Timing of Events

Suppose that we want produce a pulse on a digital line that was exactly 500 ms in length?

- What would the code look like?

Timing of Events

```
// Assume it is pin 0 of port B

PORTB = PORTB | 1;
delay_ms(500);
PORTB = PORTB & ~1;
```

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Timing of Events

This will work, but why is it undesirable?

`delay_ms()` is implemented by using a for() loop

- The microcontroller can't do anything else while it is looping
- Have to loop a precise number of times (not always easy to do)

Timing of Events: Another Example

Suppose we would want to measure the width of a pulse. How would we implement this?

Timing of Events: Another Example

How would we implement this?

```
// Wait for pin to go high
while(PINB & 0x1 == 0){};

// Now count until it goes low
for(counter = 0; PINB & 0x1; ++counter)
{
  delay_ms(1);
}
// Now: counter is the width of
//   of the pulse in ms
```

Timing of Events: Another Example

Again: the program cannot be doing anything else while it is waiting

Counter/Timers in the Mega2560

The mega2560 includes six counter/timer devices in hardware.

These can:

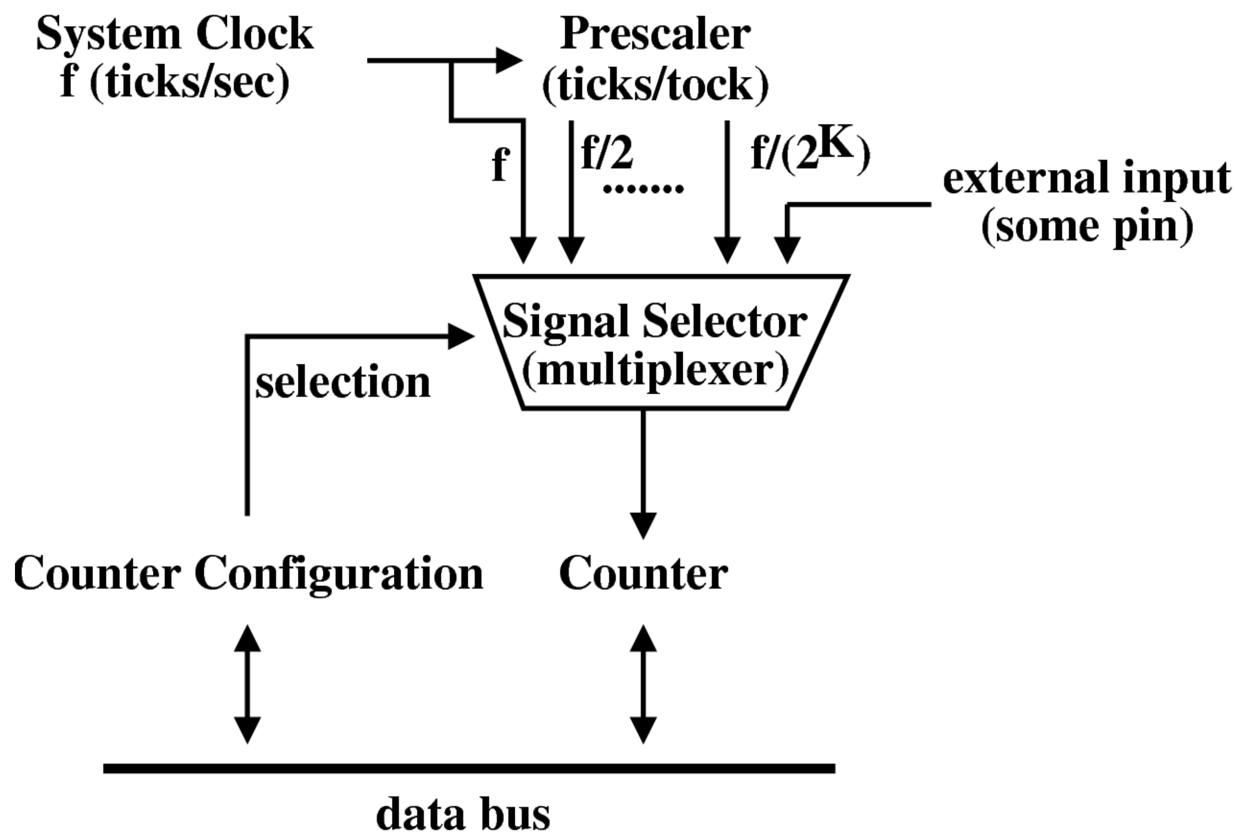
- Be used to count the number of events that have occurred (either external or internal)
- Act as a clock

Timer 0

- Two possible input sources:
  - Pin T0 (PD4)
  - System clock
    - Potentially divided by a “prescaler”
- 8-bit counter
- When the counter turns over from 0xFF to 0x0, an interrupt (an event) can be generated (more on this later)

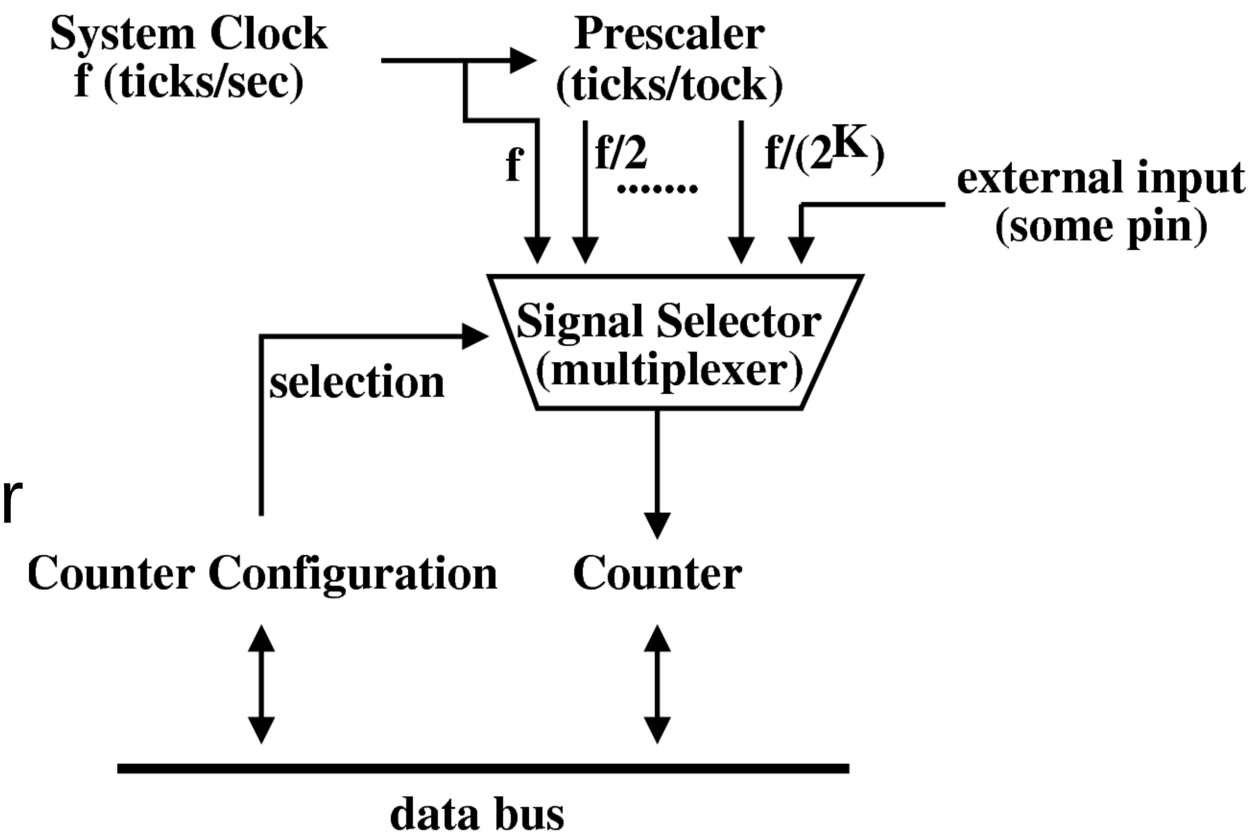
Generic Timer Implementation

- **Prescaler**: divides clock frequency



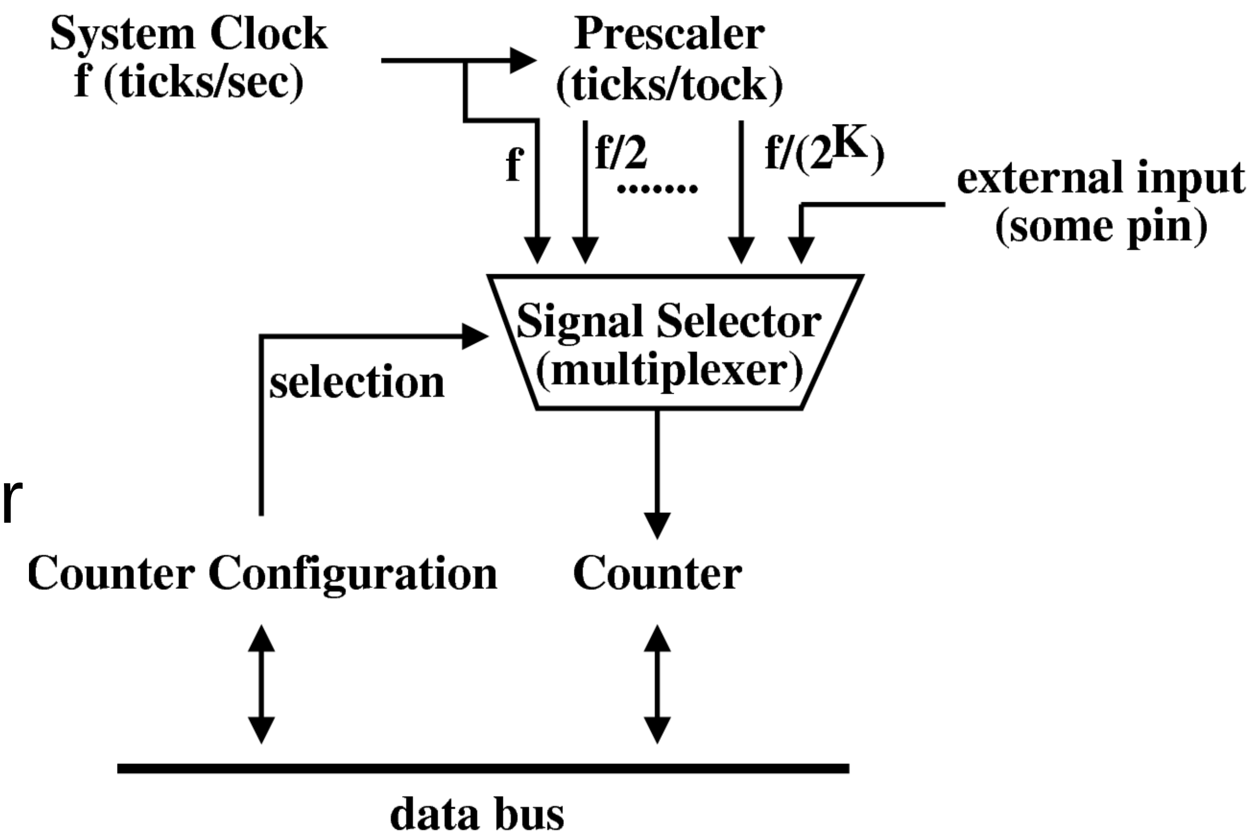
Generic Timer Implementation

- **Prescaler**: divides clock frequency
- **Multiplexer**: selects one of the inputs to drive the counter



Generic Timer Implementation

- **Prescaler**: divides clock frequency
- **Multiplexer**: selects one of the inputs to drive the counter
- **Counter**: increment on low-to-high transition of its input



Timer 0 (and Timer 1)

Possible prescalers:

- 8
- 64
- 256
- 1024

Timing Example

Suppose:

- f=16MHz clock
- Prescaler of 1024
- We wait for the timer to count from 0 to 156

How long does this take?

Timer 0 Example

$$delay = \frac{1024 * 156}{16{,}000{,}000} = 9948\ \mu s \approx 10\ ms$$

Timer 0 Code Example

```
timer0_config(TIMER0_PRE_1024);   // Init: Prescale by 1024

timer0_set(0);       // Set the counter to 0

<Do something else for a while>
while(timer0_read() < 156) {
   <Do something while waiting>
};

// Break out of while loop after ~10 ms
```

See Atmel HOWTO for example code (timer_demo2.c)

Timer 0 Example

Advantage over delay_ms():

- Can do other things while waiting
- Timing is much more precise
  - We no longer rely on a specific number of instructions to be executed

Timer 0 Example

One caution:

- “something else” cannot take very much time

(we have a solution for this – coming soon!)

Next Example

How do we time a delay of 100 usecs?

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$$counts * prescale = .0001 * clock\_freq$$
$$= .0001 * 16000000$$
$$= 1600$$

Next Example

How do we time a delay of 100 usecs?

$$counts * prescale = .0001 * clock\_freq$$

$$= .0001 * 16000000$$

$$= 1600$$

$$200 \quad * \quad 8 \quad = 1600$$

$$OR$$

$$25 \quad * \quad 64 \quad = 1600$$

Timer 0 Code Example

```
timer0_config(TIMER0_PRE_8);   // Init: Prescale by 8

timer0_set(0);        // Set the timer to 0

<Do something else for a while>
while(timer0_read() < 200) {
   <Do something while waiting>
};

// Break out of while loop after ~100 us
```

Example 3:
Timing the Width of a Pulse

- Input: port B, pin 1
- How long is the pin high?

Timing a Pulse Width: Our Original Implementation

```
// Wait for pin to go high
while(PINB & 0x1 == 0){};

// Now count until it goes low
for(counter = 0; PINB & 0x1; ++counter)
{
  delay_ms(1);
}
// Now: counter is the width of
//   of the pulse in ms
```

Example: Timing a Pulse Width

```
// Init: Prescale by 1024
timer0_config(TIMER0_PRE_1024);

// Wait for pin to go high
while(PINB & 0x2 == 0){
  <Do something while waiting>
};
timer0_set(0);        // Set the timer to 0

while((PINB & 0x2) != 0) {
  <Do something while waiting>
};
pulse_width = timer0_read();
```

Example: Timing a Pulse Width

What is the “resolution” of pulse_width?

Example: Timing a Pulse Width

What is the “resolution” of pulse_width?

- Each “tock” is:

$$delay = \frac{1024}{16{,}000{,}000} = 64\ \mu s$$

Example: Timing a Pulse Width

So, with pulse_width tocks:

$$delay = \frac{1024 * pulse\_width}{16,000,000} = 64 * pulse\_width \ \mu s$$

Example: Timing a Pulse Width

```
// Init: Prescale by 1024
timer0_config(TIMER0_PRE_1024);

// Wait for pin to go high
while(PINB & 0x2 == 0){
  <Do something while waiting>
};
timer0_set(0);       // Set the timer to 0

while((PINB & 0x2) != 0) {
  <Do something while waiting>
};
pulse_width = read_timer0();
```

Note: the longer "something" takes, the larger the possible error in timing

Other Timers Besides Timer 0

Timers 1, 3, 4, 5:

- 16 bit counter
- Prescalers: 1, 8, 64, 256, 1024

Timer 2:

- 8 bit counter
- Prescalers: 1, 8, 32, 64, 128, 256, 1024

Note

See oulib documentation for the list of possible prescalers for the timers

Pulse-Width Modulation in Hardware

- The Atmel Mega processors will perform a wide-range of timing functions in hardware
- This includes the generation of pulse-width modulated signals
- Once configured, your main program need only to set the duty cycle of the PWM signal

Pulse-Width Modulation in Hardware

- Configuration includes:
  - Signal frequency (through the prescalers)
  - Signal polarity (high then low or vice-versa)
  - Resolution for specifying the duty cycle
- Once configured:
  - You need only specify changes to the duty cycle

PWM on the Atmel Mega2560s

Timers 1, 3, 4, 5: each have 3 PWM output channels associated with them (known as A, B, and C)

For our example here:

- Use 10 bits of the 16 available with the counter
- Counter counts from 0 to 1023, and then back to 0
- Output goes high at 0
- Output goes low at specified count
  - Specified by the “output compare” register

Example

For our example, we will use:

- Timer 4, channel A
  - I/O Port H, pin 3
- 10-bit resolution
- Prescaler of 8

Initialization Example (Timer 4)

```
int main(void){
   // The timer 4 channel A pin is labeled "OC4A" on the Arduino
   //   circuit diagram
   DDRH = 0x8;

   // tocks/sec = 2,000,000/sec (with a 16,000,000 ticks/sec clock)
   timer4_config(TIMER4_PRE_8);

   // Configure for 10-bit PWM
   timer4_output_compare_config(TIMER4_OUTPUT_COMPARE_CONFIG_PWM_F_10);

   // Configure timer 4, channel A for PWM: high then low
   timer4_compare_output_A_mode_set(TIMER16B_COMPARE_OUTPUT_MODE_CLEAR);
   :
   :
```

Use Example

```
:
:
int16_t i;

 // Loop forever
while(1) {

     // Slowly increase the duty cycle on channel A
     for(i=0; i < 1024; ++i) {
            timer4_output_compare_A_set(i);
            delay_ms(1);
     };

     // Slowly bring the duty cycle back to zero
     for(i=1023; i > 0; --i) {
            timer4_output_compare_A_set(i);
            delay_ms(1);
     };
};
```

See examples_2560/pwm for more details (Atmel HOWTO)

More on timers soon (with interrupts!)