

# EEEN202 Timer Lab 1

Using the AT89C51AC3 to create a clock displaying seconds, minutes, and hours; coded in assembly in two different modes: polling and interrupt

## Operation of Timer Unit: Core/Common functions

At its core, the timer unit operates in a loop of incrementing a set of 3 registers – which represent seconds, minutes, and hours – which cascade into one another and updating the display. How the timer functions differs depending on whether it is polling or using interrupts, but several core parts remain the same:

- Set/update display routine
- Increment routine

To update the display, DIST is called; this routine writes the current time hours first then minutes and second, with colons separating them.

```

68 DIST:  MOV A,#01      //Update display routine
69         ACALL COMNWRT //Reset display
70         ACALL DELAY2
71
72
73         MOV A,R3      // MSD first
74         SWAP A        // Swapping upper and lower 8 bits
75         ANL A, #0FH   // A && #0FH for the bits
76         ORL A, #30H   // A || #30H "" ""
77         ACALL DATAWRT
78         ACALL DELAY1  // delay for proper operation
79
80         MOV A,R3
81         ANL A, #0FH   // A && #0FH
82         ORL A, #30H   // A || #30H
83         ACALL DATAWRT
84         ACALL DELAY1
85
86         MOV A, #3AH   // Adding colon to display
87         ACALL DATAWRT
88         ACALL DELAY1
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90         MOV A,R2
91         SWAP A
92         ANL A, #0FH   //MSD first
93         ORL A, #30H
94         ACALL DATAWRT
95         ACALL DELAY1
96
134 DATAWRT: // writing to display
135         MOV P1,A
136         SETB P2.0
137         CLR P2.1
138         SETB P2.2
139         ACALL DELAY1
140         CLR P2.2
141         RET
142

```

**SWAP:** Swaps the upper and lower nibbles (4 bits) of the number

**ANL and ORL - Logical AND and Logical OR**  
- Both perform their respective logic on the bits of the two operands

DIST handles writing the bits to the display by converting the most significant digit first i.e:

Written to the display first  
↓  
01:16:30

Each register that contains the time is loaded into A and the nibbles are swapped so that the number appears in reverse e.g 15 is swapped to 51

The ANL and ORL operations then apply masks that convert A into an ASCII representation of the MSD, as shown on the left

Writing the next digit is the same process, but the nibbles are not swapped. Between each magnitude of time, colons are also written to the display

Example: A = 0001 1001 (19 in BCD)

SWAP A  
ANL A, #0FH  
ORL A, #30H

SWAP A:

0001 1001 → 1001 0001

ANL A, #0FH

1001 0001  
&& ↓↓↓↓ ↓↓↓↓ → 0000 0001  
0000 1111

ONL A, #30H

0000 0001  
|| ↓↓↓↓ ↓↓↓↓ → 0011 0001  
0011 0000

0011 0001 (31H) in ASCII: 1

Whenever the display needs to be reset, SETDIS is called which clears the display:

```

29 SETDIS: MOV A,#30H      //Display initialisation routine
30
31         ACALL COMNWRT
32         ACALL DELAY1
33         MOV A,#0CH
34         ACALL COMNWRT
35         ACALL DELAY1
36         MOV A,#01
37         ACALL COMNWRT
38         ACALL DELAY2
39         MOV A,#06H
40         ACALL COMNWRT
41         ACALL DELAY1
42         RET
43

```

```

145 DELAY1: MOV R5,#30      //Short delay
146 LP1:    DJNZ R5,LP1
147         RET

```

DELAY1 loops 30 times before returning

```

149 DELAY2: MOV R5,#50      //long delay
150 HERE2:  MOV R4,#50
151 HERE:    DJNZ R4,HERE
152         DJNZ R5,HERE2
153         RET

```

DELAY2 loops for 50x50 times; R5 only decrements after R4 is zero, then is reset after R5 is decremented

**DJNZ:** Decrement and Jump if NOT Zero  
- Decreases the value indicated by the first operand by 1 and jumps to the address indicated by the second operand

The increment routine handles updating the values of the registers which hold the second, minutes, and hours – R1, R2, and R3 respectively:

```

44
45 INCT:  MOV A,R1          //Update time count routine (seconds)
46        ADD A, #1
47        DA A
48        MOV R1, A
49        CJNE A, #60H, INCE
50
51        MOV R1, #0        //Update time count routine (minute)
52        MOV A,R2
53        ADD A, #1
54        DA A
55        MOV R2, A
56        CJNE A, #60H, INCE
57
58        MOV R2, #0        //Update time count routine
59        MOV A,R3
60        ADD A, #1
61        DA A
62        MOV R3, A
63        CJNE A, #24H, INCE
64        MOV R3, #0
65
66 INCE:  RET
67
68

```

INCT increments R1 by one every time it is called; if 60, then R1 is reset and R2 is increment and so on

DA - Decimal adjust:  
- Converts an 8 bit binary digit into two 4 bit BCD digits

E.g: 0001 1000 (24) after DA is 0010 0100

CJNE - Compare then jump if not equal:  
- Jumps to indicated branch if first operand not equal with second

This routine is called every second; how the microcontroller achieves this is by using a counter to divide the clock frequency of the microcontroller – which is 12 MHz – to 1 Hz increments. The layout is slightly different for each style, but the execution is the same: Timer 0 is set to 16 counter mode and because 16 bits are not enough to divide the clock frequency down to a 1 second period, R0 is used as another counter to divide the frequency more (NOTE: the following code snippets are a mix from both styles):

```

12 MAIN:  MOV R0,#20
13        MOV R1,#0        // Set time value = 0, seconds
14        MOV R2,#0        // minutes
15        MOV R3,#0        // hours
16        ACALL SETDIS
17        MOV TMOD,#0x01   // set timer 0 to mode 1: 16 bit counter
18        MOV TH0,#0x3C    // set lower 8 bits to 0x3C
19        MOV TL0,#0xB0    // set upper 8 bits to 0xB0
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```

- ORG sets the start location of the PC
- R0 is set to 20; R1, R2, and R3 are set to 0.
- SETDIS function is called using ACALL
  - o ACALL – Absolute call: Unconditional call to a subroutine located in the same 2K block of memory as the current instruction
- TMOD is set to 16 bit counter mode

Afterwards, the program first executes REPEAT (which enables the timer) and into WAIT, the main timer loop:

```

10          // resets timer 0 if R0 != 0
11 REPEAT:  MOV TH0,#0x3C    // sets upper 8 bits to 0x3C
12          MOV TL0,#0xB0    // sets lower 8 bits to 0xB0
13          SETB TR0         // enable timer 0
14
15          // main program loop
16 WAIT:    JNB TF0,WAIT     // does Timer 0 flag = 1?
17          CLR TR0         // disable timer 0
18          CLR TF0         // sets TF0 to 0
19          DJNZ R0,REPEAT   // decrease R0 - is it 0?
20          MOV TH0,#0x3C    // reset TH0
21          MOV TL0,#0xB0    // reset TL0
22          SETB TR0         // enable timer 0
23          MOV R0,#20       // reset R0
24          CPL P2.3         // output every second
25          ACALL DIST       // Display time
26          ACALL INCT       // Increment time
27          AJMP WAIT       // reset back to top
28

```

Here the polling system is shown in effect; JNB TF0 makes the WAIT routine loop until T0 finishes counting. Then the timer is reset and R0 is decremented and the loop starts again until R0 is 0 – upon which the registers are incremented, the display is updated, and the system is reset to start counting again.

## Operation of the Timer Unit: Interrupt Mode

In interrupt mode, the program does not wait for the counter to be finished. Once the timer flag is raised, it sends an flag which triggers an interrupt service routine, which loads the current instruction/PC and registers into the stack and then executes the ISR. The code starts out declaring the origin then long jumping to MAIN

```

3          ORG 0H
4          LJMP MAIN        //bypass interrupt vector table
5
6          ORG 000BH        // Timer-Counter 0 interrupt vector
7          LJMP TINT        // Jump to Timer counter interrupt routine
8
9          ORG 30H
10
12 MAIN:    MOV R0,#20
13          MOV R1,#0        // Set time value = 0, seconds
14          MOV R2,#0        // minutes
15          MOV R3,#0        // hours
16          ACALL SETDIS     // initialise the display
17          MOV TMOD,#0x01   // set timer 0 to mode 1: 16 bit counter
18          MOV TH0,#0x3C    // set lower 8 bits to 0x3C
19          MOV TL0,#0xB0    // set upper 8 bits to 0xB0
20          SETB EA
21          SETB ET0         // Enable timer 0 interrupt (your task)
22          SETB TR0         // Start timer
23

```

Main contains all the set up for the registers and timer elements, as well setting up the necessary interrupt enables (EA, ET0). Afterwards, the program sets the PC location to the address of the interrupt vector and executes TINT:

```

162
163
164 TINT:    CLR TF0         // Timer - counter interrupt service routine ISR
165          CLR TR0         // disable timer 0
166          MOV TH0,#0x3C    // reset initial timer values
167          MOV TL0,#0xB0
168          SETB TR0         // enable timer 0
169          DJNZ R0,TINTE    // decrease R0 - is it 0?
170          ACALL INCT       // if R0 = 0, INCT registers
171          MOV R0,#20       // reset R0 count
172 TINTE:   RETI
173
174
175          END

```

TINT works like the point in polling when the TF0 is set; T0 is reset and R0 is decremented. If R0 = 0, then INCT is called and R0 is reset. Then the program counter origin is set to 30H, and the main loop, DISPL, is executed:

```
25  
26 DISPL: ACALL DIST      // Display time loop  
27         ACALL DELAY3  
28         AJMP  DISPL     // loop back to start  
29  
30
```

Compared to polling, this loop is incredibly small, and all it does is ACALL DIST to refresh the display, pauses, then loops back. This is all because of the ISR set up – all the timer resetting and incrementing operations is handled during the interrupt. More importantly, instead of the program checking every cycle if TF0 is set, the program checks if R0 is zero 20 times a second, reducing the idle time of the program.

### Pros and cons of both styles

A polling program must wait for the data it requests to be ready, meaning the whole program halts until received; interrupt-based programs simply continue a flag is raised and the interrupt service routine is executed – after which the previous instructions are loaded back in seamlessly. Because of the zero-wait time needed, interrupt routines can be much more efficient, particularly in programs which have much more instructions than just simply updating a clock display. It also means that the CPU is not wasting resources by constantly checking whether the data is done processing or not – it just continues with whatever instruction is next and then processes the ISR when it appears. ISRs also have high priority to the CPU – if the process finishes just as the CPU is finished checking on it, the CPU misses it and must complete the current cycle and go back to pick it up. ISRs are absolute and will immediately flag the CPU, decreasing the likelihood of being missed and making them great for events whose completion times are random.

Nevertheless, polling still has its uses. Its simplicity means it is great when the system is in early development and easy to debug. There are also no big memory management issues associated with polling, whereas ISRs can lead to data loss or stack management issues. ISRs must not be frequently used otherwise one runs the risk of the stack pointer being completely full due to too many ISRs occurring at once. They should also be kept small enough as they still delay the execution of the main code; the goal of ISRs is to be seamless, and larger routines may be noticeable. In non-time sensitive applications, polling can also make much more sense as interrupt just introduces unneeded complexity. It also makes sense in applications where you want the program to run sequentially in an expected order – interrupts would just disrupt that.

So, both styles are useful and can make up for the other's downsides; which one you use just depends on the context of your program.

### Pros and cons of Low-level vs High-level language

Assembly provides users with as level of control and efficiency that higher level languages do not. It provides direct and accurate control of the microcontroller's resources such as memory, ports, etc. This fine access means that Assembly code can be written much more efficiently and with higher density than higher level languages, which require a compiler to translate the human friendly language it into machine language. Depending on how intelligent compiler is in recognizing certain short cuts – such as using bit shifting operations in place of more complicated math – the resulting machine code can be more efficient when converted. Assembly on the other hand, is directly translated into binary using assemblers, which generally do not add optimisations and simply convert the instructions into their machine language equivalents.

However, Assembly is much less user friendly than higher level languages like C. Assembly uses mnemonics, whereas C is written using English statements. Assembly instruction sets are also machine dependent, meaning if you want to program another microcontroller, you will need to learn another set of instructions. To program in Assembly effectively, you also need knowledge of the microcontroller and its resources – the vector address or timers, what

registers you have access to, the size of flash memory available – whereas C requires very little knowledge of whatever device you are writing to as compilers handle all the required translations into the machine dependent code.

To summarize, Assembly is great for getting as close to metal as possible and producing very efficient programs, but is not user friendly and requires knowledge of the hardware to even begin programming properly. Higher level languages offer the safety net of code statements being legible to most and requiring very little knowledge of the hardware being used in exchange for being slower, much less efficient, and bulkier than Assembly.

### Additional Questions

1. Write an instruction sequence that could be used to read bit 1 of Port 0.

```
MOV A, P0.1
```

2. What addressing mode is used to access the upper 128 bytes of internal RAM?

Indirect addressing mode

3. Show how the content of internal address 6BH could be transferred to the accumulator.

```
MOV R0, #6BH
```

```
MOV A, @R0
```

4. What is the difference between the following instructions: ADD A,@R5 and ADD A,R5

@ is the indirect address operator, used to signify that the following bits are an address pointing to another location which contains the values. ADD A, @R5 essentially means add the contents of the memory location pointed to by R5, which could contain an 8-bit address, to the accumulator. ADD A, R5 just means add the contents of R5 to A.

5. Below shows a sequence of instructions, give the result of accumulator before and after the DA instruction.

```
MOV A,#13H
```

```
MOV R2,#18H
```

```
ADD A, R2
```

```
DA A
```

Before DA (2B): 00101011

After DA (43): 0100 0011

6. Explain the difference between AJMP, SJMP, and LJMP instructions.

All three do the same instruction of transferring the program execution to another part of the memory; the main difference comes from the maximum distance the program can jump:

- AJMP (Absolute short range jump): contains an 11 bit address, so destination must be within the same 2kB block of memory
- LJMP (Long range jump): contains an 16 bit address, meaning destination can be anywhere in the full 64kB space
- SJMP (Short range jump): contains a signed 8 bit address, meaning destination must be within -128 and 127 of the instruction

7. Describes what happens when the ACALL instruction is executed.

ACALL unconditionally calls the subroutine indicated by the address in the line. The program counter (PC) increases by 2, pushes the currently stored address onto the stack, and increments the stack pointer twice. The PC is then loaded with address called and the program continues from the new address

8. Write an instruction which is able to complement bit 7, 6, 2 and 0 of Port 2

```
CPL P0.7
```

9. What is the advantage of using EQU directive in an assembly language program?

Using EQU directives to create symbolic constants streamlines the coding flow if there is a particular value that is repeated often or if mathematical constant is needed – for example, if the program is calculating circles. It also makes changing the value of said symbolic constants easy as you only need to change one line instead of however many.

10. Describe what happens when an enabled interrupt is detected.

When the interrupt flag is triggered, the PC and registers are pushed to the stack while the interrupt service routine is executed. Once finished, the registers and PC are popped off the stack and the program continues from where the interrupt occurred.

11. Describe how you would implement a 20ms delay using timer 0. Assume the clock into the timer is 1MHz.

12. What is the vector address of Timer 1?

001BH

13. What is the next available memory where the user can write a program without interfering with the interrupt vector? Give an example of program code.

14. Upon exiting Reset, what is the contents of the stack pointer?

Upon reset, the stack pointer is set to the address 07H

15. Upon exiting Reset, which instruction is first executed

Instruction at the address 0H