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Application Manual

AB-RTCMC-32.768kHz-EOZ9-S3

DTCXO Temperature Compensated
Real Time Clock/Calendar Module
with I^2C Interface

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AB-RTCMC-32.768kHz-EOZ9-S3

Highly accurate, DTCXO Temperature Compensated Real Time Clock / Calendar Module with I²C Interface

1.0 OVERVIEW

- RTC module with built-in "Tuning Fork" crystal oscillating at 32.768 kHz
- Factory calibrated, all built-in Temperature Compensation circuitry

Time accuracy:	Temperature Range	Opt: A	Opt: B
	25°C	± 3 ppm	± 3 ppm
	0°C to + 50°C	± 4 ppm	± 5 ppm
	-10°C to + 60°C	± 5 ppm	±10 ppm
	-40°C to + 85°C	± 6 ppm	± 25 ppm
	-40°C to +125°C	± 8 ppm	± 30 ppm

- Ultra low power consumption: 800nA typ @ V_{DD} = 3.0V / T_{amb} = 25°C
- Wide clock operating voltage: 1.3 – 5.5V
- Wide interface operating voltage: 1.4 – 5.5V
- Extended operating temperature range: -40°C to +125°C
- I²C serial interface with fast mode SCL clock frequency of 400kHz
- Provides year, month, day, weekday, hours, minutes and seconds
- Highly versatile alarm and timer functions
- Integrated Low-Voltage Detector, Power-On Reset and Self-Recovery System
- Main Power Supply to Backup Battery switchover circuitry with Trickle Charger
- Programmable CLKOUT pins for peripheral devices (32.768 kHz / 1024 Hz / 32 Hz / 1 Hz)
- Small and compact package size: 3.7 x 2.5 x 0.9 mm. RoHS-compliant and 100% leadfree

1.1 GENERAL DESCRIPTION

The AB-RTCMC-32.768kHz-EOZ9-S3 is a CMOS low power, real-time clock/calendar module with built-in Thermometer and Digital Temperature Compensation circuitry (DTCXO). The temperature compensation circuitry is factory-calibrated and greatly improves the time accuracy by compensating the frequency-deviation @ 25°C and the anticipated frequency-drift over the temperature of the embedded 32.768 kHz "Tuning-Fork" crystal, even over the extended Temperature Range -40°C to +125°C. Data is transferred serially via an I²C interface with a maximum SCL clock frequency in fast mode of 400kHz, the built-in word address register is incremented automatically after each written or read data byte. Beyond standard RTC-functions like year, month, day, weekday, hours, minutes, seconds information, the AB-RTCMC-32.768kHz-EOZ9-S3 offers highly versatile Alarm and Timer-Interrupt function, programmable Clock-Output and Low-Voltage Detector.

1.2. APPLICATIONS

The AB-RTCMC-32.768kHz-EOZ9-S3 RTC module combines key functions with outstanding performance in a small ceramic package:

- Factory calibrated Temperature Compensation
- Extended temperature range up to +125°C
- Low Power consumption
- Smallest temperature compensated RTC module with embedded Xtal

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

- Automotive: Car Radio / GPS and Tracking Systems / Dashboard / Engine Controller / Car Mobile & Entertainment Systems / Tachometers
- Metering: E-meter / Heating Counter
- Outdoor: ATM & POS systems / Surveillance & Safety systems / Ticketing systems
- All kind of portable and battery operated devices
- Industrial and consumer electronics
- White goods

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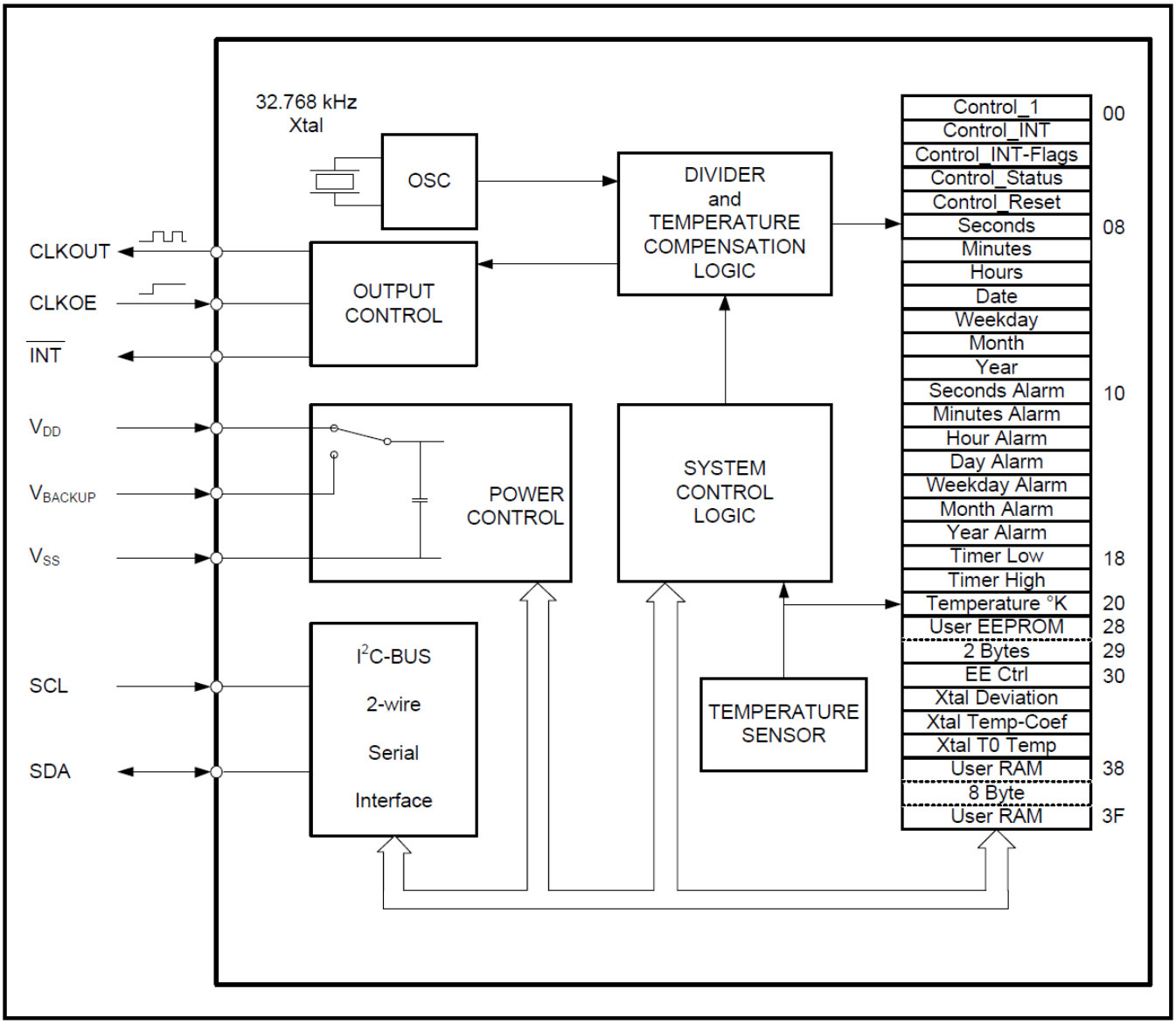
2.0 BLOCK DIAGRAM



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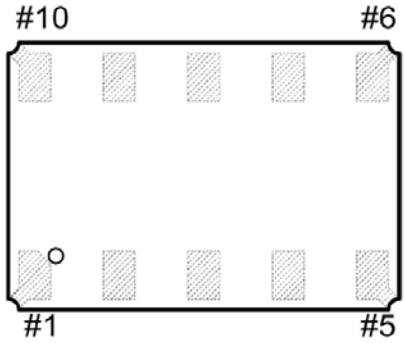
2.1 PINOUT



Pin #	Function	Pin #	Function
1	CLKOE	6	V_{SS}
2	V_{DD}	7	$\overline{INT}$
3	CLKOUT	8	N.C.
4	SCL	9	V_{BACKUP}
5	SDA	10	N.C.

2.2 PIN DESCRIPTION

Pin No.	Pin Name	Function
1	CLKOE	CLKOUT enable/disable pin; enable is active HIGH; tie to GND when not using CLKOUT
2	V_{DD}	Positive supply voltage; positive or negative steps in supply voltage may affect oscillator performance, recommend 10 nF decoupling capacitor close to device
3	CLKOUT	Clock Output pin; CLKOUT or $\overline{INT}$ function can be selected.(Control_1; bit7; Clk/Int) CLKOUT output push-pull / $\overline{INT}$ function open-drain requiring pull-up resistor
4	SCL	Serial Clock Input pin; requires pull-up resistor
5	SDA	Serial Data Input-Output pin; open-drain; requires pull-up resistor
6	V_{SS}	Ground
7	$\overline{INT}$	Interrupt output pin; open-drain; active LOW
8	N.C.	Not connected; internally used for test. do not connect other signals than ground
9	V_{BACKUP}	Backup Supply Voltage; tie to GND when not using backup supply voltage
10	N.C.	Not connected; internally used for test. do not connect other signals than ground

2.3 FUNCTIONAL DESCRIPTION

The AB-RTCMC-32.768kHz-EOZ9-S3 is a highly accurate real-time clock/calendar module due to integrated temperature compensation circuitry. The built-in Thermometer and Digital Temperature Compensation circuitry (DTCXO) provides improved time-accuracy; achieved by measuring the temperature and calculating an expected correction value based on precise, factory-calibrated Crystal parameters. The compensation of the frequency deviation @ 25°C and the Crystal's frequency-drift over the temperature range are obtained by adding or subtracting 32.768 kHz oscillator clock-pulses. Beyond standard RTC-functions like year, month, day, weekday, hours, minutes, seconds information, the AB-RTCMC-32.768kHz-EOZ9-S3 offers highly versatile Alarm and Timer-Interrupt function, programmable Clock-Output and Voltage-Low-Detector and a Main-Supply to Backup-Battery Switchover Circuitry and a 40kHz I^2C interface.

The CMOS IC contains thirty 8-bit RAM registers organized in 6 memory pages; the address counter is automatically incremented within the same memory page. All sixteen registers are designed as addressable 8-bit parallel registers, although, not all bits are implemented.

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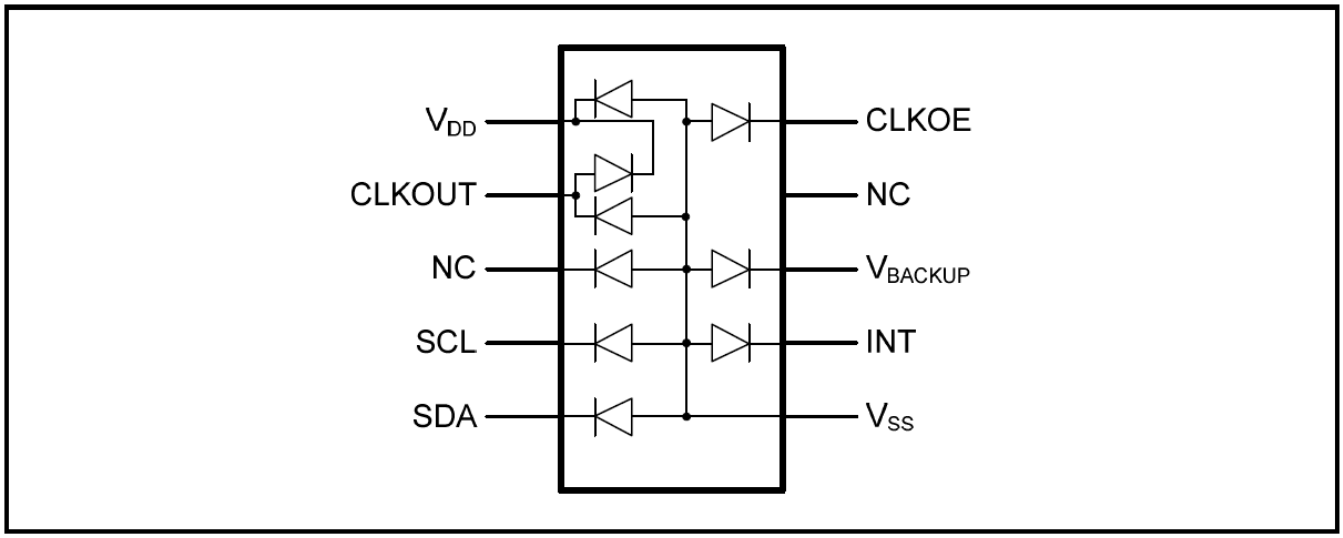
- **Memory page #00** contains of five registers (memory address 00h and 04h) used as control registers
- **Memory page #01** addresses 08h through 0Eh are used as counters for the clock function (seconds up to years). The Seconds, Minutes, Hours, Days, Weekdays, Months and Years registers are all coded in Binary-Coded-Decimal (BCD) format. When one of the RTC registers is read, the content of all counters is frozen to prevent faulty reading of the clock/calendar registers during a carry condition
- **Memory page #02** addresses 10h through 16h define the alarm condition
- **Memory page #03** addresses 18h and 19h are used for Timer function
- **Memory page #04** address 20h provides the thermometer reading value
- **Memory page #07** addresses 38h through 3Fh are available for user data

Additionally, the CMOS-IC contains six non-volatile 8-bit EEPROM registers organized in 2 memory pages; the address counter is automatically incremented within the same memory page.

- **EEPROM page #05** addresses 28h and 29h are available for EEPROM user data
- **EEPROM page #06** contains of four registers (memory address 30h through 33h) used as non-volatile control registers. These registers contain the factory programmed parameters of the Crystal's thermal characteristics, the frequency-deviation @ ambient temperature and the Thermometer's calibration values. In favor for the best time-accuracy, the factory programmed registers (memory address 31h through 33h) shall not be changed by the user without carefully studying its function

2.4 DEVICE PROTECTION DIAGRAM



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3.0 REGISTER ORGANIZATION

The registers are grouped into memory pages. The pages are addressed by the 5 most-significant-bits (MSB's bits 7 – 3), the 3 least-significant-bites (LSB's 2 – 0) select the registers within the addressed page.

30 RAM registers organized in 6 memory pages and 6 EEPROM registers organized in 2 memory pages are available. During interface access, the page address (MSB's 7 - 3) is fixed while the register address (LSB's 2 - 0) are automatically incremented. The content of all counters and registers are frozen to prevent faulty reading of the clock/calendar registers during carry condition.

The time registers in the Clock and Alarm pages are encoded in the Binary Coded Decimal format (BCD) to simplify application use. Other registers are either bit-wise or standard binary format.

3.1 REGISTER OVERVIEW

Address			Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Page Bit 7 - 3	Address Bit 2 - 0	Hex									
Control Page 00000	000	00h	Control_1	Clk/Int	TD1	TD0	SROn	EERE	TAR	TE	WE
	001	01h	Control_INT	X	X	X	SRIE	V2IE	V1IE	TIE	AIE
	010	02h	Control_INT Flag	X	X	X	SRF	V2IF	V1IF	TF	AF
	011	03h	Control_Status	EEbusy	X	PON	SR	V2F	V1F	X	X
	100	04h	Control_Reset	X	X	X	SysR	X	X	X	X
Clock Page 00001	000	08h	Seconds	X	40	20	10	8	4	2	1
	001	09h	Minutes	X	40	20	10	8	4	2	1
	010	0Ah	Hours	X	12-24	20-PM	10	8	4	2	1
	011	0Bh	Days	X	X	20	10	8	4	2	1
	100	0Ch	Weekdays	X	X	X	X	X	4	2	1
	101	0Dh	Months	X	X	X	10	8	4	2	1
	110	0Eh	Years	X	40	20	10	8	4	2	1
Alarm Page 00010	000	10h	Second Alarm	AE_S	40	20	10	8	4	2	1
	001	11h	Minute Alarm	AE_M	40	20	10	8	4	2	1
	010	12h	Hour Alarm	AE_H	X	20-PM	10	8	4	2	1
	011	13h	Days Alarm	AE_D	X	20	10	8	4	2	1
	100	14h	Weekday Alarm	AE_W	X	X	X	X	4	2	1
	101	15h	Months Alarm	AE_M	X	X	10	8	4	2	1
	110	16h	Year Alarm	AE_Y	40	20	10	8	4	2	1
Timer Page 00011	000	18h	Timer Low	128	64	32	16	8	4	2	1
	001	19h	Timer High	128	64	32	16	8	4	2	1
Temp. Page 00100	000	20h	Temperature	128	64	32	16	8	4	2	1

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(Continued)

Address			Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Page	Address	Hex									
Bit 7 - 3	Bit 2 - 0										
EEPROM User 00101	000	28h	EEPROM User	2 bytes of EEPROM for user data							
	001	29h	EEPROM User								
EEPROM Control Page 00110	000	30h	EEPROM contr.	R80k	R20k	R5k	R1k	FD1	FD0	ThE	ThP
	001	31h	Xtal Offset	Sign	64	32	16	8	4	2	1
	010	32h	Xtal Coef	128	64	32	16	8	4	2	1
	011	33h	Xtal T0	X	X	32	16	8	4	2	1
RAM Page 00111	000	38h	User RAM	8 bytes of RAM for user data							
	:	:									
	111	3Fh									

Bit positions labeled as "X" are not implemented and will return a "0" when read.

3.2. CONTROL PAGE REGISTER FUNCTION

3.2.1 CONTROL_1 (address 00h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
00h	Control_1	Clk/Int	TD1	TD0	SROn	EERE	TAR	TE	WE

Bit	Symbol	Value	Description	Reference
7	Clk/Int	0	Applies $\overline{INT}$ function on CLKOUT pin	See section 4.9
		1	Applies CLKOUT function on CLKOUT pin	
6	TD1	00 01 10 11	Select Source Clock for internal Countdown Timer	See section 4.4
5	TD0			
4	SROn	0	Disables Self Recovery function	See section 4.8
		1	Enables Self Recovery function	
3	EERE	0	Disables automatic EEPROM refresh every hour	See section 4.3
		1	Enables automatic EEPROM refresh every hour	
2	TAR	0	Disables Countdown Timer auto-reload mode	See section 4.4
		1	Enables Countdown Timer auto-reload mode	
1	TE	0	Disables Countdown Timer	See section 4.4
		1	Enables Countdown Timer	
0	WE	0	Disables 1Hz Clock Source for Watch	See section 4.7
		1	Enables 1Hz Clock Source for Watch	

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3.2.2 CONTROL_INT (address 01h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
01h	Control_INT	X	X	X	SRIE	V2IE	V1IE	TIE	AIE

Bit	Symbol	Value	Description	Reference
7 to 5	unused	X	Unused	
4	SRIE	0	Disables Self-Recovery INT	See section 4.8
		1	Enables Self-Recovery INT	
3	V2IE	0	Disables VLOW2 INT; "Low Voltage 2 detection"	See section 4.1.2
		1	Enables VLOW2 INT; "Low Voltage 2 detection"	
2	V1IE	0	Disables VLOW1 INT; "Low Voltage 1detection"	See section 4.1.2
		1	Enables VLOW1 INT; "Low Voltage 1detection"	
1	TIE	0	Disables Countdown Timer INT	See section 4.4.1
		1	Enables Countdown Timer INT	
0	AIE	0	Disables Alarm INT	See section 4.5.1
		1	Enables Alarm INT	

Bit positions labeled as "X" are not implemented and will return a "0" when read.

3.2.3 CONTROL_INT FLAG (address 02h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
02h	Control_INT Flag	X	X	X	SRF	V2IF	V1IF	TF	AF

Bit	Symbol	Value	Description	Reference
7 to 5	unused	X	Unused	
4	SRF	0	No Self-Recovery Interrupt generated	See section 4.6
		1	Self-Recovery Interrupt generated if possible deadlock is detected; clear flag to clear Interrupt	
3	V2IF	0	No VLOW2 Interrupt generated	See section 4.6
		1	VLOW2 Interrupt generated when supply voltage drops below VLOW2 threshold	
2	V1IF	0	No VLOW1 Interrupt generated	See section 4.6
		1	VLOW1 Interrupt generated when supply voltage drops below VLOW1 threshold	
1	TF	0	No Timer Interrupt generated	See section 4.6
		1	Timer Interrupt generated when Countdown Timer value reaches zero	
0	AF	0	No Alarm Interrupt generated	See section 4.6
		1	Alarm Interrupt generated when Time & Date matches Alarm setting	

Bit positions labeled as "X" are not implemented and will return a "0" when read.

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3.2.4 CONTROL_STATUS (address 03h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
03h	Control_Status	EEbusy	X	PON	SR	V2F	V1F	X	X

Bit	Symbol	Value	Description	Reference
7	EEbusy	0	EEPROM is not busy	See section 4.3
		1	Flag is set when EEPROM page is busy due to "write" or automatic EEPROM refresh in progress	
6	Unused	X	Unused	
5	PON	0	No Power-On Reset executed	See section 4.1
		1	Flag is set at Power-On, flag must be cleared by writing "0"	
4	SR	0	No Self-Recovery Reset or System Reset has been generated.	See section 4.2.1
		1	Flag is set when Self-Recovery Reset or System Reset has been generated.	
3	V2F	0	No VLOW2 Interrupt generated	See section 4.6
		1	VLOW2 Interrupt generated when supply voltage drops below VLOW2 threshold	
2	V1F	0	No VLOW1 Interrupt generated	See section 4.6
		1	VLOW1 Interrupt generated when supply voltage drops below VLOW1 threshold	
1 to 0	unused	X	Unused	

Bit positions labeled as "X" are not implemented and will return a "0" when read.

3.2.5 CONTROL_RESET (address 04h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
04h	Control_Reset	X	X	X	SysR	X	X	X	X

Bit	Symbol	Value	Description	Reference
7 to 5	unused	X	Unused	
4	SysR	0	No System Reset will be executed	See section 4.2.1
		1	Set bit = "1" triggers a System Reset. After the restart of the logic, the SysR will be cleared and in bit 4 "SR" in the register Control_Status will be set	
3 to 0	unused	X	Unused	

Bit positions labeled as "X" are not implemented and will return a "0" when read.

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3.3 WATCH PAGE REGISTER FUNCTION

Watch Page registers are coded in the Binary Coded Decimal (BCD) format; BCD format is used to simplify application use.

3.3.1 SECONDS, MINUTES, HOURS, DAYS, WEEKDAYS, MONTHS, YEARS REGISTER

Seconds (address 08h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
08h	Seconds	X	40	20	10	8	4	2	1

Bit	Symbol	Value	Description
7	X	-	Unused
6 to 0	Seconds	0 to 59	These registers hold the current seconds coded in BCD format

.

Minutes (address 09h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
09h	Minutes	X	40	20	10	8	4	2	1

Bit	Symbol	Value	Description
7	X	-	Unused
6 to 0	Minutes	0 to 59	These registers hold the current minutes coded in BCD format

Hours (address 0Ah…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0Ah	Hours	X	12-24	20-PM	10	8	4	2	1

Bit	Symbol	Value	Description
7	X	-	unused
12 hour mode			
6	12-24	0	Selects 24-hour mode
		1	Selects 12-hour (AM/PM) mode
5	AM-PM	0	Indicates AM
		1	Indicates PM
4 to 0	Hours[1)]	1 to 12	These registers hold the current hours coded in BCD format for 12 hour mode
24 hour mode [2)]			
6	12-24	0	Selects 24-hour mode
		1	Selects 12-hour (AM/PM) mode
5 to 0	Hours[1)]	0 to 23	These registers hold the current hours coded in BCD format for 24 hour mode

1) User is requested to pay attention to setting valid data only.

Days (address 0Bh…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0Bh	Days	X	X	20	10	8	4	2	1

Bit	Symbol	Value	Description
7 and 6	X	-	unused
5 to 0	Days	1 to 31	These registers hold the current days coded in BCD format [1)]

1) The RTC compensates for leap years by adding a 29th day to February if the year counter contains a value which is exactly divisible by 4; including the year 00.

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Weekdays (address 0Ch…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0Ch	Weekdays	X	X	X	X	X	4	2	1

Bit	Symbol	Value	Description
7 to 3	X	-	unused
2 to 0	Weekdays	1 to 7	These registers hold the current weekdays coded in BCD format

Weekday [1)]	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Sunday	X	X	X	X	X	0	0	1
Monday	X	X	X	X	X	0	1	0
Tuesday	X	X	X	X	X	0	1	1
Wednesday	X	X	X	X	X	1	0	0
Thursday	X	X	X	X	X	1	0	1
Friday	X	X	X	X	X	1	1	0
Saturday	X	X	X	X	X	1	1	1

1) These bits may be re-assigned by the user.

Months (address 0Dh…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0Dh	Months	X	X	X	10	8	4	2	1

Bit	Symbol	Value	Description
7 to 5	X	-	unused
4 to 0	Months	1 to 12	These registers hold the current months coded in BCD format [1)]

Month	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
January	X	X	X	0	0	0	0	1
February	X	X	X	0	0	0	1	0
March	X	X	X	0	0	0	1	1
April	X	X	X	0	0	1	0	0
May	X	X	X	0	0	1	0	1
June	X	X	X	0	0	1	1	0
July	X	X	X	0	0	1	1	1
August	X	X	X	0	1	0	0	0
September	X	X	X	0	1	0	0	1
October	X	X	X	1	0	0	0	0
November	X	X	X	1	0	0	0	1
December	X	X	X	1	0	0	1	0

1) The RTC compensates for leap years by adding a 29th day to February if the year counter contains a value which is exactly divisible by 4; including the year 00.

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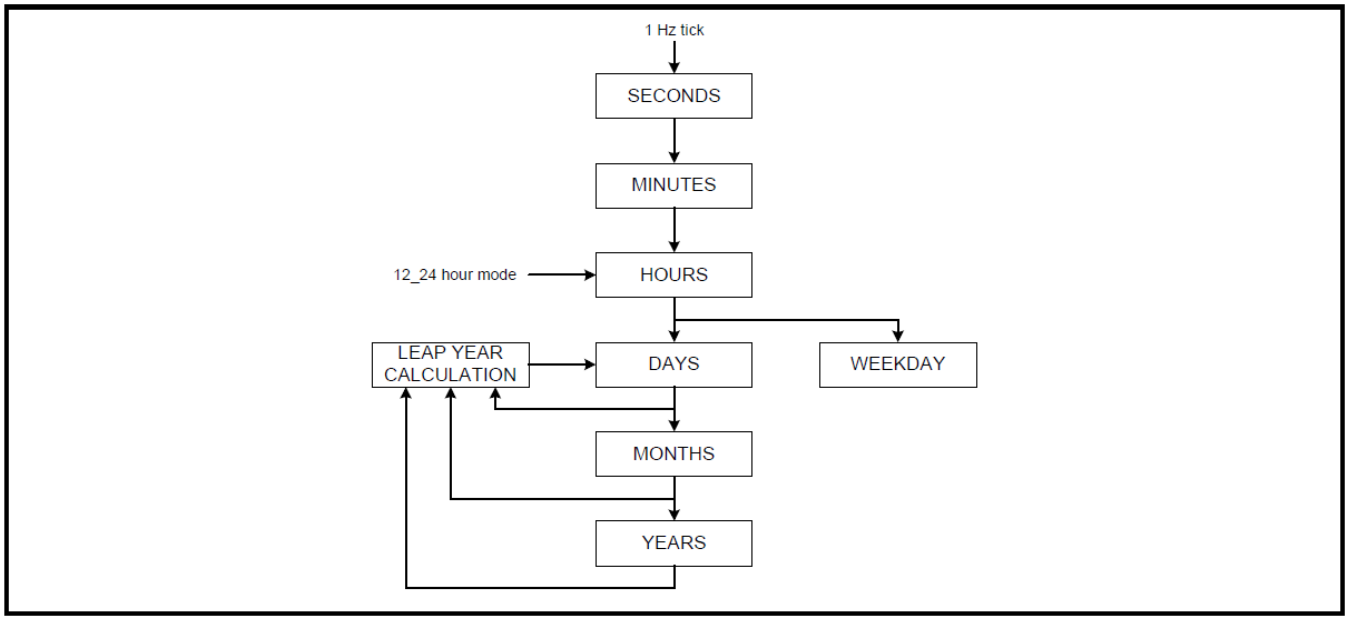
Years (address 0Eh…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0Eh	Years	X	40	20	10	8	4	2	1

Bit	Symbol	Value	Description
7	X	-	Unused
6 to 0	Years	0 to 79	These registers hold the current year 20xx coded in BCD format [1)]

1) The RTC compensates for leap years by adding a 29th day to February if the year counter contains a value which is exactly divisible by 4; including the year 00.

3.3.2 DATA FLOW OF TIME AND DATE FUNCTION



3.4 ALARM PAGE REGISTER FUNCTION

The Alarm Page registers contain alarm information. When one or more of these registers are loaded with a valid second, minute, hour, day, weekday, month or year information and its corresponding alarm enable bit (AE_x) is logic "1", then that information will be compared with the current time / date information in the Watch Page registers.

When all enabled comparisons first match (wired "AND") and the AIE Flag (bit 0 in register Control_INT) is enabled, then the AF Flag (bit 0 in register Control_INT) is set = "1" and an Interrupt signal becomes available at $\overline{INT}$ pin. Disabled Alarm registers which have their corresponding bit AE_X at logic "0" are ignored.

3.4.1. SECONDS, MINUTES, HOURS, DAYS, WEEKDAYS, MONTHS, YEARS ALARM REGISTER

Alarm Seconds (address 10h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
10h	Second Alarm	AEN_S	40	20	10	8	4	2	1

Bit	Symbol	Value	Description
7	AE_S	0	Second alarm is disabled
		1	Second alarm is enabled
6 to 0	Second alarm	0 to 59	These bits hold the Second Alarm information coded in BCD format

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Alarm Minutes (address 11h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
11h	Minute Alarm	AE_M	40	20	10	8	4	2	1

Bit	Symbol	Value	Description
7	AE_M	0	Minute alarm is disabled
		1	Minute alarm is enabled
6 to 0	Minute Alarm	0 to 59	These bits hold the Minute Alarm information coded in BCD format

Alarm Hours (address 12h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
12h	Hour Alarm	AE_H	X	20-PM	10	8	4	2	1

Bit	Symbol	Value	Description
7	AE_H	0	Hour alarm is disabled
		1	Hour alarm is enabled
6	X	-	unused
12 hour mode			
5	20-PM	0	indicates AM
		1	indicates PM
4 to 0	Hour Alarm	1 to 12	These registers hold the Hour Alarm information coded in BCD format when in 12 hour mode
24 hour mode			
5 to 0	Hour Alarm	0 to 23	These registers hold the Hour Alarm information coded in BCD format when in 24 hour mode

Alarm Days (address 13h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
13h	Day Alarm	AE_D	X	20	10	8	4	2	1

Bit	Symbol	Value	Description
7	AE_D	0	Day alarm is disabled
		1	Day alarm is enabled
6	X	-	unused
5 to 0	Days Alarm	1 to 31	These registers hold the Day Alarm information coded in BCD format

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Alarm Weekdays (address 14h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
14h	Weekday Alarm	AE_W	X	X	X	X	4	2	1

Bit	Symbol	Value	Description
7	AE_W	0	Weekday alarm is disabled
		1	Weekday alarm is enabled
6 to 3	X	-	unused
2 to 0	Weekday Alarm	1 to 7	These registers hold the Weekday Alarm information coded in BCD format

Alarm Months (address 15h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
15h	Months Alarm	AE_M	X	X	10	8	4	2	1

Bit	Symbol	Value	Description
7	AE_M	0	Month alarm is disabled
		1	Month alarm is enabled
6 to 5	X	-	unused
4 to 0	Month Alarm	1 to 12	These registers hold the Month Alarm information coded in BCD format

Alarm Years (address 16h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
16h	Years Alarm	AE_Y	40	20	10	8	4	2	1

Bit	Symbol	Value	Description
7	AE_Y	0	Year alarm is disabled
		1	Year alarm is enabled
6 to 0	Year Alarm	0 to 79	These registers hold the Year Alarm information coded in BCD format

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3.5 TIMER PAGE REGISTER FUNCTION

The Timer Page contains 2 registers forming a 16-bit countdown timer value.

Countdown Timer Value (addresses 18h / 19h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
18h	Timer Low	128	64	32	16	8	4	2	1
19h	Timer High	128	64	32	16	8	4	2	1

Address	Symbol	Value	Description
18h	Timer Low	1 to 255	These bits hold the Low Countdown Timer Value in binary format
19h	Timer High	0 to 255	These bits hold the High Countdown Timer Value in binary format

3.6 TEMPERATURE PAGE REGISTER FUNCTION

The Temperature Page register contains the result of the measured temperature ranging from -60°C (=0d) to +190°C (=250d) with 0°C corresponding to a content of =60d.

During read / write access, the content of the register Temperature is frozen in a cache memory to prevent faulty reading.

When the Thermometer is disabled by ThE = "0" (bit 1 in register EEPROM_Control), the register Temperature at address 20h can be externally written.

Temperature Value (address 20h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
20h	Temperature	128	64	32	16	8	4	2	1

Address	Symbol	Value	Description
20h	Temperature	-60 to +194°C	These bits hold the Temperature Value in binary format

3.7 EEPROM DATA PAGE REGISTER FUNCTION

The EEPROM Data Page contains 2 non-volatile EEPROM registers for user's application.

Please see section 4.3 EEPROM MEMORY ACCESS for detailed instructions how to handle EEPROM read / write access.

User EEPROM Data Registers (addresses 28h / 29h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
28h	EEPROM User	128	64	32	16	8	4	2	1
29h	EEPROM User	128	64	32	16	8	4	2	1

Address	Symbol	Value	Description
28h	EEPROM User	0 to 255	EEPROM User Data (2 Bytes)
29h	EEPROM User	0 to 255	

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3.8 EEPROM CONTROL PAGE REGISTER FUNCTION

The EEPROM Control Page contains 4 non-volatile EEPROM registers.

With Register EEPROM Control, the settings for Trickle-Charger (bit 7-4), the CLKOUT frequency (bit 3&2) and the Thermometer (bit 1&0) can be controlled.

The registers XTAL Offset, XTAL Coef and XTAL T0 contain the factory calibrated, individual crystal parameters to compensate the frequency deviation over the temperature range.

Please see section 4.3 EEPROM MEMORY ACCESS for detailed instructions how to handle EEPROM read / write access.

3.8.1 EEPROM CONTROL (address 30h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
30h	EEPROM Control	R80k	R20k	R5k	R1k	FD1	FD0	ThE	ThP

Bit	Symbol	Value	Description	Reference
7	R80k	0	Disables 80kΩ trickle charge resistor	See section 4.1
		1	Enables 80kΩ trickle charge resistor	
6	R20k	0	Disables 20kΩ trickle charge resistor	
		1	Enables 20kΩ trickle charge resistor	
5	R5k	0	Disables 5kΩ trickle charge resistor	
		1	Enables 5kΩ trickle charge resistor	
4	R1k	0	Disables 1.5kΩ trickle charge resistor	
		1	Enables 1.5kΩ trickle charge resistor	
3	FD1	00 01 10 11	Selects Clock Frequency at CLKOUT pin	See section 4.9
2	FD0			
1	ThE	0	Disables Thermometer	See section 5.2.1
		1	Enables Thermometer	
0	ThP	0	Set Temperature Scanning Interval: 1 second	
		1	Set Temperature Scanning Interval: 16 seconds	

3.8.2 XTAL OFFSET (address 31h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
31h	XTAL Offset	sign	64	32	16	8	4	2	1

Bit	Symbol	Value	Description	Reference
7	Sign	0	- Deviation (slower) of 32.768kHz frequency at T_0	See section 5.2.2
		1	+ Deviation (faster) of 32.768kHz frequency at T_0	
6 to 0	XTAL Offset [1)]	0 to 121	Frequency Offset Compensation value	

1) The XTAL Offset register value is factory programmed according to the crystal's initial frequency-tolerance. For best time-accuracy, the content of this register must not be changed by the user.

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3.8.3 XTAL TEMPERATUR COEFFICIENT (address 32h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
32h	XTAL Coef	128	64	32	16	8	4	2	1

Bit	Symbol	Value	Description	Reference
7 to 0	XTAL Coef [1)]	0 to 255	Quadratic Coefficient of Xtal's Temperature Drift	See section 5.2.2

1) The XTAL Coef register value is factory programmed according to the crystal parameters over temperature. For best time-accuracy, the content of this register must not be changed by the user.

3.8.4 XTAL TURNOVER TEMPERATUR COEFFICIENT T0 (address 33h…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
33h	XTAL T0	X	X	32	16	8	4	2	1

Bit	Symbol	Value	Description	Reference
7 to 6	X	-	Unused	
5 to 0	XTAL T0 [1)]	4 to 67	Xtal's Turnover Temperature in °C	See section 5.2.2

1) The XTAL Coef register value is factory programmed according to the crystal parameters over temperature. For best time-accuracy, the content of this register must not be changed by the user.

3.9 RAM DATA PAGE REGISTER FUNCTION

The RAM Data Page contains 8 RAM registers for user's application.

User RAM Data Registers (addresses 38h to 3Fh…bits description)

Address	Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
38h	RAM User	128	64	32	16	8	4	2	1
---	---	128	64	32	16	8	4	2	1
3Fh	RAM User	128	64	32	16	8	4	2	1

Address	Symbol	Value	Description
38h	RAM User	0 to 255	RAM User Data (8 Bytes)
---	---	---	
3Fh	RAM User	0 to 255	

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4.0 DETAILED FUNCTIONAL DESCRIPTION

4.1 POWER-UP, POWER MANAGEMENT AND BATTERY SWITCHOVER

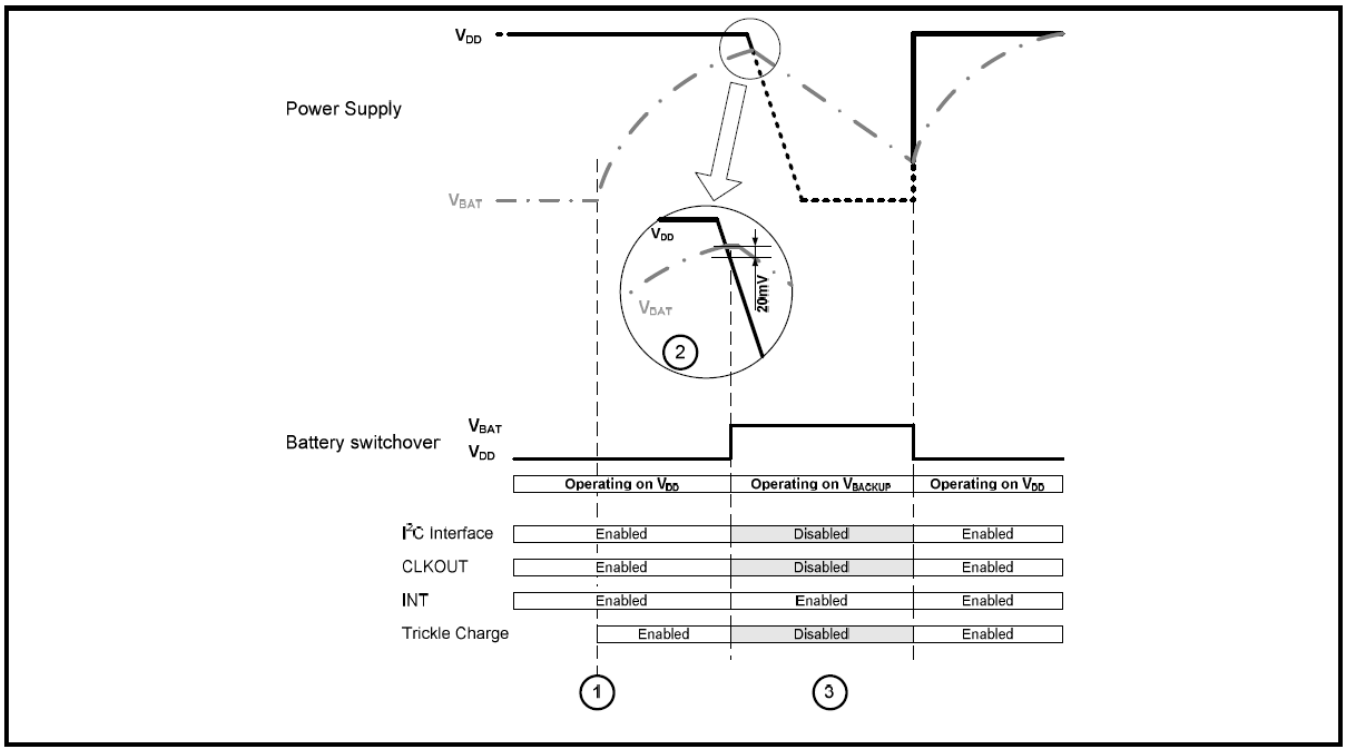
The AB-RTCMC-32.768kHz-EOZ9-S3 has two power supply pins:

- V_{DD} the main power supply input pin
- V_{BACKUP} the backup battery input pin

The AB-RTCMC-32.768kHz-EOZ9-S3 has multiple power management function implemented:

- Automatic switchover function between main power supply and backup supply voltage. The higher supply voltage is selected automatically, with a switchover hysteresis of 20mV
- Low supply voltage detection V_{LOW1} and V_{LOW2} with the possibility to generate an $\overline{INT}$ if the corresponding control bits are enabled
- Functions requiring a minimum supply voltage are automatically disabled if low supply voltage is detected
- Interface and CLKOUT are automatically disabled when the device operates in backup supply mode
- Programmable trickle charge circuitry to charge backup battery or supercap

Backup Switchover Circuitry Disables non-used Functions



① Trickle charge circuitry is enabled by software when selecting trickle-charge resistors. When back-up supply switchover-circuitry switches to the backup supply voltage, trickle charge function is disabled.

② The implemented backup switchover circuitry continuously compares V_{DD} and V_{BACKUP} voltages and connects the higher of them to the internal supply voltage V_{INT}. The switchover hysteresis from V_{DD} to V_{BACKUP} and vice versa is typically 20mV.

③ When the device is operating at the V_{BACKUP} supply voltage, non-used RTC functions are disabled to ensure optimized power consumption:

- I^2C interface Disabled when operating in V_{BACKUP} mode
- CLKOUT Disabled when operating in V_{BACKUP} mode
- $\overline{INT}$ Enabled even when operating in V_{BACKUP} mode
- Trickle Charge Disabled when operating in V_{BACKUP} mode

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4.1.1 POWER UP SEQUENCE

The device can be either powered up from main supply V_{DD} or from backup supply V_{BACKUP}.

During power-up, the chip is executing the following power-up procedure:

- The implemented battery switchover circuitry compares V_{DD} and V_{BACKUP} voltages and connects the higher of them to supply the chip
- At power-up, the chip is kept in Reset state until the supply voltage reaches an internal threshold level. Once the supply voltage is higher than this threshold level, a Reset is executed and registers are loaded with the Register Reset Values described in section 4.2.2. REGISTER RESET VALUES
- After the Reset is executed and registers are loaded with the Register Reset Values, "PON" is set = "1" (bit 5 in Register Control-Status), it needs to be cleared by writing = "0"
- Once the supply voltage reaches the oscillator start-up voltage, the oscillator-circuitry starts the 32.768 kHz "tuning-fork" Crystal typically within 500 ms
- Once the 32.768 kHz clocks are present, the Voltage Detector starts in fast mode to monitor the supply voltage, the accelerated scanning of the supply voltage will slightly increase the current consumption.
- When a supply voltage $>V_{Low2}$ is detected, the fast mode voltage detection is stopped, and the EEPROM read is enabled
- Configuration registers are loaded with the configuration data read from the EEPROM Control Page and the bits V_{Low1} and V_{Low2} are reset = "0"
- If the Thermometer is enabled by "ThE" = "1" (bit 1 in register EEPROM_Control), the temperature is measured and the frequency compensation value for time correction is calculated
- The AB-RTCMC-32.768kHz-EOZ9-S3 becomes fully functional; the correct Time / Date information needs to be loaded into the corresponding registers and bit 5 "PON" in Register Control-Status needs to be cleared by writing "0"

Note 1:
During power up, the Low Voltage Detection is monitoring the supply voltage at an accelerated scan rate increasing the current consumption of the device.
Once power supply voltage exceed V_{LOW2} threshold, the flags V_{LOW1} and V_{LOW2} are cleared and the scan rate for the low voltage detection is set to 1 second to ensure optimized power consumption.

Note 2:
Please not the different meaning of the "PON"; "V_{Low1}" and "V_{Low2}" Flags:

PON
"PON" Flag is set after Power-Up Reset is executed

- Indicating that time & date information are corrupted

V_{Low1}
V_{Low1} Flag is set when supply voltage drops below V_{Low1} threshold

- Indicating that the Thermometer might have been disabled due to low supply voltage and the temperature compensation was operating for a while with the last temperature reading causing bigger time-deviation

V_{Low2}
V_{Low2} Flag is set when supply voltage drops below V_{Low2} threshold

- Indicating a risk that the 32.768 kHz might have stopped due to low supply voltage and that the time & date information might be corrupted

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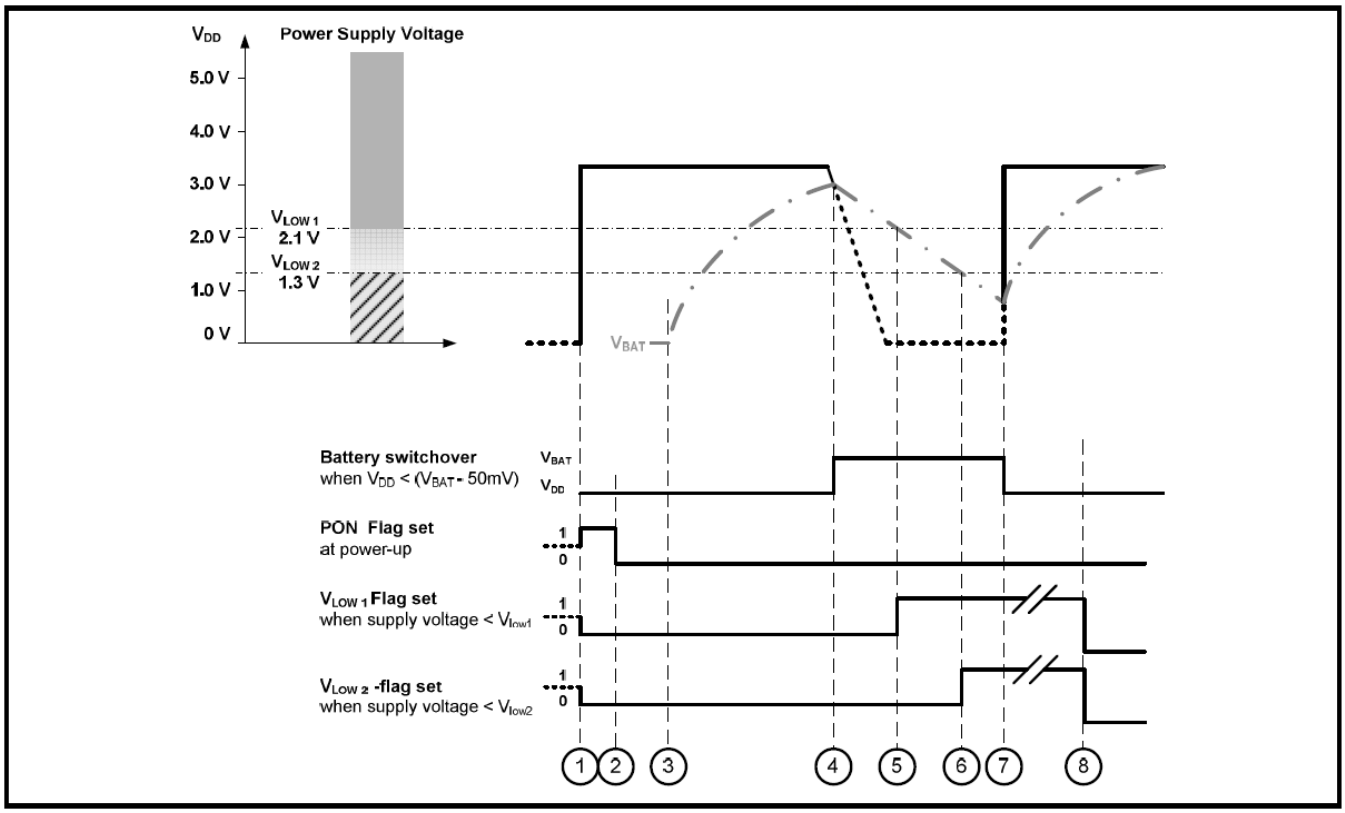
Example Power Up sequence, Low Voltage detection and Backup Supply switchover



① Power Up Reset is executed; registers are loaded with Reset Values. PON flag is set at Power up indicating that time / date information likely are corrupted.
Low voltage detection flags V_{LOW1} and V_{LOW2} are automatically cleared.

② PON Flag needs to be cleared by software writing "0".

③ Trickle charge circuitry for backup battery can be enabled by software.

④ Switchover to the backup supply voltage when V_{DD} drops below $V_{DD} < (V_{BAT} - 20mV)$.

⑤ Low voltage detection sets V_{LOW1} Flag when supply voltage drops V_{LOW1} threshold.

⑥ Low voltage detection sets V_{LOW2} Flag when supply voltage drops V_{LOW2} threshold.

⑦ Switchback from backup supply voltage to main supply voltage when V_{DD} rise above $V_{DD} > (V_{BAT} + 20mV)$.

⑧ V_{LOW1} and V_{LOW2} Flags need to be cleared by software writing "0".

4.1.2 SUPPLY VOLTAGE OPERATING RANGE AND LOW VOLTAGE DETECTION

The AB-RTCMC-32.768kHz-EOZ9-S3 has built-in low supply voltage detection which periodically monitors supply voltage levels vs. V_{LOW1} and V_{LOW2} thresholds.

If low supply voltage is detected, the corresponding flags V_{LOW1} and V_{LOW2} are set = "1". Device functions critical to low supply voltage are disabled.

During power up, the Low Voltage Detection is monitoring the supply voltage at an accelerated scan rate. If power supply voltage exceed V_{LOW2} threshold, the flags V_{LOW1} and V_{LOW2} are cleared and the scan rate for the low voltage detection is set to 1 second.

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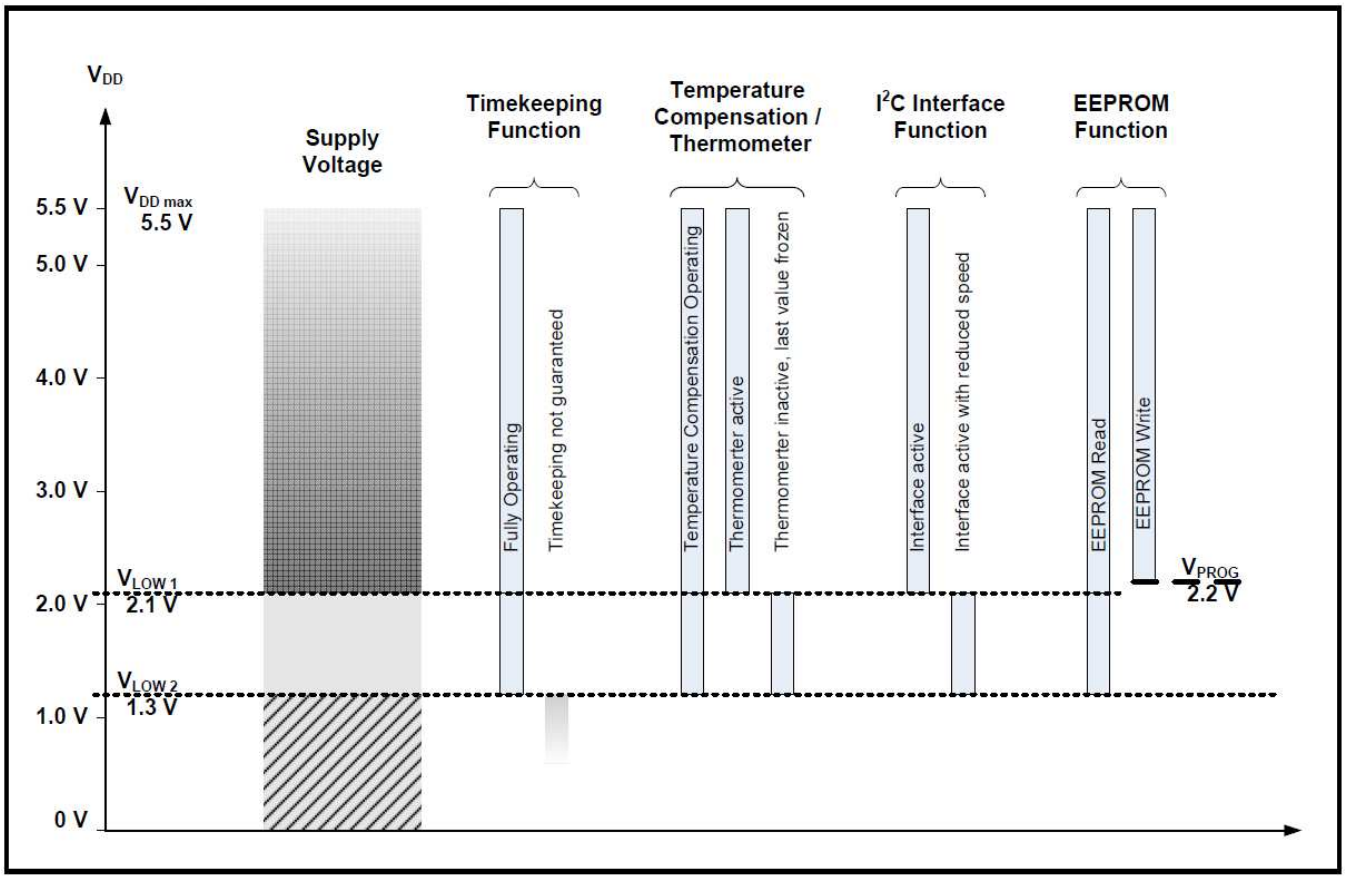
Minimum Supply Voltage and Low Voltage Detection



At first power-up, the supply voltage has to exceed V_{LOW1} threshold to enable and correctly setup all function of the device.

Timekeeping Function:
Keeping track of Time & Date depends on the 32.768kHz oscillator operates safely over the specified temperature range. Timekeeping function is guaranteed for a supply voltage down to V_{LOW2} threshold, below this voltage the 32.768kHz oscillator may stop and the time & date information might be corrupted.

Temperature Compensation:
The Frequency Compensation Unit "FCU" operates with supply voltages down to V_{LOW2} threshold. The Thermometer requires a supply voltage of ≥ V_{LOW1} threshold. Supply voltages below V_{LOW1} threshold will automatically disable the Thermometer; the last correct temperature reading is frozen in the register "Temperature". The Frequency Compensation Unit continues to operate with the last temperature-reading down to a supply voltage ≥ V_{LOW1} threshold.

I^2C interface:
The I^2C interface operates with max. SCL clock rate down to a supply voltage of ≥ V_{LOW1} threshold. Between V_{LOW1} and V_{LOW2} threshold, the interface still operates at reduced SCL clock rate.

EEPROM read / write access:
EEPROM read access is possible down to a supply voltage of ≥ V_{LOW2} threshold.
EEPROM write cycle requires a minimum supply voltage of ≥ V_{PROG} of 2.2V.

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4.2 RESET

A Reset can be initiated by 3 different ways:

- Power On Reset (automatically initiated at power-up)
- Software Reset (can be initiated by software)
- Self-Recovery System Reset (automatically initiated if enabled by Software and possible deadlock is detected)

4.2.1 POWER-UP RESET, SYSTEM RESET AND SELF-RECOVERY RESET

Power On Reset:
A Reset is automatically generated at Power On. After Power On Reset has been executed, bit 5 "PON" in Register Control_Status is set = "1", it needs to be cleared by writing = "0".

System Reset:
A Software Reset can be initiated when the System-Reset command "SysR" is set ="1" (bit 4 in Register Control_Reset). If a System-Reset is executed, the "SR" Flag (bit 4 in Register Control_Status) is set = "1", needs to be cleared by writing = "0".

It is generally recommended to make a System Reset by Software after power-up.

Note:
Please consider the Register Reset Values shown in section 4.2.2. After a Reset has been executed, Self-Recovery System "SROn" (bit 4 in Register Control_1) is set = "1" and Self-Recovery INT Enable "SRIE" (bit 4 in Register Control_INT) is set = "0".

Self-Recovery System Reset:
A Self-Recovery System Reset will be automatically initiated when the Self-Recovery function is enabled by bit 4 "SROn" in Register Control_1 is set "1" and internally a possible deadlock-state is detected. If a Self-Recovery System Reset is executed, the bit 4 "SR" in Register Control_Status is set "1" and need to be cleared by writing "0". After a Self-Recovery System Reset is executed and Register Reset Values were written, bit 4 "SRF" in Register Control_INT Flag is set "1" and needs to be cleared by writing "0".

In case of a Self Recovery System Reset is executed, an Interrupt is available if Self-Recovery-INT function is Enabled by bit 4 "SRIE" in Register Control_INT is set "1".

The purpose of the Self Recovery function is to generate an internal System Reset in case the on-chip state machine goes into a deadlock. The function is based on an internal counter that is periodically reset by the control logic. If the counter is not reset on time, a possible deadlock is detected and a System Reset will be triggered. The System Reset is executed latest after 2 temperature- or voltage-monitoring periods defined in Thermometer Period bit 0 "ThP" in Register EEPROM Control, i.e. latest after 2 or 32 seconds.

Note:
Please consider the Register Reset Values shown in section 4.2.2. After a Reset has been executed, Self-Recovery System bit 4 "SROn" in Register Control_1 = "1" and Self-Recovery INT Enable "SRIE" in Register Control_INT = "0".

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4.2.2 REGISTER RESET VALUES

Address			Function	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Page Bit 7 - 3	Address Bit 2 - 0	Hex									
Control page 00000	000	00h	Control_1	1	0	0	1	1	0	0	1
	001	01h	Control_INT	-	-	-	0	0	0	0	0
	010	02h	Control_INT Flag	-	-	-	0 [1)]	0	0	0	0
	011	03h	Control_1	EEbusy	X	0 [2)]	0 [3)]	X	X	X	X
	100	04h	Control_1	-	-	-	0	-	-	-	-
Clock page 00001	000	08h	Seconds	-	X	X	X	X	X	X	X
	001	09h	Minutes	-	X	X	X	X	X	X	X
	010	0Ah	Hours	-	X	X	X	X	X	X	X
	011	0Bh	Days	-	-	X	X	X	X	X	X
	100	0Ch	Weekdays	-	-	-	-	-	X	X	X
	101	0Dh	Months	-	-	-	X	X	X	X	X
	110	0Eh	Years	-	X	X	X	X	X	X	X
Alarm page 00010	000	10h	Second Alarm	AE_S	X	X	X	X	X	X	X
	001	11h	Minute Alarm	AE_M	X	X	X	X	X	X	X
	010	12h	Hour Alarm	AE_H	X	X	X	X	X	X	X
	011	13h	Day Alarm	AE_D	-	X	X	X	X	X	X
	100	14h	Weekday Alarm	AE_W	-	-	-	-	X	X	X
	101	15h	Month Alarm	AE_M	-	-	X	X	X	X	X
	110	16h	Year Alarm	AE_Y	X	X	X	X	X	X	X
Timer page 00011	000	18h	Timer Low	X	X	X	X	X	X	X	X
	001	19h	Timer High	X	X	X	X	X	X	X	X
Temperature page 00100	000	20h	Temperature	X	X	X	X	X	X	X	X
EEPROM User 00101	000	28h	EEPROM User	2 bytes of EEPROM for user data							
	001	29h	EEPROM User								
EEPROM Control page 00110	000	30h	EEPROM Control	0 [4)]	0 [4)]	0 [4)]	0 [4)]	0 [4)]	0 [4)]	1 [4)]	0 [4)]
	001	31h	Xtal Offset	Factory setting: Xtal frequency deviation							
	010	32h	Xtal Coef.	Factory setting: Xtal temperature coefficient							
	011	33h	Xtal T0	-	-	Factory setting: Xtal T0 temperature					
RAM page 00111	000	38h	User RAM	8 bytes of RAM for user data							
	:	:									
	111	3Fh									

– bits labeled as – are not implemented.
X bits labeled as X are undefined at power-up and unchanged by subsequent resets.
1) SRF flag (bit 4 in register Control_INT Flag) will be set = "1" after a Self Recovery System Reset was executed.
2) PON flag (bit 5 in register Control_Status) will be set = "1" after a Power On Reset was executed.
3) SR flag (bit 4 in register Control_Status) will be set = "1" after a System or Self recovery Reset was executed.
4) EEPROM Control default data are set by factory; data might be reprogrammed by customer and will remain unchanged during power down or any Reset executed.