AN1216
Application note

Implementing a periodic alarm with TIMEKEEPER® and serial real-time clocks (RTCs)

Introduction

The TIMEKEEPER® and serial real-time clock (RTC) devices provide an alarm which can be set either for a given time and day, or to repeat at a certain day in every month, or at a certain hour in every day, or at a certain minute of every hour, or at a certain second of every minute. With this functionality already provided in the hardware, the software to implement an alarm of any given period is greatly simplified, as described in this document.

Table 1. TIMEKEEPER® and serial RTC devices with alarm

TIMEKEEPER	M48T37V/Y, M48T201V/Y
Serial RTC	M41T62, M41T63, M41T64, M41T65, M41T66, M41T80, M41T81, M41T81S, M41T82, M41T83, M41T93, M41T94, M41ST85W, M41ST87W

Although specifically tailored for the M48T37V/Y device, applications can be easily adapted to use any of ST's other TIMEKEEPER or serial RTC devices that have the alarm feature. Some modifications in the MCU memory mapping (the TIMEKEEPER or RTC address space) and in the MCU register mapping (such as the pointer to register address) would need to be made.

TIMEKEEPER® configuration

The TIMEKEEPER register mapping is shown in *Table 2*. This is divided in two parts: the clock registers and the alarm registers.

Table 2. Typical TIMEKEEPER® (M48T37V/Y) register map

Address	Data								Function	Range (in BCD format)
	D7	D6	D5	D4	D3	D2	D1	D0		
7FFFh	10 Years				Year				Year	00-99
7FFEh	0	0	0	10M	Month				Month	01-12
7FFDh	0	0	10 date		Date				Date	01-31
7FFCh	0	FT	0	0	0	Day			Day	01-7
7FFBh	0	0	10 hours		Hours				Hour	00-23
7FFAh	0	10 Minutes			10 Minutes				Minute	00-59
7FF9h	ST	10 Seconds			Seconds				Second	00-59
7FF8h	W	R	S	Calibration					Control	
7FF7h	WDS	BMB4	BMB3	BMB2	BMB1	BMB0	RB1	RB0	Watchdog	
7FF6h	AFE	0	ABE	0	0	0	0	0	Interrupt	
7FF5h	RPT4	0	Al 10 Date		Alarm Date				A Date	01-31
7FF4h	RPT3	0	Al 10 Hour		Alarm Hour				A Hour	00-23
7FF3h	RPT2	Alarm 10 Minutes			Alarm Minutes				A Minute	00-59
7FF2h	RPT1	Alarm 10 Seconds			Alarm Seconds				A Second	00-59
7FF1h	1000 Years				100 Years				Century	00-99
7FF0h	WDF	AF	Z	BL	Z	Z	Z	Z	Flags	

Clock registers

The clock registers can be configured in the C language computer program as follows:

```
*TIMEKEEPER_CAL |= 0x80
*TIMEKEEPER_SEC= 00 //user clock setting : seconds parameter
*TIMEKEEPER_MIN= 00 //user clock setting : minutes parameter
*TIMEKEEPER_HOUR= 00 //user clock setting : hours parameter
*TIMEKEEPER_CAL&= 0x7F
```

The process for starting the clock and making the calibration adjustments are described in the M48T37V/Y datasheet, and in application notes AN925 and AN934.

Alarm registers

For TIMEKEEPER devices it is necessary to set the Write bit, W, at the top of the control register (at address offset 7FF8h) before proceeding to any clock modification. Modifications

to the alarm registers, though, can be made at any time, with no prior changes to the control register being necessary.

The program listing, at the end of this document, contains statements to perform the following functions:

1. The Stop bit (ST, bit 7 of the register at offset 7FF9h) has to be reset to start the TIMEKEEPER oscillator

```
*TIMEKEEPER_SEC &= 0x7F; // reset bit D7 using a mask 0x7F
```

2. The Alarm Flag Enable (AFE) bit (bit 7 of the register at offset 7FF6h) is set, thereby allowing the $\overline{IRQ}$ pin (pin 40) to output the interrupt signal (active low).

```
*TKPER_AL_IT |= 0x80; // set bit D7 using a mask 0x80
```

3. The flag register (at offset 7FF0h) must be read at the beginning of the alarm updating routine. If not, the AF flag will never be released, and the TIMEKEEPER will continuously output an interrupt to the MCU, and the system will become unresponsive.

Software configuration

The program is listed in *Alarm update management*. To understand its operation, it is important to distinguish between the three pointer variables, pointing to physical addresses in the hardware:

```
*TKPER_AL_HOUR, *TKPER_AL_MIN, *TKPER_AL_SEC
```

and the three integer variables, used as work-space by the software:

```
alarm_hour, alarm_minute, alarm_second
```

The first three variables are pointers to the physical address of the values that are stored in the device.

The three software variables are used to hold the user's data (they specify the period of the alarm in hours, minutes and seconds). This is not the same information as is stored in the TIMEKEEPER registers, as pointed to by the pointer variables, but is used in their calculation.

The program does make use of the four Repeat bits (RPT4, RPT3, RPT2 and RPT1) that are physically located in the TIMEKEEPER device. These should all be set, except for those corresponding to fields that contain significant data. For instance, to set an alarm that repeats every 3 minutes and 45 seconds, the alarm_minutes and alarm_seconds variables would be loaded with these two values. Then appropriate values would be calculated for loading in the "Alarm Minutes" and "Alarm Seconds" fields of the alarm registers (at addresses 7FF3h and 7FF2h, *TKPER_AL_MIN and *TKPER_AL_SEC, respectively), and their Repeat bits (RPT2 and RPT1, respectively) would be reset to '0'. Meanwhile, the alarm_hour variable, and the "Alarm Date" and "Alarm Hour" fields of the alarm registers (at addresses 7FF5h and 7FF4h, *TKPER_AL_DATE and *TKPER_AL_HOUR, respectively) would be treated as "Don't Care", as indicated by their Repeat bits (RPT4 and RPT3, respectively) being set. This is summarized in *Table 3*, with the three local integer variables, alarm_second, alarm_minute and alarm_hour, used to represent the period.

Table 3. Bit setting to control the period of the repeated alarm

RPT4	RPT3	RPT2	RPT1	Periodic alarm activated every
1	1	1	1	1 **second**
1	1	1	0	alarm_second **seconds** (less than 1 minute)
1	1	0	0	alarm_minute **minutes** alarm_second **seconds** (less than 1 hour)
1	0	0	0	alarm_hour **hours** alarm_minute **minutes** alarm_second **seconds** (less than 1 day)

For example, to set a period of 1 hour 49 minutes 35 seconds, the procedure is as follows:

```
RPT4 = 1
RPT3 = RPT2 = RPT1 = 0
alarm_second = 0x35
alarm_minute = 0x49
alarm_hour = 0x01
```

Or, to set a period of 49 minutes 35 seconds, the procedure is as follows:

```
RPT4 = RPT3 = 1
RPT2 = RPT1 = 0
alarm_second = 0x35
alarm_minute = 0x49
alarm_hour = Don't care
```

Software implementation

TIMEKEEPER® data format

TIMEKEEPER data is held as BCD (binary coded decimal). This is handled in the C programming language using the 'unsigned char' data type. This can be converted within the C program to other data types, such as 'integer', for numeric processing. Two functions are provided in the program at the end of this document for making this conversion.

- Char_To_Int: to take a BCD parameter, and to return the equivalent integer value
- Int_To_Char: to take an integer parameter, and to return the equivalent BCD value.

The valid ranges for the alarm fields are summarized in *Table 4*.

Table 4. TIMEKEEPER® data format

Data C language type	Int (integer) decimal	Char (character) hexadecimal	Char (character) BCD
Alarm second	0-59	00-3B	0-59

Table 4. TIMEKEEPER® data format

Data C language type	Int (integer) decimal	Char (character) hexadecimal	Char (character) BCD
Alarm minute	0-59	00-3B	0-59
Alarm hour	0-12	00-0B	0-12

Alarm update management

When the alarm signal is generated by the TIMEKEEPER® device, it is communicated to the MCU. The MCU can monitor for this event either by polling, or by using interrupts. There are two variants of each method:

- Polling
  - Read the flag register and check the AF bit (bit 6 of the register at offset 7FF0h)
  - Output the alarm signal on the TIMEKEEPER® $\overline{IRQ}$ pin (pin 40), and read it on the MCU I/O port
- Interrupts
  - Give priority to processing the alarm interrupt
  - The alarm signal is used to cause a wake-up event

The last option is ideally suited when power consumption is the critical issue. For instance, when measuring, processing and storing some metering data every three minutes, the MCU can stay in its standby state for 95% of the time, and only run at full speed, with high power consumption, during the other 5% of the time.

The other interrupt option is ideally suited when service time is the critical issue. The MCU will be interrupted from whatever processing it was currently engaged in, to service the alarm event. This can be integrated into a hierarchy of prioritized interrupts.

The two polling options are equally suited when the MCU needs to run at full speed, and full power, all of the time, executing important background work, only responding to the alarm event when it has nothing else to do.

In polling method, the MCU is always running full speed and full power consumption. In this case, the application power consumption is not a key issue and/or the process to be executed due to an alarm which has no priority. The alarm check and update is served as every other application routine.

The TIMEKEEPER $\overline{IRQ}$ pin (pin 40) is an active-low signal.

In the following program, a routine “Update_Next_Alarm” is provided to take care of the periodic update of the alarm parameters. The program has been written in ANSI C, and has been compiled and tested with an M68HC11 series MCU.

```
/* TIMEKEEPER ; M48T37V/Y PERIODIC ALARM SOURCE CODE :                          */
/* Version: 1.01                                                                */
/******************************************************************************/
/*                  Copyright (c) 1999 STMicroelectronics.                      */
/*                                                                              */
/* This program is provided "AS IS" WITHOUT WARRANTY OF ANY KIND, EITHER        */
/* EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO, THE IMPLIED WARRANTY     */
/* OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. THE ENTIRE RISK     */
```

```
/* AS TO THE QUALITY AND PERFORMANCE OF THE PROGRAM IS WITH YOU. SHOULD THE      */
/* PROGRAM PROVE DEFECTIVE, YOU ASSUME THE COST OF ALL NECESSARY SERVICING,      */
/* REPAIR OR CORRECTION.                                                        */
/********************************************************************************/

/*****************************************************************/
/*                                                               */
/*     This program controls the TIMEKEEPER alarm hardware so    */
/*     as to provide the functionality of a periodic alarm.      */
/*                                                               */
/*****************************************************************/

#include <mcu_hc11.h>                       // this was developed on HC11 platform
#include <m88xxfx.h>                       // M88 Flash+PSD register map

extern volatile unsigned char dip_sw;
/*********************************************************************/
/* TIMEKEEPER memory map                                             */
/* Depend on your system and your TIMEKEEPER.                        */
/* The device is M48T37V/Y series, 32kx8 non volatile SRAM, 16 clock     */
/* alarm registers in address 7FF8h to 7FFFh                         */
/* In this example, the TIMEKEEPER was mapped from 2000h to 9FFFh    */
/*********************************************************************/

/*
#ifndef _MEM_MAP_H
#define _MEM_MAP_H
#define        EXT_RAM_BASE (unsigned int)            0x2000
#define        TIMEKEEPER_HOUR (unsigned char *)      0x9FFB
#define        TIMEKEEPER_MIN (unsigned char *)       0x9FFA
#define        TIMEKEEPER_SEC (unsigned char *)       0x9FF9
#define        TIMEKEEPER_CAL (unsigned char *)       0x9FF8
#define        TKPER_AL_IT (unsigned char *)          0x9FF6
#define        TKPER_AL_DATE (unsigned char *)        0x9FF5
#define        TKPER_AL_HOUR (unsigned char *)        0x9FF4
#define        TKPER_AL_MIN (unsigned char *)         0x9FF3
#define        TKPER_AL_SEC (unsigned char *)         0x9FF2
#define        TKPER_FLAG (unsigned char *)           0x9FF0

#endif
  */



/*************************************************************************/
/* function Char_To_Int                                                  */
/* description :                This function convert the timekeeper data*/
/*                              (in BCD format) to an integer.           */
/* input :                      char byte                                */
/* output :                     integer                                  */
/* example :                    octet = 0x33        (51 in integer)      */
/*                              Char_To_Int = 33    (0x21 in hexa)       */
/*************************************************************************/
int Char_To_Int(unsigned char octet)
       {
        int buffer;
        buffer = (int)(octet);
        if (octet <= 0x09) return(buffer);
        if ((octet >= 0x10) & (octet <= 0x19)) return (buffer-6);
        if ((octet >= 0x20) & (octet <= 0x29)) return (buffer-12);
        if ((octet >= 0x30) & (octet <= 0x39)) return (buffer-18);
```

```
        if ((octet >= 0x40) & (octet <= 0x49)) return (buffer-24);
        if ((octet >= 0x50) & (octet <= 0x59)) return (buffer-30);
}

/*************************************************************************/
/* function Int_To_Char                                                  */
/* description :       This function convert an integer data             */
/*                     to BCD TIMEKEEPER format (unsigned char)          */
/* input :             int integ                                         */
/* output :            unsigned char                                     */
/* example :           integ = 33            (0x21 in hexa)              */
/*                     Int_To_Char = 0x33    (51 in integer)             */
/*************************************************************************/
unsigned char Int_To_Char(int integ)
       {
        char buffer;
        buffer = (unsigned char)(integ);
        if (integ <= 9) return(buffer);
        if ((integ >= 10) & (integ <= 19)) return (buffer+6);
        if ((integ >= 20) & (integ <= 29)) return (buffer+0x0C);
        if ((integ >= 30) & (integ <= 39)) return (buffer+0x12);
        if ((integ >= 40) & (integ <= 49)) return (buffer+0x18);
        if ((integ >= 50) & (integ <= 59)) return (buffer+0x1E);
       }

/*************************************************************************/
/* void Update_Next_Alarm                                                */
/* description :        After alarm interupt, it will :                  */
/*                     - reset the TIMEKEEPER IT flag                    */
/*                     - read the actual time in the clock register      */
/*                     - calculate the next alarm time                   */
/*                     - update the alarm register                       */
/*                       to prepare for the next alarm                   */
/* input :             alarm period (al_hour, al_minute, al_second)      */
/* output :            nothing                                           */
/*************************************************************************/
void Update_Next_Alarm(int al_hour,int al_minute,int al_second)
       {
        // time carry, going to be used for hour, minute and second
        // calculation process.
        unsigned char time_flag = 0;

       // intermediate storage for alarm data.
       int buffsec;
       int buffmin;
       int buffhour;

       // temporary storage
       unsigned char buffchar;

       // Touch the flag register to reset TIMEKEEPER AF flag (interupt)
       buffchar = *TKPER_FLAG;

/*****************************************************************/
/* This is to update the alarm second register.                  */
/* It will test if RPT1 is set. If not then it adds "al_second"  */
/* to second alarm register. It takes care of the minute carry.  */
/*****************************************************************/
        if (!(*TKPER_AL_SEC & 0x80))            // if !RPT1
                {                               // update register with carry
                buffsec = Char_To_Int(*TIMEKEEPER_SEC) + al_second;
                if (buffsec > 59)               // if >59
                        {                       // then restore 60sec format
```

```
                        *TKPER_AL_SEC = Int_To_Char(buffsec-60);
                        time_flag = 1;
                       }
                else *TKPER_AL_SEC = Int_To_Char(buffsec);   // normal case
                }
/*************************************************************/
/* This is to update the alarm minute register. */
/* It will test if RPT2 is set. If not then it adds "al_minute"  */
/* to alarm minute register. It takes care of the hour carry.    */
/*************************************************************/
        if (!(*TKPER_AL_MIN & 0x80))             // if !RPT2
                {                                // update register with carry
                buffmin = Char_To_Int(*TIMEKEEPER_MIN) + al_minute + time_flag;
                if (buffmin > 59)               // if >59
                        {                       // then restore 60 min format
                        *TKPER_AL_MIN = Int_To_Char(buffmin-60);
                        time_flag = 1;
                       }
                else
                       {
                        *TKPER_AL_MIN = Int_To_Char(buffmin); // normal case
                        time_flag = 0;
                       }
                }

/*************************************************************/
/* This is to update the alarm hour register.                */
/* It will test if RPT2 is set. If not then it adds "al_hour" to */
/* alarm hour register                                       */
/*************************************************************/
         if (!(*TKPER_AL_HOUR & 80))
                {
                 buffhour = Char_To_Int(*TIMEKEEPER_HOUR) + al_hour + time_flag;
                 if (buffhour > 23) *TKPER_AL_HOUR = Int_To_Char(buffhour-24);
                 else *TKPER_AL_HOUR = Int_To_Char(buffhour);
                 }
}
```

```
main(void)
        {
        int alarm_second;          // relative alarm variable
int alarm_minute;
int alarm_hour;

/*************************************************************/
/* TIMEKEEPER alarm configuration example.                   */
/*************************************************************/

                                          // Memory-mapped unsigned char pointers
        *TKPER_AL_HOUR        &= 0x7F;    // to the external hardware registers
        *TKPER_AL_MIN         &= 0x7F;    // to set a one-off alarm
        *TKPER_AL_SEC         &= 0x7F;    // for a fixed time today.

                                          // Local memory integer variables
```

```
        alarm_hour            = 1;         // to hold the repetition period
        alarm_minute          = 49;        // for an alarm (& an interrupt on pin 26)
        alarm_second          = 35;       // every 1hr 49min 35sec (for example).


        // Start the Timekeeper oscillator.
        *TIMEKEEPER_SEC       &= 0x7F;
        // RPT4 set
        *TKPER_AL_DAY         |= 0x80;
        // enable IRQ request on pin40 (M48T37V/Y)
        *TKPER_AL_IT          |= 0x80;
        while (1)
        {
/*********************************************************************/
/* read_the_port is a read of MCU I/O to detect an alarm interrupt */
/* lcd_min_display is a lcd software driver used for routine debug */
/* Those library were developed for FLASH+PSD development board.   */
/*********************************************************************/
        read_the_ports();
        lcd_min_display(0,3,*TIMEKEEPER_HOUR); // display current time
        lcd_min_display(0,7,*TIMEKEEPER_MIN);
        lcd_min_display(0,13,*TIMEKEEPER_SEC);

        if (dip_sw==0x0E)             // dip_sw is updated by read_the_port
                                      // if detect alarm interrupt from TIMEKEEPER
        {
        Update_Next_Alarm(alarm_hour,alarm_minute,alarm_second);

        lcd_min_display(1,3,*TKPER_AL_HOUR); // display next alarm time
        lcd_min_display(1,7,*TKPER_AL_MIN);
        lcd_min_display(1,13,*TKPER_AL_SEC);
        }
        }
}
```

Revision history

Table 5. Document revision history

Date	Revision	Changes
Feb-2000	1	Initial release.
03-Sep-2013	2	Updated title of document Removed references to obsolete products Added *Table 1: TIMEKEEPER® and serial RTC devices with alarm* Updated *Table 2* and text throughout the document to reflect the memory map and address of the M48T37V/Y device