Driving a Buzzer through ST7 Timer PWM Function

by 8-Bit Micro Application

INTRODUCTION

The purpose of this note is to present how to use the ST7 Timer for the generation of a PWM signal tunable in frequency and duty cycle. As an application example, this document is based on a basic “music” synthesizer through an external buzzer.

1 ST7 TIMER PWM MODE

In this part the main PWM features of the ST7 Timer are pointed out. Please refer to the ST7 datasheet for more details.

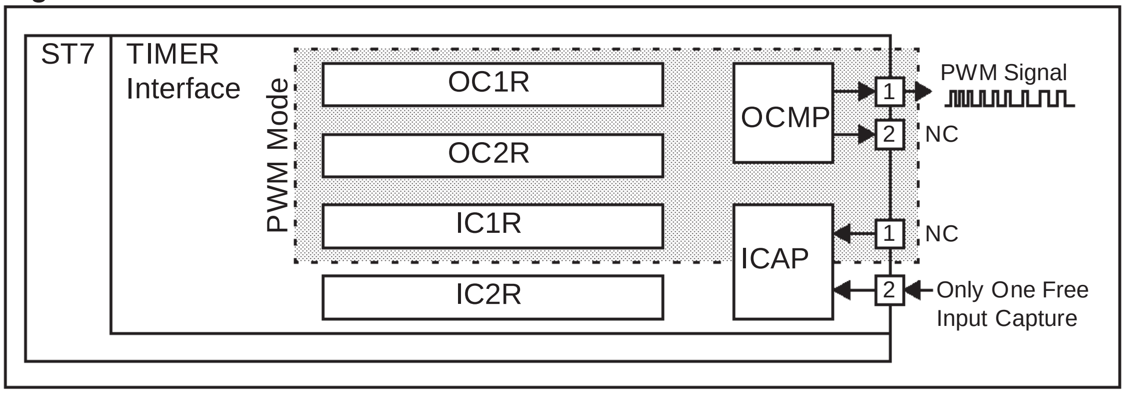
In the ST7 Timer, the PWM mode uses the following timer functions (see Figure 1.) :

– Output Compare 1 and 2 (including OCMP pins)

– Input Capture 1 (including ICAP1 pin)

This mode enables a PWM signal generation on the OCMP1 pin with a frequency and pulse length defined by the value of the OC1R and OC2R registers.

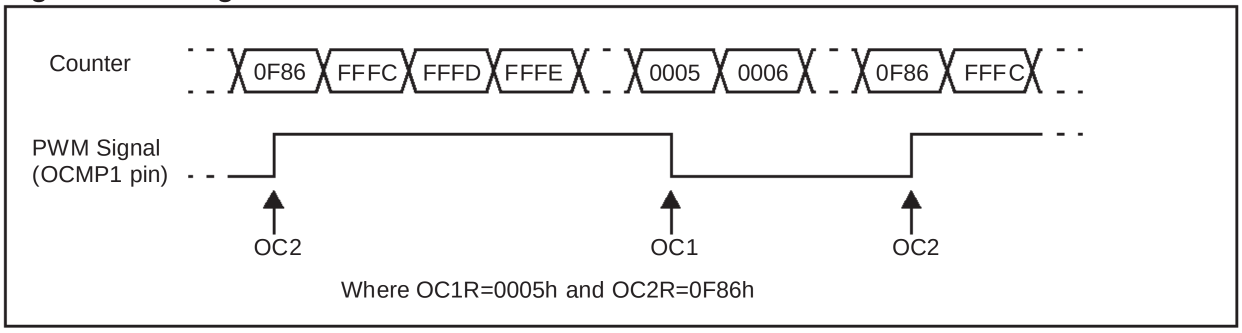
Figure 1. PWM Mode of the ST7 Timer



This PWM mode is selected setting the PWM and OC1E bits of the Control Register 2 (CR2).

The value written in the OC1R register corresponds to the elapsed time when the OCMP1 pin is maintained to Vss in a period time given by OC2R register (see Figure 2.). To insure these transitions the OLVL1 bit of the Control Register 1 (CR1) is cleared and the OLVL2 bit of the same register is set.

Figure 2. Timing of the ST7 Timer PWM Mode



2 TONE NOTE GENERATION (FREQUENCY)

In a basic music synthesizer application the tone note is given by the output frequency of the microcontroller input of the buzzer (see Table 1). In the ST7 Timer interface this frequency is given by the value written in the OC2R register.

To ensure the best accuracy, the fastest timer free running counter speed has to be chosen. Then, in front of the required frequencies and a f_{CPU} at 4-MHz the best timer clock prescaler is $f_{CPU}/2$ (CC1,CC0=”01” in the CR2 register).

As the free running counter of the ST7 Timer (in PWM mode) is reloaded with FFFCh when it matches the Output Compare 2, the corresponding time base for each note is given by the following equation in Table 1.

$$OC2R = \frac{f_{CPU}/2}{f_{TONE}}$$

Table 1. Rough Frequencies of the Basic Music Tones

Music Tone Notes	**SI_0**	**DO**	**RE**	**MI**	**FA**	**SOL**	**LA**	**SI**	**DO_2**
Tone Frequency [Hz]	503	524	587	662	701	787	878	1004	1048
OC2R [hex]	0F86	0EE4	0D4A	0BC8	0B20	09E8	08E1	07C3	0774

The “mute” tone can be obtained through a constant level on the pin. This level is obtained when OC2R < OC1R.

3 MUSIC VOLUME SETTING (DUTY CYCLE)

The volume control of the basic music synthesizer is done by the duty cycle control of the generated PWM signal. In timer PWM mode, this control is done through the OC1R register for each music tone notes (see Table 2).

The volume control scale depends on the chosen buzzer. The scale chosen in this application has 255 different steps. It is based on an around 0.25% high level duty cycle which allows a range of possible high duty cycle between ~0.25% and ~64%.

Table 2. Rough High Duty Cycle Bases of the Basic Music Tones

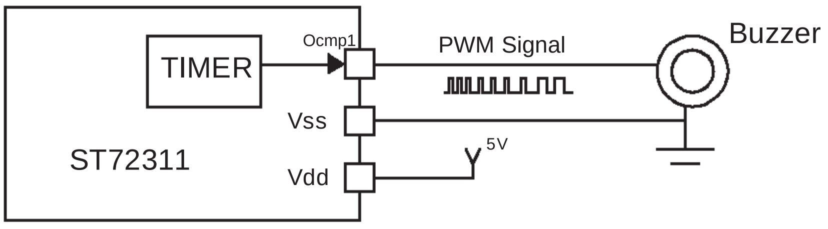
Music Tone Notes	**SI_0**	**DO**	**RE**	**MI**	**FA**	**SOL**	**LA**	**SI**	**DO_2**
OC2R [hex]	0F86	0EE4	0D4A	0BC8	0B20	09E8	08E1	07C3	0774
OC1R [hex]	000A	0009	0008	0007	0007	0006	0005	0005	0004
Duty cycle base [%]	0.25	0.24	0.24	0.23	0.25	0.24	0.22	0.25	0.21

4 BASIC MUSIC SYNTHESIZER APPLICATION

4.1 HARDWARE CONFIGURATION

The basic music synthesizer application hardware is made of a ST72311 microcontroller timer which generates a PWM signal to a buzzer VSB35EW-0701B (MURATA) as described in Figure 3.

Figure 3. Basic Music Synthesizer Application



4.2 MUSIC SCORE

A music score is made of a sequence of 8-bit information data which can be:

– a coded music note

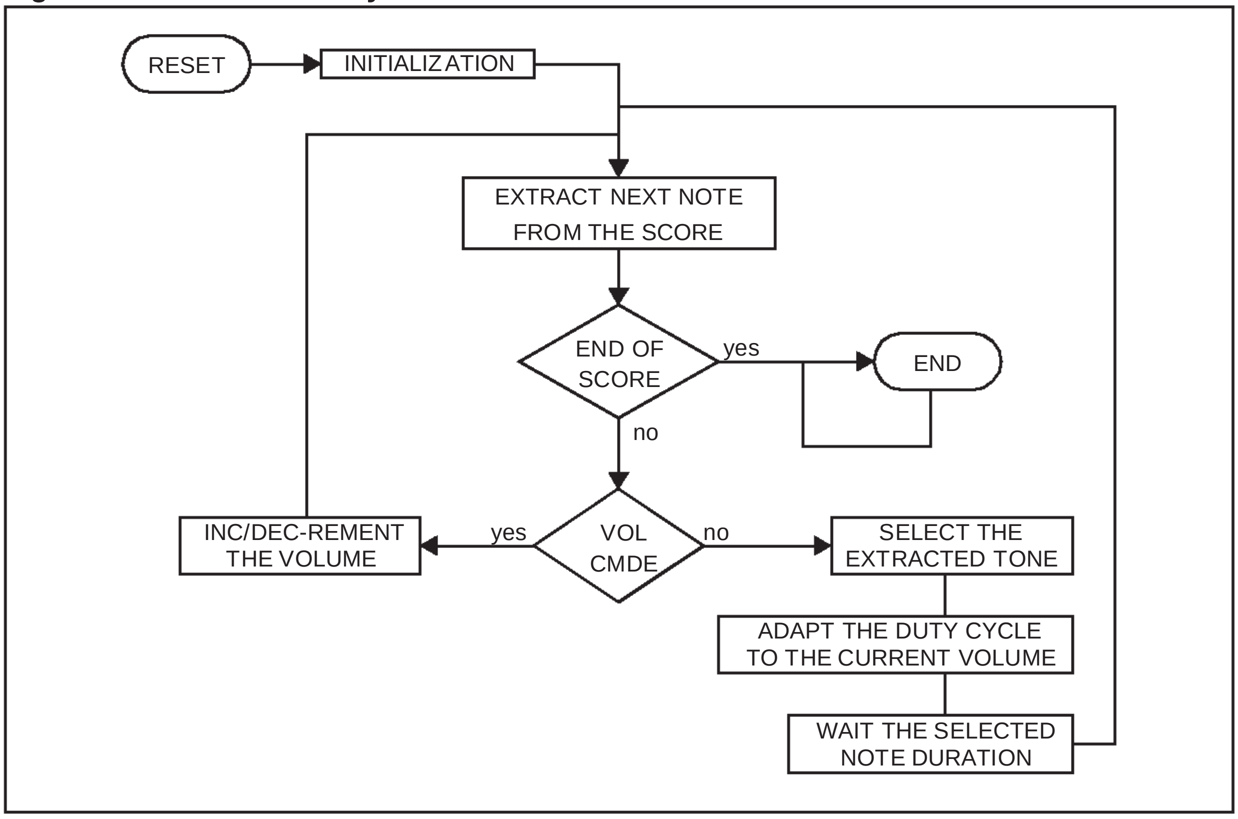
– a mute command

– a volume control command

– a score “end” flag.

The flowchart given in Figure 4. shows how a music score is played in this synthesizer application.

Figure 4. Music Score Play Flowchart

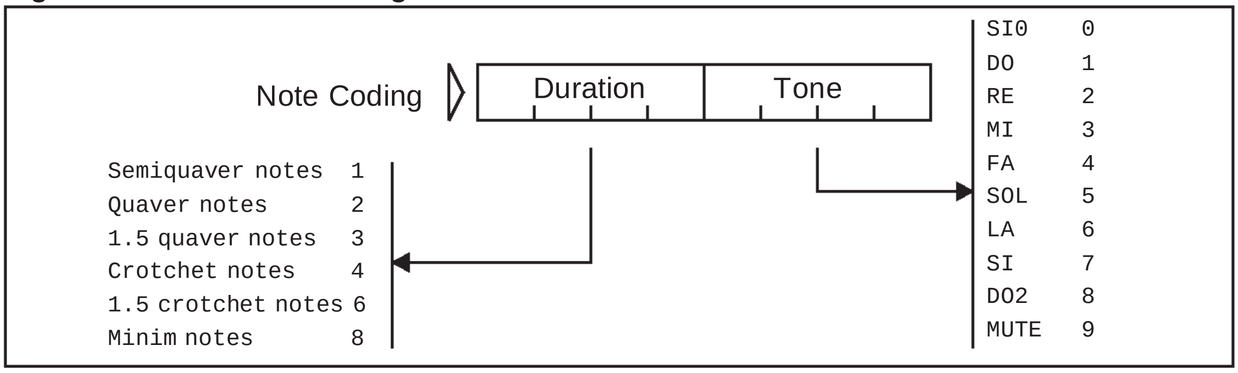

RESET
INITIALIZATION
EXTRACT NEXT NOTE FROM THE SCORE
END OF SCORE
yes
END
no
VOL CMDE
yes
INC/DEC-REMENT THE VOLUME
no
SELECT THE EXTRACTED TONE
ADAPT THE DUTY CYCLE TO THE CURRENT VOLUME
WAIT THE SELECTED NOTE DURATION

4.3 MUSIC NOTE CODING

To insure an easy music score management, a tricky music note coding is implemented. Each note is composed of two different fields: its tone (frequency) and its duration. These two fields are coded in one data byte as it is shown in Figure 5.

In this application, the music note range is based on an enhanced octave and a mute command.

Figure 5. Music Note Coding



The note duration field is based on a polling wait loop with a same tone. The coded duration [1,2,3,4,6,8] corresponds to the time of basic loop to be computed.

The tone information gives the index in the Output Compare registers table where the music note frequency and their duty cycle are coded (see Table 2). The mute index corresponds to a non audible frequency not shown in the table.

The initialization corresponds to a 100% duty cycle producing a mute tone.

4.4 VOLUME CONTROL

The volume is controlled through the duty cycle of the PWM signal.

A basic duty cycle is associated to each note as it is mentioned in Table 2. From this basic duty cycle, the volume is determined thanks to an 8-bit variable which allows 255 steps.

The volume change during a score is done through two different 8-bit commands which allow a decrement (F0h) or an increment (F1h) of the volume.

The initial volume level is given by the minimum high duty cycle which means around 0.25%.

5 SOFTWARE

The assembly code given below is for guidance only. For missing label declaration please refer to the register label description of the datasheet or the ST web software library (“ST72311 .inc” file...).

```
st7/
;***************** (c) 1998 STMicroelectronics ***********************
; PROJECT  : DRIVING BUZZER THROUGH ST7 TIMER PWM DEMO SYSTEM
; COMPILER : ST7 ASSEMBLY CHAIN
; MODULE  :  tim_buzz.asm
; CREATION DATE : 10/04/98
; AUTHOR : 8-Bit Micro Application Team
;-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
;   THE SOFTWARE INCLUDED IN THIS FILE IS FOR GUIDANCE ONLY. STMicroelectronics
;   SHALL NOT BE HELD LIABLE FOR ANY DIRECT, INDIRECT OR CONSEQUENTIAL
;   DAMAGES WITH RESPECT TO ANY CLAIMS ARISING FROM USE OF THIS SOFTWARE.
;-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
; DESCRIPTION :  ST7 Timer PWM software driver for Buzzer application.
;******************************************************************************

       TITLE   ”TIM_BUZZ.ASM”
       MOTOROLA
       #INCLUDE ”ST72311.inc”    ; ST72311 registers and memory mapping file.

;******************************************************************************
;    Macro definitions
;******************************************************************************

; Music instruction and note coding ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
       #define _END_   $FF                                 ; Music END.
       #define _VOLd   $F0                      ; Music volume decrement.
       #define _VOLi   $F1                      ; Music volume increment.

       ; Note tone definition.........................
       #define _SI0    {$00                                     ; SI-.
       #define _DO     {$01                                      ; DO.
       #define _RE     {$02                                      ; RE.
       #define _MI     {$03                                      ; MI.
       #define _FA     {$04                                      ; FA.
       #define _SOL    {$05                                     ; SOL.
       #define _LA     {$06                                      ; LA.
       #define _SI     {$07                                      ; SI.
       #define _DO2    {$08                                     ; DO+.
       #define _M      {$09                                    ; MUTE.

       ; Note length definition.......................
       #define sq      +$10}                          ; Semiquaver notes.
```

```
       #define q       +$20}                                      ; Quaver notes.
       #define qp      +$30}                                  ; 1.5 quaver notes.
       #define c       +$40}                                    ; Crotchet notes.
       #define cp      +$60}                                ; 1.5 crotchet notes.
       #define m       +$80}                                       ; Minim notes.

;******************************************************************************
;    RAM SEGMENT
;******************************************************************************

       BYTES                          ; following addresses are 8 bit length
       segment byte at 80-FF 'ram0'

.DutyCycle  DS.B  1                         ; DutyCycle percentage in [0..99].

;******************************************************************************
;    ROM SEGMENT
;******************************************************************************

       WORDS
       segment 'rom'

; Music note coding ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
;                 SI0 DO  RE  MI  FA  SOL LA  SI  DO2 MUTE
.Note_h     DC.B  $0F,$0E,$0D,$0B,$0B,$09,$08,$07,$07,$00   ; OCR1 high byte
.Note_l     DC.B  $86,$E4,$4A,$C8,$20,$E8,$E1,$C3,$74,$44    ; OCR1 low byte
.DutyTime   DC.B  $0A,$09,$08,$07,$07,$06,$05,$05,$04,$88    ; ~0.25% at Vdd

.Score  ; Music score ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

       ; "Au clair de la Lune..."
       DC.B  _M m,_DO c,_M sq,_DO c,_M sq,_DO c,_RE c,_MI m,_RE m,_M sq
       DC.B  _DO c,_MI c,_RE c,_M sq,_RE c,_DO m,_VOLi,_VOLi,_VOLi

       ; "J'ai du bon tabac..."
       DC.B  _M m,_DO c,_RE c,_MI c,_DO c,_RE m,_M sq,_RE c,_MI c,_FA c,_M sq
       DC.B  _FA cp,_MI c,_M sq,_MI cp,_M c,_DO c,_RE c,_MI c,_DO c,_RE m
       DC.B  _M sq,_RE c,_MI c,_FA m,_SOL m,_DO m,_DO m,_VOLi,_VOLi,_VOLi

       ; "Hymne a la joie"
       DC.B  _M m,_MI c,_M sq,_MI c,_FA c,_SOL c,_M sq,_SOL c,_FA c,_MI c
       DC.B  _RE c,_DO c,_M sq,_DO c,_RE c,_MI c,_M sq,_MI m,_RE m,_MI c
       DC.B  _M sq,_MI c,_FA c,_SOL c,_M sq,_SOL c,_FA c,_MI c,_RE c,_DO c
       DC.B  _M sq,_DO c,_RE c,_MI c,_RE m,_DO m,_VOLi,_VOLi,_VOLi

       ; "Star War"
       DC.B  _M m,_DO m,_SOL m,_FA q,_MI q,_RE q,_DO2 m,_SOL m
       DC.B  _FA q,_MI q,_RE q,_DO2 m,_SOL m,_FA q,_MI q,_FA q,_RE m,_RE m
       DC.B  _M c,_DO m,_SOL m,_FA q,_MI q,_RE q,_DO2 m,_SOL m
```

```
       DC.B _FA q,_MI q,_RE q,_DO2 m,_SOL m,_FA q,_MI q,_FA q,_RE m,_RE m
       DC.B _M c,_DO m,_FA c,_MI c,_RE c,_DO c,_M sq
       DC.B _DO qp,_RE q,_DO q,_SI0 c,_DO c,_RE c,_M q,
       ; ”End”
       DC.B _M m,_END_

; Program code *****************************************************************

;    ************************************
;    *    SUB-ROUTINES LIBRARY SECTION *
;    ************************************

; ------------------------------------------------------------------------------
; ROUTINE NAME : TBuzz_Init
; INPUT/OUTPUT : None.
; DESCRIPTION  : TIMER initialization for PWM mode.
; COMMENTS    :
; ------------------------------------------------------------------------------
.TBuzz_Init   ; IN: None / OUT: None.
       BRES PFOR,#4
       BSET PFDDR,#4   ; PF4 (OCMP1 of timer A used for the buzzer) is defined as an output.
       BRES TACR1,#0     ; OLVL1=0: Vss applied on OCMP1 pin when OC1 occures.
       BSET TACR1,#2     ; OLVL2=1: Vdd applied on OCMP1 pin when OC2 occures.
       LD   A,#%10010100                  ; OC1E=1 OCMP1 pin is activated.
       LD   TACR2,A                            ;  PWM=1 Active the PWM mode.
                                              ; CC10=01 Timer clock=Fcpu/2.
       CLR  A                        ; Nothing on the output OC1R=0 and OC2R=0.
       LD   TAOC1HR,A
       LD   TAOC2HR,A
       LD   TAOC2LR,A
       INC  A                             ; 100% Duty cycle at initialization.
       LD   TAOC1LR,A
       LD   A,#1                            ; 0.25% DutyCycle for Music score.
       LD   DutyCycle,A
       RET

; ------------------------------------------------------------------------------
; ROUTINE NAME : TBuzz_Wait
; INPUT/OUTPUT : Note duration (4bit MSB information) / None.
; DESCRIPTION  : Polling wait routine for note duration (based on 250ms delay).
; COMMENTS    : Quaver (Y=2), crotchet (Y=4) or minim (Y=8) duration selection
; ------------------------------------------------------------------------------
.TBuzz_Wait   ; IN: Y=duration / OUT: None.
       LD   A,Y
       SWAP A
       AND  A,#$0F                          ; Use only the rythme information.
       LD   Y,A
.Tbwt1 LD   X,#13
.Tbwt2 LD   A,#255
```

```
.Tbwt3 DEC  A
       JRNE Tbwt3
       DEC  X
       JRNE Tbwt2
       DEC  Y
       JRNE Tbwt1
       RET


; ----------------------------------------------------------------------------
; ROUTINE NAME : TBuzz_ChgDuty
; INPUT/OUTPUT : Note Index / None.
; DESCRIPTION  : Change the PWM duty cycle in the TIMER for the volume.
; COMMENTS     : Select the music volume for the current note.
; ----------------------------------------------------------------------------
.TBuzz_ChgDuty  ; IN: X=Note Index / OUT: None.
       LD   Y,DutyCycle               ; The duty cycle is given by the ratio
       LD   A,(DutyTime,X)        ; between the period length which gives the
       MUL  Y,A                   ; the frequency (OC2 registers) and the OC1
       LD   TAOC1HR,Y                                         ; registers.
       LD   TAOC1LR,A
       RET


; ----------------------------------------------------------------------------
; ROUTINE NAME : TBuzz_ChgFreq
; INPUT/OUTPUT : New note (4bit LSB information) / None.
; DESCRIPTION  : Change the PWM frequency in the TIMER for the music tone.
; COMMENTS     : Select the music volume for the current note.
; ----------------------------------------------------------------------------
.TBuzz_ChgFreq ; IN: A=New note / OUT: None.
       AND  A,#$0F                          ; Use only the note information.
       LD   X,A
       LD   A,(Note_h,X)            ; The frequency is given by the PWM period
       LD   TAOC2HR,A                       ; set through the OC2 registers.
       LD   A,(Note_l,X)
       LD   TAOC2LR,A
       RET


; ----------------------------------------------------------------------------
; ROUTINE NAME : TBuzz_PlyScor
; INPUT/OUTPUT : None.
; DESCRIPTION  : Play a music score.
; COMMENTS     :
; ----------------------------------------------------------------------------
.TBuzz_PlyScor ; IN: None / OUT: None.
       CLR  X
.Plyscr LD   A,(Score,X)                  ; Extract the note from the score.
```

```
       CP   A,#_END_                        ; Check if the score is finshed.
       JREQ Plyend
       CP   A,#_VOLd       ; Check if it is a volume instruction to be decode.
       JRULTPlynot
       JREQ Plydec    ; Decoding of a volume control instruction in the score.
       INC  DutyCycle                              ; Volume increment decoded.
       JRT  Plynxt
.PlydecDEC  DutyCycle                              ; Volume decrement decoded.
       JRT  Plynxt                        ; Next note or instruction in score.
.PlynotPUSH X                             ; Push X to be used in TBuzz_ChgFreq.
       PUSH A              ; A used in TBuzz_ChgFreq: Push A for the rythme.
       CALL TBuzz_ChgFreq     ; Change the music tone according to the score.
       CALL TBuzz_ChgDuty                ; Change or update the volume level.
       POP  Y                                           ; Load Y for the rythme.
       CALL TBuzz_Wait              ; Polling wait routine for note duration.
       POP  X                     ; Restore the score counter in X from stack.
.PlynxtINC  X; Next note.
       JRA  Plyscr
.PlyendRET


;    *******************************
;    *     MAIN-ROUTINES SECTION *
;    *******************************

.main  CALL TBuzz_Init                             ; Init TIMER peripheral.
.end   CALL TBuzz_PlyScor                                      ; Play score.
       JRA  end                                         ; Infinity main loop.


;    ********************************************
;    * INTERRUPT SUB-ROUTINES LIBRARY SECTION *
;    ********************************************

.dummy_rt   iret            ; Empty subroutine. Go back to main (iret instruction).

       segment 'vectit'
             DC.W   dummy_rt         ; FFF0-FFF1h location
             DC.W   dummy_rt         ; FFF2-FFF3h location
             DC.W   dummy_rt         ; FFF4-FFF5h location
sci_it:      DC.W   dummy_rt         ; FFE6-FFE7h location
timb_it:     DC.W   dummy_rt         ; FFE8-FFE9h location
tima_it:     DC.W   dummy_rt         ; FFEA-FFEBh location
spi_it:      DC.W   dummy_rt         ; FFEC-FFEDh location
             DC.W   dummy_rt         ; FFEE-FFEFh location
ext3_it:     DC.W   dummy_rt         ; FFF0-FFF1h location
ext2_it:     DC.W   dummy_rt         ; FFF2-FFF3h location
ext1_it:     DC.W   dummy_rt         ; FFF4-FFF5h location
ext0_it:     DC.W   dummy_rt         ; FFF6-FFF7h location
```

```
             DC.W   dummy_rt         ; FFF8-FFF9h location
             DC.W   dummy_rt         ; FFFA-FFFBh location
softit:      DC.W   dummy_rt         ; FFFC-FFFDh location
reset:       DC.W   main             ; FFFE-FFFEh location

       END
;*** (c) 1998 STMicroelectronics ********************** END OF FILE ****
```