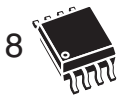
M41T80

Serial access real-time clock with alarm

Features

- Counters for tenths/hundredths of seconds, seconds, minutes, hours, day, date, month, year, and century
- 32 KHz crystal oscillator integrating load capacitance (12.5 pF) providing exceptional oscillator stability and high crystal series resistance operation
- Serial interface supports I^2C bus (400 kHz)
- 2.0 to 5.5 V clock operating voltage
- 32 KHz square wave on power-up to drive a microcontroller in low-power mode
- Programmable (1 Hz to 32 KHz) square wave
- Programmable alarm and interrupt function
- Low operating current of 200 µA
- Operating temperature of –40 to 85 °C
- ECOPACK® package available



SO8
8-pin SOIC

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1 Description

The M41T80 is a low power serial RTC with a built-in 32.768 kHz oscillator (external crystal controlled). Eight registers (see *Table 3: Clock register map on page 14*) are used for the clock/calendar function and are configured in binary coded decimal (BCD) format. An additional 12 registers provide status/control of alarm, 32 KHz output, and square wave functions. Addresses and data are transferred serially via a two line, bi-directional I^2C interface. The built-in address register is incremented automatically after each WRITE or READ data byte.

Functions available to the user include a time-of-day clock/calendar, alarm interrupts, 32 KHz output, and programmable square wave output. The eight clock address locations contain the century, year, month, date, day, hour, minute, second and tenths/hundredths of a second in 24-hour BCD format. Corrections for 28, 29 (leap year - valid until year 2100), 30 and 31 day months are made automatically.

The M41T80 is supplied in an 8-pin SOIC.

Figure 1. Logic diagram

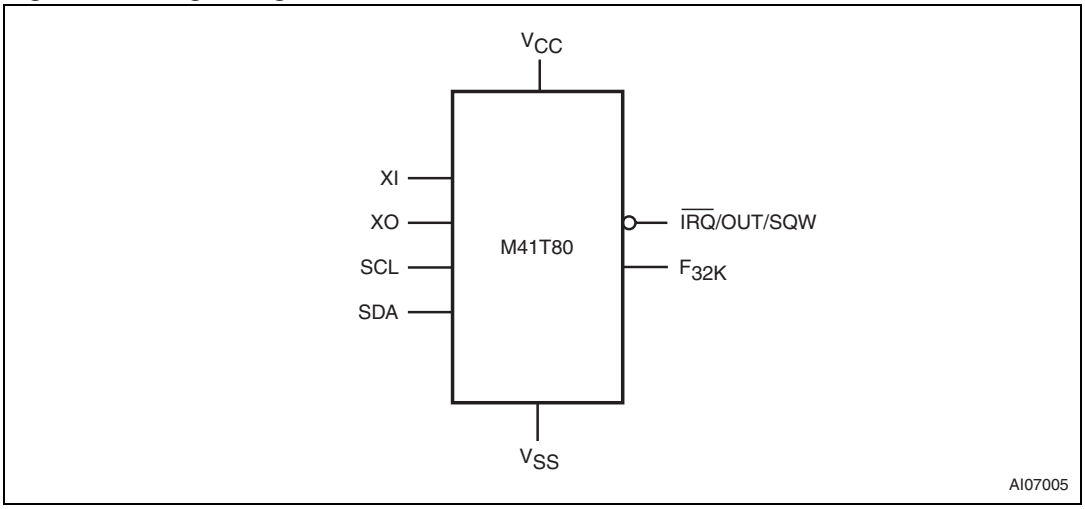
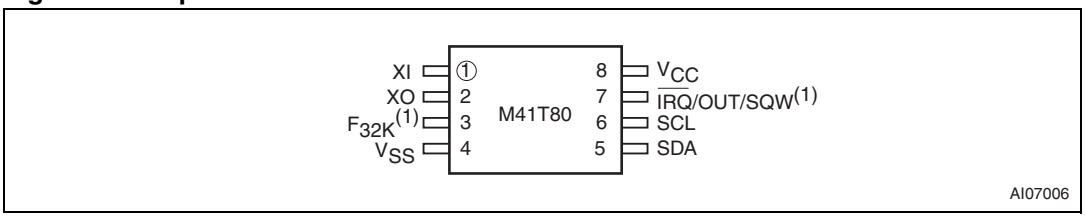


Table 1. Signal names

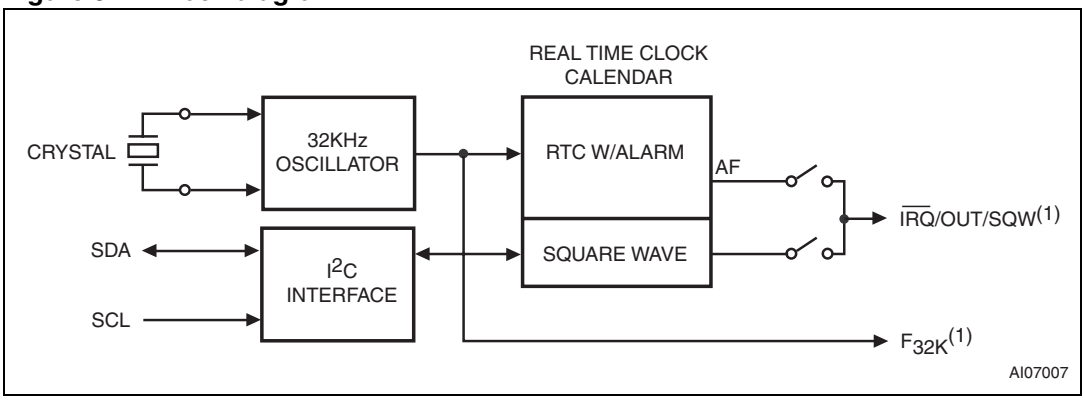
XI	Oscillator input
XO	Oscillator output
$\overline{IRQ}$/OUT/SQW	Interrupt / output driver / square wave (open drain)
SDA	Serial data input/output
SCL	Serial clock input
F_{32K}	32 KHz square wave output (open drain)
V_{CC}	Supply voltage
V_{SS}	Ground

Figure 2. 8-pin SOIC connections



1. Open drain output

Figure 3. Block diagram



1. Open drain output

2 Operation

The M41T80 clock operates as a slave device on the serial bus. Access is obtained by implementing a start condition followed by the correct slave address (D0h). The 20 bytes contained in the device can then be accessed sequentially in the following order:

- 1st byte: tenths/hundredths of a second register
- 2nd byte: seconds register
- 3rd byte: minutes register
- 4th byte: century/hours register
- 5th byte: day register
- 6th byte: date register
- 7th byte: month register
- 8th byte: year register
- 9th byte: control register
- 10th byte: 32KE bit
- 11th - 16th bytes: alarm registers
- 17th - 19th bytes: reserved
- 20th byte: square wave register

2.1 2-Wire bus characteristics

The bus is intended for communication between different IC's. It consists of two lines: a bi-directional data signal (SDA) and a clock signal (SCL). Both the SDA and SCL lines must be connected to a positive supply voltage via a pull-up resistor.

The following protocol has been defined:

- Data transfer may be initiated only when the bus is not busy.
- During data transfer, the data line must remain stable whenever the clock line is high.
- Changes in the data line, while the clock line is high, will be interpreted as control signals.

Accordingly, the following bus conditions have been defined:

2.1.1 Bus not busy

Both data and clock lines remain high.

2.1.2 Start data transfer

A change in the state of the data line, from high to low, while the clock is high, defines the START condition.

2.1.3 Stop data transfer

A change in the state of the data line, from low to high, while the clock is high, defines the STOP condition.

2.1.4 Data valid

The state of the data line represents valid data when after a start condition, the data line is stable for the duration of the high period of the clock signal. The data on the line may be changed during the Low period of the clock signal. 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.

By definition a device that gives out a message is called “transmitter,” the receiving device that gets the message is called “receiver.” The device that controls the message is called “master.” The devices that are controlled by the master are called “slaves.”

2.1.5 Acknowledge

Each byte of eight bits is followed by one acknowledge bit. This acknowledge bit is a low level put on the bus by the receiver whereas the master generates an extra acknowledge related clock pulse. A slave receiver which is addressed is obliged to generate an acknowledge after the reception of each byte that has been clocked out of the slave transmitter.

The device that acknowledges has to pull down the SDA line during the acknowledge clock pulse in such a way that the SDA line is a stable low during the high period of the acknowledge related clock pulse. Of course, setup and hold times must be taken into account. A master receiver must signal an end of data to the slave transmitter by not generating an acknowledge on the last byte that has been clocked out of the slave. In this case the transmitter must leave the data line high to enable the master to generate the STOP condition.

Figure 4. Serial bus data transfer sequence

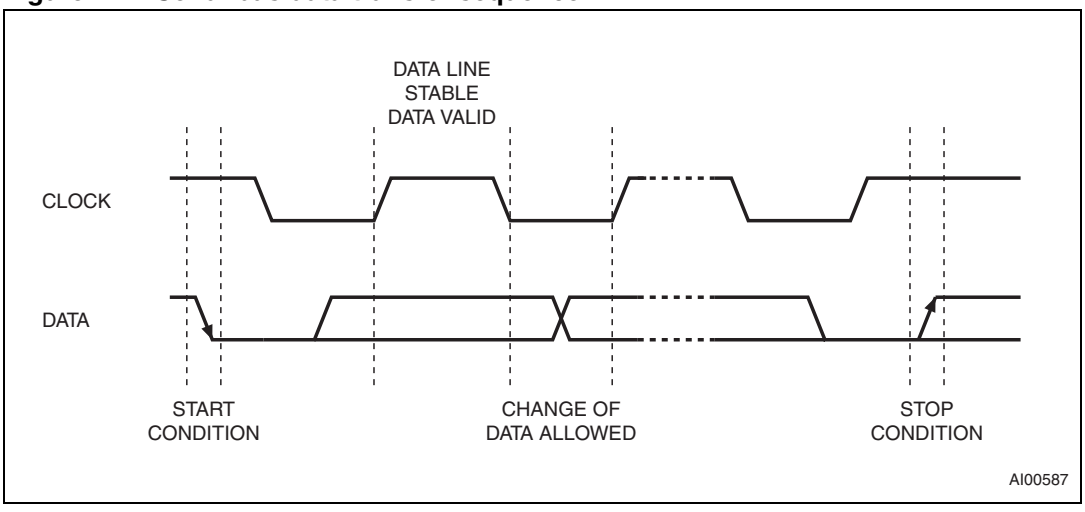


Figure 5. Acknowledgement sequence

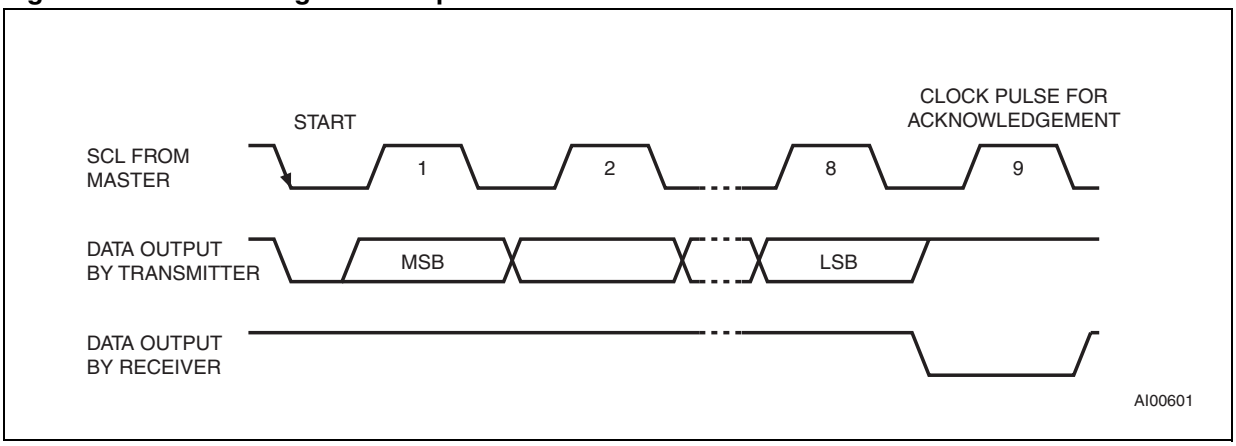


Figure 6. Bus timing requirements sequence

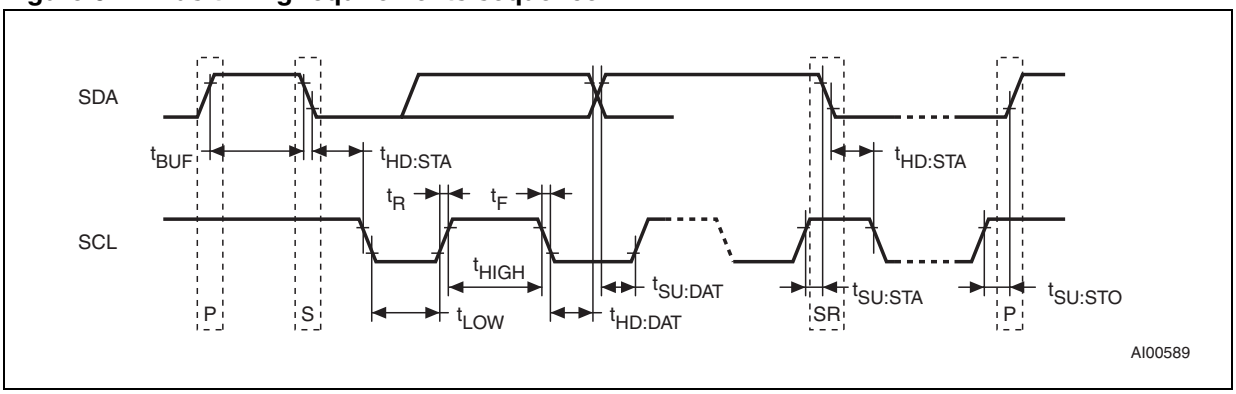


Table 2. AC characteristics

Sym	Parameter[1]	Min	Typ	Max	Units
f_{SCL}	SCL clock frequency	0		400	kHz
t_{LOW}	Clock low period	1.3			µs
t_{HIGH}	Clock high period	600			ns
t_R	SDA and SCL rise time			300	ns
t_F	SDA and SCL fall time			300	ns
$t_{HD:STA}$	START condition hold time (after this period the first clock pulse is generated)	600			ns
$t_{SU:STA}$	START condition setup time (only relevant for a repeated start condition)	600			ns
$t_{SU:DAT}$[2]	Data setup time	100			ns
$t_{HD:DAT}$	Data hold time	0			µs
$t_{SU:STO}$	STOP condition setup time	600			ns
t_{BUF}	Time the bus must be free before a new transmission can start	1.3			µs

1. Valid for ambient operating temperature: T_A = –40 to 85 °C; V_{CC} = 2.0 to 5.5 V (except where noted).
2. Transmitter must internally provide a hold time to bridge the undefined region (300 ns max) of the falling edge of SCL.

2.2 READ mode

In this mode the master reads the M41T80 slave after setting the slave address (*Figure 8: READ mode sequence*). Following the WRITE mode control bit (R/$\overline{W}$=0) and the acknowledge bit, the word address 'An' is written to the on-chip address pointer. Next the START condition and slave address are repeated followed by the READ mode control bit (R/$\overline{W}$=1). At this point the master transmitter becomes the master receiver. The data byte which was addressed will be transmitted and the master receiver will send an acknowledge bit to the slave transmitter. The address pointer is only incremented on reception of an acknowledge clock. The M41T80 slave transmitter will now place the data byte at address An+1 on the bus, the master receiver reads and acknowledges the new byte and the address pointer is incremented to “An+2.”

This cycle of reading consecutive addresses will continue until the master receiver sends a STOP condition to the slave transmitter.

The system-to-user transfer of clock data will be halted whenever the address being read is a clock address (00h to 07h). The update will resume due to a stop condition or when the pointer increments to any non-clock address (08h-13h).

Note: This is true both in READ mode and WRITE mode.

An alternate READ mode may also be implemented whereby the master reads the M41T80 slave without first writing to the (volatile) address pointer. The first address that is read is the last one stored in the pointer (see *Figure 9: Alternative READ mode sequence*).

Figure 7. Slave address location

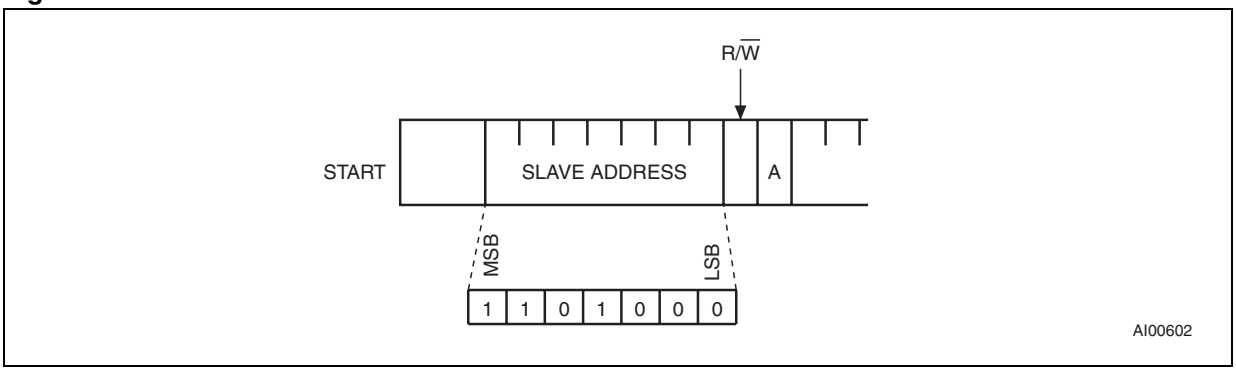


Figure 8. READ mode sequence

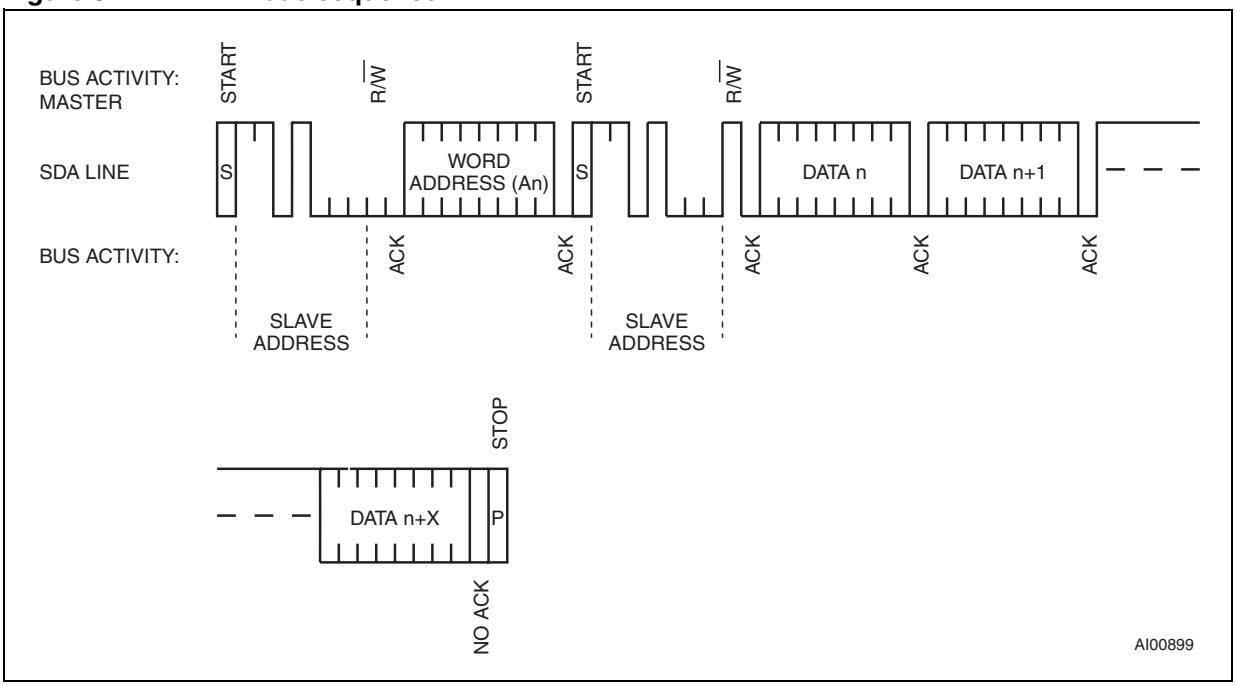
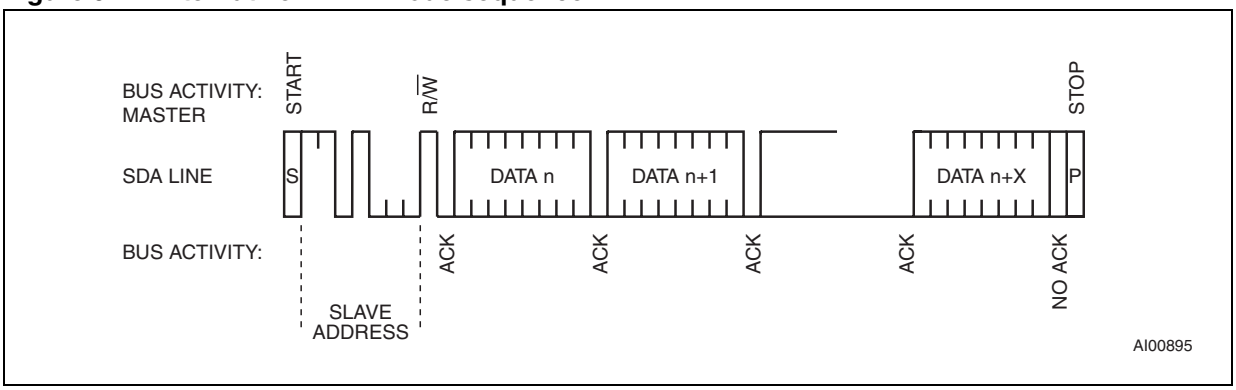


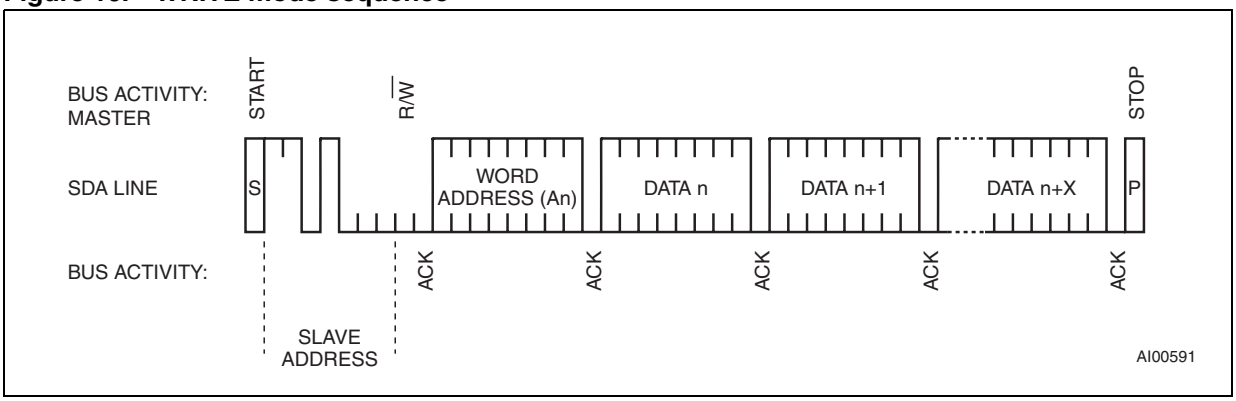
Figure 9. Alternative READ mode sequence



2.3 WRITE mode

In this mode the master transmitter transmits to the M41T80 slave receiver. Bus protocol is shown in *Figure 10: WRITE mode sequence on page 12*. Following the START condition and slave address, a logic '0' (R/$\overline{W}$=0) is placed on the bus and indicates to the addressed device that word address “An” will follow and is to be written to the on-chip address pointer. The data word to be written to the memory is strobed in next and the internal address pointer is incremented to the next address location on the reception of an acknowledge clock. The M41T80 slave receiver will send an acknowledge clock to the master transmitter after it has received the slave address see *Figure 7: Slave address location on page 11* and again after it has received the word address and each data byte.

Figure 10. WRITE mode sequence



3 Clock operation

The M41T80 is driven by a quartz-controlled oscillator with a nominal frequency of 32,768 Hz. The accuracy of the real-time clock depends on the frequency of the quartz crystal that is used as the time-base for the RTC.

The 20-byte register map (see *Table 3: Clock register map on page 14*) is used to both set the clock and to read the date and time from the clock, in a binary coded decimal format. Tenths/hundredths of seconds, minutes, and hours are contained within the first four registers.

Note: A WRITE to any clock register will result in the tenths/hundredths of seconds being reset to "00," and tenths/hundredths of seconds cannot be written to any value other than "00."

Bits D6 and D7 of clock register 03h (century/hours register) contain the CENTURY ENABLE bit (CEB) and the CENTURY bit (CB). Setting CEB to a '1' will cause CB to toggle, either from '0' to '1' or from '1' to '0' at the turn of the century (depending upon its initial state). If CEB is set to a '0,' CB will not toggle. Bits D0 through D2 of Register 04h contain the day (day of week). Registers 05h, 06h, and 07h contain the date (day of month), month and years. The ninth clock register is the control register. Bit D7 of register 01h contains the STOP bit (ST). Setting this bit to a '1' will cause the oscillator to stop. If the device is expected to spend a significant amount of time on the shelf, the oscillator may be stopped to reduce current drain. When reset to a '0' the oscillator restarts within four seconds (typically one second).

The eight clock registers may be read one byte at a time, or in a sequential block. Provision has been made to assure that a clock update does not occur while any of the eight clock addresses are being read. If a clock address is being read, an update of the clock registers will be halted. This will prevent a transition of data during the READ.

3.1 Clock registers

The M41T80 offers 20 internal registers which contain clock, alarm, 32 KHz, flag, square wave, and control data. These registers are memory locations which contain external (user accessible) and internal copies of the data (usually referred to as BiPORT™ cells). The external copies are independent of internal functions except that they are updated periodically by the simultaneous transfer of the incremented internal copy. The internal divider (or clock) chain will be reset upon the completion of a WRITE to any clock address.

The system-to-user transfer of clock data will be halted whenever the address being read is a clock address (00h to 07h). The update will resume either due to a stop condition or when the pointer increments to any non-clock address (08h-13h).

Clock and alarm registers store data in BCD. Control, 32 KHz, and square wave registers store data in binary format.

Table 3. Clock register map(1)

Addr	D7	D6	D5	D4	D3	D2	D1	D0	Function/range BCD format	
00h	0.1 seconds				0.01 seconds				10s/100s of seconds	00-99
01h	ST	10 seconds			Seconds				Seconds	00-59
02h	0	10 minutes			Minutes				Minutes	00-59
03h	CEB	CB	10 hours		Hours (24-hour format)				Century/ hours	0-1/00-23
04h	0	0	0	0	0	Day of week			Day	01-7
05h	0	0	10 date		Date: day of month				Date	01-31
06h	0	0	0	10M	Month				Month	01-12
07h	10 years				Year				Year	00-99
08h	OUT	0	0	0	0	0	0	0	Control	
09h	32KE	0	0	0	0	0	0	0	32 KHz	
0Ah	AFE	SQWE	0	Al 10M	Alarm month				Al month	01-12
0Bh	RPT4	RPT5	Al 10 date		Alarm date				Al date	01-31
0Ch	RPT3	0	Al 10 hour		Alarm hour				Al hour	00-23
0Dh	RPT2	Alarm 10 minutes			Alarm minutes				Al min	00-59
0Eh	RPT1	Alarm 10 seconds			Alarm seconds				Al sec	00-59
0Fh	0	AF	0	0	0	0	0	0	Flags	
10h	0	0	0	0	0	0	0	0	Reserved	
11h	0	0	0	0	0	0	0	0	Reserved	
12h	0	0	0	0	0	0	0	0	Reserved	
13h	RS3	RS2	RS1	RS0	0	0	0	0	SQW	

1. Keys:
ST = Stop bit
0 = Must be set to '0'
32KE = Enable bit for 32 KHz output
CEB = Enable for century bit
CB = Century bit
OUT = Data bit for OUT pin
AFE = Alarm flag enable bit
RPT1-RPT5 = Alarm repeat mode bits
AF = Alarm flag (read only)
SQWE = Square wave enable
RS0-RS3 = SQW frequency select

3.2 Setting alarm clock registers

Address locations 0Ah-0Eh contain the alarm settings. The alarm can be configured to go off at a prescribed time on a specific month, date, hour, minute, or second or repeat every year, month, day, hour, minute, or second.

Bits RPT5-RPT1 put the alarm in the repeat mode of operation. *Table 4: Alarm repeat modes* shows the possible configurations. Codes not listed in the table default to the once per second mode to quickly alert the user of an incorrect alarm setting.

When the clock information matches the alarm clock settings based on the match criteria defined by RPT5-RPT1, the AF (alarm flag) is set. If AFE (alarm flag enable) is also set (and SQWE is '0.'), the alarm condition activates the $\overline{\text{IRQ}}$/OUT/SQW pin.

Note: If the address pointer is allowed to increment to the flag register address, an alarm condition will not cause the interrupt/flag to occur until the address pointer is moved to a different address. It should also be noted that if the last address written is the "Alarm Seconds," the address pointer will increment to the flag address, causing this situation to occur.

The $\overline{\text{IRQ}}$/OUT/SQW output is cleared by a READ to the flags register as shown in *Figure 11*. A subsequent READ of the flags register is necessary to see that the value of the alarm flag has been reset to '0.'

Figure 11. Alarm interrupt reset waveform

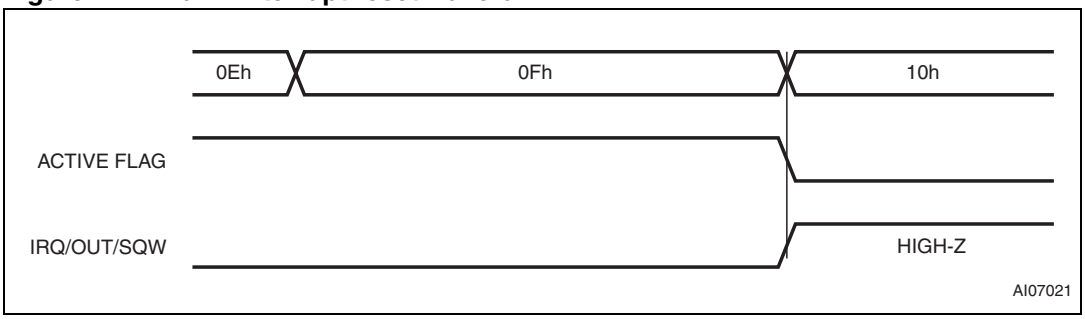


Table 4. Alarm repeat modes

RPT5	RPT4	RPT3	RPT2	RPT1	Alarm setting
1	1	1	1	1	Once per second
1	1	1	1	0	Once per minute
1	1	1	0	0	Once per hour
1	1	0	0	0	Once per day
1	0	0	0	0	Once per month
0	0	0	0	0	Once per year

Table 5. Square wave output frequency

Square wave bits				Square wave	
RS3	RS2	RS1	RS0	Frequency	Units
0	0	0	0	None	-
0	0	0	1	32.768	kHz
0	0	1	0	8.192	kHz
0	0	1	1	4.096	kHz
0	1	0	0	2.048	kHz
0	1	0	1	1.024	kHz
0	1	1	0	512	Hz
0	1	1	1	256	Hz
1	0	0	0	128	Hz
1	0	0	1	64	Hz
1	0	1	0	32	Hz
1	0	1	1	16	Hz
1	1	0	0	8	Hz
1	1	0	1	4	Hz
1	1	1	0	2	Hz
1	1	1	1	1	Hz

3.3 Full-time 32 KHz square wave output

The M41T80 offers the user a special 32 KHz square wave function which defaults to output on the F_{32K} pin (pin 3) as long as V_{CC} is valid, and the oscillator is running (ST bit = '0'). This function is available within four seconds of initial power-up and can only be disabled by setting the 32KE bit to '0' or the ST bit to '1.' If not used, the F_{32K} pin should be disconnected and allowed to float.

Note: The F_{32K} pin is an open drain which requires an external pull-up resistor.

3.4 Century bit

Bits D7 and D6 of clock register 03h contain the CENTURY ENABLE bit (CEB) and the CENTURY bit (CB). Setting CEB to a '1' will cause CB to toggle, either from a '0' to '1' or from '1' to '0' at the turn of the century (depending upon its initial state). If CEB is set to a '0,' CB will not toggle.

3.5 Output driver pin

When the AFE bit and SQWE bit are not set, the $\overline{IRQ}$/OUT/SQW pin becomes an output driver that reflects the contents of D7 of the control register. In other words, when D7 (OUT bit) of address location 08h is a '0,' then the $\overline{IRQ}$/OUT/SQW pin will be driven low.

Note: The $\overline{IRQ}$/OUT/SQW pin is an open drain which requires an external pull-up resistor.

3.6 Preferred power-on default

When powering the device up from ground (0 V), the following register bits are set to a '0' state: ST; AFE; and SQWE. The following bits are set to a '1' state: OUT and 32KE (see *Table 6: Preferred power-on default values on page 17*).

Table 6. Preferred power-on default values

Condition	ST	OUT	AFE	SQWE	32KE
Power-up(1)	0	1	0	0	1

1. If V_{CC} falls to a voltage, 0 V < V_{CC} < 2.0 V, these bits should be rewritten by the user.

4 Maximum rating

Stressing the device above the rating listed in the “absolute maximum ratings” table may cause permanent damage to the device. These are stress ratings only and operation of the device at these or any other conditions above those indicated in the operating sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. Refer also to the STMicroelectronics SURE Program and other relevant quality documents.

Table 7. Absolute maximum ratings

Symbol	Parameter	Value	Unit
T_{STG}	Storage temperature (V_{CC} off, oscillator off)	–55 to 125	°C
V_{CC}	Supply voltage	–0.3 to 7	V
T_{SLD}(1)	Lead solder temperature for 10 seconds	260	°C
V_{IO}	Input or output voltages	–0.3 to +6	V
I_O	Output current	20	mA
P_D	Power dissipation	1	W

1. For SO package, lead-free (Pb-free) lead finish: reflow at peak temperature of 260 °C (the time above 255 °C must not exceed 30 seconds).

5 DC and AC parameters

This section summarizes the operating and measurement conditions, as well as the DC and AC characteristics of the device. The parameters in the following DC and AC Characteristic tables are derived from tests performed under the measurement conditions listed in the relevant tables. Designers should check that the operating conditions in their projects match the measurement conditions when using the quoted parameters.

Table 8. Operating and AC measurement conditions (1)

Parameter	M41T80
Supply voltage (V_{CC})	2.0 to 5.5 V
Ambient operating temperature (T_A)	–40 to 85 °C
Load capacitance (C_L)	100 pF
Input rise and fall times	≤ 50 ns
Input pulse voltages	$0.2V_{CC}$ to $0.8V_{CC}$
Input and output timing ref. voltages	$0.3V_{CC}$ to $0.7V_{CC}$

1. Output Hi-Z is defined as the point where data is no longer driven.

Figure 12. AC measurement I/O waveform

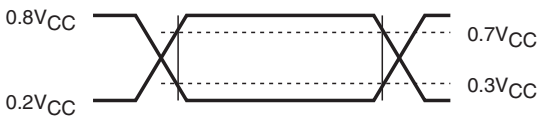


Table 9. Capacitance

Symbol	Parameter(1)(2)	Min	Max	Unit
C_{IN}	Input capacitance		7	pF
C_{OUT}(3)	Output capacitance		10	pF
t_{LP}	Low-pass filter input time constant (SDA and SCL)		50	ns

1. Effective capacitance measured with power supply at 5 V; sampled only, not 100% tested.
2. At 25 °C, f = 1 MHz.
3. Outputs deselected.

Table 10. DC characteristics

Symbol	Parameter	Test condition(1)			Min	Typ	Max	Unit
I_{LI}	Input leakage current	0 V ≤ V_{IN} ≤ V_{CC}					±1	µA
I_{LO}	Output leakage current	0 V ≤ V_{OUT} ≤ V_{CC}					±1	µA
I_{CC1}	Supply current	Switch freq (SCL) = 400 kHz		3.0 V			30	µA
				5.5 V			200	µA
I_{CC2}(2)	Supply current (standby)	All inputs = V_{CC} – 0.2 V Switch freq (SCL) = 0 Hz	32KE = 1 or SQWE = 1	3.0 V		1.8	3.0	µA
				5.5 V			35	µA
			32KE = 0 and SQWE = 0	3.0 V		1.5	2.4	µA
				5.5 V			31	µA
V_{IL}	Input low voltage				–0.3		0.3V_{CC}	V
V_{IH}	Input high voltage				0.7V_{CC}		V_{CC} + 0.3	V
V_{OL}	Output low voltage	I_{OL} = 3.0 mA					0.4	V
	Output low voltage (open drain)(3)	I_{OL} = 10 mA					0.4	V
	Pull-up supply voltage (open drain)	$\overline{IRQ}$/OUT/SQW, F_{32K}, SCL, SDA					5.5	V

1. Valid for ambient operating temperature: T_A = –40 to 85 °C; V_{CC} = 2.0 to 5.5 V (except where noted).
2. At 25 °C.
3. For $\overline{IRQ}$/FT/OUT, $\overline{RST}$, and 32 KHz pins (open drain)

Table 11. Crystal electrical characteristics

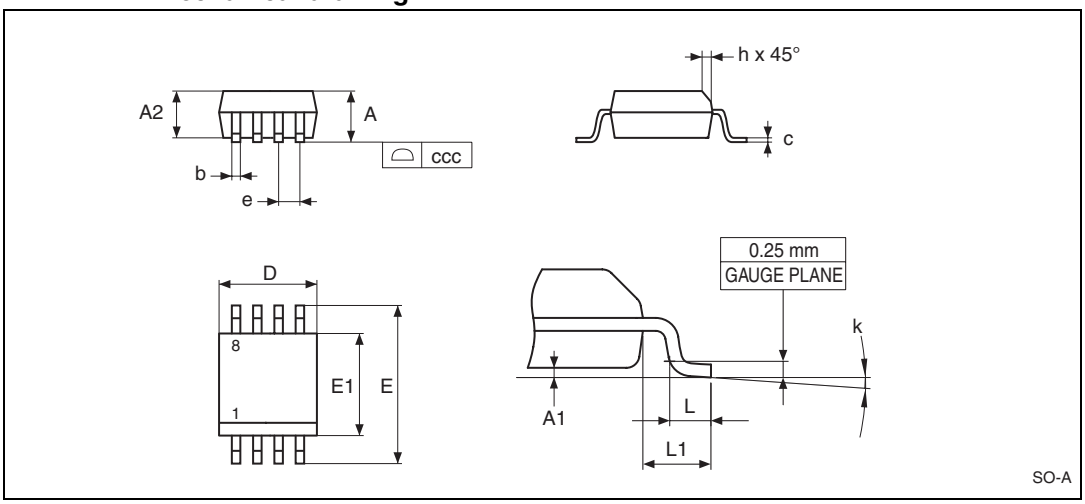
Sym	Parameter(1) (2)	Min	Typ	Max	Units
f_O	Resonant frequency		32.768		kHz
R_S	Series resistance			60	kΩ
C_L	Load capacitance		12.5		pF

1. Externally supplied if using the SO8 package. STMicroelectronics recommends the KDS DT-38: 1TA/1TC252E127, Tuning Fork Type (thru-hole) or the DMX-26S: 1TJS125FH2A212, (SMD) quartz crystal for industrial temperature operations.
2. Load capacitors are integrated within the M41T80. Circuit board layout considerations for the 32.768 kHz crystal of minimum trace lengths and isolation from RF generating signals should be taken into account.

6 Package mechanical data

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: *www.st.com*. ECOPACK® is an ST trademark.

Figure 13. SO8 – 8-lead plastic small outline, 150 mils body width, package mechanical drawing



1. Drawing is not to scale.

Table 12. SO8 – 8-lead plastic small outline, 150 mils body width, package mechanical data

Symbol	millimeters			inches		
	Typ	Min	Max	Typ	Min	Max
A			1.75			0.069
A1		0.10	0.25		0.004	0.010
A2		1.25			0.049	
b		0.28	0.48		0.011	0.019
c		0.17	0.23		0.007	0.009
ccc			0.10			0.004
D	4.90	4.80	5.00	0.193	0.189	0.197
E	6.00	5.80	6.20	0.236	0.228	0.244
E1	3.90	3.80	4.00	0.154	0.150	0.157
e	1.27	–	–	0.050	–	–
h		0.25	0.50		0.010	0.020
k		0°	8°		0°	8°
L		0.40	1.27		0.016	0.050
L1	1.04			0.041		

Figure 14. Carrier tape for SO8 package

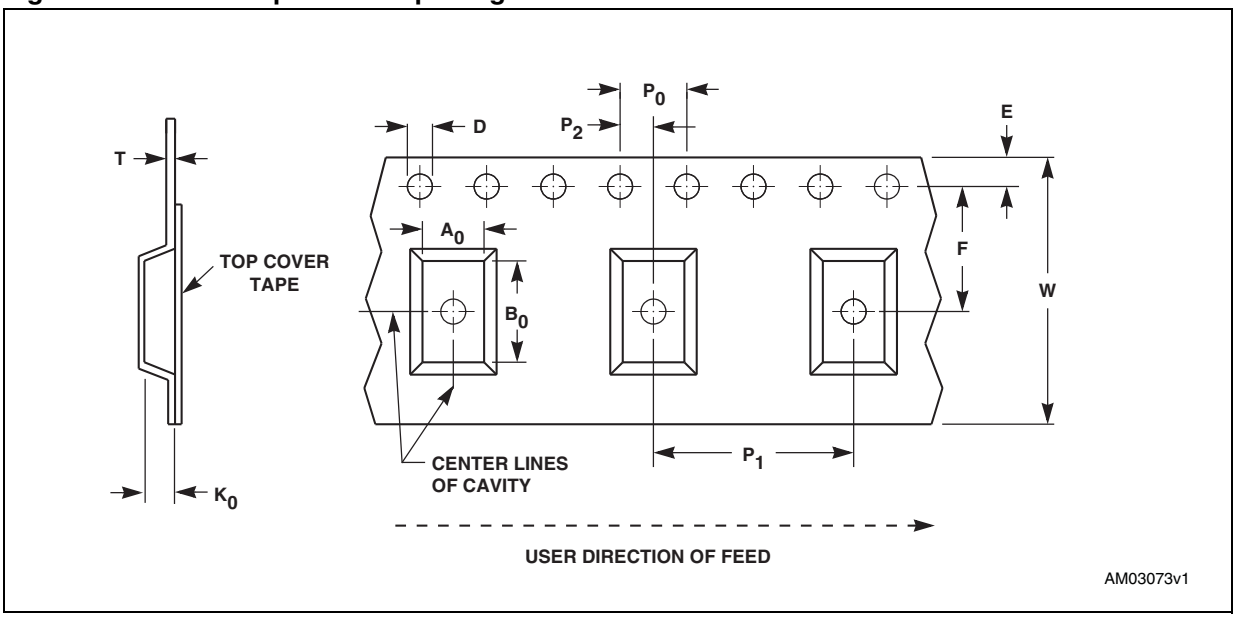


Table 13. Carrier tape dimensions for SO8 package

Package	W	D	E	P_0	P_2	F	A_0	B_0	K_0	P_1	T	Unit	Bulk qty
SO8	12.00 ±0.30	1.50 +0.10/ –0.00	1.75 ±0.10	4.00 ±0.10	2.00 ±0.10	5.50 ±0.05	6.50 ±0.10	5.30 ±0.10	2.20 ±0.10	8.00 ±0.10	0.30 ±0.05	mm	2500

Figure 15. Reel schematic

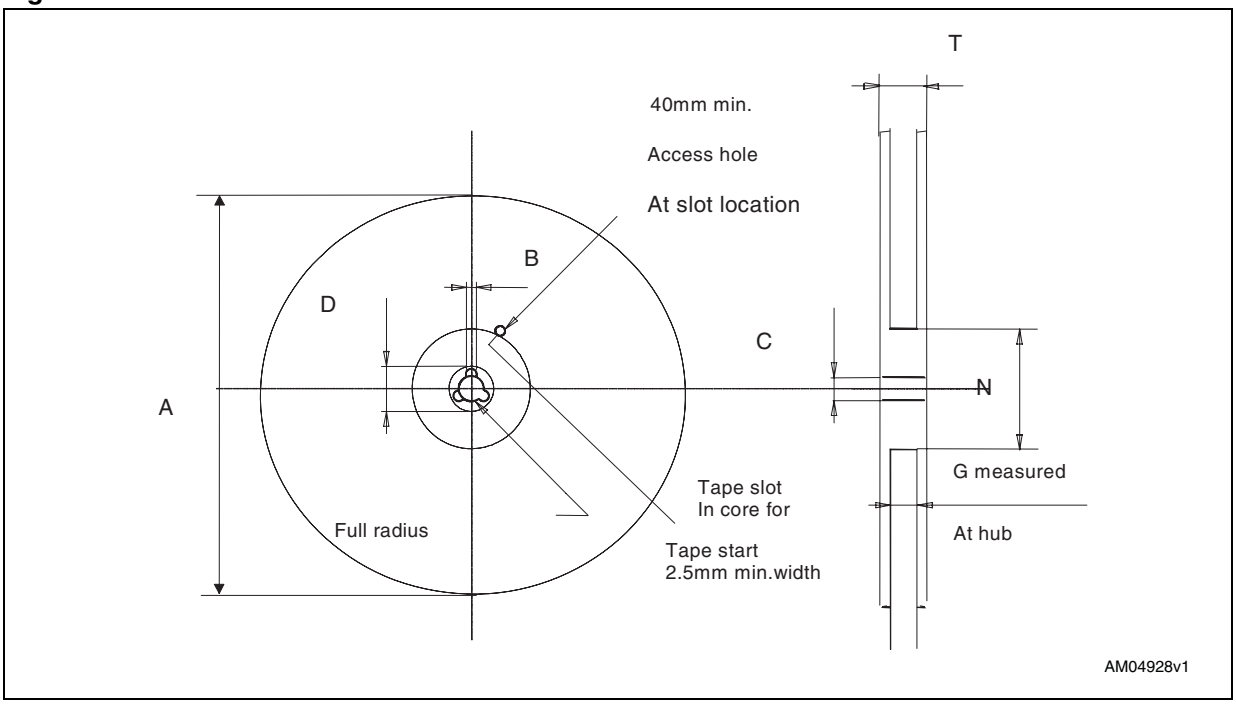


Table 14. Reel dimensions for 12 mm carrier tape - SO8 package (150 mils body width)

A (max)	B (min)	C	D (min)	N (min)	G	T (max)
330 mm (13-inch)	1.5 mm	13 mm ± 0.2 mm	20.2 mm	60 mm	12.4 mm + 2/–0 mm	18.4 mm

Note: The dimensions given in Table 14 incorporate tolerances that cover all variations on critical parameters.

7 Part numbering

Table 15. Ordering information scheme

Example: M41T 80 M 6 E

Device type

M41T

Supply voltage and write protect voltage

80 = V_{CC} = 2.0 to 5.5 V

Package

M = SO8

Temperature range

6 = –40 °C to 85 °C

Shipping method

E = ECOPACK® package, tubes (1)

F = ECOPACK® package, tape & reel

1. Shipping in tubes is not recommended for new design. Contact local ST sales office for availability.

For other options, or for more information on any aspect of this device, please contact the ST sales office nearest you.

8 Revision history

Table 16. Revision history

Date	Revision	Changes
Oct-2002	1	First issue
15-Jun-2004	2	Reformatted; add lead-free information; update characteristics (*Table 7*, *Table 10*, *Table 15*)
29-Aug-2006	3	Changed document to new template; added new features in *Features on page 1*; updated package mechanical data in *Section 6: Package mechanical data*; small text changes for entire document, ECOPACK® compliant.
15-Apr-2010	4	Updated *Table 7*, *10*, text in *Section 6*; reformatted document, minor textual changes.
03-Aug-2011	5	Added footnote to *Table 15: Ordering information scheme* concerning shipping method; added tape and reel specifications (*Figure 14*, *15*, *Table 13*, *14*).

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