Computer Labs: The i8254 Timer/Counter

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Lab 2: The PC's Timer/Counter - Part I

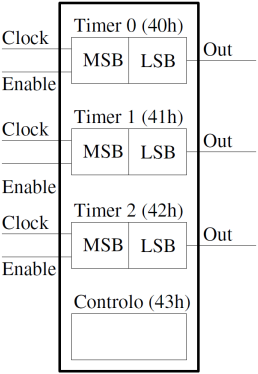
- Write a set of functions:

  ```
  int timer_test_config(unsigned long timer)
  int timer_test_time_base(unsigned long freq)
  ```

  that require programming the PC's Timer/Counter
- These functions are at a high level for ease of grading
  - The idea is that you design the lower level functions (with the final project in mind)
  - In this lab we have also defined the lower level functions
- What's new?
  - Program an I/O controller: the PC's timer counter (i8254)
  - Use interrupts (Part II)

The i8254

- It is a programmable timer/counter
  - Each PC has a functionally equivalent circuit, nowadays it is integrated in the so-called south-bridge
  - Allows to measure time in a precise way, independently of the processor speed
- It has 3 16-bit counters, each of which
  - May count either in binary or BCD
  - Has 6 counting modes



i8254 Counting Modes

Mode 0 Interrupt on terminal count – for counting events

- `OUT` goes high and remains high when count reaches 0

Mode 1 Hardware retriggerable one-shot

- `OUT` goes low and remains low until count reaches 0, the counter is reloaded on a rising edge of the `ENABLE` input

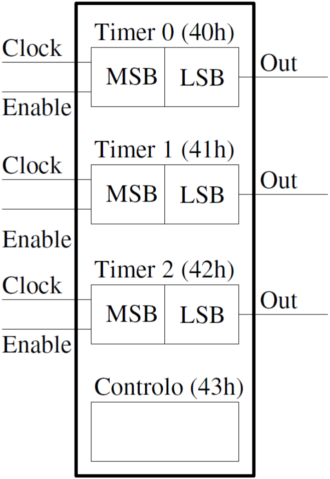
Mode 2 Rate Generator (divide-by-N counter)

- `OUT` goes low for one clock cycle when count reaches 0, the counter is reloaded with its initial count afterwards, and ...

Mode 3 Square Wave Generator – for Lab 2

- Similar to mode 2, except for the duty-cycle: `OUT` will be high for half of the cycle and low for the remaining half of the cycle

i8254 Block Diagram



- Three independent 16-bit counters
  - Ports 40h, 41h and 42h
  - MSB and LSB addressable separately
  - independent counting modes
- An 8 bit-control register
  - Port `43h`
  - Programming of each counter independently

i8254 Control Word

- Written to the Control Register (`0x43`)

Bit	Value	Function
7,6		**Counter selection**
	00	0
	01	1
	10	2
5,4		**Counter Initialization**
	01	LSB
	10	MSB
	11	LSB followed by MSB
3,2,1		**Counting Mode**
	000	0
	001	1
	x10	2
	x11	3
	100	4
	101	5
0		**BCD**
	0	Binary (16 bits)
	1	BCD (4 digits)

Example

- Timer 2 in mode 3
- Couting value: 1234 = 0x04D2

Control Register: `10111110`

Timer2 LSB `0xD2`

Timer2 MSB `0x04`

i8254: Read-Back Command

- Allows to retrieve
  - the programmed configuration
  - and/or the current counting value

  of one or more timers
- Written to the Control Register (`0x43`)
  - The configuration (status) is read from the timer's data register
    - The 6 LSBs match that of the Control Word
  - The counting value too
    - If both status and count are requested, the status is the first value returned

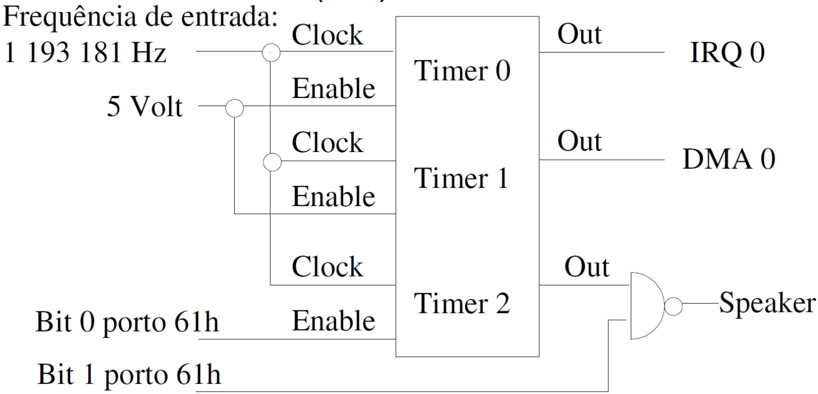
Read-Back Command Format

Bit	Value	Function
7,6		**Read-Back Command**
	11	
5		$\overline{\text{COUNT}}$
	0	Read counter value
4		$\overline{\text{STATUS}}$
	0	Read programmed mode
3		**Select Timer 2**
	1	Yes
2		**Select Timer 1**
	1	Yes
1		**Select Timer 0**
	1	Yes
0		**Reserved**

Read-Back Status Format

Bit	Value	Function
7		**Output**
6		**Null Count**
5,4		**Counter Initialization**
3,2,1		**Programmed Mode**
0		**BCD**

i8254: Use in the PC (1/2)



- Timer 0 is used to provide a time base.
- Timer 1 is used for DRAM refresh
  - Via DMA channel 0

  (Not sure this is still true.)
- Timer 2 is used for tone generation

i8254: Use in the PC (2/2)

- The i8254 is mapped in the I/0 address space:

  ```
  Timer 0:          0x40
  Timer 1:          0x41
  Timer 2:          0x42
  Control Register: 0x43
  ```

- Need to use `IN/OUT` assembly instructions
  - Minix 3 provides the `SYS_DEVIO` kernel call for doing I/O

    ```
    #include <minix/syslib.h>

    int sys_inb(port_t port, unsigned long *byte);
    int sys_outb(port_t port, unsigned long byte);
    ```

- Need to write to the control register before accessing any of the timers

Minix 3 and Timer 0

- At start up, Minix 3 programs Timer 0 to generate a square wave with a fixed frequency
  - Timer 0 will generate an interrupt at a fixed rate:
    - Its output is connected to `IRQ0`
- Minix 3 uses these interrupts to measure time
  - The interrupt handler increments a global variable on every interrupt
  - The value of this variable increments at a fixed, known, rate
- Minix 3 uses this variable mainly for:
  - Keeping track of the date/time
  - Implementing SW timers

Lab 2: Part 1 - Reading Timer Configuration

What to do? Read timer X configuration in Minix

```
int timer_test_config(unsigned long timer)
```

1. Write read-back command to read input timer configuration:
   - Make sure 2 MSBs are both 1
   - Read only the status
2. Read the timer port
3. Display the configuration in a user-friendly way

How to design it? Try to develop an API that can be used in the project.

```
int timer_get_config(unsigned long timer, unsigned char *st)
int timer_show_config(unsigned long timer);
```

Lab 2: Part 1 - Setting the Time-Base

What to do? Change the rate at which Timer 0 generates interrupts.

```
int timer_test_time_base(unsigned long freq)
```

1. Write control word to configure Timer 0:
   - **Do not change 4 least-significant bits**
     - Mode (3)
     - BCD/Binary counting

     You need to read the Timer 0 configuration first.
   - Preferably, LSB followed by MSB
2. Load Timer 0 with the value of the divisor to generate the frequency corresponding to the desired rate
   - Depends on the previous step

How to design it? Try to develop an API that can be used in the project.

```
int timer_set_frequency(unsigned char timer,
                        unsigned long freq)
```

How do we know it works? Use the `date` command.

Lab 2: Grading Criteria

SVN (10%) Whether or not your code is in the right place (under `lab2/`, of the repository's root)

- Also, evidence of incremental development approach

Makefile (10%) Compilation out of the box

Execution (50%) Make sure you test your code thoroughly

Code (30%)

functions as specified

input parameters must be validated

return values of function/kernel calls must be checked

global variables only if you cannot do what you want, or if they can be considered fields/members of an object (if using object oriented design)

symbolic constants i.e. use `#define`

kernel calls with appropriate arguments

Self-evaluation **Must submit** it by filling a Google Form (check the handout)

- Please follow exactly the instructions, otherwise you may be penalized

Further Reading

- Lab 2 Handout
- i8254 Data-sheet