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R8C/2x

Low Power Consumption Mode Using Low Speed Periodic Wakeup

Introduction

This application note explains how to setup the R8C/29 peripherals in order to achieve very low power consumption by switching the clock options and using MCU WAIT mode. The application can easily be ported to any of the R8C/2x series as they share most of the clock peripheral settings.

Contents

1-Usage

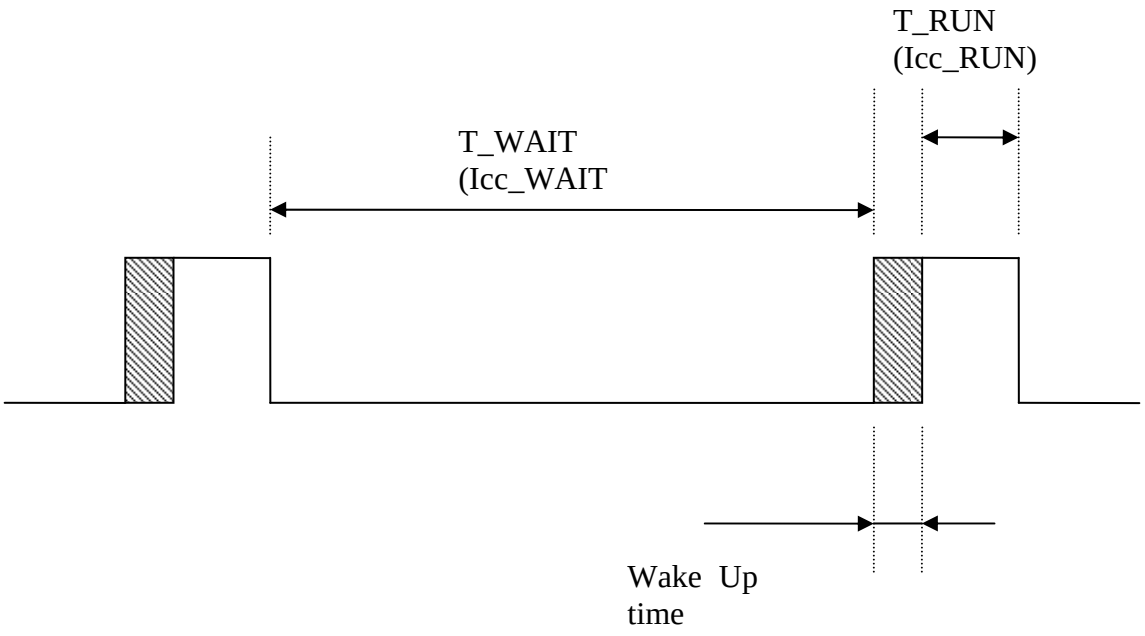
In many low power applications the power consumption of the microcontroller is key to achieve long life battery. In order to achieve this, most of these applications use MCU sleep mode with a low speed resonator (typically a 32KHZ clock crystal) for periodic wakeup.
The R8C/2x series are the first microcontrollers, in the R8C series, that have a 32KHZ clock capability.

Typical applications are security sensors, smoke sensors, automatic meter reading (water or gas meters), radio frequency serial interfaces,…

The final battery lifetime depends of wake up time, sleep time and current consumption in each mode. In most cases the energy could be calculated as below:

W = Icc_RUN*RUN_Time + Icc_WAIT*WAIT_Time + Icc_WAKE*WAKE_Time

Depending on the ratio RUN_Time/WAIT_Time the impact depends more on Icc_RUN or Icc_WAIT.



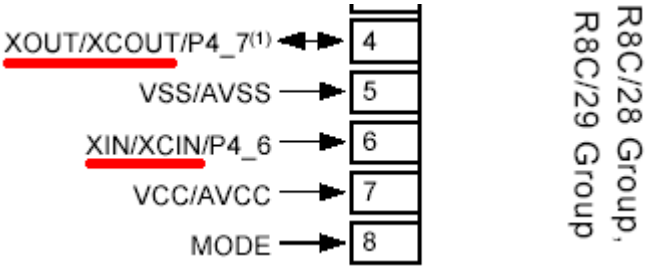
2-R8C low power modes

2.1-Available oscillators

The R8C/29 has 4 possible clock sources, external high speed (up to 20MHZ), external low speed (32KHZ), internal low speed (125KHZ) and internal high speed ring (40MHZ). Any of above mentioned clock sources can be used as CPU source clock with the restriction for a maximum of 20MHZ CPU clock (which means a minimum division of 2 of the high speed ring oscillator).

After reset by default the CPU uses the On-Chip Oscillator divided by 8 which means about 125KHZ/8 = 15KHZ CPU speed operation.

As R8C/29 only has 2 pins for external oscillators (high speed or low speed) which means the application software should define in special function registers (sfr) which type of resonator is physically attached to the device.



2.11-On-Chip Oscillators

As mentioned above the R8C/29 has a 125KHZ (low speed ring) and a 40MHZ (high speed ring) oscillator. The low speed ring oscillator targets low power consumption and isn't calibrated nor adjustible with a wide tolerance in frequency (from 30KHz to 250KHz), the high speed oscillator however is calibrated in factory prior to shipment to achieve few percent precision.

In this application the MCU will use the high speed ring oscillator divided by 2 in run mode and the physical external oscillator is a low speed 32KHZ.

2.2-Run modes

R8C and M16C have 3 main CPU modes which are STOP, WAIT and RUN.

In STOP mode all clocks stop oscillating, MCU can only exit this mode by an external signal (interrupt, timer overflow on external pulse counting or Reset). This mode is the best for power consumption but requires an external signal to wake up.

In WAIT mode the CPU is stopped but clocks are provided to the peripherals so that timers and UARTs can operate normally. This is the mode used in this application note and gives the best compromise for periodic wake up without having external specific hardware (beside the 32KHz resonator).

In RUN mode CPU and peripherals are provided with all clocks, the power consumption can be adjusted by dividing clock source to the CPU (division factors are 2, 4, 8 and 16).

In this application note WAIT (32KHZ) and RUN (20MHZ) are used, the wakeup source is the timer RA overflow.

2.3-Power consumption

The power consumption depends on clock speed and CPU mode. As mentioned above mainly 2 modes are used, for each of these modes the measured power consumption is respectively 10mA and 2.5µA under 3V operation.

The R8C use advanced technology that limits the core voltage far below the 5.5V maximum operating voltage, thanks to this the supply current has almost no dependence on the device power supply voltage.

3-R8C peripheral usage

3.1-Timers

R8C/29 contains two 8-bit timers with 8-bit prescaler (timers RA and RB), one 16-bit timer (timer RC), and a timer with a 4-bit counter, and an 8-bit counter (timer RE).
Among this set of timers the 32KHZ clock (fc32) can be used as count source only for timer RE or timer RA.
As timer RE can generate interrupts only every second or every minute it doesn't give the expected flexibility for wakeup, this is the main reason to use timer RA in order to get better wakeup resolution.

4-Software description.

The code has been created with NC30WA\V530R02 which is the RENESAS M16C60/R8C "C compiler" under HEW4 environment and E8 on chip debugger for test and evaluation.

The hardware is based on MB-R8C14 on which R8C/29 was implemented.

4.1-Return from WAIT process.

The R8C (and M16C) return from WAIT state following an interrupt or reset signal.

When the interrupt occurs the CPU resumes from WAIT state and starts the interrupt sequence using same clock as before entering the WAIT state.

It is mandatory to enable the interrupts otherwise the CPU will require a hardware RESET (or non maskable interrupt) to release from WAIT.

In the interrupt routine (Timer RA) the ring oscillator is switched on (125KHZ oscillating) then high speed ring oscillator is started (please read carefully usage precautions).

4.2-Routines description

void Init_Sfr(void).

Initializes R8C/29 main registers initialization, 32KHz external oscillator and high speed 40MHz ring oscillator start.

void clock_increment(void).

Basic routine to update a dummy real-time clock.

void TA_int(void)

Timer RA interrupt routine. Exits from WAIT state, switches CPU clock from 32KHz to high speed 20MHZ clock (based on high speed 40MHz ring oscillator)

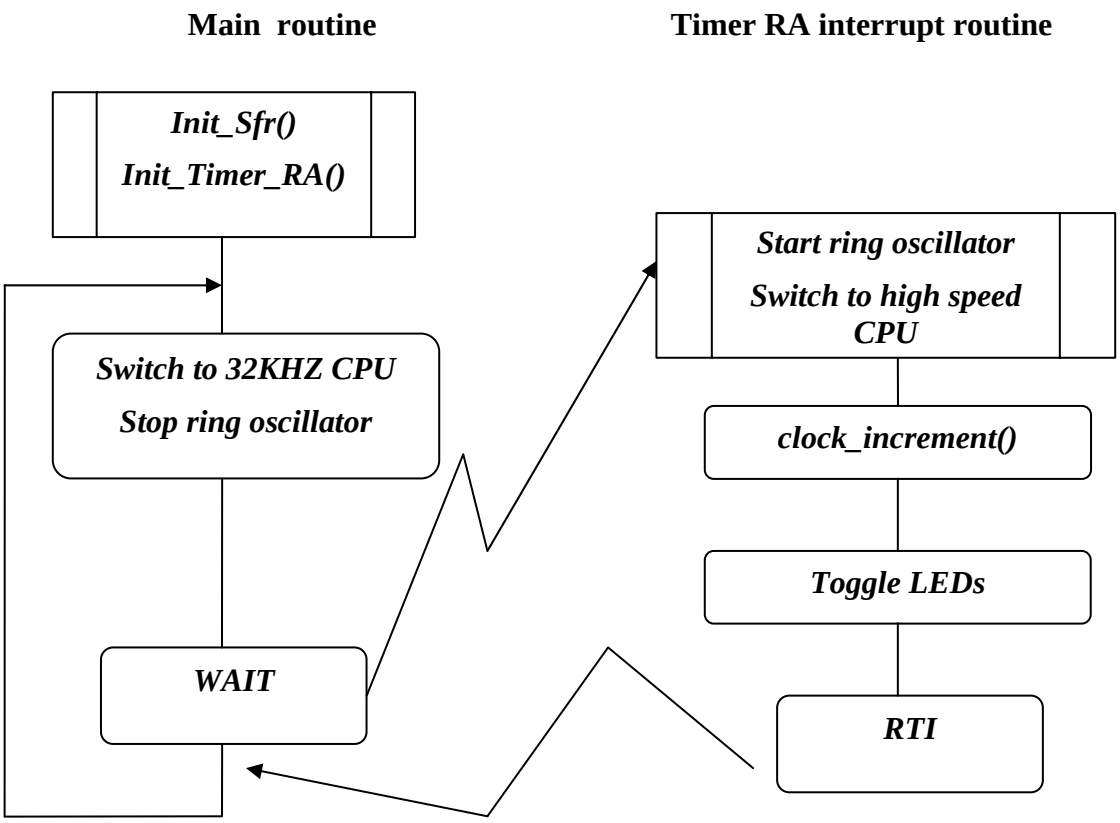
void Init_Timer_RA(void)

Initialises timer RA to the correct periodic wakeup time and enables timer RA interrupt.

void main(void)

Never ending main loop, with periodic switch of the CPU clock to 32KHz and executes WAIT.

4.3-Flowchart



5-Code

```
#include "sfr_r829.h"
#define DI asm("fclr i")
#define EI asm("fset i")
#define WAIT asm("wait")
#define LED1 p3_3
#define LED2 p1_3
#define OFF 0
#define ON 1
#define T_15_625ms 3
#define T_31_25ms  7
#define T_62_5ms   15
#define T_125ms    31
#define T_250ms    63
#define T_375ms    95
#define T_500ms    127
#define T_625ms    159
#define T_750ms    191
#define T_875ms    223
#define T_1s       255
// CHANGE BELLOW PARAMETERS FOR SLEEP TIME ADJUSTMENT
// Uncomment 1 line only
//#define TSLEEP T_15_625ms
//#define TSLEEP T_31_25ms
//#define TSLEEP T_62_5ms
//#define TSLEEP T_125ms
//#define TSLEEP T_250ms
//#define TSLEEP T_375ms
//#define TSLEEP T_500ms
//#define TSLEEP T_625ms
//#define TSLEEP T_750ms
//#define TSLEEP T_875ms
#define TSLEEP T_1s

#define T_RUN
struct heure{
    char tic;
    char seconde;
    char minute;
    char hour;
};

typedef struct{
    struct heure time;
    char day;
    char month;
    int year;
}whats_the_day_today;

whats_the_day_today date;
// -------------------------------------------------------------
// Initialises SFR's
// -------------------------------------------------------------
// Input Parameters :     None
```

```
// -----------------------------------------------------------------
// Returned Parameters :  None
// -----------------------------------------------------------------
// Modified globales:     None
// -----------------------------------------------------------------
void Init_Sfr(void)
{
prcr  = 1; // Enable access to clock registers
fra2  = 0x01;// High speed ring divided by 2 (20MHZ clock)
cm0   = 0x3E; // 0011 1110 Starts XC (32KHZ clock)
cm1   = 0x0A; // 0000 1010
ocd   = 0x04;// Enable on-chip oscillator clock
fra0  = 0x01; // High speed oscillator ON
fra0  = 0x03; // Select high speed oscillator
prcr  = 0; // Protect SFR
prcr  =8;
vca1  =8;
vca2  = 0;
vw0c  =0;
prcr  = 0;// Protect SFR
adcon1=0;// Make sure Vref is cutted
p1    =0;
p3    =0;
p4    =0;
pur0  =0;
pur1  =0;
prcr  =4;// Allow access to PD0
prcr  = 0;// Protect SFR
pd1   =0xff;
pd3  =0xba;// Set only P3_0 to input (TA output)
pd4   =0x00;// Set all to input
}
// -----------------------------------------------------------------
// Clock increment routine
// -----------------------------------------------------------------
// Input Parameters :     None
// -----------------------------------------------------------------
// Returned Parameters :  None
// -----------------------------------------------------------------
// Modified globales:     None
// -----------------------------------------------------------------
void clock_increment(void)
{
      date.time.seconde++;
      if (date.time.seconde==60)
      {
      date.time.minute++;
      date.time.seconde=0;
      if (date.time.minute==60)
             {
            date.time.hour++;
            date.time.minute=0;
            if(date.time.hour==24)
            {
                date.day++;
```

```
                date.time.hour=0;
                if(date.day==31)
                {
                    date.month++;
                    date.day=0;
                    if(date.month==13)
                    {
                        date.year++;
                        date.month=0;
                    }
                }
            }
        }
    }
}
```

```
// -----------------------------------------------------------
// Switches device from 32KHZ to high speed operation
// -----------------------------------------------------------
// Input Parameters :     None
// -----------------------------------------------------------
// Returned Parameters :  None
// -----------------------------------------------------------
// Modified globales:     None
// -----------------------------------------------------------
#pragma INTERRUPT /B TA_int
void TA_int(void)
{
// Start high speed operation
prcr  =9;
vca2  = 0;// VDC low power bit
cm14  =0;// Starts Low speed oscillator
cm14  =0;// Stop low speed ring oscillator
ocd2  =1;
fra0  = 1;// Starts High speed oscillator
fra0  = 3;// Switches to High speed oscillator
prcr  = 0;// Protect access to Clock registers
LED1 ^= 1;// Toggle LED1 state
LED2 ^= 1;// Toggle LED2 state
clock_increment();// This routine is executed at 20MHZ
}
// -----------------------------------------------------------
// Initialises Timer RA using fc32 input.
// -----------------------------------------------------------
// Input Parameters :     None
// -----------------------------------------------------------
// Returned Parameters :  None
// -----------------------------------------------------------
// Modified globales:     None
// -----------------------------------------------------------
void Init_Timer_RA(void)
{
trapre = 3;// Divide by (3+1)*32=128
tra   = TSLEEP;
tramr= 0x41;// Pulse output mode counting from fc32 (32KHZ/32)
tracr= 1;
traioc= 6;
traic= 6;// Set priority to 6 for Timer RA
}
// -----------------------------------------------------------
// Main routine, loops into WAIT mode waked-up every TSLEEP
// by Timer RA Interrupt
// -----------------------------------------------------------
// Input Parameters :     None
// -----------------------------------------------------------
// Returned Parameters :  None
// -----------------------------------------------------------
// Modified globales:     None
// -----------------------------------------------------------
void main(void)
{
```

```
Init_Sfr();
Init_Timer_RA();
asm("fset i");// Enable Interrupt
LED1 = ON; LED2 = OFF;
date.time.seconde = 0;
date.time.minute = 0;
date.time.hour = 0;
date.day = 1;
date.month = 1;
date.year = 2006;
for(;;)
      {
      prcr = 1;// Unprotect access to Clock registers
      if(date.time.seconde > 1) // Wait for 32KHZ stabilization
         cm0 = 0x36; // switch 32KHZ oscillator to low drive
// Switch to 32KHZ clock and Stop main clock
      ocd = 0;// Select XCin Clock
      cm1 = 0x10;// Stop low speed ring oscillator
      fra0 = 1;// Switch to low speed oscillator
      fra0 = 0;// Stop High speed oscillator
      prcr =8;// Unprotect access to VCA register
      vca2= 1;// VDC low power bit
      prcr= 0;// Protect

// Go to WAIT mode with 32KHZ clock function
      WAIT;// Wait Timer RA interrupt (Here Icc is 2.2µA)
// These NOP's are for the cache flush
//(see caution section in hardware manual)
      asm("nop"); asm("nop"); asm("nop"); asm("nop");
      };
}
```

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