8254 PROGRAMMABLE INTERVAL TIMER
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- Consists of three independent 16-bit programmable counters (timers).

- Each counter is capable of counting in binary or binary-coded decimal (BCD).
  - Maximum allowable input frequency to any counter is 10 MHz

- Useful where the microprocessor must control real-time events.
  - Usage includes real-time clocks, event counters, and motor speed/direction control.
Timer appears in the PC decoded at ports 40H–43H to do the following:

- Generate a basic timer interrupt that occurs at approximately 18.2 Hz
- Cause the DRAM memory system to be refreshed
- Provide a timing source to the internal speaker and other devices.

Timer in the PC is an 8253 instead of 8254. The 8254, a higher-speed version of the 8253
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- **Pin Definitions for 8254**
  - **A0, A1**: The address inputs select one of four internal registers within the 8254.
  - **CLK**: The clock input is the timing source for each of the internal counters. This input is often connected to the PCLK signal from the microprocessor system bus controller.
  - **CS**: Chip select enables 8254 for programming and reading or writing a counter.
  - **G**: The gate input controls the operation of the counter in some modes of operation.

<table>
<thead>
<tr>
<th>$A_1$</th>
<th>$A_0$</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>Counter 0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>Counter 1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>Counter 2</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Control word</td>
</tr>
</tbody>
</table>
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- **Pin Definitions for 8254**
  - **OUT**: A counter output is where the waveform generated by the timer is available.
  - **RD**: Read causes data to be read from the 8254 and often connects to the IORC signal.
  - **VCC**: Power connects to the +5.0 V power supply.
  - **GND**: Ground connects to the system ground bus.
  - **WR**: Write causes data to be written to the 8254 and often connects to write strobe IOWC.
Each timer contains:

- a CLK input which provides the basic operating frequency to the timer
- a gate input pin which controls the timer in some modes
- an output (OUT) connection to obtain the output of the timer
The signals that connect to the processor are

- the data bus pins (D7–D0),
- RD, WR, CS, and
- address inputs A1 and A0.

Address inputs are present to select any of the four internal registers.

- used for programming, reading, or writing to a counter
Timer zero generates an 18.2 Hz signal that interrupts the microprocessor at interrupt vector 8 for a clock tick.
  - often used to time programs and events in DOS

Timer 1 is programmed for 15 µs, used on the PC to request a DMA action used to refresh the dynamic RAM.

Timer 2 is programmed to generate a tone on the PC speaker.
Programming the 8254

- Each counter is programmed by writing a control word, followed by the initial count.

- The control word allows the programmer to select the counter, mode of operation, and type of operation (read/write).

- Also selects either a binary or BCD count.
Programming the 8254

- SC1: Selects a BCD when a logic 1
- SC0: Selects the mode (mode 0 - mode 5)
- RW1: Read/write control
  - 00 = counter latch command
  - 01 = read/write least-significant byte only
  - 10 = read/write most-significant byte only
  - 11 = read/write least-significant byte first, followed by the most-significant byte
- M2, M1, M0: Selects counter
  - 00 = counter 0
  - 01 = counter 1
  - 10 = counter 2
  - 11 = read-back command
Programming the 8254

- Each counter may be programmed with a count of 1 to FFFFH; A count of 0 is equal to FFFFH+1 (65,536) or 10,000 in BCD.

- Timer 0 is used in the PC with a divide-by count of 64K (FFFFH) to generate the 18.2 Hz (18.196 Hz) interrupt clock tick.
  - timer 0 has a clock input frequency of 4.77 MHz + 4 or 1.1925 MHz

- The order of programming is important for each counter, but programming of different counters may be interleaved for better control.
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- Programming the 8254

Example - 1

Write code to set up three counters located at I/O address 40h as follows:

- Counter 0: Binary counter operating in mode 0 with a value of 1234h
- Counter 1: BCD counter operating in mode 2 with a value of 0100h
- Counter 2: Binary counter operating in mode 4 with a value of 1FFFh
Programming the 8254

Example – 1, cont’d

Mode word for counter 0 = 00 11 000 0 = 30h
Mode word for counter 1 = 01 11 010 1 = 75h
Mode word for counter 2 = 10 11 100 0 = B8h

MOV AL,30H ;SET UP COUNTER 0 MODE
OUT 43H,AL
MOV AL,75H ;SET UP COUNTER 1 MODE
OUT 43H,AL
MOV AL,0B8H ;SET UP COUNTER 2 MODE
OUT 43H,AL
MOV AL,34H ;LOAD COUNTER 0
OUT 40H,AL
MOV AL,12H
OUT 40H,AL
MOV AL,00H ;LOAD COUNTER 1
OUT 41H,AL
MOV AL,01H
OUT 41H,AL
MOV AL,0FFH ;LOAD COUNTER 2
OUT 42H,AL
MOV AL,1FH
OUT 42H,AL
Programming the 8254: Modes of Operation

- six modes (0–5) available to each of the 8254 counters
- each mode functions with the CLK input, the gate (G) control signal, and OUT signal
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- Programming the 8254: Modes of Operation, MODE 0
  - Allows 8254 to be used as an events counter.
  - Output becomes logic 0 when the control word is written and remains until N plus the number of programmed counts.
  - Note that gate (G) input must be logic 1 to allow the counter to count.
  - If G becomes logic 0 in the middle of the count, the counter will stop until G again becomes logic 1.
Programming the 8254: Modes of Operation, MODE 1

- Causes function as a retrigerable, monostable multivibrator (one-shot).
- G input triggers the counter so it develops a pulse at the OUT connection that becomes logic 0 for the duration of the count.
- If the count is 10, the OUT connection goes low for 10 clocking periods when triggered.
- If G input occurs within the output pulse, the counter is reloaded and the OUT connection continues for the total length of the count.
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Programming the 8254: Modes of Operation, MODE 2

- Allows the counter to generate a series of continuous pulses one clock pulse wide.
- Pulse separation is determined by the count.
- For a count of 10, output is logic 1 for nine clock periods and low for one clock period.
- The cycle is repeated until the counter is programmed with a new count or until the G pin is placed at logic 0.
- G input must be logic 1 for this mode to generate a continuous series of pulses.

![Diagram of Mode 2 operation with CLK and OUT waveforms.*]
Program the 8254: Modes of Operation, MODE 3

- Generates a continuous square wave at the OUT connection, provided the G pin is logic 1.
- If the count is even, output is high for one half of the count and low for one half of the count.
- If the count is odd, output is high for one clocking period longer than it is low.
- If the counter is programmed for a count of 5, the output is high for three clocks and low for two clocks.

Mode 3

CLK * Count of 6 loaded
Programming the 8254: Modes of Operation, MODE 4

- Allows a single pulse at the output.
- If count is programmed as 10, output is high for 10 clocking periods and low for one period.
  - the cycle does not begin until the counter is loaded with its complete count
- Operates as a software triggered one-shot.
- As with modes 2 and 3, this mode also uses the G input to enable the counter.
  - G input must be logic 1 for the counter to operate for these three modes

*Trigger with count of 8
Programming the 8254: Modes of Operation, MODE 5

- A hardware triggered one-shot that functions as mode 4.
- except it is started by a trigger pulse on the G pin instead of by software
- This mode is also similar to mode 1 because it is retriggerable.
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- Programming the 8254

Recall example 1...

Counter 0: Binary counter operating in mode 0 with a value of 1234h
- Counter triggered by control word write
- Output goes high after 1234h (4660d) clock cycles

Counter 1: BCD counter operating in mode 2 with a value of 0100h
- Counter triggered by control word write
- Output pulses low (for one clock cycle) every 0100h (translated to BCD is 4 decimal, ) clock cycles

Counter 2: Binary counter operating in mode 4 with a value of 1FFFh
- Counter triggered by control word write
- One shot produced after a delay of 1FFFh (=8191d) cycles
Example

Write a program to initialize counter 2 in mode 0 with a count of CO30H. Assume address for control register = 0BH, counter 0 = 08H, counter 1 = 09H and counter 2 = 0AH.

Sol. : Control word

<table>
<thead>
<tr>
<th>SC&lt;sub&gt;1&lt;/sub&gt;</th>
<th>SC&lt;sub&gt;2&lt;/sub&gt;</th>
<th>RW&lt;sub&gt;1&lt;/sub&gt;</th>
<th>RW&lt;sub&gt;0&lt;/sub&gt;</th>
<th>M&lt;sub&gt;2&lt;/sub&gt;</th>
<th>M&lt;sub&gt;1&lt;/sub&gt;</th>
<th>M&lt;sub&gt;0&lt;/sub&gt;</th>
<th>BCD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

= B0H
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Example

Source Program

MOV AL, B0H
OUT 0BH, AL ; Loads control word (B0H) in the control register.

MOV AL, 30H
OUT 0AH, AL ; Loads lower byte of (30H) the count.

MOV AL, 0COH
OUT 0AH, AL ; Loads higher byte (COH) of the count.
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Programming the 8254

- An 8254 connected to I/O ports 0700H, 0702H, 0704H, and 0706H.
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Programming the 8254

- To program 100Khz Square wave in out 0 and 200Khz continuous pulse in out 1
  - Input clock is 8 Mhz;
  - G input is pulled up
  - 700H, 702H, 704H and 706H are the four registers for control
- Find out the counter values for loading
  - 8Mhz/ 100Khz= 80 decimal for counter 0
  - 8Mhz/ 200Khz= 40 decimal for counter 1
- Find the control words for counters
  - 00110110 for counter 0
  - 0111 0100 for counter 1
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Programming the 8254

```
PUSH AX ;save registers
PUSH DX

MOV DX, 706H ;address control word
MOV AL, 00110110B ;program counter 0
OUT DX, AL ;for mode 3

MOV AL, 01110100B ;program counter 1
OUT DX, AL ;for mode 2

MOV DX, 700H ;address counter 0
MOV AL, 80 ;load count of 80
OUT DX, AL
XOR AL, AL
OUT DX, AL

MOV DX, 702H ;address counter 1
MOV AL, 40 ;load count of 40
OUT DX, AL
XOR AL, AL
OUT DX, AL

POP DX ;restore registers
POP AX
RET```

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Programming the 8254: Reading a Counter

- Each counter has an internal latch read with the read counter port operation.
  - The latches will normally follow the count.
- If counter contents are needed, the latch can remember the count by programming the counter latch control word.
- Counter contents are held in a latch until read.

![Diagram showing counter latch control word and counter select pins]

Select counter:
- 00 = counter 0
- 01 = counter 1
- 10 = counter 2
- 11 = read-back command
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Programming the 8254

Example - 2

Say we want to read the contents of counter 2 on the fly. The count is to be loaded into the AX register. Assume that the 8254 is located at I/O address 40h
Programming the 8254

Example – 2, cont’d

First, latch the contents of counter 2, and then its value can be read from a temporary storage register.

```
MOV AL,10000000b ;Latch counter 2
OUT 43h,AL
IN AL,42h ;Read the lower byte
MOV BL,AL ;Store it temporarily
IN AL,42h
MOV AH,AL
MOV AL,BL ;Counter contents now
MOV AL,BL ;resides in AX
```
**8254 PROGRAMMABLE INTERVAL TIMER**

- Programming the 8254: *Reading a Counter*
  - When a read from the latch or counter is programmed, the latch tracks the contents.
  - When necessary for contents of more than one counter to be read at the same time, the read-back control word is used.

![Diagram of 8254 counter bits]

- Select counter bits
- Latch status of selected counters
- Latch count of selected counters
Programming the 8254: Reading a Counter

- With the read-back control word, the CNT bit is logic 0 to cause the counters selected by CNT0, CNT1, and CNT2 to be latched.
- If the status register is to be latched, then the ST bit is placed at logic 0.
- The status register, which shows:

```
<table>
<thead>
<tr>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>OUT</td>
<td>NULL</td>
<td>RW1</td>
<td>RW0</td>
<td>M2</td>
<td>M1</td>
<td>M0</td>
<td>BCD</td>
</tr>
</tbody>
</table>
```

- Logic 1 for BCD counter
- Counter mode
- Read/write operation
- NULL = 1 if counter is 0
- The level of the OUT pin