HT8 MCU LXT (32.768kHz) Application Guidelines

D/N: AN0489E

Introduction

The Holtek HT8 MCUs provide an external 32.768kHz low speed crystal oscillator (LXT) as one of the choices for the microcontroller system clock. This is an oscillator which can also provide a clock source for the Watchdog Timer and Time Base Interrupt functions, selected through a combination of configuration options and relevant control registers. The LXT oscillator has low power consumption, which can accommodate users' demand for low-power products. This document will introduce the LXT basic principles, characteristics, functions and factors which influence accuracy, which will enable users to have a deeper understanding of the LXT and master its usage.

Note: This document refers to the HT66F0175/0185 8-Bit Flash MCU datasheet.

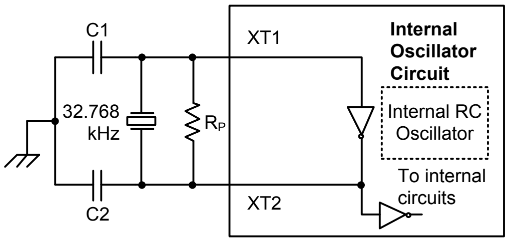
Functional Description

LXT Oscillator Basic Principles

The external 32.768kHz low speed crystal oscillator has a fixed clock frequency of 32.768kHz which requires a 32.768kHz crystal, a resistor R_P as well as two capacitors C1 and C2 to be connected between pins XT1 and XT2. The external resistor and capacitor components connected to the 32.768kHz crystal are necessary to provide oscillation.

For oscillator stability and to minimise the effects of noise and crosstalk, it is important to ensure that the crystal and any associated resistors and capacitors along with interconnecting lines are all located as close to the MCU as possible.

The LXT oscillation circuit and external component recommended values are shown below:



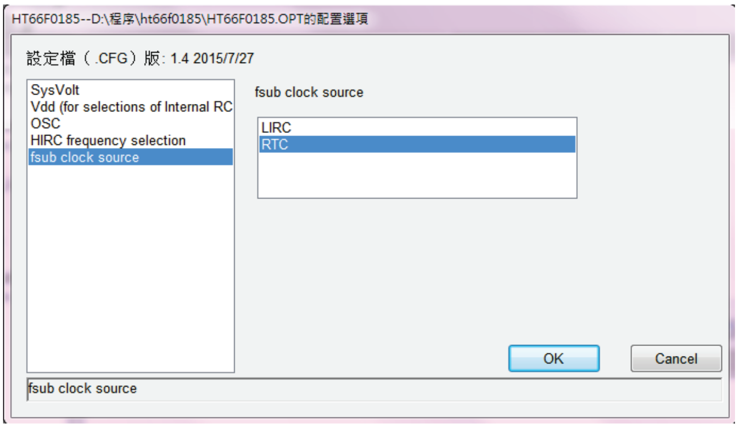
Note: 1. R_P, C1 and C2 are required.
2. Although not shown XT1/XT2 pins have a parasitic capacitance of around 7pF.

External LXT Oscillator

LXT Oscillator C1 and C2 Values		
Crystal Frequency	**C1**	**C2**
32.768kHz	10pF	10pF
Note: 1. C1 and C2 values are for guidance only. 2. R_P=5MΩ~10MΩ is recommended.		

32.768kHz Oscillator Recommended Capacitor Values

Whether pins XT1/XT2 are used as the LXT oscillator external pins or general purpose I/O pins is determined by a configuration option. If the LXT oscillator is not used as a clock source, these two pins can be used as general purpose I/O pins or as other pin-shared functions. If the LXT oscillator is used as a clock source, a 32.768kHz crystal should be connected between the XT1 and XT2 pins.



LXT Basic Characteristics

Operational Power Consumption

- SLOW Mode

  The LXT oscillator can be selected through relevant registers to be used as a system clock when the microcontroller enters the SLOW mode. The microcontroller has a lower operating current in this mode, in the order a few tens of micro-amps, while the f_H clock will be switched off.

Ta=25°C

Symbol	Parameter	Test Condition		Min.	Typ.	Max.	Unit
		V_{DD}	Condition				
I_{DD}	Operating Current – LXT	3V	$f_{SYS}=f_{SUB}=f_{LXT}$=32.765kHz	—	10	20	μA
		5V	no load, all peripherals off	—	30	50	μA

- Standby Modes

  When the system enters the IDLE/SLEEP mode, the system clock will be switched off to reduce power consumption. However, some applications require an additional clock source to maintain their internal timer functions, this additional clock is sourced from the LXT or LIRC oscillator.

Ta=25°C

Symbol	Parameter	Test Condition		Min.	Typ.	Max.	Unit
		V_{DD}	Condition				
I_{STB}	Standby Current (IDLE0 Mode)	3V	No load, all peripherals off, f_{SUB} on	—	3	5	μA
		5V		—	5	10	μA
	Standby Current (SLEEP1 Mode)	3V	f_{SUB} on, WDT on, no load, all peripherals off	—	—	3	μA
		5V		—	—	5	μA

LXT Oscillator Start Mode

The LXT oscillator can function in one of two modes, the Quick Start Mode or the Low-power Mode. The mode selection is executed using the LXTLP bit in the TBC register.

LXTLP	LXT Operating Mode
0	Quick Start
1	Low-power

After power on, the LXTLP bit will be automatically cleared to zero by default ensuring that the LXT oscillator is in the Quick Start operating mode. However, after the LXT oscillator has fully powered up it can be placed into the Low-power mode by setting the LXTLP bit high. The oscillator will continue to run but with reduced current consumption. In power sensitive applications, such as battery applications, the power consumption must be kept to a minimum. To reduce power consumption, it is recommended that the application program sets the LXTLP bit high after power-on and oscillation start-up are both completed. It should be noted that, no matter what condition the LXTLP bit is set to, the LXT oscillator will always function normally and the only difference is that it will take more time to start up if in the Low-power mode.

The LXT oscillator start-up time is related to the external C1/C2 capacitors and the MCU operating voltage. Lower capacitance values or a higher MCU operating voltage allow a shorter crystal oscillation startup time. Users should choose appropriate capacitance and operating voltages, and clear the LXTLP to zero to shorten the oscillator start-up time.

LXTLP	C_L (pF)	R_P (MΩ)	V_{DD} (V)	C1/C2 (pF)	Start-up Time (ms)	Note
0	12.5	10	3.0	20	≈ 1450	The YIC 32768Hz crystal load capacitor C_L is 12.5pF, change the V_{DD} voltage and external capacitance and test the crystal oscillator start-up time. (Here the HT66F0185 is taken as an example)
				10	≈ 748	
			5.0	20	≈ 1210	
				10	≈ 684	

Crystal Performance

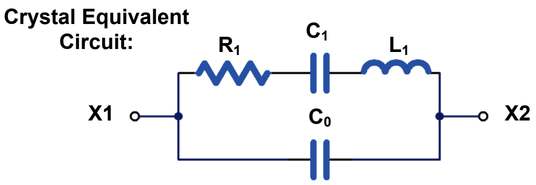
Negative Resistance (-R)

Looking at the two terminals of the quartz crystal oscillation circuit, the impedance characteristic value generated during oscillation will have the characteristics of Negative Resistance (-R). The oscillation circuit must provide sufficient amplification gain to compensate the mechanical energy loss of the quartz crystal resonance. The negative impedance is not one of the product parameters, however it is an important specification for oscillation circuit design.

Equivalent Series Resistance (ESR)

The Equivalent Series Resistance (ESR) is the mechanical energy loss of the crystal oscillator. A higher ESR value results in higher losses in the crystal oscillator. If the ESR value is too high, the oscillator may be unstable or even stop oscillating. Each crystal oscillator has a maximum ESR limit value. The lower the actual ESR value is, when compared with the recommended maximum value, the better the oscillator startup and stability will be.

A common ESR value for the 32768Hz crystal ranges from30kΩ to 100kΩ.



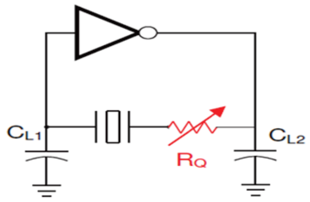
$ESR = R1\,(1+C_0/C_L)^2$; $C_L = (C_{L1} \times C_{L2}) / (C_{L1}+C_{L2}) + C_{stray}$

C_{L1}: X1 external capacitor, C_{L2}: X2 external capacitor, C_{stray}: Stray capacitance

Negative Resistance Measurement Method

The safety factor (SF) can be measured by using the negative resistance and the stability of crystal oscillator can be determined. For the negative resistance measurement method, an additional resistor R_Q is added in series with the crystal. This additional series test resistor R_Q will increase before the oscillator starts up or a running oscillator stops. It is recommended to reduce the resistance value before the oscillator resumes running, through which the key value can be determined. This can be done using an SMD potentiometer, which is suitable for RF applications, thus greatly reducing the possible parasitic value increment. As all parameters and parasitic values generated by the potentiometer affect the final parameters of the oscillator circuit. The final value of $R_Q$max should be verified by a single SMD resistor.

The measurement circuit is shown below:



Oscillation Redundancy (OA)

$OA = R_Q max + ESR$

Safety Factor (SF)

$SF = \frac{OA}{ESR} = \frac{R_{Qmax} + ESR}{ESR}$

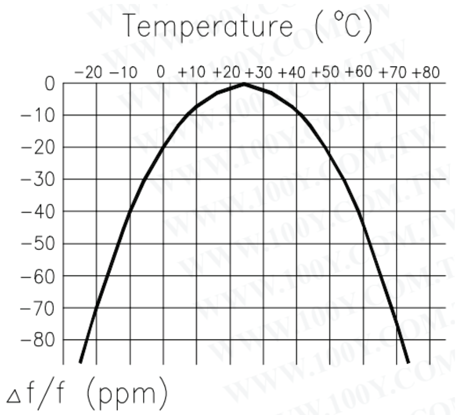
The safety factor (SF) is listed below:

Safety Factor (SF)	Assessment
SF < 2	Unsafe
2 ≤ SF < 3	Applicable
3 ≤ SF < 5	Safe
SF ≥ 5	High safety

* According to the above analysis, users should choose an appropriate low ESR or load capacitor when selecting the crystal oscillator.

LXT Oscillator Characteristics (V, T)

The oscillator is composed of an internal oscillator circuit and an external crystal circuit, providing the MCU with stable frequencies used as time references. It should be noted that the quartz crystal frequency error will be greatly influenced by environmental temperature, but will be less affected by the operating voltage. The influence of temperature on frequency can be seen in the following temperature-frequency graph for a MERCURY 32.768kHz crystal, which has a frequency error of ±5PPM at a temperature of 25°C.

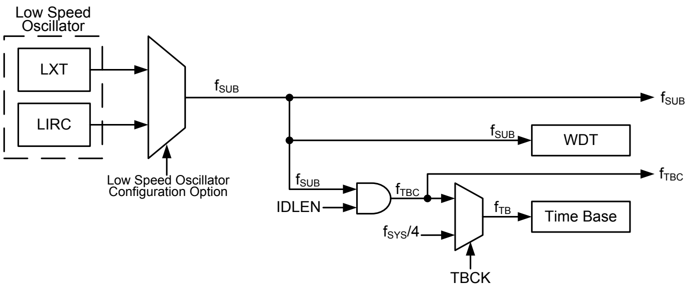


It should be noted that high frequency circuits should not be placed near the LXT circuit during layout otherwise the oscillation characteristics will be affected. The LXT oscillation circuit should be located as close to the XT1 and XT2 pins as possible, while the C1/C2 capacitor routing to V_{SS} should be as short as possible.

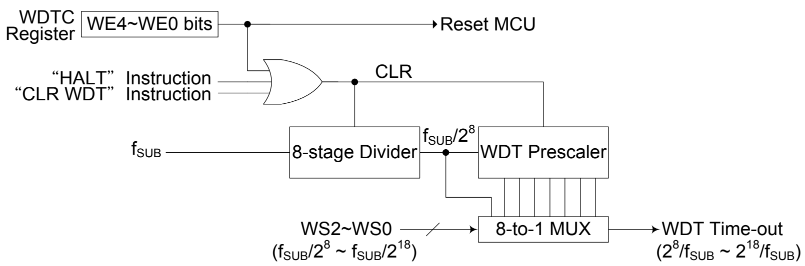
LXT Used as WDT Clock Source

The Watchdog Timer clock source is provided by the internal clock, f_{SUB}, which is in turn supplied by the LIRC or LXT oscillator. In this case the LXT should be selected to be the WDT clock source through a configuration option. There are five bits, WE4~WE0, which provide an enable/disable control of the Watchdog Timer. The Watchdog Timer source clock is then subdivided by a ratio of 2^8 to 2^{18} to give longer timeouts, the actual value being chosen using the WS2~WS0 bits in the WDTC register.

Refer to the datasheet for more detailed information about the WDT usage and considerations.



Low Frequency Oscillator Options



Watchdog Timer

WDTC Register

Bit	7	6	5	4	3	2	1	0
Name	WE4	WE3	WE2	WE1	WE0	WS2	WS1	WS0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	1	0	1	0	0	1	1

- **WE4~WE0**: WDT function enable control
  10101: Disable
  01010: Enable
  Other values: Reset MCU
  When these bits are changed by environmental noise the microcontroller will be reset. The reset operation will be activated after a delay time, t_{SRESET}, and the WRF bit in the CTRL register will be set high.
- **WS2~WS0:** WDT time-out period selection
  000: $2^8/f_{SUB}$
  001: $2^{10}/f_{SUB}$
  010: $2^{12}/f_{SUB}$
  011: $2^{14}/f_{SUB}$
  100: $2^{15}/f_{SUB}$
  101: $2^{16}/f_{SUB}$
  110: $2^{17}/f_{SUB}$
  111: $2^{18}/f_{SUB}$

These three bits determine the division ratio of the watchdog timer source clock, which in turn determines the time-out period.

CTRL Register

Bit	7	6	5	4	3	2	1	0
Name	FSYSON	—	—	—	—	LVRF	LRF	WRF
R/W	R/W	—	—	—	—	R/W	R/W	R/W
POR	0	—	—	—	—	x	0	0

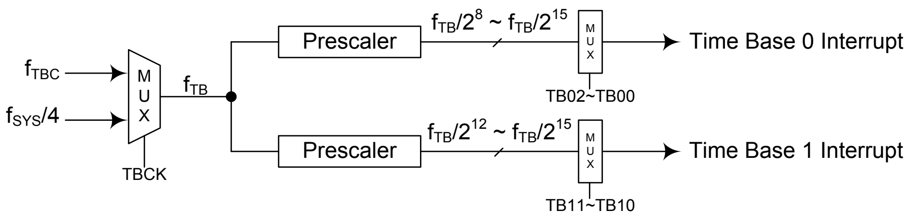
"x": Unknown

- **FSYSON**: f_{SYS} control bit in IDLE Mode
  Described elsewhere.
- Unimplemented, read as "0"
- **LVRF**: LVR function reset flag
  Described elsewhere.
- **LRF**: LVR control register software reset flag
  Described elsewhere.
- **WRF**: WDT control register software reset flag
  0: Not occurred
  1: Occurred
  This bit is set high by the WDT Control register software reset and cleared by the application program. Note that this bit can only be cleared to zero by the application program.

LXT Used as Time Base Clock Source

The Time Base clock source can be $f_{SYS}/4$ or f_{TBC}, the f_{TBC} originates from either the LXT or LIRC oscillator. Select the LXT oscillator to be a clock source by setting a configuration option and also setting the TBCK bit in the TBC register high. After the TBC register and relevant interrupt enable bits are properly configured, when the interrupt is enabled, the stack is not full and the Time Base overflows, a subroutine call to their respective vector locations will take place. When the interrupt is serviced, the respective interrupt request flag, TBnF, will be automatically reset and the EMI bit will be cleared to disable other interrupts.

Refer to the datasheet for more detailed information for the Time Base usage and register configurations.



Time Base Interrupts

TBC Register

Bit	7	6	5	4	3	2	1	0
Name	TBON	TBCK	TB11	TB10	LXTLP	TB02	TB01	TB00
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	1	1	0	1	1	1

- **TBON**: Time Base function enable control
  0: Disable
  1: Enable
- **TBCK**: Time Base clock source select
  0: f_{TBC}
  1: $f_{SYS}/4$
- **TB11~TB10**: Time Base1 time-out period selection
  000: $2^{12}/f_{TB}$
  001: $2^{13}/f_{TB}$
  010: $2^{14}/f_{TB}$
  011: $2^{15}/f_{TB}$
- **LXTLP**: LXT Low Power control
  0: Disable – LXT Quick Start
  1: Enable – LXT Low-power
- **TB02~TB00**: Time Base 0 time-out period selection
  000: $2^{8}/f_{TB}$
  001: $2^{9}/f_{TB}$
  010: $2^{10}/f_{TB}$
  011: $2^{11}/f_{TB}$
  100: $2^{12}/f_{TB}$
  101: $2^{13}/f_{TB}$
  110: $2^{14}/f_{TB}$
  111: $2^{15}/f_{TB}$

Conclusion

This document has introduced the LXT oscillator of the HT8 series MCUs to help users to have a deeper understanding of the LXT basic principles, characteristics, usage and factors which influence accuracy. Users should choose an appropriate crystal and determine the resistor and capacitor values accordingly to achieve optimal effects.

Refer to the HT8 series MCU datasheets for more detailed information.

Reference Files

Reference file: HT66F0175/0185 datasheet

For more information, refer to the Holtek official website http://www.holtek.com/en.

Version and Modification Information

Date	Author	Issue
2018.4.30	陳美玲	Initial version

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