Source Control Drawing

Part Description:	**Application Manual**
Customer Part Number:	
Abracon Part Number:	**AB-RTCMC-32.768kHz-IBO5-S3**

Customer Approval

(Please return this copy as a certification of your approval)

Approved by:	
Approval Date:	

Abracon LLC Headquarters:

2 Faraday, Suite B
Irvine, CA-92618
Ph: (949) 546-8000
Fax: (949) 546-8001

Internal Use Only	
	500251

Revision History

Revision	ECO	Description	Date	Prep'd By	Ck'd By	Ck'd By	Appr'd By
		Initial Release	11/9/2015	YH	SR	CB	JE

Table of Contents

1. Overview

- Ultra-low supply current (all at 3V):
  - 17 nA with RC oscillator
  - 22 nA with RC oscillator and Autocalibration (ACP = 512 seconds)
  - 60 nA with crystal oscillator
- Baseline timekeeping features:
  - 32.768 kHz built-in "Tuning Fork" crystal oscillator with integrated load capacitor/resistor
  - Counters for hundredths, seconds, minutes, hours, date, month, year, century, and weekday
  - Alarm capability on all counters
  - Programmable output clock generation (32.768 kHz to 1/year)
  - Countdown timer with repeat function - Automatic leap year calculation
- Advanced timekeeping features:
  - Integrated power optimized RC oscillator
  - Factory calibrated frequency offset compensation to ± 2 ppm
  - Advanced RC calibration to ± 16 ppm
  - Automatic calibration of RC oscillator to the compensated crystal oscillator
  - Watchdog timer with hardware reset
  - Up to 512 bytes of general purpose RAM
- Power management features:
  - Integrated ~1 Ω power switch for off-chip components such as a host MCU
  - System sleep manager for managing host processor wake/sleep states
  - Reset output generator
  - Supercapacitor trickle charger with programmable charging current
  - Automatic switchover to V_{BACKUP}
  - External interrupt monitor
  - Programmable low battery detection threshold
  - Programmable analog voltage comparator
- I^2C (up to 400 kHz) serial interface
- Operating voltage 1.5-3.6 V
- Clock and RAM retention voltage 1.5-3.6 V
- Operating temperature –40 to +85 °C
- All inputs include Schmitt Triggers
- Available in small and compact package size, RoHS-compliant and 100% lead-free package: 3.7 x 2.5 x 0.9 mm

1.1. General Description

The AB-RTCMC-32.768kHz-IBO5-S3 3 Real Time Clock with Power Management provides a groundbreaking combination of ultra-low power coupled with a highly sophisticated feature set. The power requirement is significantly lower than any other industry RTC (as low as 17 nA). The AB-RTCMC-32.768kHz-IBO5-S3 includes an on-chip oscillator to provide a minimum power consumption, full RTC functions including battery backup and programmable counters and alarms for timer and watchdog functions, and either an I^2C serial interface for communication with a host controller. An integrated power switch and a sophisticated system sleep manager with counter, timer, alarm, and

interrupt capabilities allows the AB-RTCMC-32.768kHz-IBO5-S3 to be used as a supervisory component in a host microcontroller based system.

1.2. Applications

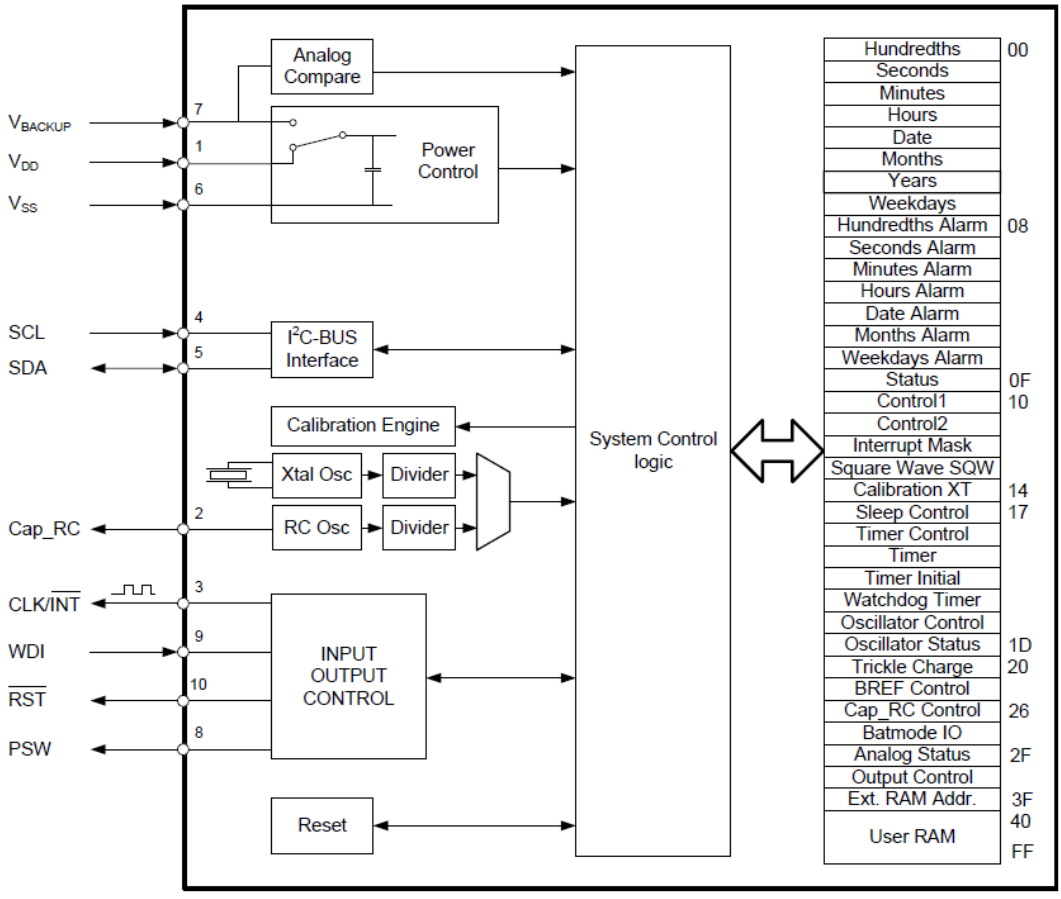
The AB-RTCMC-32.768kHz-IBO5-S3 RTC module has been specially designed for ultimate low power consumption:

- 60 nA with crystal oscillator (at 3V)
- 22 nA with RC oscillator and Autocalibration (ACP = 512 sec. at 3V)
- 17 nA with RC oscillator (at 3V)
- Permits to operate this RTC module several hours at Backup Supply Voltage using low-cost MLCC

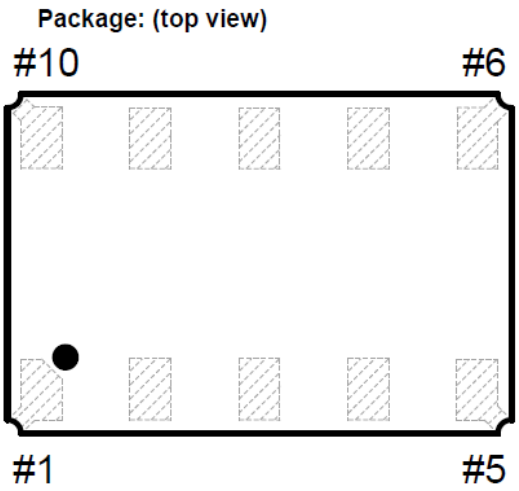
These unique features make this product perfectly suitable for many applications:

- Communication: Wireless Sensors and Tags, Handsets, Communications equipment
- Automotive: Navigation & Tracking Systems / Dashboard / Tachometers / Car Audio & Entertainment Systems
- Metering: E-Meter / Heating Counter / Smart Meters / PV Converter
- Outdoor: ATM & POS systems / Ticketing Systems
- Medical: Glucose Meter / Health Monitoring Systems
- Safety: Security & Camera Systems / Door Lock & Access Control
- Consumer: Gambling Machines / TV & Set Top Boxes / White Goods
- Automation: Data Logger / Home & Factory Automation / Industrial and Consumer Electronics

2. Block Diagram



2.1. Pinout



#1	V_{DD}	#10	$\overline{RST}$
#2	Cap_RC	#9	WDI
#3	CLK / $\overline{INT}$	#8	PSW
#4	SCL	#7	V_{BACKUP}
#5	SDA	#6	V_{SS}

2.2. Pin Description

Symbol	Pin No.	Description
V_{DD}	1	Primary power connection. If a single power supply is used, it must be connected to V_{DD}.
Cap_RC	2	Autocalibration filter connection. A 47 pF ceramic capacitor should be placed between this pin and V_{SS} for improved Autocalibration mode timing accuracy.
CLK/ $\overline{INT}$	3	Clock Output / Interrupt. Primary interrupt output connection. It is an open drain output. An external pull-up resistor must be added to this pin. It should be connected to the host device and is used to indicate when the RTC can be accessed via the I^2C interface. CLK / $\overline{INT}$ may be configured to generate several signals as a function of the CLKS field (see CONFIGURATION REGISTERS, 11h - Control2). CLK / $\overline{INT}$ is also asserted low on a power up until the AB-RTCMC-32.768kHz-IBO5-S3 has exited the reset state and is accessible via the I^2C interface. 1. CLK / $\overline{INT}$ can drive the static value of the CLKB bit. 2. CLK / $\overline{INT}$ can drive the inverse of the combined interrupt signal IRQ (see INTERRUPTS). 3. CLK / $\overline{INT}$ can drive the square wave signal SQW (see CONFIGURATION REGISTERS, 13h – Square Wave SQW) if enabled by SQWE. 4. CLK / $\overline{INT}$ can drive the inverse of the alarm interrupt signal AIRQ (see INTERRUPTS).
SCL	4	I^2C Serial Clock Input. A pull-up resistor is required on this pin.
SDA	5	I^2C Serial Data. A pull-up resistor is required on this pin.
V_{SS}	6	Ground connection
V_{BACKUP}	7	Backup Supply Voltage. If a backup voltage is not present, V_{BACKUP} is normally left floating or grounded, but it may also be used to provide the analog input to the internal comparator (see ANALOG COMPARATOR). Requires series resistor. The optimal total series impedance = V_{BACKUP} power source ESR (Equivalent Series Resistance) + external resistor value = 1.5 kΩ.

(Continued)

Symbol	Pin No.	Description
PSW	8	Power Switch Output. Secondary interrupt output connection. It is an open drain output. This pin can be left floating if not used. PSW may be configured to generate several signals as a function of the PSWS field (see CONFIGURATION REGISTERS, 11h - Control2). This pin will be configured as an ~1 Ω switch if the PSWC bit is set. 1. PSW can drive the static value of the PSWB bit. 2. PSW can drive the square wave signal SQW (see CONFIGURATION REGISTERS, 13h - Square Wave SQW) if enabled by SQWE. 3. PSW can drive the inverse of the combined interrupt signal IRQ (see INTERRUPTS). 4. PSW can drive the inverse of the alarm interrupt signal AIRQ (see INTERRUPTS). 5. PSW can drive the inverse or the not inverse of the timer interrupt signal TIRQ. 6. PSW can function as the power switch output for controlling the power of external devices (see SLEEP CONTROL).
WDI	9	Watchdog Timer reset input connection. It may also be used to generate an External interrupt with polarity selected by the EIP bit if enabled by the EIE bit. The value of the WDI pin may be read in the WDIS register bit. This pin does not have an internal pull-up or pull-down resistor and so one must be added externally. It must not be left floating or the RTC may consume higher current. Instead, it must be connected directly to either V_{DD} or V_{SS} if not used.
$\overline{RST}$	10	Reset Output. It is an open drain output. If this pin is used, an external pull-up resistor must be added to this pin. If the pin is not used, it can be left floating. The polarity is selected by the RSTP bit, which will initialize to 0 on power up to produce an active low output. See AUTOCALIBRATION FAILURE INTERRUPT ACIRQ for details of the generation of $\overline{RST}$.

2.3. Functional Description

The AB-RTCMC-32.768kHz-IBO5-S3 is an ultra-low power CMOS Real-Time Clock / Calendar module with built-in "Tuning-Fork" crystal with the nominal frequency of 32.768 kHz and an on-chip auto-calibrated RC-oscillator; no external components are required for the oscillator circuitry.

The oscillator frequency on all devices is tested not to exceed a time deviation of ± 20 ppm (parts per million) at 25°C, which equates to about ± 52 seconds per month.

This time accuracy can be further improved to ± 2 ppm (factory calibrated at 25°C) or better by individually measuring the frequency-deviation in the application at a given temperature and programming a correction value into the frequency compensation register.

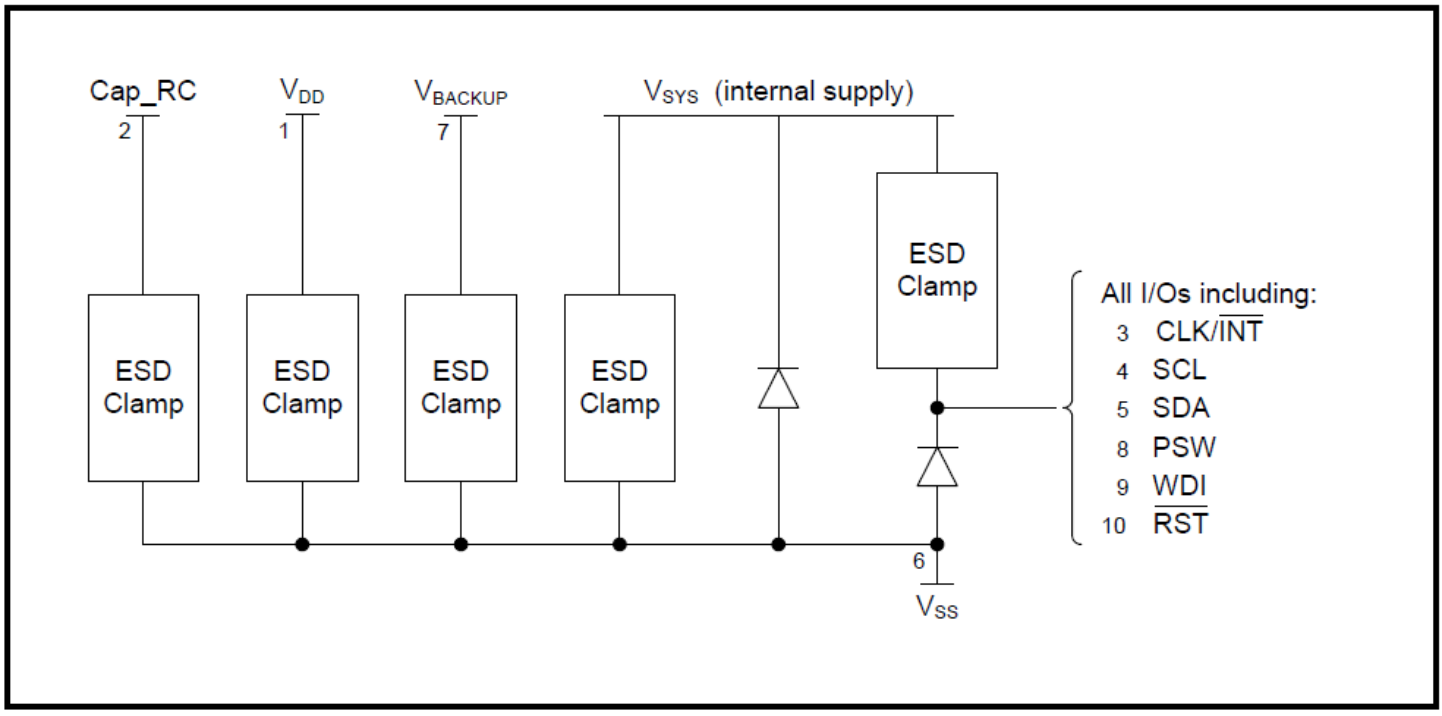
Up to 512 bytes/registers of general purpose ultra-low leakage RAM enable the storage of key parameters when operating on backup power.

The registers are accessed by selecting a register address and then performing read or write operations. Multiple reads or writes may be executed in a single access, with the address automatically incrementing after each byte.

2.4. Device Protection Diagram

The following Figure illustrates the internal ESD structure. The ESD Clamp devices are not simple diodes and are more complex structured. The V_{DD}, V_{BACKUP} and Cap_RC pins have these ESD clamps as well as the internal V_{SYS} supply, which route a positive ESD discharge to V_{SS}. Note that the V_{SYS} internal supply is switched between the V_{DD} and V_{BACKUP} supplies dependent upon the mode of operation. In V_{BACKUP} mode (when V_{DD} goes away with a V_{BACKUP} supply present), the internal V_{SYS} supply is switched to V_{BACKUP} by additional internal circuitry. In V_{DD} mode (when V_{DD} is present and regardless if a supply is present on V_{BACKUP} or not), the internal V_{SYS} supply is switched to V_{DD} by additional internal circuitry. Note that V_{SYS} does not directly touch a pin, but all of the positive charge injected onto the other digital I/O pads (CLK/$\overline{\text{INT}}$, SCL, SDA, PSW, WDI and $\overline{\text{RST}}$) gets routed to this ESD clamp on V_{SYS}. In addition, there are simple diodes between V_{SYS} and V_{SS} as well as between the digital I/O pads and V_{SS} as shown in the diagram. These diodes take care of negative discharges to any of those pads.

Internal ESD structure:



3. Register Organization

Registers are accessed by selecting a register address and then performing read or write operations. Multiple reads or writes may be executed in a single access, with the address automatically incrementing after each byte. The following tables Register Definitions (00h to 0Fh) and Register Definitions (10h to FFh) summarize the function of each register. In the table Register Definitions (00h to 0Fh), the GPx bits (where x is between 0 and 27) are 28 register bits which may be used as general purpose storage. These bits are not described in the sections below. All of the GPx bits are cleared when the AB-RTCMC-32.768kHz-IBO5-S3 powers up, and they can therefore be used to allow software to determine if a true Power On Reset (POR) has occurred or hold other initialization data.

3.1. Register Overview

Register Definitions (00h to 1Fh):

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
00h	Hundredths	80	40	20	10	8	4	2	1
01h	Seconds	GP0	40	20	10	8	4	2	1
02h	Minutes	GP1	40	20	10	8	4	2	1
03h	Hours (24 hour)	GP3	GP2	20	10	8	4	2	1
	Hours (12 hour)	GP3	GP2	AM/PM	10	8	4	2	1
04h	Date	GP5	GP4	20	10	8	4	2	1
05h	Months	GP8	GP7	GP6	10	8	4	2	1
06h	Years	80	40	20	10	8	4	2	1
07h	Weekdays	GP13	GP12	GP11	GP10	GP9	4	2	1
08h	Hundredths Alarm	80	40	20	10	8	4	2	1
09h	Seconds Alarm	GP14	40	20	10	8	4	2	1
0Ah	Minutes Alarm	GP15	40	20	10	8	4	2	1
0Bh	Hours Alarm (24 hour)	GP17	GP16	20	10	8	4	2	1
	Hours Alarm (12 hour)	GP17	GP16	AM/PM	10	8	4	2	1
0Ch	Date Alarm	GP19	GP18	20	10	8	4	2	1
0Dh	Months Alarm	GP22	GP21	GP20	10	8	4	2	1
0Eh	Weekdays Alarm	GP27	GP26	GP25	GP24	GP23	4	2	1
0Fh	Status	CB	BAT	WDF	BLF	TF	AF	EVF	X
10h	Control1	STOP	12/24	PSWB	CLKB	RSTP	ARST	PSWC	WRTC
11h	Control2	RESERVED		X	PSWS			CLKS	
12h	Interrupt Mask	CBE	IM		BLIE	TIE	AIE	EIE	X
13h	Square Wave SQW	SQWE	RESERVED		SQWS				
14h	Calibration XT	CMDX	OFFSETX						
15h	Calibration RC Upper	CMDR	OFFSETRU[13:8]						
16h	Calibration RC Lower	OFFSETRL[7:0]							
17h	Sleep Control	SLP	SLRST	EIP	X	SLF	SLW		
18h	Countdown Timer Control	TE	TM	TRPT	ARPT			TFS	
19h	Countdown Timer	128	64	32	16	8	4	2	1
1Ah	Timer Initial Value	128	64	32	16	8	4	2	1
1Bh	Watchdog Timer	WDS	WDM					WD	
1Ch	Oscillator Control	OSEL	ACAL		BOS	FOS	IOPW	OFIE	ACIE
1Dh	Oscillator Status Register	XTCAL		LKP	OMODE	RESERVED		OF	ACF
1Eh	RESERVED	RESERVED							
1Fh	Configuration Key	CONFKEY							

Register Definitions (20h to FFh):

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
20h	Trickle Charge	TCS				DIODE		ROUT	
21h	BREF Control	BREF				RESERVED			
22h	RESERVED	RESERVED							
23h	RESERVED	RESERVED							
24h	RESERVED	RESERVED							
25h	RESERVED	RESERVED							
26h	Cap_RC Control	CAPRC							
27h	IO Batmode Register	IOBM	RESERVED						
28h	ID0 (Read only)	Part Number – MS Byte = 00011000 (18h)							
29h	ID1 (Read only)	Part Number – LS Byte = 00000101 (05h)							
2Ah	ID2 (Read only)	Revision – Major = 00010					Revision – Minor = 011		
2Bh	ID3 (Read only)	Lot[7:0]							
2Ch	ID4 (Read only)	Lot[9]	Unique ID[14:8]						
2Dh	ID5 (Read only)	Unique ID[7:0]							
2Eh	ID6 (Read only)	Lot[8]	Wafter					RESERVED	
2Fh	Analog Stat. (Read only)	BREFD	BMIN	RESERVED				VINIT	RESERVED
30h	Output Control Register	WDBM	X	WDDS	X	RSTSL	X	X	CLKSL
3Fh	Extension RAM Address	X	BPOL	WDIS	X	RESERVED	XADA	XADS	
40h : 7Fh	Standard RAM	RAM data (4 x 64 bytes = 256 bytes)							
80h : FFh	Alternate RAM	RAM data (2 x 128 bytes = 256 bytes)							

3.2. Time and Date Registers

00h – Hundredths

This register holds the count of hundredths of seconds, in two binary coded decimal (BCD) digits. Values will be from 00 to 99. Note that in order to divide from 32.768 kHz, the hundredths register will not be fully accurate at all times but will be correct every 500 ms. Maximum jitter of this register will be less than 1 ms. The Hundredths Counter is not valid if the RC Oscillator is selected.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
00h	Hundredths	80	40	20	10	8	4	2	1
	Reset	1	0	0	1	1	0	0	1

Bit	Symbol	Value	Description
7:0	Hundredths	00 to 99	Holds the count of hundredths of seconds, coded in BCD format

01h –Seconds

This register holds the count of seconds, in two binary coded decimal (BCD) digits. Values will be from 00 to 59.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
01h	Seconds	GP0	40	20	10	8	4	2	1
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7	GP0	0 or 1	Register bit for general purpose use
6:0	Seconds	00 to 59	Holds the count of seconds, coded in BCD format

02h –Minutes

This register holds the count of minutes, in two binary coded decimal (BCD) digits. Values will be from 00 to 59.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
02h	Minutes	GP1	40	20	10	8	4	2	1
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7	GP1	0 or 1	Register bit for general purpose use
6:0	Minutes	00 to 59	Holds the count of minutes, coded in BCD format

03h –Hours

This register holds the count of hours, in two binary coded decimal (BCD) digits. Values will be from 00 to 23 if the 12/24 bit (see CONFIGURATION REGISTERS, 10h - Control1) is clear. If the 12/24 bit is set, the AM/PM bit will be 0 for AM hours and 1 for PM hours, and hour values will range from 1 to 12.

Hours Register (24 Hour Mode):

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
03h	Hours	GP3	GP2	20	10	8	4	2	1
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7	GP3	0 or 1	Register bit for general purpose use
6	GP2	0 or 1	Register bit for general purpose use
5:0	Hours	00 to 23	Holds the count of hours, coded in BCD format

Hours Register (12 Hour Mode):

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
03h	Hours	GP3	GP2	AM/PM	10	8	4	2	1
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7	GP3	0 or 1	Register bit for general purpose use
6	GP2	0 or 1	Register bit for general purpose use
5	AM/PM	0	AM hours
		1	PM hours
4:0	Hours	01 to 12	Holds the count of hours, coded in BCD format

04h –Date

This register holds the current day of the month, in two binary coded decimal (BCD) digits. Values will range from 01 to 31. Leap years are correctly handled from 1900 to 2199.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
04h	Date	GP5	GP4	20	10	8	4	2	1
	Reset	0	0	0	0	0	0	0	1

Bit	Symbol	Value	Description
7	GP5	0 or 1	Register bit for general purpose use
6	GP4	0 or 1	Register bit for general purpose use
5:0	Date	01 to 31	Holds the count of day of the month, coded in BCD format

05h –Months

This register holds the current month, in two binary coded decimal (BCD) digits. Values will range from 01 to 12.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
05h	Months	GP8	GP7	GP6	10	8	4	2	1
	Reset	0	0	0	0	0	0	0	1

Bit	Symbol	Value	Description
7	GP8	0 or 1	Register bit for general purpose use
6	GP7	0 or 1	Register bit for general purpose use
5	GP6	0 or 1	Register bit for general purpose use
4:0	Months	01 to 12	Holds the current month, coded in BCD format

06h – Years

This register holds the current year, in two binary coded decimal (BCD) digits. Values will range from 00 to 99.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
06h	Years	80	40	20	10	8	4	2	1
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7:0	Years	00 to 99	Holds the current year, coded in BCD format. When the Years register rolls over from 99 to 00 the Century bit CB will be toggled (see CONFIGURATION REGISTERS, 0Fh - Status) if the CBE bit is a 1 (see CONFIGURATION REGISTERS,12h - Interrupt Mask).

07h –Weekdays

This register holds the current day of the week. Values will range from 0 to 6.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
07h	Weekdays	GP13	GP12	GP11	GP10	GP9	4	2	1
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7	GP13	0 or 1	Register bit for general purpose use
6	GP12	0 or 1	Register bit for general purpose use
5	GP11	0 or 1	Register bit for general purpose use
4	GP10	0 or 1	Register bit for general purpose use
3	GP9	0 or 1	Register bit for general purpose use
2:0	Weekdays	0 to 6	Holds the weekday counter value

3.3. Alarm Registers

08h – Hundredths Alarm

This register holds the alarm value for hundredths of seconds, in two binary coded decimal (BCD) digits. Values will range from 00 to 99. It holds the special values FFh and (F0h to F9h) when ARPT bit is 7. See TIMER REGISTERS, 18h - Countdown Timer Control.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
08h	Hundredths Alarm	80	40	20	10	8	4	2	1
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7:0	Hundredths Alarm	FFh	Once per hundredth in XT mode. Once per second in RC mode. ARPT bit must be 7.
		F0h to F9h	Once per tenth in XT mode. Once per second in RC mode. ARPT bit must be 7.
		00 to 99	Holds the alarm value for hundredths of seconds, coded in BCD format. If the ARPT bit is 0 to 6.

09h –Seconds Alarm

This register holds the alarm value for seconds, in two binary coded decimal (BCD) digits. Values will range from 00 to 59.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
09h	Seconds Alarm	GP14	40	20	10	8	4	2	1
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7	GP14	0 or 1	Register bit for general purpose use
6:0	Seconds Alarm	00 to 59	Holds the alarm value for seconds, coded in BCD format.

0Ah –Minutes Alarm

This register holds the alarm value for minutes, in two binary coded decimal (BCD) digits. Values will range from 00 to 59.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0Ah	Minutes Alarm	GP15	40	20	10	8	4	2	1
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7	GP15	0 or 1	Register bit for general purpose use
6:0	Minutes Alarm	00 to 59	Holds the alarm value of minutes, coded in BCD format

0Bh –Hours Alarm

This register holds the alarm value for hours, in two binary coded decimal (BCD) digits. Values will range from 00 to 23 if the 12/24 bit (see CONFIGURATION REGISTERS, 10h - Control1) is clear. If the 12/24 bit is set, the AM/PM bit will be 0 for AM hours and 1 for PM hours, and hour values will be from 1 to 12.

Hours Register (24 Hour Mode):

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0Bh	Hours Alarm	GP17	GP16	20	10	8	4	2	1
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7	GP17	0 or 1	Register bit for general purpose use
6	GP16	0 or 1	Register bit for general purpose use
5:0	Hours Alarm	00 to 23	Holds the alarm value of hours, coded in BCD format

Hours Register (12 Hour Mode):

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0Bh	Hours Alarm	GP17	GP16	AM/PM	10	8	4	2	1
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7	GP17	0 or 1	Register bit for general purpose use
6	GP16	0 or 1	Register bit for general purpose use
5	AM/PM	0	AM hours
		1	PM hours
4:0	Hours Alarm	01 to 12	Holds the alarm value of hours, coded in BCD format

0Ch –Date Alarm

This register holds the alarm value for the date, in two binary coded decimal (BCD) digits. Values will range from 01 to 31. Leap years are correctly handled from 1900 to 2199.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0Ch	Date Alarm	GP19	GP18	20	10	8	4	2	1
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7	GP19	0 or 1	Register bit for general purpose use
6	GP18	0 or 1	Register bit for general purpose use
5:0	Date Alarm	01 to 31	Holds the alarm value of the date, coded in BCD format

0Dh –Months Alarm

This register holds the alarm value for months, in two binary coded decimal (BCD) digits. Values will range from 01 to 12.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0Dh	Months Alarm	GP22	GP21	GP20	10	8	4	2	1
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7	GP22	0 or 1	Register bit for general purpose use
6	GP21	0 or 1	Register bit for general purpose use
5	GP20	0 or 1	Register bit for general purpose use
4:0	Months Alarm	01 to 12	Holds the alarm value of months, coded in BCD format

0Eh –Weekdays Alarm

This register holds the alarm value for the day of the week. Values will range from 0 to 6.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0Eh	Weekdays Alarm	GP27	GP26	GP25	GP24	GP23	4	2	1
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7	GP27	0 or 1	Register bit for general purpose use
6	GP26	0 or 1	Register bit for general purpose use
5	GP25	0 or 1	Register bit for general purpose use
4	GP24	0 or 1	Register bit for general purpose use
3	GP23	0 or 1	Register bit for general purpose use
2:0	Weekdays Alarm	0 to 6	Holds the weekdays alarm value

3.4. Configuration Registers

0Fh – Status

This register holds a variety of status bits. The register may be written at any time to clear or set any status flag. If the ARST bit is set (see 10h - Control1), any read of the Status Register will clear interrupt flags in this register (WDF, BLF, TF, AF and EVF). The bits CB and BAT are not affected.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0Fh	Status	CB	BAT	WDF	BLF	TF	AF	EVF	X
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7	CB	Century Bit. This bit will be toggled when the Years register rolls over from 99 to 00 if the CBE bit is a 1 (see 12h - Interrupt Mask register). Assuming that the current Year is in the 20xx century the CB bit has to be set to 1.	
		0	Assumes the century is 19xx or 21xx. – Default value
		1	Assumes it is 20xx for leap year calculations
6	BAT	(Read only) V_{BACKUP} Power State	
		0	System is in POR or VDD Power state
		1	System is in VBACKUP Power state
5	WDF	Watchdog Timer Flag	
		0	No Watchdog Timer timeout trigger detected
		1	The Watchdog Timer is enabled and is triggered, and the WDS bit is 0 (see TIMER REGISTERS, 1Bh Watchdog Timer).
4	BLF	Battery Low Flag	
		0	No crossing of the reference voltage detected
		1	The battery voltage VBACKUP crossed the reference voltage selected by BREF (see ANALOG CONTROL REGISTERS, 21h - BREF Control) in the direction selected by BPOL (see RAM REGISTERS, 3Fh - Extension RAM Address)
3	TF	Countdown Timer Flag	
		0	No zero detected
		1	Countdown Timer is enabled and reaches zero
2	AF	Alarm Flag	
		0	No match detected
		1	The Alarm function is enabled and all selected Alarm registers match their respective counters
1	EVF	External Event Flag	
		0	No external trigger detected
		1	An external trigger is detected on the WDI pin. The EIE bit (see CONFIGURATION REGISTERS , 12h - Interrupt Mask) must be set in order for this interrupt to occur, but subsequently clearing EIE will not automatically clear this flag
0	X	0	Unused flag. Always 0.

10h – Control1

This register holds some major control signals.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
10h	Control1	STOP	12/24	PSWB	CLKB	RSTP	ARST	PSWC	WRTC
	Reset	0	0	0	1	0	0	1	1

Bit	Symbol	Value	Description
7	STOP	0	The clocking system is not stopped
		1	Stops the clocking system. The XT and RC Oscillators are not stopped. In XT Mode the 32.768 kHz clock output will continue to run. In RC Mode, the RC clock output will continue to run. Other clock output selections will produce static outputs. This bit allows the clock system to be precisely started, by setting it to 1 and back to 0
6	12/24	0	The Hours register operates in 24 hour mode
		1	The Hours register operates in 12 hour mode
5	PSWB	0 or 1	A static bit value which may be driven on the PSW pin. The PSWB bit cannot be set to 1 if the LKP bit is 1 (see OSCILLATOR REGISTERS, 1Dh – Oscillator Status).
4	CLKB	0 or 1	A static bit value which may be driven on the CLK/$\overline{\text{INT}}$ pin. This bit also defines the default value for the square wave signal SQW when SQWE is not asserted high. The default value of CLKB is 1 (high impedance).
3	RSTP	$\overline{\text{RST}}$ Pin Polarity	
		0	The $\overline{\text{RST}}$ pin is asserted low
		1	The $\overline{\text{RST}}$ pin is asserted high
2	ARST	Auto Reset Enable (Interrupt Flags in Status Register)	
		0	The interrupt flags must be explicitly cleared by writing the Status register
		1	A read of the Status register will cause the interrupt flags in the Status register to be cleared (WDF, BLF, TF, AF, EVF)
1	PSWC	PSW Pin Control (1Ω/normal)	
		0	The PSW pin is a normal open drain output
		1	The PSW pin is driven by an approximately 1 Ω pull-down which allows the AB-RTCMC-32.768kHz-IBO5-S3 to switch power to other system devices through this pin
0	WRTC	Write RTC	
		0	Prevents inadvertent software access to the Counters
		1	In order to write to any of the Counter registers (Hundredths, Seconds, Minutes, Hours, Date, Months, Years or Weekdays)

11h – Control2

This register holds additional control and configuration signals for the flexible output pins CLK/$\overline{\text{INT}}$ and PSW.

Note that PSW and CLK/$\overline{\text{INT}}$ are open drain outputs

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
11h	Control2	RESERVED		X	PSWS			CLKS	
	Reset	0	0	1	1	1	1	0	0
	Set X to 0			0					

Bit	Symbol	Value	Description
7:6	RESERVED	00 to 11	RESERVED
5	X	0 or 1	Unused, but has to be 0 to avoid extraneous leakage
4:2		PSW Pin Function Selection	
		000	Inverse of the combined interrupt signal IRQ if at least one interrupt is enabled, else static PSWB
		001	SQW if SQWE = 1, else static PSWB
		010	RESERVED
		011	Inverse AIRQ if AIE is set, else static PSWB
		100	TIRQ if TIE is set, else static PSWB
		101	Inverse TIRQ if TIE is set, else static PSWB
		110	SLEEP signal
		111	Static PSWB
1:0		CLK/$\overline{\text{INT}}$ Pin Function Selection	
		00	Inverse of the combined interrupt signal IRQ if at least one interrupt is enabled, else static CLKB
		01	SQW if SQWE = 1, else static CLKB
		10	SQW if SQWE = 1, else inverse of the combined interrupt signal IRQ if at least one interrupt is enabled, else static CLKB
		11	Inverse AIRQ if AIE is set, else static CLKB

12h – Interrupt Mask

This register holds the interrupt enable bits and other configuration information.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
12h	Interrupt Mask	CBE	IM		BLIE	TIE	AIE	EIE	X
	Reset	1	1	1	0	0	0	0	0

Bit	Symbol	Value	Description
7	CBE	Century Bit Enable	
		0	The CB bit will never be automatically updated
		1	The CB bit will toggle when the Years register rolls over from 99 to 00
6:5	IM	Alarm Interrupt Mode. This controls the duration of the Inverse AIRQ interrupt as shown below. The interrupt output always goes high when the corresponding flag in the Status Register is cleared. In order to minimize current drawn by the AB-RTCMC-32.768kHz-IBO5-S3 this field should be kept at 3h	
		00	Level (static) for both XT mode and RC mode
		01	1/8192 seconds for XT mode. 1/64 seconds for RC mode
		10	1/64 seconds for both XT mode and RC mode
		11	1/4 seconds for both XT mode and RC mode – Default value
4	BLIE	Battery Low Interrupt Enable	
		0	Disables the battery low interrupt
		1	The battery low detection will generate an interrupt BLIRQ
3	TIE	Timer Interrupt Enable	
		0	Disables the timer interrupt
		1	The Countdown Timer will generate a TIRQ interrupt signal and set the TF flag when the timer reaches 0
2	AIE	Alarm Interrupt Enable	
		0	Disables the alarm interrupt
		1	A match of all the enabled alarm registers will generate an AIRQ interrupt signal
1	EIE	External Interrupt Enable	
		0	Disables the external interrupt
		1	The WDI input pin will generate an external interrupt EIRQ when the edge specified by EIP occurs (see CONFIGURATION REGISTERS, 12h - Interrupt Mask)
0	X	0	Unused, but has to be 0 to avoid extraneous leakage

13h – Square Wave SQW

This register holds the control for the square wave signal SQW. Note that some frequency selections are not valid if the RC Oscillator is selected.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
13h	Square Wave SQW	SQWE	RESERVED		SQWS				
	Reset	0	0	1	0	0	1	1	0

Bit	Symbol	Value	Description
7	SQWE	Square Wave Enable (Internal SQW)	
		0	The square wave signal SQW is held at the static value of CLKB
		1	The square wave signal SQW is enabled
6:5	RESERVED	00 to 11	RESERVED
4:0	SQWS	Square Wave Selection (Internal SQW)	
		00000 to 11111	Selects the frequency of the square wave signal SQW, as shown in the following table. Note that some selections are not valid if the RC oscillator is selected. Some selections also produce short pulses rather than square waves, and are intended primarily for test usage

SQWS	Square Wave Signal SQW Select	SQWS	Square Wave Signal SQW Select
00000	1 century (2)	10000	1/2 Hz
00001	32.768kHz (1)	10001	1/4 Hz
00010	8.192 kHz (1)	10010	1/8 Hz
00011	4.096 kHz (1)	10011	1/16 Hz
00100	2.048 kHz (1)	10100	1/32 Hz
00101	1.024 kHz (1)	10101	1/60 Hz (1 minute)
00110	512 Hz (1) – Default value	10110	16.384 kHz (1) – Highest calibrated frequency in XT mode
00111	256 Hz (1)	10111	100 Hz (1) (2)
01000	128 Hz (3)	11000	1 hour (2)
01001	64 Hz – highest calibrated frequency in RC mode	11001	1 day (2)
01010	32 Hz	11010	TIRQ
01011	16 Hz	11011	Inverse TIRQ
01100	8 Hz	11100	1 year (2)
01101	4Hz	11101	1 Hz to Counters (2)
01110	2Hz	11110	1/32 Hz from Autocalibration (2)
01111	1Hz	11111	1/8 Hz from Autocalibration (2)

(1) Not applicable if the RC Oscillator is selected.
(2) Pulses for Test Usage.
(3) If the RC Oscillator is selected the frequency is typically 122 Hz.

3.5. Calibration Registers

14h – Calibration XT

This register holds the control signals for the digital calibration function of the XT Oscillator. This register is initialized with a factory value which calibrates the XT Oscillator. The highest modified frequency is 16.384 kHz (see XT OSCILLATOR DIGITAL CALIBRATION).

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
14h	Calibration XT	CMDX	OFFSETX						
	Reset	0	Preconfigured (Factory Calibrated)						

Bit	Symbol	Value	Description
7	CMDX	XT Calibration Adjust Mode	
		0	Normal Mode, each adjustment step is ± 2 ppm. The calibration period is 32 seconds.
		1	Coarse Mode, each adjustment step is ± 4 ppm. The calibration period is 16 seconds.
6:0	OFFSETX	-64 to +63	The amount to adjust the effective time. This is a two's complement number with a range of -64 to +63 adjustment steps (Factory Calibrated).

OFFSETX (7 Bits)	Unsigned Value	Two's complements	Correction Value in ppm (*)	
			CMDX = 0	CMDX = 1
011'1111	63	63	120.163	240.326
011'1110	62	62	118.256	236.511
:	:	:	:	:
000'0001	1	1	1.907	3.815
000'0000	0	0	0.000	0.000
111'1111	127	-1	-1.907	-3.815
111'1110	126	-2	-3.815	-7.629
:	:	:	:	:
100'0001	65	-63	-120.163	-240.326
100'0000	64	-64	-122.070	-244.141

(*) Calculated with 5 decimal places ($1'000'000/2^{19} = 1.90735$ ppm)

15h – Calibration RC Upper

This register holds the control signals for the fine digital calibration function of the low power RC Oscillator. This register is initialized with a factory value which calibrates the RC Oscillator. The highest modified frequency is 64 Hz (see RC OSCILLATOR DIGITAL CALIBRATION).

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
15h	Calibration RC Upper	CMDR		OFFSETRU					
	Reset	Preconfigured		Preconfigured (Factory Calibrated)					

Bit	Symbol	Value	Description
7:6	CMDR	00 to 11	The calibration adjust mode for the RC calibration adjustment. CMDR selects the highest possible calibration period used in the RC Calibration process as shown in the following table.
5:0	OFFSETRU	000000 to 111111	The upper 6 bits of the OFFSETR field, which is used to set the amount to adjust the effective time. OFFSETR is a two's complement number with a range of -2^{13} to $+2^{13}-1$ adjustment steps (Factory Calibrated). See Table 1.

CMDR	Calibration Period	Minimal Adjustment Step	Maximum Adjustment
00	8192 seconds	+/-1.91ppm	+/-1.56%
01	4096 seconds	+/-3.82ppm	+/-3.13%
10	2048 seconds	+/-7.63ppm	+/-6.25%
11	1024 seconds	+/-15.26ppm	+/-12.5%

16h – Calibration RC Lower

This register holds the lower 8 bits of the OFFSETR field for the digital calibration function of the low power RC Oscillator. This register is initialized with a factory value which calibrates the RC Oscillator. The highest modified frequency is 64 Hz (see RC OSCILLATOR DIGITAL CALIBRATION).

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
16h	Calibration RC Lower	OFFSETRL							
	Reset	Preconfigured (Factory Calibrated)							

Bit	Symbol	Value	Description
7:0	OFFSETRL	00h to FFh	The lower 8 bits of the OFFSETR field, which is used to set the amount to adjust the effective time. OFFSETR is a two's complement number with a range of -2^{13} to $+2^{13}-1$ adjustment steps (Factory Calibrated). See Table 1.

Table 1: Calibration RC

OFFSETX (14 Bits)	Unsigned Value	Two's complements	Correction Value in ppm (*)			
			CMDR = 00	CMDR = 01	CMDR = 10	CMDR = 11
01'1111'1111'1111	8191	8191	15623	31246	62492	124985
01'1111'1111'1110	8190	8190	15621	31242	62485	124970
:	:	:	:	:	:	:
00'0000'0000'0001	1	1	1.907	3.815	7.629	15.259
00'0000'0000'0000	0	0	0.000	0.000	0.000	0.000
11'1111'1111'1111	16383	-1	-1.907	-3.815	-7.629	-15.259
11'1111'1111'1110	16382	-2	-3.815	-7.629	-15.259	-30.518
:	:	:	:	:	:	:
10'0000'0000'0001	8193	-8191	-15623	-31246	-62492	-124985
10'0000'0000'0000	8192	-8192	-15625	-31250	-62500	-125000

(*) Calculated with 5 decimal places ($1'000'000/2^{19}$ = 1.90735 ppm)

3.6. Sleep Control Register

17h – Sleep Control

This register controls the Sleep function of the Power Control system.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
17h	Sleep Control	SLP	SLRST	EIP	X	SLF	SLW		
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7	SLP	Sleep Request signal, see also SLEEP CONTROL STATE MACHINE	
		0	The Sleep Control State Machine is in RUN mode. If either STOP is 1 or no interrupt is enabled, SLP will remain at 0 even after an attempt to set it to 1.
		1	When set to 1, the Sleep Control State Machine will transition to the SWAIT state as long as a valid interrupt is enabled. This bit will be cleared when the Sleep Control State Machine returns to the RUN state.
6	SLRST	Reset $\overline{RST}$ when in SLEEP mode	
		0	$\overline{RST}$ does not indicate the SLEEP state.
		1	Asserts $\overline{RST}$ low when the Sleep Control State Machine is in the SLEEP state.
5	EIP	External Interrupt Polarity	
		0	The external interrupt will trigger on a falling edge of the WDI pin.
		1	The external interrupt will trigger on a rising edge of the WDI pin.
4	X	0	Unused, but has to be 0 to avoid extraneous leakage.
3	SLF	Sleep Flag	
		0	No previous SLEEP state occurred.
		1	Flag is set when the AB-RTCMC-32.768kHz-IBO5-S3 enters Sleep Mode. This allows software to determine if a SLEEP has occurred since the last time this bit was read.
2:0	SLW	Sleep Wait Periods. The number of ~8 ms waiting periods after SLP is set until the Sleep Control State Machine goes into the SLEEP state. If SLW is not 0, the actual delay is guaranteed to be between SLW and (SLW + 1) periods.	
		SLW	Wait Time
		000 (0)	The transition will occur with no delay.
		001 (1)	8 to 16 ms
		010 (2)	16 to 24 ms
		011 (3)	24 to 32 ms
		100 (4)	32 to 40 ms
		101 (5)	40 to 48 ms
		110 (6)	48 to 56 ms
		111 (7)	56 to 64 ms

3.7. Timer Registers

18h – Countdown Timer Control

This register controls the Countdown Timer function. Note that the TFS = 00 frequency selection is slightly different depending on whether the 32.768 kHz XT Oscillator or the RC Oscillator is selected. In some RC Oscillator modes, the interrupt pulse output is specified as RC Pulse. In these cases the interrupt output will be a short negative going pulse which is typically between 100 and 400 µs. This allows control of external devices which require pulses shorter than the minimum 7.8 ms pulse created directly by the RC Oscillator.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
18h	Countdown Timer Control	TE	TM	TRPT	ARPT			TFS	
	Reset	0	0	1	0	0	0	1	1

Bit	Symbol	Value	Description
7	TE	Timer Enable	
		0	The Countdown Timer retains the current value. The clock to the Timer is disabled for power minimization.
		1	The Countdown Timer will count down.
6	TM	Timer Mode Along with TRPT, this controls the Countdown Timer Interrupt function as shown in Table 2. A Pulse interrupt will cause the inverse of the combined interrupt signal IRQ signal to be driven low for the time shown in Table 2 or until the flag is cleared. A Level Interrupt will cause the inverse of the combined interrupt signal IRQ signal to be driven low by a Countdown Timer interrupt until the associated flag is cleared.	
		0	Pulse (TRPT is 0 or 1)
		1	Level if TRPT = 0. Pulse if TRPT = 1.
5	TRPT	Timer Repeat Along with TM, this controls the Countdown Timer Interrupt function as shown in Table 2.	
		0	Single is selected. The Countdown Timer will halt when it reaches zero. If TM = 0, it allows the generation of periodic interrupts of virtually any frequency. If TM = 1, it is a Level.
		1	Repeat is selected. The Countdown Timer reloads the value from the Timer Initial register upon reaching 0, and continues counting.
4:2	ARPT	Alarm Repeat	
		0 to 7	These bits enable the Alarm Interrupt repeat function together with the Hundredths Alarm register value, as shown in the following table.
1:0	TFS	Timer Frequency Selection	
		00 to 11	Select the clock frequency and interrupt pulse width of the Countdown Timer, as defined in Table 2. The RC Pulse is a short negative going 100-400 µs pulse.

ARPT	08h- Hundredths Alarm Register Value	Repeat When
7	FFh	Once per hundredth (100 Hz) (1)
	F0h to F9h	Once per tenth (10 Hz) (1)
	00 to 99	Hundredths match (once per second) (2)
6		Hundredths and seconds match (once per minute) (2)
5		Hundredths, seconds and minutes match (once per hour) (2)
4		Hundredths, seconds, minutes and hours match (once per day) (2)
3		Hundredths, seconds, minutes, hours and weekday match (once per week) (2)
2		Hundredths, seconds, minutes, hours and date match (once per month) (2)
1		Hundredths, seconds, minutes, hours, date and month match (once per year) (2)
0		Alarm Disabled

(1) Once per second if RC Oscillator selected.
(2) The Hundredths are not valid if the RC Oscillator is selected.

Table 2: Countdown Timer Function Select

TM	TRPT	TFS	Interrupt Signal		Countdown Timer Frequency		Interrupt Pulse Width	
			Pulse/Level	Single/Repeat	XT Oscillator	RC Oscillator	XT Oscillator	RC Oscillator
0	0	00	Pulse	Single	4096 Hz	Typ. 122 Hz	1/4096 s	Typ. 1/122 s
0	0	01	Pulse	Single	64 Hz	64 Hz	1/128 s	Typ. 1/122 s
0	0	10	Pulse	Single	1 Hz	1 Hz	1/64 s	1/64 s
0	0	11	Pulse	Single	1/60 Hz	1/60 Hz	1/64 s	1/64 s
0	1	00	Pulse	Repeat	4096 Hz	Typ. 122 Hz	1/4096 s	Typ. 1/122 s
0	1	01	Pulse	Repeat	64 Hz	64 Hz	1/128 s	Typ. 1/122 s
0	1	10	Pulse	Repeat	1 Hz	1 Hz	1/64 s	1/64 s
0	1	11	Pulse	Repeat	1/60 Hz	1/60 Hz	1/64 s	1/64 s
1	0	00	Level	Single	4096 Hz	Typ. 122 Hz	-	-
1	0	01	Level	Single	64 Hz	64 Hz	-	-
1	0	10	Level	Single	1 Hz	1 Hz	-	-
1	0	11	Level	Single	1/60 Hz	1/60 Hz	-	-
1	1	00	Pulse	Repeat	4096 Hz	Typ. 122 Hz	1/4096 s	RC Pulse
1	1	01	Pulse	Repeat	64 Hz	64 Hz	1/4096 s	RC Pulse
1	1	10	Pulse	Repeat	1 Hz	1 Hz	1/4096 s	RC Pulse
1	1	11	Pulse	Repeat	1/60 Hz	1/60 Hz	1/4096 s	RC Pulse

19h – Countdown Timer

This register holds the current value of the Countdown Timer. It may be loaded with the desired starting value when the Countdown Timer is stopped.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
19h	Countdown Timer	128	64	32	16	8	4	2	1
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7:0	Countdown Timer	0 to 255	The current value of the Countdown Timer in binary format.

1Ah – Timer Initial Value

This register holds the value which will be reloaded into the Countdown Timer when it reaches zero if the TRPT bit is a 1. This allows for periodic timer interrupts (see calculation below).

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1Ah	Timer Initial Value	128	64	32	16	8	4	2	1
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7:0	Countdown Timer	0 to 255	The value in binary format reloaded into the Countdown Timer when it reaches zero if the TRPT bit is a 1.

Calculation of the period:

$$period = (Timer\ Initial\ Value + 1)\frac{1}{Countdown\ Timer\ Frequency}$$

Example: For a period of 4 minutes (240 seconds) and with a Countdown Timer Frequency of 1 Hz (TFS = 10) a Timer Initial Value of 239 is needed:

$$period = (239 + 1)\frac{1}{1\ Hz} = 240\ seconds$$

1Bh – Watchdog Timer

This register controls the Watchdog Timer function.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1Bh	Watchdog Timer	WDS	WDM					WD	
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7	WDS	Watchdog Timer Steering	
		0	The Watchdog Timer will generate a WIRQ interrupt signal and sets the WDF flag to 1 when it times out.
		1	The Watchdog Timer will generate a Reset $\overline{RST}$ when it times out. $\overline{RST}$ pin is asserted low within 1/16 second of the timer reaching zero and remains asserted low for 1/16 second. The WDF flag is not set.
6:2	WDM	Watchdog Timer cycle Multiplier	
		0	Disables the Watchdog Timer function.
		1 to 31	Watchdog Multiplier value. The number of clock cycles which must occur before the Watchdog Timer times out. See table below.
1:0	WD	Watchdog timer Clock Frequency	
		00	16 Hz
		01	4 Hz
		10	1 Hz
		11	¼ Hz

WD	Clock Period	WDM	Timeout
00	62.5 ms	1 to 31	62.5 to 1937.5 ms
01	250 ms	1 to 31	250 to 7750 ms
10	1 second	1 to 31	1 to 31 seconds
11	4 seconds	1 to 31	4 to 124 seconds

3.8. Oscillator Registers

1Ch – Oscillator control

This register controls the overall Oscillator function. It may only be written if the Configuration Key register value CONFKEY contains the value A1h. An Autocalibration cycle is initiated immediately whenever this register is written with a value in the ACAL field which is not zero.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1Ch	Oscillator Control	OSEL	ACAL		BOS	FOS	IOPW	OFIE	ACIE
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7	OSEL	Oscillator Selection	
		0	Request the XT Oscillator to generate a 32.768 kHz clock to the timer circuit. Note that if the XT Oscillator is not operating, the oscillator switch will not occur. The OMODE field (see OSCILLATOR REGISTERS,1Dh – Oscillator Status) indicates the actual oscillator which is selected.
		1	Request the RC Oscillator to generate the clock for the timer circuits (nominal 128 Hz).
6:5	ACAL	Autocalibration Mode Controls the automatic calibration function (see AUTOCALIBRATION FREQUENCY AND CONTROL).	
		00	No Autocalibration
		01	RESERVED
		10	Autocalibrate every 1024 seconds (~17 minutes)
		11	Autocalibrate every 512 seconds (~8.5 minutes)
4	BOS	Oscillator Switch when V_{BACKUP}	
		0	No automatic oscillator switching occurs.
		1	The oscillator will automatically switch to the RC oscillator (Autocalibration Mode according to the ACAL field) when the system is powered from the battery (V_{BACKUP} Power state).
3	FOS	Oscillator Switch when XT Oscillator Failure	
		0	No automatic oscillator switching occurs.
		1	The oscillator will automatically switch to the RC oscillator (Autocalibration Mode according to the ACAL field) when an XT oscillator failure is detected.
2	IOPW	I^2C in Function of the PSW Pin Configuration and Setting	
		0	The I^2C interface remains enabled independent of the PSW control bits PSWC and PSWS.
		1	The I^2C interface will be disabled when the PSW pin is configured as the low resistance power switch (PSWC = 1) and set to open (PSW pin = 1, high impedance). In order for the I2C interface to be disabled, the PSW pin must be configured for the sleep function by setting the PSWS field to a value of 6. This insures that a powered down I2C master (i.e., the host controller) does not corrupt the AB-RTCMC-32.768kHz-IBO5-S3.
1	OFIE	XT Oscillator Failure Interrupt Enable	
		0	Disables the XT oscillator failure interrupt.
		1	An XT Oscillator Failure will generate an OFIRQ interrupt signal.

Bit	Symbol	Value	Description
0	ACIE	Autocalibration Failure Interrupt Enable	
		0	Disables the Autocalibration Failure Interrupt
		1	An Autocalibration Failure will generate an ACIRQ interrupt signal.

1Dh – Oscillator Status Register

This register holds several miscellaneous bits used to control and observe the oscillators.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1Dh	Oscillator Status	XTCAL		LKP	OMODE	RESERVED		OF	ACF
	Reset	0	0	1	0	0	0	1	0

Bit	Symbol	Value	Description
7:6	XTCAL	Extended Crystal Calibration This field defines the compensation of a higher XT oscillator frequency, independent of the normal Crystal Calibration function controlled by the Calibration XT Register. The frequency generated by the Crystal Oscillator is slowed by 122 ppm times the value in the XTCAL field. Normally, this field remains 00.	
		00	0 ppm
		01	-122 ppm
		10	-244 ppm
		11	-366 ppm
5	LKP	Locking of the PSW Pin	
		0	PSW pin is not locked.
		1	Locks PSW pin. The PSWB bit (see CONFIGURATION REGISTERS, 10h – Control1) cannot be set to 1. This is typically used when PSW is configured as a power switch, and setting PSWB to a 1 would turn off the switch (high impedance).
4	OMODE	(read only) – Oscillator Mode. If the STOP bit is set, the OMODE bit is invalid.	
		0	The XT Oscillator is selected to drive the internal clocks.
		1	The RC Oscillator is selected to drive the internal clocks.
3:2	RESERVED	00 to 11	RESERVED
1	OF	XT Oscillator Failure	
		0	No XT oscillator failure has occurred.
		1	XT Oscillator Failure. This bit is set on a power on reset (POR), when both the system and battery voltages have dropped below acceptable levels. It is also set if an XT Oscillator Failure occurs, indicating that the crystal oscillator is running at less than 8 kHz. It can be cleared by writing a 0 to the bit.
0	ACF	Autocalibration Failure	
		0	No autocalibration failure has occurred.
		1	Set when an Autocalibration Failure occurs, indicating that either the RC Oscillator frequency is too different from 128 Hz to be correctly calibrated or the XT Oscillator did not start.

3.9. Miscellaneous Registers

1Fh – Configuration Key

This register contains the Configuration Key CONFKEY, which must be written with specific values in order to access some registers and functions. CONFKEY is reset to 00h on any register write.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1Fh	Configuration Key	CONFKEY							
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7:0	CONFKEY	Configuration Key. Written with specific values in order to access some registers and functions.	
		A1h	Writing a value of A1h enables write access to the Oscillator Control register.
		3Ch	Writing a value of 3Ch does not update the CONFKEY value, but generates a Software Reset (see SOFTWARE RESET).
		9Dh	Writing a value of 9Dh enables write access to the Trickle Charge Register (20h), the BREF Register (21h), the CAPRC Register (26h), the IO Batmode Register (27h) and the Output Control Register (30h).
		00h	CONFKEY is reset to 00h on any register write.

3.10.Analog Control Registers

20h – Trickle Charge

This register controls the Trickle Charger. The Configuration Key CONFKEY must be written with the value 9Dh in order to enable access to this register. See TRICKLE CHARGER.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
20h	Trickle charge	TCS				DIODE		ROUT	
	Reset	0	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7:4	TCS	1010	Trickle Charge Select. A value of 1010 enables the trickle charge function. All other values disable the Trickle Charger.
3:2	DIODE	Diode for the Trickle Charger	
		00	Disables the Trickle Charger.
		01	Inserts a schottky diode into the trickle charge circuit, with a voltage drop of 0.3V.
		10	Inserts a standard diode into the trickle charge circuit, with a voltage drop of 0.6V.
		11	Disables the Trickle Charger.
1:0	ROUT	Resistor for the Trickle Charger	
		00	Disables the Trickle Charger.
		01	The series resistor of the trickle charge circuit is 3 kΩ
		10	The series resistor of the trickle charge circuit is 6 kΩ
		11	The series resistor of the trickle charge circuit is 11 kΩ

21h – BREF Control

This register controls the reference voltages used for the Analog Comparator. CONFKEY must be written with the value 9Dh in order to enable access to this register.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
21h	BREF Control	BREF				RESERVED			
	Reset	1	1	1	1	0	0	0	0

Bit	Symbol	Value	Description	
7:4	BREF	Voltage Reference This selects the voltage reference which is compared to the battery voltage VBACKUP to produce the BREFD signal (see ANALOG CONTROL REGISTERS, 2Fh – Analog Status and BREF ELECTRICAL CHARACTERISTICS). The valid BREF values are 7h, Bh, Dh, and Fh. All other values are RESERVED.		
			V_{BACKUP} Falling Voltage (TYP), (BPOL = 0)	V_{BACKUP} Rising Voltage (TYP), (BPOL = 1)
		0111	2.5V	3.0V
		1011	2.1V	2.5V
		1101	1.8V	2.2V
		1111	1.4V – Default value	1.6V – Default value
3:0	RESERVED	0000 to 1111	RESERVED	

27h – IO Batmode Register

This register holds the IOBM bit which controls the enabling and disabling of the I^2C interface when a Brownout Detection occurs. It may only be written if the Configuration Key CONFKEY contains the value 9Dh. All undefined bits must be written with 0.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
27h	IO Batmode	IOBM	RESERVED						
	Reset	1	0	0	0	0	0	0	0

Bit	Symbol	Value	Description
7	IOBM	I^2C in V_{BACKUP} Power state	
		0	The I^2C interface is disabled in the V_{BACKUP} Power state in order to prevent erroneous accesses to the AB-RTCMC-32.768kHz-IBO5-S3 if the bus master loses power.
		1	The AB-RTCMC-32.768kHz-IBO5-S3 will not disable the I^2C interface even if V_{DD} goes away and VBACKUP is still present. This allows external access while the AB-RTCMC-32.768kHz-IBO5-S3 is powered by V_{BACKUP}.
6:0	RESERVED	0000000	RESERVED – must write only 0000000.

2Fh – Analog Status Register (Read only)

This register holds eight status bits which indicate the voltage levels of the V_{DD} and V_{BACKUP} power inputs.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
2Fh	Analog Status (Read only)	BREFD	BMIN	RESERVED				VINIT	RESERVED
	Reset								

Bit	Symbol	Value	Description
7	BREFD	0	The V_{BACKUP} input voltage is below the BREF threshold.
		1	The V_{BACKUP} input voltage is above the BREF threshold.
6	BMIN	0	The V_{BACKUP} input voltage is below the minimum operating voltage (1.2 V).
		1	The V_{BACKUP} input voltage is above the minimum operating voltage (1.2 V).
5:2	RESERVED	0000 to 1111	RESERVED
1	VINIT	0	The V_{DD} input voltage is below the minimum power up voltage (1.6 V).
		1	The V_{DD} input voltage is above the minimum power up voltage (1.6 V).
0	RESERVED	0 or 1	RESERVED

30h – Output Control Register

This register holds bits which control the behavior of the I^2C pins under various power down conditions. The Configuration Key CONFKEY must be written with the value 9Dh in order to enable access to this register.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
30h	Output Control	WDBM	X	WDDS	X	RSTSL	X	X	CLKSL
	Reset	0	0	0	0	0	0	0	0
	Set X to 1				1				

Bit	Symbol	Value	Description
7	WDBM	0	The WDI input is disabled when the AB-RTCMC-32.768kHz-IBO5-S3 is powered from V_{BACKUP}.
		1	The WDI input is enabled when the AB-RTCMC-32.768kHz-IBO5-S3 is powered from V_{BACKUP}.
6	X	0	Unused, but has to be 0 to avoid extraneous leakage. Disables an internal input when the AB-RTCMC-32.768kHz-IBO5-S3 is powered from V_{BACKUP}.
5	WDDS	0	The WDI input is enabled when the AB-RTCMC-32.768kHz-IBO5-S3 is in Sleep Mode.
		1	The WDI input is disabled when the AB-RTCMC-32.768kHz-IBO5-S3 is in Sleep Mode. If WDI is disabled, it will appear as a 1 to the internal logic.
4	X	1	Unused, but has be set to 1 to avoid extraneous leakage. Disables an internal input when the AB-RTCMC-32.768kHz-IBO5-S3 is in Sleep Mode.

Bit	Symbol	Value	Description
3	RSTSL	0	The $\overline{RST}$ output pin is completely disconnected when the AB-RTCMC-32.768kHz-IBO5-S3 is in Sleep Mode.
		1	The output pin is enabled when the AB-RTCMC-32.768kHz-IBO5-S3 is in Sleep Mode. $\overline{RST}$
2	X	0	Unused, but has to be 0 to avoid extraneous leakage. If 0, an internal output is completely disconnected when the AB-RTCMC-32.768kHz-IBO5-S3 is in Sleep Mode.
1	X	0	Unused, but has to be 0 to avoid extraneous leakage. If 0, an internal output is completely disconnected when the AB-RTCMC-32.768kHz-IBO5-S3 is in Sleep Mode.
0	CLKSL	0	The CLK / $\overline{INT}$ output pin is completely disconnected when the AB-RTCMC-32.768kHz-IBO5-S3 is in Sleep Mode.
		1	The CLK / $\overline{INT}$ output pin is enabled when the AB-RTCMC-32.768kHz-IBO5-S3 is in Sleep Mode.

3.11.ID Registers

28h – ID0 – Part Number Upper Register (Read only)

This register holds the upper eight bits of the part number in BCD format, which is always 18h for the AB-RTCMC-32.768kHz IBO5-S3.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
28h	ID0-Part Number Upper (Read only)	Part Number – Digit 3				Part Number – Digit 2			
	Reset	0	0	0	1	1	0	0	0

29h – ID1 – Part Number Lower Register (Read only)

This register holds the lower eight bits of the part number in BCD format, which is always 05h for the AB-RTCMC-32.768kHz IBO5-S3.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
29h	ID1-Part Number Lower (Read only)	Part Number – Digit 1				Part Number – Digit 0			
	Reset	0	0	0	0	0	1	0	1

2Ah – ID2 – Part Revision (Read only)

This register holds the revision number of the part.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
2Ah	ID2-Part Revision (Read only)	MAJOR					MINOR		
	Reset	0	0	0	1	0	0	1	1

Bit	Symbol	Value	Description
7:3	MAJOR	00010	This field holds the major revision of the AB-RTCMC-32.768kHz-IBO5-S3.
2:0	MINOR	011	This field holds the minor revision of the AB-RTCMC-32.768kHz-IBO5-S3.

2Bh – ID3 – Lot Lower (Read only)

This register holds the lower 8 bits of the manufacturing lot number.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
2Bh	ID3-Lot Lower (Read only)	Lot [7:0]							
	Reset	Preconfigured Lot Number							

Bit	Symbol	Value	Description
7:0	Lot [7:0]	00h to FFh	This field holds the low 8 bits of the manufacturing lot number.

2Ch – ID4 – Unique ID Upper (Read only)

This register holds part of the manufacturing information of the part, including bit 9 of the manufacturing lot number and the upper 7 bits of the unique part identifier. The 15-bit ID field contains a unique value for each AB-RTCMC-32.768kHz-IBO5-S3 part.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
2Ch	ID4-ID Upper (Read only)	Lot [9]	ID [14:8]						
	Reset	Preconfigured Value							

Bit	Symbol	Value	Description
7	Lot [9]	0 or 1	This field holds bit 9 of the manufacturing lot number.
6:0	ID [14:8]	0000000 to 1111111	This field holds the upper 7 bits of the unique part ID.

2Dh – ID5 – Unique ID Lower (Read only)

This register holds the lower 8 bits of the unique part identifier. The 15-bit ID field contains a unique value for each AB-RTCMC-32.768kHz-IBO5-S3 part.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
2Dh	ID5-ID Lower (Read only)	ID [7:0]							
	Reset	Preconfigured Value							

Bit	Symbol	Value	Description
7:0	ID [7:0]	00h to FFh	This field holds the lower 8 bits of the unique part ID.

2Eh – ID6 – Wafer (Read only)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
2Eh	ID6-Wafer (Read only)	Lot [8]	Wafer					RESERVED	
	Reset	Preconfigured Value							

Bit	Symbol	Value	Description
7	Lot [8]	0 or 1	This field holds bit 8 of the manufacturing lot number.
6:2	Wafer	00000 to 11111	This field holds the manufacturing wafer number.
1:0	RESERVED	00 to 11	RESERVED

3.12.RAM Registers

3Fh – Extension RAM Address

This register controls access to the Extension RAM, and includes some miscellaneous control bits.

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
3Fh	Extension RAM Address	X	BPOL	WDIS	X	RESERVED	XADA	XADS	
	Reset	0	0	Read only		0	0	0	0

Bit	Symbol	Value	Description
7	X	0	Unused, but must be set to 0 to avoid extraneous leakage. If 0, an internal output is completely disconnected when the AB-RTCMC-32.768kHz-IBO5-S3 is powered from V_{BACKUP}.
6	BPOL	BLF Polarity	
		0	The Battery Low flag BLF is set when the V_{BACKUP} voltage goes below the BREF threshold.
		1	The Battery Low flag BLF is set when the V_{BACKUP} voltage goes above the BREF threshold.
5	WDIS	0	(read only) – WDI status. Currently low level on the WDI pin.
		1	(read only) – WDI status. Currently high level on the WDI pin.
4	X	0	(read only) – Unused
3	RESERVED	0 or 1	RESERVED
2	XADA	0 or 1	This bit supplies the upper bit for the Alternate RAM address space.
1:0	XADS	00 to 11	This field supplies the two upper bits for the Standard RAM address space.

40h – 7Fh – Standard RAM

64 bytes of RAM space. The data in the RAM is held when using battery power. The upper 2 bits of the effective memory RAM address are taken from the XADS field, and the lower 6 bits are taken from the address offset, supporting a total RAM of 256 bytes. The initial values of the RAM locations are undefined.

XADS	Standard RAM Address			Effective RAM	RAM Data
Upper 2 bits			Lower 6 bits	Upper 2 & Lower 6	
00	40h : 7Fh	01000000 (64) : 01111111 (127)	000000 (0) : 111111 (63)	**00**000000 (0) : **00**111111 (63)	64 bytes
01				**01**000000 (64) : **01**111111 (127)	64 bytes
10				**10**000000 (128) : **10**111111 (191)	64 bytes
11				**11**000000 (192) : **11**111111 (255)	64 bytes
Total RAM Data				00000000 (0) : 11111111 (255)	256 bytes

80h – FFh – Alternate RAM

128 bytes of RAM space. The data in the RAM is held when using battery power. The upper bit of the effective RAM address is taken from the XADA bit, and the lower 7 bits are taken from the address offset, supporting a total RAM of 256 bytes. The initial values of the RAM locations are undefined.

XADS	Alternate RAM Address			Effective RAM	RAM Data
Upper bit			Lower 7 bits	Upper 1 & Lower 7	
0	80h : FFh	10000000 (128) : 11111111 (127)	0000000 (0) : 1111111 (127)	**0**0000000 (0) : **0**1111111 (127)	128 bytes
1				**1**0000000 (128) : **1**1111111 (255)	128 bytes
Total RAM Data				00000000 (0) : 11111111 (255)	256 bytes

3.13.Register Reset Values Summary

Register Definitions (00h to 16h):

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
00h	Hundredths	1	0	0	1	1	0	0	1
01h	Seconds	0	0	0	0	0	0	0	0
02h	Minutes	0	0	0	0	0	0	0	0
03h	Hours	0	0	0	0	0	0	0	0
04h	Date	0	0	0	0	0	0	0	1
05h	Months	0	0	0	0	0	0	0	1
06h	Years	0	0	0	0	0	0	0	0
07h	Weekdays	0	0	0	0	0	0	0	0
08h	Hundredths Alarm	0	0	0	0	0	0	0	0
09h	Seconds Alarm	0	0	0	0	0	0	0	0
0Ah	Minutes Alarm	0	0	0	0	0	0	0	0
0Bh	Hours Alarm	0	0	0	0	0	0	0	0
0Ch	Date Alarm	0	0	0	0	0	0	0	0
0Dh	Months Alarm	0	0	0	0	0	0	0	0
0Eh	Weekdays Alarm	0	0	0	0	0	0	0	0
0Fh	Status	0	0	0	0	0	0	0	0
10h	Control1	0	0	0	1	0	0	1	1
11h	Control2	0	0	1	1	1	1	0	0
12h	Interrupt Mask	1	1	1	0	0	0	0	0
13h	Square Wave SQW	0	0	1	0	0	1	1	0
14h	Calibration XT	0	Preconfigured (Factory Calibrated)						
15h	Calibration RC Upper	Preconfigured	Preconfigured (Factory Calibrated)						
16h	Calibration RC Lower	Preconfigured (Factory Calibrated)							

Register Definitions (17h to FFh):

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
17h	Sleep Control	0	0	0	0	0	0	0	0
18h	Countdown Timer Control	0	0	1	0	0	0	1	1
19h	Countdown Timer	0	0	0	0	0	0	0	0
1Ah	Timer Initial Value	0	0	0	0	0	0	0	0
1Bh	Watchdog Timer	0	0	0	0	0	0	0	0
1Ch	Oscillator Control	0	0	0	0	0	0	0	0
1Dh	Oscillator Status Register	0	0	1	0	0	0	1	0
1Fh	Configuration Key	0	0	0	0	0	0	0	0
20h	Trickle Charge	0	0	0	0	0	0	0	0
21h	BREF Control	1	1	1	1	0	0	0	0
26h	Cap_RC Control	0	0	0	0	0	0	0	0
27h	IO Batmode Register	1	0	0	0	0	0	0	0
28h	ID0 (Read only)	0	0	0	1	1	0	0	0
29h	ID1 (Read only)	0	0	0	0	0	1	0	1
2Ah	ID2 (Read only)	0	0	0	1	0	0	1	1
2Bh	ID3 (Read only)	Preconfigured Lot Number							
2Ch	ID4 (Read only)	Preconfigured Value							
2Dh	ID5 (Read only)	Preconfigured Value							
2Eh	ID6 (Read only)	Preconfigured Value							
2Fh	Analog Stat. (Read only)								
30h	Output Control Register	0	0	0	0	0	0	0	0
3Fh	Extension RAM Address	0	0	Read Only		0	0	0	0

4. Detailed Functional Description

The AB-RTCMC-32.768kHz-IBO5-S3 serves as a companion part for host processors including microcontrollers, radios, and digital signal processors. It tracks time as in a typical RTC product and additionally provides unique power management functionality that makes it ideal for highly energy-constrained applications. To support such operation, the AB-RTCMC-32.768kHz-IBO5-S3 includes 3 distinct feature groups: 1) baseline timekeeping features, 2) advanced timekeeping features, and 3) power management features. Functions from each feature group may be controlled via I/O offset mapped registers. These registers are accessed using the I^2C serial interface. Each feature group is described briefly below and in greater detail in subsequent sections.

1. The baseline timekeeping feature group supports two modes: a) XT oscillator mode and b) XT Autocalibration mode.

    a. In XT mode the 32.768 kHz crystal is active and the 16.384 kHz level is digitally offset compensated for a maximum frequency accuracy (factory calibrated) and has an ultra-low current draw of 60 nA. The baseline timekeeping feature group also includes a standard set of counters monitoring hundredths of a second up through centuries. A complement of countdown timers and alarms may additionally be set to initiate interrupts or resets on several of the outputs.

    b. The XT Autocalibration mode has the same features as the XT mode but additionally calibrates the RC oscillator periodically to the compensated XT oscillator.

2. The advanced timekeeping feature group supports two additional oscillation modes: a) RC oscillator mode, and b) RC Autocalibration mode.

a. At only 17 nA, the temperature-compensated RC oscillator mode with factory calibrated frequency at the 64 Hz level provides an even lower current draw than the XT oscillator for applications with reduced frequency accuracy requirements. A proprietary calibration algorithm allows the AB-RTCMC-32.768kHz-IBO5-S3 to digitally tune the RC oscillator frequency to ± 16 ppm to the digitally offset compensated XT oscillator frequency with the accuracy as low as ± 2 ppm at a given temperature.

b. In Autocalibration mode, the RC oscillator is used as the primary oscillation source and is periodically calibrated against the digitally tuned XT oscillator. Autocalibration may be done automatically every 8.5 minutes or 17 minutes and may also be initiated via software. This mode enables average current draw of only 22 nA with frequency accuracy similar to the XT oscillator. The advanced timekeeping feature group also includes a rich set of input and output configuration options that enables the monitoring of external interrupts (e.g., pushbutton signals), the generation of clock outputs, and watchdog timer functionality.

3. Power management features built into the AB-RTCMC-32.768kHz-IBO5-S3 enable it to operate as a backup device in both line-powered and battery-powered systems. An integrated power control module automatically detects when main power (V_{DD}) falls below a threshold and switches to backup power (V_{BACKUP}). Up to 512 bytes of ultra-low leakage RAM enable the storage of key parameters when operating on backup power.

The AB-RTCMC-32.768kHz-IBO5-S3 is the first RTC to incorporate a number of more advanced power management features. In particular, the AB-RTCMC-32.768kHz-IBO5-S3 includes a finite Sleep Control State Machine (integrated with the power control) that can control a host processor as it transitions between sleep/reset states and active states. Digital outputs can be configured to control the reset signal or interrupt input of the host controller. The AB-RTCMC-32.768kHz-IBO5-S3 additionally integrates a power switch with ~1 Ω impedance that can be used to cut off ground current on the host microcontroller and reduce sleep current to <1 nA. The AB-RTCMC-32.768kHz-IBO5-S3 parts can wake up a sleeping system using internally generated timing interrupts or externally generated interrupts generated by digital inputs (e.g., using a pushbutton) or an analog comparator. The aforementioned functionality enables users to seamlessly power down host processors, leaving only the energy-efficient AB-RTCMC-32.768kHz-IBO5-S3 chip awake. The AB-RTCMC-32.768kHz-IBO5-S3 also includes voltage detection on the backup power supply.

Each functional block is explained in detail in the remainder of this section. Functional descriptions refer to the registers shown in the two Tables in Section REGISTER OVERVIEW. A detailed description of all registers can be found in Section REGISTER ORGANIZATION.

4.1. I^2C Interface

The I^2C interface is for bidirectional, two-line communication between different ICs or modules. The device is accessed at addresses D2h/D3h, and supports Fast Mode (up to 400 kHz). The I^2C interface consists of two lines: one bi-directional data line (SDA) and one clock line (SCL). Both lines are connected to a positive supply via pull-up resistors. Data transfer is initiated only when the interface is not busy.

I^2C termination resistors should be above 2.2 kΩ, and for systems with short I^2C bus wires/traces and few connections these terminators can typically be as large as 22 kΩ (for 400 kHz operation) or 56 kΩ (for 100 kHz operation). Larger resistors will produce lower system current consumption.

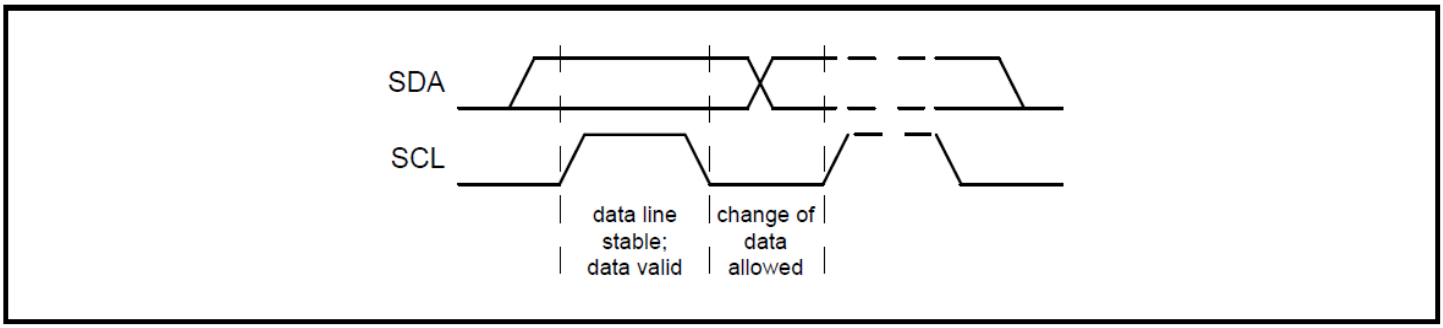
4.1.1. Bus not Busy

Both SDA and SCL remain high.

4.1.2. 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 a control signals. Data changes should be executed during the LOW period of the clock pulse (see figure below).

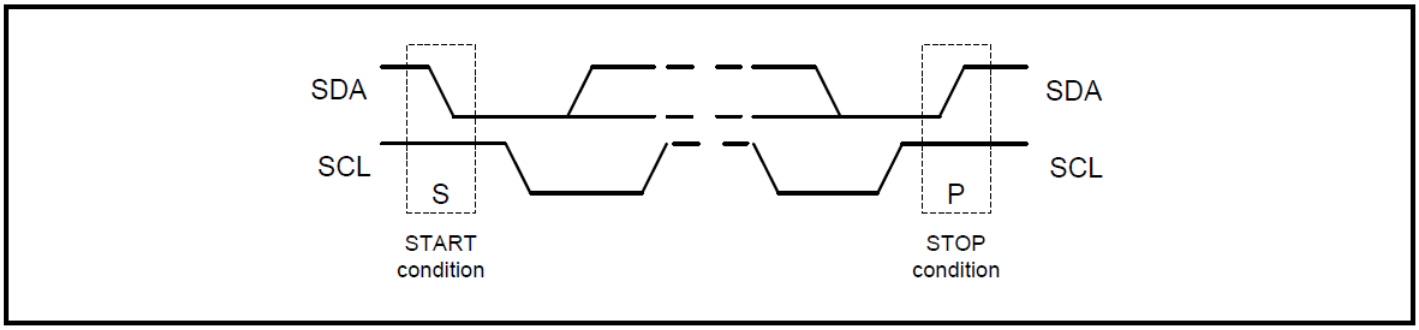
Bit transfer:



4.1.3. 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 below).

Definition of START and STOP conditions:



A START condition which occurs after a previous START but before a STOP is called a RESTART condition, and functions exactly like a normal STOP followed by a normal START.

4.1.4. Data Valid

After a START condition, SDA is stable for the duration of the high period of SCL. The data on SDA may be changed during the low period of SCL. There is one clock pulse per bit of data. Each data transfer is initiated with a START condition and terminated with a STOP condition. The number of data bytes transferred between the START and STOP conditions is not limited. The information is transmitted byte-wide and each receiver acknowledges with a ninth bit.

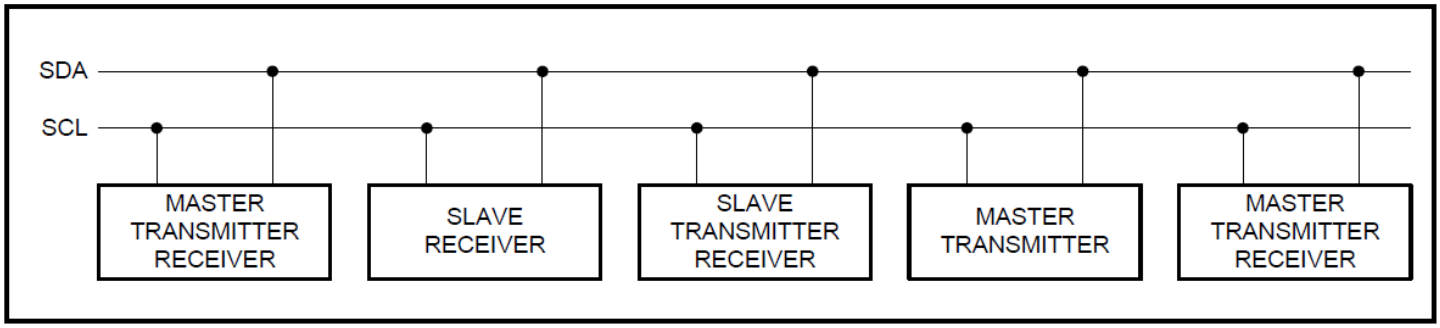
4.1.5. System Configuration

Since multiple devices can be connected with the I^2C bus, all I^2C bus devices have a fixed and unique device number built-in to allow individual addressing of each device.

The device that controls the I^2C bus is the Master; the devices which are controlled by the Master are the Slaves. A device generating a message is a Transmitter; a device receiving a message is the Receiver. The AB-RTCMC-32.768kHz-IBO5-S3 acts as a Slave-Receiver or Slave-Transmitter.

Before any data is transmitted on the I^2C bus, the device which should respond is addressed first. The addressing is always carried out with the first byte transmitted after the start procedure. The clock signal SCL is only an input signal, but the data signal SDA is a bidirectional line.

System configuration:



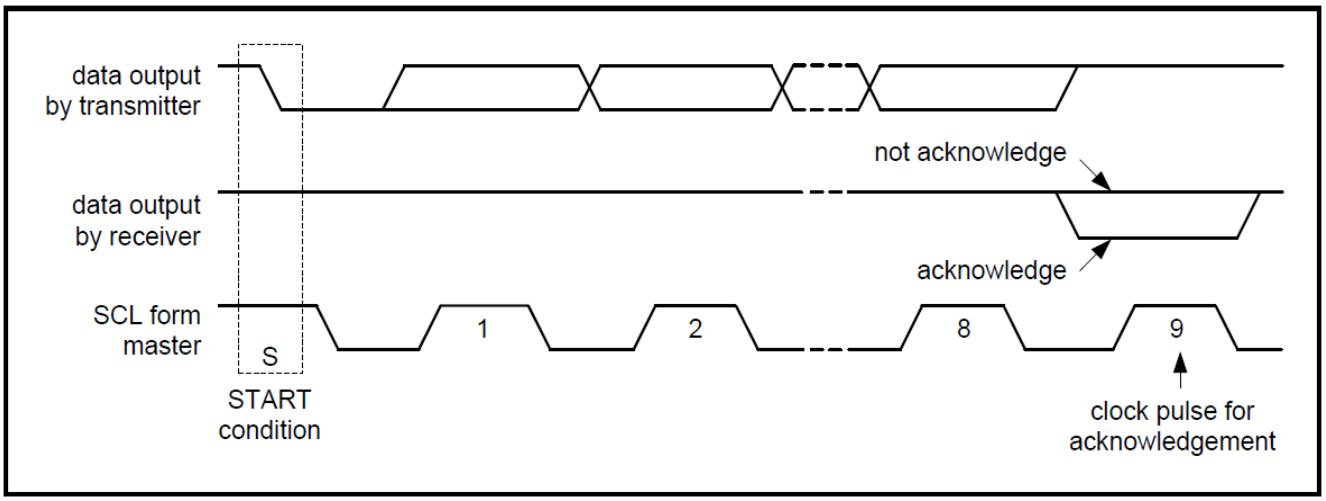
4.1.6. Acknowledge

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 cycle after the reception of each byte
- Also a master receiver must generate an acknowledge cycle 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 related acknowledge 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 cycle 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

Acknowledgement on the I^2C bus is shown on the figure below.

Acknowledgement on the I^2C bus:



4.1.7. Addressing

On the I^2C bus the 7-bit slave address 1101001b is reserved for the AB-RTCMC-32.768kHz-IBO5-S3. The entire I^2C bus slave address byte is shown in the table below.

I^2C slave address byte:

Bit	Slave Address							
	7 MSB	6	5	4	3	2	1	0 LSB
	1	1	0	1	0	0	1	R/$\overline{W}$

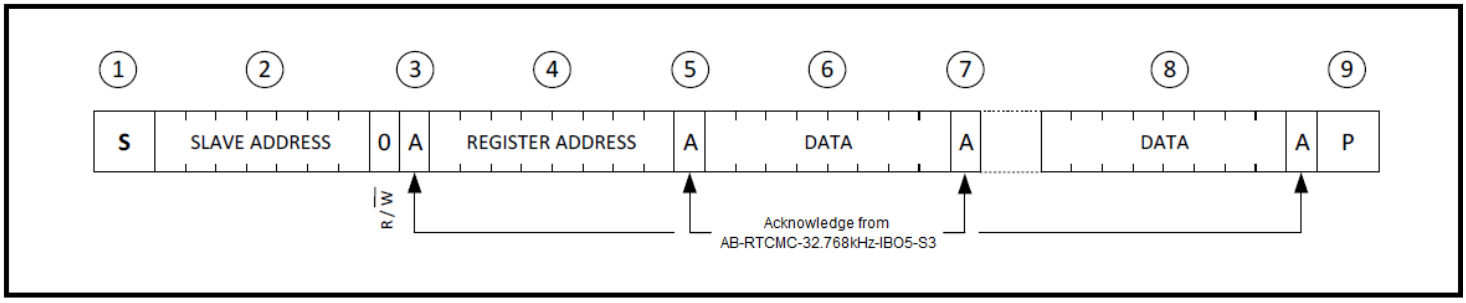
After a START condition, the I^2C slave address has to be sent to the AB-RTCMC-32.768kHz-IBO5-S3 device. The R/$\overline{W}$ bit defines the direction of the following single or multiple byte data transfer. The 7-bit address is transmitted MSB first. If this address is 1101001b, the AB-RTCMC-32.768kHz-IBO5-S3 is selected, the eighth bit indicate a write (R/$\overline{W}$ = 0) or a read (R/$\overline{W}$ = 1) operation (results in D2h or D3h) and the AB-RTCMC-32.768kHz-IBO5-S3 supplies the ACK. The AB-RTCMC-32.768kHz-IBO5-S3 ignores all other address values and does not respond with an ACK.

In the write operation, a data transfer is terminated by sending either the STOP condition or the START condition of the next data transfer.

4.1.8. Write Operation

Master transmits to Slave-Receiver at specified address. The Register Address is an 8-bit value that defines which register is to be accessed next. After reading or writing one byte, the Register Address is automatically incremented by 1.

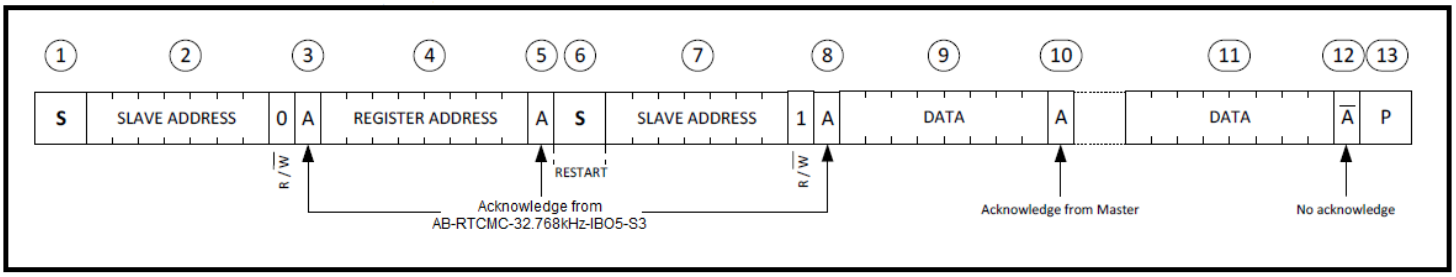
1) Master sends out the START condition.
2) Master sends out Slave Address, D2h for the AB-RTCMC-32.768kHz-IBO5-S3; the R/$\overline{W}$ bit is a 0 indicating a write operation.
3) Acknowledgement from the AB-RTCMC-32.768kHz-IBO5-S3.
4) Master sends out the Register Address to the AB-RTCMC-32.768kHz-IBO5-S3.
5) Acknowledgement from the AB-RTCMC-32.768kHz-IBO5-S3.
6) Master sends out the Data to write to the specified address in step 4).
7) Acknowledgement from the AB-RTCMC-32.768kHz-IBO5-S3.
8) Steps 6) and 7) can be repeated if necessary. The address will be incremented automatically in the AB-RTCMC-32.768kHz-IBO5-S3.
9) Master sends out the STOP Condition.



4.1.9. Read Operation at Specific Address

Master reads data after setting Register Address:

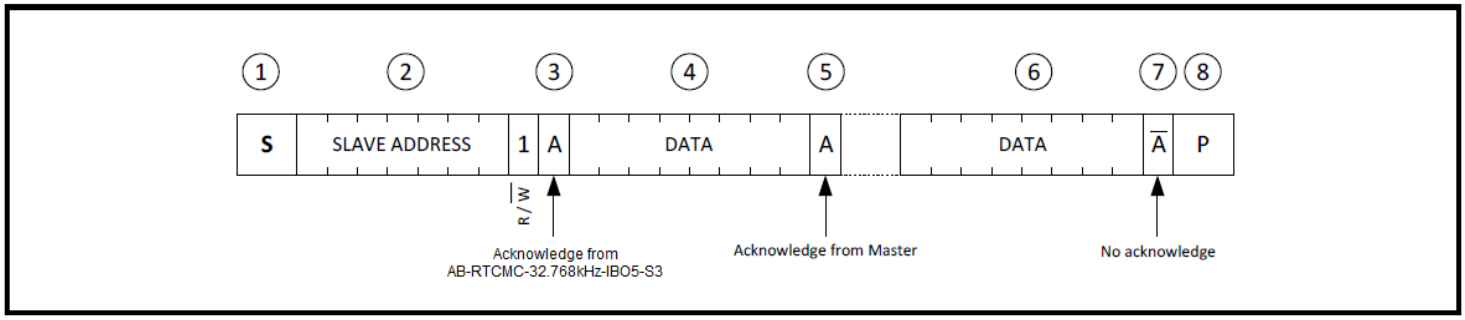
1) Master sends out the START condition.
2) Master sends out Slave Address, D2h for the AB-RTCMC-32.768kHz-IBO5-S3; the R/$\overline{W}$ bit is a 0 indicating a write operation.
3) Acknowledgement from the AB-RTCMC-32.768kHz-IBO5-S3.
4) Master sends out the Register Address to the AB-RTCMC-32.768kHz-IBO5-S3.
5) Acknowledgement from the AB-RTCMC-32.768kHz-IBO5-S3.
6) Master sends out the RESTART condition (STOP condition followed by START condition)
7) Master sends out Slave Address, D3h for the AB-RTCMC-32.768kHz-IBO5-S3; the R/$\overline{W}$ bit is a 1 indicating a read operation.
8) Acknowledgement from the AB-RTCMC-32.768kHz-IBO5-S3.
   At this point, the Master becomes a Receiver, the Slave becomes the Transmitter.
9) The Slave sends out the Data from the Register Address specified in step 4).
10) Acknowledgement from the Master.
11) Steps 9) and 10) can be repeated if necessary.
    The address will be incremented automatically in the AB-RTCMC-32.768kHz-IBO5-S3.
12) The Master, addressed as Receiver, can stop data transmission by not generating an acknowledge on the last byte that has been sent from the Slave-Transmitter. In this event, the Slave-Transmitter must leave the data line HIGH to enable the Master to generate a STOP condition.
13) Master sends out the STOP condition.



4.1.10.Read Operation

Master reads Slave-Transmitter immediately after first byte:

1) Master sends out the START condition.
2) Master sends out Slave Address, D3h for the AB-RTCMC-32.768kHz-IBO5-S3; the R/$\overline{W}$ bit is a 1 indicating a read operation.
3) Acknowledgement from the AB-RTCMC-32.768kHz-IBO5-S3.
   At this point, the Master becomes a Receiver, the Slave becomes the Transmitter
4) The AB-RTCMC-32.768kHz-IBO5-S3 sends out the Data from the last accessed Register Address incremented by 1.
5) Acknowledgement from the Master.
6) Steps 4) and 5) can be repeated if necessary.
   The address will be incremented automatically in the AB-RTCMC-32.768kHz-IBO5-S3.
7) The Master, addressed as Receiver, can stop data transmission by not generating an acknowledge on the last byte that has been sent from the Slave-Transmitter. In this event, the Slave-Transmitter must leave the data line HIGH to enable the Master to generate a STOP condition.
8) Master sends out the STOP condition.



4.2. XT Oscillator

The AB-RTCMC-32.768kHz-IBO5-S3 includes a very power efficient crystal (XT) oscillator which runs at 32.768 kHz. This oscillator is selected by setting the OSEL bit to 0 and includes a low jitter calibration function.

4.3. RC Oscillator

The AB-RTCMC-32.768kHz-IBO5-S3 includes an extremely low power RC oscillator which runs at typically 122 Hz (Fnom = 128 Hz). This oscillator is selected by setting the OSEL bit to 1. Switching between the XT and RC Oscillators is guaranteed to produce less than one second of error in the Calendar Counters. The AB-RTCMC-32.768kHz-IBO5-S3 may be configured to automatically switch to the RC Oscillator when VDD drops below its threshold by setting the BOS bit, and/ or be configured to automatically switch if an XT Oscillator failure is detected by setting the FOS bit.

4.4. RTC Counter Access

When reading any of the counters in the RTC using a burst operation, the 1 Hz and 100 Hz clocks are held off during the access. This guarantees that a single burst will either read or write a consistent timer value (other than the Hundredths Counter – see HUNDREDTHS SYNCHRONIZATION). There is a watchdog function to insure that a very long pause on the interface does not cause the RTC to lose a clock.

On a write to any of the Calendar Counters, the entire timing chain up to 100 Hz (if the XT Oscillator is selected) or up to 1Hz (if the RC Oscillator is selected) is reset to 0. This guarantees that the Counters will begin counting immediately

after the write is complete, and that in the XT oscillator case the next 100 Hz clock will occur exactly 10 ms later. In the RC Oscillator case, the next 1 Hz clock will occur exactly 1 second later. This allows a burst write to configure all of the Counters and initiate a precise time start. Note that a Counter write may cause one cycle of a Square Wave SQW output to be of an incorrect period.

The WRTC bit must be set in order to write to any of the Counter registers. This bit can be cleared to prevent inadvertent software access to the Counters.

4.5. Hundredths Synchronization

If the Hundredths Counter is read as part of the counter burst, there is a small probability (approximately 1 in 109) that the Hundredths Counter rollover from 99 to 00 and the Seconds Counter increment will be separated by the read. In this case, correct read information can be guaranteed by the following algorithm.

1. Read the Counters, using a burst read. If the Hundredths Counter is neither 00 nor 99, the read is correct.
2. If the Hundredths Counter was 00, perform the read again. The resulting value from this second read is guaranteed to be correct.
3. If the Hundredths Counter was 99, perform the read again.
    a. If the Hundredths Counter is still 99, the results of the first read are guaranteed to be correct. Note that it is possible that the second read is not correct.
    b. If the Hundredths Counter has rolled over to 00, and the Seconds Counter value from the second read is equal to the Seconds Counter value from the first read plus 1, both reads produced correct values. Alternatively, perform the read again. The resulting value from this third read is guaranteed to be correct.
    c. If the Hundredths Counter has rolled over to 00, and the Seconds Counter value from the second read is equal to the Seconds Counter value from the first read, perform the read again. The resulting value from this third read is guaranteed to be correct.

4.6. Generating Hundredths of a Second

The generation of an exact 100 Hz signal for the Hundredths Counter requires a special logic circuit. The 2.048 kHz clock signal is divided by 21 for 12 iterations, and is alternately divided by 20 for 13 iterations. This produces an effective division of:

$$(21 * 12 + 20 * 13)/25 = 20.48$$

producing an exact long-term average 100 Hz output, with a maximum jitter of less than 1 ms. The Hundredths Counter is not available when the RC Oscillator is selected.

4.7. Watchdog Timer

The AB-RTCMC-32.768kHz-IBO5-S3 includes a Watchdog Timer, which can be configured to generate an interrupt or a reset if it times out. The Watchdog Timer is controlled by the Watchdog Timer Register (see TIMER REGISTERS, 1Bh - Watchdog Timer). The WD field selects the frequency at which the timer is decremented, and the WDM field determines the multiplier value loaded into the timer when it is restarted. If the timer reaches a value of zero, the WDS bit determines whether an interrupt is generated at CLK/$\overline{\text{INT}}$ (if WDS is 0) or the $\overline{\text{RST}}$ output pin is asserted low (if WDS is 1). If interrupt selected and timer reaching zero, the WDF flag in the Status Register is set to 1, which may be cleared by setting the WDF flag to zero. If reset is selected, the $\overline{\text{RST}}$ output pin is asserted low within 1/16 second of the timer reaching zero and remains asserted low for 1/16 second, and the WDF flag is not set.

Two actions will restart the Watchdog Timer:

1. Writing the Watchdog Timer Register with a new watchdog value.
2. A change in the level of the WDI pin.

If the Watchdog Timer generates an interrupt or reset, the Watchdog Timer Register must be written in order to restart the Watchdog Timer function. If the WDM field is 0, the Watchdog Timer function is disabled.

The WDM multiplier field describes the maximum timeout delay. For example, if WD = 01 so that the clock period is 250 ms, a WDM value of 9 implies that the timeout will occur between 2000 ms and 2250 ms after writing the Watchdog Timer Register.

4.8. Digital Calibration

4.8.1. XT Oscillator Digital Calibration

In order to improve the accuracy of the XT oscillator, a Distributed Digital Calibration function is included (see CALIBRATION REGISTERS, 14h - Calibration XT). This function uses a calibration value, OFFSETX, to adjust the clock period over a 16 second or 32 second calibration period. When the 32.768 kHz XT oscillator is selected, the clock at the 16.384 kHz level of the divider chain is modified on a selectable interval. Clock pulses are either added or subtracted to ensure accuracy of the counters. If the CMDX bit is a 0 (normal calibration), OFFSETX cycles of the 16.384 kHz clock level are gated (negative calibration) or replaced by 32.768 kHz level pulses (positive calibration) within every 32 second calibration period. In this mode, each step in OFFSETX modifies the clock frequency by 1.907 ppm, with a maximum adjustment of ~+120/-122 ppm. If the CMDX bit is 1 (coarse calibration), OFFSETX cycles of the 16.384 kHz clock level are gated or replaced by the 32.768 kHz level pulses within every 16 second calibration period. In this mode, each step in OFFSETX modifies the clock frequency by 3.815 ppm, with a maximum adjustment of ~+240/-244 ppm. OFFSETX contains a two's complement value, so the possible steps are from -64 to +63 (7 bits). Note that unlike other implementations, the Distributed Digital Calibration guarantees that the clock is precisely calibrated every 32 seconds with normal calibration and every 16 seconds when coarse calibration is selected.

The pulses which are added to or subtracted from the 16.384 kHz clock level are spread evenly over each 16 or 32 second period using the Distributed Calibration algorithm. This insures that in XT mode the maximum cycle-to-cycle jitter in any clock of a frequency 16.384 kHz or lower caused by calibration will be no more than one 16.384 kHz period. This maximum jitter applies to all clocks in the AB-RTCMC-32.768kHz-IBO5-S3, including the Calendar Counter, Countdown Timer and Watchdog Timer clocks and the clock driven onto the CLK/$\overline{\text{INT}}$ pin.

In addition to the normal calibration, the AB-RTCMC-32.768kHz-IBO5-S3 also includes an Extended Calibration field to compensate a higher XT oscillator frequency. The frequency generated by the Crystal Oscillator may be reduced by -122 ppm multiplied by the value in the XTCAL (see OSCILLATOR REGISTERS, 1Dh – Oscillator Status Register) field (0, -122, -244 or -366 ppm). The clock is still precisely calibrated in 16 or 32 seconds. Normally, this field remains 0.

- At POR, the CMDX and OFFSETX values in register 14h are initialized with factory calibrated; non-volatile frequency offset compensation values (± 2 ppm at 25°C).
- Customer can adjust these values by overwriting the register 14h with new calculated values. See process below.

The XT oscillator calibration values CMDX, OFFSETX and XTCAL are determined by the following process:

1. Set the CMDX, OFFSETX and XTCAL register fields to 0 to ensure calibration is not occurring.
2. Select the XT oscillator by setting the OSEL bit to 0.
3. Configure a square wave SQW output on the output pin CLK/$\overline{\text{INT}}$ of frequency Fnom = 32’768 Hz.
4. Measure the frequency Fmeas at the output pin in Hz.
5. Compute the adjustment value required in ppm: PAdj = ((32’768 – Fmeas)*1’000’000)/32’768
6. Compute the adjustment value in steps: Adj = PAdj/(1’000’000/219) = PAdj/(1.90735)
7. If Adj < -320, the XT frequency is too high to be calibrated
8. Else if Adj < -256, set XTCAL = 3, CMDX = 1, OFFSETX = (Adj +192)/2
9. Else if Adj < -192, set XTCAL = 3, CMDX = 0, OFFSETX = Adj +192
10. Else if Adj < -128, set XTCAL = 2, CMDX = 0, OFFSETX = Adj +128
11. Else if Adj < -64, set XTCAL = 1, CMDX = 0, OFFSETX = Adj + 64
12. Else if Adj < 64, set XTCAL = 0, CMDX = 0, OFFSETX = Adj
13. Else if Adj < 128, set XTCAL = 0, CMDX = 1, OFFSETX = Adj/2
14. Else the XT frequency is too low to be calibrated

4.8.2. RC Oscillator Digital Calibration

The RC Oscillator has a Distributed Digital Calibration function similar to that of the XT Oscillator (see CALIBRATION REGISTERS, 15h - Calibration RC Upper and 16h - Calibration RC Lower). However, because the RC Oscillator has a greater fundamental variability, the range of calibration is much larger, with four calibration ranges selected by the CMDR field. When the RC oscillator is selected, the clock at the 64 Hz level of the divider chain is modified on a selectable interval using the calibration value OFFSETR. Clock pulses are either added or subtracted to ensure accuracy of the counters. If the CMDR field is 00, OFFSETR cycles of the 64 Hz clock level are gated (negative calibration) or replaced by 128 Hz level pulses (positive calibration) within every 8’192 second calibration period. In this mode, each step in OFFSETR modifies the clock frequency by 1.907 ppm, with a maximum adjustment of +15’623/-15’625 ppm (+/- 1.56%). If the CMDR field is 01, OFFSETR cycles of the 64 Hz clock level are gated or replaced by the 128 Hz level pulses within every 4’096 second calibration period. In this mode, each step in OFFSETR modifies the clock frequency by 3.815 ppm, with a maximum adjustment of +31’246/ -31’250 ppm (+/-3.12%). If the CMDR field is 10, OFFSETR cycles of the 64 Hz clock level are gated (negative calibration) or replaced by 128 Hz level pulses (positive calibration) within every 2’048 second calibration period. In this mode, each step in OFFSETR modifies the clock frequency by 7.63 ppm, with a maximum adjustment of +62’487/-62’500 ppm (+/- 6.25%). If the CMDR field is 11, OFFSETR cycles of the 64 Hz clock level are gated or replaced by pulses from the 128 Hz clock level within every 1’024 second calibration period. In this mode, each step in OFFSETR modifies the clock frequency by 15.26 ppm, with a maximum adjustment of +124’985/-125’000 ppm (+/-12.5%). OFFSETR contains a two's complement value, so the possible steps are from -8’192 to +8’191 (14 bits).

The pulses which are added to or subtracted from the 64 Hz clock level are spread evenly over each 8’192, 4’096, 2’048 or 1’024 second period using the Distributed Calibration algorithm. This insures that in RC mode the maximum cycle-to-cycle jitter in any clock of a frequency 64 Hz or lower caused by calibration will be no more than one 64 Hz period. This

maximum jitter applies to all clocks in the AB-RTCMC-32.768kHz-IBO5-S3, including the Calendar Counter, Countdown Timer and Watchdog Timer clocks and the clock driven onto the CLK/$\overline{\text{INT}}$ pins.

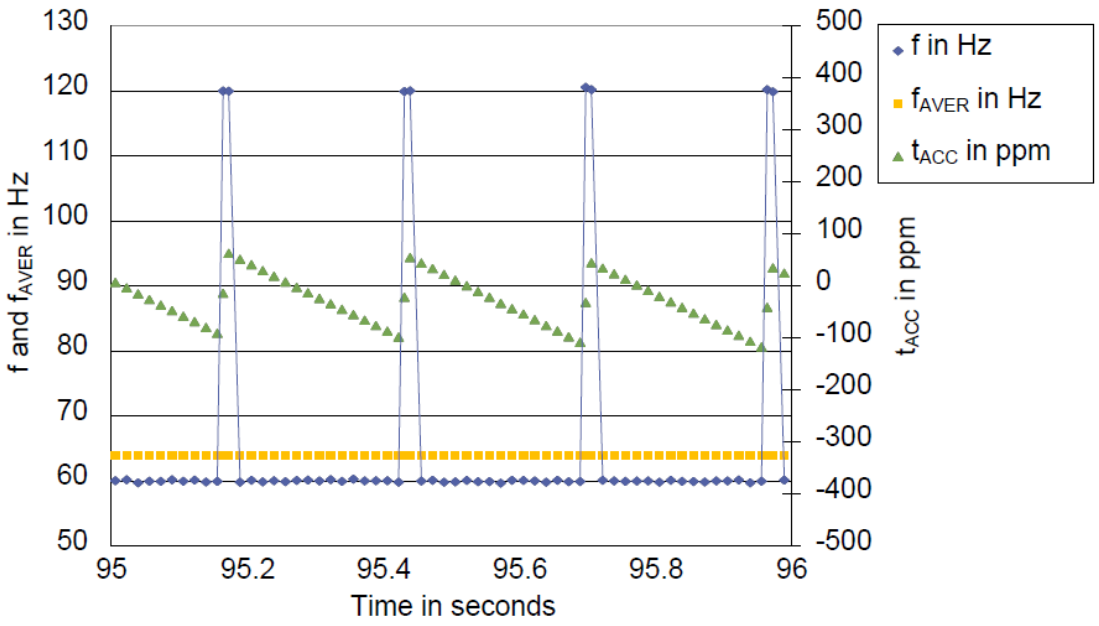
- At POR, the CMDR and OFFSETR (OFFSETRU and OFFSETRL) values in register 15h and 16h are initialized with factory calibrated, non-volatile frequency offset compensation values (± 16 ppm at 25°C, VDD = 2.8 V).
- Customer can adjust these values by overwriting the registers 15h and 16h with new calculated values. See process below.
- The RC oscillator digital calibration is also used by the XT Autocalibration and RC Autocalibration function (see XT AUTOCALIBRATION MODE and RC AUTOCALIBRATION MODE).

The RC oscillator calibration values CMDR and OFFSETR are determined by the following process:

1. Set the CMDR and OFFSETR register fields to 0 to insure calibration is not occurring.
2. Select the RC oscillator by setting the OSEL bit to 1.
3. Configure a square wave SQW output on the output pin CLK/$\overline{\text{INT}}$ of frequency Fnom = 128 Hz.
4. Measure the frequency Fmeas at the output pin.
5. Compute the adjustment value required in ppm as ((128 – Fmeas)*1’000’000)/Fmeas = PAdj
6. Compute the adjustment value in steps as PAdj/(1’000’000/219) = PAdj/(1.90735) = Adj
7. If Adj < -65’536, the RC frequency is too high to be calibrated
8. Else if Adj < -32’768, set CMDR = 3, OFFSETR = Adj/8
9. Else if Adj < -16’384, set CMDR = 2, OFFSETR = Adj/4
10. Else if Adj < -8’192, set CMDR = 1, OFFSETR = Adj/2
11. Else if Adj < 8’192, set CMDR = 0, OFFSETR = Adj
12. Else if Adj < 16’384, set CMDR = 1, OFFSETR = Adj/2
13. Else if Adj < 32’768, set CMDR = 2, OFFSETR = Adj/4
14. Else if Adj < 65’536, set CMDR = 3, OFFSETR = Adj/8
15. Else the RC frequency is too low to be calibrated

The following figure shows the modified clock at the 64 Hz level with the achieved average time accuracy in ppm at 96 seconds (arbitrary). The average calculation was started at the time t0 = 0 seconds (TA = 25°C and VDD = 3.0 V).

Example with the modified RC oscillator clock at the 64 Hz level:

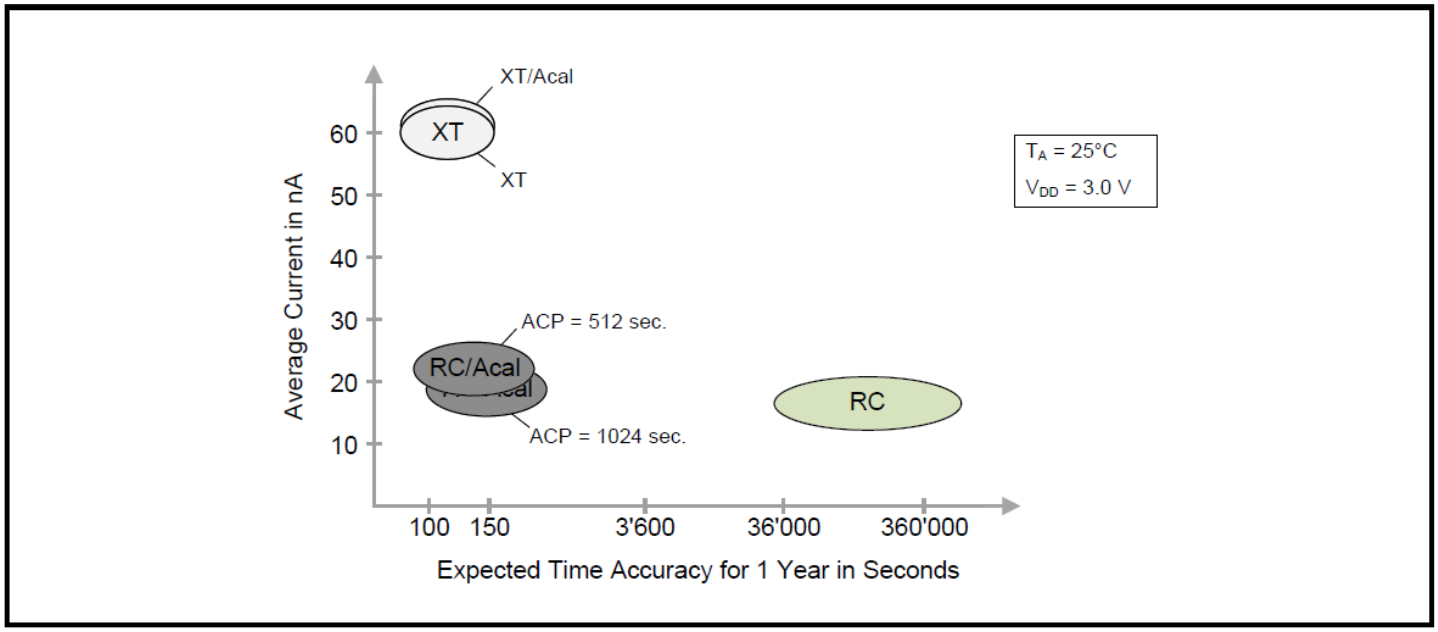


Symbol	Description	Unit
f	Frequency of every measured period. The RC oscillator frequency in this example is about 120 Hz and therefore the divided frequency about 60 Hz.	Hz
f_{AVER}	The average frequency from t_0 to the current time (64 Hz level: after 96 seconds: -120 ppm to +20 ppm).	Hz
t_{ACC}	The average time accuracy from t_0 to the current time (after 96 seconds: -120 ppm to +20 ppm).	ppm

4.9. Autocalibration

The AB-RTCMC-32.768kHz-IBO5-S3 includes the capability of using the internal RC Oscillator for all timing functions. For increased accuracy at a small power penalty, the RC Oscillator may be periodically calibrated to the digitally calibrated Crystal (XT) Oscillator which is turned on only during this calibration. The overall process is referred to as Autocalibration and under most conditions produces a clock with long term accuracy essentially indistinguishable from the digitally calibrated XT Oscillator alone, as shown in the RC/Acal bubble in the following Figure.

Basic Mode Comparison:



4.10.Basic Autocalibration Operation

The AB-RTCMC-32.768kHz-IBO5-S3 includes a very powerful automatic calibration feature, referred to as Autocalibration, which allows the RC Oscillator to be automatically calibrated to the digitally calibrated XT Oscillator. The digitally calibrated XT Oscillator typically has much better stability than the RC Oscillator, but the RC Oscillator requires significantly less power. Autocalibration enables many system configurations to achieve accuracy and stability similar to that of the digitally calibrated XT Oscillator while drawing current similar to that of the RC Oscillator. Autocalibration functions in two primary modes: XT Autocalibration Mode and RC Autocalibration Mode.

4.10.1.Autocalibration Operation

The Autocalibration operation counts the number of calibrated XT clock cycles within a specific period as defined by the RC Oscillator and then loads new values into the Calibration RC Upper and RC Lower registers which will then adjust the RC Oscillator output to match the digitally calibrated XT frequency. In most cases Autocalibration is configured by the host controller over the serial interface when the AB-RTCMC-32.768kHz-IBO5-S3 is initialized.

4.10.2.XT Autocalibration Mode

XT Autocalibration Mode is used when the digitally calibrated XT Oscillator is normally active, but the system is configured to switch to the RC Oscillator on a failure or a switchover to battery power (see also AUTOMATIC SWITCHOVER SUMMARY). In XT Autocalibration Mode, the OSEL register bit is set to 0, ACAL is set to 10 or 11 and the AB-RTCMC-32.768kHz-IBO5-S3 uses the XT Oscillator whenever the system power V_{DD} is above the V_{DDSWF} voltage. The RC Oscillator is periodically automatically calibrated to the XT Oscillator. If the BOS bit is set, when V_{DD} drops below the V_{DDSWF} threshold the system will switch to using V_{BACKUP}, the clocks will begin using the RC Oscillator (Autocalibration Mode according to the ACAL field) and the XT Oscillator will be disabled to reduce power requirements. Because the RC Oscillator has been continuously calibrated to the digitally calibrated XT Oscillator, it will be already very accurate when the switch occurs. When V_{DD} is again above the threshold, the system will switch back to use the XT Oscillator in the XT Autocalibration Mode. It is possible to gain or lose up to one second during a switchover between the oscillators.

4.10.3.RC Autocalibration Mode

RC Autocalibration Mode is used when the RC Oscillator is always used as the clock but it is desired to maintain the frequency of the RC Oscillator as close to the digitally calibrated XT Oscillator as possible. In RC Autocalibration Mode, the OSEL register bit is set to 1, ACAL is set to 10 or 11 and the AB-RTCMC-32.768kHz-IBO5-S3 uses the RC Oscillator at all times. However, periodically the XT Oscillator is turned on and the RC Oscillator is calibrated to the XT Oscillator. This allows the system to operate most of the time with the XT Oscillator off but allow continuous calibration of the RC Oscillator and maintain high accuracy for the RC Oscillator.

4.10.4.Autocalibration Frequency and Control

The Autocalibration function is controlled by the ACAL field in the Oscillator Control register as shown in the following Table. If ACAL is 00, no Autocalibration occurs. If ACAL is 10 or 11, Autocalibration occurs every 1024 or 512 seconds, which is referred to as the Autocalibration Period (ACP). In RC Autocalibration Mode, an Autocalibration operation results in the digitally calibrated XT Oscillator being enabled for roughly 50 seconds. The 512 second Autocalibration cycles have the XT Oscillator enabled approximately 10% of the time, while 1024 second Autocalibration cycles have the XT Oscillator enabled approximately 5% of the time.

ACAL Value	Autocalibration Mode
00	No Autocalibration
01	RESERVED
10	Autocalibrate every 1024 seconds (~ 17 minutes)
11	Autocalibrate every 512 seconds (~ 8.5 minutes)

If ACAL is 00 and is then written with a different value, an Autocalibration cycle is immediately executed. This allows Autocalibration to be completely controlled by software. As an example, software could choose to execute an Autocalibration cycle every 2 hours by keeping ACAL at 00, getting a two hour interrupt using the alarm function, generating an Autocalibration cycle by writing ACAL to 10 or 11, and then returning ACAL to 00.

4.10.5.Cap_RC Pin

In order to produce the optimal accuracy for the Autocalibrated RC Oscillator, a 47 pF capacitor must be connected between the Cap_RC pin and VSS. In order to enable the filter, the value A0h must be written to CAPRC at address 26h (Section ANALOG CONTROL REGISTERS). The Cap_RC filter is disabled by writing 00h to CAPRC. No other values should be written to this register. The Configuration Key CONFKEY must be written with the value 9Dh immediately prior to writing to the Cap_RC Control Register CAPRC.If the filter capacitor is not connected to the Cap_RC pin or is not enabled, the Autocalibrated RC Oscillator frequency will typically be between 10 and 50 ppm lower than the digitally calibrated XT Oscillator. If the capacitor is connected to the Cap_RC pin and enabled, the RC Oscillator frequency will be within the accuracy range specified in the OSCILLATOR PARAMETERS table of the XT Oscillator.

4.10.6.Autocalibration Failure

If the operating temperature of the AB-RTCMC-32.768kHz-IBO5-S3 exceeds the Autocalibration range specified in the Oscillator Parameters table or internal adjustment parameters are altered incorrectly, it is possible that the basic frequency of the RC Oscillator is so far away from the nominal 128 Hz value (off by more than 12%) that the RC Calibration circuitry does not have enough range to correctly calibrate the RC Oscillator. If this situation is detected during an Autocalibration operation, the ACF interrupt flag is set, an interrupt is generated if the ACIE register bit is set and the Calibration RC registers (15h and 16h) are not updated.

If an Autocalibration failure is detected while running in RC Autocalibration mode, it is advisable to switch into XT Autocalibration mode to maintain the timing accuracy. This is done by first ensuring a XT oscillator failure has not occurred (OF flag = 0) and then clearing the OSEL bit. The ACAL field should remain set to either 11 (512 second period) or 10 (1024 second period). After the switch occurs, the OMODE bit is cleared.

While continuing to operate in XT Autocalibration mode, the following steps can be used to determine when it is safe to return to RC Autocalibration mode.

1. Clear the ACF flag and ACIE register bit.
2. Setup the Countdown Timer or Alarm to interrupt after the next Autocalibration cycle completes or longer time period.
3. After the interrupt occurs, check the status of the ACF flag.
4. If the ACF flag is set, it is not safe to return to RC Autocalibration mode. Clear the ACF flag and repeat steps 2-4.
5. If the ACF flag is still cleared, it is safe to return to RC Autocalibration mode by setting the OSEL bit.

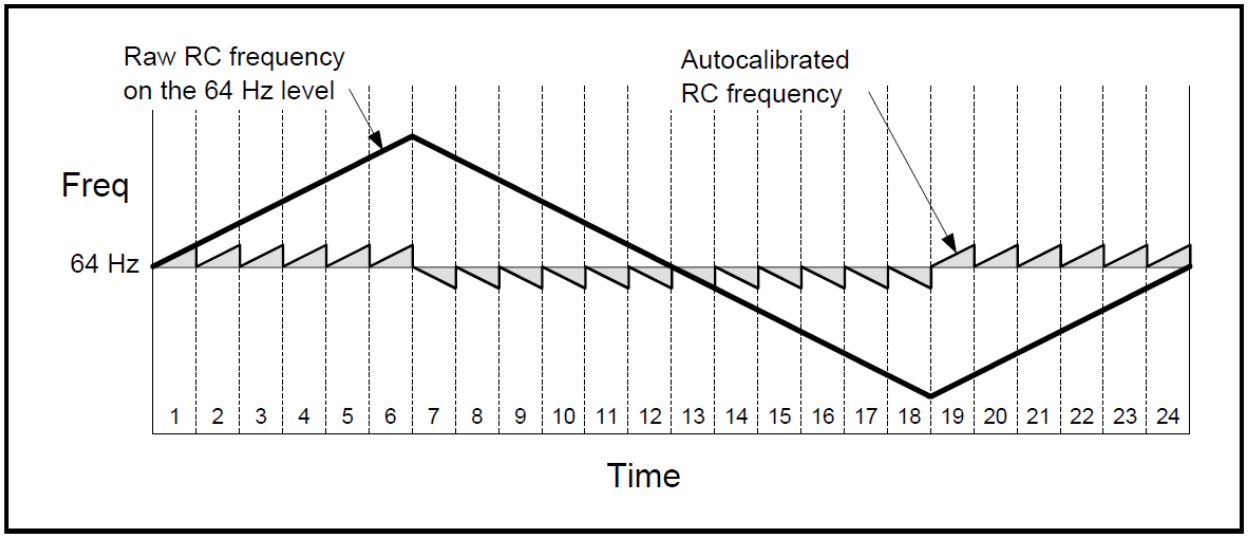
As mentioned in the RC oscillator section, switching between XT and RC oscillators is guaranteed to produce less than one second of error. However, this error needs to be considered and can be safely managed when implementing the steps above. For example, switching between oscillator modes every 48 hours will produce less than 6 ppm of deviation.

4.10.7.Frequency Accuracy in RC Autocalibration Mode

RC Autocalibration Mode is typically the most useful mode, because it allows a dramatic reduction in the power used by the AB-RTCMC-32.768kHz-IBO5-S3 while maintaining the accuracy of the internal clock. The RC is always used as the internal clock so that no time deviations occur as can be seen with XT Autocalibration Mode and automatic switchover. RC Autocalibration Mode is the only applicable mode in systems where there is only a single battery supply, which is very common. Because the RC Oscillator is fundamentally less stable with temperature (typically +/- 1%, or 10’000 ppm, over the full temperature range) than the digitally calibrated XT Oscillator (typically within 150 ppm over the full temperature range), many applications cannot use the RC Oscillator alone as the timing clock. RC Autocalibration improves the accuracy of the RC Oscillator by continuously adjusting it to match the calibrated XT Oscillator.

Autocalibration maintains the RC Oscillator at a frequency very close to the digitally calibrated XT Oscillator, but there are obviously small deviations which can occur on each cycle. However, as temperature and the raw RC Oscillator frequency vary, deviations typically cancel each other out and produce very low accumulated deviation. The following Figure shows a time sequence with varying frequency. The heavy shaded line shows the variation of the raw RC Oscillator on the 64 Hz level, and the vertical dashed lines indicate the boundaries of Autocalibration Periods (ACPs, either 512 or 1024 seconds). The RC Oscillator is calibrated within a small number of PPM at the beginning of each ACP to the digitally calibrated XT Oscillator, so the calibrated RC frequency is the saw tooth function in the center of the figure, with the accumulated deviation in each ACP shown by the shaded triangles.

Autocalibration Deviation Cancellation:

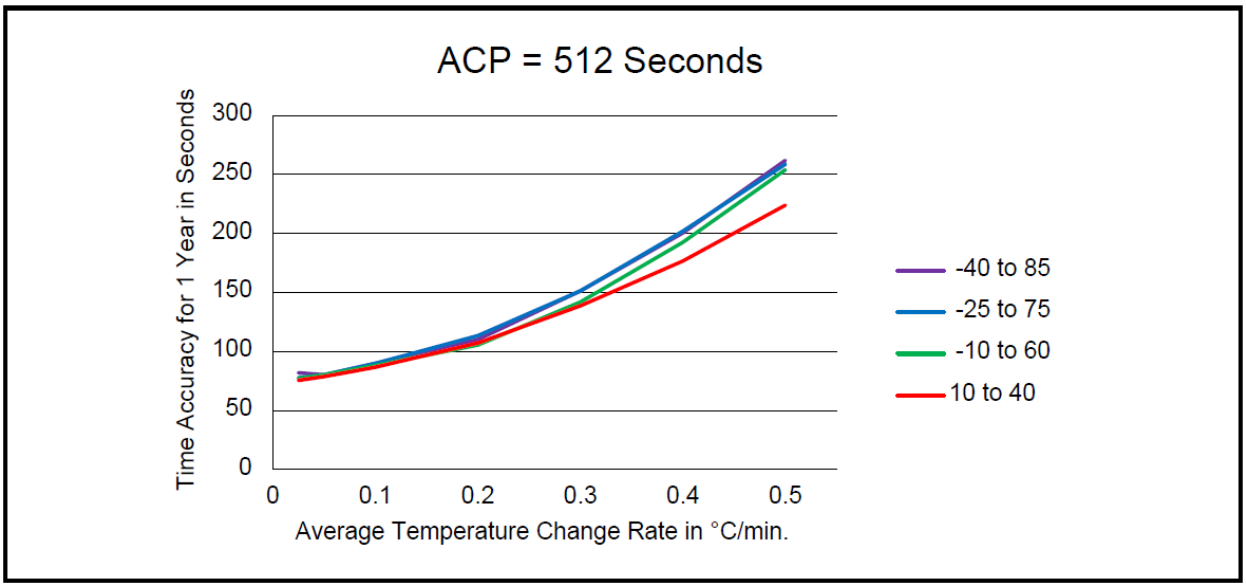


Although some deviation is accumulated in each ACP, it can be seen that the positive deviations which occur when the frequency is rising are cancelled by the negative deviations when the frequency is falling. Over any significant period of time, the net accumulated deviation is almost completely determined by the frequency difference between the beginning and end of the period and the rate of change of the frequency with time.

Since the frequencies of both the RC and the XT Oscillators are functions of temperature, and temperature changes are easy to understand and quantify, accumulated deviation is measured as a function of the temperature profile. The behavior of RC Autocalibration has been modeled by varying the temperature in a random way and simulating the desired period, which in the cases below is one year. The temperature rises or falls at a random rate between twice the average rate specified and the negative of that value, and is limited to the specified maximum and minimum temperatures. One thousand simulations were executed, and the specified deviation is the worst case result of all iterations.

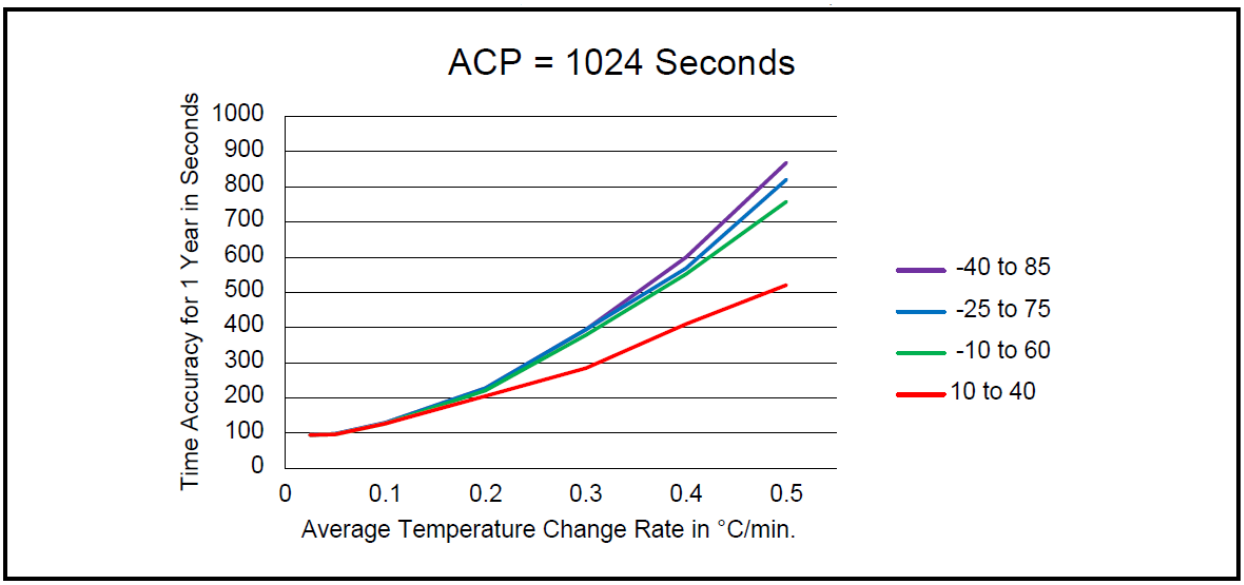
The following Figure shows the maximum accumulated time deviation relative to the digitally calibrated XT Oscillator as a function of the maximum temperature range and the average temperature change rate over a one year period, in seconds (31 seconds in a year = 1 ppm), with an Autocalibration Period of 512 seconds. Note that even the lowest average change rate of 0.025 equates to one degree C every 40 minutes, which is still quite fast when averaged over an entire year. At this change rate, the deviation over the full temperature range is less than 95 seconds (<3 ppm).

Autocalibration Time Deviation relative to the digitally calibrated XT Oscillator, ACP = 512 seconds:



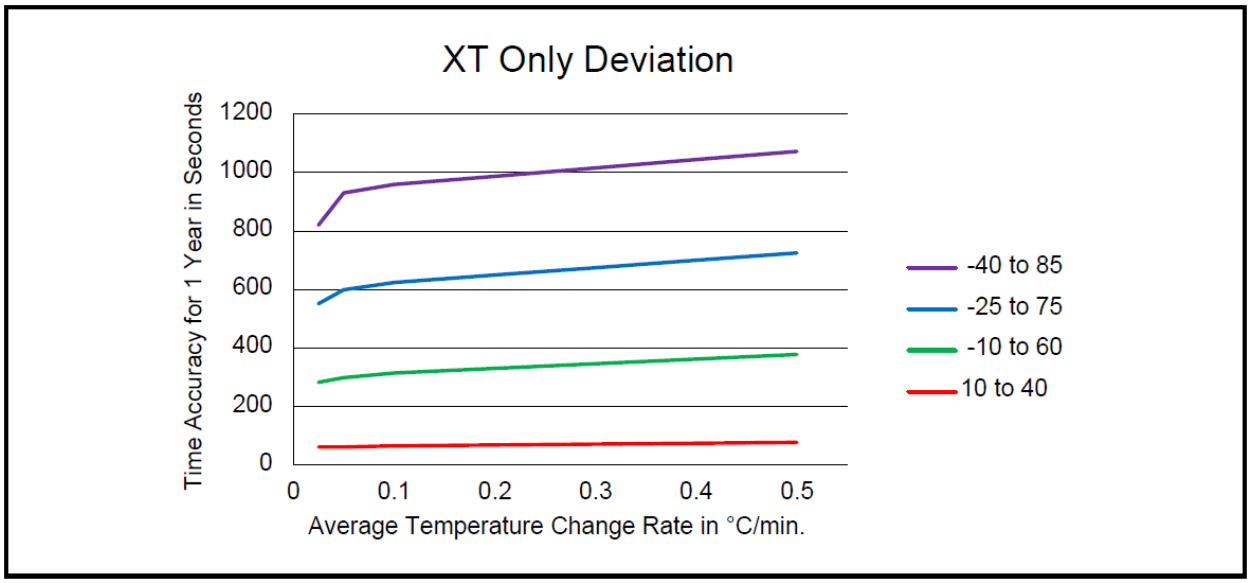
The following Figure shows the results when the ACP is 1024 seconds. At high temperature change rates, this setting produces roughly 3 times the deviation of the 512 second case, but the deviations for low change rates are still negligible.

Autocalibration Time Deviation relative to the digitally calibrated XT Oscillator, ACP = 1024 seconds:



The deviations in both of the cases above for relatively low temperature change rates are less than the deviation introduced by the XT Oscillator itself. The following Figure shows the raw XT deviation, which is more strongly a function of the maximum temperature range than the calibrated RC deviation. The XT deviation is a similar function of the temperature change rate but is more influenced by the maximum temperature variation. Deviations in the XT Oscillator are larger when the temperature is further away from the nominal 25 degrees C, and therefore it is expected that the accumulated deviation will be greater if the temperature range is larger.

Raw Deviation, XT Oscillator:



4.10.8.A Real World Example

Even if the temperature occasionally reaches the extremes of the allowable range and changes relatively quickly, in most real applications the temperature is reasonably stable. A proposed "real world" temperature profile assumes that for 30 days per year the temperature has a maximum range of -25 to 75 degrees C and an average change rate of 1 degree C every 5 minutes (0.2 °C/min.). For the remainder of the year, the maximum temperature range is 10 to 40 degrees C with a maximum change rate of 1 degree C every 40 minutes (0.025 °C/min.). Using this profile, the accumulated deviations over the year (including the XT deviation in the calibrated RC cases) are shown in following Table. As can be seen, with an ACP of 512 the clock accuracy using Autocalibration is quite close to the deviation achieved by the XT alone. Extending to an ACP of 1024 seconds adds a small incremental deviation.

Real World Accumulated Deviations for 1 Year (1 ppm = 31.6 seconds in a year):

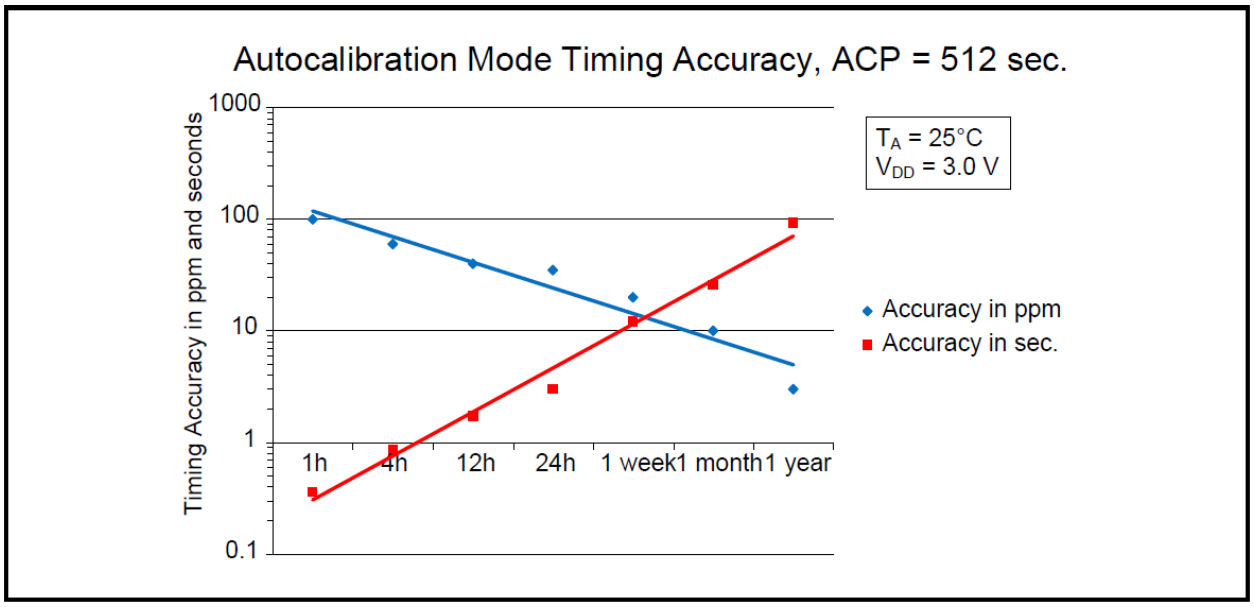
Mode	Conditions	Accumulated Deviation	Unit
XT only	Calibrated (0ppm at 25°C)	-3.3	ppm/year
		-104	s/year
RC Autocalibration	ACP = 512 seconds	±6.1	ppm/year
		±192	s/year
	ACP = 1024 seconds	±8.4	ppm/year
		±245	s/year

4.10.9.RC Autocalibration Timing Accuracy Example

The RC Oscillator displays relatively high internal jitter caused by pulse addition or subtraction of the Autocalibration process as well as the inherent thermal noise jitter of the RC Oscillator itself. This jitter introduces significant time accuracy errors for short time periods.

The following Figure shows a typical Autocalibration mode timing accuracy for the time periods from 1 hour to 1 year relative to the digitally calibrated XT Oscillator, ACP = 512 seconds. The temperature does not varying. TA = 25°C, V_{DD} = 3.0V.

Autocalibration Mode Timing Accuracy Example:



4.10.10. Power Analysis

The power comparisons between the various cases are quite straightforward. During an Autocalibration, the XT Oscillator is powered up for 50 seconds. Therefore if the AB-RTCMC-32.768kHz-IBO5-S3 draws 60 nA when the XT Oscillator is running and 17 nA when the XT Oscillator is off, the average current for each ACP case is shown in the following Table. Even the shortest ACP results in a savings of more than 60% of the current.

Autocalibration Current (TA = 25°C, V_{DD} = 3.0V):

	Average Current (nA)
XT only	60
Cal RC, ACP = 512 seconds	22
Cal RC, ACP = 1024 seconds	19

4.10.11. Disadvantages Relative to the XT Oscillator

Maximum Output Clock Frequency

The primary disadvantage of using the autocalibrated RC Oscillator is that the highest calibrated output clock frequency which can be generated is 64 Hz (i.e., circa the half of the uncalibrated RC Oscillator frequency). In applications where a higher frequency clock is required, the XT Oscillator must be used. If such a clock is required only occasionally, the AB-RTCMC-32.768kHz-IBO5-S3 may be temporarily placed in XT Mode by setting the OSEL bit to 0, and then returned to RC Mode by setting OSEL back to 1 when the high frequency clock is no longer required. The AB-RTCMC-32.768kHz-IBO5-S3 will continue to autocalibrate the RC Oscillator while the XT Oscillator is selected, but the calendar counters may gain or lose up to 1 second on each of the oscillator switchovers.

Large/Rapid Temperature Fluctuations

The XT Oscillator may also be preferable to Autocalibration when there are frequent, rapid and large temperature changes. In such a situation, the digitally calibrated XT Oscillator may provide a measurable improvement in accuracy, although at a significant power penalty relative to using Autocalibration.

Short Term Jitter

A third disadvantage of using the RC Oscillator is that it displays higher internal jitter relative to the XT oscillator. This jitter is caused by pulse addition or subtraction of the Autocalibration process as well as the inherent thermal noise jitter of the RC Oscillator itself. This jitter may introduce significant frequency errors over short time periods. In both cases the mean of the jitter is zero, and the following Table shows the standard deviation of the clock period for several short time periods including both jitter and temperature effects. A typical worst case metric is 4 standard deviations, which covers approximately 99.99% of all cases.

Time Interval	Std. Dev. (ppm)	Std. Dev. (ms)
0.5 hours	90.9	163.6
1 hour	45.5	163.8
2 hours	32.3	232.6
4 hours	22.5	324.0
1 day	9.3	803.5
2 days	6.5	1123.2
3 days	5.3	1373.8
1 week	3.5	2116.8

4.11.XT Oscillator Failure Detection

If the 32.768 kHz XT Oscillator generates clocks at less than 8 kHz for a period of more than 32 ms, the AB-RTCMC-32.768kHz-IBO5-S3 detects an XT Oscillator Failure. The XT Oscillator Failure function is controlled by several bits in the OSCILLATOR REGISTERS (see 1Ch Oscillator Control and 1Dh - Oscillator Status Register). The OF flag is set when an XT Oscillator Failure occurs, and is also set when the AB-RTCMC-32.768kHz-IBO5-S3 initially powers up. If the OFIE bit is set, the OF flag will generate an interrupt OFIRQ.

If the FOS bit is set and the AB-RTCMC-32.768kHz-IBO5-S3 is currently using the XT Oscillator, it will automatically switch to the RC Oscillator on an XT Oscillator Failure. This guarantees that the system clock will not stop in any case. The OMODE bit indicates the currently selected oscillator, which will not match the oscillator requested by the OSEL bit if the XT Oscillator is not running.

The OF flag will be set when the AB-RTCMC-32.768kHz-IBO5-S3 powers up, and will also be set whenever the XT Oscillator is stopped. This can happen when the STOP bit is set or the OSEL bit is set to 1 to select the RC Oscillator. Since the XT Oscillator is stopped in RC Autocalibration mode (see RC AUTOCALIBRATION MODE), OF will always be set in this mode. The OF flag should be cleared whenever the XT Oscillator is enabled prior to enabling the OF interrupt with OFIE.

4.12.Interrupts

The AB-RTCMC-32.768kHz-IBO5-S3 may generate a variety of interrupts which are ORed into the IRQ signal. This may be driven onto either the CLK/$\overline{\text{INT}}$ pin or the PSW pin depending on the configuration of the CLKS and PSWS fields (see CONFIGURATION REGISTERS, 11h - Control2).

4.12.1.Interrupt Summary

The possible interrupts are summarized in the following Table. All enabled interrupts are ORed into the IRQ signal when their respective flags are set. Note that most interrupt outputs use the inverse of the interrupt, denoted as e.g. inverse IRQ. The fields are:

- Interrupt - the name of the specific interrupt.
- Function - the functional area which generates the interrupt.
- Enable - the register bit which enables the interrupt. Note that for the Watchdog interrupt, WDS is the steering bit, so that the flag generates an Interrupt if WDS is 0 and a Reset if WDS is 1. In either case, the WDM field must be non-zero to generate the Interrupt or Reset.
- Pulse/Level/Repeat - some interrupts may be configured to generate a pulse based on the register bits in this column. "Level Only" implies that only a level may be generated, and the interrupt will only go away when the flag is reset by software.
- Flag - the register bit which indicates that the function has occurred. Note that the flag being set will only generate an interrupt signal on an external pin if the corresponding interrupt enable bit is also set.

Interrupt	Function	Enable	Pulse/Level/Repeat	Flag
AIRQ	Alarm Match	AIE	IM, ARPT	AF
TIRQ	Countdown Timer	TIE, TE	TM, TRPT, TFS	TF
WIRQ	Watchdog Timer (WDI)	WDS = 0, WDM, WD	Level only	WDF
BLIRQ	Battery Low	BLIE, BREF, BPOL	Level only	BLF
EIRQ	External Interrupt (WDI)	EIE, EIP	Level only	EVF
OFIRQ	XT Oscillator Failure	OFIE	Level only	OF
ACIRQ	Autocalibration Failure	ACIE	Level only	ACF
IRQ = AIRQ + TIRQ + WIRQ + BLIRQ + EIRQ + OFIRQ + ACIRQ				

4.12.2.Alarm Interrupt AIRQ

The AB-RTCMC-32.768kHz-IBO5-S3 may be configured to generate the AIRQ interrupt when the values in the Time and Date Registers match the values in the Alarm Registers. Which register comparisons are required to generate AIRQ is controlled by the ARPT field as described in TIMER REGISTERS, 18h - Countdown Timer Control, allowing software to specify the interrupt interval. When an Alarm Interrupt is generated, the AF flag is set and an output signal is generated based on the AIE bit and the pin configuration settings. The IM field controls the period of the signal, including both level and pulse configurations.

4.12.3.Countdown Timer Interrupt TIRQ

The AB-RTCMC-32.768kHz-IBO5-S3 may be configured to generate the TIRQ interrupt when the Countdown Timer is enabled by the TE bit and reaches the value of zero, which will set the TF flag. The TM, TRPT and TFS fields control the interrupt timing (see TIMER REGISTERS, 18h - Countdown Timer Control), and the TIE bit and the pin configuration settings control the output signal generation.

4.12.4. Watchdog Timer Interrupt WIRQ

The AB-RTCMC-32.768kHz-IBO5-S3 may be configured to generate the WIRQ interrupt when the Watchdog Timer reaches its timeout value. This sets the WDF flag and is described in section WATCHDOG TIMER.

4.12.5. Battery Low Interrupt BLIRQ

The AB-RTCMC-32.768kHz-IBO5-S3 may be configured to generate the BLIRQ when the voltage on the V_{BACKUP} pin crosses one of the thresholds set by the BREF field. The polarity of the detected crossing is set by the BPOL bit.

4.12.6. External Interrupt EIRQ

The AB-RTCMC-32.768kHz-IBO5-S3 may be configured to generate the EIRQ interrupt when the WDI input toggles. The register bit EIP control whether the rising or falling transitions generate the respective interrupt. Changing EIP may cause an immediate interrupt, so the interrupt flag should be cleared after changing this bit.

The value of the WDI pin may be directly read in the WDIS bit (see RAM REGISTERS, 3Fh - Extension RAM Address). By connecting the input such as a pushbutton to WDI, software can debounce the switch input using software configurable delays.

4.12.7. XT Oscillator Failure Interrupt OFIRQ

The AB-RTCMC-32.768kHz-IBO5-S3 may be configured to generate the OFIRQ interrupt if the XT oscillator fails (see XT OSCILLATOR FAILURE DETECTION).

4.12.8. Autocalibration Failure Interrupt ACIRQ

The AB-RTCMC-32.768kHz-IBO5-S3 may be configured to generate the ACIRQ interrupt if an Autocalibration operation fails (see AUTOCALIBRATION FAIL).

4.12.9. Servicing Interrupts

When an interrupt is detected, software must clear the interrupt flag in order to prepare for a subsequent interrupt. If only a single interrupt is enabled, software may simply write a zero to the corresponding interrupt flag to clear the interrupt. However, because all of the flags in the Status register are written at once, it is possible to clear an interrupt which has not been detected yet if multiple interrupts are enabled. The ARST register bit is provided to insure that interrupts are not lost in this case. If ARST is a 1, a read of the Status register will produce the current state of all the interrupt flags in the Status register (WDF, BLF, TF, AF and EVF) and then clear them. An interrupt occurring at any time relative to this read is guaranteed to either produce a 1 on the Status read, or to set the corresponding flag after the clear caused by the Status read. After servicing all interrupts which produced 1s (ones) in the read, software should read the Status register again until it returns all zeros in the flags, and service any interrupts with flags of 1.

Note that the OF and ACF interrupts are not handled with this process because they are in the Oscillator Status register, but error interrupts are very rare and typically do not create any problems if the interrupts are cleared by writing the flag directly.

4.13.Power Control and Switching

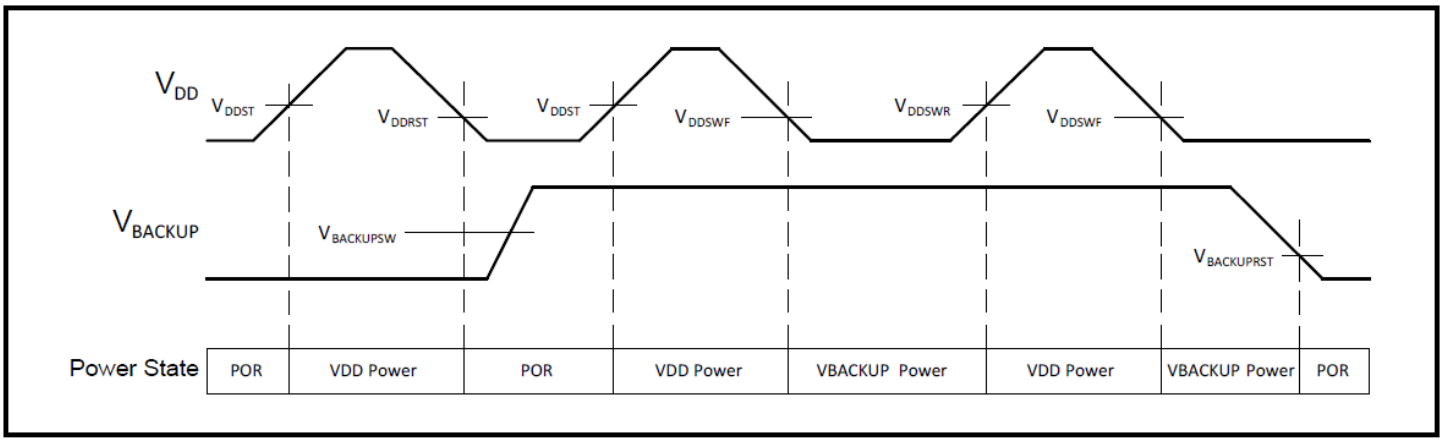
The main power supply to the AB-RTCMC-32.768kHz-IBO5-S3 is the V_{DD} pin, which operates over the range specified by the V_{DDIO} parameter if there are I^2C interface operations required, and the range specified by the V_{DD} parameter if only timekeeping operations are required. The AB-RTCMC-32.768kHz-IBO5-S3 also include a backup supply which is provided on the V_{BACKUP} pin and must be in the range specified by the V_{BACKUP} parameter in order to supply battery power if V_{DD} is below V_{DDSWF}. Refer to Table in Section POWER SUPPLY PARAMETERS for the specifications related to the power supplies and switchover. There are several functions which are directly related to the V_{BACKUP} input. If a single power supply is used it must be connected to the V_{DD} pin.

The following Figure illustrates the various power states and the transitions between them. There are three power states:

1. POR – the power on reset state. If the AB-RTCMC-32.768kHz-IBO5-S3 is in this state, all registers including the Counter Registers are initialized to their reset values.
2. V_{DD} Power – the AB-RTCMC-32.768kHz-IBO5-S3 is powered from the V_{DD} supply.
3. V_{BACKUP} Power – the AB-RTCMC-32.768kHz-IBO5-S3 is powered from the V_{BACKUP} supply.

Initially, V_{DD} is below the V_{DDST} voltage, V_{BACKUP} is below the $V_{BACKUPSW}$ voltage and the AB-RTCMC-32.768kHz-IBO5-S3 is in the POR state. V_{DD} rising above the V_{DDST} voltage causes the AB-RTCMC-32.768kHz-IBO5-S3 to enter the V_{DD} Power state. If V_{BACKUP} remains below $V_{BACKUPSW}$, V_{DD} falling below the V_{DDRST} voltage returns the AB-RTCMC-32.768kHz-IBO5-S3 to the POR state.

Power States:



If V_{BACKUP} rises above $V_{BACKUPSW}$ in the POR state, the AB-RTCMC-32.768kHz-IBO5-S3 remains in the POR state. This allows the AB-RTCMC-32.768kHz-IBO5-S3 to be built into a module with a battery included, and minimal current will be drawn from the battery until V_{DD} is applied to the module the first time.

If the AB-RTCMC-32.768kHz-IBO5-S3 is in the V_{DD} Power state and V_{BACKUP} rises above $V_{BACKUPSW}$, the AB-RTCMC-32.768kHz-IBO5-S3 remains in the V_{DD} Power state but automatic switchover becomes available. V_{BACKUP} falling below $V_{BACKUPSW}$ has no effect on the power state as long as V_{DD} remains above V_{DDSWF}. If V_{DD} falls below the V_{DDSWF} voltage while V_{BACKUP} is above $V_{BACKUPSW}$ the AB-RTCMC-32.768kHz-IBO5-S3 switches to the V_{BACKUP} Power state. V_{DD} rising above V_{DDSWR} returns the AB-RTCMC-32.768kHz-IBO5-S3 to the V_{DD} Power state. There is hysteresis in the rising and falling V_{DD} thresholds to insure that the AB-RTCMC-32.768kHz-IBO5-S3 does not switch back and forth between the supplies if V_{DD} is near the thresholds. V_{DDSWF} and V_{DDSWR} are independent of the V_{BACKUP} voltage and allow

the AB-RTCMC-32.768kHz-IBO5-S3 to minimize the current drawn from the V_{BACKUP} supply by switching to V_{BACKUP} only at the point where V_{DD} is no longer able to power the device.

If the AB-RTCMC-32.768kHz-IBO5-S3 is in the VBACKUP Power state and VBACKUP falls below VBACKUPRST, the AB-RTCMC-32.768kHz-IBO5-S3 will return to the POR state.

Whenever the AB-RTCMC-32.768kHz-IBO5-S3 enters the V_{BACKUP} Power state, the BAT status bit (Read Only) (see CONFIGURATION REGISTERS, 0Fh - Status) is set and may be polled by software if the I^2C bus is driven by V_{BACKUP}. If the XT oscillator is selected and the BOS bit is set (see OSCILLATOR REGISTERS, 1Ch - Oscillator Control), the AB-RTCMC-32.768kHz-IBO5-S3 will automatically switch to the RC oscillator in the V_{BACKUP} Power state in order to conserve battery power (Autocalibration Mode according to the ACAL field). If the IOBM bit is clear (see ANALOG CONTROL REGISTERS, 27h – IO Batmode Register), the I^2C interface is disabled in the V_{BACKUP} Power state in order to prevent erroneous accesses to the AB-RTCMC-32.768kHz-IBO5-S3 if the bus master loses power.

4.13.1.Automatic Switchover Summary

When the AB-RTCMC-32.768kHz-IBO5-S3 switches over from V_{DD} Power state to the V_{BACKUP} Power state and vice versa an Automatic Oscillator Switchover can be controlled by the BOS bit. The Autocalibration Mode is according to the ACAL field.

Automatic Oscillator Switchover using the BOS bit:

BOS	Used Oscillator		Description
	V_{DD} Power State	V_{BACKUP} Power State	
0	RC	RC	No automatic oscillator switching occurs.
	RC Autocalibration	RC Autocalibration	
	XT	XT	
	XT Autocalibration	XT Autocalibration	
1	RC	RC	The oscillator will automatically switch to the RC oscillator (Autocalibration Mode according to ACAL)
	RC Autocalibration	RC Autocalibration	
	XT	RC	
	XT Autocalibration	RC Autocalibration	

When using the FOS bit to control the switchover, an Automatic Oscillator Switchover occurs when a XT oscillator failure is detected and FOS is set to 1.

4.13.2.Battery Low Flag and Interrupt

If the V_{BACKUP} voltage drops below the Falling Threshold selected by the BREF field (see ANALOG CONTROL REGISTERS, 21h – BREF Control), the BLF flag (see CONFIGURATION REGISTERS, 0Fh - Status) is set. If the BLIE interrupt enable bit (see CONFIGURATION REGISTERS, 12h - Interrupt Mask) is set, the BLIRQ interrupt is generated. This allows software to determine if a backup battery has been drained. Note that the BPOL bit must be set to 0. The algorithm in the ANALOG COMPARATOR section should be used when configuring the BREF value.

If the V_{BACKUP} voltage is above the rising voltage which corresponds to the current BREF setting, BREFD will be set. At that point the V_{BACKUP} voltage must fall below the falling voltage in order to clear the BREFD bit and the BAT status bit is set and a falling edge BLF interrupt is generated. If BREFD is clear, the V_{BACKUP} voltage must rise above the rising voltage in order to clear the BREFD bit and generate a rising edge BLF interrupt.

4.13.3.Analog Comparator

If a backup battery is not required, the V_{BACKUP} pin may be used as an analog comparator input. The voltage comparison level is set by the BREF field. If the BPOL bit is 0, the BLF flag will be set when the V_{BACKUP} voltage crosses from above the BREF Falling Threshold to below it. If the BPOL bit is 1, the BLF flag will be set when the V_{BACKUP} voltage crosses from below the BREF Rising Threshold to above it. The BREFD bit (see ANALOG CONTROL REGISTERS, 2Fh – Analog Status Register (Read Only)) may be read to determine if the V_{BACKUP} voltage is currently above the BREF threshold (BREFD = 1) or below the threshold (BREFD = 0).

There is a reasonably large delay t_{BREF} (on the order of seconds) between changing the BREF field and a valid value of the BREFD bit. Therefore, the algorithm for using the Analog Comparator should comprise the following steps:

1. Set the BREF and BPOL fields to the desired values.

2. Wait longer than the maximum t_{BREF} time.

3. Clear the BLF flag, which may have been erroneously set as BREFD settles.

4. Check the BREFD bit to insure that the V_{BACKUP} pin is at a level for which an interrupt can occur. If a falling interrupt is desired (BPOL = 0), BREFD should be 1. If a rising interrupt is desired (BPOL = 1), BREFD should be 0.

If the comparison voltage on the V_{BACKUP} pin can remain when V_{DD} goes to 0, it is recommended that a Software Reset is generated to the AB-RTCMC-32.768kHz-IBO5-S3 after power up.

4.13.4.Pin Control and Leakage Management (Power Control)

Like most ICs, the AB-RTCMC-32.768kHz-IBO5-S3 may draw unnecessary leakage current if an input pin floats to a value near the threshold or an output pin is pulled to a power supply. Because external devices may be powered from V_{DD}, extra care must be taken to insure that any input or output pins are handled correctly to avoid extraneous leakage when V_{DD} goes away and the AB-RTCMC-32.768kHz-IBO5-S3 is powered from V_{BACKUP}. The 30h – Output Control Register (see ANALOG CONTROL REGISTERS), the 27h – IO Batmode Register (see ANALOG CONTROL REGISTERS) and the 3Fh - Extension RAM Address register (see RAM REGISTERS) include bits to manage this leakage, which should be used as follows:

1. IOBM (Bit 7, address 27h) should be cleared if the I^2C bus master is powered down when the AB-RTCMC-32.768kHz-IBO5-S3 is in the V_{BACKUP} Power state.

2. WDBM (Bit 7, address 30h) should be cleared if the WDI pin is connected to a device which is powered down when the AB-RTCMC-32.768kHz-IBO5-S3 is in the V_{BACKUP} Power state.

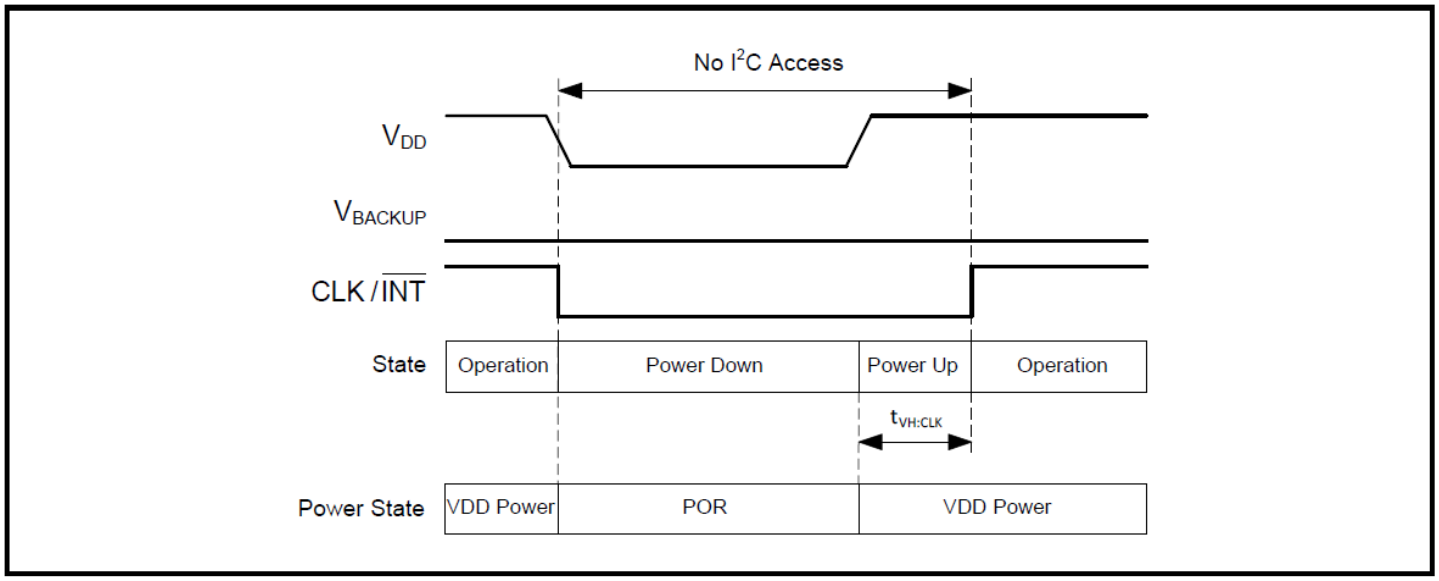
3. X (Bit 6, address 30h) is unused, but has to be 0 to avoid extraneous leakage. Disables an internal input when the AB-RTCMC-32.768kHz-IBO5-S3 is in the V_{BACKUP} Power state.

4. X (Bit 7, address 3Fh) is unused, but must be set to 0 to avoid extraneous leakage. If 0, an internal output is completely disconnected when the AB-RTCMC-32.768kHz-IBO5-S3 is in the V_{BACKUP} Power state.

4.13.5.Power Up Timing

When the voltage levels on both the V_{DD} and V_{BACKUP} signals drop below V_{DDRST}, the AB-RTCMC-32.768kHz-IBO5-S3 will enter the Power On Reset state (POR). Once V_{DD} rises above V_{DDST}, the AB-RTCMC-32.768kHz-IBO5-S3 will enter the V_{DD} Power state. The access via the I^2C interface will be disabled for a period of $t_{VH:CLK}$. The CLK/$\overline{INT}$ pin will be low at power up, and will go high when $t_{VH:CLK}$ expires. Software should poll the CLK/ $\overline{INT}$ value to determine when the AB-RTCMC-32.768kHz-IBO5-S3 may be accessed. The following Figure illustrates the timing of a power down/up operation.

Power Up Timing:



4.14.Reset Summary

The AB-RTCMC-32.768kHz-IBO5-S3 controls the $\overline{RST}$ output in a variety of ways, as shown in the following Table. The assertion of $\overline{RST}$ is a low signal if the RSTP bit is 0, and the assertion is high if RSTP is 1. RSTP always powers up as a zero so that on power $\overline{RST}$ is always asserted low.

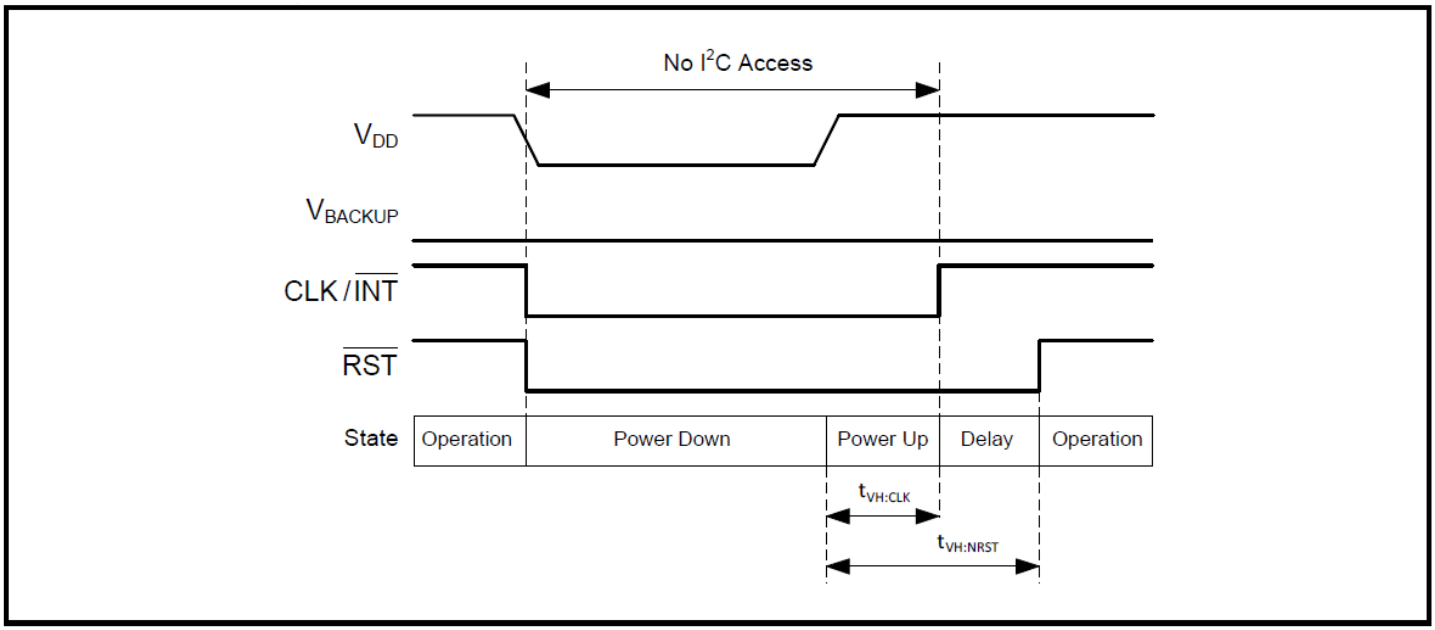
Reset Summary:

Function	Enable
Power Up	Always Enabled
Watchdog	WDS
Sleep	SLRST

4.14.1.Power Up Reset

When the AB-RTCMC-32.768kHz-IBO5-S3 powers up (see POWER UP TIMING) CLK/$\overline{INT}$ and $\overline{RST}$ will be asserted low until I^2C accesses are enabled. At that point CLK/$\overline{INT}$ will go high, and $\overline{RST}$ will continue to be asserted low for the delay $t_{VH:NRST}$, and will then be deasserted to high. The following Figure illustrates the reset timing on Power Up. Software should sample the CLK/$\overline{INT}$ signal prior to accessing the AB-RTCMC-32.768kHz-IBO5-S3.

Power Up Reset Timing:



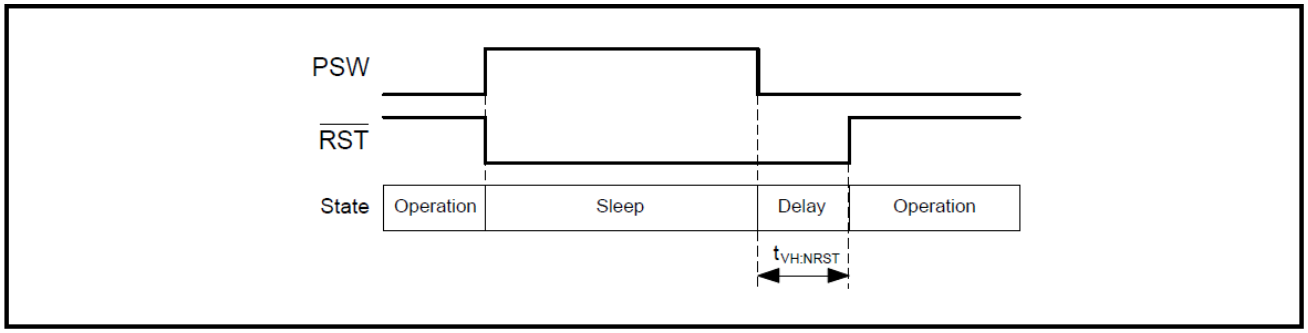
4.14.2.Watchdog Timer

If the WDS bit is 1, expiration of the Watchdog Timer (see WATCHDOG TIMER) will cause $\overline{RST}$ to be asserted low for approximately 60 ms.

4.14.3.Sleep

If the SLRST bit is set, $\overline{RST}$ will be asserted low whenever the AB-RTCMC-32.768kHz-IBO5-S3 is in Sleep Mode (see SLEEP CONTROL). Once a trigger is received and the AB-RTCMC-32.768kHz-IBO5-S3 exits Sleep Mode, $\overline{RST}$ will continue to be asserted low for the $t_{VH:NRST}$ delay. The following Figure illustrates the timing of this operation.

Sleep Reset Timing:



4.15.Software Reset

Software may reset the AB-RTCMC-32.768kHz-IBO5-S3 by writing the special value of 3Ch to the Configuration Key CONFKEY at register address 1Fh. This will provide the equivalent of a power on reset (POR) by initializing all of the AB-RTCMC-32.768kHz-IBO5-S3 registers. A software reset will not cause the $\overline{RST}$ signal to be asserted low.

4.16.Sleep Control State Machine

The AB-RTCMC-32.768kHz-IBO5-S3 includes a sophisticated Sleep Control system that allows the AB-RTCMC-32.768kHz-IBO5-S3 to manage power for other chips in a system. The Sleep Control system provides two outputs which may be used for system power control:

1. A reset ($\overline{RST}$) may be generated to put any host controller into a minimum power mode and to control sequencing during power up and power down operations.

2. A power switch signal (PSW) may be generated, which allows the AB-RTCMC-32.768kHz-IBO5-S3 to completely power down other chips in a system by allowing the PSW pin to float. The PSWS field must be set to a value of 6 to select the SLEEP signal.

   a. When setting PSWC bit to 1 (default value), PSW is configured as an open drain pin with approximately 1 Ω resistance. This allows the AB-RTCMC-32.768kHz-IBO5-S3 to directly switch power with no external components for small systems, or to control a single external transistor for higher current switching. If the I^2C master (i.e., the host controller) is powered down by the power switch, the IOPW bit should be set to insure that a floating bus does not corrupt the AB-RTCMC-32.768kHz-IBO5-S3.

   b. When setting PSWC bit to 0, PSW will be configured as a high true Sleep state which may be used as an interrupt.

The Sleep Control State Machine in the Figure in Section SLEEP STATE receives several inputs which it uses to determine the current Sleep State:

1. $\overline{POR}$ - the indicator that power on reset state is finished and power is valid, i.e. the AB-RTCMC-32.768kHz-IBO5-S3 is in either the V_{DD} Power state or the V_{BACKUP} Power state.

2. SLP - the Sleep Request signal which is generated by a software access to the bit SLP.

3. VAL - the OR of the enabled valid interrupt request from the Alarm comparison, Countdown Timer, Watchdog Timer and External Interrupt (WDI pin). The Battery Low detection interrupt, the Autocalibration Failure interrupt and the XT Oscillator Failure interrupt are not integrated to the internal VAL information but also ORed to the internal IRQ signal.

4. TF- the timeout signal from the Countdown Timer, indicating that it has decremented to 0.

4.16.1.RUN State

RUN is the normal operating state of the AB-RTCMC-32.768kHz-IBO5-S3. PSW is 0, RST is 1, SLP is 0, and SLF flag holds the state of the previous Sleep. The SLF flag should be cleared by software before entering the SWAIT state.

4.16.2.SWAIT State (Sleep_Wait State)

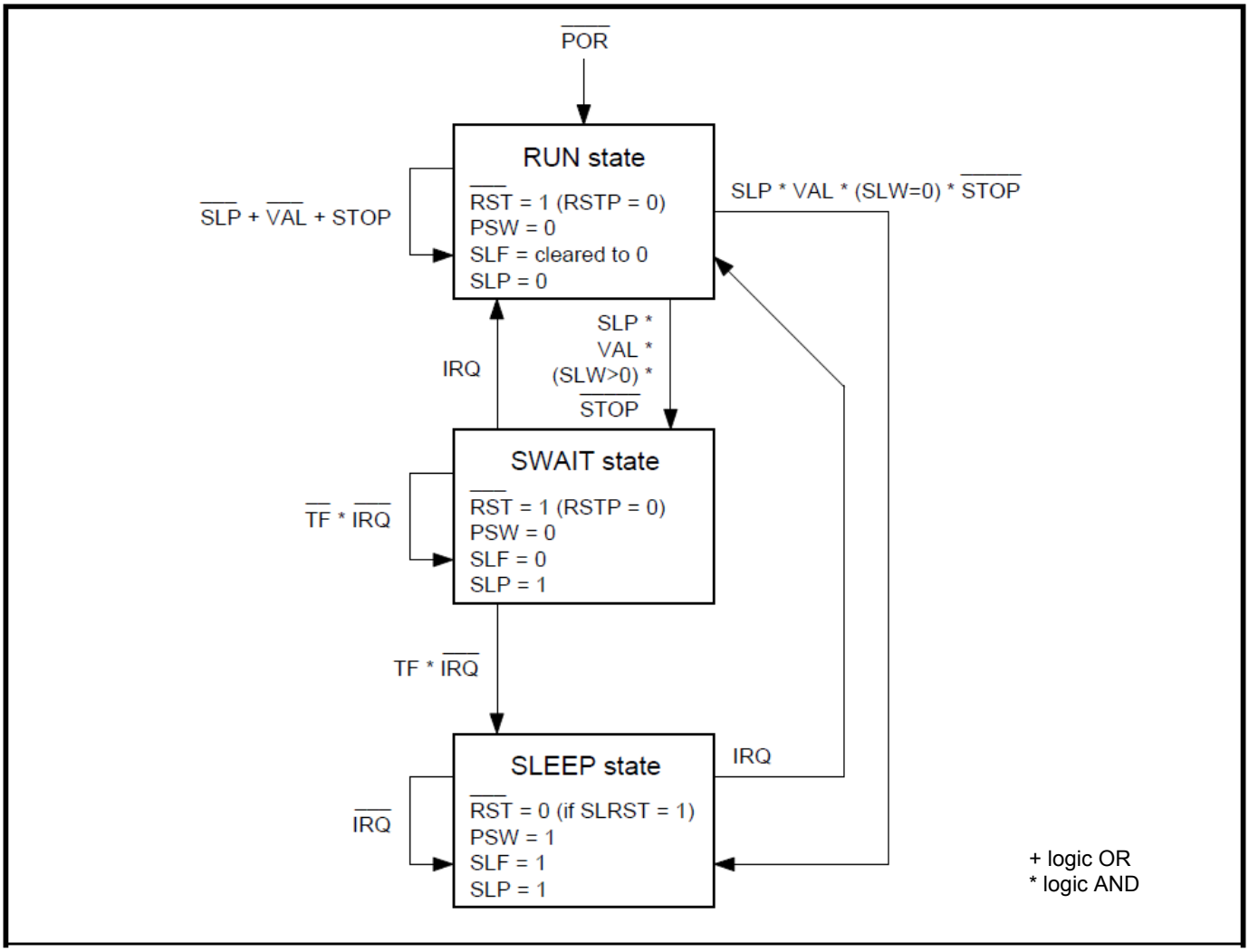
Software can put the chip to sleep by setting the SLP bit, as long as a valid interrupt is enabled (indicated by the internal status signal VAL being asserted high) (see SLP PROTECTION). If the SLW field is between 1 and 7 the Sleep Control State Machine moves to the SWAIT state and waits for between SLW and (SLW+1) times the ~8 ms periode. This allows software to perform additional cleanup functions after setting SLP before the MCU is shut down. Operation is the same in SWAIT as it is in RUN, and if an enabled operational interrupt occurs (combined interrupt signal IRQ) the Sleep Control State Machine returns to the RUN state and clears the SLP bit. PSW stay at 0, $\overline{RST}$ stay at 1 and the SLF flag is still 0.

If SLW is set to 0, the Sleep Control State Machine moves immediately to the SLEEP state. If the MCU is configured to be powered down in Sleep Mode, the I^2C operation to write the Sleep Register must be the last instruction executed by the MCU.

4.16.3.SLEEP State

Once the programmed number of periods has elapsed in the SWAIT state, the TF signal is asserted and the machine moves to the SLEEP state, putting the AB-RTCMC-32.768kHz-IBO5-S3into Sleep Mode. In this case PSW is asserted high, and $\overline{RST}$ is asserted low if SLRST = 1. Once an enabled operational interrupt occurs (combined interrupt signal IRQ), the Sleep Control State Machine returns to the RUN state, re-enables power and removes reset as appropriate. The SLF flag in the Sleep Register is set when the SLEEP state is entered, allowing software to determine if a SLEEP has occurred.

Sleep Control State Machine:



Interrupt functions
VAL: Minimum one valid interrupt is enabled (internal status signal).
IRQ: An enabled interrupt occurs (internal combined interrupt signal).
Bits and fields
SLP bit: Sleep Request signal
SLW field: Number of ~8 ms waiting periods
STOP bit: Stops clocking system
SLF bit: Flag is set when the AB-RTCMC-32.768kHz-IBO5-S3 enters SLEEP state. Can be cleared by software.
TF bit: Countdown Timer Flag. Set when timer reaches zero.
Outputs
$\overline{\text{RST}}$ pin
PSW pin

4.16.4.SLP Protection

Since going into Sleep Mode may prevent an MCU from accessing the AB-RTCMC-32.768kHz-IBO5-S3, it is critical to insure that the AB-RTCMC-32.768kHz-IBO5-S3 can receive an interrupt signal (combined interrupt signal IRQ). To guarantee this, the SLP signal cannot be set unless the STOP bit is 0 and at least one of the following interrupt functions are enabled (sets the internal status signal VAL to 1):

1. The AIE bit is 1, enabling an Alarm interrupt.
2. The TIE and the TE bits are 1, enabling a Countdown Timer interrupt.
3. The EIE bit is 1, enabling the External interrupt.
4. The WDM field is not zero and the WDS bit is zero, enabling a Watchdog Interrupt.

In addition, SLP cannot be set if there is an interrupt pending. Software should read the SLP bit after attempting to set it. If SLP is not asserted, the attempt to set SLP was unsuccessful either because a correct trigger was not enabled or because an interrupt was already pending. Once SLP is set, software should continue to poll it until the Sleep actually occurs, in order to handle the case where a trigger occurs before the AB-RTCMC-32.768kHz-IBO5-S3 enters Sleep Mode.

4.16.5.PSWS, PSWB and LKP

If the PSWS field is set to the initial value of 7, the PSW pin will be driven with the static value of the PSWB bit which is initially zero. If this pin is used as the power switch, setting PSWB will remove power from the system and may prevent further access to the AB-RTCMC-32.768kHz-IBO5-S3. In order to insure that this does not happen inadvertently, the LKP bit must be cleared in order to change the PSWB bit to a 1.

Note that in this power switch environment the PSWS register field must not be written to any value other than 6 or 7, even if the PSW pin would remain at zero, because it is possible that a short high pulse could be generated on the PSW pin which could create a power down.

4.16.6.Pin Control and Leakage Management (Sleep Control)

Like most ICs, the AB-RTCMC-32.768kHz-IBO5-S3 may draw unnecessary leakage current if an input pin floats to a value near the threshold or an output pin is pulled to a power supply. Because Sleep Mode can power down external devices connected to the AB-RTCMC-32.768kHz-IBO5-S3, extra care must be taken to insure that any input or output pins are handled correctly to avoid extraneous leakage. The Output Control register includes bits to manage this leakage, which should be used as follows:

1. CLKSL (Bit 0, address 30h) should be cleared if the CLK/$\overline{\text{INT}}$ pin is connected to a device which is powered down in Sleep Mode.
2. RSTSL (Bit 3, address 30h) should be cleared if the $\overline{\text{RST}}$ pin is connected to a device which is powered down in Sleep Mode.
3. WDDS (Bit 5, address 30h) should be set if the WDI pin is connected to a device which is powered down in Sleep Mode.
4. X (Bit 1, address 30h) is unused, but has to be 0 to avoid extraneous leakage. If 0, an internal output is completely disconnected when the AB-RTCMC-32.768kHz-IBO5-S3 is in Sleep Mode.
5. X (Bit 2, address 30h) is unused, but has to be 0 to avoid extraneous leakage. If 0, an internal output is completely disconnected when the AB-RTCMC-32.768kHz-IBO5-S3 is in Sleep Mode.

6. X (Bit 4, address 30h) is unused, but must be set to 1 to avoid extraneous leakage. Disables an internal input when the AB-RTCMC-32.768kHz-IBO5-S3 is in Sleep Mode.

The Oscillator Control register includes a bit to manage the I2C interface:

7. IOPW (Bit 2, address 1Ch) must be set to 1 to avoid extraneous leakage. If 1, the I^2C interface pins are disabled in Sleep Mode. This is a particularly important function because there are multiple leakage paths in the I^2C interface.

4.17.System Power Control Applications

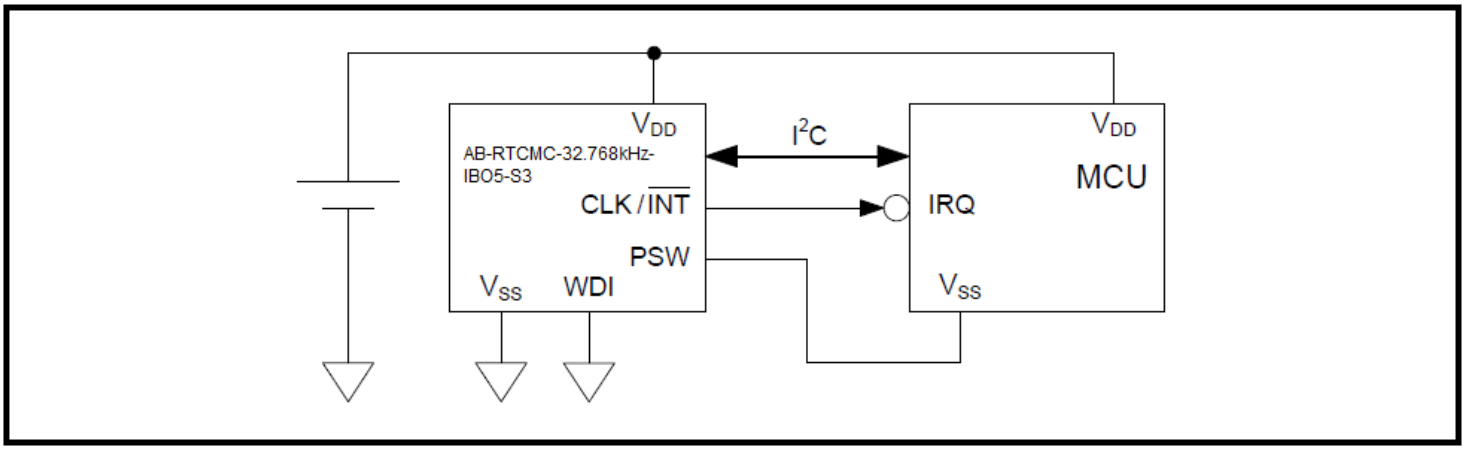
In addition to fundamentally low power RTC operation, the AB-RTCMC-32.768kHz-IBO5-S3 includes the capability to effectively manage the power of other devices in a system. It allows the creation of extremely power efficient systems with minimal additional components. This configuration is typically used when the entire system is powered from a battery.

4.17.1.V_{SS} Power Switched

The following Figure illustrates the recommended implementation, in which the internal power switch of the AB-RTCMC-32.768kHz-IBO5-S3 is used to completely turn off the MCU and/or other system elements. In this case the PSW output is configured to generate the system sleep function, the PSWC bit is asserted to high and the SLRST bit is set to 0. Under normal circumstances, the PSW pin is pulled to V_{SS} with approximately 1 Ω of resistance, so that the MCU receives full power. The MCU initiates a sleep operation by setting SLP to 1, and when the AB-RTCMC-32.768kHz-IBO5-S3 enters the SLEEP state the PSW pin is opened and power is completely removed from the MCU. This results in significant additional power savings relative to the other alternatives because even very low power MCUs require more current in their lowest power state than the AB-RTCMC-32.768kHz-IBO5-S3.

The AB-RTCMC-32.768kHz-IBO5-S3 normally powers up selecting the PSWB bit to drive the PSW pin, and the default value of the PSWB bit is zero. This insures that the power switch is enabled at power up. If the power switch function is used, software should only change the PSW selection between PSWB (111b) and SLEEP (110b) to insure no glitches occur in the power switching function.

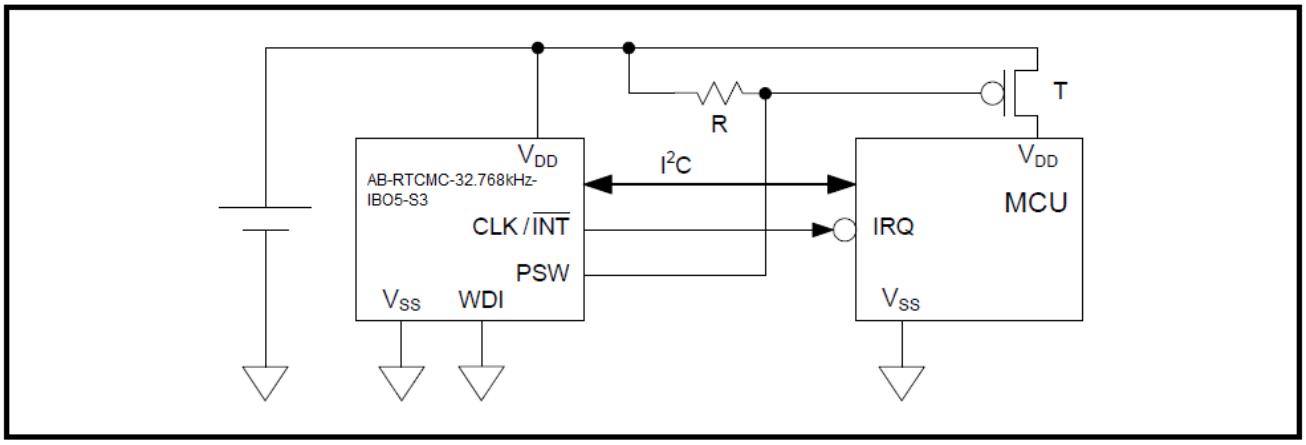
Switched V_{SS} Power Control:



4.17.2. V_{DD} Power Switched

The following Figure illustrates the application in which an external transistor switch T is used to turn off power to the MCU. The SLP function operates identically to the V_{SS} switched case above, but this implementation allows switching higher current and maintains a common ground. R can be on the order of megohms, so that negligible current is drawn when the circuit is active and PSW is low.

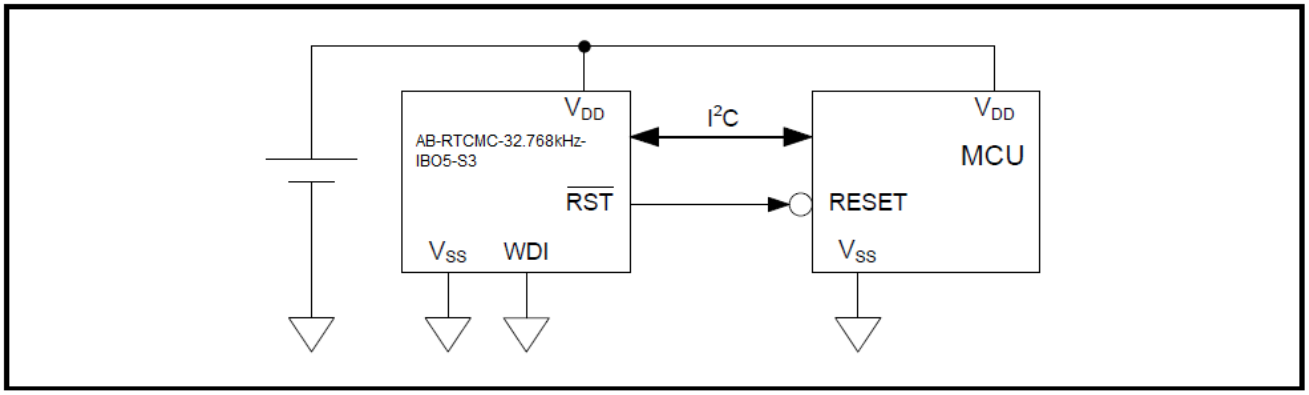
Switched V_{DD} Power Control:



4.17.3. Reset Driven

The following Figure illustrates the application in which the AB-RTCMC-32.768kHz-IBO5-S3 communicates with the system MCU using the reset function. In this case the MCU sets the SLRST bit so that when the AB-RTCMC-32.768kHz-IBO5-S3 enters the SLEEP state, it brings $\overline{RST}$ low to reset the MCU, and initiates a sleep operation. When the trigger occurs, the AB-RTCMC-32.768kHz-IBO5-S3 releases the MCU from reset, and may also generate an interrupt which the MCU can query to determine how reset was exited. Since some MCUs use much less power when reset, this implementation can save system power.

Reset Driven Power Control:

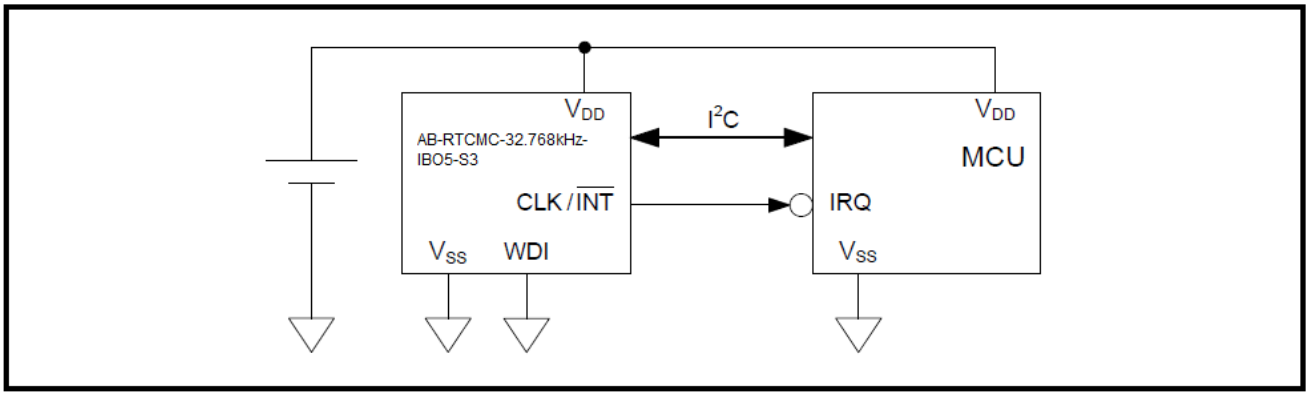


One potential issue with this approach is that many MCUs include internal pull-up resistors on their reset inputs, and the current drawn through that resistor when the reset input is held low is generally much higher than the MCU would draw in its inactive state. Any additional pull-up resistor should be removed and the $\overline{RST}$ output of the AB-RTCMC-32.768kHz-IBO5-S3 should be configured like a push-pull output.

4.17.4.Interrupt Driven

The following Figure illustrates the simplest application, in which the AB-RTCMC-32.768kHz-IBO5-S3 communicates with the system MCU using an interrupt. The MCU can go into standby mode, reducing power somewhat, until the AB-RTCMC-32.768kHz-IBO5-S3 generates an interrupt based on an alarm or a timer function. This produces smaller power savings than other alternatives, but allows the MCU to wake in the shortest time.

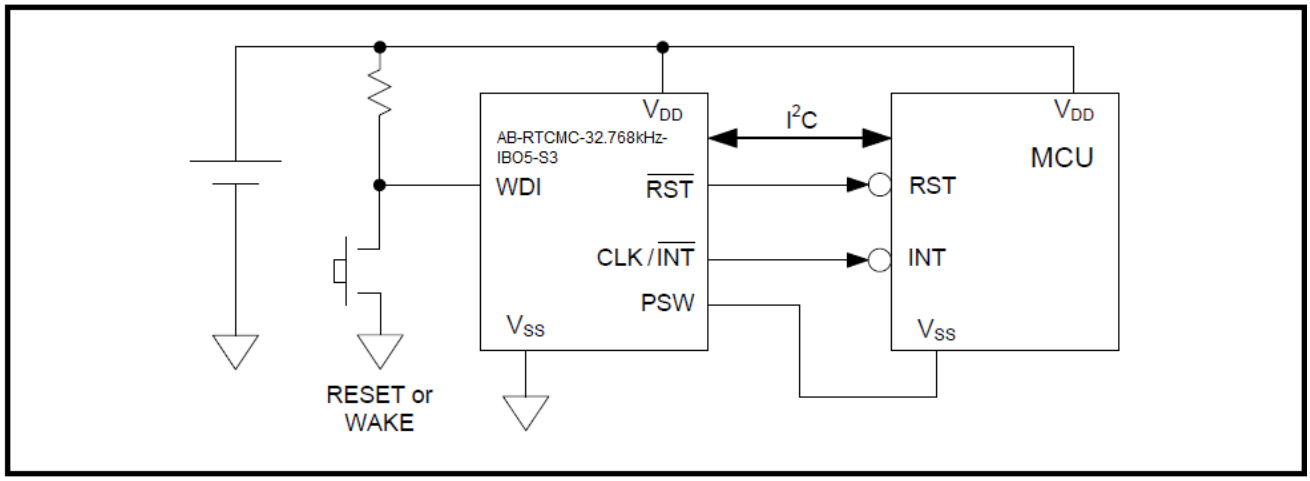
Interrupt Driven Power Control:



4.18.Typical System Implementation

The following Figure is a more detailed view of a typical system using the V_{SS} Power Switched approach. The V_{SS} pin of the MCU, and potentially other system components, is switched using the PSW pin of the AB-RTCMC-32.768kHz-IBO5-S3. The CLK/$\overline{INT}$ pin of the AB-RTCMC-32.768kHz-IBO5-S3 is connected to an interrupt input of the MCU, allowing the MCU to utilize the RTC interrupt functions of the AB-RTCMC-32.768kHz-IBO5-S3 when it is awake. The $\overline{RST}$ output of the AB-RTCMC-32.768kHz-IBO5-S3 is connected to the reset input of the MCU, enabling the AB-RTCMC-32.768kHz-IBO5-S3 to control power on reset and integrate an external MCU reset button RESET. The MCU controls the AB-RTCMC-32.768kHz-IBO5-S3 over the I^2C channel.

System Example:



The key value of the AB-RTCMC-32.768kHz-IBO5-S3 in this type of system is the ability to put the MCU into an off state, and providing a very rich variety of triggers which can cause the AB-RTCMC-32.768kHz-IBO5-S3 to wake the MCU from the off state. There are a number of different triggers which may be useful.

4.18.1.Alarms

The system may require the MCU to wake up at particular times, which is accomplished by configuring the Alarm Interrupt function of the AB-RTCMC-32.768kHz-IBO5-S3.

4.18.2.Countdown Timer

The system may require the MCU to wake up at periodic intervals which do not necessarily correspond to specific calendar times. The Countdown Timer of the AB-RTCMC-32.768kHz-IBO5-S3 provides highly flexible time interval configuration to support this function.

4.18.3.Wake Button/Switch

A very common requirement is the capability to wake the system with a manual input such as a pushbutton or switch, typified by the WAKE button in the System Example above. The external interrupt input WDI may be simply connected to the button. The WDI input includes a Schmitt trigger circuitry to enable clean interrupts. If additional debouncing of the input is required, the AB-RTCMC-32.768kHz-IBO5-S3 provides direct access to the interrupt input pin to facilitate software implementations.

4.18.4.External Device Input

In some systems an external device such as a wakeup radio may provide a signal which must wake the MCU. The AB-RTCMC-32.768kHz-IBO5-S3 external interrupt WDI pin provides this capability.

4.18.5.Analog Input

Some systems include analog signals, such as light sensors or detectors on radio antennas, which must wake the MCU. The Analog Comparator function, which allows the voltage on the V_{BACKUP} input of the AB-RTCMC-32.768kHz-IBO5-S3 to be compared with a configurable voltage threshold and generate an interrupt, can easily be used in this application, and it allows flexible configuration, both in voltage levels and in transition direction to support different environments. The Analog Comparator may also be used to provide a second external digital interrupt if necessary by selecting the proper digital threshold.

4.18.6.Battery Low Detection

The Analog Comparator can provide a battery low detection function. In this case the V_{DD} pin would be tied to the V_{BACKUP} pin, and the thresholds would be adjusted to insure that the Battery Low interrupt occurs prior to any Brownout Detection on the V_{DD} input. This allows software to prepare for a potential battery failure in advance without having to poll the battery level.

4.18.7.Error

Any failure interrupt in the AB-RTCMC-32.768kHz-IBO5-S3 may also be configured to wake the MCU. This can be particularly valuable for an XT Oscillator Failure detection, when software may need to respond to the error in order to report the problem quickly.

4.19.Saving Parameters

If the MCU is powered down in Sleep Mode, there is often some data which must be preserved until the next power up. The internal RAM of the AB-RTCMC-32.768kHz-IBO5-S3 is always available, so software can easily save any necessary parameters prior to entering Sleep Mode and retrieve them when the MCU wakes up.

4.20.Power Switch Electrical Characteristics

The power switch on the AB-RTCMC-32.768kHz-IBO5-S3 PSW pin has a typical on resistance of 1 Ω over the full temperature range so that currents up to 50 mA may be handled without appreciable voltage drop. This allows the AB-RTCMC-32.768kHz-IBO5-S3 to switch power to multiple devices in most systems, which can be particularly important for components without internal Sleep functions. If the PSW pin is not used as a power switch, the maximum leakage current of the ~1 Ω switch is less than 250 pA at 25 °C.

4.21.Avoiding Unexpected Leakage Paths

One potential problem which can occur when the AB-RTCMC-32.768kHz-IBO5-S3 powers other devices down is that unexpected leakage paths can be created between the powered AB-RTCMC-32.768kHz-IBO5-S3 and the unpowered device. The AB-RTCMC-32.768kHz-IBO5-S3 can be configured to disable inputs and outputs in Sleep Mode to prevent leakage. In general, any input or output pin connected to a device which is powered down should be disabled. Any pins which remain powered in Sleep Mode, such as pushbutton inputs used to wake the system, must not be disabled.

See chapter 4.16.6 PIN CONTROL AND LEAKAGE MANAGEMENT (SLEEP CONTROL)

4.22.System Power Analysis

The AB-RTCMC-32.768kHz-IBO5-S3 can significantly improve the power characteristics of many different types of systems. A specific example will be presented, and several other generalizations can be made from this. The fundamental advantage provided by the AB-RTCMC-32.768kHz-IBO5-S3 is that it allows the system designer to essentially ignore the sleep current of other system components, which allows the utilization of components which have be optimized for other parameters, such as active power, cost or functionality.

4.22.1.Using an External RTC with Power Management

The key element in any system power analysis is the usage profile, and for this example we assume the system is active for T_{act} and inactive for T_{inact}. I_{act} is the current drawn when the system is active, and I_{inact} is the current drawn when the system is inactive. The average current I_{avg} is therefore:

$I_{avg} = (T_{act} * I_{act} + T_{inact} * I_{inact})/(T_{act} + T_{inact})$

An example will use a PIC16LF1947 MCU, which is highly optimized for low power operation. This MCU draws 80 nA in Sleep Mode, 1.8 µA in Sleep Mode with the internal oscillator and RTC active, and 120 µA in 500 KHz active mode. Assume a usage profile where the system in active for 1 second every 30 minutes, so that T_{act} is 1 and T_{inact} is 1799. If this MCU is used alone and supplies the RTC functions, the average current for the usage profile is:

I_{avg} = (1 * 120 µA + 1799* 1.8 µA)/1800 = 1.865 µA // PIC alone

If the AB-RTCMC-32.768kHz-IBO5-S3 is used to provide the RTC functionality in RC Autocalibration Mode (<20 nA continuous current, when T_A = 25°C, V_{DD} = 3.0V, ACP = 1024 seconds) and the PIC is placed into Sleep Mode, the average current for the usage profile is dramatically lower:

I_{avg} = (1 * 120 µA + 1799* 80 nA)/1800 + 20 nA = 166 nA // PIC in Sleep mode & AB-RTCMC-32.768kHz-IBO5-S3

This is a significant improvement, but the current can be further reduced by having the AB-RTCMC-32.768kHz-IBO5-S3switch power to the MCU. The resulting average current is ~50% lower:

Iavg = (1 * 120 µA + 1799* 0 nA)/1800 + 20 nA = 86 nA // PIC switched & AB-RTCMC-32.768kHz-IBO5-S3

4.22.2.Managing MCU Active Power

In many cases, the duration of the active time is a function of how much processing must be accomplished, and can therefore be assumed to be a linear function of the MCU clock frequency in active mode. The examples in the previous section assumed that the MCU ran for 1 second at 500 KHz, so 500'000 cycles of an 8-bit processor were required. Like most MCUs, the PIC has a relatively constant active current as a function of clock frequency, so using a higher internal frequency in the same MCU would have little effect on the overall power. However, there may be other MCUs (such as those with 32-bit processors) which have better active power efficiency but poor sleep power, and power switching with the AB-RTCMC-32.768kHz-IBO5-S3 eliminates any sleep power considerations.

4.22.3.Lower Cost MCU

Lower cost MCUs often have poor sleep power characteristics relative to sleep optimized parts. Since the AB-RTCMC-32.768kHz-IBO5-S3 eliminates sleep power considerations, these lower cost processors may provide equivalent overall average power at significant cost savings.

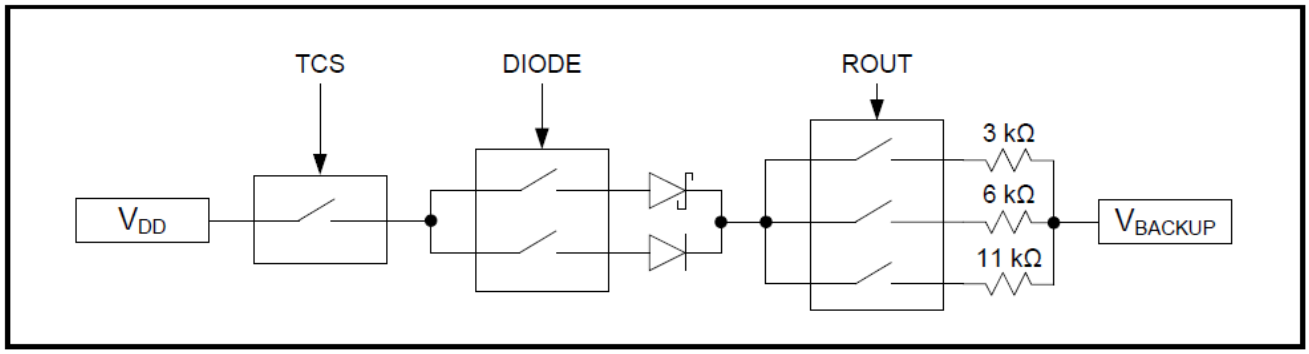
4.22.4.High Performance Processors

In some applications very high performance processors such as DSPs must be used due to real time processing requirements. These processors are generally not optimized for sleep performance, but they may be used in applications with low duty cycles. One example of this is fingerprint recognition, which is rarely accessed but must provide very fast response with complex processing. The AB-RTCMC-32.768kHz-IBO5-S3 power management functions enable a system design where the processor is powered down the vast majority of the time, providing low average power combined with very high instantaneous performance.

4.23.Trickle Charger

The devices supporting the V_{BACKUP} pin include a trickle charging circuit which allows a battery or supercapacitor connected to the V_{BACKUP} pin to be charged from the power supply connected to the V_{DD} pin. The circuit of the Trickle Charger is shown in the following Figure. The Trickle Charger configuration is controlled by the 20h - Trickle Charge register (see ANALOG CONTROL REGISTERS). The Trickle Charger is enabled if a) the TCS field is 1010, b) the DIODE field is 01 or 10 and c) the ROUT field is not 00. A diode, with a typical voltage drop of 0.6V, is inserted in the charging path if DIODE is 10. A Schottky diode, with a typical voltage drop of 0.3V, is inserted in the charging path if DIODE is 01. The series current limiting resistor is selected by the ROUT field as shown in the figure.

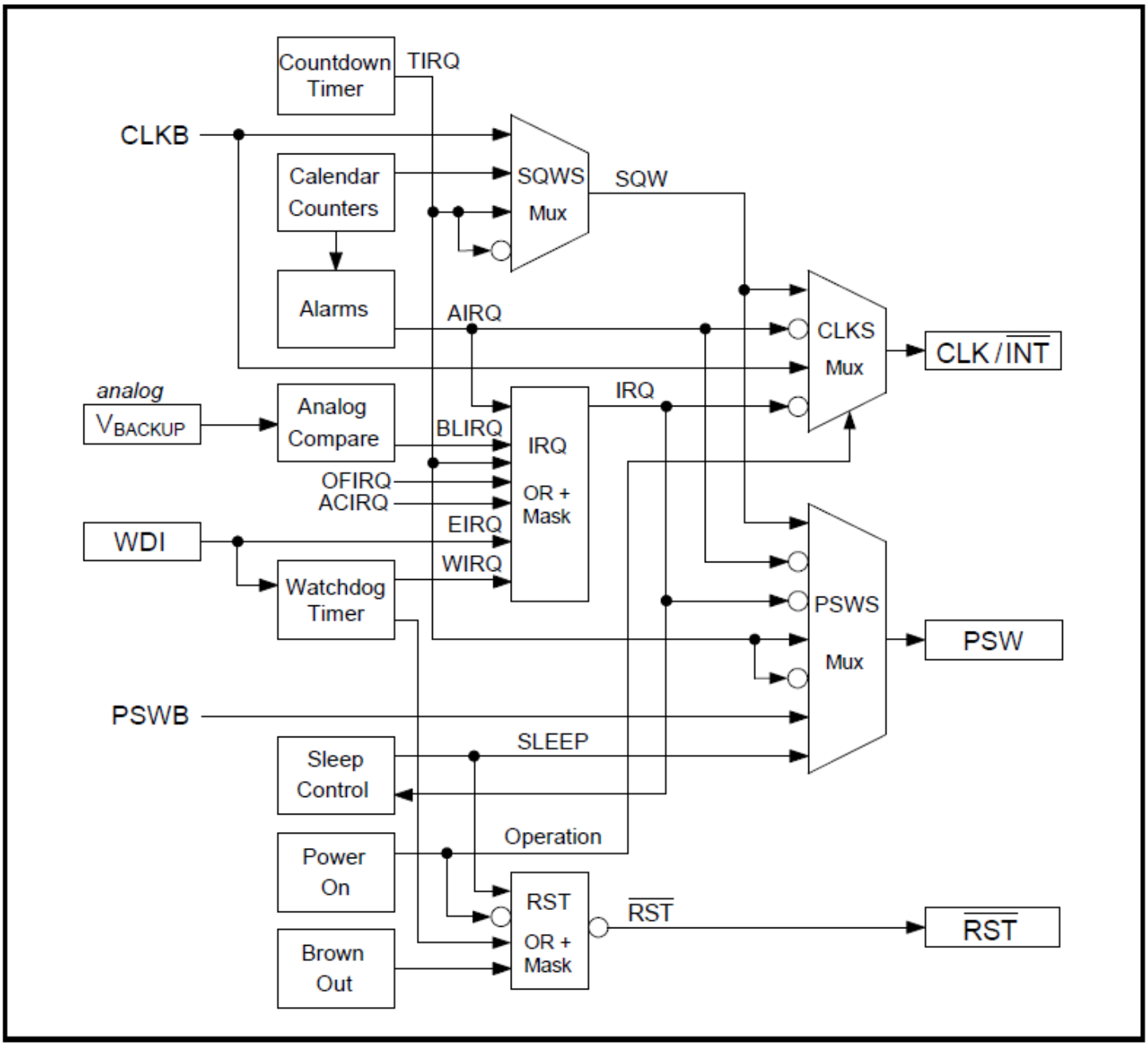
Trickle Charger:



5. Digital Architecture Summary

The following Figure illustrates the overall architecture of the pin inputs and outputs of the AB-RTCMC-32.768kHz-IBO5-S3.

Digital Architecture Summary:



6. Electrical Specifications

6.1. Absolute Maximum Ratings

The following Table lists the absolute maximum ratings.

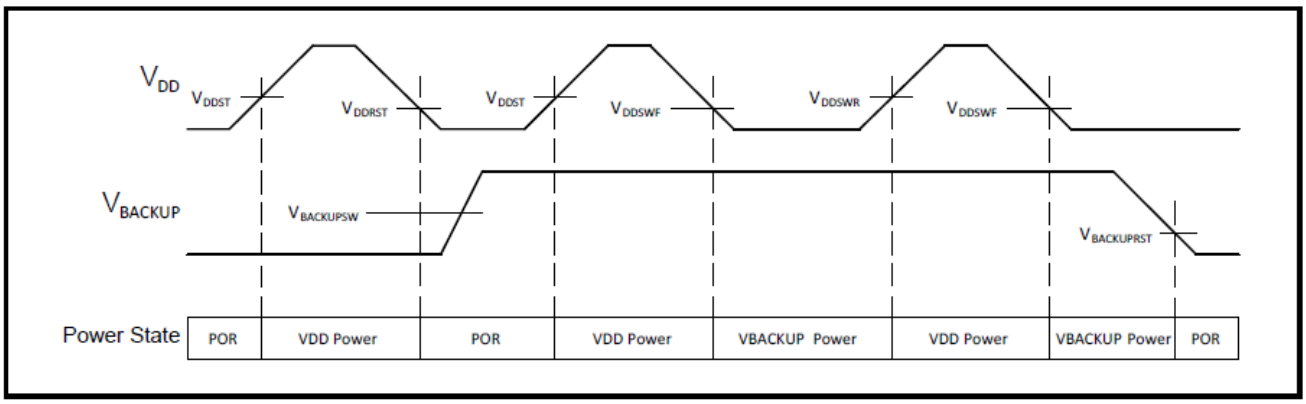
Absolute Maximum Ratings:

Parameters		Min.	Typ.	Max.	Units	Notes
Power Supply Voltage (V_{DD})		-0.3		3.8	V	
Backup Supply voltage (V_{BACKUP})		-0.3		3.8	V	
Input Voltage (V_I)	V_{DD} Power state	-0.3		V_{DD} + 0.3	V	
	V_{BACKUP} Power State	-0.3		V_{BACUUP} + 0.3	V	
Output Voltage (V_O)	V_{DD} Power state	-0.3		V_{DD} + 0.3	V	
	V_{BACKUP} Power State	-0.3		V_{BACUUP} + 0.3	V	
Input Current (I_I)		-10		10	mA	
Output Current (I_O)		-20		20	mA	
PSW Output Continuous Current (I_{OPC})				50	mA	
PSW Output Pulsed Current (I_{OPP})				150	mA	1 second pulse
ESD Voltage (V_{ESD})	CDM			±500	V	Charged Device Model
	HBM			±4000	V	Human Body Model
Latch-up Current (I_{LU})				100	mA	
Operating Temperature Range (T_{OP})		-40		+85	ºC	
Storage Temperature (T_{STG})		-55		+125	ºC	Stored as bare product
Lead Temperature (T_{SLD})				+300	ºC	Hand soldering for 10s
Reflow Soldering Temperature (T_{REF})				+260	ºC	Reflow profile per JEDEC J-STD-020D

6.2. Power Supply Parameters

The following Figure and Table describe the power supply and switchover parameters. See POWER CONTROL AND SWITCHING for a detailed description of the operations.

Power Supply Switchover:



For all tables, T_A = -40 °C to 85 °C, TYP values at 25 °C.

Power Supply and Switchover Parameters:

Parameters	Type	Power State	Test Conditions	Min.	Typ.	Max.	Units
System Power Voltage (V_{DD})	Static	V_{DD} Power	Clocks operating and RAM and registers retained	1.5		3.6	V
V_{DD} I^2C Interface Voltage (V_{DDIO})	Static	V_{DD} Power	I^2C operation	1.5		3.6	V
V_{DD} Start-up Voltage (V_{DDST}) (1)	Rising	POR->V_{DD} Power		1.6			V
V_{DD} Reset Voltage (V_{DDRST})	Falling	V_{DD} Power -> POR	$V_{BACKUP} < V_{BACKUP, MIN}$ or no V_{BACKUP}		1.3	1.5	V
V_{DD} Rising Switch-over Threshold Voltage (V_{DDSWR})	Rising	V_{BACKUP} Power ->V_{DD} Power	$V_{BACKUP} \geq V_{BACKRST}$		1.6	1.7	V
V_{DD} Falling Switch-over Threshold Voltage (V_{DDSWF})	Falling	V_{DD} Power -> V_{BACKUP} Power	$V_{BACKUP} \geq V_{BACKSW, MIN}$	1.2	1.5		V
V_{DD} Switch-over Threshold Hysteresis (V_{DDSWH}) (2)	Hyst.	V_{DD} Power <-> V_{BACKUP} Power			70		mV
V_{DD} Falling Slew Rate to Switch to V_{BACKUP} State (V_{DDFS}) (4)	Falling	V_{DD} Power -> V_{BACKUP} Power	$V_{DD} < V_{DDSW, MAX}$	0.7	1.4		V
Backup Voltage (V_{BACKUP})	Static	V_{BACKUP} Power	Clocks operating and RAM and registers retained	1.4		3.6	V
Backup Switchover Voltage Range (V_{BACKSW}) (5)	Static	V_{DD} Power -> V_{BACKUP} Power		1.6		3.6	V
Falling Backup POR Voltage ($V_{BACKRST}$) (7)	Falling	V_{BACKUP} Power -> POR	$V_{DD} < V_{DDSWF}$		1.1	1.4	V
V_{BACK} Margin above V_{DD} (V_{BMRG}) (3)	Static	V_{BACKUP} Power		200			mV
V_{BACK} Supply Series Resistance ($R_{BACKESR}$) (6)	Static	V_{BACKUP} Power		1.0	1.5		kΩ

(1) V_{DD} must be above V_{DDST} to exit the POR state, independent of the V_{BACKUP} voltage.
(2) Difference between V_{DDSWR} and V_{DDSWF}.
(3) V_{BACKUP} must be higher than V_{DD} by at least this voltage to insure the AB-RTCMC-32.768kHz-IBO5-S3 remains in the V_{BACKUP} Power state.
(4) Maximum V_{DD} falling slew rate to guarantee correct switchover to V_{BACKUP} Power state. There is no V_{DD} falling slew rate requirement if switching to the V_{BACKUP} power source is not required.
(5) V_{BACKUP} voltage to guarantee correct transition to V_{BACKUP} Power state when V_{DD} falls.
(6) Total series resistance of the power source attached to the V_{BACKUP} pin. The optimal value is 1.5 kΩ, which may require an external resistor. V_{BACKUP} power source ESR (Equivalent Series Resistance) + external resistor value = 1.5 kΩ.

6.3. Operating Parameters

The following Table lists the operating parameters. For this table, T_A = -40 °C to 85 °C, TYP values at 25 °C.

Operating Parameters:

Parameters	Test Conditions	V_{DD}	Min.	Typ.	Max.	Units
Positive-going Input Threshold Voltage (V_{T+})		3.0V		1.5	2.0	V
		1.8V		1.1	1.25	
Negative-going Input Threshold Voltage (V_{T-})		3.0V	0.8	0.9		V
		1.8V	0.5	0.6		
Input Leakage Current (I_{ILEAK})		3.0V		0.02	80	nA
Input Capacitance (C_I)				3		pF
PSW Output Resistance to V_{DD} (R_{DSON})	PSW enabled	1.7V		1.7	5.8	Ω
		1.8V		1.6	5.4	
		3.0V		1.1	3.8	
		3.6V		1.05	3.7	
Output Leakage Current (I_{OLEAK})		1.7V – 3.6V		0.02	80	nA

6.4. Oscillator Parameters

The following Table lists the oscillator parameters. For this Table, T_A = -40 °C to 85 °C unless otherwise indicated. V_{DD} = 1.7 to 3.6V, TYP values at 25 °C and 3.0V. See also XT FREQUENCY CHARACTERISTICS.

Oscillator Parameters:

Parameters	Test Conditions	Min.	Typ.	Max.	Units
Crystal Frequency (F_{XT})			32.768		kHz
XT Oscillator Failure Detection Frequency (F_{OF})			8		kHz
Calibrated RC Oscillator Frequency (F_{RCC}) (1)	Factory calibrated at +25°C, V_{DD} = 2.8V		64		Hz
Uncalibrated RC Oscillator Frequency (F_{RCU})	Calibration disabled (OFFSETR=0) – 128Hz level	89	122	200	Hz
Uncalibrated RC Oscillator Cycle-to-Cycle Jitter, |Median| (J_{RCCC})	Calibration disabled (OFFSETR=0) – 128Hz level		2000		ppm
	Calibration disabled (OFFSETR=0) – 1Hz level		500		
RC Oscillator Cycle-to-Cycle Jitter, MIN, MAX (J_{RCCC})	128Hz level at +25°C	-1		1	%
	128Hz level -10 to +70°C	-3.5		3.5	
	128Hz level -40 to +85°C	-10		10	
XT Mode Digital Calibration Accuracy (A_{XT}) (1)	Calibrated at an initial temperature and voltage. Factory calibrated at +25°C, V_{DD} = 3.0V	-2		+2	ppm

(Continued)

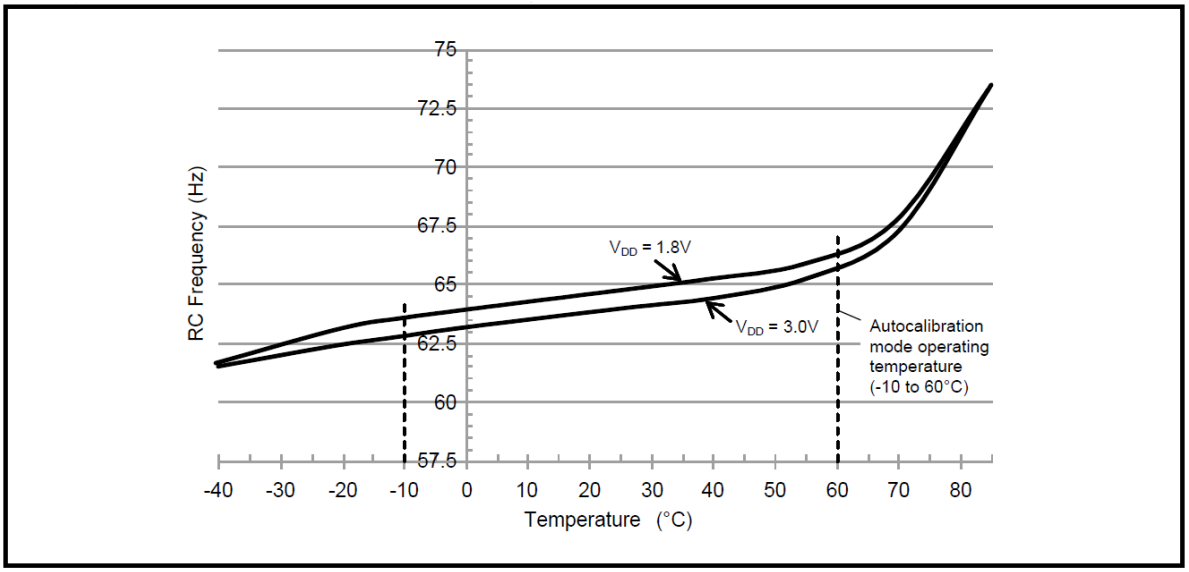
Parameters	Test Conditions	Min.	Typ.	Max.	Units
Autocalibration Mode Timing Accuracy, 512 second period, T_A = -10 to +60°C (A_{AC}) (1)	24 hour run time		35		ppm
	1 week run time		20		
	1 month run time		10		
	1 year run time		3		
Autocalibration Mode Operating Temperature (T_{AC}) (2)		-10		+60	°C

(1) Timing accuracy is specified at 25°C after digital calibration of the internal RC oscillator and digital calibration of the 32.768 kHz crystal. The 32.768 kHz tuning fork crystal has a negative temperature coefficient with a parabolic frequency deviation, which can result in a change of up to 150 ppm across the entire operating temperature range of -40°C to 85°C in XT mode. Autocalibration mode timing accuracy is specified relative to XT mode timing accuracy from -10°C to 60°C.

(2) Outside of this temperature range, the RC oscillator frequency change due to temperature may be outside of the allowable RC digital calibration range (+/-12%) for autocalibration mode. When this happens, an autocalibration failure will occur and the ACF interrupt flag is set. The AB-RTCMC-32.768kHz-IBO5-S3 should be switched to use the XT oscillator as its clock source when this occurs. Please see the AUTOCALIBRATION FAILURE section for more details.

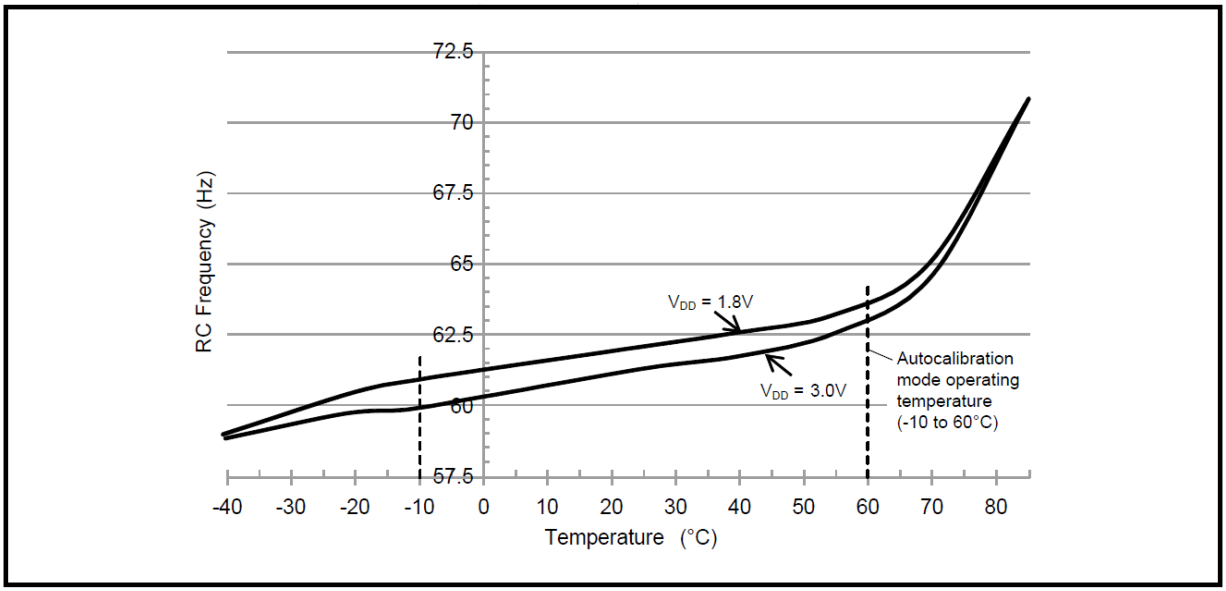
The following Figure shows the typical calibrated RC oscillator frequency variation vs. temperature. The RC oscillator is factory calibrated at 2.8V, 25°C (OFFSETR = Preconfigured reset value).

Factory Calibrated RC Oscillator, Typical Frequency Variation vs. Temperature (64 Hz level is modified):



The following Figure shows the typical uncalibrated RC oscillator frequency variation vs. temperature.

Uncalibrated RC Oscillator at 64 Hz level, Typical Frequency Variation vs. Temperature:



6.5. XT Frequency Characteristics

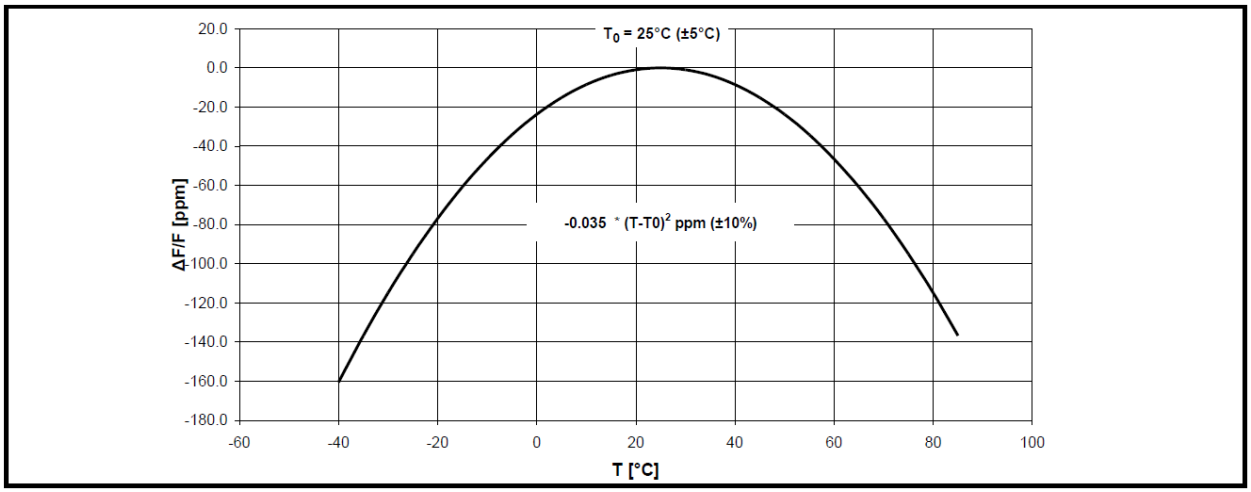
For this Table, T_A = -40 °C to 85 °C unless otherwise indicated. V_{DD} = 1.7 to 3.6V, TYP values at 25 °C and 3.0V, f_{OSC}= 32.768 kHz.

XT Frequency Characteristics:

Parameters	Test Conditions	Min.	Typ.	Max.	Units
Frequency Accuracy (ΔF/F)	T_A = +25°C; Calibration disabled (OFFSETX=0)		±100 (1)		ppm
Frequency vs. Temperature Characteristics ($\Delta F/F_0$)	T_{OPR} = -40 to +85°C	$-0.035^{ppm}/_{°C^2} * (T_{OPR}-T_0)^2$ ±10%			ppm
Turnover Temperature (T_0)		+20	+25	+30	°C
Aging First Year	T_A = +25°C			±3	ppm
Oscillator Start-up Voltage	T_A= -40 to +85°C	1.6			V
Oscillator Start-up Time	V_{DD} = 1.7V – 3.6V		1.0		s
CLKOUT Duty Cycle	F_{CLKOUT} = 32.768kHz; T_A = +25°C	50	60	70	%

(1) The XT mode digital calibration accuracy is +/-2 ppm, see OSCILLATOR PARAMETERS.

6.5.1. XT Frequency vs. Temperature Characteristics



6.6. V_{DD} Supply Current

The following Table lists the current supplied into the V_{DD} power input under various conditions. For this table, T_A = -40 °C to 85 °C, V_{BACKUP} = 0 V to 3.6 V, TYP values at 25 °C, V_{DD} Power state.

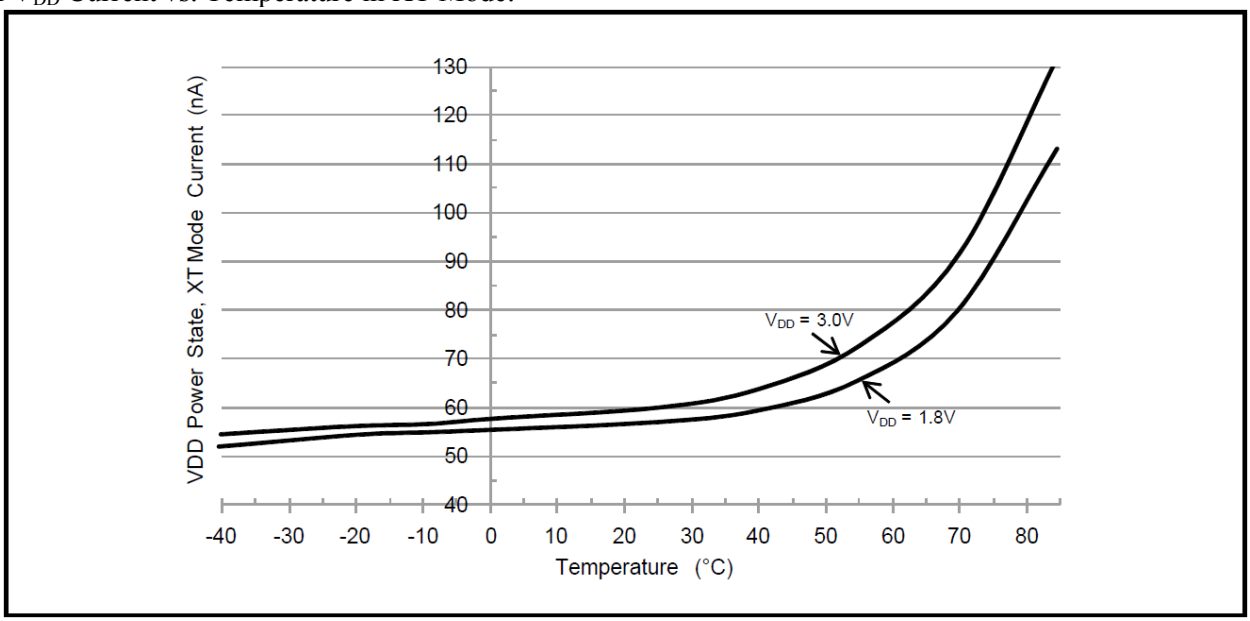
V_{DD} Supply Current:

Parameters	Test Conditions	V_{DD}	Min.	Typ.	Max.	Units
V_{DD} Supply Current during I2C burst Read/Write ($I_{VDD:I2C}$)	400kHz bus speed, 2.2k pull-up resistors on SCL/SDA (1)	3.0V		6	10	µA
		1.8V		1.5	3	
V_{DD} Supply Current in XT Oscillator Mode ($I_{VDD:XT}$)	Time keeping mode with XT oscillator running (2)	3.0V		60	330	nA
		1.8V		27	290	
V_{DD} Supply Current in RC Oscillator Mode ($I_{VDD:RC}$)	Time keeping mode with only the RC oscillator running (XT oscillator is off) (2)	3.0V		17	220	nA
		1.8V		14	170	
Average V_{DD} Supply Current in Autocalibrated RC Oscillator Mode ($I_{VDD:ACAL}$)	Time keeping mode with only the RC oscillator running and Autocalibration enabled. ACP=512 seconds (2)	3.0V		22	235	nA
		1.8V		18	190	
Additional V_{DD} Supply Current with CLK/$\overline{INT}$ at 32.768kHz ($I_{VDD:CK32}$)	Time keeping mode with XT oscillator running, 32.768kHz square wave on CLK/$\overline{INT}$ (3)	3.0V		0.71		µA
		1.8V		0.34		
Additional V_{DD} Supply Current with CLK/$\overline{INT}$ at 64Hz ($I_{VDD:CK64}$)	All time keeping mode, 64Hz square wave on CLK/$\overline{INT}$ (3)	3.0V		0.6		nA
		1.8V		0.3		

(1) Excluding external peripherals and pull-up resistor current. All other inputs (besides SDA and SCL) are at 0V or V_{DD}.
Test conditions: Continuous burst read/write, 55h data pattern, 25 µs between each data byte, 20 pF load on each bus pin.
(2) All inputs and outputs are at 0V or V_{DD}.
(3) All inputs and outputs except CLK / $\overline{INT}$ are at 0V or V_{DD}. 15 pF load on CLK / $\overline{INT}$, pull-up resistor current not included.

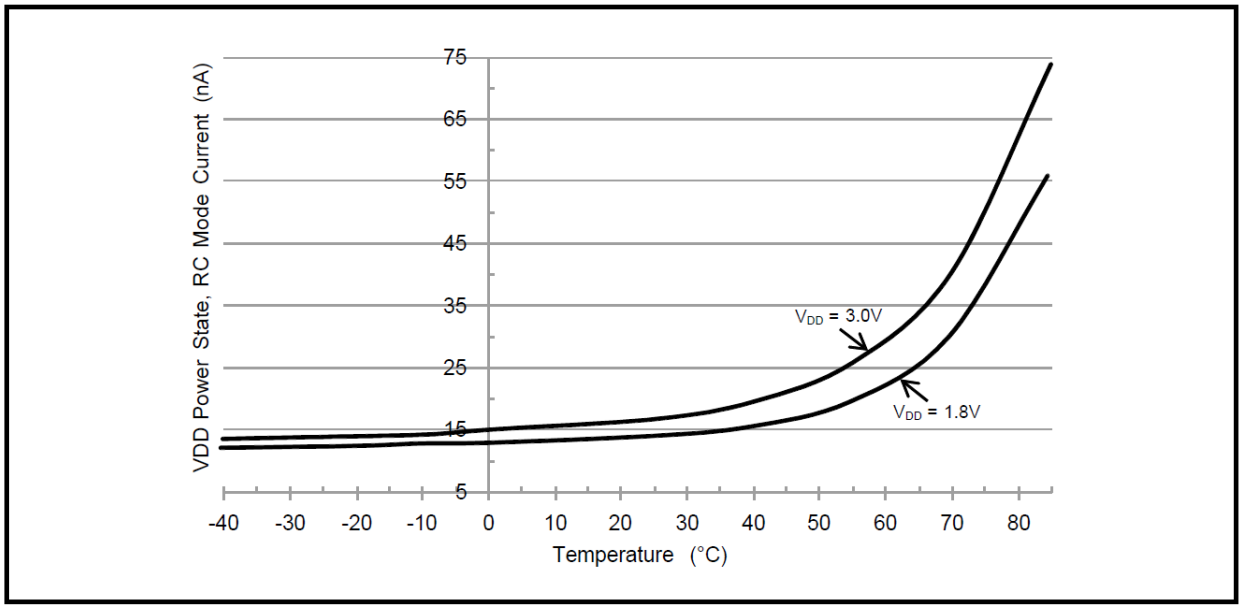
The following Figure shows the typical V_{DD} power state operating current vs. temperature in XT mode.

Typical V_{DD} Current vs. Temperature in XT Mode:



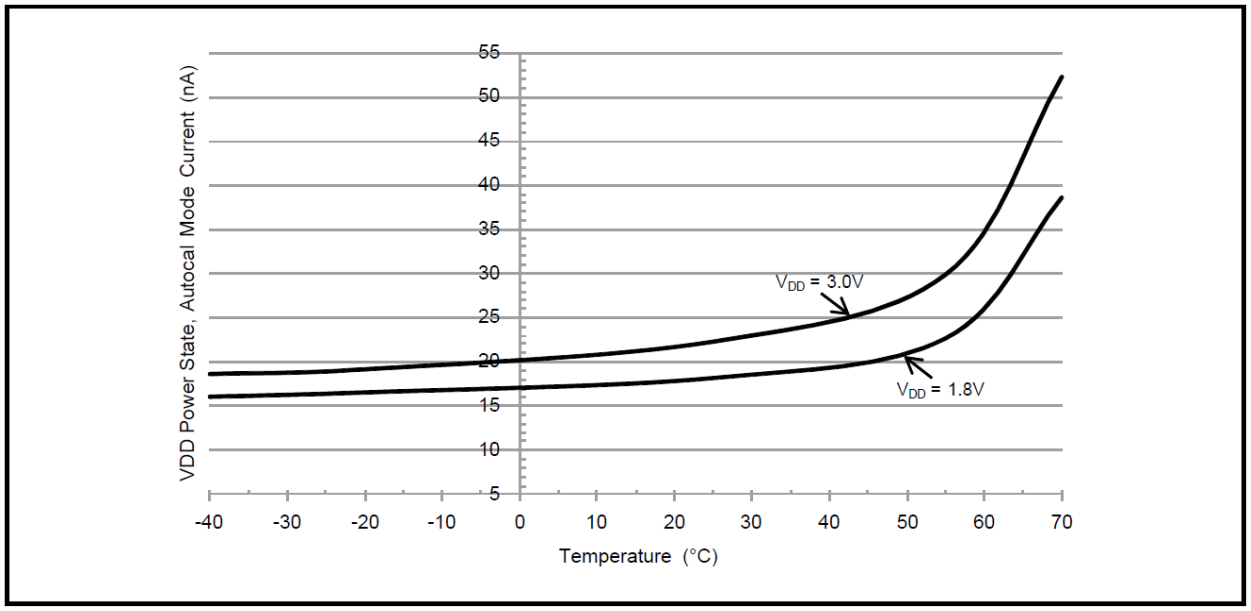
The following Figure shows the typical V_{DD} power state operating current vs. temperature in RC mode.

Typical V_{DD} Current vs. Temperature in RC Mode:



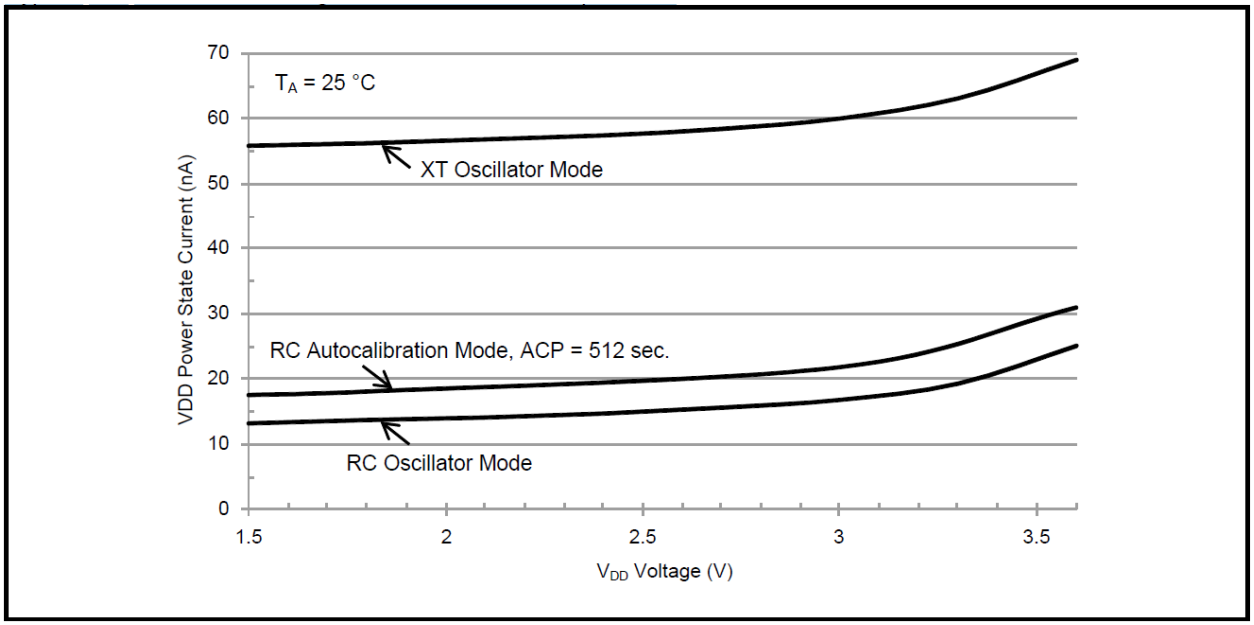
The following Figure shows the typical V_{DD} power state operating current vs. temperature in RC Autocalibration mode.

Typical V_{DD} Current vs. Temperature in RC Autocalibration Mode, ACP = 512 seconds:



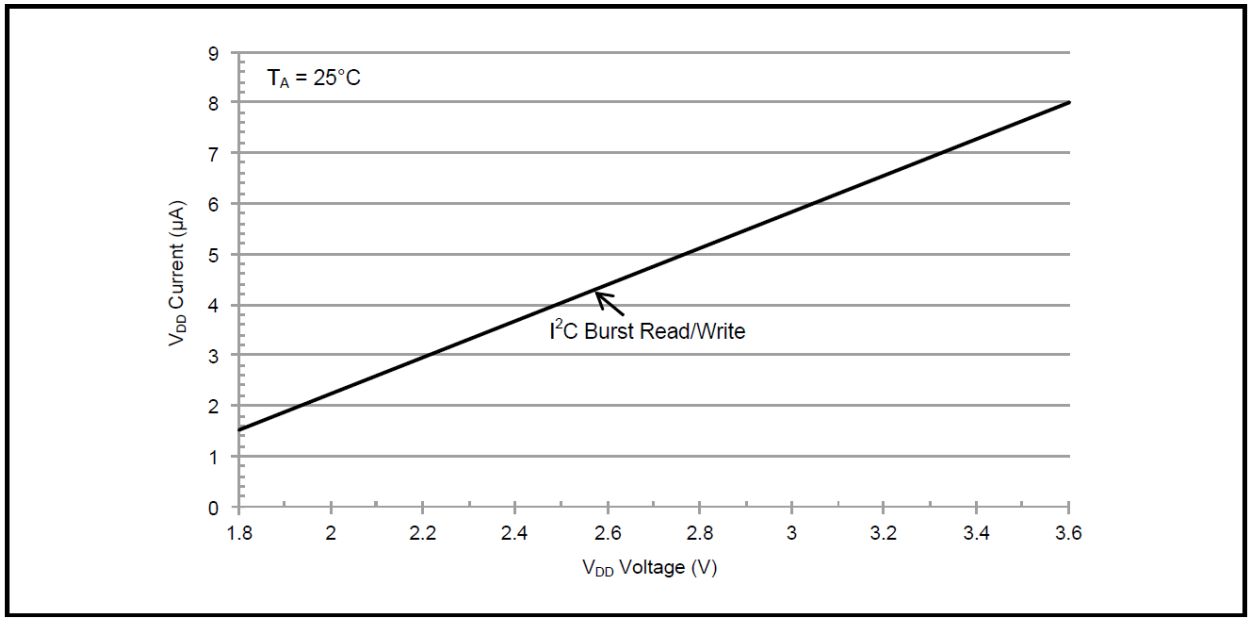
The following Figure shows the typical V_{DD} power state operating current vs. voltage for XT Oscillator and RC Oscillator modes and the average current in RC Autocalibrated mode with ACP = 512 seconds.

Typical V_{DD} Current vs. Voltage, Different Modes of Operation:



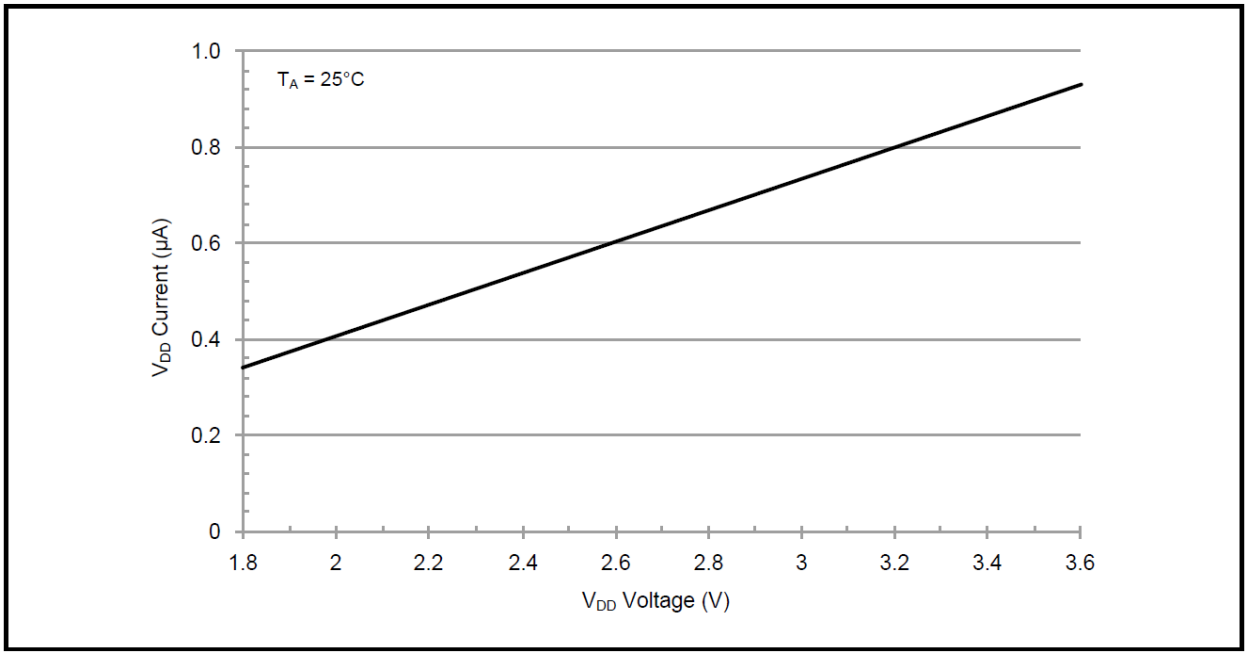
The following Figure shows the typical V_{DD} power state operating current during continuous I^2C burst read and write activity. Test conditions: T_A = 25 °C, 55h data pattern, 25 µs between each data byte, 20 pF load on each bus pin, pull-up resistor current not included.

Typical V_{DD} Current vs. Voltage, I^2C Burst Read/Write:



The following Figure shows the typical additional V_{DD} power state operating current with a 32.768 kHz clock output on the CLK/$\overline{INT}$ pin. Test conditions: T_A = 25 °C. All inputs and outputs except CLK/$\overline{INT}$ are at 0 V or V_{DD}. 15 pF capacitive load on the CLK/$\overline{INT}$ pin, pull-up resistor current not included.

Typical additional V_{DD} Current vs. Voltage, 32.768 kHz Clock Output:



6.7. V_{BACKUP} Supply Current

The following Table lists the current supplied into the V_{BACKUP} power input under various conditions. For this table, T_A = -40 °C to 85 °C, TYP values at 25 °C, MAX values at 85 °C, V_{BACKUP} Power state.

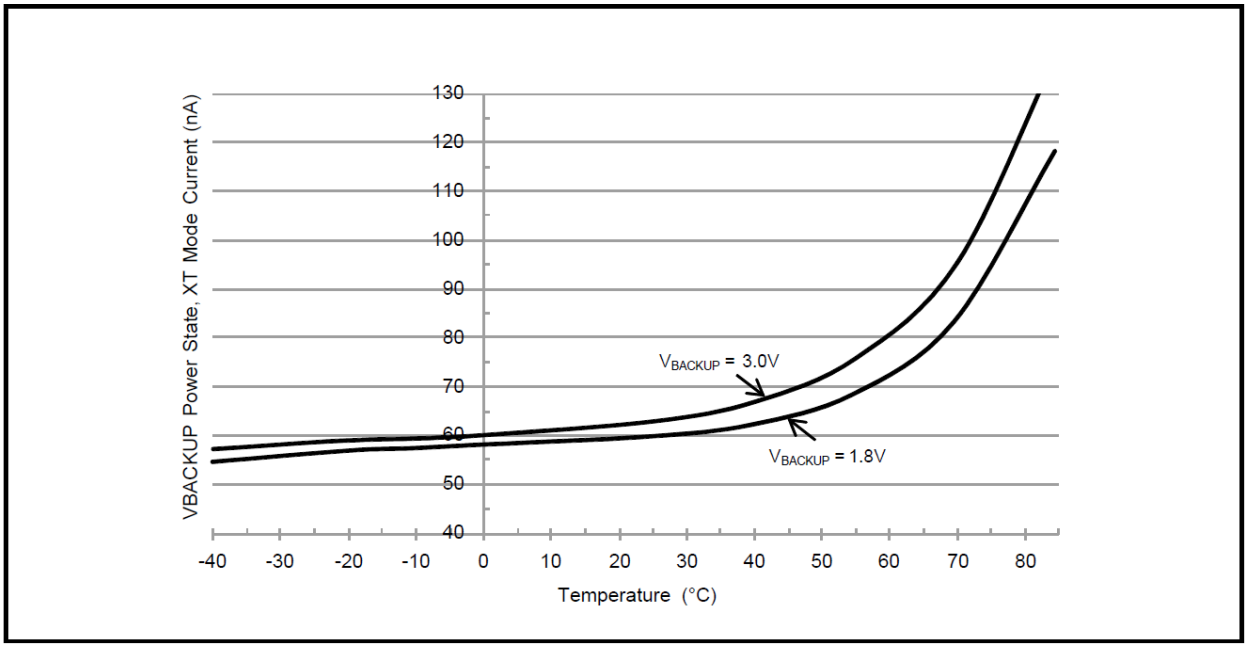
V_{BACKUP} Supply Current:

Parameters	Test Conditions	V_{DD}	V_{BACK}	Min.	Typ.	Max.	Units
V_{BACKUP} Supply Current in XT Oscillator Mode ($I_{VBACK:XT}$)	Time keeping mode with XT oscillator running (1)	<V_{DDSWF}	3.0V		63	330	nA
			1.8V		60	290	
V_{BACKUP} Supply Current in RC Oscillator Mode ($I_{VBACK:RC}$)	Time keeping mode with only the RC oscillator running (XT oscillator is off) (1)	<V_{DDSWF}	3.0V		19	220	nA
			1.8V		16	170	
Average V_{BACKUP} Supply Current in Autocalibrated RC Oscillator Mode ($I_{VBACK:ACAL}$)	Time keeping mode with only the RC oscillator running and Autocalibration enabled. ACP=512 seconds (1)	<V_{DDSWF}	3.0V		25	235	nA
			1.8V		21	190	
V_{BACKUP} Supply Current in V_{DD} powered mode ($I_{VBACK:VDD}$)	V_{DD} powered mode (1)	1.7-3.6V	3.0V	-5	0.6	20	nA
			1.8V	-10	0.5	16	

(1) Test conditions: All inputs and outputs are at 0V or V_{DD}.

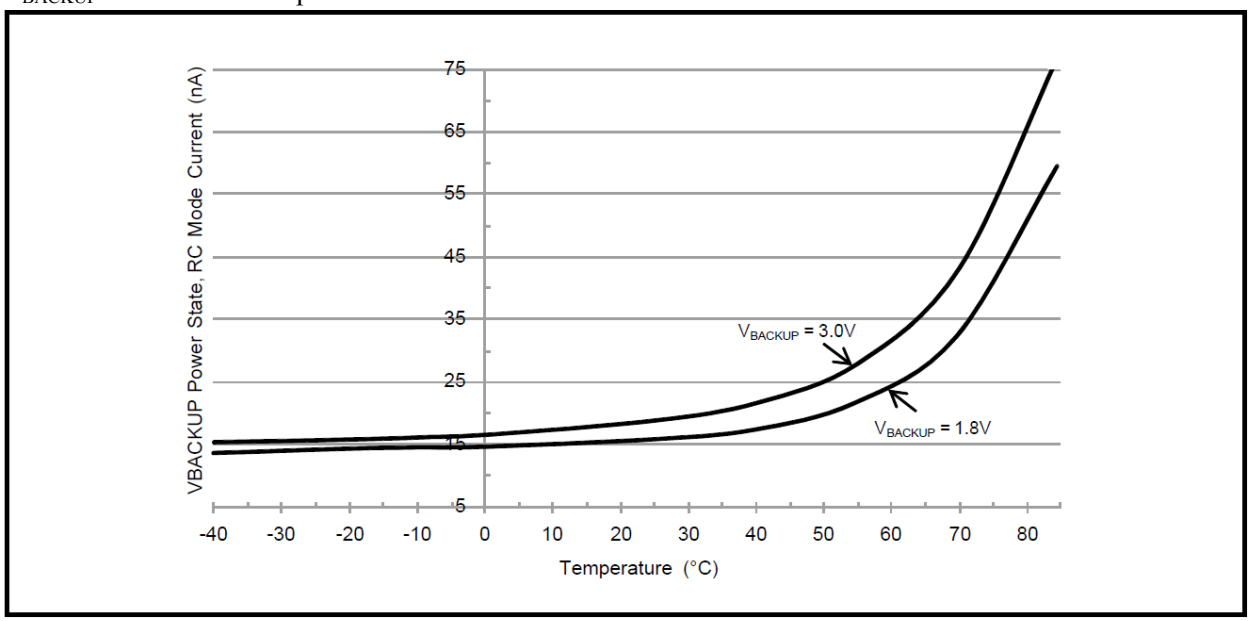
The following Figure shows the typical V_{BACKUP} power state operating current vs. temperature in XT mode.

Typical V_{BACKUP} Current vs. Temperature in XT Mode:



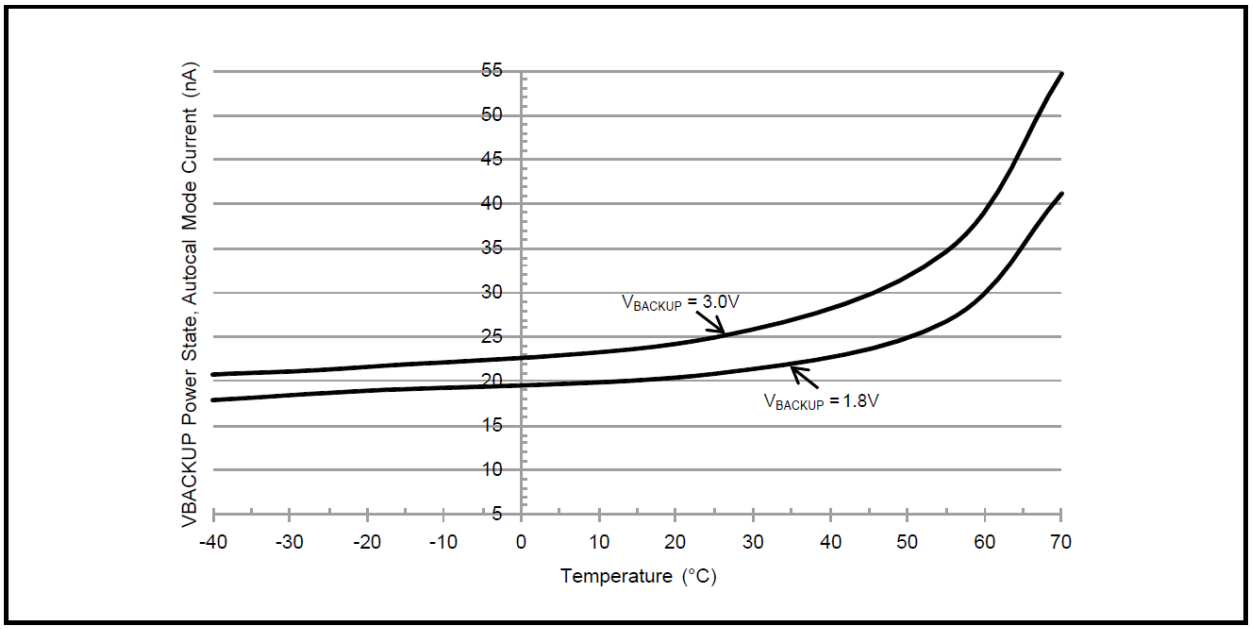
The following Figure shows the typical V_{BACKUP} power state operating current vs. temperature in RC mode.

Typical V_{BACKUP} Current vs. Temperature in RC Mode:



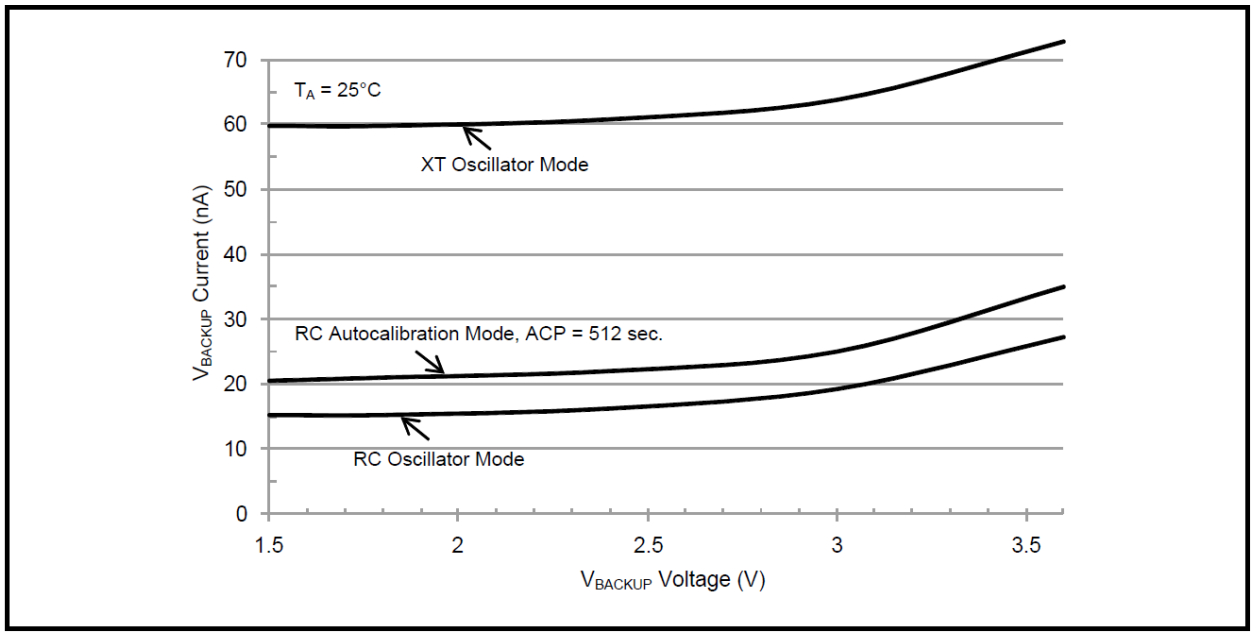
The following Figure shows the typical V_{BACKUP} power state operating current vs. temperature in RC Autocalibration mode.

Typical V_{BACKUP} Current vs. Temperature in RC Autocalibration Mode, ACP = 512 seconds:



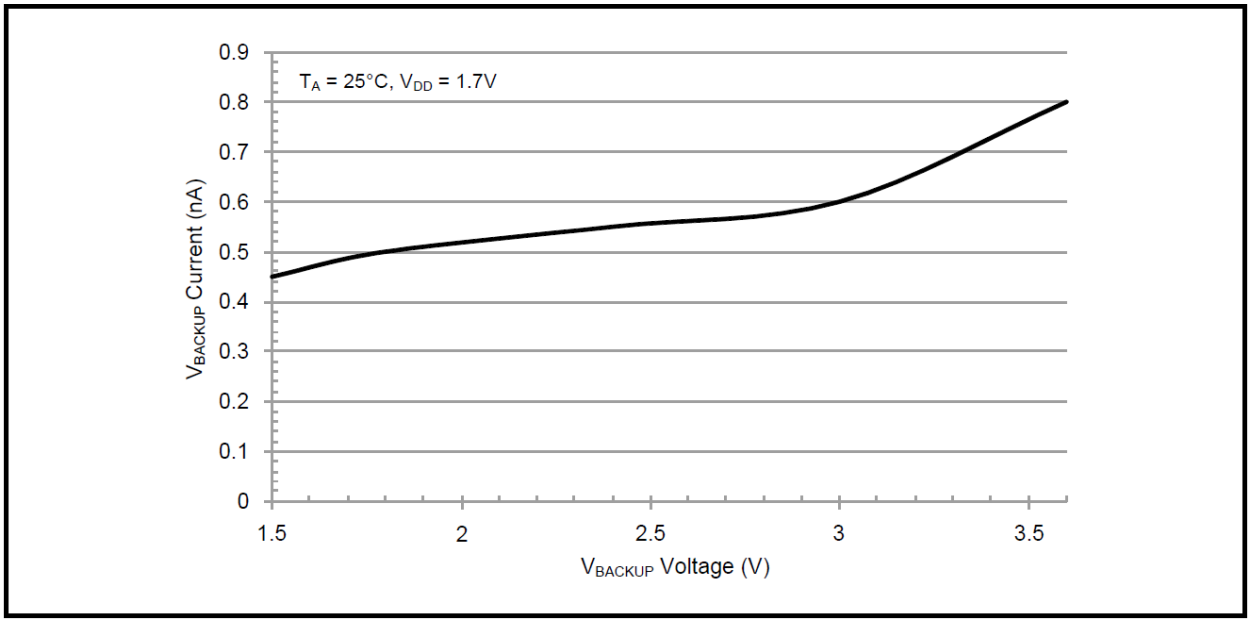
The following Figure shows the typical V_{BACKUP} power state operating current vs. voltage for XT Oscillator and RC Oscillator modes and the average current in RC Autocalibrated mode with ACP = 512 seconds, VDD = 0 V.

Typical V_{BACKUP} Current vs. Voltage, Different Modes of Operation:



The following Figure shows the typical V_{BACKUP} current when operating in the V_{DD} power state, V_{DD} = 1.7 V.

Typical V_{BACKUP} Current vs. Voltage in V_{DD} Power State:



6.8. BREF Electrical Characteristics

The following Table lists the parameters of the V_{BACKUP} voltage thresholds. BREF values other than those listed in the table are not supported. For this table, T_A = -20 °C to 70 °C, TYP values at 25 °C, V_{DD} = 1.7 to 3.6V.

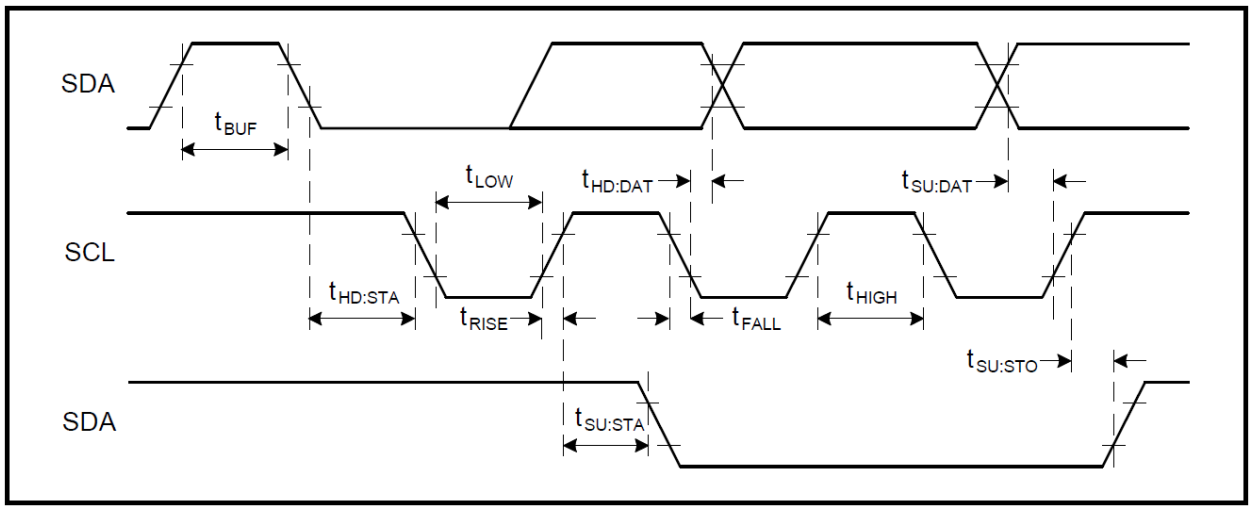
BREF Parameters:

Parameters	BREF	Min.	Typ.	Max.	Units
V_{BACKUP} Falling Threshold (V_{BRF})	0111	2.3	2.5	3.3	V
	1011	1.9	2.1	2.8	
	1101	1.6	1.8	2.5	
	1111		1.4		
V_{BACKUP} Rising Threshold (V_{BRR})	0111	2.6	3.0	3.4	V
	1011	2.1	2.5	2.9	
	1101	1.9	2.2	2.7	
	1111		1.6		
V_{BACKUP} Threshold Hysteresis (V_{BRH})	0111		0.5		V
	1011		0.4		
	1101		0.4		
	1111		0.2		
BREF/BPOL Change to BBOD Valid (t_{BREF})	All valid BREF values		1000		ms
V_{BACKUP} Analog Comparator Recommended Operating Temperature Range (T_{BR})	All valid BREF Values	-20		+70	°C

6.9. I²C AC Electrical Characteristics

The following Figure and Table describe the I²C AC electrical parameters.

I²C AC Parameter Definitions:



For the following Table, T_A = -40 °C to 85 °C, TYP values at 25 °C.

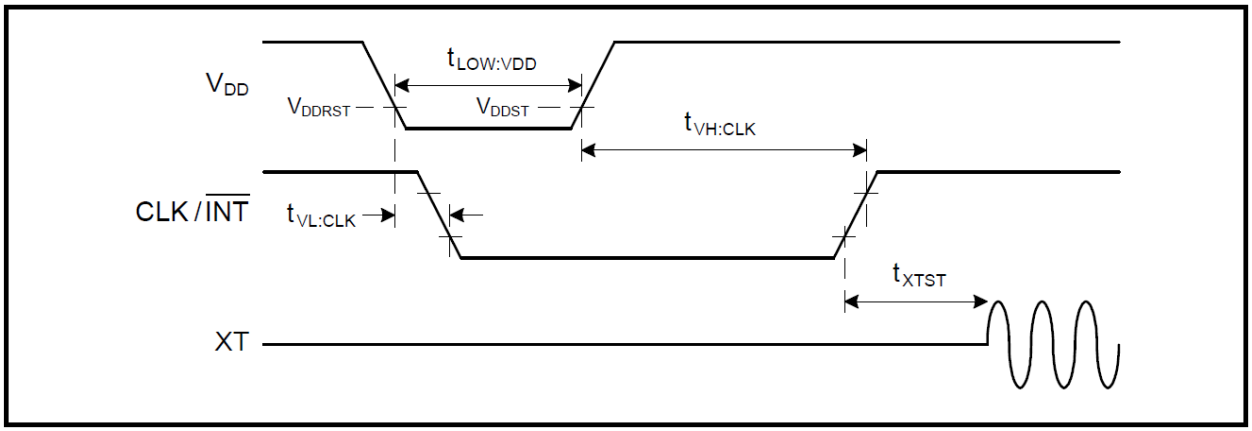
I²C AC Electrical Parameters:

Parameters	V_{DD}	Min.	Typ.	Max.	Units
SCL Input Clock Frequency (f_{SCL})	1.7 – 3.6V	10		400	kHz
Low Period of SCL Clock (t_{LOW})	1.7 – 3.6V	1.3			µs
High Period of SCL Clock (t_{HIGH})	1.7 – 3.6V	600			ns
Rise Time of SDA and SCL (t_{RISE})	1.7 – 3.6V			300	ns
Fall Time of SDA and SCL (t_{FALL})	1.7 – 3.6V			300	ns
START Condition Hold Time ($t_{HD:STA}$)	1.7 – 3.6V	600			ns
START Condition Setup Time ($t_{SU:STA}$)	1.7 – 3.6V	600			ns
SDA Setup Time ($t_{SU:DAT}$)	1.7 – 3.6V	100			ns
SDA Hold Time ($t_{HD:DAT}$)	1.7 – 3.6V	0			ns
STOP Condition Setup Time ($t_{SU:STO}$)	1.7 – 3.6V	600			ns
Bus Free Time before a New Transmission (t_{BUF})	1.7 – 3.6V	1.3			µs

6.10.Power On AC Electrical Characteristics

The following Figure and Table describe the power on AC electrical characteristics for the CLK/$\overline{INT}$ pin and XT oscillator.

Power On AC Electrical Characteristics:



For the following Table, T_A = -40 °C to 85 °C, V_{BACKUP} < 1.2 V

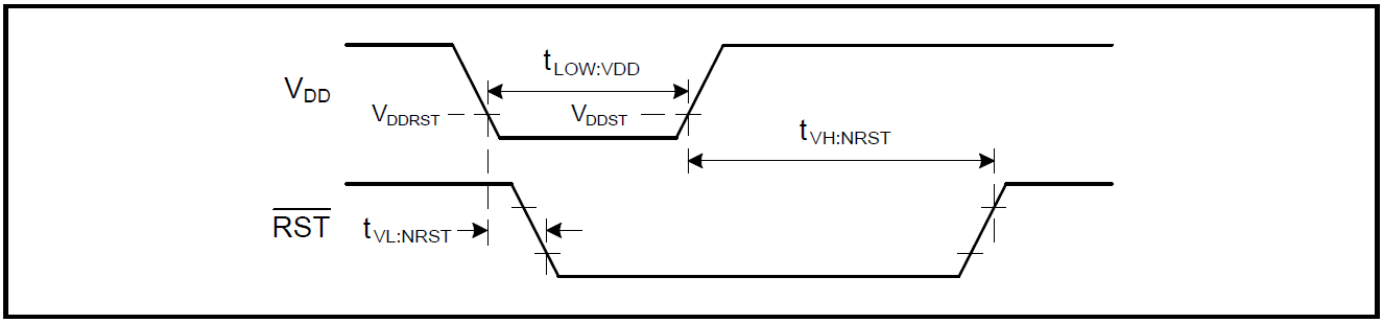
Power On AC Electrical Parameters:

Parameters	V_{DD}	T_A	Min.	Typ.	Max.	Units
Low Period of V_{DD} to Ensure a Valid POR ($t_{LOW:VDD}$)	1.7 – 3.6V	+85°C		0.1		s
		+25°C		0.1		
		-20°C		1.5		
		-40°C		10		
V_{DD} Low to CLK/$\overline{INT}$ Low ($t_{VL:CLK}$)	1.7 – 3.6V	+85°C		0.1		s
		+25°C		0.1		
		-20°C		1.5		
		-40°C		10		
V_{DD} High to CLK/$\overline{INT}$ High ($t_{VH:CLK}$)	1.7 – 3.6V	+85°C		0.4		s
		+25°C		0.5		
		-20°C		3		
		-40°C		20		
CLK/$\overline{INT}$ High to XT Oscillator Start (t_{XTST})	1.7 – 3.6V	+85°C		0.4		s
		+25°C		0.4		
		-20°C		0.5		
		-40°C		1.5		

6.11. $\overline{RST}$ AC Electrical Characteristics

The following Figure and Table describe the $\overline{RST}$ AC electrical characteristics.

$\overline{RST}$ AC Parameter Characteristics:



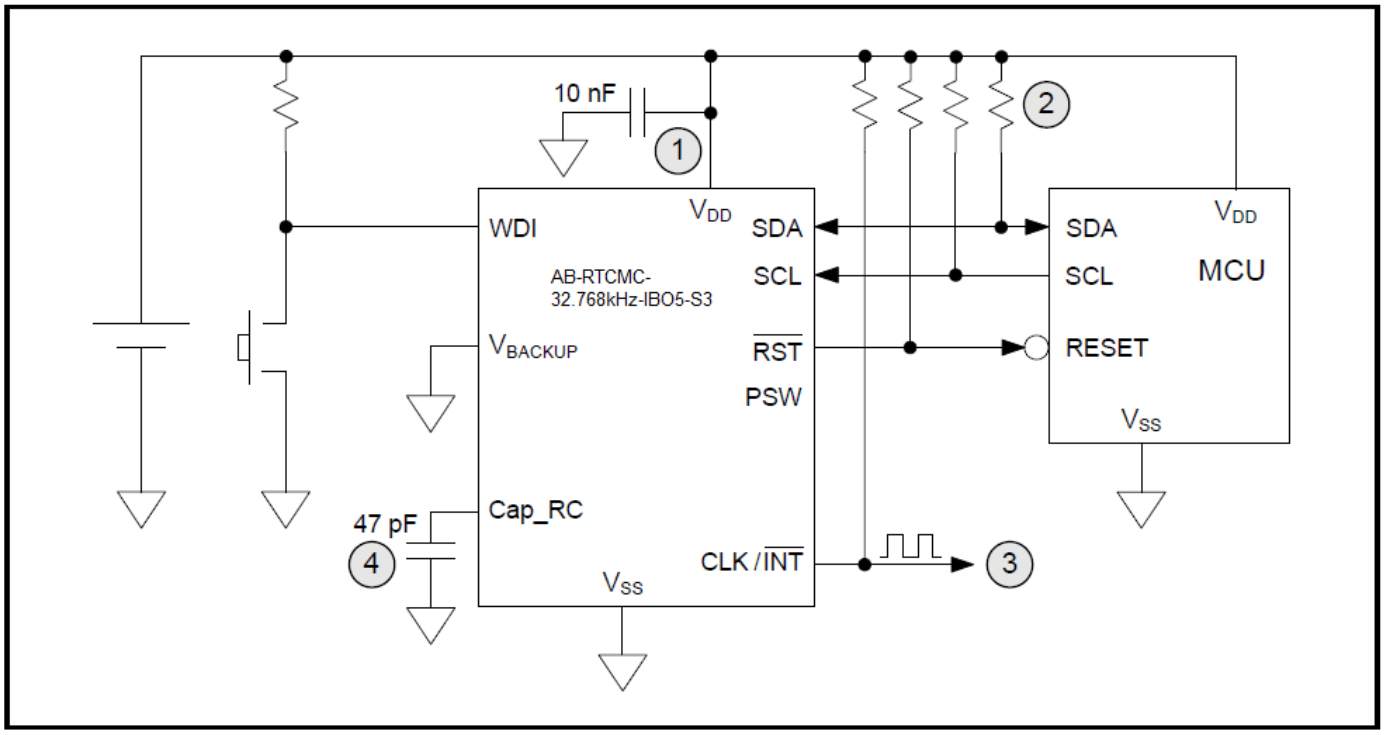
For the following Table, T_A = -40 °C to 85 °C, V_{BACKUP} < 1.2 V.

$\overline{RST}$ AC Electrical Parameters:

Parameters	V_{DD}	T_A	Min.	Typ.	Max.	Units
Low Period of V_{DD} to Ensure a Valid POR ($t_{LOW:VDD}$)	1.7 – 3.6V	+85°C		0.1		s
		+25°C		0.1		
		-20°C		1.5		
		-40°C		10		
V_{DD} Low to $\overline{RST}$ Low ($t_{VL:NRST}$)	1.7 – 3.6V	+85°C		0.1		s
		+25°C		0.1		
		-20°C		1.5		
		-40°C		10		
V_{DD} High to $\overline{RST}$ High ($t_{VH:NRST}$)	1.7 – 3.6V	+85°C		0.5		s
		+25°C		0.5		
		-20°C		3.5		
		-40°C		25		

7. Application Information

7.1. Operating AB-RTCMC-32.768kHz-IBO5-S3



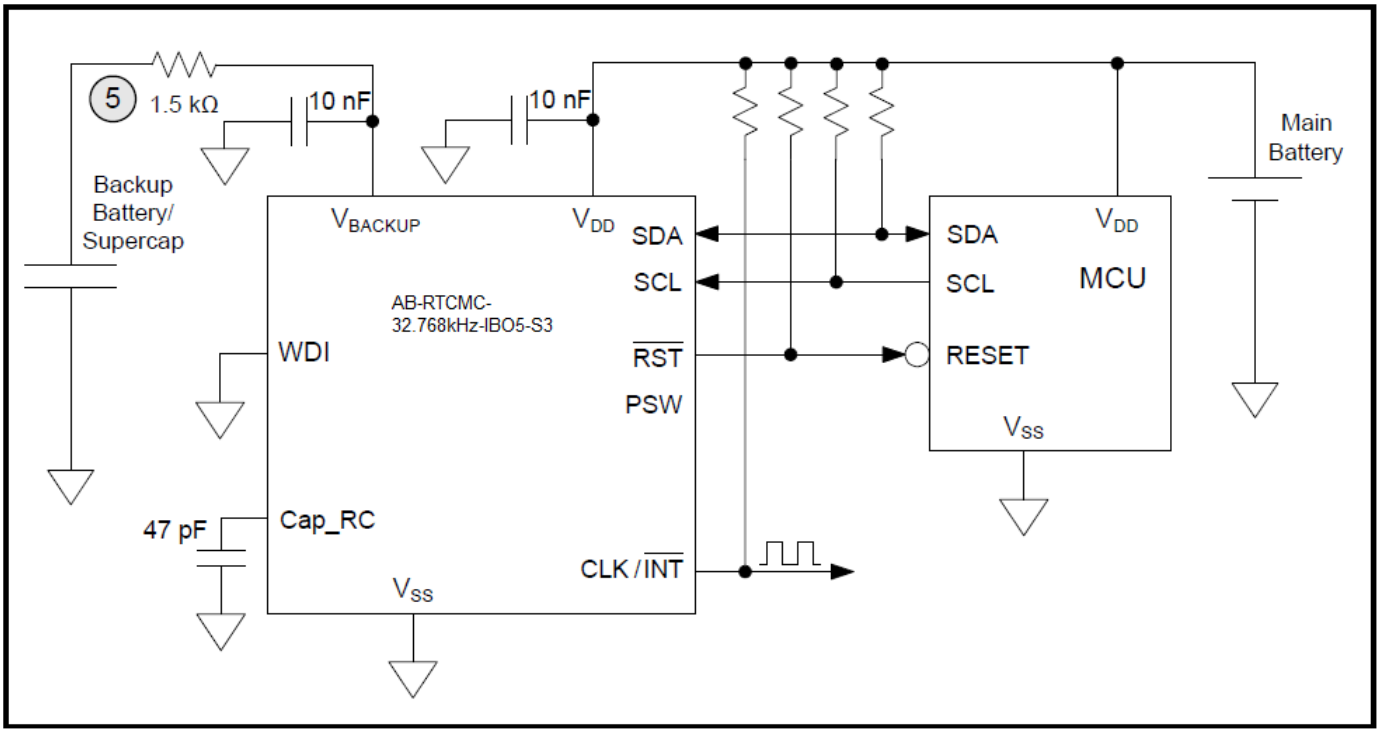
(1) A 10 nF decoupling capacitor is recommended close to the device.

(2) CLK/ $\overline{\text{INT}}$, $\overline{\text{RST}}$ and interface lines SCL, SDA are open drain and require pull-up resistors to VDD.

(3) CLK/ $\overline{\text{INT}}$ offers selectable frequencies 32.768 kHz to 1/60 Hz for application use. If not used, it is recommended to disable CLK/ $\overline{\text{INT}}$ for optimized current consumption (SQWE = 0 and CLKB = 1).

(4) A 47 pF ceramic capacitor must be placed between the Cap_RC pin and V_{SS} for improved Autocalibration mode timing accuracy.

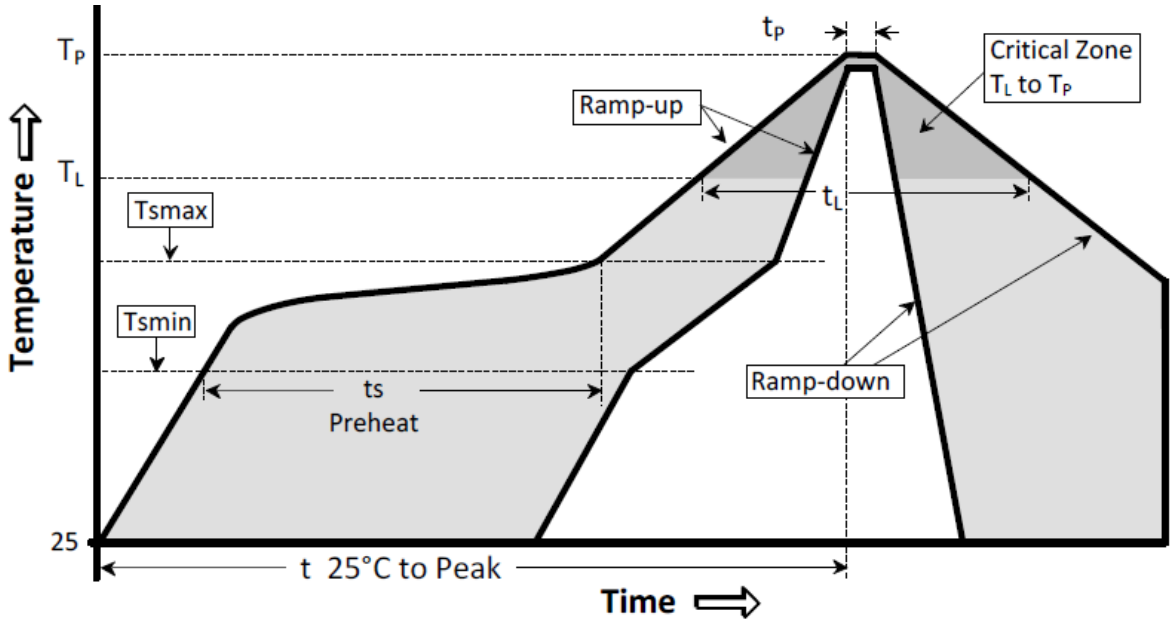
7.2. Operating AB-RTCMC-32.768kHz-IBO5-S3 with Backup Battery/Supercap



(5) Total series resistance of the power source attached to the V_{BACKUP} pin. The optimal value is 1.5 kΩ, which may require an external resistor. V_{BACKUP} power source ESR (Equivalent Series Resistance) + external resistor value = 1.5 kΩ. In particular when using a Lithium Battery it is recommended to insert a protection resistor to limit battery current and to prevent damage in case of soldering issues causing short between supply pins.

8. Recommended Reflow Temperature (Lead-free Soldering)

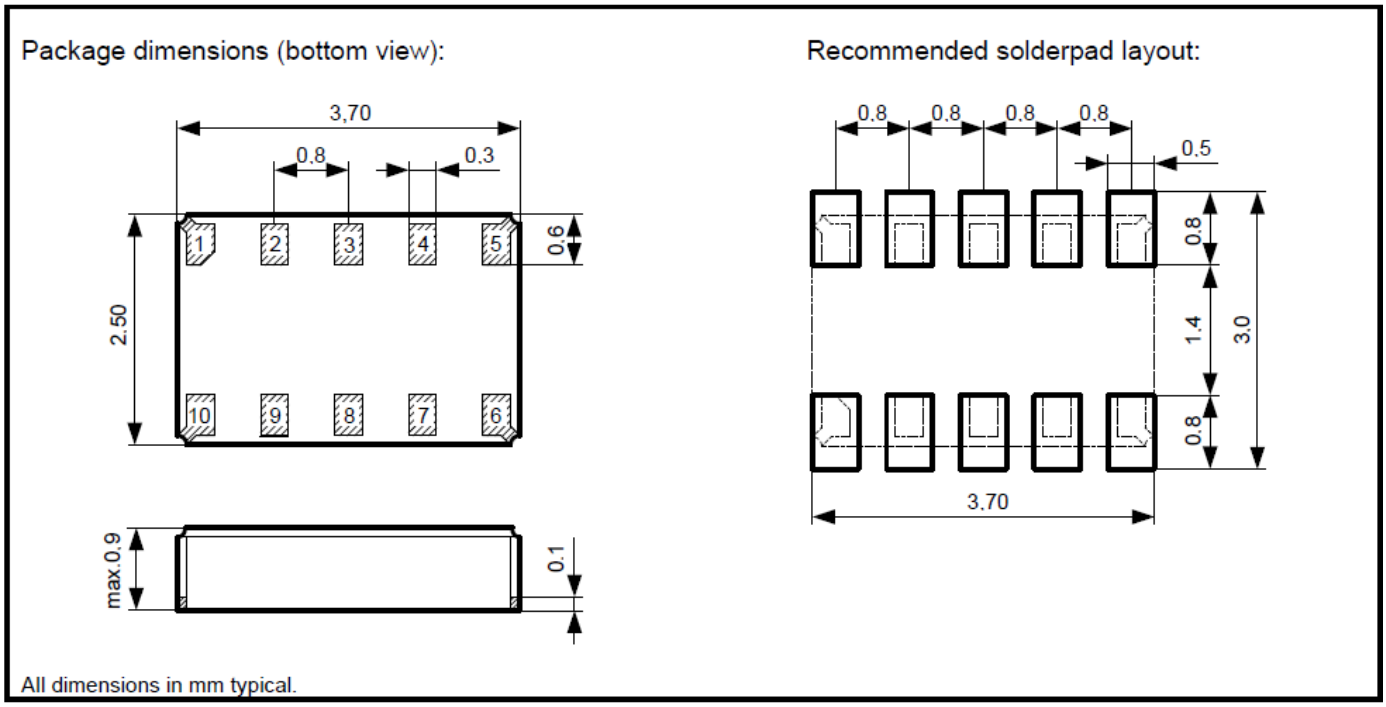
Maximum Reflow Conditions in accordance with IPC/JEDEC J-STD-020C "Pb-free"



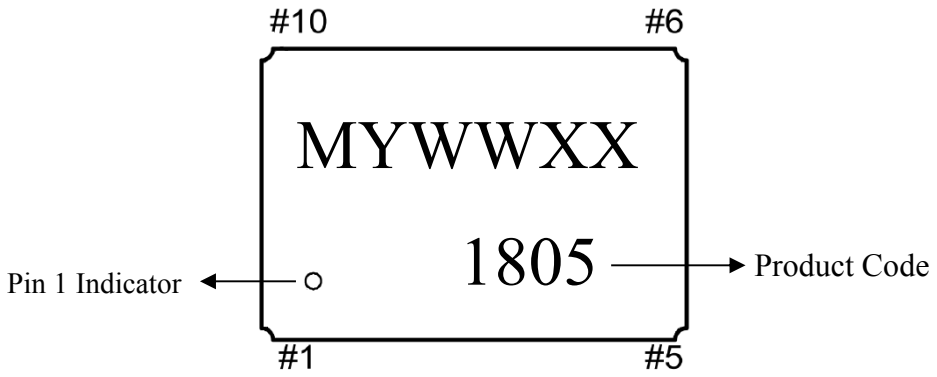
Temperature	Conditions	Units
Average Ramp-up Rate (T_{Smax} to T_P)	3°C/second max	°C/s
Ramp Down Rate (T_{cool})	6°C/second max	°C/s
Time 25°C to Peak Temperature ($T_{to\text{-}peak}$)	8 minutes max	m
Preheat		
Temperature Min (T_{Smin})	150	°C
Temperature Max (T_{Smax})	200	°C
Time Ts_{min} to Ts_{max} (ts)	60 ~ 180	sec
Time Above Liquidus		
Temperature Liquidus (T_L)	217	°C
Time above Liquidus (t_L)	60 ~150	sec
Peak Temperature		
Peak Temperature (T_P)	260	°C
Time within 5°C of Peak Temperature (t_P)	20 ~ 40	sec

9. Package

9.1. Dimensions and Solder-pads Layout



9.2. Marking



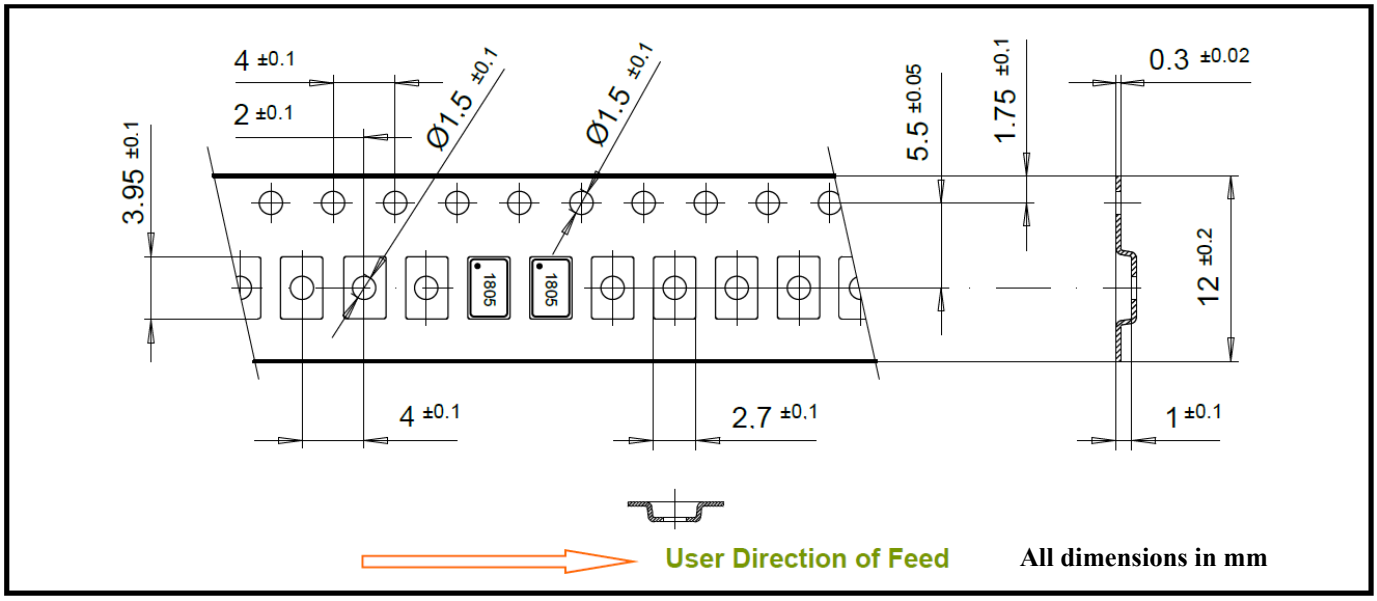
M: Internal Code
Y: Year. e.g. 5 for 2015
WW: Week. e.g 08 for the 8th week of the year
XX: Lot Code

Pin #	Function	Pin #	Function
1	V_{DD}	6	V_{SS}
2	Cap_RC	7	V_{BACKUP}
3	CLK/$\overline{INT}$	8	PSW
4	SCL	9	WDI
5	SDA	10	$\overline{RST}$

10. Packing Information

10.1. Carrier Tape

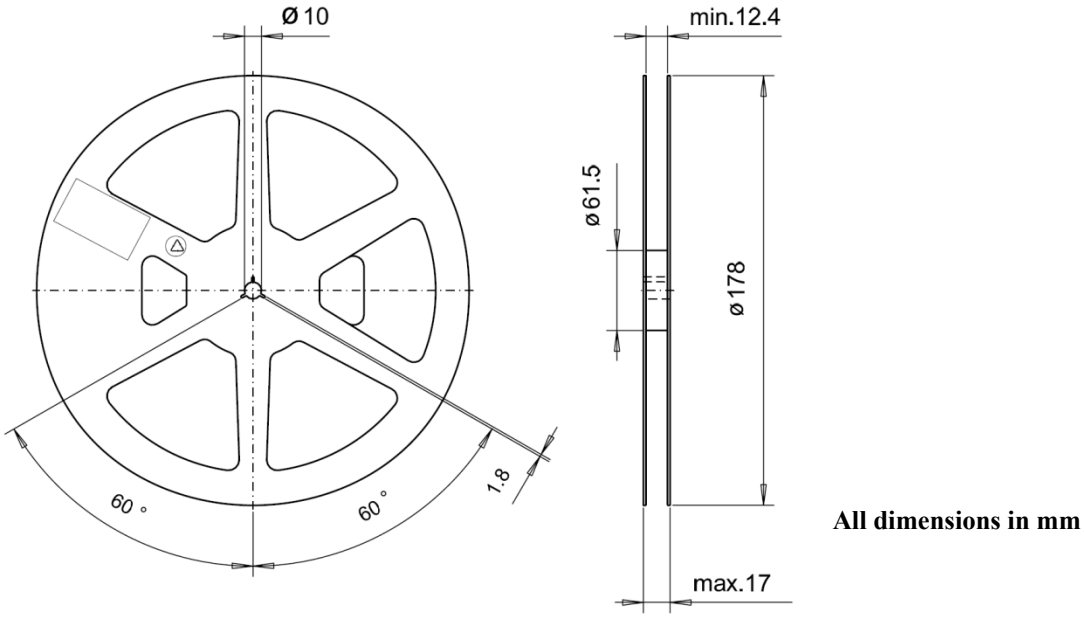
12 mm Carrier-Tape: Material: Polystyrene / Butadine or Polystyrol black, conductive
Cover Tape: Base Material: Polyester, conductive 0.061 mm
Adhesive Material: Pressure-sensitive Synthetic Polymer



Tape Leader and Trailer: 300 mm minimum.

10.2. Reel 7 Inch for 12mm Tape

7" Reel: Material: Plastic, Polystyrol
Qty/Reel: 1000pcs



10.3.Handling Precautions for Crystals or Modules with Embedded Crystals

The built-in tuning-fork crystal consists of pure Silicon Dioxide in crystalline form. The cavity inside the package is evacuated and hermetically sealed in order for the crystal blank to function undisturbed from air molecules, humidity and other influences.

Shock and vibration
Keep the crystal from being exposed to **excessive mechanical shock and vibration**. Abracon guarantees that the crystal will bear a mechanical shock of 5000g / 0.3 ms.

The following special situations may generate either shock or vibration:

Multiple PCB panels - Usually at the end of the pick & place process the single PCBs are cut out with a router. These machines sometimes generate vibrations on the PCB that have a fundamental or harmonic frequency close to 32.768 kHz. This might cause breakage of crystal blanks due to resonance. Router speed should be adjusted to avoid resonant vibration.

Ultrasonic Cleaning - Avoid cleaning processes using ultrasonic energy. These processes can damages crystals due to mechanical resonance of the crystal blank.

Overheating, rework high-temperature-exposure
Avoid overheating the package. The package is sealed with a sealring consisting of 80% Gold and 20% Tin. The eutectic melting temperature of this alloy is at 280°C. Heating the sealring up to >280°C will cause melting of the metal seal which then, due to the vacuum, is sucked into the cavity forming an air duct. This happens when using hot-air-gun set at temperatures >300°C.

Use the following methods for re-work:

- Use a hot-air- gun set at 270°C
- Use 2 temperature-controlled soldering irons, set at 270°C, with special-tips to contact all solder-joints from both sides of the package at the same time, remove part with tweezers when pad solder is liquid.

11. Notes

i) The parts are manufactured in accordance with this specification. If other conditions and specifications which are required for this specification, please contact ABRACON for more information.

ii) ABRACON will supply the parts in accordance with this specification unless we receive a written request to modify prior to an order placement.

iii) In no case shall ABRACON be liable for any product failure from in appropriate handling or operation of the item beyond the scope of this specification.

iv) When changing your production process, please notify ABRACON immediately.

v) ABRACON's products are COTS – Commercial-Off-The-Shelf products; suitable for Commercial, Industrial and, where designated, Automotive Applications. ABRACON's products are not specifically designed for Military, Aviation, Aerospace, Life-dependant Medical applications or any application requiring high reliability where component failure could result in loss of life and/or property. For applications requiring high reliability and/or presenting an extreme operating environment, written consent and authorization from ABRACON is required. Please contact ABRACON for more information.

vi) All specifications and Marking will be subject to change without notice

12. ABRACON LLC – TERMS & CONDITIONS OF SALE

The following are the terms and conditions under which Abracon LLC ("AB") agrees to sell, to the entity named on the face hereof ("Buyer"), the products specified on the face hereof (the "Products"). Notwithstanding Buyer's desire to use standardized RFQs, purchase order forms, order forms, acknowledgment forms and other documents which may contain terms in addition to or at variance with these terms, it is expressly understood and agreed that other forms shall neither add to, nor vary, these terms whether or not these terms are referenced therein. Buyer may assent to these terms by written acknowledgment, implication and/or by acceptance or payment of goods ordered any of which will constitute assent.

1. **Prices**: Prices shown on the face hereof are in US dollars, with delivery terms specified herein and are exclusive of any other charges including, without limitation, fees for export, special packaging, freight, insurance and similar charges. AB reserves the right to increase the price of Products by written notice to Buyer at least thirty (30) days prior to the original date of shipment. When quantity price discounts are quoted by AB, the discounts are computed separately for each type of product to be sold and are based upon the quantity of each type and each size ordered at any one time. If any discounted order is reduced by Buyer with AB's consent, the prices shall be adjusted to the higher prices, if applicable, for the remaining order.

2. **Taxes**: Unless otherwise specified in the quotation, the prices do not include any taxes, import or export duties, tariffs, customs charges or any such other levies. Buyer agrees to reimburse AB the amount of any federal, state, county, municipal, or other taxes, duties, tariffs, or custom charges AB is required to pay. If Buyer is exempt from any such charges, Buyer must provide AB with appropriate documentation.

3. **Payment Terms**: For each shipment, AB will invoice Buyer for the price of the Products plus all applicable taxes, packaging, transportation, insurance and other charges. Unless otherwise stated in a separate agreement or in AB's quotation, payments are due within thirty (30) days from the date of invoice, subject to AB's approval of Buyer's credit application. All invoicing disputes must be submitted in writing to AB within ten (10) days of the receipt of the invoice accompanied by a reasonably detailed explanation of the dispute. Payment of the undisputed amounts shall be made timely. AB reserves the right to require payment in advance or C.O.D. and otherwise modified credit terms. When partial shipments are made, payments for such shipments shall become due in accordance with the above terms upon submission of invoices. If, at the request of Buyer, shipment is postponed for more than thirty (30) days, payment will become due thirty days after notice to Buyer that Products are ready for shipment. Any unpaid due amounts will be subject to interest at one decimal five percent (1.5%) per month, or, if less, the maximum rate allowed by law.

4. **Delivery and Shipment**: Shipment dates are estimates only. Failure to deliver by a specified date shall neither entitle Buyer to any compensation nor impose any liability on AB. AB reserves the right to ship and bill ten percent more or less than the exact quantity specified on the face hereof. All shipments will be made Ex Works as per Incoterms 2000 from AB's place of shipment. In the absence of specific instructions, AB will select the carrier. Claims against AB for shortages must be made in writing within ten (10) days after the arrival of the shipment. AB is not required to notify Buyer of the shipment. Buyer shall pay all freight charges, insurance and other shipping expenses. Freight charges, insurance and other shipping expenses itemized in advance of actual shipment, if any, are estimates only that are calculated on the basis of standard tariffs and may not reflect actual costs. Buyer must pay actual costs.

5. **Purchase Order Changes and Cancellations**: Purchase orders for standard AB Products may not be canceled within sixty (60) days of the original shipping date. Purchase orders for non-standard AB Products are non-cancelable and non-returnable. All schedule changes must be

requested at least thirty (30) days prior to original shipping date. Maximum schedule change "push-out" shall be no more than thirty (30) days from original shipping date. AB may terminate or cancel this order, in whole or in part, at any time prior to the completion of performance by written notice to Buyer without incurring any liability to Buyer for breach of contract or otherwise. AB reserves the right to allocate Products in its sole discretion among Buyer and other potential buyers, or defer or delay the shipment of any Product, which is in short supply due to any reason.

6. **Title and Risk of Loss**: AB's responsibility for any loss or damage ends, and title passes, when Products are delivered Ex Works as per Incoterms 2000 at AB's designated shipping location to carrier, to Buyer or to Buyer's agent, whichever occurs first.

7. **Packing**: Packaging shall be AB's standard shipping materials or as specified on the face hereof. Any cost of non-standard packaging and handling requested by Buyer shall be abided by AB provided Buyer gives reasonable prior notice and agrees in writing to pay additional costs.

8. **Security Interest**: Buyer hereby grants AB a purchase money security interest in the Products sold and in the proceeds of resale of such Products until such time as Buyer has paid all charges. AB retains all right and remedies available to AB under the Uniform Commercial Code.

9. **Specifications**: Specifications for each Product are the specifications specified in the published datasheets of such Product, as of the date of AB's quotation (the "Specifications"). Except as otherwise agreed, AB reserves the right to modify the Specifications at any time without adversely affecting the functionality.

10. **Acceptance**: Unless Buyer notifies AB in writing within ten (10) days from the date of receipt of Products that the Products fail to conform to the Specifications, the Products will be deemed accepted by Buyer. No such claim of non-conformity shall be valid if (i) the Products have been altered, modified or damaged by Buyer, (ii) the rejection notice fails to explain the non-conformance in reasonable detail and is not accompanied by a test report evidencing the non-conformity, or (iii) rejected Products are not returned to AB within thirty (30) days of rejection; provided, that no Product returns may be made without a return material authorization issued by AB.

11. **Limited Warranties and Disclaimers**: AB warrants to Buyer that each Product, for a period of twelve (12) months from shipment date thereof, will conform to the Specifications and be free from defects in materials and workmanship. AB's sole liability and Buyer's exclusive remedy for Products that fail to conform to this limited warranty ("Defective Products") is limited to repair or replacement of such Defective Products, or issue a credit or rebate of no more than the purchase price of such Defective Products, at AB's sole option and election. This warranty shall not apply: (i) if Products have been damaged or submitted to abnormal conditions (mechanical, electrical, or thermal) during transit, storage, installation, or use; or (ii) if Products are subject to Improper Use (as defined below); or (iii) if the non-conformance of Products results from misuse, neglect, improper testing, storage, installation, unauthorized repair, alteration, or excess usage at or beyond the maximum values (temperature limit, maximum voltage, and other Specification limits) defined by AB; (iv) to any other default not attributable to AB; or (v) removal, alteration, or tampering of the original AB product labeling. This warranty does not extend to Products or components purchased from entities other than AB or AB's authorized distributors or to third-party software or documentation that may be supplied with any Product. In the event no defect or breach of warranty is discovered by AB upon receipt of any returned Product, such Product will be returned to Buyer at Buyer's expense and Buyer will reimburse AB for the transportation charges, labor, and associated charges incurred in testing the allegedly Defective Product. The above warranty is for Buyer's benefit only, and is non-transferable. OTHER THAN THE LIMITED WARRANTY SET FORTH ABOVE, AB MAKES NO WARRANTIES, EXPRESS, STATUTORY, IMPLIED, OR OTHERWISE AND SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NON-INFRINGEMENT, TO THE MAXIMUM EXTENT PERMITTED BY LAW. WITHOUT LIMITING THE GENERALITY OF THE FOREGOING DISCLAIMERS, AB INCORPORATES BY REFERENCE ANY PRODUCT-SPECIFIC WARRANTY DISCLAIMERS SET FORTH IN THE PUBLISHED PRODUCT DATASHEETS.

12. **Limitation of Liability**: AB SHALL HAVE NO LIABILITY FOR LOSS ARISING FROM ANY CLAIM MADE AGAINST BUYER, OR FOR SPECIAL, INDIRECT, RELIANCE, INCIDENTAL, CONSEQUENTIAL, OR PUNITIVE DAMAGES INCLUDING, WITHOUT LIMITATION, LOSS OF USE, PROFITS, REVENUES, OR COST OF PROCUREMENT OF SUBSTITUTE GOODS BASED ON ANY BREACH OR DEFAULT OF AB, HOWEVER CAUSED, AND UNDER ANY THEORY OF LIABILITY. BUYER'S SOLE REMEDY AND AB'S SOLE AND TOTAL LIABILITY FOR ANY CAUSE OF ACTION, WHETHER IN CONTRACT (INCLUDING BREACH OF WARRANTY) OR TORT (INCLUDING NEGLIGENCE OR MISREPRESENTATION) OR UNDER STATUTE OR OTHERWISE SHALL BE LIMITED TO AND SHALL NOT EXCEED THE AGGREGATE AMOUNTS PAID BY BUYER TO AB FOR PRODUCTS WHICH GIVE RISE TO CLAIMS. BUYER SHALL ALWAYS INFORM AB OF ANY BREACH AND AFFORD AB REASONABLE OPPORTUNITY TO CORRECT ANY BREACH. THE FOREGOING LIMITATIONS SHALL APPLY REGARDLESS OF WHETHER AB HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES AND NOTWITHSTANDING THE FAILURE OF ESSENTIAL PURPOSE OF ANY LIMITED REMEDY.

13. **Improper Use**: Buyer agrees and covenants that, without AB's prior written approval, Products will not be used in life support systems, human implantation, nuclear facilities or systems or any other application where Product failure could lead to loss of life or catastrophic property damage (each such use being an "Improper Use"). Buyer will indemnify and hold AB harmless from any loss, cost, or damage resulting from Improper Use of the Products.

14. **Miscellaneous**: In the event of any insolvency or inability to pay debts as they become due by Buyer, or voluntary or involuntary bankruptcy proceeding by or against Buyer, or appointment of a receiver or assignee for the benefit of creditors of Buyer, AB may elect to cancel any unfulfilled obligations. No Products or underlying information or technology may be exported or re-exported, directly or indirectly, contrary to US law or US Government export controls. AB will be excused from any obligation to the extent performance thereof is caused by, or arises in connection with, acts of God, fire, flood, riots, material shortages, strikes, governmental acts, disasters, earthquakes, inability to obtain labor or materials through its regular sources, delay in delivery by AB's supplies or any other reason beyond the reasonable control of AB. In the event any one or more of the provisions contained herein shall for any reason be held to be invalid, illegal, or unenforceable in any respect, such invalidity, illegality, or unenforceability shall not affect any other provision hereof and these terms shall be construed as if such invalid, illegal, or unenforceable provision had never been contained herein. A waiver of a breach or default under these terms shall not be a waiver of any subsequent default. Failure of AB to enforce compliance with any of these terms shall not constitute a waiver of such terms. These terms are governed by the laws of the State of California without reference to conflict of law principles. The federal and state courts located within the State of California will have exclusive jurisdiction to adjudicate any dispute arising out of these terms.