$, unless otherwise specified.

| Symbol | Parameter | Conditions | | Min | Typ | Max 85 °C | Max 105 °C | Unit |
|--------------------------------|--|---|-----|-----|------|--------------|---------------|------|
| Supplies | | | | | | | | |
| V_{DD} | supply voltage | | [1] | 1.2 | - | | 5.5 | V |
| V_{BAT} | battery supply voltage | | | 1.2 | - | | 5.5 | V |
| V_{low} | low voltage | | | - | 1.15 | - | - | V |
| I_{DD} supply current [2] | interface active; supplied by V_{DD} | | | | | | | |
| | | SPI-bus ($f_{SCL} = 6.5\text{ MHz}$) | | - | - | 800 | 800 | μA |
| | | I ² C-bus ($f_{SCL} = 400\text{ kHz}$) | | - | - | 200 | 200 | μA |
| | interface inactive ($f_{SCL} = 0\text{ Hz}$) [3]; TCR[1:0] = 00 (see Table 16) | | | | | | | |
| | PWRMNG[2:0] = 111 (see Table 22); COF[2:0] = 111 (see Table 18) TC_DIS = 1 (see Table 5); 100TH_S_DIS = 1 (see Table 5) | | | | | | | |
| | $V_{DD} = 1.2\text{ V}$ | | | - | 93 | 420 | 735 | nA |
| | $V_{DD} = 3.3\text{ V}$ | | | - | 106 | 365 [4] | 655 | nA |
| | $V_{DD} = 5.5\text{ V}$ | | | - | 137 | 465 | 850 | nA |
| | PWRMNG[2:0] = 111 (see Table 22); COF[2:0] = 111 (see Table 18) TC_DIS = 0 (see Table 5); 100TH_S_DIS = 1 (see Table 5) | | | | | | | |
| | $V_{DD} = 1.2\text{ V}$ | | | - | 98 | 520 | 925 | nA |
| | $V_{DD} = 3.3\text{ V}$ | | | - | 112 | 500 | 855 | nA |
| | $V_{DD} = 5.5\text{ V}$ | | | - | 141 | 600 | 1080 | nA |
| | PWRMNG[2:0] = 111 (see Table 22); COF[2:0] = 000 (see Table 18) TC_DIS = 0 (see Table 5); 100TH_S_DIS = 0 (see Table 5); | | | | | | | |
| | $V_{DD} = 1.2\text{ V}$ | | [5] | - | 460 | 770 | 1325 | nA |
| | $V_{DD} = 3.3\text{ V}$ | | [6] | - | 1075 | 1435 | 1925 | nA |
| | $V_{DD} = 5.5\text{ V}$ | | [6] | - | 1735 | 2210 | 2835 | nA |
| | PWRMNG[2:0] = 000 (see Table 22); COF[2:0] = 111 (see Table 18) TC_DIS = 0 (see Table 5); 100TH_S_DIS = 0 (see Table 5) | | | | | | | |

Table 89. Static characteristics...continued

$V_{DD} = 1.2\text{ V to }5.5\text{ V}$; $V_{SS} = 0\text{ V}$; $T_{amb} = -40\text{ °C to }+105\text{ °C}$, unless otherwise specified.

| Symbol | Parameter | Conditions | | Min | Typ | Max 85 °C | Max 105 °C | Unit |
|--------------------------------|----------------------------------|--|-----|------|------|--------------|----------------|------|
| | | $V_{DD} = 1.8\text{ V}$, $V_{BAT} = 1.5\text{ V}$ | | - | 113 | 550 | 1220 | nA |
| | | $V_{DD} = 3.3\text{ V}$, $V_{BAT} = 3.3\text{ V}$ | | - | 133 | 550 | 920 | nA |
| | | $V_{DD} = 5.5\text{ V}$, $V_{BAT} = 3.3\text{ V}$ | | - | 169 | 650 | 1290 | nA |
| | | $V_{BAT} = 1.2\text{ V}$, I_{BAT} | [7] | - | 112 | 580 | 970 | nA |
| | | $V_{BAT} = 3.3\text{ V}$, I_{BAT} | [7] | - | 125 | 530 | 830 | nA |
| | | $V_{BAT} = 5.5\text{ V}$, I_{BAT} | [7] | - | 154 | 680 | 1130 | nA |
| I_{DD} supply current [2] | | PWRMNG[2:0] = 000 (see Table 22); COF[2:0] = 000 (see Table 18) TC_DIS = 0 (see Table 5); 100TH_S_DIS = 0 (see Table 5) | | | | | | |
| | | $V_{DD} = 1.8\text{ V}$, $V_{BAT} = 1.5\text{ V}$ | [5] | - | 650 | 965 | 1495 | nA |
| | | $V_{DD} = 3.3\text{ V}$, $V_{BAT} = 3.3\text{ V}$ | [5] | - | 1100 | 1450 | 1970 | nA |
| | | $V_{DD} = 5.5\text{ V}$, $V_{BAT} = 3.3\text{ V}$ | [5] | - | 1770 | 2260 | 2890 | nA |
| | | $V_{BAT} = 1.2\text{ V}$, I_{BAT} | [7] | - | 130 | 395 | 905 | nA |
| | | $V_{BAT} = 3.3\text{ V}$, I_{BAT} | [7] | - | 185 | 435 | 880 | nA |
| | | $V_{BAT} = 5.5\text{ V}$, I_{BAT} | [7] | - | 280 | 580 | 1135 | nA |
| $I_{L(bat)}$ | battery leakage current | V_{DD} is active supply; $V_{BAT} = 3.0\text{ V}$ | | - | 0.1 | - | - | nA |
| Power management | | | | | | | | |
| $V_{th(sw)bat}$ | battery switch threshold voltage | | | 2.3 | 2.5 | | 2.7 | V |
| $V_{th(bat)low}$ | low battery threshold voltage | | | 2.3 | 2.5 | | 2.7 | V |
| Inputs [8] | | | | | | | | |
| V_I | input voltage | | | -0.5 | - | - | $V_{DD} + 0.5$ | V |
| V_{IL} | LOW-level input voltage | | | - | - | - | $0.25V_{DD}$ | V |
| | | $T_{amb} = -40\text{ °C to }+85\text{ °C}$; $V_{DD} > 2.0\text{ V}$ | | - | - | - | $0.3V_{DD}$ | V |

Nano-power highly accurate RTC with integrated quartz crystal for automotive applications

Table 89. Static characteristics...continued

 $V_{DD} = 1.2\text{ V to }5.5\text{ V}$; $V_{SS} = 0\text{ V}$; $T_{amb} = -40\text{ °C to }+105\text{ °C}$, unless otherwise specified.

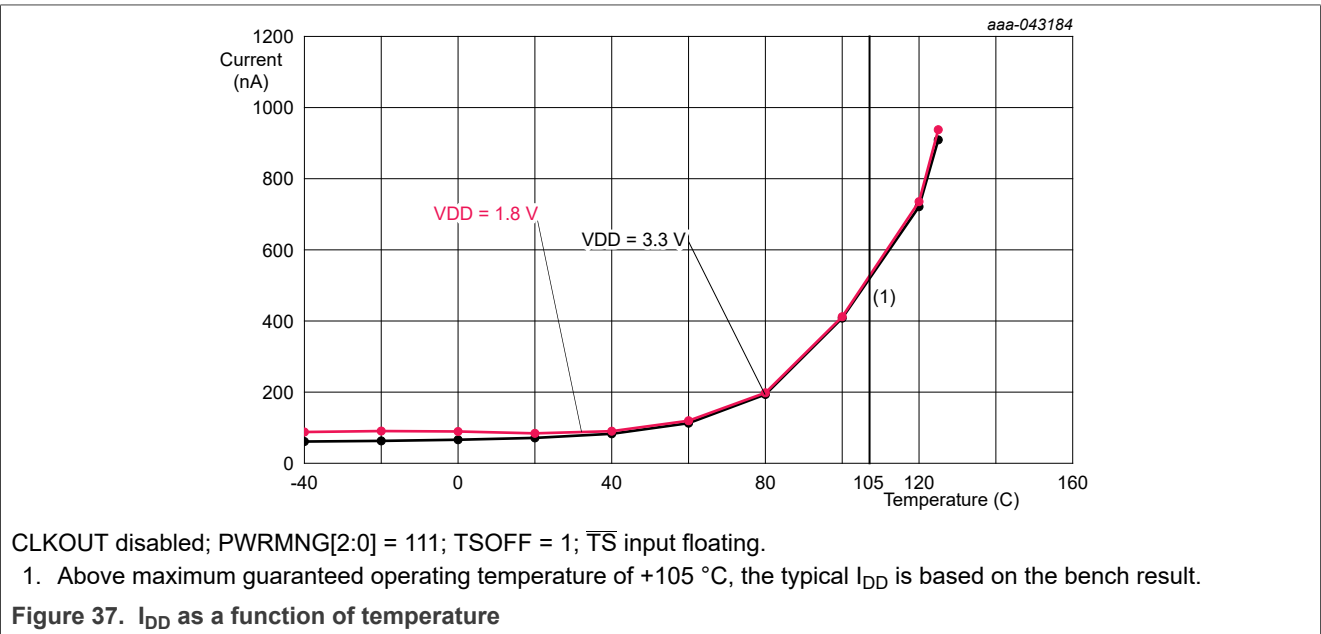
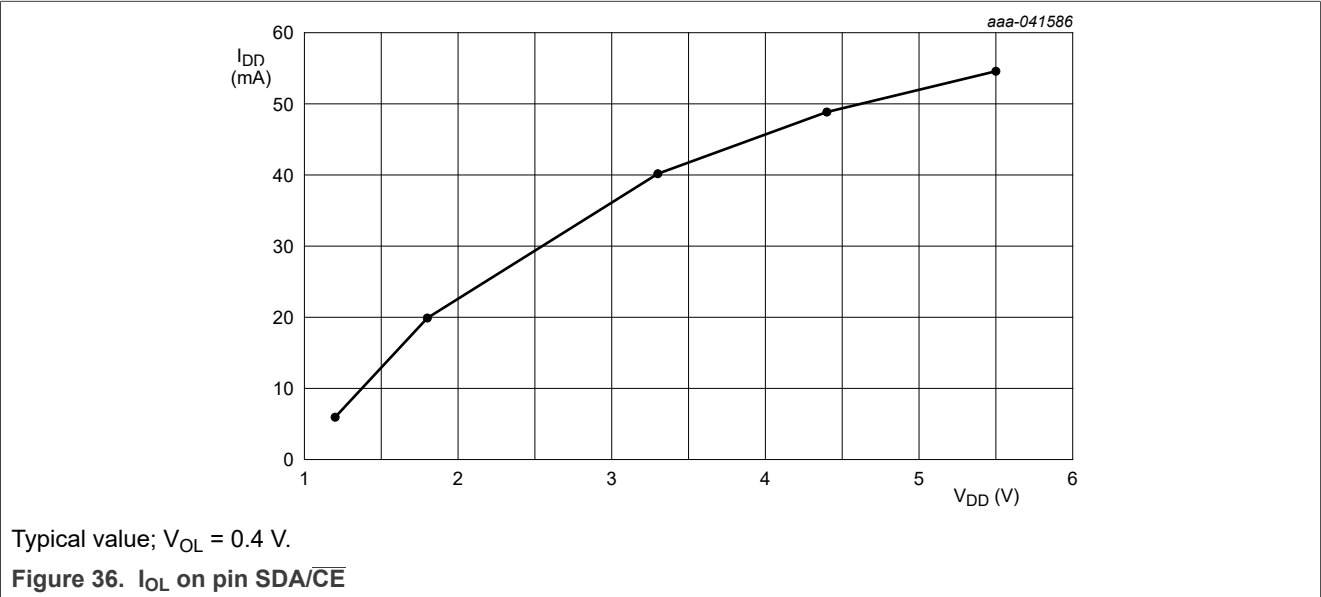
| Symbol | Parameter | Conditions | | Min | Typ | Max 85 °C | Max 105 °C | Unit |
|----------------|---------------------------|---|------|-------------|-----|--------------|---------------|---------------|
| V_{IH} | HIGH-level input voltage | | | $0.7V_{DD}$ | - | - | - | V |
| I_{LI} | input leakage current | $V_I = V_{DD}$ or V_{SS} | | - | 0 | - | - | μA |
| | | post ESD event | | -1 | - | - | +1 | μA |
| C_i | input capacitance | | [9] | - | - | - | 7 | pF |
| Outputs | | | | | | | | |
| V_O | output voltage | on pins $\overline{\text{INTA}}/\overline{\text{B}}$, referring to external pull-up | | -0.5 | - | - | 5.5 | V |
| | | on pin BBS | [10] | 1.2 | - | - | 5.5 | V |
| V_{OH} | HIGH output voltage | on pin SDO, CLKOUT at 1 mA source current | | $0.8V_{DD}$ | - | - | V_{DD} | V |
| V_{OL} | LOW output voltage | on pins CLKOUT, $\overline{\text{INTA}}/\overline{\text{B}}$ and SDO at 1 mA sink current | | V_{SS} | - | - | $0.2V_{DD}$ | V |
| | | on pin SDA, $V_{DD} > 2.0\text{ V}$, 3 mA sink current | | - | - | - | 0.4 | V |
| | | on pin SDA, $V_{DD} < 2.0\text{ V}$, 2 mA sink current | | - | - | - | $0.2V_{DD}$ | V |
| I_{OL} | LOW-level output current | output sink current; $V_{OL} = 0.4\text{ V}$ | | | | | | |
| | | on pin SDA/ $\overline{\text{CE}}$ | [11] | 3 | - | - | - | mA |
| | | on all other outputs | | 1.0 | - | - | - | mA |
| I_{OH} | HIGH-level output current | output source current; on pin SDO, CLKOUT; $V_{OH} = 0.8 * V_{DD}$ | | 1.0 | - | - | - | mA |
| I_{LO} | output leakage current | $V_O = V_{DD}$ or V_{SS} | | - | 0 | - | - | μA |
| | | post ESD event | | -1 | - | - | +1 | μA |

[1] For reliable oscillator start-up and OTP refresh at power-on: V_{DD} needs to be above 1.8 V.[2] MAX I_{DD} and I_{BAT} determined by characterization.[3] Timer source clock = $\frac{1}{60}$ Hz, level of pins SDA/ $\overline{\text{CE}}$, SDI, and SCL is V_{DD} or V_{SS} .[4] Production tested I_{DD} parameter.[5] Any load in the application driven by CLKOUT adds to this value, e.g. 10 pF, $V_{DD} = 3\text{ V}$ will add $32768\text{ Hz} * 10\text{ pF} * 3.3\text{ V} = 1.1\text{ }\mu\text{A}$.[6] Any load in the application driven by CLKOUT adds to this value, e.g. 10 pF, $V_{DD} = 3\text{ V}$ will add $32768\text{ Hz} * 10\text{ pF} * 3.3\text{ V} = 1.1\text{ }\mu\text{A}$.[7] When the device is supplied by the V_{BAT} pin instead of the V_{DD} pin, $V_{DD} = 0\text{ V}$. The device can only start up from V_{DD} .[8] The I²C-bus and SPI-bus interfaces of PCA2131 are 5 V tolerant.

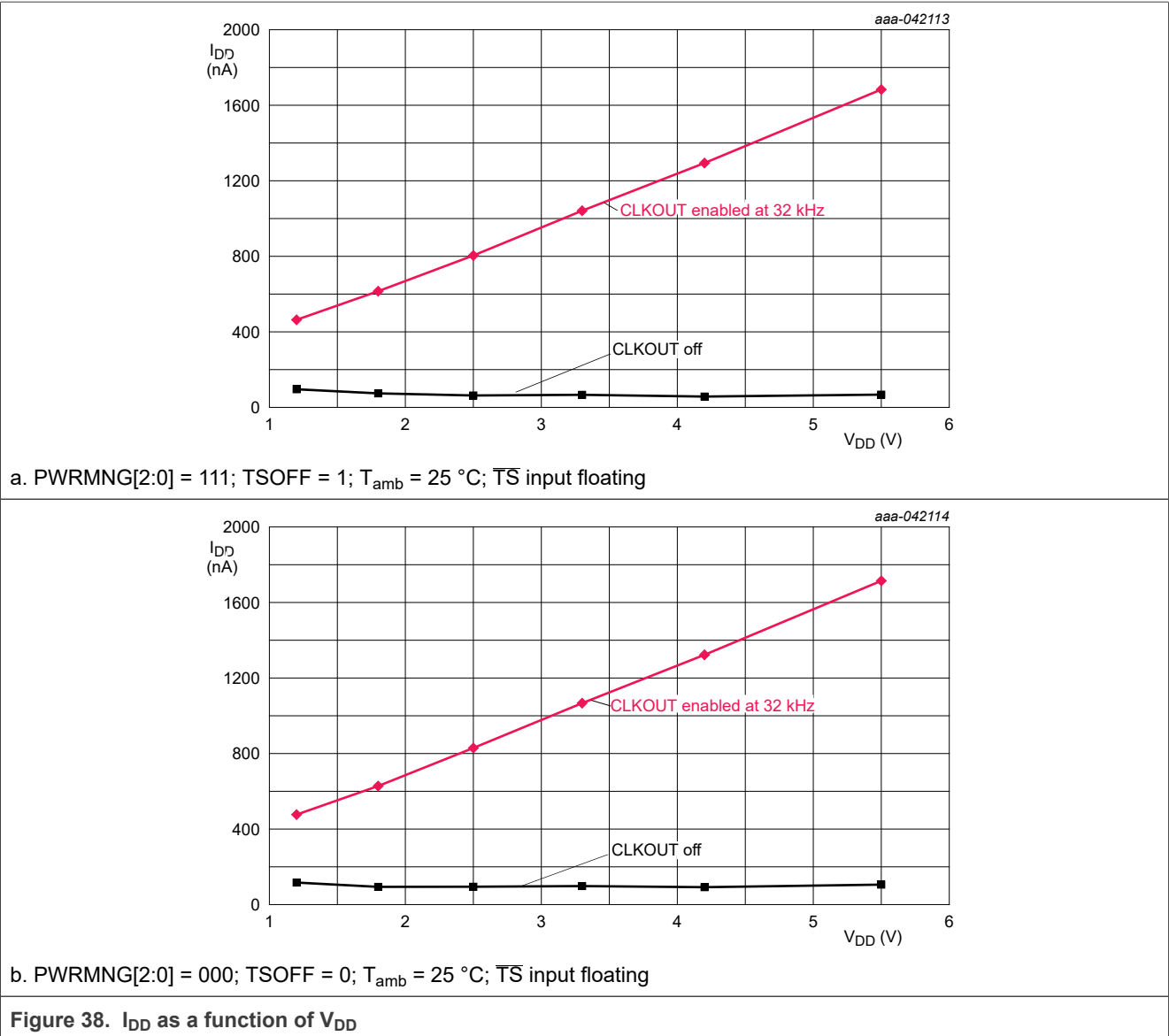
[9] Tested on sample basis.

[10] Pin BBS is internally connected to either V_{DD} or V_{BAT} , see section [Section 7.5.3](#).[11] For further information, see [Figure 36](#).

9.1 Current consumption characteristics, typical



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9.2 Frequency characteristics

Table 90. Frequency characteristics
V_{DD} = 1.2 V to 5.5 V; V_{SS} = 0 V; T_{amb} = +25 °C, unless otherwise specified.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|----------------|------------------|--|--------------|--------|-----|------|
| f _o | output frequency | on pin CLKOUT; V _{DD} = 3.3 V; COF[2:0] = 000; AO[3:0] = 1000 | - | 32.768 | - | kHz |
| Δf/f | time accuracy | V _{DD} or V _{BAT} = 3.3 V, T _{amb} = -40 °C to +85 °C | | | | |
| | | TC_DIS = 0 | [1] [2] -8 | ±3 | +8 | ppm |
| | | TC_DIS = 1 | [1] [2] -200 | | +4 | ppm |

Nano-power highly accurate RTC with integrated quartz crystal for automotive applications

Table 90. Frequency characteristics...continued

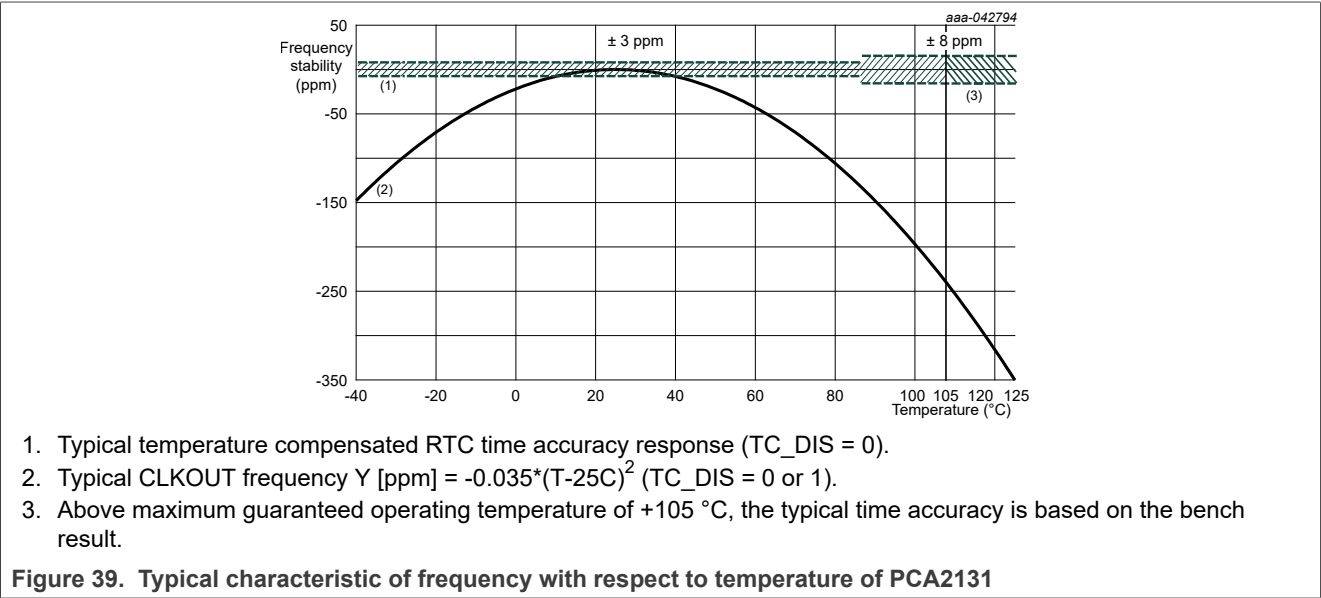
$V_{DD} = 1.2\text{ V to }5.5\text{ V}$; $V_{SS} = 0\text{ V}$; $T_{amb} = +25\text{ }^{\circ}\text{C}$, unless otherwise specified.

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|----------------------------|--------------------------------------|--|---------|------|-----|-----|-------|
| | | V_{DD} or $V_{BAT} = 3.3\text{ V}$, $T_{amb} = +85\text{ }^{\circ}\text{C to }+105\text{ }^{\circ}\text{C}$ | | | | | |
| | | TC_DIS = 0 | [1] [2] | -15 | ±8 | +15 | ppm |
| | | TC_DIS = 1 | [1] [2] | -320 | | -50 | ppm |
| | | TC_DIS = 1, $T_{amb} = 25\text{ }^{\circ}\text{C}$ | [1] [2] | -3 | | +3 | ppm |
| $\Delta f_{xtal}/f_{xtal}$ | relative crystal frequency variation | crystal aging | | | | | |
| | | PCA2131 | | | | | |
| | | first year; V_{DD} or $V_{BAT} = 3.3\text{ V}$ | [3] | -3 | - | +3 | ppm |
| $\Delta f/\Delta V$ | frequency variation with voltage | on pin CLKOUT | | - | ±1 | - | ppm/V |
| Jitter | Output clock peak to peak jitter | on pin CLKOUT | | - | 50 | - | ns |

[1] ±1 ppm corresponds to a time deviation of ±0.0864 seconds per day.

[2] Only valid if CLKOUT frequencies are not equal to 32.768 kHz or if CLKOUT is disabled.

[3] Not production tested. Effects of reflow soldering are included (see application note AN13203).



10 Dynamic characteristics

10.1 SPI-bus timing characteristics

Table 91. SPI-bus characteristics

$V_{DD} = 1.2\text{ V to }5.5\text{ V}$; $V_{SS} = 0\text{ V}$; $T_{amb} = -40\text{ °C to }+105\text{ °C}$, unless otherwise specified. All timing values are valid within the operating supply voltage at ambient temperature and referenced to V_{IL} and V_{IH} with an input voltage swing of V_{SS} to V_{DD} (see [Figure 40](#)).

| Symbol | Parameter | Conditions | | V _{DD} = 1.2 V to 3.3 V | | V _{DD} = 3.3 V to 5.5 V | | Unit |
|------------------------|---------------------|--------------------------|-----|----------------------------------|------|----------------------------------|------|------|
| | | | | Min | Max | Min | Max | |
| Pin SCL | | | | | | | | |
| f _{clk(SCL)} | SCL clock frequency | | | - | 0.5 | - | 6.5 | MHz |
| t _{clk(H)} | clock HIGH time | | | 1000 | - | 70 | - | ns |
| t _{clk(L)} | clock LOW time | | | 1000 | - | 70 | - | ns |
| t _r | rise time | for SCL signal | | - | 100 | - | 100 | ns |
| t _f | fall time | for SCL signal | | - | 100 | - | 100 | ns |
| Pin SDA/CE | | | | | | | | |
| t _{su(CE_N)} | CE_N set-up time | | | 300 | - | 30 | - | ns |
| t _{h(CE_N)} | CE_N hold time | | | 325 | - | 25 | - | ns |
| t _{rec(CE_N)} | CE_N recovery time | | | 1500 | - | 1500 | - | ns |
| t _{w(CE_N)} | CE_N pulse width | | | - | 0.99 | - | 0.99 | s |
| Pin SDI | | | | | | | | |
| t _{su} | set-up time | set-up time for SDI data | | 250 | - | 20 | - | ns |
| t _h | hold time | hold time for SDI data | | 250 | - | 20 | - | ns |
| Pin SDO | | | | | | | | |
| t _{d(R)SDO} | SDO read delay time | C _L = 50 pF | | - | 550 | - | 55 | ns |
| t _{dis(SDO)} | SDO disable time | | [1] | - | 150 | - | 25 | ns |

[1] No load value; bus is held up by bus capacitance; use RC time constant with application values.

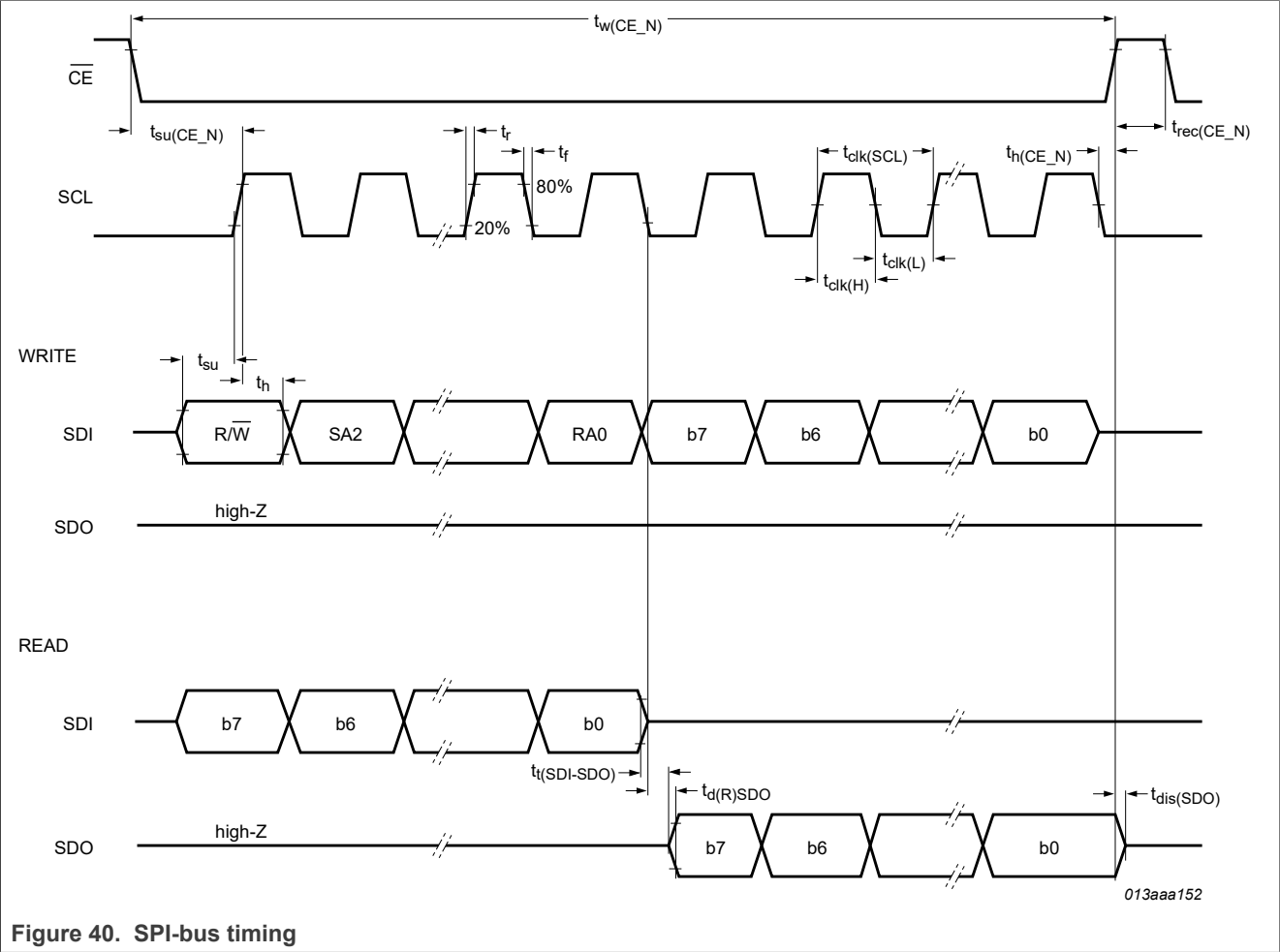


Figure 40. SPI-bus timing

10.2 I²C-bus timing characteristics

Table 92. I²C-bus characteristics

All timing characteristics are valid within the operating supply voltage and ambient temperature range and reference to 30 % and 70 % with an input voltage swing of V_{SS} to V_{DD} (see [Figure 41](#)).

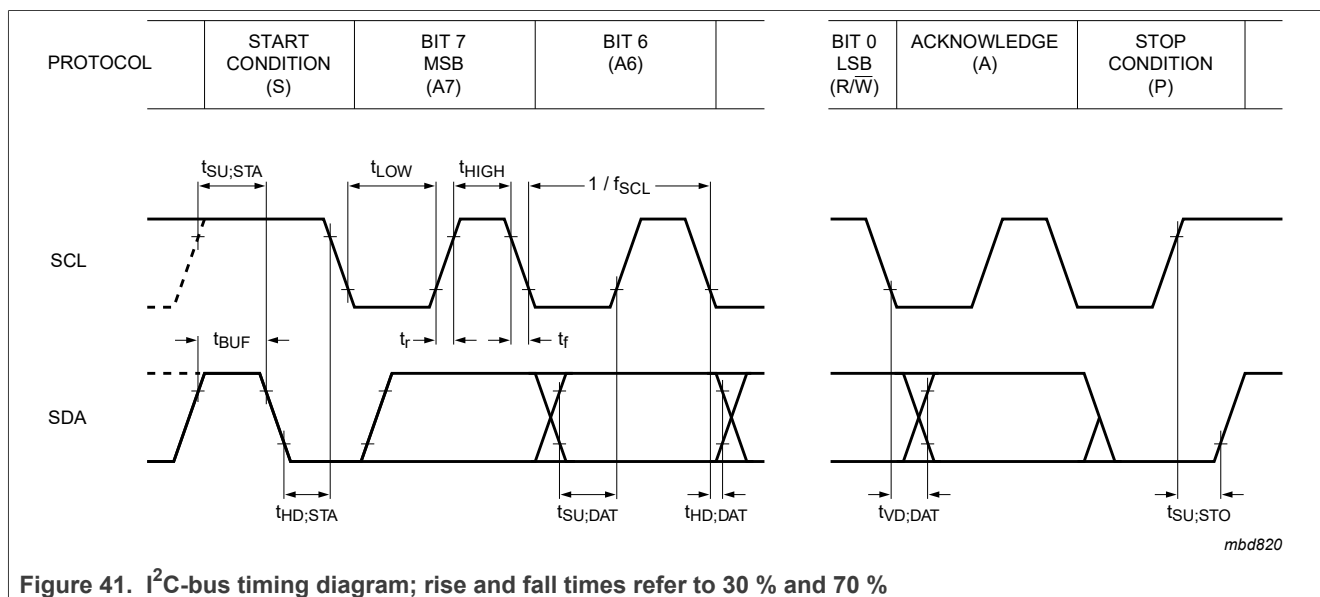
| Symbol | Parameter | | Standard mode | | Fast-mode (Fm) | | Unit |
|---------------------|--|-----|---------------|-----|----------------|-----|------|
| | | | Min | Max | Min | Max | |
| Pin SCL | | | | | | | |
| f _{SCL} | SCL clock frequency | [1] | 10 | 100 | 10 | 400 | kHz |
| t _{LOW} | LOW period of the SCL clock | | 4.7 | - | 1.3 | - | µs |
| t _{HIGH} | HIGH period of the SCL clock | | 4.0 | - | 0.6 | - | µs |
| Pin SDA/CE | | | | | | | |
| t _{SU;DAT} | data set-up time | | 250 | - | 100 | - | ns |
| t _{HD;DAT} | data hold time | | 0 | - | 0 | - | ns |
| Pins SCL and SDA/CE | | | | | | | |
| t _{BUF} | bus free time between a STOP and START condition | | 4.7 | - | 1.5 | - | µs |

Table 92. I²C-bus characteristics...continued

All timing characteristics are valid within the operating supply voltage and ambient temperature range and reference to 30 % and 70 % with an input voltage swing of V_{SS} to V_{DD} (see [Figure 41](#)).

| Symbol | Parameter | | Standard mode | | Fast-mode (Fm) | | Unit |
|--------------|---|-----------|---------------|-------|----------------|-----|---------|
| | | | Min | Max | Min | Max | |
| $t_{SU;STO}$ | set-up time for STOP condition | | 4.0 | - | 0.6 | - | μs |
| $t_{HD;STA}$ | hold time (repeated) START condition | | 4.0 | - | 0.6 | - | μs |
| $t_{SU;STA}$ | set-up time for a repeated START condition | | 4.7 | - | 0.6 | - | μs |
| t_r | rise time of both SDA and SCL signals | [2][3][4] | - | 1 000 | $20 + 0.1C_b$ | 300 | ns |
| t_f | fall time of both SDA and SCL signals | [2][3][4] | - | 300 | $20 + 0.1C_b$ | 300 | ns |
| $t_{VD;ACK}$ | data valid acknowledge time | [5] | - | 3.45 | - | 0.9 | μs |
| $t_{VD;DAT}$ | data valid time | [6] | - | 3.45 | - | 0.9 | μs |
| t_{SP} | pulse width of spikes that must be suppressed by the input filter | [7] | - | 50 | - | 50 | ns |

- [1] The minimum SCL clock frequency is limited by the bus time-out feature which resets the serial bus interface if either the SDA or SCL is held LOW for a minimum of 25 ms. The bus time-out feature must be disabled for DC operation.
- [2] A master device must internally provide a hold time of at least 300 ns for the SDA signal (refer to the V_{IL} of the SCL signal) in order to bridge the undefined region of the falling edge of SCL.
- [3] C_b is the total capacitance of one bus line in pF.
- [4] The maximum t_r for the SDA and SCL bus lines is 300 ns. The maximum fall time for the SDA output stage, t_f is 250 ns. This allows series protection resistors to be connected between the SDA/CE pin, the SCL pin, and the SDA/SCL bus lines without exceeding the maximum t_r .
- [5] $t_{VD;ACK}$ is the time of the acknowledgment signal from SCL LOW to SDA (out) LOW.
- [6] $t_{VD;DAT}$ is the minimum time for valid SDA (out) data following SCL LOW.
- [7] Input filters on the SDA and SCL inputs suppress noise spikes of less than 50 ns.



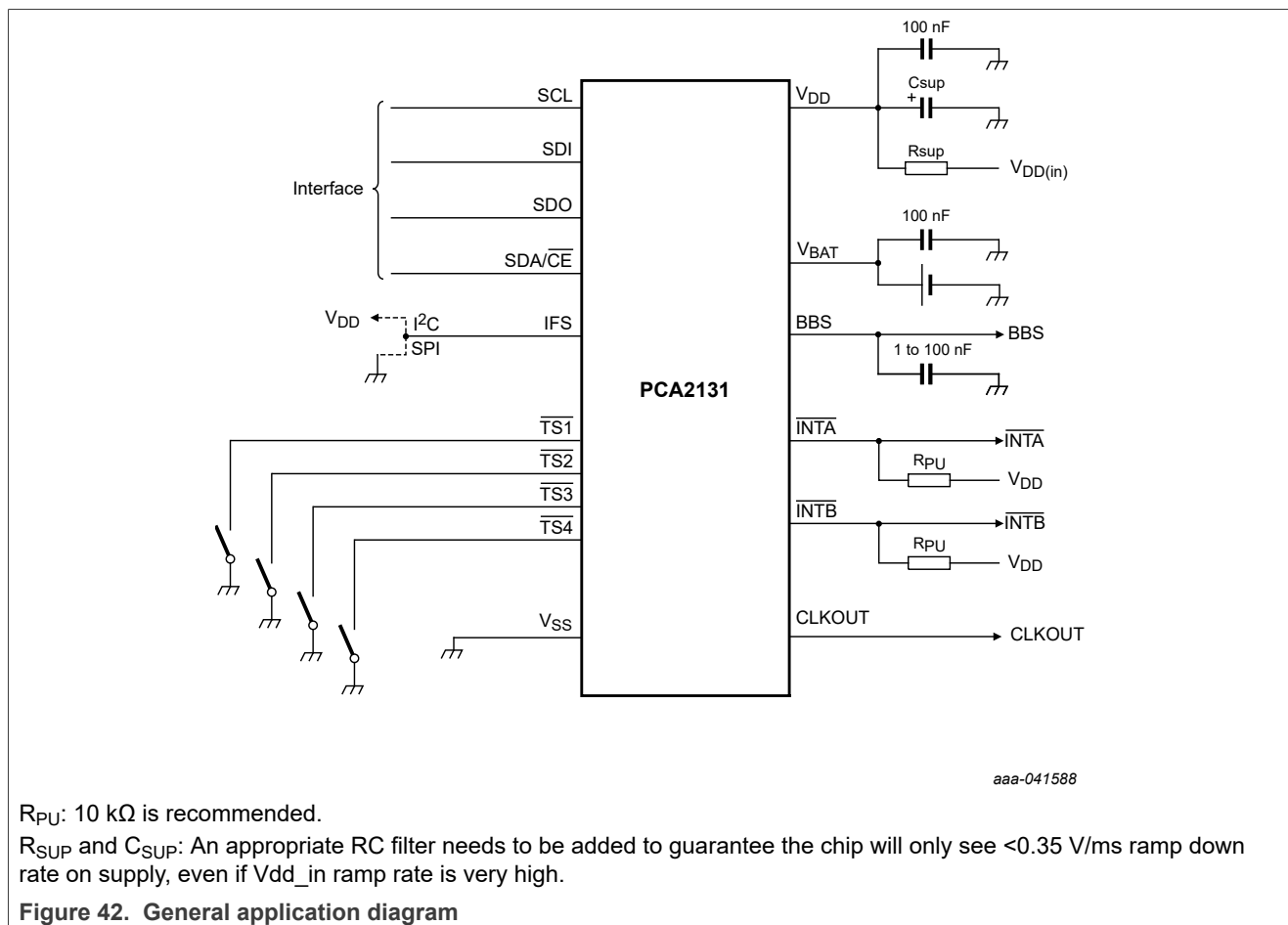
11 Application information

The PCA2131TF/Q900 is AEC-Q100 compliant for automotive applications. The operating temperature range is from $-40\text{ }^{\circ}\text{C}$ to $+105\text{ }^{\circ}\text{C}$ and the time accuracy with temperature compensation is:

- $\pm 3\text{ ppm}$ typical with $\pm 8\text{ ppm}$ min/max from $-40\text{ }^{\circ}\text{C}$ to $+85\text{ }^{\circ}\text{C}$
- $\pm 8\text{ ppm}$ typical with $\pm 15\text{ ppm}$ min/max from $+85\text{ }^{\circ}\text{C}$ to $+105\text{ }^{\circ}\text{C}$

Above the maximum guaranteed operating temperature of $+105\text{ }^{\circ}\text{C}$ to the maximum ambient temperature of $+125\text{ }^{\circ}\text{C}$ the PCA2131TF/Q900 TCXO, RTC and digital interfaces (I²C and SPI) functions continue to be operational with the supply current increasing proportionally to temperature (see [Figure 37](#) for the trend). The temperature compensation circuitry also continues to function and typical time accuracy of $\pm 8\text{ ppm}$ has been measured on the bench.

The general application diagram is shown in [Figure 42](#).



12 Package outline

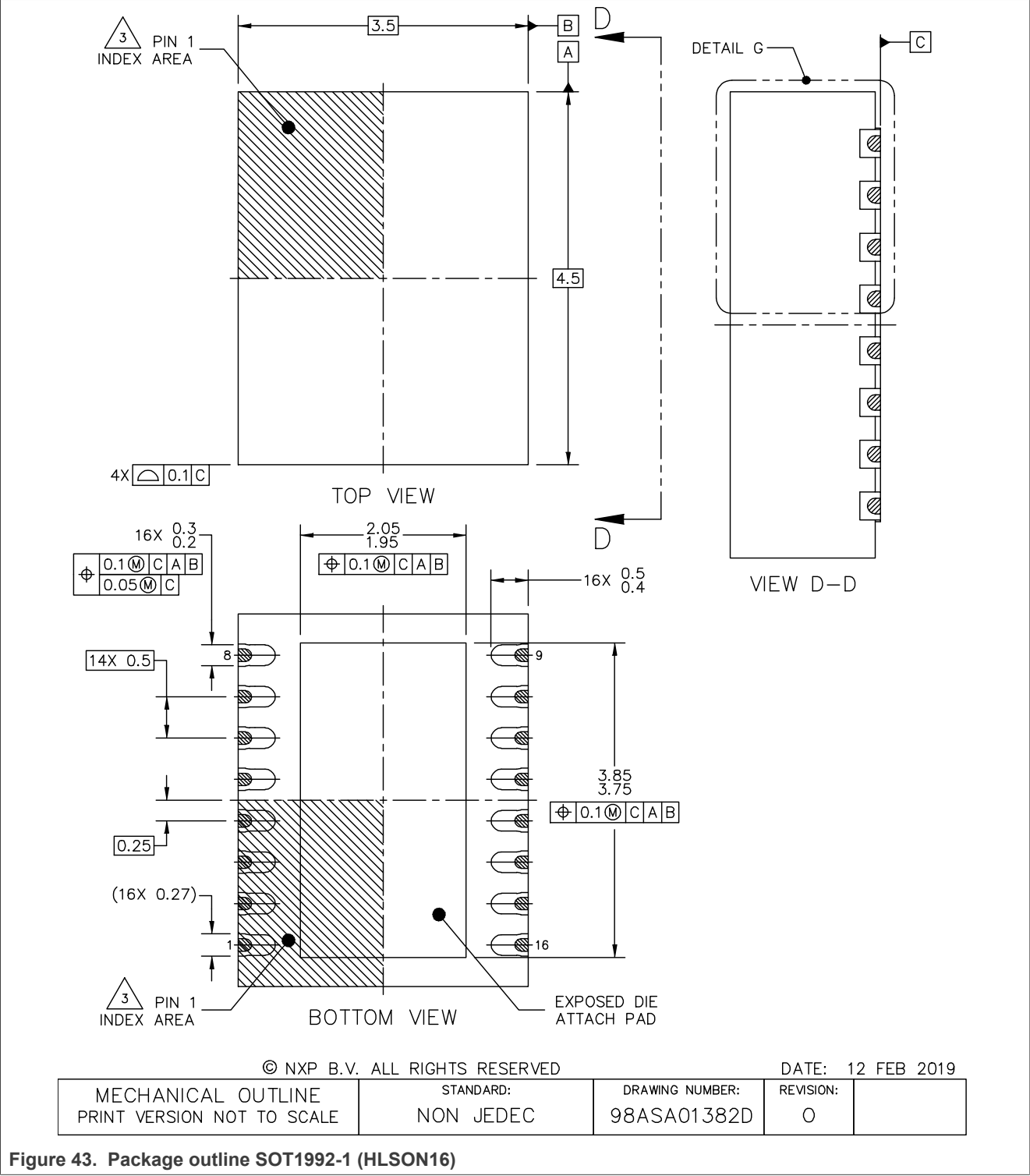
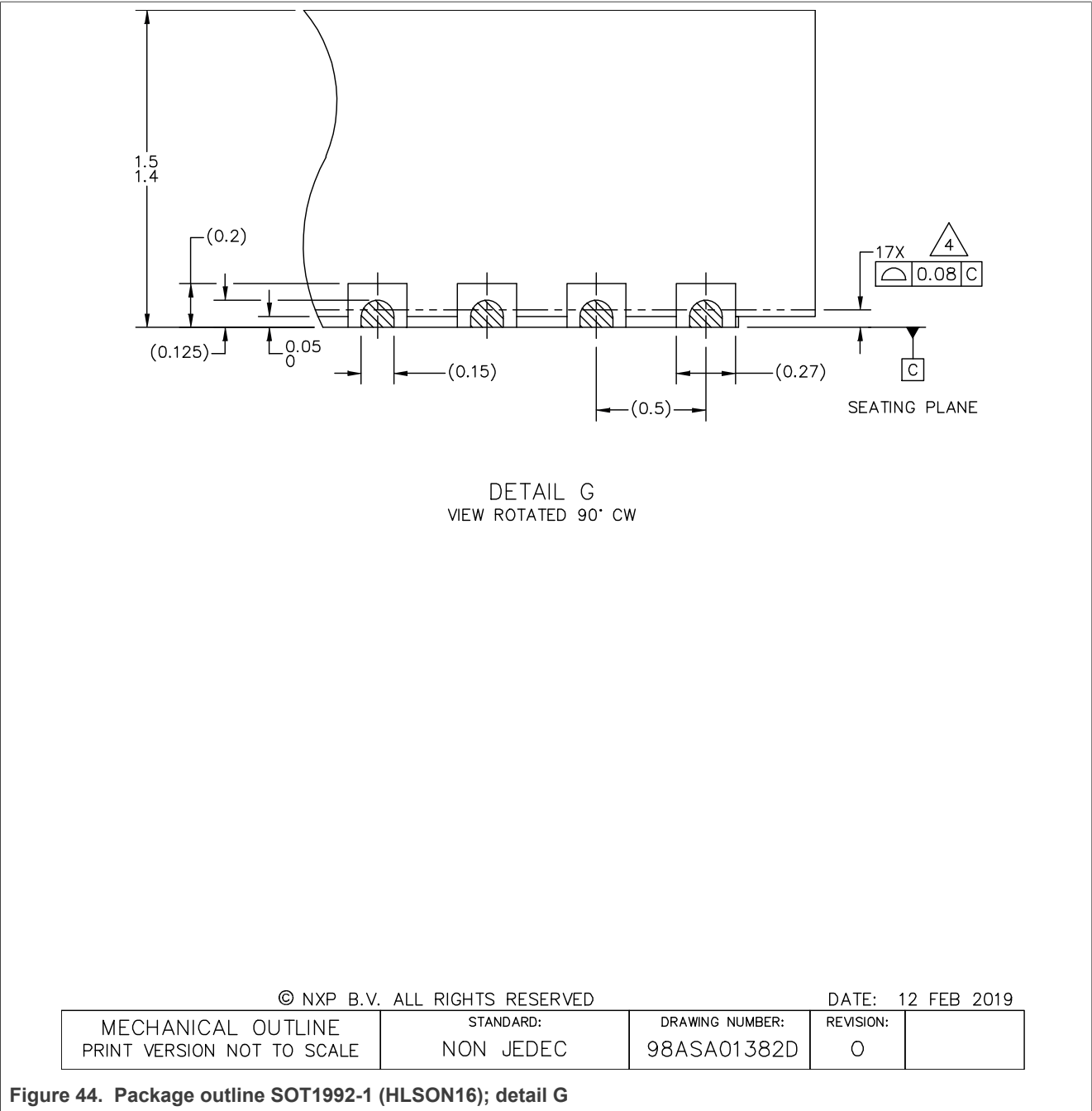


Figure 43. Package outline SOT1992-1 (HLSON16)



Nano-power highly accurate RTC with integrated quartz crystal for automotive applications

- NOTES:
- 1. ALL DIMENSIONS ARE IN MILLIMETERS.
 - 2. DIMENSIONING AND TOLERANCING PER ASME Y14.5M–1994.
 - 3. PIN 1 FEATURE SHAPE, SIZE AND LOCATION MAY VARY.
 - 4. COPLANARITY APPLIES TO LEADS.
 - 5. MIN. METAL GAP SHOULD BE 0.2 MM.

| | | | | |
|--|------------------------|--------------------------------|-------------------|--|
| © NXP B.V. ALL RIGHTS RESERVED | | | DATE: 12 FEB 2019 | |
| MECHANICAL OUTLINE PRINT VERSION NOT TO SCALE | STANDARD: NON JEDEC | DRAWING NUMBER: 98ASA01382D | REVISION: 0 | |

Figure 45. Package outline SOT1992-1 (HLSON16); notes

13 Packing information

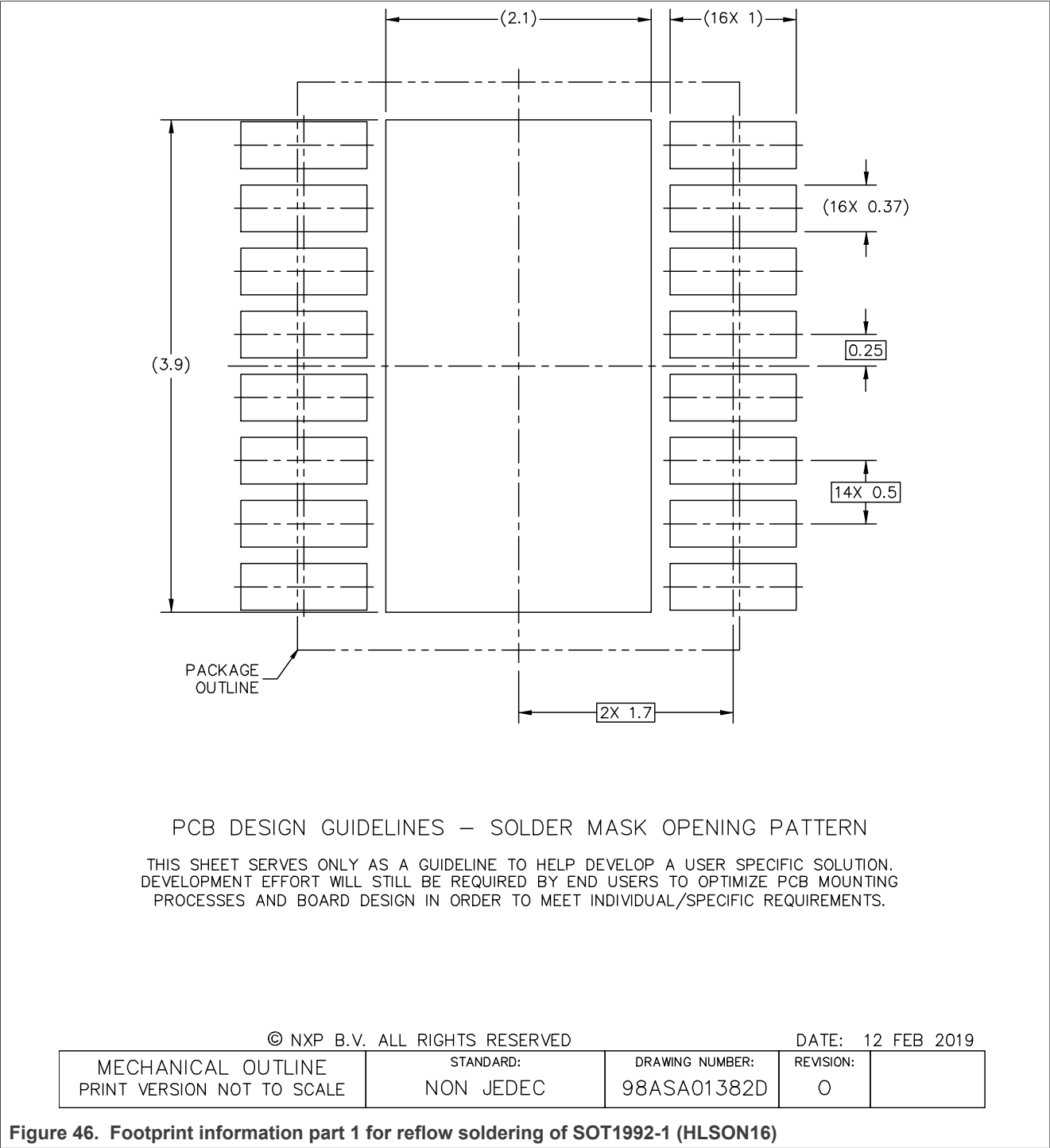
13.1 Tape and reel information

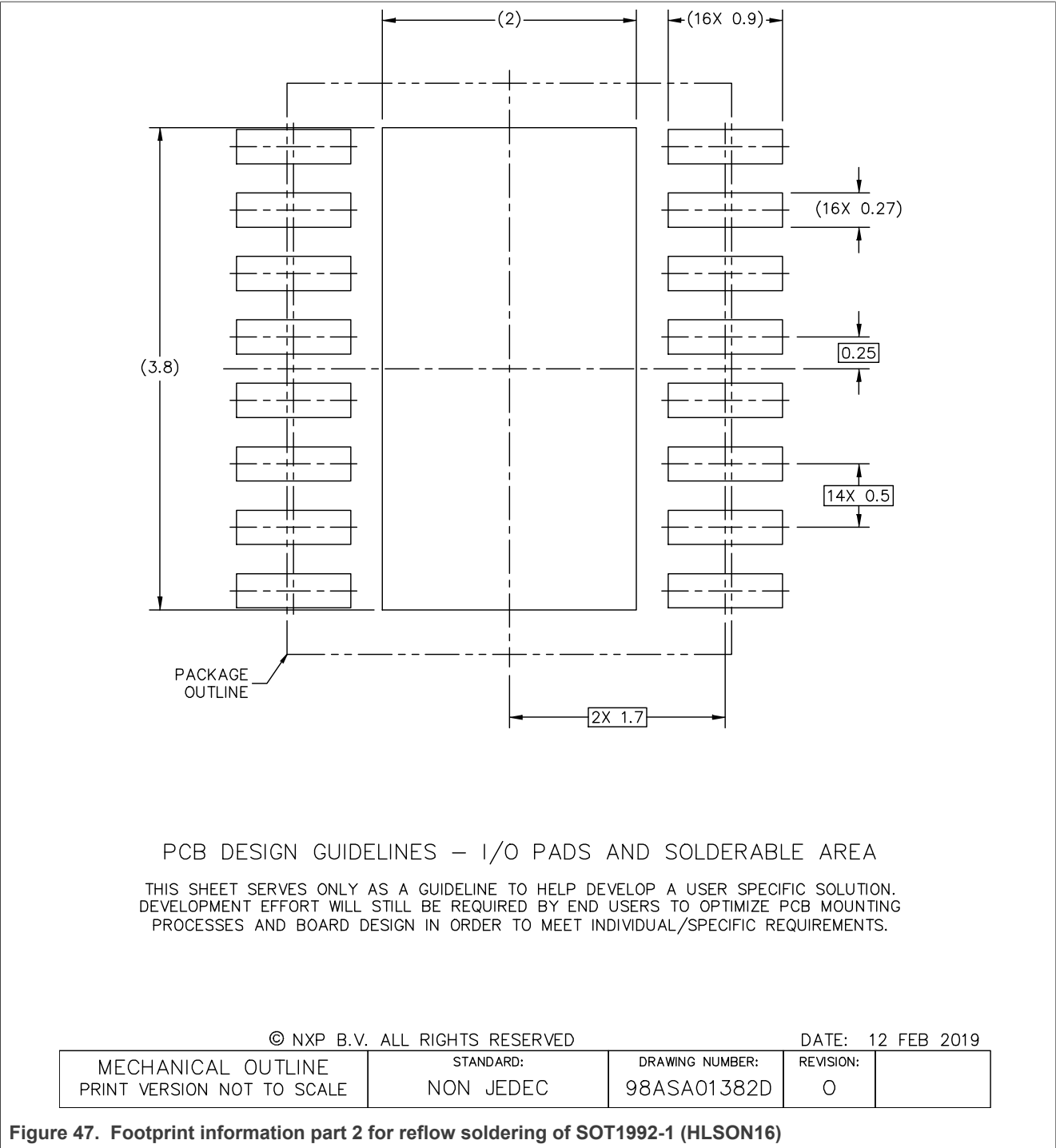
For tape and reel packing information, see [\[2\]](#)

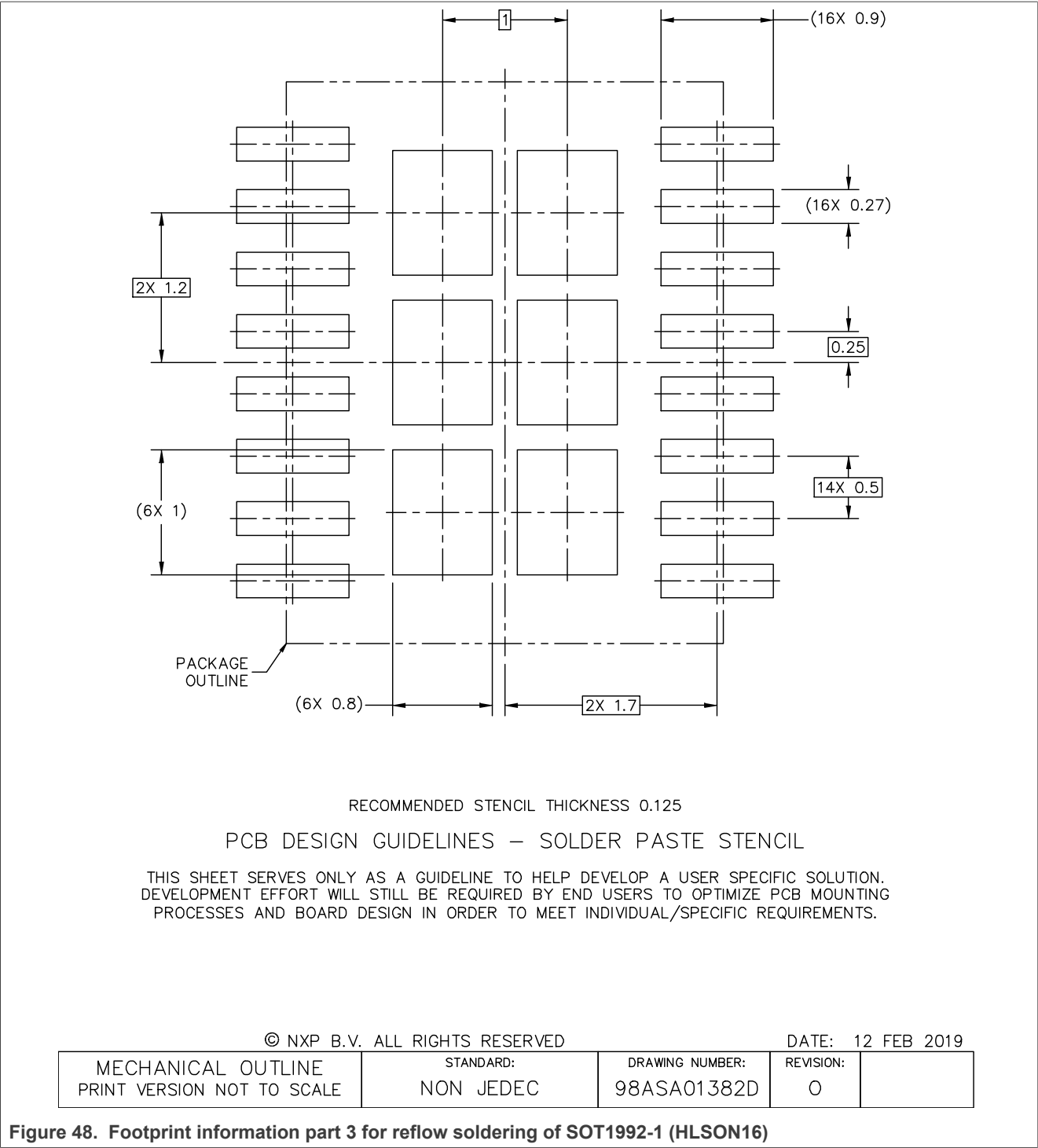
14 Soldering

For information about soldering, see [\[1\]](#).

14.1 Footprint information







15 Appendix

15.1 Real-time clock selection

Table 93. Selection of Real-Time Clocks

| Type name | Alarm, Timer, Watchdog | Interrupt output | Interface | I _{DD} , typical (nA) | Battery backup | Timestamp, tamper input | AEC-Q100 compliant | Special features | Packages |
|-----------|------------------------|------------------|------------------|--------------------------------|----------------|-------------------------|--------------------|---|---|
| PCF8563 | X | 1 | I ² C | 250 | - | - | - | - | SO8, TSSOP8, HVSON10 |
| PCF8564A | X | 1 | I ² C | 250 | - | - | - | integrated oscillator caps | WLCSP |
| PCA8565 | X | 1 | I ² C | 600 | - | - | segment B, grade 1 | high robustness, T _{amb} = -40 °C to 125 °C | TSSOP8, HVSON10 |
| PCA8565A | X | 1 | I ² C | 600 | - | - | - | integrated oscillator caps, T _{amb} = -40 °C to 125 °C | WLCSP |
| PCF85063 | - | 1 | I ² C | 220 | - | - | - | basic functions only, no alarm | HXSON8 |
| PCF85063A | X | 1 | I ² C | 220 | - | - | - | tiny package | SO8, DFN2626-10, TSSOP8 |
| PCF85063B | X | 1 | SPI | 220 | - | - | - | tiny package | DFN2626-10 |
| PCA85073A | X | 1 | I ² C | 220 | - | - | segment B, grade 2 | tiny package | TSSOP8 |
| PCF85263A | X | 2 | I ² C | 230 | X | 1 | - | time stamp, battery backup, stopwatch 1/100 s | SO8, TSSOP10, WLCSP12, TSSOP8, DFN2626-10 |
| PCF85363A | X | 2 | I ² C | 230 | X | 1 | - | time stamp, battery backup, stopwatch 1/100s, 64 Byte RAM | TSSOP10, DFN2626-10, TSSOP8 |
| PCF8523 | X | 2 | I ² C | 150 | X | - | - | lowest power 150 nA in operation, FM+ 1 MHz | SO8, HVSON8, TSSOP14, WLCSP |
| PCF2123 | X | 1 | SPI | 100 | - | - | - | lowest power 100 nA in operation | TSSOP14, HVQFN16, WLCSP12 |
| PCA21125 | X | 1 | SPI | 820 | - | - | segment B, grade 1 | high robustness, T _{amb} = -40 °C to 125 °C | TSSOP14 |

Nano-power highly accurate RTC with integrated quartz crystal for automotive applications

Table 93. Selection of Real-Time Clocks...continued

| Type name | Alarm, Timer, Watchdog | Interrupt output | Interface | I _{DD} , typical (nA) | Battery backup | Timestamp, tamper input | AEC-Q100 compliant | Special features | Packages |
|-----------|------------------------|------------------|--------------------------|--------------------------------|----------------|-------------------------|--------------------|---|------------------------------|
| PCF2131 | X | 2 | I ² C and SPI | 60 | X | 4 | - | temperature compensated, quartz built in, calibrated | HLSON16 with wettable flanks |
| PCA2131 | X | 2 | I ² C and SPI | 106 | X | 4 | segment B, grade 2 | temperature compensated, quartz built in, calibrated T _{amb} = -40 °C to 105 °C | HLSON16 with wettable flanks |

16 Abbreviations

Table 94. Abbreviations

| Acronym | Description |
|------------------|---|
| AM | Ante Meridiem |
| BCD | Binary Coded Decimal |
| CDM | Charged Device Model |
| CMOS | Complementary Metal-Oxide Semiconductor |
| DC | Direct Current |
| GPS | Global Positioning System |
| HBM | Human Body Model |
| I ² C | Inter-Integrated Circuit |
| IC | Integrated Circuit |
| LSB | Least Significant Bit |
| MCU | Microcontroller Unit |
| MM | Machine Model |
| MSB | Most Significant Bit |
| PM | Post Meridiem |
| POR | Power-On Reset |
| PORO | Power-On Reset Override |
| PPM | Parts Per Million |
| RC | Resistance-Capacitance |
| RTC | Real-Time Clock |
| SCL | Serial CLock line |
| SDA | Serial DAta line |
| SPI | Serial Peripheral Interface |
| SRAM | Static Random Access Memory |
| TCXO | Temperature Compensated Xtal Oscillator |
| Xtal | crystal |

17 References

- [1] AN13203 Application and soldering information for the PCF2131 and PCA2131 RTC
- [2] SOT1992-1_518 HLSON16; Reel pack; SMD, 13", packing information
- [3] UM10204 I²C-bus specification and user manual
- [4] UM10569 Store and transport requirements

18 Revision history

Table 95. Revision history

| Document ID | Release date | Data sheet status | Change notice | Supersedes |
|----------------|--|--------------------|---------------|---------------|
| PCA2131 v.2.0 | 20231005 | Product data sheet | - | PCA2131 v.1.0 |
| Modifications: | <ul style="list-style-type: none">• Table 4: 05h - corrected bits 6 to 4 and 2 to 1• Table 25: Corrected duplicate header bit 6 to bit 7• Table 92: $t_{VD;DAT}$ unit corrected to μs• Table 93: PCF2127 and PCA/F2129 are NRND and removed from selection table; PCA2131 corrected to Grade 2 which is 105 °C | | | |
| PCA2131 v.1.0 | 20211015 | Product data sheet | - | - |

19 Legal information

19.1 Data sheet status

| Document status ^{[1][2]} | Product status ^[3] | Definition |
|-----------------------------------|-------------------------------|---|
| Objective [short] data sheet | Development | This document contains data from the objective specification for product development. |
| Preliminary [short] data sheet | Qualification | This document contains data from the preliminary specification. |
| Product [short] data sheet | Production | This document contains the product specification. |

[1] Please consult the most recently issued document before initiating or completing a design.

[2] The term 'short data sheet' is explained in section "Definitions".

[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL <http://www.nxp.com>.

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