



**ACCURATE TIMEBASE FOR LOW-COST
ST7 APPLICATIONS WITH INTERNAL RC OSCILLATOR**

by Microcontroller Division Applications

INTRODUCTION

The ST7 microcontroller contains an internal RC oscillator, which may vary due to internal component variation depending upon the surrounding conditions. This can lead to the wrong calculation of the timing for the different peripherals like Timers, SCI etc. Timing calculation for the peripheral can be done based on the internal RC frequency given in the datasheet, but due to the variations in internal RC frequency from component to component, this leads to wrong timing results in the application.

The purpose of this application note is to present a software solution for accurate timing by calibrating the internal peripheral parameters against the variation of the internal RC oscillator. This note focuses on ST7 MCUs with a non-calibrated RC. A 50 Hz, 5 V source is applied as a reference frequency to find the real internal RC oscillator frequency. The deviation of the internal frequency with respect to the datasheet frequency is applied to correct the peripheral parameter values to obtain timing accuracy. This solution provides an innovative way to compensate the internal RC oscillator variation and to develop low cost applications.

Software is developed with using the ST7 software library (available free on the ST web site). Software shows, how to calibrate PWM signal of TIMER A to produce a 5 KHz frequency. It also gives an idea of how to calibrate the baud rate of the SCI (here it is calibrated for 9600 baud). An externally calibrated source (ex. Function generator) is used to apply 50 Hz and 5 V as a reference.

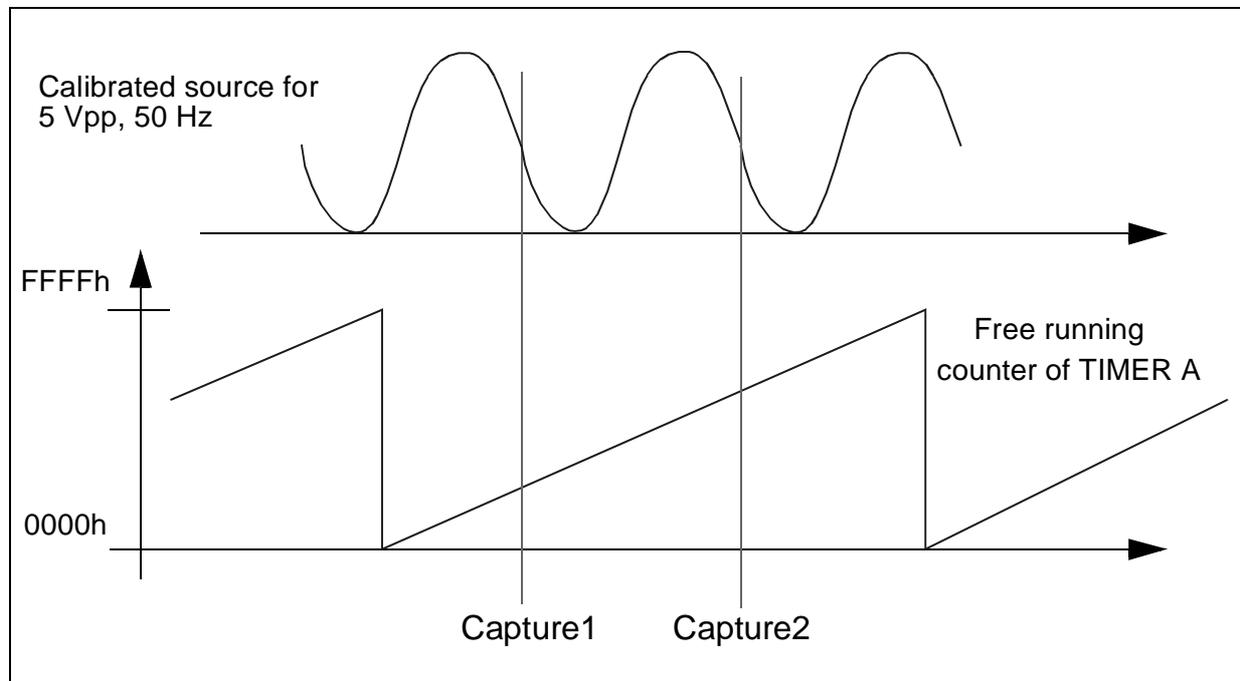
1 SOFTWARE SOLUTION

1.1 MEASUREMENT PRINCIPLE

To measure the frequency of the internal RC, software uses the input capture pin of 16-bit TIMER A. A calibrated source is applied with 50Hz on the capture pin. Every falling edge on this pin generates an interrupt (at 20ms time duration).

Software has taken the internal RC frequency of typically 4 MHz as per the datasheet. The TIMER clock is selected as $f_{cpu}/2$ (1 MHz). Counter overflow is generated after 65.532 ms (0xFFFF). This internal RC frequency should be chosen between the datasheet. max. and min. RC frequency values. Capture1 and Capture2 are stored as shown in Figure 1.

Figure 1. Timer Input Capture to measure the Reference frequency.



Here two possibilities can occur during the calculation of the capture elapsed time. If Capture1 and Capture2 are on the single counter (as shown in Figure 1), time is calculated simply by

$$\text{Capture Counter} = \text{Capture2} - \text{Capture1}$$

Second possibility is that counter overflow generates between the measurement of the Capture1 and Capture2. This leads to a more complex calculation given by

$$\text{Capture Counter} = ((0xffff - \text{capture1}) + \text{capture2})$$

This Measured Capture Counter is compared with the Ideal Capture Counter. Ideal Capture Counter is calculated manually and here for the $f_{cpu} = 2$ MHz, it gives 0x4E20. With this information Internal RC deviation is found.

$$\text{InternalRCDeviationFraction} = \frac{\text{MeasuredCaptureCounter}}{\text{CalculatedCaptureCounter}}$$

This fraction can be used to calibrate the other peripheral parameters to add precision to the the timing calculations.

If a Mains Supply is used as an external source, this solution works for an European Supply (50 Hz)). If a US supply (60 Hz) is used, the calculated Capture Counter will be 0x411B to find the fraction for internal RC deviation.

A software routine is developed to find this fraction and utilize it to calibrate the peripheral parameters. this routine is included in the application. The basic software takes less than 30ms to find the fraction, which gives the deviation of real RC frequency with reference to the datasheet frequency. This application includes a glitch filter algorithm and also takes the average of 8 samples for finding the fraction. The basic algorithm and the average + glitch algorithms are described in the next chapters. The software takes less than 325ms with the averaging and glitch algorithms.

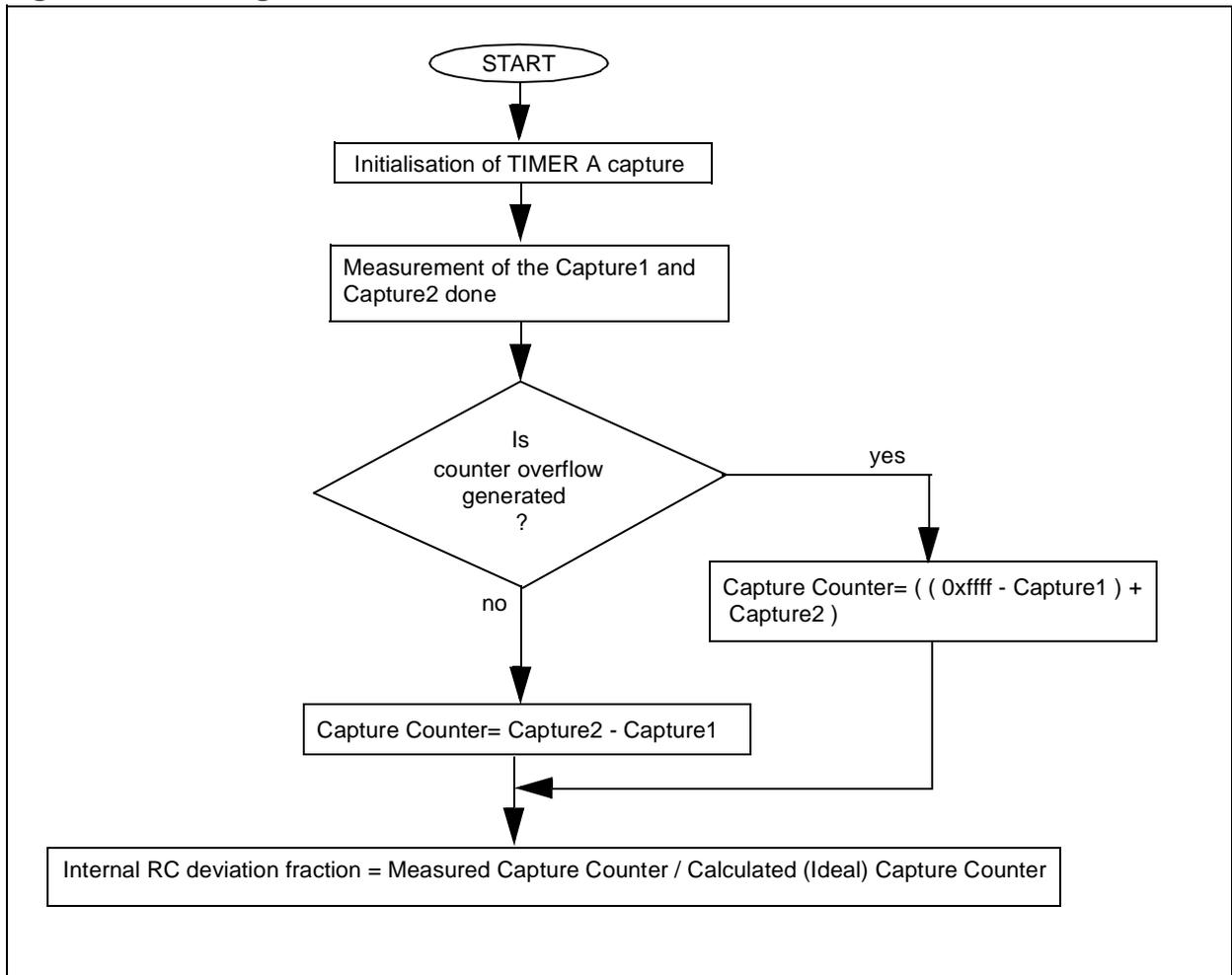
This routine execution time includes the 8 capture elapsed times, waiting times for the captures and the loop calculations inside the routine. The routine execution time is affected mostly by the capture waiting times. This routine will run in the background of the main application, so MCU can run other tasks during this 30ms (basic software algorithm) or 325ms (for average and glitch algorithm) period.

1.2 BASIC ALGORITHM

This algorithm measures the deviation of internal RC oscillator frequency in terms of Fraction. This will take 30ms to find the fraction. Software is developed in “C” language with the help of the ST7 software library. It needs 9 bytes of RAM.

The software works as shown in the following flow chart for a single sample.

Figure 2. Basic Algorithm Flowchart

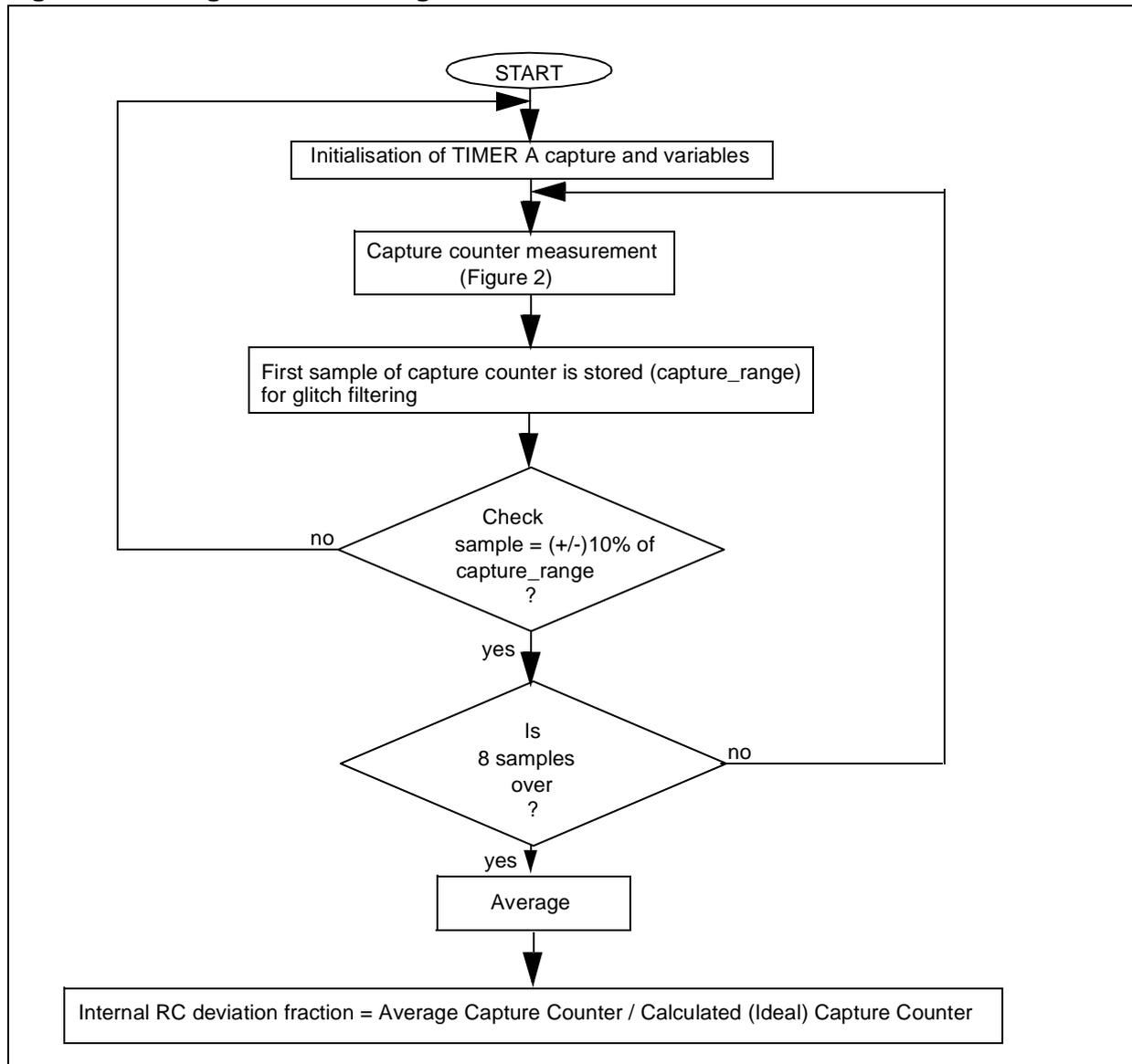


1.3 AVERAGING AND GLITCH ALGORITHM

This algorithm an added feature to section 1.2. When the 50 Hz source has noise or spikes, this algorithm helps to prevent a wrong measurement of the reference signal. If you develop a permanent hardware circuit to generate the 50 Hz signal, then it may contain noise signals as well as glitches or spikes. This algorithm is a must in this case.

This software uses 12 bytes of RAM and takes 325 ms (one loop to find the average of 8 samples) to find the deviation fraction. The flowchart shows how this algorithm works.

Figure 3. Average and Glitch Algorithm Flowchart



1.4 CALIBRATION OF PERIPHERAL PARAMETERS

1.4.1 PWM Counter

Software calibrates the PWM of TIMER to produce the pulse train at 5 KHz frequency. Normal PWM counter is given by the equation,

$$PWMCOUNTER = \left(\frac{t \times f_{cpu}}{PRESC} - 5 \right)$$

where, PWMCOUNTER = Counter value to load in OCiR register

t = Pulse period (in seconds)

f_{cpu} = CPU clock frequency

PRESC = Prescaler selection

Variation in the internal RC affects the f_{cpu} in above equation. The measured fraction (section 1.3) is applied to this term of the equation. This leads above equation to the new version,

$$PWMCOUNTER = \left(\frac{t \times f_{cpu} \times fraction}{PRESC} - 5 \right)$$

Calibration software calculates PWM counter value using the second equation. It takes care of the internal RC variation and loads the correct value in the OCiR register to produce the desired frequency.

Here for the 5 KHz frequency generation, PWMCOUNTER will be 95 for f_{cpu} = 2 MHz. When you convert into Hex value from decimal, resolution will be of 1 count. So the accuracy is [(1/95)*100] = 1.05%. The accuracy will be proportional to the variation in t and same as the counter.

1.4.2 SCI Baud rate

SCI applications are the real time-critical applications. The transmit baud rate can be determined with the following equation,

$$Tx = \frac{f_{cpu}}{(16 \times PR) \times TR \times ETPR}$$

where, Tx = Baud rate for transmission

f_{cpu} = CPU clock frequency

PR = SCI generic prescaler

TR = Transmission rate divisor

ETPR = Extended Transmit Prescaler Division

The above equation is used normally without the ETPR selection. Due to the flexibility of ETPR range (1 to 255), this software solution calibrates the SCI baud rate using the ETPR register. Software keeps PR=1 and TR=1. Again the fraction is applied to the numerator of the equation as the variation affects the fcpu only. The equation becomes,

$$Tx = \frac{f_{cpu} \times fraction}{(16 \times PR) \times TR \times ETPR}$$

To calibrate the baud rate, software loads the value of 9600 in Tx. This gives the value in terms of (PR * TR * ETPR). Software loads TR=PR=1, So the value is directly assigned to the ETPR register. This value is loaded into the PR, TR and ETPR bits. For the 9600 baud rate, this calibration gives ~9300 baud rate (where internal RC varies (-25%)). This software is able to communicate with the PC hyperterminal after using this calibration.

Here for the 9600 baud rate calculation, ETPR = 13, PR = TR = 1, for fcpu = 2 MHz. When you convert into Hex value from decimal, resolution will be of 0.5 count. So the accuracy is [(0.5/13)*100] = 3.84%. Accuracy will be proportional to variations in Baud rate and same as that of the ETPR. For higher baud rate values, you have to go for a resolution 0.25 (logic can be extended as shown in software) to achieve better accuracy.

If SCI doesn't have the ETPR prescaler then we can load PR=1 and assign the counted value to TR directly.

2 CONCLUSION

This software solution allows you to work with any time critical applications irrespective of the variations of the internal RC oscillator frequency. Software is calibrated with reference to the base of 4 MHz.

Software is developed using the ST7 software library functions. It takes less than 30ms for the simple calibration version. With the averaging and glitch algorithms, it takes less than 325 ms.

Software includes correction for the PWM counter value and the SCI baud rate. The PWM counter value gives the frequency with an accuracy of 1-2% and the SCI baud rate gives an accuracy of 3-4% after using this calibration software, when internal RC oscillator varies by (-25%).

3 SOFTWARE EXAMPLE

This software example includes all the algorithms. It includes a basic algorithm for finding the fraction and also contains average and glitch algorithms. It has calibration routines for the PWM counter and SCI baud rate.

3.1 MAIN PROGRAM

```
/******  
COPYRIGHT 2002 STMicroelectronics  
Source File Name: main.c  
Group      : IPSW, CMG - IPDF  
Author     : MCD Application Team  
Date First Issued: 01/07/2002  
*****Documentation*****  
General Purpose - This routine provides internal RC deviation measurement and  
                  calibration of PWM counter and SCI baud rate.  
*****Revision History*****  
Date: 01/07/2002      Release: 1.0  
*****/  
#include "ST7lib_config.h"          /*Configuration File*/  
unsigned char cap;  
unsigned int capture1,capture2;  
const unsigned char buff1[36]= " SCI CALIBRATION DONE " ;  
/******  
      MAIN APPLICATION BEGINS  
*****/  
#define TIMERB_PWM_CAL  
#define SCI_CAL  
void main (void)  
{  
/******  
  Variable declaration for measuring the capture inputs with averaging and  
  glitch filter algorithm  
*****/  
  unsigned char i;  
  unsigned int capture_range;  
  float fraction=0.0;  
/******  
  Variable declaration for calibrating PWM w.r.t Internal RC frequency  
*****/  
  unsigned int PWM_CNT, PWM_CNT1;  
/******  
  Variable declaration to calibrate SCI baudrate w.r.t Internal RC frequency  
*****/  
  unsigned char CALTR;  
  float CALTR_TEMP = 0.0;  
/******  
      Initialisation of the variables  
*****/  
  cap=capture1=capture2=0;  
  PWM_CNT = 0; PWM_CNT1 = 0; CALTR =0;  
  capture_range = 0;
```

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```

/*****
  Enable MCC to watch the real internal RC oscillator frequency
  *****/
  MCC_Init(MCC_DEFAULT);
  MCC_Init(MCO_ENABLE);
/*****
  TIMER A Library called to capture the rising edge at the pin PF4
  *****/
  TIMERA_Init(TIMER_FCPU_2); /*Timer clock is fcpu/2=1 MHz at fosc=4MHz*/
  TIMERA_ICAP_Mode(TIMER_ICAP_1, TIMER_EDGE_0);
  TIMERA_IT_Enable(TIMER_ICAP_IT_ENABLE);
  EnableInterrupts;
/*****
  Loop to capture 8 samples and to do averaging of it with using glitch
  filter algorithm to protect the wrong signal capture
  *****/
  for (i=0;i<8;i++) /*averaging done for 8 samples*/
  {
    while (cap != 2); /*wait loop for two captures*/
                                /*management the possibility of overflow of counter*/
    if (capture2 < capture1)
    {
      capture2 = ((0xffff - capture1) + capture2);
    }
    else
    {
      capture2 = (capture2 - capture1);
    }
    capture2 = capture2 >> 3;

    /*****Glitch filtering Algorithm *****/
    if (i==0)
    {
      capture_range = capture2;
    }
    fraction = fraction + capture2;
    if((capture2>(1.1*capture_range))||(capture2<(0.9 * capture_range)))
    {
      fraction =0; i=0;
    }
    capture1=capture2=cap=0;
  }
  /*fraction = Measured RC frequency/assumed internal RC Frequency (here 4 MHz)*/
  fraction = ((float)fraction/0x4e20);
  Nop;
/*****
  TIMER PARAMETER CALIBRATION
  *****/
#ifdef TIMERB_PWM_CAL
/***** Timer PWM generation for 5 KHz frequency*****/
/*****
  100 value to get 100 microseconds at 2MHz fcpu, equation is used as
  per ST72F521 datasheet
  *****/
  PWM_CNT = (int)(200 * fraction); /*numerator calculation*/

```

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```
PWM_CNT = PWM_CNT >> 1;          /*division by 2*/
PWM_CNT = PWM_CNT - 5;
PWM_CNT1 = (int)(400 * fraction); /*numerator calculation*/
PWM_CNT1 = PWM_CNT1 >> 1;        /*division by 2*/
PWM_CNT1 = PWM_CNT1 - 5;
TIMERB_Init(TIMER_FCPU_2);
TIMERB_PWM_Mode(TIMER_OUTPUT1_R, TIMER_OUTPUT2_F, PWM_CNT, PWM_CNT1);
Nop;
#endif
/*****
                SCI TRANSMIT TIME CALIBRATION
*****/
#ifdef SCI_CAL
#ifdef SCI_POLLING_TX
/*****
    SCI transmit time calibration for 9600 baudrate at fcpu=2MHz, this
    communication is done with Hyperterminal of PC with the configuration:
    baudrate=9600, Databits-8, stop bit-1, parity-None and Flowcontrol-None
*****/
CALTR_TEMP = (float) (13 * fraction);
/*****Value 13 = PR*TR*ETPR, where PR=TR=1. ETPR = 13*****/
CALTR = (char) (13 * fraction);
CALTR_TEMP = (float) (CALTR_TEMP - CALTR);
if (CALTR_TEMP > 0.5)
{
    CALTR = CALTR + 1;
}
/*****SCI library called to send the message on Hyperterminal*****/
SCI_Init(SCI_DEFAULT_PARAM1, SCI_DEFAULT_PARAM2);
SCI_Extend_Baudrate(SCI_PR_1 + SCI_TR_1 + SCI_RR_1, CALTR, CALTR);
SCI_Mode(SCI_TX_ENABLE);
SCI_PutBuffer(buff1, sizeof (buff1));
SCI_PutByte(0x55);
while (!(SCI_IsTransmitCompleted()));
#endif
#endif
}
/*****
                END OF MAIN
*****/
/*****
Interrupt Subroutine for TIMER
*****/
#ifdef _HIWARE_          /* test for HIWARE Compiler */
#pragma TRAP_PROC SAVE_REGS /* additional registers will be saved */
#else
#ifdef _COSMIC_          /* test for Cosmic Compiler */
@interrupt             /* Cosmic interrupt handling */
#else#error"Unsupported Compiler!" /* Compiler Defines not found!*/
#endif
#endif
void TIMERA_IT_Routine ()
{
    if (!cap)
    {
```

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```
    while (TIMERA_Status_Flag(TIMER_FLAG_ICF1) != TRUE);
    cap++;
    capture1 = TIMERA_ICAP_Getvalue(TIMER_ICAP_1);
    TIMERA_Clear_Flag(TIMER_FLAG_ICF1);
}
else if (cap)
{
    while (TIMERA_Status_Flag(TIMER_FLAG_ICF1) != TRUE);
    capture2 = TIMERA_ICAP_Getvalue(TIMER_ICAP_1);
    TIMERA_Clear_Flag(TIMER_FLAG_ICF1);
    cap++;
}
}
/**** (c) 2002 STMicroelectronics *****/
```

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