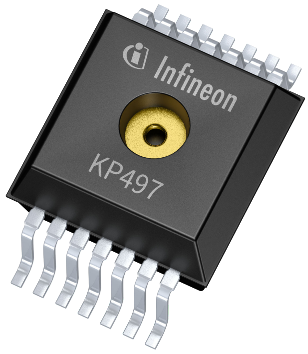
XENSIV™ Smart barometric pressure sensor



AEC Qualified
RoHS
ISO 26262 compliant

Features

- Pressure sensor with:
  - measurement range 20 kPa to 250 kPa
  - ±2 kPa accuracy for absolute pressure measurement
  - ±1 kPa accuracy for measurement of pressure differences
- Integrated z-axis accelerometer with:
  - measurement range -100 g to +100 g
  - ±2 g accuracy
- Highly flexible autonomous state providing wake-up for host on threshold violation with:
  - wide range of measurement intervals from <10 ms to >10 min
  - threshold detection for absolute value, overall change and rate of change for both pressure and acceleration
  - multi-stage pressure or acceleration monitoring or both
  - reconfiguration in the field
  - z-axis shock detection
- Supply current in autonomous state:
  - 44 µA at 50 ms intervals
  - 5.1 µA at 300 ms intervals
- 3 kB non-volatile memory for storing customer data
- I^2C and 3-pin SPI slave interface
- Temperature range -40°C to +105°C
- ISO 26262 Safety Element out of Context for safety requirements up to ASIL A.

Potential applications

- Automotive battery management system (BMS)
  - Thermal runaway detection
  - Battery shock monitoring as part of economic evaluation of battery health
  - Supports highest security requirements in battery management systems
  - Storage of battery passport data without additional external memory
  - Simplified logistics through storage of configurations for multiple platforms at once
- Industrial control
- Weather stations
- Altimeters

Product validation

Product validation according to AEC-Q100, Grade 1. Qualified for automotive applications.

Description

KP497 is an advanced low power barometric air pressure sensor. Besides a pressure sensor, it also provides a one-axis acceleration sensor, a temperature sensor, and a voltage sensor. KP497 can be operated as a normal digital sensor via the I^2C or SPI interface. Additionally, KP497 features a multi-phase low power autonomous state in which the sensor regularly performs measurements and evaluates pre-defined thresholds. In the autonomous state, KP497 can trigger a wake-up when a user defined threshold is exceeded. The selection of the measurements as well as their intervals and thresholds for each phase can be configured independently. These configurations are stored in the internal non-volatile memory, are retained even when the power supply is cut, and can be changed in the field via the serial interface.

Product Name	Ordering Code	Marking	Package
KP497	SP006004123	KP497	PG-DSOSP-14-84

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1 Block diagram

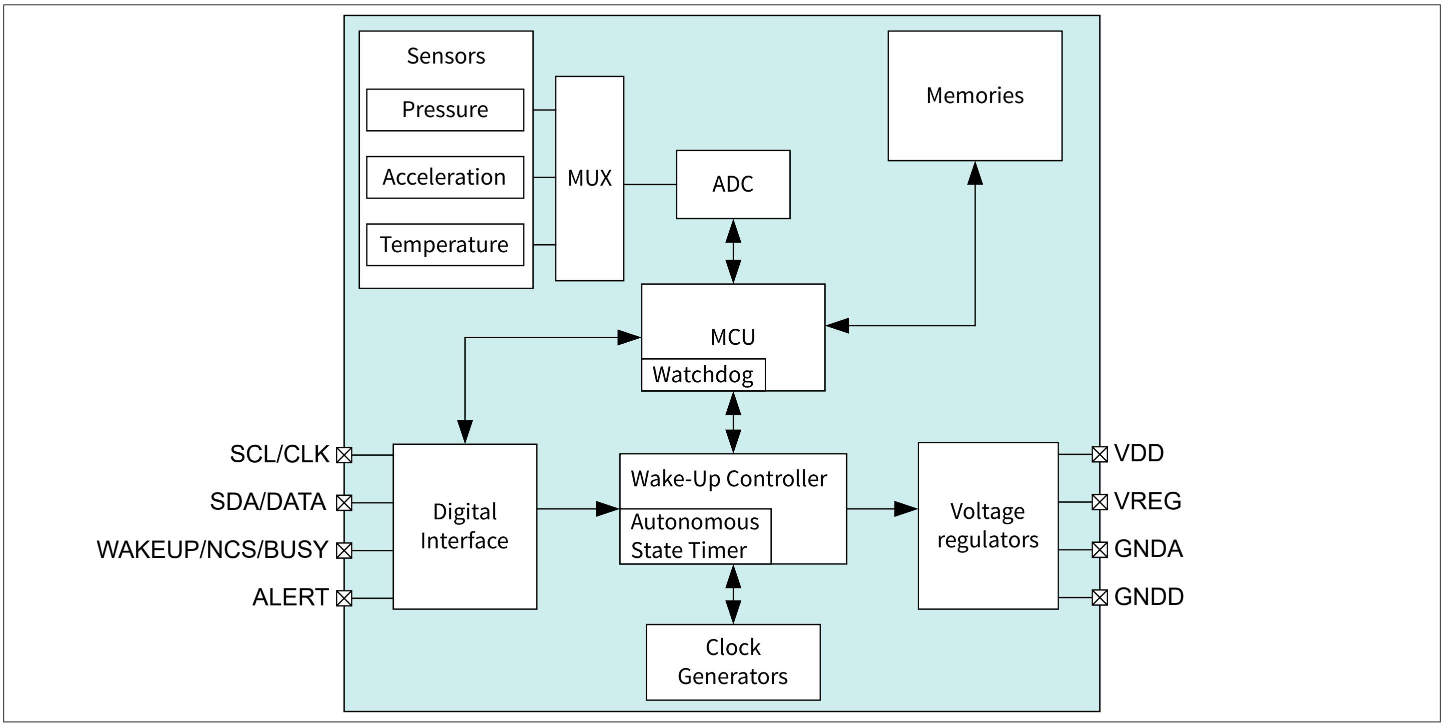

Figure 1 KP497 block diagram

2 Pin configuration

Figure 2 shows the pin assignment of KP497. The function of pins 1, 2 and 3 depend on which serial interface is used.

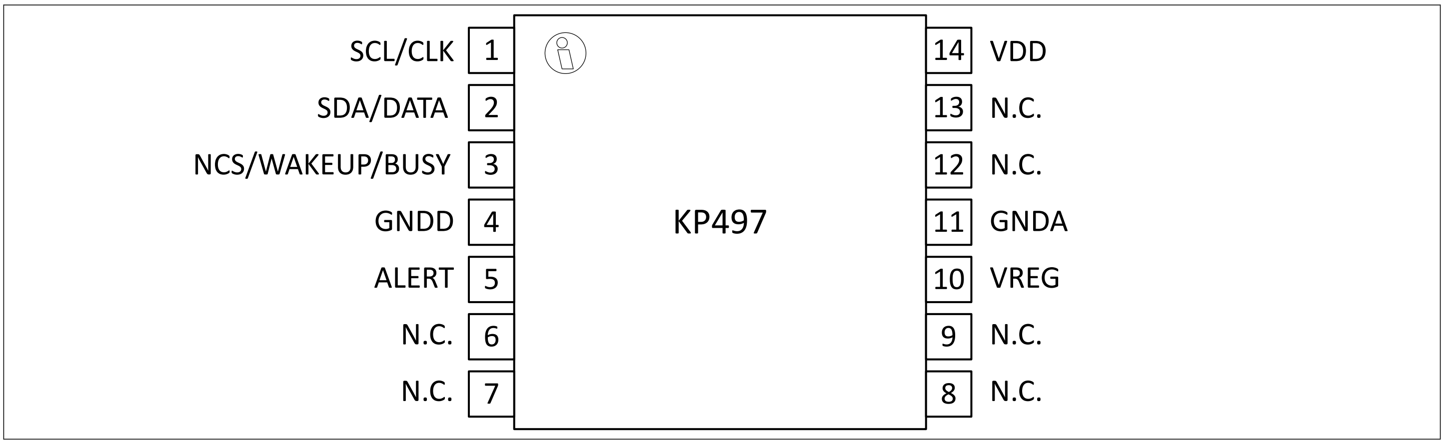

Figure 2 Pin configuration

Table 1 below describes the functionality of each pin.

Table 1 Pin assignment for each serial interface

Pin No.	Name	Function
1	SCL/CLK	I^2C serial clock / SPI clock
2	SDA/DATA	I^2C serial data / SPI data
3	NCS/WAKEUP/BUSY	SPI Not-Chip-Select / External Wake-Up / Device busy signal
4	GNDD	Digital ground
5	ALERT	Alert pin intended for wake-up of external master
10	VREG	Internal regulated power supply
11	GNDA	Analog ground
14	VDD	Power supply

3 General product characteristics

3.1 Absolute maximum ratings

Any stress exceeding the specified absolute maximum ratings in Table 2 may cause permanent damage to the device. The values given are stress ratings only and functional operation of the device at these conditions outside the ranges specified in Table 3 and Table 4 is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Table 2 Absolute maximum ratings

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Max. Supply voltage	V_{DD_MAX}	-0.3	–	3.8	V	Voltage at VDD pin
Input voltage at PP0, PP1, PP2, PP3	V_{IN_PPx}	-0.3	–	VDD+0.3	V	
DC current	I_{DC}	-10	–	10	mA	Maximum Input/Output Current at any Pin
Transient Latch-up Current	I_{LU}	±100	–	–	mA	Maximum transient current at any pin according JEDEC78 class II level A
Output Short-Circuit Capability	V_{SC}	0	–	3.8	V	Short to VDD, GND or neighbor pin for max. 10 min at VDD = 3.8 V. Note: VREG must not be shorted to VDD
ESD robustness HBM	V_{HBM}	±2000	–	–	V	All pins tested according to AEC-Q100-002
ESD robustness CDM, Corner Pins	$V_{CDM\ C}$	±750	–	–	V	Corner pins tested according to AEC-Q100-011
ESD robustness CDM	V_{CDM}	±500	–	–	V	Non-corner pins tested according to AEC-Q100-011
Maximum Pressure	p_{MAX}	–	–	2500	kPa	Static
Max. Static Acceleration	a_{MAX}	–	–	3500	g	24 hour continuously for ±x, ±y, and ±z direction respectively
Mechanical shock	a_{SHOCK}	–	–	6000	g	0.3 ms half sine pulses. 5 shocks in ±x, ±y, and ±z direction (30 shocks in total). Device unpowered.

3.2 Operating conditions

The following functional range must not be exceeded in order to ensure correct operation of the device. All parameters specified in the following sections refer to these operation conditions unless otherwise indicated.

Table 3 Operating conditions

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Ambient Temperature	T_{OP}	-40	–	105	°C	
Relative Humidity range	RH	0	–	100	%	
Flash programming temperature range	T_{FLASH}	-20	–	90	°C	Change of Autonomous State Configurations or Data Storage allowed only in this temepature range
Flash write cycles	N_{WRITE}	–	–	100		T_{OP} = -20°C to 90°C; Number of times each Autonomous State Configuration or 32 byte block of Data Storage can be written

3.3 Electrical characteristics

Table 4 Electrical characteristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Supply Voltage Range	V_{DD}	2.5	–	3.6	V	Specification valid within this range.
External Capacitor at VDD	C_{VDD}	–	10	–	nF	
External Capacitor at VREG	C_{VREG}	7	10	13	nF	
Reset release threshold	V_{THR}	1.8	–	1.9	V	Device releases from Reset when voltage at VDD pin exceeds V_{THR}.
Supply current in ON State	I_{ON}	–	1.66	2	mA	V_{DD} = 3.3 V. Applies as long as no Flash write is performed[1)] Currents due to external components on pins SCL/SLK, SDA/DATA, WAKEUP/NCS and ALERT not included.[2)]

(table continues...)

Table 4 (continued) Electrical characteristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Supply current in Autonomous State, Short intervals	I_{AS_short}	–	44	–	µA	Average over one measurement interval, one pressure measurement per Autonomous State Timer interval, Autonomous State Timer interval = 50 ms.[3)] Currents due to external components on pins SCL/SLK, SDA/DATA, WAKEUP/NCS and ALERT not included.[2)]
Supply current in Autonomous State, Long intervals	I_{AS_Long}	–	5.1	–	µA	Average over one measurement interval, one pressure measurement per Autonomous State Timer interval, Autonomous State Timer interval = 300 ms, T_{OP} = 25°C.[3)] Currents due to external components on pins SCL/SLK, SDA/DATA, WAKEUP/NCS and ALERT not included.[2)]
Current during flash write access	I_{FLASH_WRITE}	–	–	6	mA	T_{OP} = +25°C, V_{DD} = 3.3 V Applies while a flash write is performed[1)]
Power On time	t_{INI}	–	–	10	ms	Time from V_{DD} exceeding V_{THR} until serial interface ready. The ALERT pin must remain high during this time.[4)]
Watchdog period	T_{WD}	0.7	–	1.3	s	

1) Whenever a command stores data in the device's Flash memory (for example when storing a Autonomous State configuration), the current consumption specified by I_{FLASH_WRITE} applies.

2) External components on pins SCL/SLK, SDA/DATA, WAKEUP/NCS and ALERT can cause additional current consumption.
One such example is the low phase of the clock when I²C is selected: During the low phase of the clock, the I²C master pulls the SCL line actively low. At the same time, the internal pull-up resistor at pin 1 is activated. This causes a connection of the supply voltage through the internal pull-up resistor of KP497 and through the I²C master to ground and therefore an additional current consumption.

3) More details on how to determine the average current consumption will be provided in a separate document.

4) At reset, the ALERT pin is set to input with internal pull-up resistor until the serial interface is ready. During this time, the external master must not apply a low level to the ALERT pin. Additionally, the voltage V_{IH} on the ALERT pin must be exceeded latest 3 ms after the supply voltage at the VDD pin reaches the V_{THR}.
After this start-up phase, the ALERT pin is automatically reconfigured as output high and remains output until the next reset.

4 Sensor Characteristics

4.1 Pressure sensor characteristics

The pressure value p_{SERIAL} provided on the serial interface is a 16-bit value. The measured absolute pressure p_{IN} in kPa can be calculated from p_{SERIAL} as

$$p_{IN}[\text{kPa}] = p_{SERIAL}/16 \tag{1}$$

Table 5 below provides the specification for p_{IN}[kPa] provided on the serial interface.

Table 5 Pressure sensor characteristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Pressure measurement range	p_{IN}	20	–	250	kPa	Absolute Pressure
Pressure resolution	p_{RES}	0.0625	0.0625	0.0625	kPa/LSB	Resolution of measurement value on serial interface
Pressure random measurement error	p_{NOISE}	–	–	0.5	kPa	3 sigma
Relative Pressure measurement error	$p_{ERROR,Rel}$	-1	–	+1	kPa	Error for the pressure change Δp obtained from the difference of two absolute pressure measurements. Includes random error. Time between the two measurements < 1 day. -10 kPa < Δp < 10 kPa, temperature change -5°C < ΔT < 5°C. 3 sigma specification
Pressure measurement error	p_{ERROR}	-2	–	2	kPa	Includes random error. -20°C ≤ T_{OP} ≤ 105°C 20 kPa ≤ p_{IN} ≤ 200 kPa
Pressure measurement error	p_{ERROR}	-3	–	3	kPa	Includes random error. -20°C ≤ T_{OP} ≤ 105°C 200 kPa ≤ p_{IN} ≤ 250 kPa
Pressure measurement error	p_{ERROR}	-3	–	3	kPa	Includes random error. -40°C ≤ T_{OP} ≤ -20°C 20 kPa ≤ p_{IN} ≤ 200 kPa

(table continues...)

Table 5 (continued) Pressure sensor characteristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Pressure measurement error	p_{ERROR}	-4	–	4	kPa	Includes random error. -40°C ≤ T_{OP} ≤ -20°C 200 kPa ≤ p_{IN} ≤ 250 kPa

Figure 3 below provides a graphical representation of the pressure measurement tolerances of KP497 over temperature and pressure.

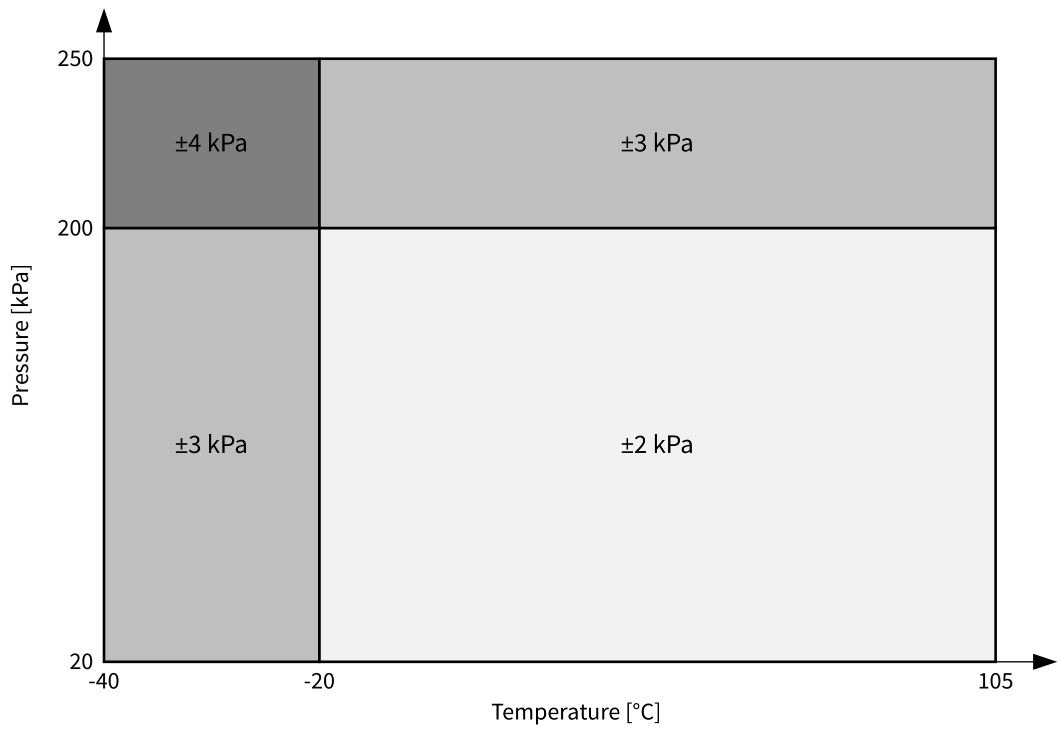

Figure 3 KP497 pressure measurement tolerances

4.2 Acceleration sensor characteristics

The device measures the acceleration in z-axis direction. The axis definitions are illustrated in Figure 4 below.

The acceleration value a_{SERIAL} provided on the serial interface is a 16-bit value. The measured absolute acceleration a_{IN}[g] can be calculated from a_{SERIAL} as

$$a_{IN}[g] = a_{SERIAL}/16 \quad (2)$$

Table 6 below provides the specification for a_{IN}[g] provided on the serial interface.

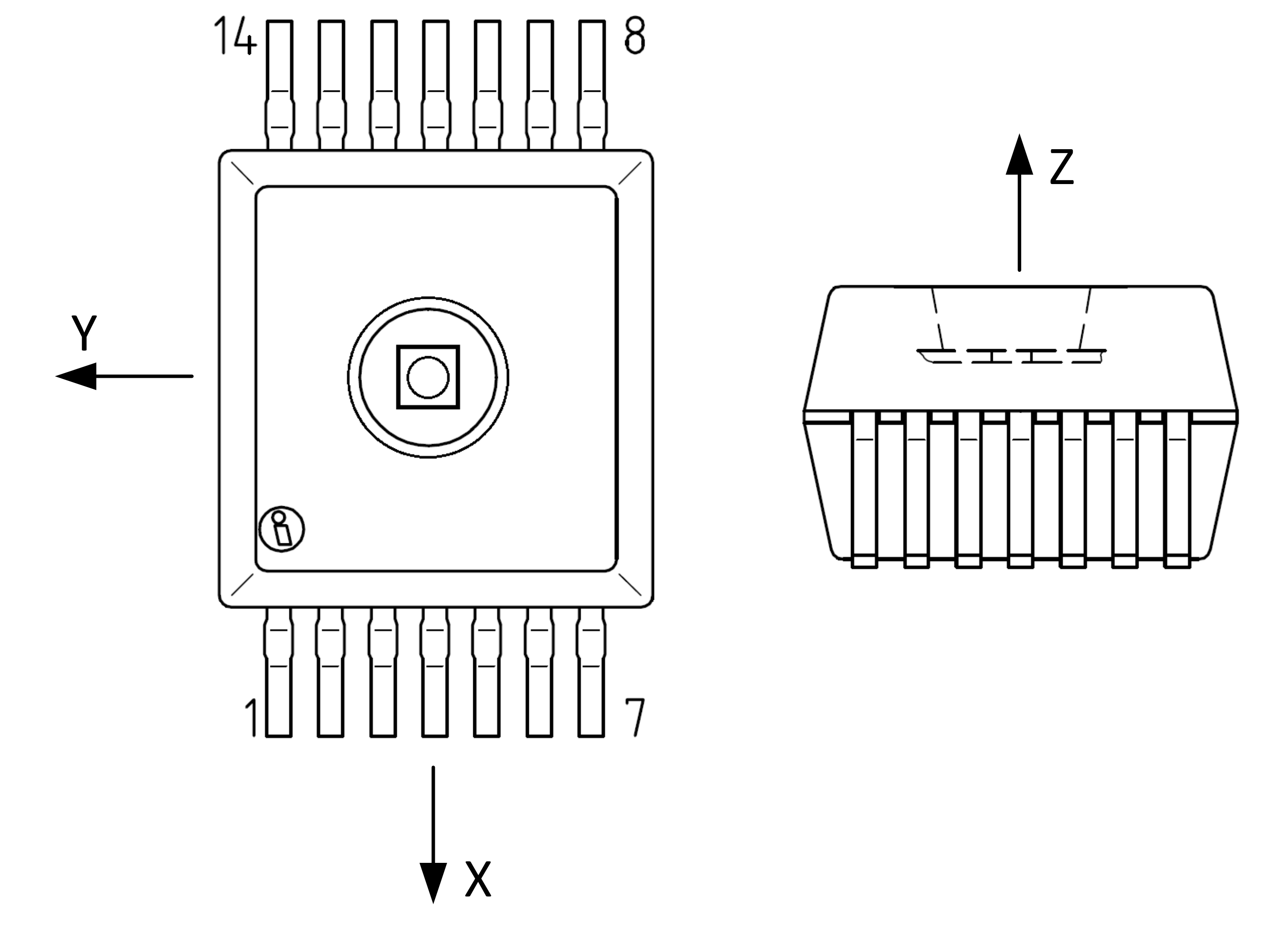

Figure 4 **KP497 acceleration axis definition**

Table 6 **Acceleration sensor characteristics**

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Acceleration measurement range	a_{IN}	-100	–	100	g	

(table continues...)

Table 6 (continued) Acceleration sensor characteristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Acceleration resolution	a_{RES}	0.0625	0.0625	0.0625	g/LSB	Resolution of measurement value on serial interface
Acceleration measurement error	a_{ERROR}	-2	–	2	g	Includes random error. -20 g ≤ a_{IN} ≤ +20 g
Acceleration measurement error	a_{ERROR}	-3	–	3	g	Includes random error. -100 g ≤ a_{IN} ≤ -20 g and +20 g ≤ a_{IN} ≤ +100 g -20°C ≤ T_{OP} ≤ 105°C
Acceleration measurement error	a_{ERROR}	-4	–	4	g	Includes random error. -100 g ≤ a_{IN} ≤ -20 g and +20 g ≤ a_{IN} ≤ +100 g -40°C ≤ T_{OP} ≤ -40°C

4.3 Temperature sensor characteristics

The temperature value T_{SERIAL} provided on the serial interface is a 16-bit value. The measured absolute temperature T_{IN}[°C] can be calculated from T_{SERIAL} as

$$T_{IN}[°C] = T_{SERIAL}/128 \tag{3}$$

Table 7 below provides the specification for T_{IN}[°C] provided on the serial interface.

Table 7 Temperature sensor characteristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Temperature measurement range	T_{MEAS_RANGE}	-40	–	105	°C	
Temperature Sensor Total Error	T_{ERR}	-3	–	3	°C	Includes random error.
Temperature Sensor Total Error, RT	T_{ERR_RT}	-2	–	2	°C	Includes random error. -20°C ≤ T_{OP} ≤ +90°C

5 Functional description

5.1 Device States

Table 8 provides an overview of the device states. More detailed information for each device state is provided in the corresponding subsections Reset State, On State, Sleep, Autonomous State, and Acceleration Recording.

Table 8 KP497 Device states

State	Purpose / Description
Reset State	The sensor is fully re-initialized and a basic diagnosis check is performed to ensure that communication on the serial interface is reliable. If this check is successful, the device automatically enters On State.
On State	The device is controlled through the serial interface. The external master can trigger measurements, read out data collected during Autonomous State, perform diagnosis checks and initiate state transitions.
Sleep	The sensor is inactive and has lowest power consumption.
Autonomous State	The device autonomously performs regular measurements and evaluates thresholds. The Autonomous State is highly configurable regarding selection of measurements, measurement intervals, thresholds and the action taken upon violation of a threshold. One central option for the action when a threshold is violated is the generation of an alarm by pulling the ALERT pin high. The state is optimized to minimize the average current consumption.
Acceleration Recording	Acceleration Recording can be selected as a possible action when an acceleration threshold is violated. During Acceleration Recording, the device takes a predefined amount of acceleration samples and afterwards provides the results on the serial interface in a condensed form.

The possible transitions between the states are summarized in Figure 5.

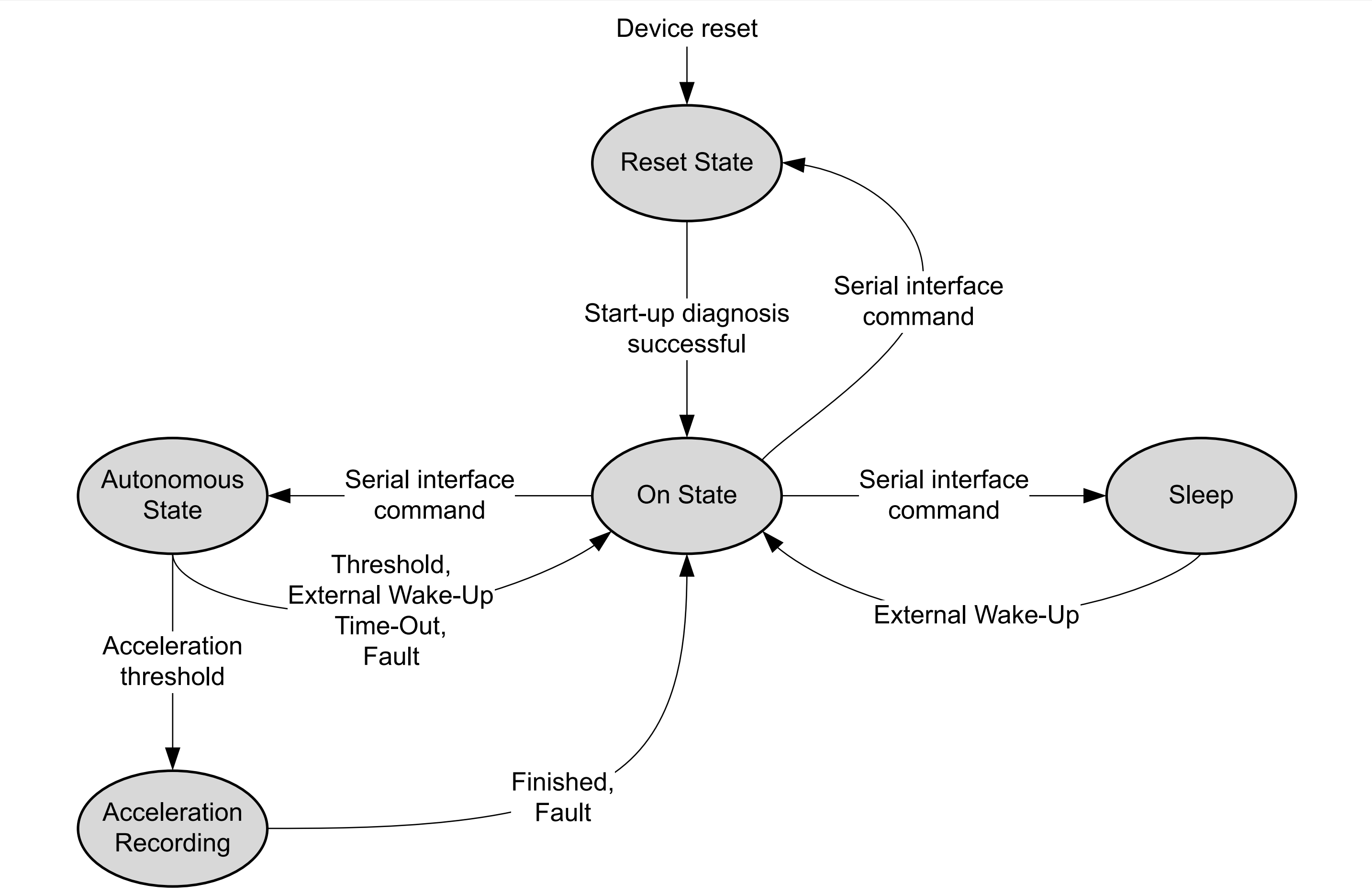

Figure 5 **State transitions**

5.1.1 Reset State

After release from device reset, the device enters the Reset State. During the Reset State the device is first fully (re-)initialized.

During t_{INI}, the four pins SCL/CLK, SDA/DATA, NCS/WAKEUP/BUSY and ALERT are input pins with internal pull-up resistors active. For a proper initialization of the device, the external master must avoid any change in the levels applied to these four pins. Moreover, no low level may be applied to the ALERT pin. This is particularly important for the Power On reset (POR) and for the Softreset triggered through the serial interface.

The external circuitry must additionally be designed such that the Input High Voltage on the ALERT pin is exceeded latest 3 ms after the supply voltage at the VDD pin reaches the Reset release threshold. Otherwise, t_{INI} can increase up to 4 seconds.

As part of the (re-)initialization, the device tries to recover the selection of the serial interface. If the recovery of the serial interface is successful, the device automatically enters On State. The time needed from release from reset until the serial interface is ready for communication in On State is given by t_{INI}.

In case the serial interface cannot be recovered, the further behavior in Reset State depends on the reset source:

- In case of POR or Softreset, the device initiates the serial interface selection. Once the serial interface was selected, the device automatically transitions to On State. In this case, t_{INI} is the time from release from reset until the serial interface selection starts.
- For the remaining reset sources, the device enters an endless loop with the ALERT pin actively high. The only possibility to recover the device is then to generate a POR by cutting the power supply.

5.1.2 On State

The On State is the central device state of KP497. It is automatically entered

- after device reset,
- after external wake-up from Sleep or Autonomous State,
- when in Autonomous State a threshold is violated for which the device is configured to transition to On State,
- if a fault occurs during Autonomous State or during Acceleration Recording,
- when Acceleration recording is finished.

In On State, the external master can trigger a transition of the device to either Sleep or Autonomous State.

When On State is entered, the device always generates an alert. The alert can be cleared by the external master when reading out the Device Status Register (see KP497 User Manual for details).

In On State, the selected serial interface is active and the device is controlled by the external master. The external master can

- trigger pressure, acceleration or temperature measurements,
- read out data acquired during Autonomous State or Acceleration recording,
- trigger a transition to Sleep or Autonomous State,
- trigger a self diagnosis of the device,
- trigger a soft reset of the device,
- read out the Device Status Register,
- read out the sensor ID and product code,
- store the selected serial interface in Flash for recovery of the serial interface at reset, and
- read and write the configurations for Autonomous State,
- write or read data in the nonvolatile memory for data storage

by sending commands via the serial interface to KP497. After KP497 receives the command, it takes some time for the device to process and acquire the return data. During this time, the NCS/WAKEUP/BUSY pin is actively pulled low by KP497. Once the device finishes processing and the results are available to be read out by the external master, the NCS/WAKEUP/BUSY pin is automatically set to input with pull-up resistor again. The external master can then collect the results via the serial interface. A detailed description is provided in the KP497 User Manual.

All data exchanged on the serial interface are protected by a 16-bit CRC. The CRC is calculated using the CCITT polynomial 0x1021 with a preload value of 0xFFFF. The external master is responsible for adding the CRC value at the end of the data sent to KP497 and to check the CRC of data provided by KP497. Further details are provided in the KP497 User Manual.

The following flow diagram summarizes the behavior of KP497 in On State:

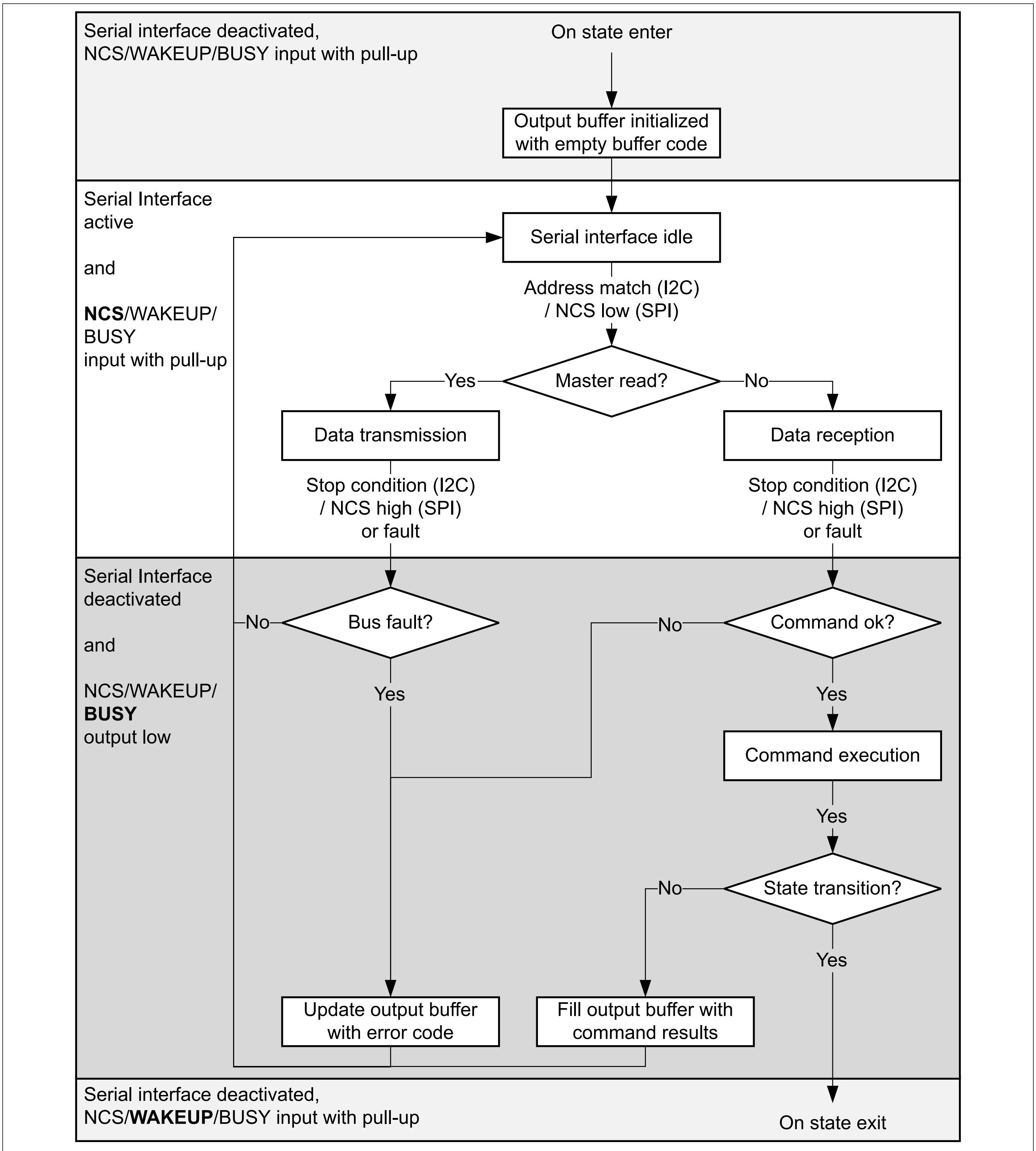

Figure 6 **Flow diagram for KP497 On State**

5.1.3 Sleep

During Sleep, the device is inactive and has the lowest average current consumption. It will not respond to any communication on the serial interface. Sleep can only be left by an External Wake-Up.

5.1.4 Autonomous State

The Autonomous State (AS) is a highly configurable state that allows to autonomously monitor pressure or acceleration or both with optimal power efficiency. The AS is configured and entered by serial interface commands in On State. While in AS, the serial interface is deactivated and commands sent by the master have no effect. Instead, the device regularly takes measurements and uses the measurement results to evaluate thresholds.

The measurement intervals, the thresholds and their evaluation as well as the action performed by KP497 when a threshold is violated, *i.e.* when the measurement result exceeds an upper or falls below a lower threshold, are controlled through one or more configurations. In order to use AS, these configurations must first be programmed into the device (see Chapter 5.1.4.7 for details)

As an additional measure to avoid operation outside the functional range of the device, KP497 also performs regular temperature measurements in Autonomous State. When the temperature falls below T_{UT} or rises above T_{OT} the device transitions to On State.

5.1.4.1 Autonomous State Timer

In order to perform the measurments in regular intervals, the device features an integrated timer, called the Autonomous State Timer. It serves as pre-counter for both the pressure and the acceleration measurements in AS. Additionally, both pressure and acceleration measurement have individual post-counters, such that different measurement intervals can be used for pressure and acceleration measurements.

5.1.4.2 Autonomous State Measurement Buffers

Additional to evaluating thresholds, the pressure and acceleration values acquired in AS are added to dedicated measurement buffers. The device has one dedicated buffer for pressure and one for acceleration measurements.

Each of these two buffers can hold up to L_{MEAS_BUFFER} measurement values and is implemented as a ring buffer. *I.e.* when a buffer already holds L_{MEAS_BUFFER} values, every time the corresponding measurement is performed and therefore a new value is added, the oldest measurement value is overwritten. That way, the buffer always holds the most recent measurement results.

When AS is entered from On State, or when the configuration changes due to a violation of a threshold or due to a time-out, the measurement buffers are cleared. After the device transitions from AS to On State, the measurement buffers can be read out through the serial interface.

5.1.4.3 Autonomous State Threshold Actions

When a threshold is violated, the device performs one of the following four actions:

1. Transition to On State.
2. Change of configuration for Autonomous State without alert.
3. Change of configuration for Autonomous State with alert.
4. Transition to Acceleration Recording. This option is only available for acceleration thresholds.

Options 2 and 3 for the action performed when a threshold is violated allow to implement a multi-stage monitoring, where the measurement intervals and thresholds are different in each stage.

5.1.4.4 Autonomous State History

During AS, the device maintains a history of configurations. When a threshold is violated, for which option 2 or 3 of the actions listed above is selected, the configuration used before the threshold was violated is added to the AS History. The AS History is implemented as a ring buffer. That means that when a new configuration is added to the AS History and there are already $L_{HISTORY}$ configurations stored, the oldest entry is replaced by the new one. Moreover, entering AS from On State clears the AS History.

After the device transitions from AS to On State, the AS History can be read out through the serial interface.

5.1.4.5 Autonomous State Time-Out

The main purpose of the AS History is to restore the previous configuration at time-out: When a time-out occurs, the device changes to the newest configuration in the AS History and the corresponding entry in the AS History is removed. In other words, at time-out the AS History behaves like a last-in first-out buffer. In case the AS History is empty at time-out, the device transitions to On State instead. For each configuration, the time-out can be enabled and disabled independently. Similarly, the dedicated postcounter for the time-out can be set for each AS configuration separately. The pre-counter for time-out is the AS Timer.

5.1.4.6 Autonomous State Thresholds

The device supports the following four types of thresholds for both pressure and acceleration measurements:

Table 9 Threshold types in Autonomous State

Threshold type	Description
Absolute	The last measurement result is directly compared to the threshold value(s).
Relative to On State	When the device transitions from On State to AS, a reference measurement is taken. For each measurement, the value of this reference measurement is subtracted from the new value. The resulting difference is compared to the threshold value(s).
Relative to configuration start	When the device changes the configuration for AS (either at transition from On State to AS or when a threshold is violated), a reference measurement is taken. For each measurement, the value of this reference measurement is subtracted from the new value. The resulting difference is compared to the threshold value(s).
Rate of change	The device performs a linear fit over the last N_{Grad} values in the measurement buffer. The number N_{Grad} of measurement values used for the linear fit is configurable. The result of the linear fit is then compared to the threshold value(s). Since there need to be at least N_{Grad} values in the measurement buffer, the threshold is evaluated only from the N_{Grad}-th measurement onwards after changing the configuration or after entering AS.

For both, pressure and acceleration, up to two of these threshold types can be selected at a time. The selection of threshold types for pressure and acceleration can be different. Moreover, for each threshold type, an upper or a lower threshold value or both can be defined.

5.1.4.7 Autonomous State Configurations

The AS uses configurations that are stored in the device's flash memory. Up to N_{CONFIG} configurations can be stored. Initially, there are no pre-defined configurations. Therefore, the system integrator must ensure to write the configurations before AS is entered for the first time.

Since the configurations are stored in the flash memory, they are retained over all device states and when the device is unpowered. At the same time, each configuration can be (re-)written at any time, as long as it is not written more than N_{WRITE} times.

The configurations are written through commands on the serial interface in On State without the need for any further considerations like additional signals, increased supply voltage or special circuitry. In other words, the external master can update the configurations at any time while the device is in On State.

Each Autonomous State configuration consists of the following settings:

- A number from 0 to 31 that serves as identifier (ID) of the configuration. Each number can be assigned only once. Providing a configuration with an ID that is already in use overwrites the existing configuration. The ID is used to select the AS Configuration when entering AS from On State or when the configuration changes due to a violation of a threshold.
- Period of the AS Timer.
- Number of samples taken during Acceleration Recording, if one of the selected measurements is acceleration and at least one of its thresholds is set to transition to Acceleration Recording.
- Time-Out postcounter value as well as enabling or disabling of time-out.
- Two measurement configurations with the following settings:
  - Selection between pressure, acceleration or no measurement. The sensor selection for the two measurement configurations must be different from one another.

- Setting of postcounter for measurement.
- Two threshold configurations with the following settings:
  - Selection between absolute threshold, relative threshold to On State, relative threshold to Autonomous State, rate of change threshold. The threshold type selection for the two threshold configurations must be different from one another.
  - Number N_{Grad} of samples used for linear fit to calculate rate of change. This setting is used only, when the rate of change threshold is selected and ignored otherwise.
  - Enabling or disabling of the lower threshold.
  - Threshold value for the lower threshold.
  - Selection of the action performed when the lower threshold is exceeded.
  - Enabling or disabling of the upper threshold.
  - Threshold value for the upper threshold.
  - Selection of the action performed when the upper threshold is exceeded.

5.1.4.8 Autonomous State Flow

Figure 7 below shows the flow during Autonomous State:

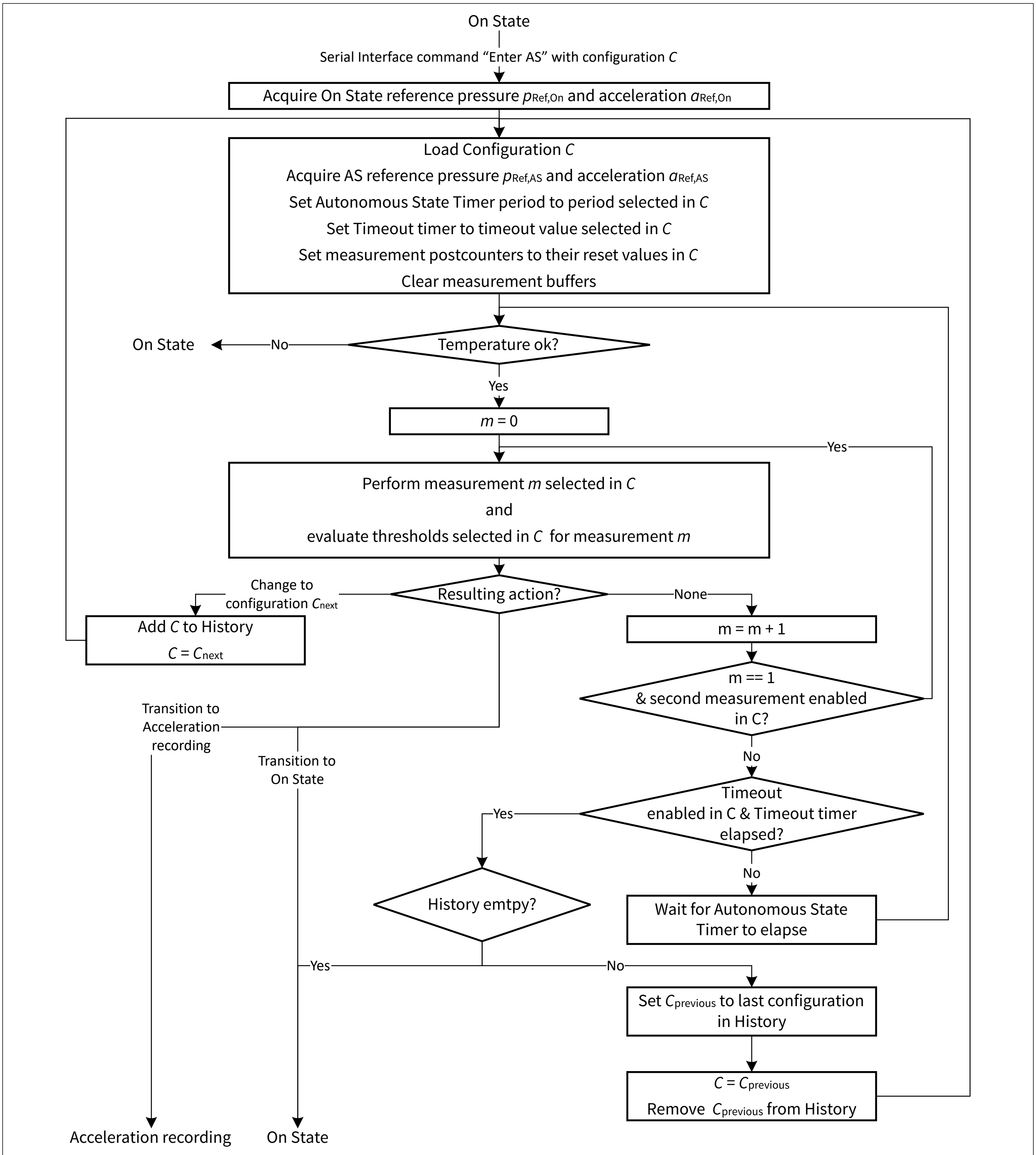

Figure 7 **Autonomous State Flow**

The detailed flow of the block "Perform measurement m selected in C and evaluate thresholds selected in C for measurement m" in Figure 7 is shown in the following figure:

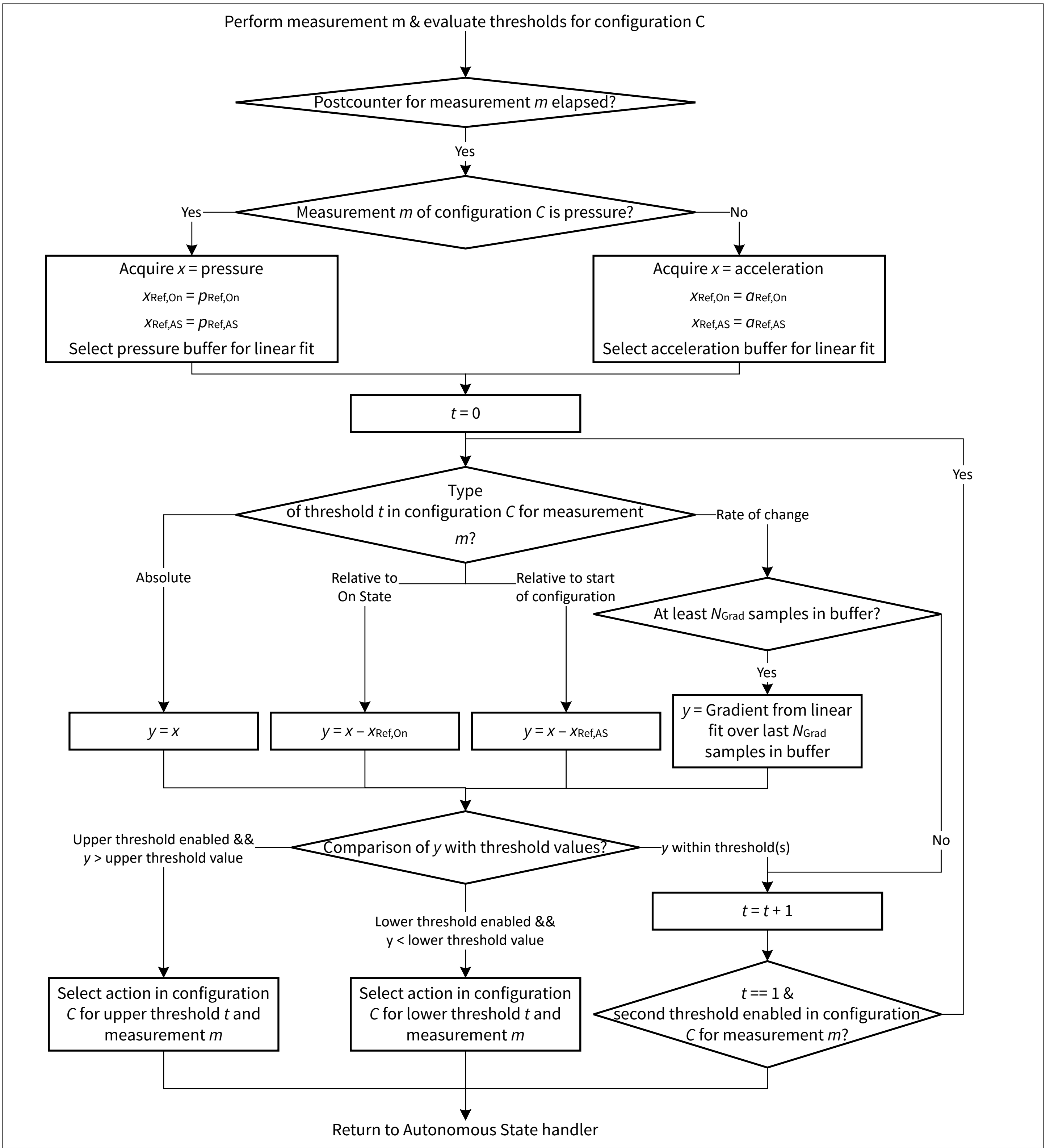

Figure 8 **Flow of measurement and threshold evaluation during Autonomous State**

5.1.4.9 Autonomous State characteristics

Table 10 Autonomous State characteristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Selectable range for Autonomous State Timer	t_{AUTO}	0	–	733.184	s	Timer tolerances not included.
Autonomous State Timer Tolerance	TOL_{AS_TIMER}	-30	–	+30	%	Total tolerance of clock source for Autonomous State Timer including temperature drift
Configuration History buffer size	$L_{HISTORY}$	–	16	–	–	Number of configurations that can be stored internally for changing back to previous Autonomous State Configuration when a Time-Out occurs during Autonomous State.
Autonomous State Measurement Buffer size	L_{MEAS_BUFFER}	–	16	–	–	
Number of supported Autonomous State configurations	N_{CONFIG}	–	32	–	–	
Selectable range for number of measurements for gradient calculation	N_{Grad}	2	–	L_{MEAS_BUFFER}	–	
Selectable range for number of measurements during acceleration recording	N_{REC}	1	–	65535	–	
Pressure sampling time in Autonomous State	t_{AUTO_PRESS}	–	1.55	–	ms	T_{OP} = 25°C

(table continues...)

Table 10 (continued) Autonomous State characteristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Acceleration sampling time in Autonomous State	t_{AUTO_ACC}	–	0.86	–	ms	T_{OP} = 25°C
Pressure+Acceleration sampling time in Autonomous State	t_{AUTO_P+A}	–	1.95	–	ms	T_{OP} = 25°C
Autonomous State under-temperature threshold	T_{UT}	-40	-37	-34	°C	If the temperature falls below this value, the device transitions from Autonomous State to On State
Autonomous State over-temperature threshold	T_{OT}	119	122	125	°C	If the temperature rises above this value, the device transitions from Autonomous State to On State

5.1.5 Acceleration Recording

During Acceleration Recording, the device takes regular acceleration measurements. In contrast to AS, the measurement results are not compared to thresholds. Instead, the device takes a predefined number of samples. The number of samples taken during Acceleration Recording is defined as part of the AS configuration from which Acceleration Recording is entered. Similarly, the measurement interval is the same as the measurement interval in the AS configuration last used. Once all samples are taken, the device transitions to On State.

From the acceleration measurements performed during Acceleration Recording, the KP497 determines

- the maximum acceleration value of all samples taken during Acceleration Recording,
- the minimum acceleration value of all samples taken during Acceleration Recording, and
- a histogram of the acceleration values taken during Acceleration Recording. During Acceleration recording, the histogram consists of N_{BINS_REC}-1 bins with a width of a_{BIN_REC} and one bin for the acceleration range -a_{BIN_REC} < a < +a_{BIN_REC}. The bins are symmetrically distributed around 0 g. All measurement values that exceed the maximum value for the upper most bin are added to the upper most bin. All measurement values that are below the lowest bin are added to the lowest bin.

After acceleration recording, the maximum, minimum and histogram can be read out via the serial interface. The size of the bins for the histogram can be adjusted in the range.

5.1.5.1 Acceleration Recording characteristics

Table 11 Acceleration Recording characteristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Nominal bin width during recording	a_{BIN_REC}	–	2	–	g	Applies to all bins except the bin around 0 g. The bin around 0 g has a width of $2 \times a_{BIN\_REC}$ Measurement errors are not included.
Number of bins during recording	N_{BINS_REC}	–	61	–	–	

5.2 Data Storage

3 kB of the internal Flash memory of KP497 are available to store data. The data stored in these 3 kB are not used by KP497. The external master can write and read data to this Flash area in blocks of 32 byte whenever the device is in On State through the serial interface. However, for each 32 byte block writing must be limited to maximum N_{WRITE} times.

The available memory is split into three sections. Each section has a size of 1 kB and has its last two bytes reserved as lockbyte. This sectorization as well as the location of lockbytes is illustrated in Figure 9.

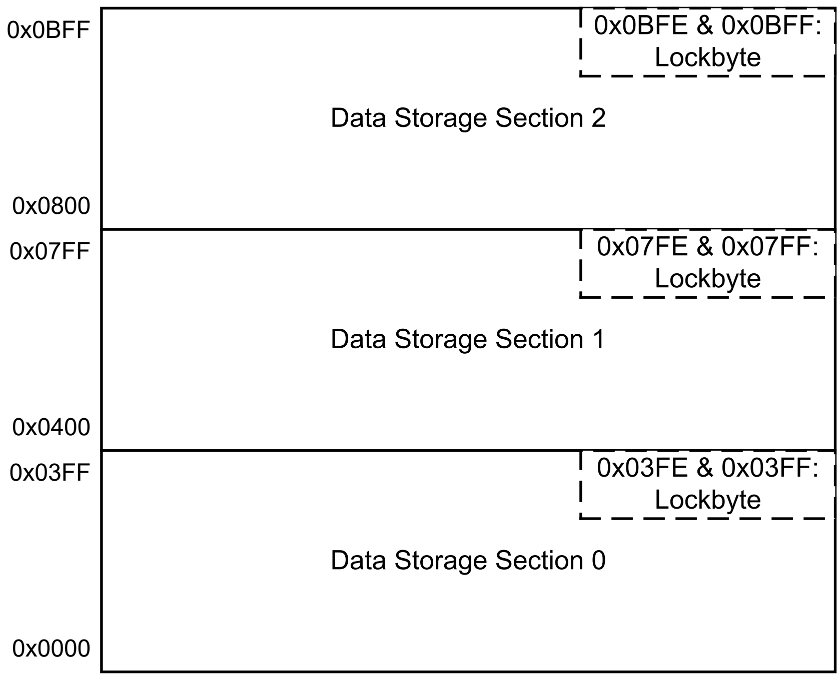

Figure 9 Sectorization and lockbyte location of flash memory available for data storage

When the external master writes a value within a Hamming distance of at most 3 from the value 0x6969 to the lockbyte of a sector, this sector gets locked after one of the following three events:

- a reset occurred, or
- the device enters Sleep State, or
- the device enters the low power state as part of Autonomous State with a nominal Autonomous State Timer period of at least 300 ms.

Once the sector is locked, the data of this sector cannot be changed any more. Read out of data from a locked sector remains possible.

5.3 Digital interface

For interacting with the external master, the KP497 features an external wake-up, an alert and two serial interfaces.

The available serial interfaces are I^2C and 3-wire SPI. Both interfaces support slave mode only. Moreover, only one of the two interfaces can be active.

5.3.1 Alert

The ALERT pin of KP497 is dedicated to wake-up the external master whenever an action is required.

When the device enters On State, the ALERT pin is pulled high actively by the device. It remains actively high until it is explicitly cleared by the external master. If Sleep or Autonomous State is entered without the ALERT pin being cleared, the ALERT pin remains high even during Sleep or Autonomous State.

In Autonomous State it is possible to have the alert pin actively high temporarily when the device transitions to another Autonomous State Configuration due to violation of a threshold. in this case the ALERT pin is set to output low when the next measurement in Autonomous State is performed.

During reset, this pin is an input pin with internal pull-up resistor until the serial interface selection starts or, if the serial interface is recovered, until On State is entered.

5.3.2 External Wake-Up

The device features an external wake-up. The external wake-up is always active in Autonomous State and Sleep. After external wake-up the device enters On State.

For external wake-up, the WAKEUP pin is used. The WAKEUP pin is a digital input pin with internal pulling resistor. In order to generate an external wake-up, this pin must be pulled low.

The external wake-up is level sensitive. Therefore, in order to enter and remain in Autonomous State or Sleep, a high level must be applied to the WAKEUP pin either by actively pulling it high or through the internal pull-up resistor.

5.3.3 Serial interface selection after Power On and Softreset

Initially, the serial interface of KP497 is not configured. Instead, the serial interface of KP497 can be selected after Power-On by applying certain levels to the pins SCL/CLK and SDA/DATA while pulling NCS/WAKEUP/BUSY low. The selection mechanism is described in more detail in the User Manual.

Once the serial interface is selected this way, the serial interface can be locked by a dedicated serial interface command. The serial interface locked by the command can be set to be different from the serial interface currently in use. Once the serial interface is locked, it cannot be changed any more and the device always uses the locked serial interface even after reset.

As long as the serial interface is not locked, the serial interface selected remains active until the next reset and after each Power-On reset or Softreset, the serial interface must be selected anew.

It is recommended to always lock the serial interface.

5.3.4 Digital interface characteristics (common for SPI and I2C)

Table 12 Digital interface characteristics (common for SPI and I2C)

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Input High Voltage	V_{IH}	0.8	–	–	V_{DD}	
Input Low Voltage	V_{IL}	–	–	0.2	V_{DD}	
Output High Voltage	V_{OH}	V_{DD} -0.3	–	–	V	I_{load} = 1 mA
Output Low Voltage	V_{OL}	–	–	0.3	V	I_{load} = -1 mA
SCL/CLK and SDA/DATA Input Capacitance	$C_{IN\_1,2}$	–	–	10	pF	
SCL/CLK and SDA/DATA Input Leakage Current	$I_{IN\_1,2}$	-1	–	1	µA	For lowest current consumption the input high voltage should be VDD - 0.05 V or higher. The input low voltage should be maximal 0.05 V.
NCS/WAKEUP Input Leakage Current	I_{IN_3}	-1	–	1	µA	T_{OP} = -40°C to 90°C. For lowest current consumption the input high voltage should be VDD - 0.05 V or higher. The input low voltage should be maximal 0.05 V.
NCS/WAKEUP Input Leakage Current, HT	$I_{IN\_3\_HT}$	-2	–	2	µA	T_{OP} = 90°C to 125°C. For lowest current consumption the input high voltage should be VDD - 0.05 V or higher. The input low voltage should be maximal 0.05 V.
Equivalent pull-up resistors NCS/ WAKEUP and ALERT	R_{PULL_3V}	15	–	70	kΩ	V_{IN_PPx} = 1.5 V, V_{DD}=3 V; Valid for pins NCS/WAKEUP/BUSY and ALERT.

5.3.5 I2C slave interface

The 7-bit I^2C slave address is fixed to 0x36. This address is followed by the read/write bit. Therefore, including the read/write bit, the address for a write access to KP497 is 0x6C and for a read access 0x6D.

After an address match is detected by KP497, the device does not service the Watchdog until a stop condition is detected or another failure occurs on the I^2C bus. Therefore, the duration of an I^2C frame from start to stop condition may not be longer than the T_{WD}.

The device also acknowledges the address byte with the reserved I^2C address 0x2E. However, full I^2C commands sent to this address are not acknowledged and not executed.

Table 13 I2C characteristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
I2C datarate	DR_{I2C}	–	–	1000	kbit/s	
Equivalent pull-up resistors at SCL and SDA	R_{PULLUP}	5.9	8.4	11	kΩ	
I2C inactive time	$t_{d,I2C}$	13	–	–	µs	After the stop condition of an I^2C read, the external master needs to wait at least $t_{d,I2C}$ before generation of the next start condition. The I^2C inactive time after a master write depends on the data sent to KP497 and is typically longer than $t_{d,I2C}$.

5.3.6 SPI slave interface

The device's SPI interface is a 3-pin half-duplex SPI consisting of chip select (NCS pin), clock (CLK pin) and data (DATA pin). During communication with KP497 via SPI, the external master must pull the NCS pin low.

The SPI mode is fixed to mode 3. Therefore, received data is sampled on the rising edge, while transmitted data is shifted out on the falling edge. Moreover, the clock must be high when the external master pulls the NCS pin low and when the external master releases the NCS pin.

In order to read data from KP497, the external master must first send the byte 0x6C and then keep the NCS pin low and the clock running until all data is received from KP497.

As long as the external master holds the NCS pin low the device does not service the Watchdog. Therefore, the duration of a SPI frame from pulling the NCS pin low until releasing the NCS pin may not be longer than the T_{WD}.

The timings for the SPI interface are specified in Table 14 below while Figure 10 provides the definition of these timings.

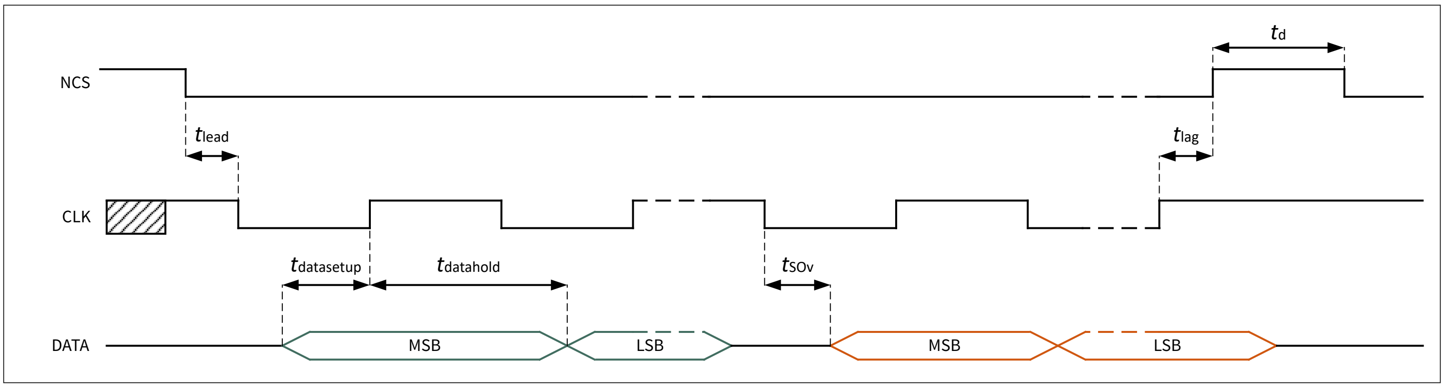

Figure 10 SPI timing

Table 14 SPI characteristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
SPI datarate	DR_{SPI}	–	–	250	kbit/s	
DATA setup time	$t_{datasetup}$	200	–	–	ns	
DATA hold time	$t_{datahold}$	200	–	–	ns	
DATA valid time	t_{SOv}	–	–	1	µs	
NCS lead time	t_{lead}	2	–	–	µs	
NCS trail time	t_{lag}	2	–	–	µs	
NCS inactive time	$t_{d,SPI}$	21	–	–	µs	Applies to SPI master read. The SPI inactive time after a master write depends on the data sent to KP497 and is typically longer than $t_{d,SPI}$.
CLK duty cycle	DC_{CLK}	30	–	70	%	Amount of time that CLK must be high during each SPI clock cycle in percent of one SPI clock period.

5.4 Self Diagnosis

The device incorporates various self diagnosis features. They can be grouped into three categories: Always Active Self Diagnosis, Internally Triggered Self Diagnosis Checks and Externally Triggered Diagnosis Checks.

5.4.1 Always Active Self Diagnosis

The Diagnosis Checks listed in Table 15 below constantly monitor the device.

Table 15 Always Active Self Diagnosis Checks

Diagnosis Check	Description
Under voltage Detection	The Undervoltage Detector monitors the supply voltage applied on VDD. When the voltage drops below the threshold where correct operation of the device cannot be ensured anymore, an Undervoltage reset is triggered.
Power On reset (POR)	When the supply voltage on VDD drops below a second threshold lower than the Undervoltage threshold, the device triggers a Power On reset instead.
Error Correction Code (ECC)	The ECC monitors the integrated Flash memory for bit failures. If a 1 bit failure occurs within a 32 byte long flash line, this failure is corrected. 2 bit failures within a flash line are always detected. For 3 or more bit failures within a flash line the ECC provides partial coverage. When a 2 bit failure within a flash line is detected, a ECC reset is triggered.
Brown-Out Detection (BOD)	The Brown-Out Detector monitors the internal regulated voltage domain. If the regulated voltage drops below an internal threshold, proper functioning of the device cannot be ensured any more and a BOD reset is triggered.

(table continues...)

Table 15 (continued) Always Active Self Diagnosis Checks

Diagnosis Check	Description
Watchdog (WD)	The WD prevents the CPU from being stuck. If the CPU is stuck, a WD reset is triggered when the WD timer elapses.
Hardfault detection	If the MCU performs an invalid operation, the device triggers a Softreset and the hardfault source is indicated in the Device Status Register

5.4.2 Internally Triggered Self Diagnosis Checks

Table 16 below lists checks that are performed in On State whenever certain serial interface commands are executed as well as during Autonomous State when performing certain actions. For each of these checks, Table 16 also describes in more detail when these checks are performed in each state as well as the device's reaction and the possibility for read-out, if a check fails.

Table 16 Internally Triggered Self Diagnosis Checks

Diagnosis Check	Description	Execution and failure reaction	
		On State	**Autonomous State**
Calibration data check	All sensor calibration data is protected by a CRC. The check determines the validity of the calibration data by checking the correctness of the CRC.	The checks are performed every time a measurement is triggered through the serial interface. The checks are sensor specific, e.g., when performing a pressure measurement, the check is performed for the pressure sensor only. The result of the checks is provided as part of the read-out of the measurement result.	The check is performed every time a measurement is performed. The checks are sensor specific, e.g., when performing a pressure measurement the check is performed for the pressure sensor only. If at least one of the checks fails, the device transitions to On State and the failed check is indicated in the Device Status Register.
Wirebond check	The sensor is capable to detect a malfunction of the wirebonds between the pressure or acceleration sensor and the ASIC.		
ADC and numerical under-/overflow	The analog signal received by the ADC as well as its numerical output are checked against the valid ranges.		
Accelerometer breakage check	The sensor is capable to detect, if the acceleration sensor beam is broken.	The checks are performed every time an acceleration measurement is triggered through the serial interface. The result of the checks is provided as part of the read-out of the measurement result.	The check is performed every time an acceleration measurement is performed. If the check fails, the device transitions to On State and the failed check is indicated in the Device Status Register.

(table continues...)

Table 16 (continued) Internally Triggered Self Diagnosis Checks

Diagnosis Check	Description	Execution and failure reaction	
		On State	Autonomous State
Autonomous State configuration check	Each Autonomous State configuration that is defined by the user is protected by a CRC. The check determines the validity of the calibration data by checking the correctness of the CRC.	The check is performed whenever the command to enter Autonomous State is received. If the check fails, the device does not enter Autonomous State and remains in On State instead.	The check is performed, whenever the Autonomous State configuration changes due to the violation of a threshold. Moreover, for long Autonomous State Timer periods, it is performed once Autonomous State Timer period. If the check fails, the device transitions to On State and the failure is indicated by the Device Status Register.
Temperature monitoring	During Autonomous State, the temperature is monitored to ensure that the device is not operated outside its functional temperature range.	-	The temperature is measured every time the Autonomous State Timer elapses and checks the temperature against thresholds. If the temperature is outside these thresholds, the device transitions to On State and the failure is indicated by the Device Status Register.

Attention: ***The valid ranges for the ADC and numerical under-/overflow are wider than the actual operating range. Therefore, this check cannot be used to precisely determine whether for example the pressure is within the valid measurement range.***

5.4.3 Externally Triggered Diagnosis Checks

The checks listed in Table 17 below can be performed while the device is in On State. They need to be triggered by the user through the serial interface. After triggering, the result of these checks can be read-out through the serial interface.

Table 17 Externally Triggered Self Diagnosis Checks

Diagnosis Check	Description
Signal path and ADC check	A check of the signal path and the ADC is performed. This is achieved by applying an internal test voltage to the analog signal chain and performing an ADC conversion. The result of the ADC conversion finally is checked against the applied internal voltage.
Memory check	A CRC check of the internal memories of KP497 is performed.

(table continues...)

Table 17 (continued) Externally Triggered Self Diagnosis Checks

Diagnosis Check	Description
Clock check	The frequencies of the internal clocks for the Autonomous State Timer, the ADC and the CPU are checked against each other. Additionally, the external master can check the frequency of the clock for the ADC and the CPU by measuring the busy signal during the Self-Test command: During the execution of the Self Test command, KP497 pulls the BUSY pin actively low. By measuring the time that the BUSY pin is pulled low and comparing it to the nominal execution time specified in the User Manual, the external master can determine the deviation of the clock for the ADC and the CPU from its nominal frequency.

5.4.4 Device Reset

In order to avoid device operation out of operating range or a persisting malfunction the device contains a reset circuit. Reset may be triggered by the sources described in table Always Active Self Diagnosis. Additionally, the device offers a Softreset that can be triggered in On State by the external master via serial interface command. The device is released from reset as soon as the voltage on the VDD pin increases above the reset release threshold V_{THR}. At release from reset, the device enters the Reset State.

After the device transitioned from Reset State to On State, the external master can read out the reset source via the Device Status Register.

5.4.5 Device Status Register

KP497 features a status register. The status register collects information about the occurrence of the following events:

- Device reset
- External Wake-Up
- Autonomous State Time-Out
- Threshold violations
- Diagnosis checks during Autonomous State
- Status of Acceleration recording

For the threshold violations, the status register contains two bits for each combination of measurement and threshold type. One of those two bits indicates a violation of the upper threshold and the other bit a violation of the lower threshold.

6 Application Information

The external components and external connections required by KP497 depend on whether I²C or SPI is used as serial interface and are shown in Figure 11 and Figure 12. The capacitors connected to pins VDD and VREG in these figures are specified in Table 4. The capacitor at VDD is used to reduce peak currents that occur when the internal voltage regulator starts up. In order to further suppress these peak current a larger capacitance than specified for C_{VDD} can be used.

6.1 I2C interface

Figure 11 shows the typical application diagram when using I²C. The connection indicated by the dashed line is optional and allows the external master to use the BUSY pin of KP497 to identify when the result of the previous serial interface command is ready.

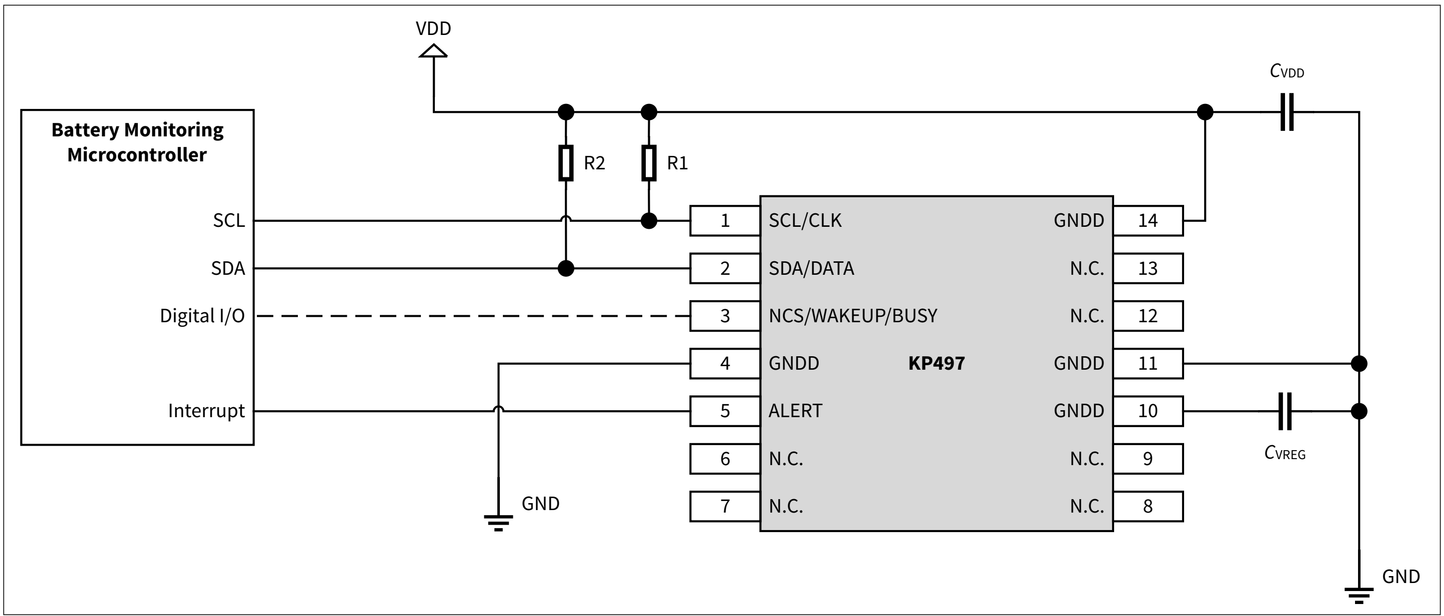

Figure 11 KP497 Application diagram for using I²C interface

The I²C pins of KP497 contain internal pull-up resistors. However, depending on the capacitive load and data rate the external pull-up resistors R1 and R2 may be required. The correct value of the pull-ups is in the responsibility of the system integrator. If only internal pull-up resistors are used the maximal load capacitance at either pin is 32 pF at 400 kbit/s. Even with external pull-up resistors the maximal load capacitance at either pin is 80 pF at 1000 kbit/s.

If external pull-up resistors are used, they must be at least 1.5 kΩ.

6.2 SPI interface

Figure 12 shows the minimal application diagram when using SPI with a 4-wire SPI master.

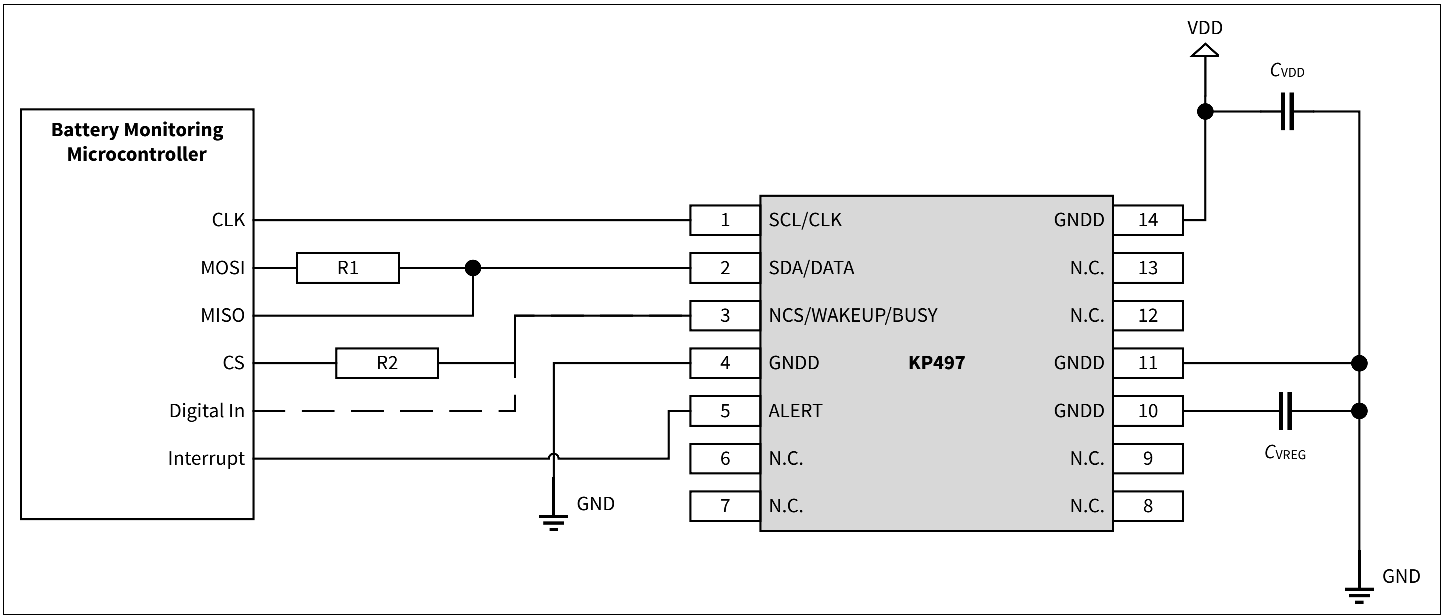

Figure 12 Application diagram for using SPI interface

The resistor R1 at the MOSI pin of the external master is intended to prevent the MOSI pin of the external master from working against the output on the DATA pin of KP497 while KP497 sends data via SPI. A value of around 10 kΩ is recommended for R1.

The resistor R2 is used to reduce the current flowing through KP497's pull-up resistor on NCS/WAKEUP/BUSY while the SPI master pulls the line low. At the same time, it must be small enough to ensure that the voltage on the pin of KP497 is within the range specified by V_{IL}. A value of 3 kΩ is recommended for R2.

The dashed line from the NCS/WAKEUP/BUSY and the "Digital In" of the Battery Monitoring Microcontroller in Figure 12 is an optional connection that allows to monitor the NCS/WAKEUP/BUSY pin in case the external master does not support changing the CS pin to an input pin in between SPI transactions. When adding this connection, the external master can determine when the SPI interface of KP497 is ready by detecting when KP497 releases its NCS/WAKEUP/BUSY pin again.

7 Package Information

The package type is PG-DSOSP-14-84. The green package fulfills the solder condition for Pb-free assembly. The moisture sensitivity is MSL 1, the solder profile is according to JEDEC-J-STD-020D, with a peak temperature of 250°C.

7.1 Package Drawing

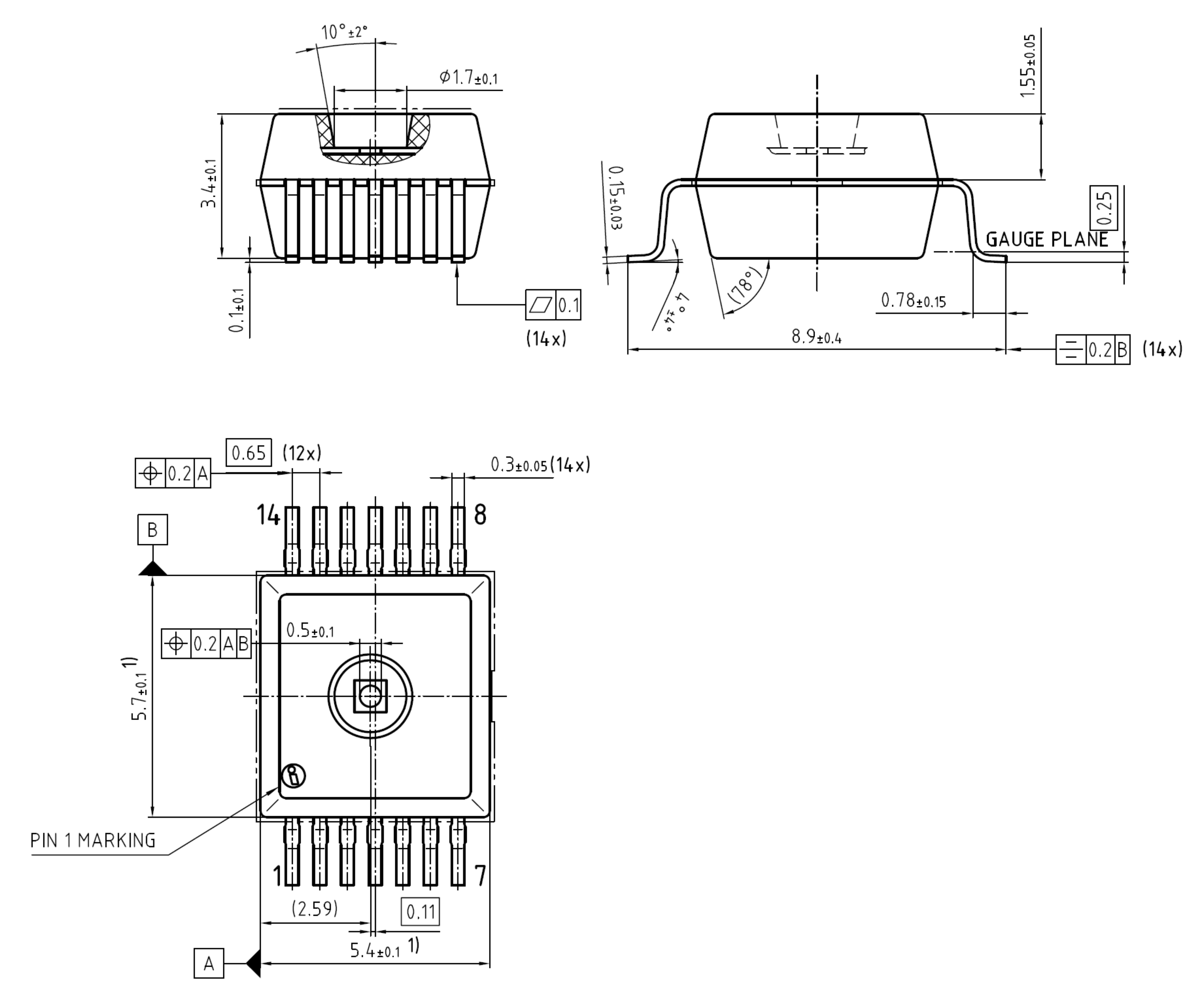

Figure 13

7.2 Package Marking

The laser marking consists of four fields:

- 11 digit Lot Code
- 5 digit Date Code, always starting with G followed by 2 digit year code and 2 digit week code, where YY is the production year minus 2000 and WW is the calendar week.
- 5 digit Product Identifier, where x depends on the product variant.
- Pin 1 marking

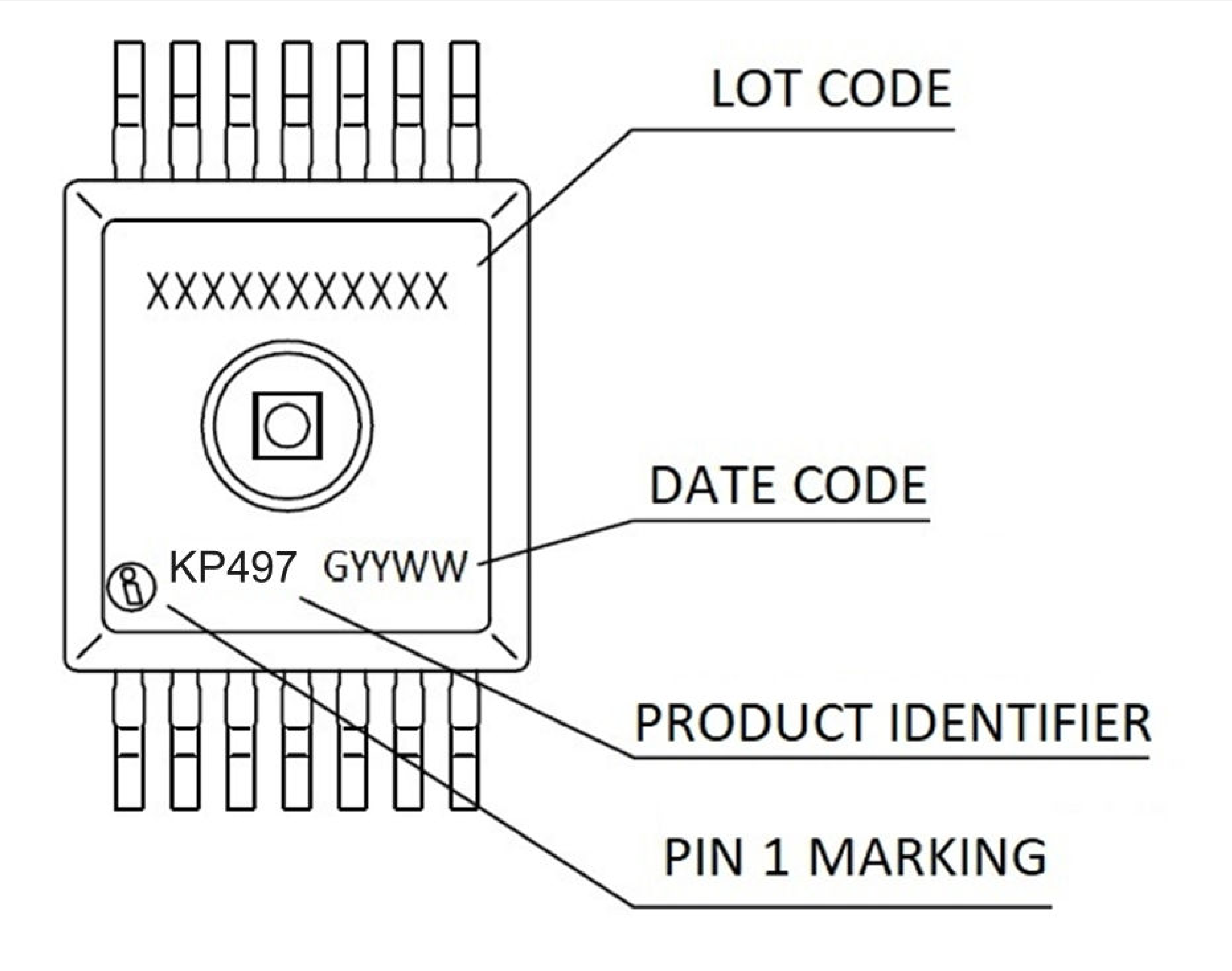

Figure 14 Package Marking

8 Revision history

Table 18 Revision history

Document version	Date of release	Description of changes
1.00	2025-11-05	Initial release
1.01	2025-12-04	Package Information added

Trademarks

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