EE281

A Few Words From Dilbert

Embedded System
Design Laboratory

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Lecture #2 Outline

- Status Check
- AVR Processor Resources
  - Interrupts
  - Timers
- Extra Lab Time?

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Status Check

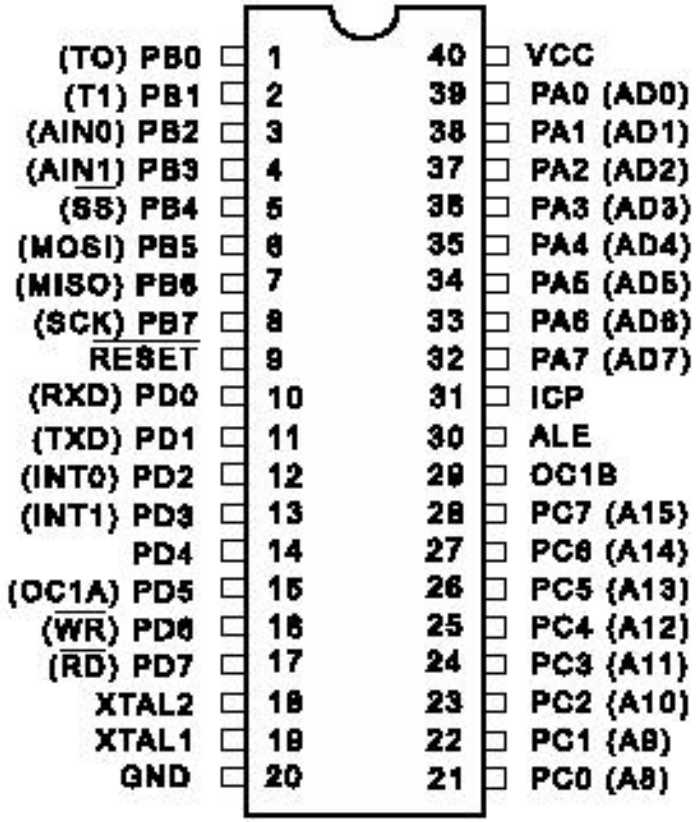
- How is Lab #1 going?
- Got access to the EE281 lab yet?
- More STK500 kits are coming…

AVR Processor Resources

- Interrupts
- Timers
- UART (Universal Asynchronous Receiver/Transmitter)
- A/D Converters (Analog to Digital)
- SPI (Serial Peripheral Interface)
- Analog Comparator

AVR AT90S8515 Pinout

- General Purpose Ports
  - PORTA
  - PORTB
  - PORTC
  - PORTD
  - (Special Functions)
- Special Purpose Pins
  - Crystal (XTAL1/XTAL2)
  - RESET
  - ICP, OLE, OC1B
- Power (VCC/GND)



EE281 '8515 Functional Architecture

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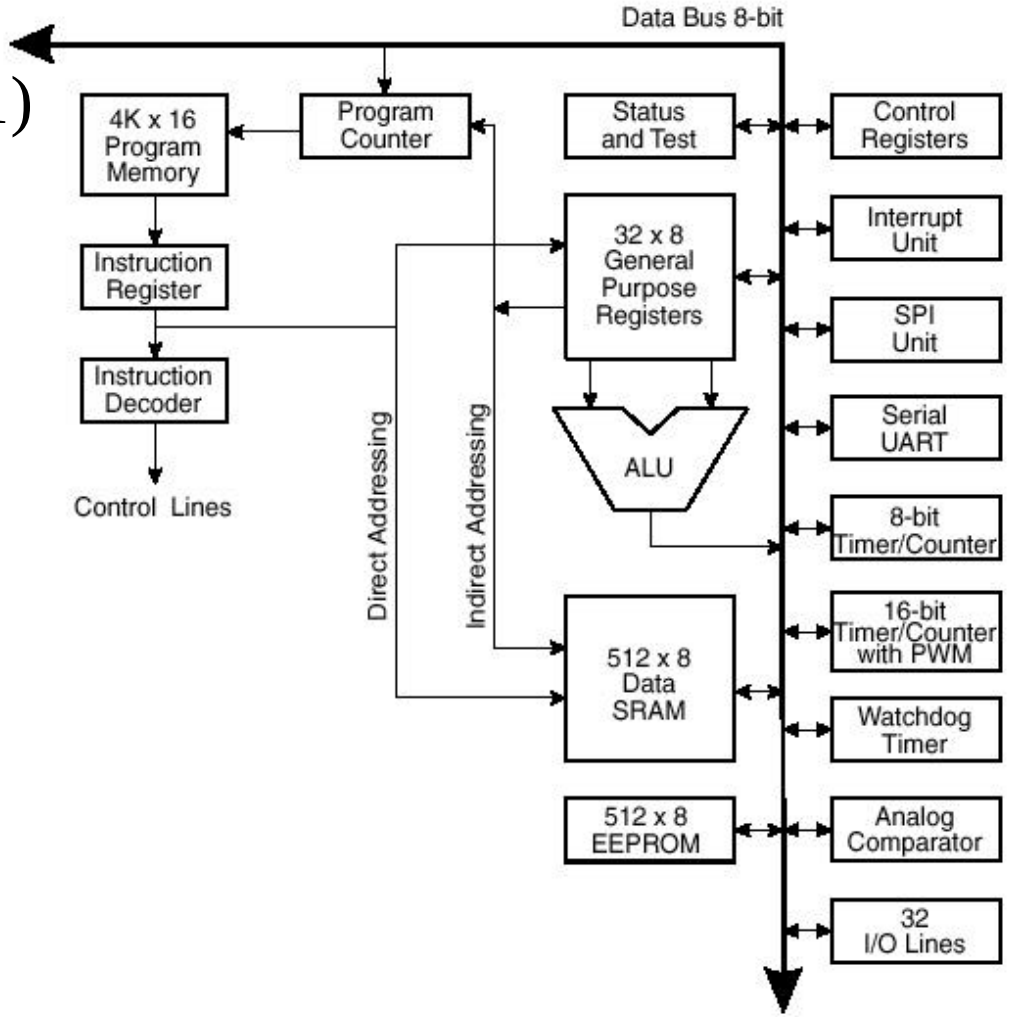
- 32 Registers (R0-R31)
- 4K Prog ROM
- 512 bytes RAM
- 512 bytes EEPROM
- 32 I/O lines
- 13 Interrupts
- Lots of fun built-in peripherals



Interrupts

- Interrupts halt normal code execution in order to go do something more important or time sensitive
- Interrupt "Handlers"
  - Using the Interrupt Vectors
- Interrupts are used for:
  - RESET
  - Timers and Time-Critical Code
  - Hardware signaling
    - "I'm done"
    - "Something's happened that you want to know about"
    - "I have something for you"

Interrupt Vectors

Table 2. Reset and Interrupt Vectors

Vector No.	Program Address	Source	Interrupt Definition
1	$000	RESET	External Reset, Power-on Reset and Watchdog Reset
2	$001	INT0	External Interrupt Request 0
3	$002	INT1	External Interrupt Request 1
4	$003	TIMER1 CAPT	Timer/Counter1 Capture Event
5	$004	TIMER1 COMPA	Timer/Counter1 Compare Match A
6	$005	TIMER1 COMPB	Timer/Counter1 Compare Match B
7	$006	TIMER1 OVF	Timer/Counter1 Overflow
8	$007	TIMER0, OVF	Timer/Counter0 Overflow
9	$008	SPI, STC	Serial Transfer Complete
10	$009	UART, RX	UART, Rx Complete
11	$00A	UART, UDRE	UART Data Register Empty
12	$00B	UART, TX	UART, Tx Complete
13	$00C	ANA_COMP	Analog Comparator

Interrupts: Code Example

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```
; setup reset/interrupt vectors
        .cseg
        .org    0x000
    rjmp   reset                ; $000 HW Reset or Watchdog Handler
    rjmp   reset                ; $001 External IRQ 0 Handler
    rjmp   reset                ; $002 External IRQ 1 Handler
    rjmp   reset                ; $003 Timer/Counter1 Capture Event Handler
    rjmp   reset                ; $004 Timer/Counter1 Compare Match A Handler
    rjmp   reset                ; $005 Timer/Counter1 Compare Match B Handler
    rjmp   reset                ; $006 Timer/Counter1 Overflow Handler
    rjmp   Timer0Isr            ; $007 Timer/Counter0 Overflow Handler
    rjmp   reset                ; $008 SPI Serial Transfer Complete Handler
    rjmp   reset                ; $009 UART Rx Complete Handler
    rjmp   reset                ; $00A UART Data Register Empty Handler
    rjmp   reset                ; $00B UART Tx Complete Handler
    rjmp   reset                ; $00C Analog Comparator Handler

; begin code

reset:              ; your main code goes here

Timer0Isr:          ; Timer0 overflow interrupt code here
          RETI      ; don't forget to return from your interrupt!
```

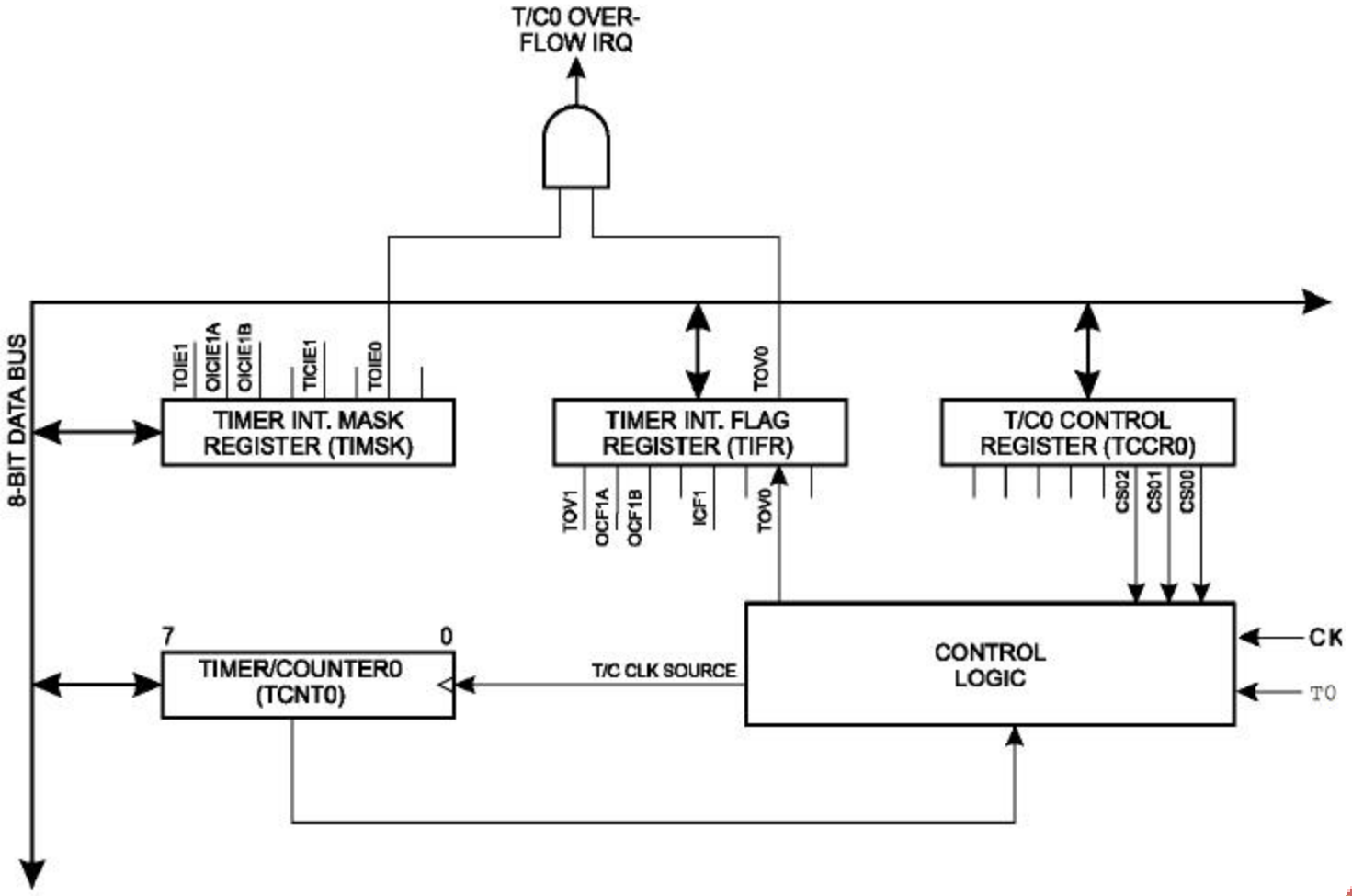
Timers: Why we need them

- Provide accurately timed delays or actions independent of code execution time
- How are Timers used?
  - Accurate delay
    - Read the timer, store value as K. Loop until timer reaches K+100.
  - Schedule important events
    - Setup an *Output Compare* to trigger an interrupt at a precise time
  - Measure time between events
    - When event#1 happens, store timer value as K
    - When event#2 happens, read timer value and subtract K
    - The difference is the time elapsed between the two events

AVR Timer/Counter 0

- 8 Bit Up Counter
  - counts from 0 to 255 (0xFF), then loops to 0
  - Internal or External Clock source
    - Prescaler
- Interrupt on Overflow
  - Transition from 255 to 0 can trigger interrupt if desired

AVR Timer/Counter 0 (cont'd)



AVR Timer/Counter 1

- 16 Bit Up Counter
  - Counts from 0 to 65535 (0xFFFF), then loops
  - Internal clock source with prescaler or External Clock
- Dual Comparators
- Interrupts possible on:
  - Overflow
  - Compare A/B
  - Input Capture of external event on ICP pin
- Can also act as an 8, 9 or 10 bit PWM Up-Down Counter

EE281 AVR Timer/Counter 1 (cont'd)

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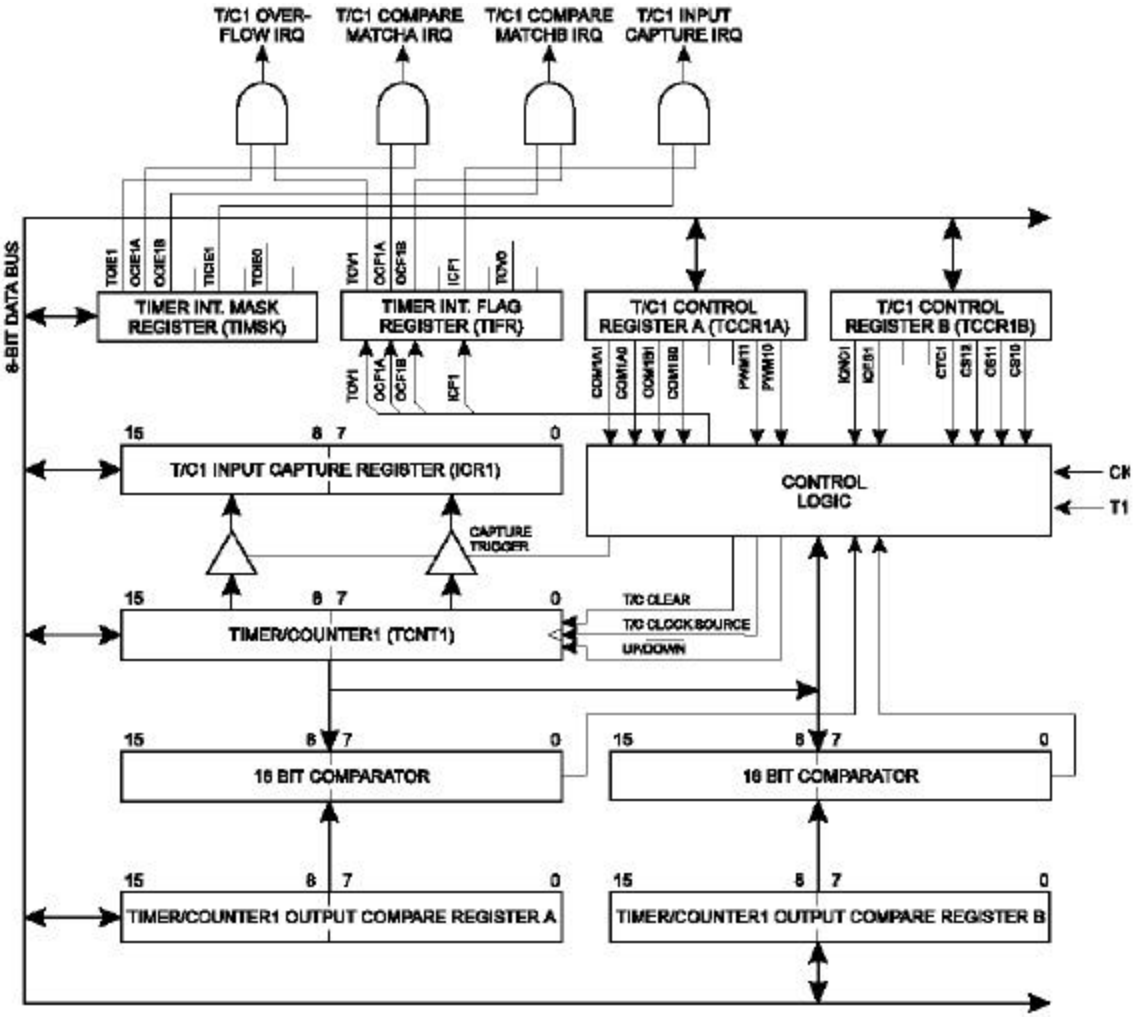
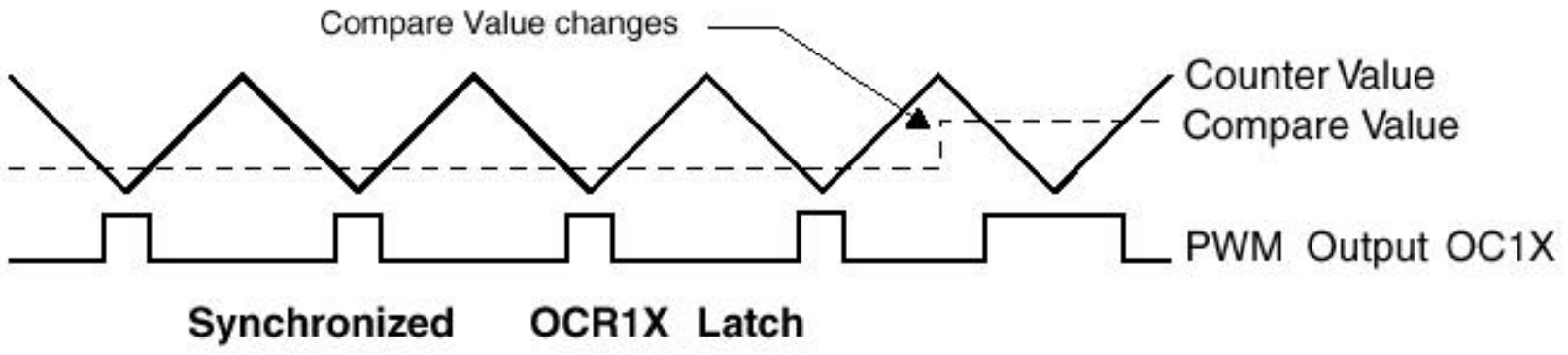


Timer 1 and Output Compare

- The 8515 has two *output compares* (OCR1A/B)
  - OCR1A/B are 16-bit registers
  - When the value of OCR1x matches that of Timer1:
    - A user-defined action can take place on the OC1x pin (set/clear/inv)
    - An interrupt can be triggered
    - Timer1 can be cleared to zero
  - Once set up, output compares operate continuously without software intervention
  - Great for:
    - Precise recurring timing
    - Frequency/Tone generation (maybe sound effects)
    - All kinds of digital signal generation
      - Infrared communications
      - Software-driven serial ports

Timer 1 and PWM

- Pulse-Width Modulation
  - Useful for using digital circuits to achieve analog-like control of motors, LEDs, etc
  - Timer 1 has two channels of PWM output on OCR1A and OCR1B



Timer Control: I/O space

- Timer 0
  - Timer/Counter0 (TCNT0)
  - Control Register (TCCR0)
- Timer 1
  - Timer/Counter1 (TCNT1)
  - Control Register A & B (TCCR1A/B)
  - Input Capture Register (ICR1)
  - Timer/Counter1 Output Compare Register A and B (OCR1A/B)
- Timer Interrupt Registers
  - Timer Interrupt Mask Register (TIMSK)
  - Timer Interrupt Flag Register (TIFR)
  - Common to Both Timers

Timer/Counter Clock Sources

- Prescaler
  - Shut Off
  - Divided System Clock
  - External Input (rising or falling)

CS02	CS01	CS00	Description
0	0	0	Stop, the Timer/Counter0 is stopped.
0	0	1	CK
0	1	0	CK/8
0	1	1	CK/64
1	0	0	CK/256
1	0	1	CK/1024
1	1	0	External Pin T0, falling edge
1	1	1	External Pin T0, rising edge

Timer: Example Code

- Timer0.asm
  - Gives a complete example of one way to use timer 0 with a timer interrupt handler
  - Heavily commented
  - Highlights helpful coding practices for all programs
    - Use .equ to define constants
    - Use .def to define register “nicknames”
  - Available on the course website