Sound Effects for the COP800 Family

National Semiconductor
Application Note 663
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October 1989

This application note describes the creation of sound effects using National Semiconductor's COP800 family of microcontrollers. The following applications are described in detail:

1. Whistle
2. White Noise
3. Explosion
4. Bomb
5. Laser Gun

These applications were developed on a COP820C using a 20 MHz crystal and a 1 μs instruction cycle time. By making the appropriate changes to control registers within the routines, slower clock speeds may be used. Program flow diagrams and complete source codes are included in this document.

I. WHISTLE

The whistle routine utilizes the timer underflow interrupt and employs the TIO function on pin G3. Each timer underflow causes the TIO pin to toggle. This creates a tone whose frequency remains constant as long as the timer autoreload register value remains unchanged. In order to create a desending or ascending whistle tone, the autoreload register value is increased or decreased after every thirty-two timer interrupts (FCNTR register is used to count the interrupts). When the maximum or minimum frequency has been reached, the autoreload value must be reinitialized so that the whistle frequency does not exceed the desired range.

II. WHITE NOISE

White noise is generated by using a random number generating algorithm called a RING COUNTER. One random number is extracted periodically and placed into the MICROWIRE/PLUS™ serial shift register. These bits are shifted onto the serial output (SO) pin which is wired to a transistor amplifier that drives a speaker. The serial input (SI) and serial output (SO) pins must be tied together.

The RING COUNTER is a pseudo-random number generator which operates on the principle of a linear feedback shift register (see *Figure 1*). This shift register is not to be confused with the MICROWIRE/PLUS serial shift register. Rather it is created using two bytes of data memory (RAM), and the carry flag. Each bit is called a ''stage'' with the carry flag being ''stage 1'' and bit 0 of the two byte data register being ''stage 17''. Using a seventeen stage shift register results in a clean tone with little distortion.

Implementation of the ring counter shift register is accomplished by a rotate right with carry instruction (RRC A). The linear feedback function is accomplished using an ''exclusive or'' on stages fourteen and seventeen. This particular choice of feedback stages results in a complete cycle of bit combinations, ($2^{17} - 1$), as long as the loop does not begin with zero in the RNGVAL register.

The ''exclusive or'' function is not explicit in that the XOR instruction is not used. Rather, stages seventeen and fourteen are tested in software using the principle that if only one of them is set then the result is a logic one, otherwise the result is logic zero. It turns out that since the rotate occurs prior to the test, the actual bits tested are the carry flag (stage 1) and bit 2 (stage 15).

A short example using four bits can be used to demonstrate how the ring counter works (see *Figure 2*). If you perform the ''exclusive or'' on stages three and four, then a complete cycle results. If instead, you use stages two and four, two cycles of six and one cycle of three results depending on the bit combination you begin with.

III. EXPLOSION

The explosion sound effect is generated by manipulating the white noise algorithm to begin with a high pitch and progress to a lower pitch. This is done by altering the rate (contained in the register LUPREG) at which the random numbers are extracted from the ring counter before being placed into the MICROWIRE/PLUS serial shift register (SIOR). If for example LUPREG initially contains the value 4, the white noise will be at a high pitch. By incrementing this number after every ten timer interrupts (using the register TCNTR) the white noise pitch will be reduced. Several other registers are used to provide control of strategic portions of sound within the routine. First and last tones are controlled with FIRSTR and LASTR. The value in EXITR is used to control the overall length of the explosion and the length of each tone is controlled by the register TCNTR. To vary the white noise pitch, the register LUPCNT is used. The value in LUPCNT is incremented each time the pitch of the white noise is decreased within the timer interrupt routine. Prior to entering the ring count loop, LUPCNT is loaded into LUPREG. The serial input (SI) pin must be tied to the serial output (SO) pin.

IV. BOMB

The bomb sound effect combines the descending whistle with an explosion at the end. The TIMER I/O (TIO) and serial input (SI) pins must be tied to the serial output (SO) pin. The explosion portion of this routine was altered slightly in that the first tone control register (FIRSTR) was removed. The first initialization of TCNTR, the tone control register, provides a means to control the first tone length. Subsequent tones are controlled (at label NF2 in the timer interrupt routine) where TCNTR is reinitialized. Both versions were retained for comparison and in the event that greater control of the first tone is needed.

V. LASER GUN

The laser gun sound effect combines the output from the white noise routine and the COP800 timer I/O (TIO) pin (tie TIO to SO). The SI pin is not tied to SO in this application and the ring counter uses only nine stages instead of seventeen.

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RRD-B30M75/Printed in U. S. A.

The registers used for program control are EXITR, TCNTR, and the TIMER. By adjusting the value in EXITR the duration of the laser ''shot'' can be shortened or lengthened. (A value larger than 03F hex may create problems.) By adjusting the TIMER values (TVALO, TVALHI) and the tone counter (TCNTR) value, interesting variations in the laser sound can be attained.

NOTE: This note applies to all routines that use both the timer interrupt and the ring counter: In order to return to the main program from which the subroutine was called, the stack pointer must be manually restored during the timer interrupt before executing the return (RET) instruction. The reason for this is that the timer interrupt is two levels below the main program. A simple return statement will only serve to return to the ring counter routine from the point at which the timer interrupt occurred. By adding two to the stack pointer (SP + 2), the return statement will force the address of the instruction following the JSR in MAIN into the program counter (PC) from which point execution will continue.

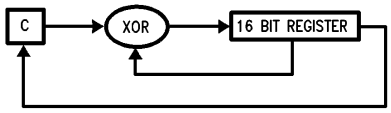

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FIGURE 1. 17 Stage Ring Counter

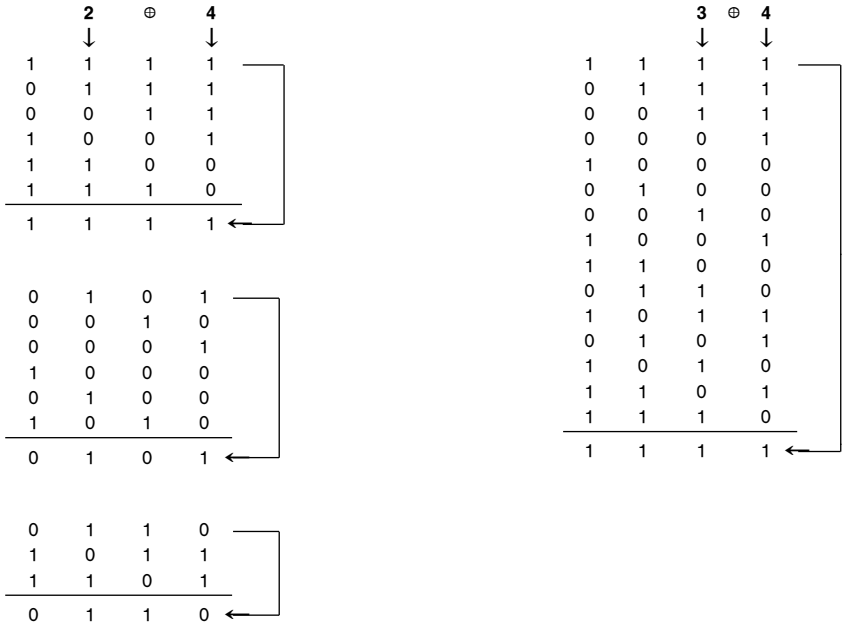
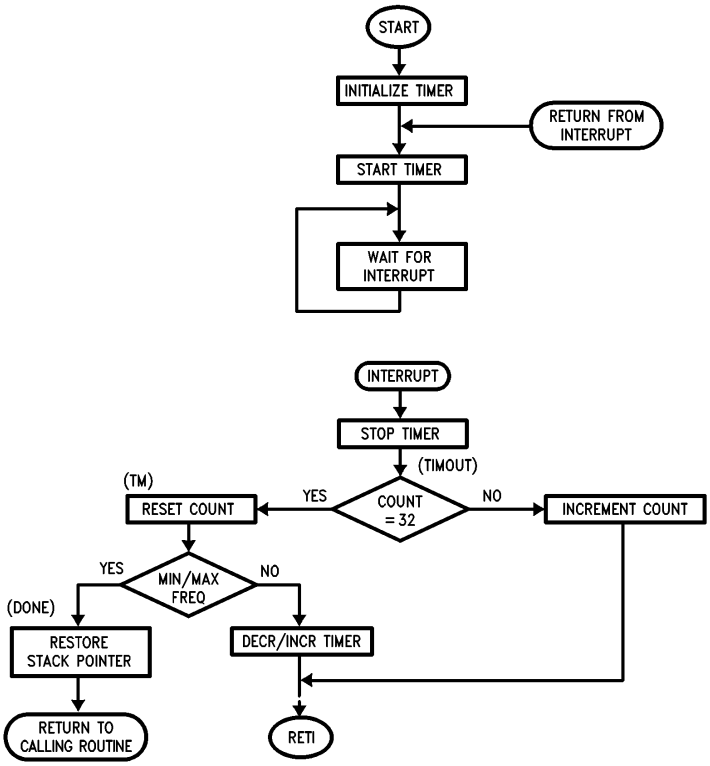


FIGURE 2. Example Showing Possible Cycles from a 4 Stage Ring Counter

Whistle Flow Diagram



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Descending Whistle

```
 1                      ;
 2                      ;
 3                      ; TIMER INTERRUPT IS USED.
 4                      ; OUTPUT ON TIMER I/O (TIO) PIN.
 5                      ; USE 20 MHz XTAL, 1 µs INSTR CYCLE FOR THIS DEMO.
 6                      ;
 7                      ; WRITTEN BY: JERRY LEVENTER
 8                      ; DATE:       OCTOBER 4, 1989
 9                      ;
10                             .TITLE WHISTLE1
11                             .CHIP   820
12                      ;
13       00D5                  PORTGC  =   0D5          ; PORT G CONFIGURATION
14       00E9                  SIOR    =   0E9          ; SIO SHIFT REGISTER
15       00EA                  TMRLO   =   0EA          ; TIMER LOW BYTE
16       00EB                  TMRHI   =   0EB          ; TIMER HIGH BYTE
17       00EC                  TAULO   =   0EC          ; TIMER REGISTER LOW BYTE
18       00ED                  TAUHI   =   0ED          ; TIMER REGISTER HIGH BYTE
19       00EE                  CNTRL   =   0EE          ; CONTROL REGISTER
20       00EF                  PSW     =   0EF          ; PSW REGISTER
21       0004                  TRUN    =   4
22       0005                  TPND    =   5
23       0002                  BUSY    =   2
24       0000                  GIE     =   0
25                      ;
26                      ; ****  SPECIAL REGISTERS AND CONSTANTS ****
27                      ;
28       002F                  WSLO    =   02F          ; TIMER VALUES
29       0000                  WSLHI   =   000
30       00F0                  FCNTR   =   0F0          ; FREQUENCY COUNT REGISTER
31       0000                  FCNT    =   000
32       00FF                  MINFREQ =   0FF          ; MIN FREQUENCY CONSTANT
33                      ;
34                      ; *********************************
35                      ; **** BEGIN DEMO PROGRAM HERE ****
36                      ; *********************************
37                      ;
38 0000  DD2F          MAIN:   LD      SP,#02F          ; DEFAULT INITIALIZATION OF SP
38 0002  3005                  JSR     WHISTLE          ; ***CALLING ROUTINE FOR DEMO***
40 0004  FF                    JP      .
41 0005  BCD508        WHISTLE:LD      PORTGC,#008      ; TIO PIN (G3) AS OUTPUT
42 0008  BCEEA2                LD      CNTRL,#0A2       ; PWM WITH TIO TOGGLE, 8Tc
43 000B  BCEA2F                LD      TMRLO,#WSLO      ; WHISTLE VALUE FOR TIMER
44 000E  BCEB00                LD      TMRHI,#WSLHI
45 0011  BCEC2F                LD      TAULO,#WSLO
46 0014  BCED00                LD      TAUHI,#WSLHI
47 0017  D000                  LD      FCNTR,#FCNT      ; INIT FREQ COUNT
48 0019  BCEF11        LUP:    LD      PSW,#011         ; ENTI, GIE = 1, TPND = 0
49 001C  BDEE7C                SBIT    TRUN,CNTRL       ; START TIMER
50 001F  FF                    JP      .                ; SELF LOOP TIL TIMER INTERRUPT
51 0020  F8                    JP      LUP              ; RUN TIL LAST HISTLE FREQ
52                      ;
53                      ; **** INTERRUPT ROUTINE ****
54                      ;
55       00FF                  .=0FF
56 00FF  BDEF75                IFBIT   TPND, PSW        ; TEST TIMER PENDING FLAG
57 0102  01                    JP      TIMOUT
58 0103  FF                    JP      .                ; ERROR
```

Descending Whistle (Continued)

```
59 0104  BDEE6C     TIMOUT: RBIT    TRUN,CNTRL       ; STOP THE TIMER
60 0107  BDF075             IFBIT   5,FCNTR          ; COUNT CYCLES
61 010A  06                 JP      TM
62 010B  9DF0               LD      A,FCNTR          ; INCREMENT COUNT
63 010D  8A                 INC     A
64 010E  9CF0               X       A,FCNTR
65 0110  8D                 RETSK
66 0111  D000       TM:     LD      FCNTR,#FCNT      ; RESET COUNT
67 0113  DEEC               LD      B,#TAUL0
68 0115  AE                 LD      A,[B]            ; CHANGE FREQUENCY
69 0116  92FF               IFEQ    A,#MINFREQ       ; TIMER = MIN FREQ?
70 0118  03                 JP      DONE             ; YES
71 0119  8A                 INC     A
72 011A  A6                 X       A,[B]            ; STORE FREQ IN AUTO RELOAD
73 011B  8D                 RETSK
74 011C  9DFD       DONE:   LD      A,SP             ; *** RESTORE STACK POINTER ***
75 011E  9402               ADD     A,#002           ; *** AND RETURN TO CALLING ***
76 0120  9CFD               X       A,SP             ; *** ROUTINE.              ***
77 0122  8E                 RET
78                          .END
```

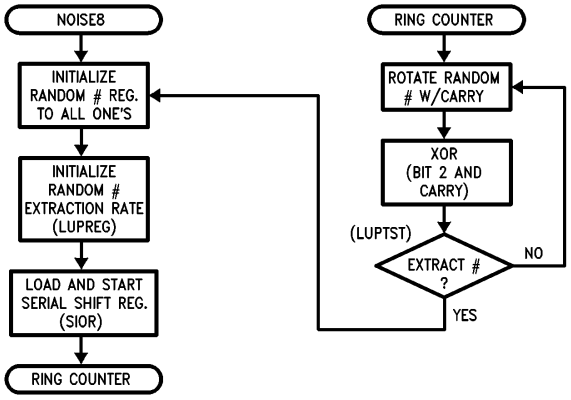
Ascending Whistle

```
 1                  ;
 2                  ;
 3                  ; OUTPUT ON TIMER I/O (TIO) PIN.
 4                  ; USES TIMER INTERRUT.
 5                  ; USE 20 MHz XTAL, 1 µs INSTR CYCLE FOR THIS DEMO.
 6                  ;
 7                  ; WRITTEN BY: JERRY LEVENTER
 8                  ; DATE:       OCTOBER 4, 1989
 9                  ;
10                  ;
11                        .TITLE WHISTLE2
12                        .CHIP   820
13                  ;
14       00D5             PORTGC  =   0D5          ; PORT G CONFIGURATION
15       00EA             TMRLO   =   0EA          ; TIMER LOW BYTE
16       00EB             TMRHI   =   0EB          ; TIMER HIGH BYTE
17       00EC             TAULO   =   0EC          ; TIMER REGISTER LOW BYTE
18       00ED             TAUHI   =   0ED          ; TIMER REGISTER HIGH BYTE
19       00EE             CNTRL   =   0EE          ; CONTROL REGISTER
20       00EF             PSW     =   0EF          ; PSW REGISTER
21       0004             TRUN    =   4
22       0005             TPND    =   5
23       0002             BUSY    =   2
24       0000             GIE     =   0
25                  ;
26                  ; **** SPECIAL REGISTERS AND CONSTANTS ****
27                  ;
28       00FF             WSLO    =   0FF          ; TIMER VALUES
29       0001             WSLHI   =   001
30       000A             MAXFREQ =   00A          ; LAST FREQUENCY CONSTANT
31       00F0             FCNTR   =   0F0          ; TIMER COUNT REGISTER
32       0010             FCNT    =   010          ; COUNTER CONSTANT
33                  ;
34                  ; *********************************
35                  ; ****    BEGIN PROGRAM HERE    ****
36                  ; ***************************** ****
37                  ;
38 0000  DD2F       MAIN:  LD      SP,#02F          ; DEFAULT INITIALIZATION OF SP
39 0002  3005              JSR     WHISTLE2         ; *** CALLING ROUTINE FOR DEMO ***
40 0004  FF                JP      .
41                  WHISTLE2:
42 0005  BCD508            LD      PORTGC,#008      ; TIO PIN (G3) AS OUTPUT
43 0008  BCEEA0            LD      CNTRL,#0A0       ; PWM WITH TIO TOGGLE,
44 000B  BCEAFF            LD      TMRLO,#WSLO      ; WHISTLE VALUE FOR TIMER
45 000E  BCEB01            LD      TMRHI,#WSLHI
46 0011  BCECFF            LD      TAULO,#WSLO
47 0014  BCED01            LD      TAUHI,#WSLHI
48 0017  D010              LD      FCNTR,#FCNT      ; INITIALIZE COUNTER
49 0019  BCEF11     LUP:   LD      PSW,#011         ; ENTI, GIE = 1, TPND = 0
50 001C  BDEE7C            SBIT    TRUN,CNTRL       ; START TIMER
51 001F  FF                JP      .                ; SELF LOOP UNTIL TIMER
52 0020  F8                JP      LUP              ; INTERRUPT
```

Ascending Whistle (Continued)

```
53                      ;
54                      ; **** INTERRUPT ROUTINE ****
55                      ;
56          00FF                .=0FF
57 00FF     BDEF75              IFBIT   TPND,PSW        ; TEST TIMER PENDING FLAG
58 0102     01                  JP      TIMOUT
59 0103     FF                  JP      .
60 0104     BDEE6C      TIMOUT: RBIT    TRUN,CNTRL      ; STOP THE TIMER
61 0107     BDF075              IFBIT   5,FCNTR         ; FREQUENCY TIMED OUT?
62 010A     06                  JP      TM              ; YES, CHANGE FREQUENCY
63 010B     9DF0                LD      A,FCNTR         ; NO, KEEP GOING
64 010D     8A                  INC     A               ; INCREMENT COUNT
65 010E     9CF0                X       A,FCNTR
66 0110     8D                  RETSK                   ; RETURN
67 0111     D010        TM:     LD      FCNTR,#FCNT     ; RESET COUNTER
68 0113     9DEC                LD      A,TAUL0         ; CHANGE FREQUENCY
69 0115     920A                IFEQ    A,#MAXFREQ      ; TIMER = MAX FREQUENCY ?
70 0117     05                  JP      DONE            ; YES
71 0118     94FF                ADD     A,#0FF          ; INCREMENT FREQUENCY
72 011A     9CEC                X       A,TAUL0         ; STORE FREQ IN AUTO RELOAD
73 011C     8D                  RETSK
74 011D     9DFD        DONE:   LD      A,SP            ; *** RESTORE STACK POINTER ***
75 011F     9402                ADD     A,#002          ; *** AND RETURN TO CALLING ***
76 0121     9CFD                X       A,SP            ; *** ROUTINE.              ***
77 0123     8E                  RET
78                      .END
```

White Noise



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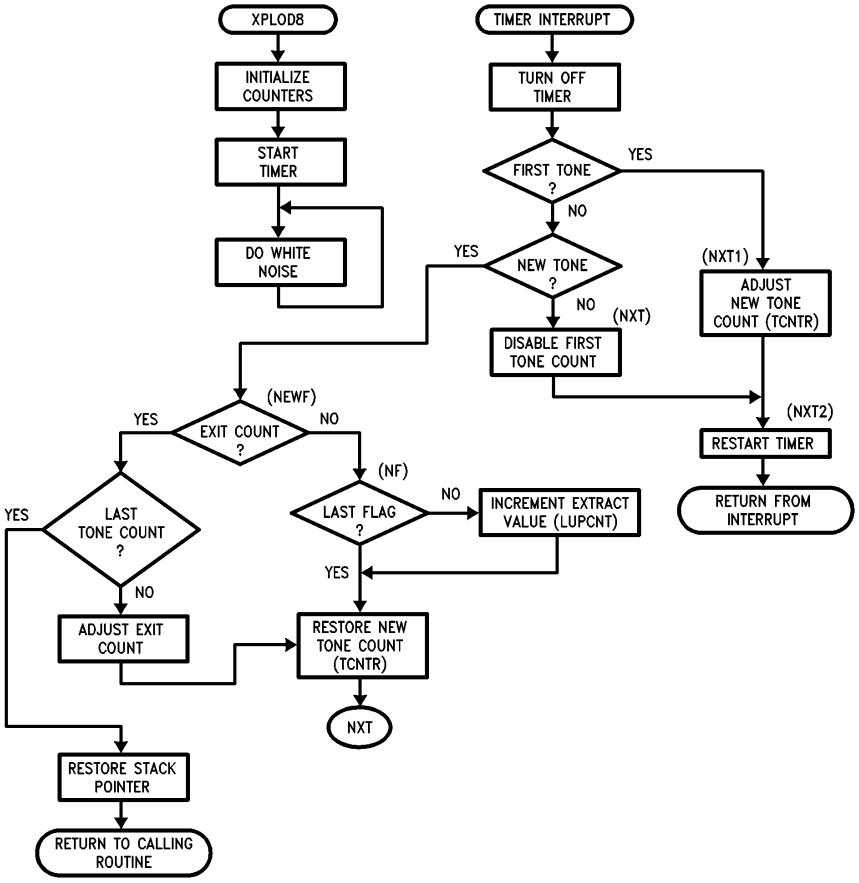
White Noise (Continued)

```
 1                      ;
 2                      ;
 3                      ;
 4                      ;
 5                      ; TIE SERIAL INPUT (SI)PIN TO SERIAL OUTPUT (SO) PIN.
 6                      ; OUTPUT IS ON THE SERIAL OUTPUT (SO) PIN.
 7                      ; NO INTERRUPT IS USED.
 8                      ; USE 20 MHz XTAL, 1 μs INSTR CYCLE FOR THIS DEMO.
 9                      ;
10                      ; WRITTEN BY: JERRY LEVENTER
11                      ; DATE:       OCTOBER 4, 1989
12                      ;
13                             .TITLE NOISE8
14                             .CHIP   820
15                      ;
16       00D5                  PORTGC  =   0D5          ; PORT G CONFIGURATION
17       00E9                  SIOR    =   0E9          ; SERIAL SHIFT REGISTER
18       00EA                  TMRLO   =   0EA          ; TIMER LOW BYTE
19       00EB                  TMRHI   =   0EB          ; TIMER HIGH BYTE
20       00EC                  TAULO   =   0EC          ; TIMER REGISTER LOW BYTE
21       00ED                  TAUHI   =   0ED          ; TIMER REGISTER HIGH BYTE
22       00EE                  CNTRL   =   0EE          ; CONTROL REGISTER
23       00EF                  PSW     =   0EF          ; PSW REGISTER
24       0002                  BUSY    =   2            ; BUSY BIT
25                      ;
26                      ; ****  SPECIAL REGISTERS AND CONSTANTS ****
27                      ;
28       0002                  RNGVAL  =   002          ; RANDOM NUMBER LOCATION
29       00FF                  LUPREG  =   0FF          ; EXTRACTION RATE REGISTER
30       0000                  FLAG    =   000          ; RANDOM NUMBER BYTE FLAG
31       0004                  COUNT   =   4            ; EXTRACTION RATE CONSTANT
32                      ;
33                      ; ********************************
34                      ; ****    BEGIN PROGRAM HERE       ****
35                      ; ****************************    ****
36                      ;
37 0000  DD2F                  LD      SP,#02F          ; DEFAULT INITIALIZATION OF SP
38 0002  BCD530         NOISE: LD      PORTGC,#030      ; SO AND SK AS OUTPUTS
39 0005  BCEE8B                LD      CNTRL,#08B       ; SK = DIV BY 8, TIMER RELOAD
40 0008  A1                    SC                       ; INIT STAGE 1
41 0009  5D                    LD      B,#RNGVAL        ; POINT TO RANDOM # LOCATION
42 000A  9AFF                  LD      [B+],#0FF        ; INIT RING VAL TO ONE'S
43 000C  9EFF                  LD      [B],#0FF         ; B POINTS TO UPPER BYTE
44 000E  9CE9           SHIFT: X       A,SIOR           ; PLACE # IN SIOR
45 0010  BDEF7A                SBIT    BUSY,PSW         ; START SHIFTING
46 0013  DF04                  LD      LUPREG,#004      ; RESTORE EXTRACTION COUNT
47                      ;
```

White Noise (Continued)

```
48                  ; ********************************************
49                  ; RING COUNTER (17 STAGE)
50                  ; THIS IS A SEVENTEEN STAGE RING COUNTER (LINEAR
51                  ; FEEDBACK SHIFT REGISTER) WITH THE RRC COMMAND.
52                  ; THE COUNTER'S 14TH AND 17TH STAGES THROUGH AN
53                  ; EXCLUSIVE-OR SERVE AS THE FEEDBACK FUNCTION.
54                  ; THIS 14, 17 RING COUNTER BREAKS DOWN INTO
55                  ; 1 CYCLE OF [(2 ** 17) - 1] COUNTS. SINCE THE EXCLUSIVE OR
56                  ; OCCURS AFTER THE ROTATE, IT IS THE 15TH AND CARRY
57                  ; STAGES THAT ARE XOR'D (BIT 2 AND CARRY).
58                  ;
59                  ;                      STAGE
60                  ;                    ---------------
61                  ; BEFORE ROTATE:       14   17
62                  ; AFTER ROTATE:        15   CARRY
63                  ;
64                  ; CARRY BIT = STAGE ONE
65                  ; LOW ORDER BIT = STAGE 17
66                  ; ********************************************
67                  ;
68 0015  AE          RING:   LD      A,[B]           ; GET RANDOM #
69 0016  B0                  RRC     A               ; ROTATE UPPER BYTE
70 0017  A3                  X       A,[B-]
71 0018  AE                  LD      A,[B]
72 0019  B0                  RRC     A               ; ROTATE LOWER BYTE
73 001A  A6                  X       A,[B]
74 001B  9804                LD      A,#004          ; PERFORM XOR
75 001D  85                  AND     A,[B]
76 001E  9200                IFEQ    A,#000
77 0020  05                  JP      LUPTST
78 0021  88                  IFC
79 0022  02                  JP      RC
80 0023  A1                  SC
81 0024  01                  JP      LUPTST
82 0025  A0          RC:     RC
83 0026  AA          LUPTST: LD      A,[B+]          ; POINT TO UPPER BYTE
84 0027  CF                  DRSZ    LUPREG          ; EXTRACT THIS NUMBER ?
85 0028  EC                  JP      RING            ; NO, KEEP ROTATING
86 0029  E4                  JP      SHIFT           ; YES, SEND IT
87                           .END
```

Explosion



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Explosion (Continued)

```
                        ;
                        ;
                        ; TIMER INTERRUPT IS USED.
                        ; SI MUST BE TIED TO SO. OUTPUT ON SO.
                        ; USE 20 MHz XTAL, 1 µs INSTR CYCLE FOR THIS DEMO.
                        ;
                        ; WRITTEN BY: JERRY LEVENTER
                        ; DATE:       OCTOBER 4, 1989
                        ;
                               .TITLE XPLOD8
                               .CHIP   820
                        ;
       00D5                    PORTGC  =   0D5          ; PORT G CONFIGURATION
       00E9                    SIOR    =   0E9          ; SIO SHIFT REGISTER
       00EA                    TMRLO   =   0EA          ; TIMER LOW BYTE
       00EB                    TMRHI   =   0EB          ; TIMER HIGH BYTE
       00EC                    TAULO   =   0EC          ; TIMER REGISTER LOW BYTE
       00ED                    TAUHI   =   0ED          ; TIMER REGISTER HIGH BYTE
       00EE                    CNTRL   =   0EE          ; CONTROL REGISTER
       00EF                    PSW     =   0EF          ; PSW REGISTER
       0004                    TRUN    =   4
       0005                    TPND    =   5
       0002                    BUSY    =   2
                        ;
                        ; ****  SPECIAL REGISTERS AND CONSTANTS ****
                        ;
                        ;       ANY REGISTER USED FOR THE DRSZ TEST MUST
                        ;       BE INITIALIZED TO AT LEAST "1".
                        ;
       00F5                    FIRSTR  =   0F5          ; FIRST TONE CONTROL REGISTER
       0002                     FIRST  =   002          ;  FIRST TONE CONSTANT
       00F6                    LASTR   =   0F6          ; LAST TONE CONTROL REGISTER
       0002                     LAST   =   002          ;  LAST TONE CONSTANT
       00F7                    EXITR   =   0F7          ; ROUTINE DURATION REGISTER
       0010                     EXIT   =   010          ;  EXIT CONSTANT
       0002                    RNGVAL  =   002          ; HOLDS CURRENT RANDOM #
       00F8                    TCNTR   =   0F8          ; TONE DURATION REGISTER
       000A                     TCNT   =   0A           ;  TONE CONSTANT
       0020                     TCNT1  =   020          ;   "FIRST" TONE CONSTANT
       00F9                    LUPREG  =   0F9          ; EXTRACTION RATE REGISTER
       0004                     XTRCT  =   004          ;  EXTRACT CONSTANT
       00FA                    LUPCNT  =   0FA          ; EXTRACTION VARIABLE REGISTER
       0000                    TEMP    =   000          ; LAST TONE FLAG
       00FF                    TVALO   =   0FF          ; TIMER VALUES
       0010                    TVALHI  =   010
                        ;
                        ; *********************************
                        ; ****    BEGIN PROGRAM HERE    ****
                        ; *********************************
                        ;
0000   DD2F             MAIN:   LD      SP,#02F          ; DEFAULT INITIALIZATION OF SP
0002   3005                     JSR     XPLOD            ; **** XPLOD CALLING ROUTNE ****
0004   FF                       JP      .                ; **** SELF LOOP FOR DEMO ****
0005   BCD530           XPLOD:  LD      PORTGC,#030
0008   BCEE8A                   LD      CNTRL,#08A       ; SK = DIV BY 8, PWM ON
000B   BCEF11                   LD      PSW,#011         ; ENABLE TIMER INTERRUPT
000E   BCEAFF                   LD      TMRLO,#TVALO     ; INITIALIZE TIMER
0011   BCEB10                   LD      TMRHI,#TVALHI
0014   BCECFF                   LD      TAULO,#TVALO
0017   BCED10                   LD      TAUHI,#TVALHI
```

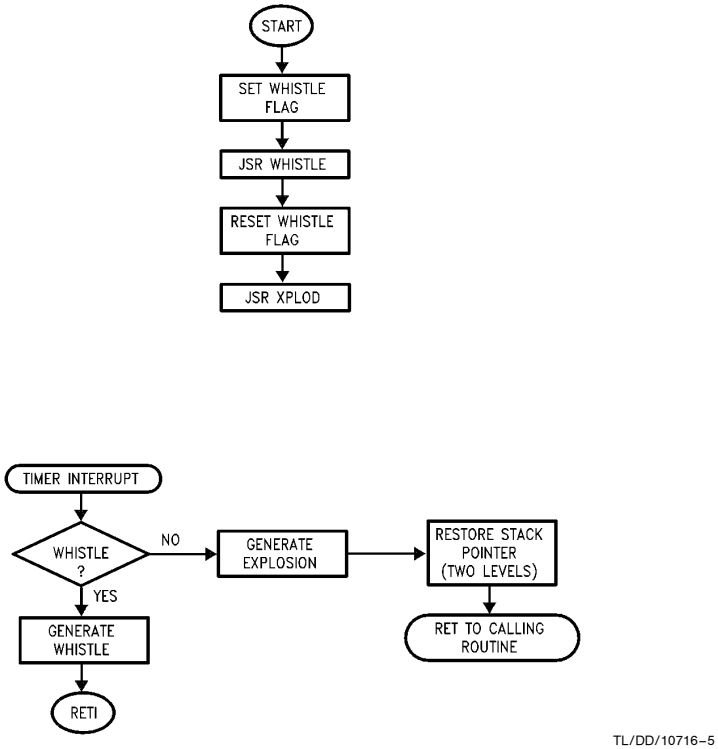
Explosion (Continued)

```
 61 001A  D502              LD      FIRSTR,#FIRST    ; LENGTHEN FIRST TONE
 62 001C  D602              LD      LASTR,#LAST      ; LENGTHEN LAST TONE
 63 001E  D710              LD      EXITR,#EXIT      ; INITIALIZE EXIT COUNT
 64 0020  D80A              LD      TCNTR,#TCNT      ; INITIALIZE TONE COUNT
 65 0022  DA04              LD      LUPCNT,#XTRCT    ; INITIALIZE EXTRACTION RATE
 66 0024  BD0068            RBIT    0,TEMP           ; RESET LAST TONE FLAG
 67 0027  BDEE7C            SBIT    TRUN,CNTRL       ; START TIMER
 68 002A  A1        NOISE:  SC                       ; INIT. STAGE 1
 69 002B  5D                LD      B,#RNGVAL        ; POINT TO RANDOM NUMBER
 70 002C  9AFF              LD      [B+],#0FF        ; INIT TO ALL ONE'S
 71 002E  9EFF              LD      [B],#0FF
 72 0030  9CE9      SHIFT:  X       A,SIOR           ; LOAD AND START SIOR
 73 0032  BDEF7A            SBIT    BUSY,PSW
 74 0035  9DFA              LD      A,LUPCNT         ; RESTORE EXTRACTION COUNT
 75 0037  9CF9              X       A,LUPREG
 76                 ;
 77                 ; *********************************
 78                 ; RING COUNTER (17 STAGE)
 79                 ;
 80                 ; THIS IS A SEVENTEEN STAGE RING COUNTER (LINEAR
 81                 ; FEEDBACK SHIFT REGISTER) WITH THE RRC COMMAND.
 82                 ; THE COUNTER'S 14th AND 17th STAGES THROUGH AN
 83                 ; EXCLUSIVE-OR SERVE AS THE FEEDBACK FUNCTION.
 84                 ; THIS 14, 17 RING COUNTER BREAKS DOWN INTO
 85                 ; 1 CYCLE OF [(2 ** 17) - 1] COUNTS. SINCE THE EXCLUSIVE OR
 86                 ; OCCURS AFTER THE ROTATE, IT IS THE 15th AND CARRY
 87                 ; STAGES THAT ARE XOR'D (BIT 2 AND CARRY).
 88                 ;
 89                 ;                    STAGE
 90                 ;                  ---------------
 91                 ; BEFORE ROTATE:     14   17
 92                 ; AFTER ROTATE:      15   CARRY
 93                 ;
 94                 ;  CARRY BIT = STAGE 1
 95                 ;  LOW ORDER BIT OF 16 BIT REGISTER = STAGE 17
 96                 ;  *********************************
 97                 ;
 98 0039  AE        RING:   LD      A,[B]            ; GET RANDOM #
 99 003A  B0                RRC     A                ; ROTATE UPPER BYTE
100 003B  A3                X       A,[B-]
101 003C  AE                LD      A,[B]
102 003D  B0                RRC     A                ; ROTATE LOWER BYTE
103 003E  A6                X       A,[B]
104 003F  9804              LD      A,#004           ; PERFORM XOR
105 0041  85                AND     A,[B]
106 0042  9200              IFEQ    A,#000
107 0044  05                JP      TSLUP
108 0045  88                IFC
109 0046  02                JP      RC
110 0047  A1                SC
111 0048  01                JP      TSTLUP
112 0049  A0        RC:     RC
113 004A  AA        TSTLUP: LD      A,[B+]           ; POINT TO UPPER BYTE
114 004B  C9                DRSZ    LUPREG           ; EXTRACT THIS # ?
115 004C  EC                JP      RING             ; NO, KEEP ROTATING
116 004D  AE                LD      A,[B]            ; YES
117 004E  E1                JP      SHIFT
```

Explosion (Continued)

```
118                 ;
119                 ; **** TIMER INTERRUPT ROUTINE ****
120                 ;
121       00FF      ;       .=      OFF
122 00FF  BDEF75              IFBIT   TPND,PSW        ; TEST TIMER PND FLAG
123 0102  02                  JP      TMOUT
124 0103  2005                JMP     XPLOD
125 0105  BDEE6C    TMOUT:    RBIT    TRUN,CNTRL      ; STOP TIMER
126 0108  DEFA                LD      B,#LUPCNT
127 010A  C5                  DRSZ    FIRSTR          ; TEST FOR FIRST TONE
128 010B  213B                JMP     NXT1            ; AND ADJUST
129 010D  C8                  DRSZ    TCNTR           ; TEST FOR NEW TONE
130 010E  01                  JP      NXT             ; NO
131 010F  0D                  JP      NEWF
132 0110  D501      NXT:      LD      FIRSTR,#1       ; DISABLE FIRST TONE REG
133 0112  BDEF7C    NXT2:     SBIT    4,PSW           ; ENABLE TIMER INTERRUPT
134 0115  BDEF6D              RBIT    5,PSW           ; RESET TPND FLAG
135 0118  5D                  LD      B,#RNGVAL       ; POINT TO RANDOM#
136 0119  BDEE7C              SBIT    TRUN,CNTRL      ; RESTART TIMER
137 011C  8F                  RETI                    ; RETURN
138 011D  C7        NEWF:     DRSZ    EXITR           ; TEST EXIT COUNT
139 011E  10                  JP      NF              ; NO
140 011F  C6                  DRSZ    LASTR           ; ENABLE LAST TONE
141 0120  01                  JP      LST
142 0121  06                  JP      NLST
143 0122  D709      LST:      LD      EXITR,#09       ; SET LAST TONE LENGTH
144 0124  BD0078              SBIT    0,TEMP          ; SET LAST TONE FLAG
145 0127  0F                  JP      NF2
146 0128  9DFD      NLST:     LD      A,SP            ; *** RESTORE STACK POINTER  ***
147 012A  9402                ADD     A,#002          ; *** FROM TIMER INTERRUPT   ***
148 012C  9CFD                X       A,SP            ; *** AND RETURN TO MAIN     ***
149 012E  8E                  RET
150 012F  BD0070    NF:       IFBIT   0,TEMP          ; LAST TONE ?
151 0132  04                  JP      NF2             ; YES
152 0133  AE                  LD      A,[B]           ; NEW TONE
153 0134  9404      NF4:      ADD     A,#04           ; INCR EXTRACTION VALUE
154 0136  A6                  X       A,[B]
155 0137  D80A      NF2:      LD      TCNTR,#TCNT     ; REINITIALIZE TONE TIME
156 0139  2110                JMP     NXT
157 013B  D820      NXT1:     LD      TCNTR,#TCNT1    ; ADJUST FIRST TONE LENGTH
158 013D  2112                JMP     NXT2
159                           .END
```

Bomb



TL/DD/10716–5

Bomb (Continued)

```
 1                ;
 2                ;
 3                ; THE SERIAL INPUT (SI) AND TIMER I/O (TIO) PINS
 4                ; MUST BE TIED TO THE SERIAL OUTPUT (SO) PIN.
 5                ; OUTPUT IS ON SO.
 6                ; USE 20 MHz XTAL, 1 µs INSTR CYCLE FOR THIS DEMO.
 7                ;
 8                ; WRITTEN BY: JERRY LEVENTER
 9                ; DATE:       OCTOBER 4, 1989
10                ;
11                ;
12                       .TITLE BOMB8
13                       .CHIP   820
14                ;
15       00D5            PORTGC  =   0D5          ; PORT G CONFIGURATION
16       00E9            SIOR    =   0E9          ; SIO SHIFT REGISTER
17       00EA            TMRLO   =   0EA          ; TIMER LOW BYTE
18       00EB            TMRHI   =   0EB          ; TIMER HIGH BYTE
19       00EC            TAULO   =   0EC          ; TIMER REGISTER LOW BYTE
20       00ED            TAUHI   =   0ED          ; TIMER REGISTER HIGH BYTE
21       00EE            CNTRL   =   0EE          ; CONTROL REGISTER
22       00EF            PSW     =   0EF          ; PSW REGISTER
23       0004            TRUN    =   4
24       0005            TPND    =   5
25       0002            BUSY    =   2
26       0000            GIE     =   0
27                ;
28                ; ****  EXPLOSION REGISTERS AND CONSTANTS ****
29                ;
30                ; SOME OF THE FOLLOWING REGISTERS USE THE DRSZ
31                ; TEST AND MUST THEREFORE BE INITIALIED TO AT
32                ; LEAST "1".
33                ;
34       00F6            LASTR   =   0F6          ; CONTROL LAST TONE
35       0002             LAST   =   002          ; LAST TONE CONSTANT
36       0004             LAST2  =   004          ; EXIT CONSTANT
37       00F7            EXITR   =   0F7          ; TOTAL TIME TILL EXIT
38       0010             EXIT   =   010          ; EXIT CONSTANT
39       00F3            RNGVAL  =   0F3          ; HOLDS CURRENT RING VALUE
40       00F8            TCNTR   =   0F8          ; TIME FOR EACH TONE FREQ
41       000A             TCNT   =   0A           ; CONSTANT VALUE
42       00F9            LUPREG  =   0F9          ; TONE COUNT INSIDE RING
43       00FA            LUPCNT  =   0FA          ; TONE COUNT OUTSIDE RING (VARIABLE)
44       0000            FLAG    =   000          ; FLAG REGISTER FOR SUBROUTINES
45                ;
46       00FF            TVALO   =   0FF
47       001A            TVALHI  =   01A
48                ;
49                ;**** WHISTLE REGISTERS AND CONSTANTS ****
50                ;
51       002F            WSLO    =   02F          ; TIMER VALUES
52       0000            WSLHI   =   000
53       00FF            MINFQ   =   0FF          ; FINAL (LOW FREQ) TIMER VALUE
54                ;
55       00F0            FCNTR   =   0F0          ; FREQUENCY COUNT REGISTER
56       0000             FCNT   =   000
```

Bomb (Continued)

```
 57                     ;
 58                     ;  *********************************
 59                     MAIN:
 60 0000  DD2F                 LD      SP,#02F           ; DEFAULT INITIALIZATION OF SP
 61 0002  BD0078               SBIT    0,FLAG            ; SET SUBROUTINE FLAG
 62                                                      ; 1 = WHISTLE
 63                                                      ; 0 = EXPLOSION
 64 0005  3157                 JSR     WHISTLE
 65 0007  BD0068       MAIN2:  RBIT    0,FLAG
 66 000A  300D                 JSR     BOMB
 67 000C  FF                   JP      .                 ; *** STOP HERE OR REPEAT ***
 68                     ;  *********************************
 69                     ;
 70 000D  BCD530       BOMB:   LD      PORTGC,#030       ; CONFIGURE "S0" AS OUTPUT
 71 0010  BCEE8A               LD      CNTRL,#08A        ; SK = DIV BY 8, PWM ON
 72 0013  BCEF11               LD      PSW,#011          ; ENABLE TIMER INTERRUPT
 73 0016  BCEAFF               LD      TMRL0,#TVAL0      ; INITIALIZE TIMER
 74 0019  BCEB1A               LD      TMRHI,#TVALHI
 75 001C  BCECFF               LD      TAUL0,#TVAL0
 76 001F  BCED1A               LD      TAUHI,#TVALHI
 77 0022  D602                 LD      LASTR,#LAST       ; INITIALIZE LAST TONE FLAG
 78 0024  D710                 LD      EXITR,#EXIT       ; INITIALIZE EXIT COUNT
 79 0026  D80A                 LD      TCNTR,#TCNT       ; INITIALIZE TONE COUNT
 80 0028  DA0A                 LD      LUPCNT,#10        ; INITIALIZE FIRST TONE FREQUENCY
 81 002A  BD0069               RBIT    1,FLAG            ; RESET LAST TONE FLAG BIT
 82                     ;
 83 002D  A1           NOISE:  SC                        ;
 84 002E  DEF3                 LD      B,#RNGVAL         ; POINT TO RING VALUE
 85 0030  9AFF                 LD      [B+],#0FF         ; INIT TO ALL ONE'S
 86 0032  9EFF                 LD      [B],#0FF
 87 0034  BDEE7C               SBIT    TRUN,CNTRL        ; START THE TIMER
 88 0037  BEF6A        SHIFT:  RBIT    BUSY,PSW
 89 003A  9CE9                 X       A,SIOR            ; RANDOM # TO SIO
 90 003C  BDEF7A               SBIT    BUSY,PSW
 91 003F  9DFA                 LD      A,LUPCNT          ; RESTORE EXTRACTION COUNT
 92 0041  9CF9                 X       A,LUPREG
 93                     ;
 94                     ; *********************************
 95                     ; RING COUNTER (17 STAGE)
 96                     ;
 97                     ; THIS IS A SEVENTEEN STAGE RING COUNTER (LINEAR
 98                     ; FEEDBACK SHIFT REGISTER) WITH THE RRC COMMAND.
 99                     ; THE COUNTER'S 14th AND 17th STAGES THROUGH AN
100                     ; EXCLUSIVE-OR SERVE AS THE FEEDBACK FUNCTION.
101                     ; THIS 14, 17 RING COUNTER BREAKS DOWN INTO
102                     ; 1 CYCLE OF [(2 ** 17) - 1] COUNTS. SINCE THE EXCLUSIVE OR
103                     ; OCCURS AFTER THE ROTATE, IT IS THE 15th AND CARRY
104                     ; STAGES THAT ARE XOR'D (BIT 2 AND CARRY).
105                     ;
106                     ; BEFORE ROTATE: 14 17
107                     ; AFTER ROTATE:  15 CARRY
108                     ;
109                     ;  CARRY BIT = STAGE ONE
110                     ;  LOW ORDER BIT = STAGE 17
```

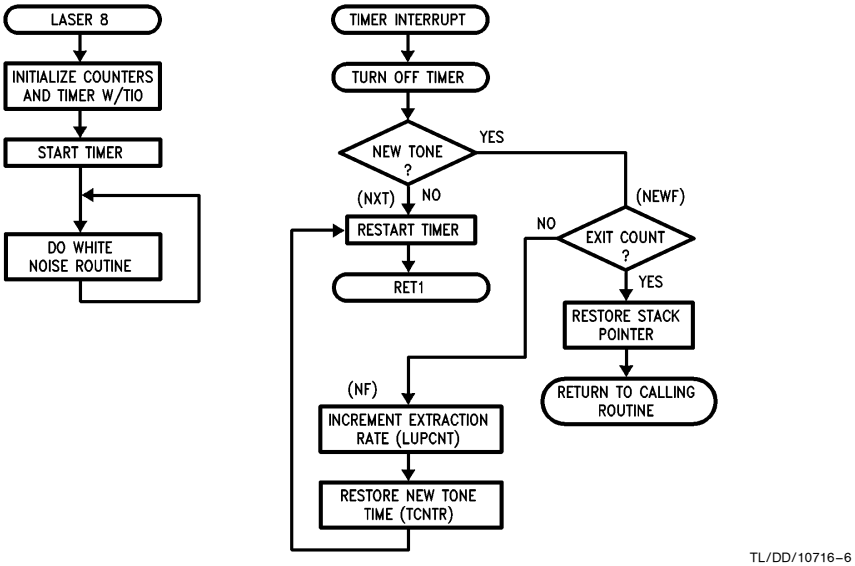
Bomb (Continued)

```
111                     ; ************************************
112 0043  AE            RING:  LD      A,[B]              ;  GET RANDOM #
113 0044  B0                   RRC     A                  ;  ROTATE UPPER BYTE
114 0045  A3                   X       A,[B-]
115 0046  AE                   LD      A,[B]
116 0047  B0                   RRC     A                  ;  ROTATE LOWER BYTE
117 0048  A2                   X       A,[B+]
118 0049  9804                 LD      A,#004             ;  PERFORM XOR
119 004B  85                   AND     A,[B]
120 004C  9200                 IFEQ    A,#000
121 004E  05                   JP      TSTLUP
122 004F  88                   IFC
123 0050  02                   JP      RC
124 0051  A1                   SC
125 0052  01                   JP      TSTLUP
126 0053  A0            RC:    RC
127 0054  C9            TSLUP: DRSZ    LUPREG             ;  POINT TO UPPER BYTE
128 0055  ED                   JP      RING               ;  EXTRACT THIS # ?
129 0056  AE                   LD      A,[B]              ;  NO, KEEP ROTATING
130 0057  2037                 JMP     SHIFT              ;  YES
131                     ;
132                     ; **** INTERRUPT ROUTINE ****
133                     ;
134       00FF                 .=      0FF
135 00FF  BDEF75               IFBIT   TPND,PSW           ;  TEST FOR EXIT
136 0102  01                   JP      TMOUT
137 0103  FF                   JP      .                  ;  ERROR
138                     ;
139 0104 BDEE6C         TMOUT  RBIT    TRUN,CNTRL         ;  STOP TIMER
140 0107 BD0070                IFBIT   0,FLAG             ;  BRANCH TO ROUTINE
141 010A  213B                 JMP     WSINT              ;  SET = WHISTLE, RESET = EXPLOSION
142                     ;
143 010C DEFA                  LD      B,#LUPCNT
144 010E C8                    DRSZ    TCNTR              ;  TEST FOR NEW TONE
145 010F 01                    JP      NXT                ;  NO, DON'T INCREMENT LUPCNT
146 0110 0C                    JP      NEWF               ;  YES
147 0111 BDEF7C         NXT:   SBIT    4,PSW              ;  ENABLE TIMER INTRRUPT
148 0114 BDEF6D                RBIT    5,PSW              ;  RESET TIMER PENDING FLAG
149 0117 DEF3                  LD      B,#RNGVAL          ;  POINT TO RANDOM #
150 0119 BDEE7C                SBIT    TRUN,CNTRL         ;  RESTART TIMER
151 011C 8F                    RETI                       ;  RETURN TO RING COUNTER
152 011D C7             NEWF:  DRSZ    EXITR              ;  DO LAST TONE ?
153 011E 10                    JP      NF                 ;  NO
154 011F  C6                   DRSZ    LASTR              ;  IS LAST TONE DONE?
155 0120  01                   JP      LST                ;  NO
156 0121  06                   JP      NLST               ;  YES, RETURN TO MAIN
157 0122  D704          LST:   LD      EXITR,#LAST2       ;  LENGTHEN THE LAST TONE
158 0124  BD0079               SBIT    1,FLAG             ;  SET LAST TONE FLAG
159 0127  0F                   JP      NF2
160 0128  9DFD          NLST:  LD      A,SP               ;  ** RESTORE STACK POINTER **
161 012A  9402                 ADD     A,#002             ;  ** AND RETURN TO MAIN    **
162 012C  9CFD                 X       A,SP
163 012E  8E                   RET
164                     ;
165 012F  BD0071        NF:    IFBIT   1,FLAG             ;  LAST TONE ?
166 0132  04                   JP      NF2                ;  YES, DON'T INCREMENT LUPCNT
167 0133  AE                   LD      A,[B]              ;  NEW TONE
168 0134  9404                 ADD     A,#04              ;  INCR EXTRACT COUNT (LUPCNT)
169 0136  A6                   X       A,[B]
170 0137  D80A          NF2:   LD      TCNTR,#TCNT        ;  REINITIALIZE TONE TIME
171 0139  2111                 JMP     NXT
```

Bomb (Continued)

```
172                     ; ************************************
173 013B  BDF075        WSINT:      IFBIT   5,FCNTR          ; READY FOR NEW FREQUENCY ?
174 013E  06                        JP      TM               ; YES
175 013F  9DF0                      LD      A,FCNTR          ; NO, INCREMENT COUNT
176 0141  8A                        INC     A
177 0142  9CF0                      X       A,FCNTR
178 0144  8D                        RETSK                    ; NO, RETURN TO WHISTLE
179 0145  D000          TM:         LD      FCNTR,#FCNT      ; RESET NEW FREQUENCY COUNT
180 0147  DEEC                      LD      B,#TAUL0         ; POINT TO AUTORELOAD REG
181 0149  AE                        LD      A,[B]            ; CHANGE FREQUENCY
182 014A  92FF                      IFEQ    A,#MINFQ         ; TIMER = MIN FREQ ?
183 014C  03                        JP      DONE
184 014D  8A                        INC     A
185 014E  A6                        X       A,[B]            ; STORE FREQ IN AUTO RELOAD
186 014F  8D                        RETSK
187 0150  9DFD          DONE:       LD      A,SP             ; ** RESTORE STACK POINTER **
188 0152  9402                      ADD     A,#002           ; ** AND RETURN TO MAIN    **
189 0154  9CFD                      X       A,SP
190 0156  8E                        RET
191                     ; ********************************
192 0157  BCD508        WHISTLE:    LD      P0RTGC,#008      ; TI0 PIN (G3) AS OUTPUT
193 015A  BCEEA2                    LD      CNTRL,#0A2       ; PWM WITH TI0 TIGGLE, 8Tc
194 015D  D000                      LD      FCNTR,#FCNT      ; INIT FREQ COUNTER
195 015F  BCEA2F                    LD      TMRL0,#WSL0      ; WHISTLE VALUE FOR TIMER
196 0162  BCEB00                    LD      TMRHI,#WSLHI
197 0165  BCEC2F                    LD      TAUL0,#WSL0
198 0168  BCED00                    LD      TAUHI,#WSLHI
199                     ;
200 016B  BCEF11        BEGIN       LD      PSW,#011         ; ENTI, GIE = 1, TPND = 0
201 016E  BDEE7C                    SBIT    TRUN,CNTRL       ; START TIMER
202 0171  FF                        JP      .                ; LOOP UNTIL TIMER INTERRUPT
203 0172  F8                        JP      BEGIN            ; RETURN HERE FROM INTERRUPT
204                                 .END
```

Laser Gun



TL/DD/10716–6

Laser Gun (Continued)

```
 1                      ;
 2                      ; TIMER INTERRUPT IS USED.
 3                      ; THE SERIAL OUTPUT PIN (SO) AND THE TIO PIN MUST BE
 4                      ; TIED TOGETHER.
 5                      ; OUTPUT IS ON SO AND TIO.
 6                      ;
 7                      ; TO ALTER THE DURATION OF THE LASER SHOT CHANGE THE
 8                      ; "EXIT" VALUE, HOWEVER, DO NOT EXCEED 03F HEX.
 9                      ; THE TIMER VALUES (TVALO, TVALHI) COMBINED WITH THE
10                      ; TONE COUNT (TNCTR) CAN BE ADJUSTED TO ACHIEVE A
11                      ; VARIETY OF SOUNDS.
12                      ;
13                      ; USE 20 MHz XTAL, 1 µs INSTR CYCLE TIME FOR THIS DEMO.
14                      ;
15                      ;
16                      ; WRITTEN BY: JERRY LEVENTER
17                      ; DATE:       OCTOBER 4, 1989
18                      ;
19                      ;
20                             .TITLE LASER8
21                             .CHIP   820
22                      ;
23       00D5                  PORTGC  =   0D5          ; PORT G CONFIGURATION
24       00E9                  SIOR    =   0E9          ; SIO SHIFT REGISTER
25       00EA                  TMRLO   =   0EA          ; TIMER LOW BYTE
26       00EB                  TMRHI   =   0EB          ; TIMER HIGH BYTE
27       00EC                  TAULO   =   0EC          ; TIMER REGISTER LOW BYTE
28       00ED                  TAUHI   =   0ED          ; TIMER REGISTER HIGH BYTE
29       00EE                  CNTRL   =   0EE          ; CONTROL REGISTER
30       00EF                  PSW     =   0EF          ; PSW REGISTER
31       0004                  TRUN    =   4
32       0005                  TPND    =   5
33       0002                  BUSY    =   2
34                      ;
35                      ; ****  SPECIAL REGISTERS AND COUNTERS ****
36                      ; ANY REGISTER THAT IS USED FOR THE DRSZ TEST,
37                      ; MUST BE INITIALIZED TO AT LEAST "1".
38                      ;
39       00F7                  EXITR   =   0F7          ; ROUTINE DURATION REGISTER
40       003F                   EXIT   =   03F          ;  EXIT CONSTANT
41       0002                  RNGVAL  =   002          ; HOLDS CURRENT RANDOM #
42       00F8                  TCNTR   =   0F8          ; TONE DURATION REGISTER
43       0020                   TCNT   =   020          ;  TONE CONSTANT
44       00F9                  LUPREG  =   0F9          ; EXTRACTION RATE REGISTER
45       0003                   XTRCT  =   003          ;  EXTRACT CONSTANT
46       00FA                  LUPCNT  =   0FA          ; EXTRACTON VARIABLE REGISTER
47       00FF                  TVALO   =   0FF          ; TIMER VALUES
48       0000                  TVALHI  =   000
49                      ;
50                      ;*******************************
51                      ;****   BEGIN PROGRAM HERE    ****
52                      ;*******************************
53                      ;
54 0000                 MAIN:   LD      SP,#02F      DD2F; DEFAULT INITIALIZATION OF SP
55 0002                 LUP:    LD      EXITR,#EXIT  D73F; INITIALIZE SHOT DURATION
56 0004                         JSR     LASER8       3018; *** LASER CALLING ROUTINE ***
57 0006                         LD      EXITR,#EXIT  D73F
58 0008                         JSR     LASER8       3018
```

Laser Gun (Continued)

```
 59 000A  D73F              LD      EXITR,#EXIT
 60 000C  3018              JSR     LASER8
 61 000E  D715              LD      EXITR,#015        ; EXIT COUNT CAN BE INITIALIZED
 62 0010  3018              JSR     LASER8            ; INSIDE PROGRAM IF SHOT RATE
 63 0012  D715              LD      EXITR,#015        ; DOES NOT CHANGE.
 64 0014  3018              JSR     LASER8
 65 0016  B8                NOP
 66 0017  EA                JP      LUP               ; **** LOOP FOR DEMO ****
 67                  ;
 68 0018  BCD530     LASER8: LD     PORTGC,#030
 69 001B  BCEEAA            LD      CNTRL,#0AA        ; SK = DIV BY 8, PWM/TIO TIMER
 70 001E  BCEF11            LD      PSW,#011          ; ENABLE TIMER INTERRUPT
 71 0021  BCEAFF            LD      TMRLO,#TVALO      ; INITIALIZE TIMER
 72 0024  BCEB00            LD      TMRHI,#TVALHI
 73 0027  BCECFF            LD      TAULO,#TVALO
 74 002A  BCED00            LD      TAUHI,#TVALHI
 75                  ;      LD      EXITR,#EXIT       ; INITIALIZE EXIT COUNT
 76 002D  D820              LD      TCNTR,#TCNT       ; INITIALIZE TONE COUNT
 77 002F  DA03              LD      LUPCNT,#XTRCT     ; INITIALIZE EXTRACTION RATE
 78 0031  BDEE7C            SBIT    TRUN,CNTRL        ; START TIMER
 79 0034  A1         NOISE:  SC                        ; INIT. STAGE 1
 80 0035  5D                LD      B,#RNGVAL         ; POINT TO RANDOM NUMBER
 81 0036  9EFF              LD      [B],#0FF          ; INIT RANDOM #
 82 0038  9CE9       SHIFT:  X       A,SIOR            ; LOAD AND START SIOR
 83 003A  BDEF7A            SBIT    BUSY,PSW
 84 003D  9DFA              LD      A,LUPCNT          ; RESTORE EXTRACTION COUNT
 85 003F  9CF9              LD      A,LUPREG
 86                  ;
 87                  ; *********************************
 88                  ; RING COUNTER
 89                  ;
 90                  ; THIS IS A NINE STAGE RING COUNTER (LINEAR
 91                  ; FEEDBACK SHIFT REGISTER) WITH THE RRC COMMAND.
 92                  ; THE COUNTER'S 8th AND 9th STAGES, THROUGH AN
 93                  ; EXCLUSIVE-OR SERVE AS THE FEEDBACK FUNCTION.
 94                  ; SINCE THE EXCLUSIVE OR OCCURS AFTER THE ROTATE,
 95                  ; IT IS THE 1st AND 9th STAGES THAT ARE XOR'D,
 96                  ; (THE CARRY FLAG AND BIT 0).
 97                  ;
 98                  ;  CARRY BIT = STAGE 1
 99                  ;  LOW ORDER BIT = STAGE 9
100                  ; *********************************
101 0041  AE         RING:   LD      A,[B]             ; GET RANDOM #
102 0042  B0                 RRC     A                 ; ROTATE UPPER BYTE
103 0043  A6                 X       A,[B]             ;
104 0044  9800               LD      A,#000            ; PERFORM XOR
105 0046  85                 AND     A,[B]
106 0047  9200               IFEQ    A,#000
107 0049  05                 JP      TSTLUP
108 004A  88                 IFC
109 004B  02                 JP      RC
110 004C  A1                 SC
111 004D  01                 JP      TSTLUP
112 004E  A0         RC:     RC
```

Laser Gun (Continued)

```
113 004F  C9          TSTLUP: DRSZ    LUPREG          ; EXTRACT THIS # ?
114 0050  F0                  JP      RING            ; NO, KEEP ROTATING
115 0051  AE                  LD      A,[B]           ; YES
116 0052  E5                  JP      SHIFT
117                   ;
118                   ; **** TIMER INTERRUPT ROUTINE ****
119                   ;
120       00FF                .=      0FF
121 00FF  BDEF75              IFBIT   TPND,PSW        ; TEST TIMER PND FLAG
122 0102  01                  JP      TMOUT
123 0103  FF                  JP      .               ; ERROR
124                   ;
125 0104  BDEE6C      TMOUT:  RBIT    TRUN,CNTRL      ; STOP TIMER
126 0107  DEFA                LD      B,#LUPCNT
127 0109  C8                  DRSZ    TCNTR           ; TEST FOR NEW TONE
128 010A  01                  JP      NXT             ; NO
129 010B  0B                  JP      NEWF
130 010C  BDEF7C      NXT:    SBIT    4,PSW           ; ENABLE TIMER INTERRUPT
131 010F  BDEF6D              RBIT    5,PSW           ; RESET TPND FLAG
132 0112  5D                  LD      B,#RNGVAL       ; POINT TO RANDOM #
133 0113  BDEE7C              SBIT    TRUN,CNTRL      ; RESTART TIMER
134 0116  8F                  RETI                    ; RETURN
135 0117  C7          NEWF:   DRSZ    EXITR           ; EXIT COUNT = 0 ?
136 0118  07                  JP      NF              ; NO
137 0119  9DFD        NLST:   LD      A,SP            ; *** RESTORE STACK POINTER ***
138 011B  9402                ADD     A,#002          ; *** FROM TIMER INTERRUPT  ***
139 011D  9CFD                X       A,SP            ; *** AND RETURN TO MAIN    ***
140 011F  8E                  RET
141 0120  AE          NF:     LD      A,[B]           ; NEW TONE
142 0121  9404                ADD     A,#04           ; INCR EXTRACTION VALUE
143 0123  A6                  X       A,[B]
144 0124  D820                LD      TCNTR,#TCNT     ; REINITIALIZE TONE TIME
145 0126  E5                  JP      NXT
146                           .END
```

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