CSEP567-- tonight

I. Reentrancy and Atomic Operations
II. Pulse-width modulation
III. Color

I. Reentrancy and Atomic Operations

Reentrancy and Atomic Operations

- 3 rules:
  - Use shared variables in an atomic way
  - Don't call non-reentrant functions
  - Don't use hardware in a non-atomic way

a Function containing:

```
temp = foobar;
temp += 1;
foobar = temp;
```

OR

```
foobar+=1;
```

What does the compiler do?

Compiler output:

(x86 compiler)

```
moveax,[foobar]
incax
mov[foobar],ax
```

Atomic version:

```
inc[foobar]
```

Moral: Don't trust your compiler!

Automatic variables

```
int foo;
void some_function(void) {
foo++;
}

void some_function(void) {
int foo;
foo++;
}
```


Keeping Code Reentrant

```
long I;
void do_something(void) {
  disable_interrupts();
  i+=0x1234;
  enable_interrupts();
}
```

Doesn't work! if called from code with interrupts disabled…

Better:

```
long I;
void do_something(void) {
  push interrupt_state;
  disable_interrupts();
  i+=0x1234;
  pop interrupt_state;
}
```

Or, use semaphores or RTOS locking mechanism

Hardware reentrancy

```
int timer_hi;
interrupt timer(){
  ++timer_hi;
}

long read_timer(void) {
  unsigned int low, high;
  low = inword(hardware_register);
  high=timer_hi;
  return (high<<16 + low);
}
```

This code will fail, occasionally…

One failure mode:

1. `read_timer` reads the hardware and gets 0xffff
2. immediately the timer hardware increments to 0x000
3. The overflow triggers an interrupt. The ISR runs, and increments `timer_hi` to 0x0001, not 0x0000 as in step 1
4. The ISR returns, our `read_timer` concatenates the new 0x0001 with the previously read 0xffff, and returns 0x1ffff– WRONG!!!

Or, while interrupts are disabled:

1. `read_timer` starts. The timer is 0xffff with no overflows.
2. Before much else happens it increments to 0x0000. With interrupts off the pending interrupt gets deferred.
3. `read_timer` returns a value of 0x0000 instead of the correct 0x10000, or the reasonable 0xffff.

A once-a-month bug? How do you find it?

Solutions:

- Stop the timer BEFORE reading!
  Downside: we lose time.
- Or, read `timer_hi`, then the hardware timer, then re-read `timer_hi`. Iterate until the two variable reads are equal.

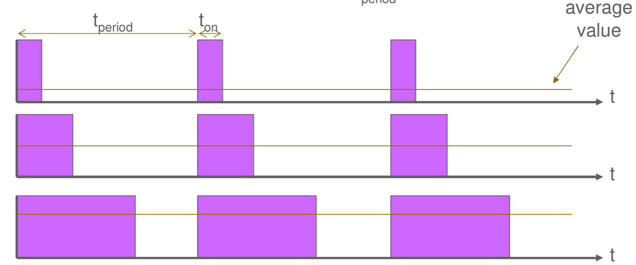
  Downside: can take a long time in a heavily loaded system

II. Pulse Width Modulation

Pulse-width modulation

- Pulse a digital signal to get an average "analog" value
- The longer the pulse width, the higher the voltage

Pulse-width ratio = $\frac{t_{on}}{t_{period}}$



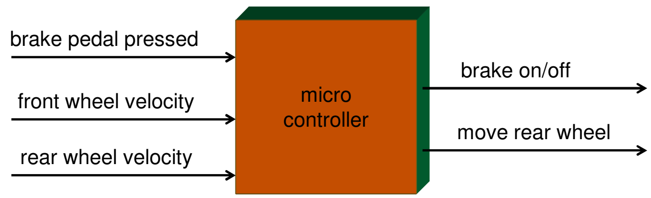
Why pulse-width modulation works

- Most mechanical systems are low-pass filters
  - Consider frequency components of pulse-width modulated signal
  - Low frequency components affect components
    - They pass through
  - High frequency components are too fast to fight inertia
    - They are "filtered out"
- Electrical RC-networks are low-pass filters
  - Time constant (τ = RC) sets "cutoff" frequency that separates low and high frequencies

Anti-lock brake system

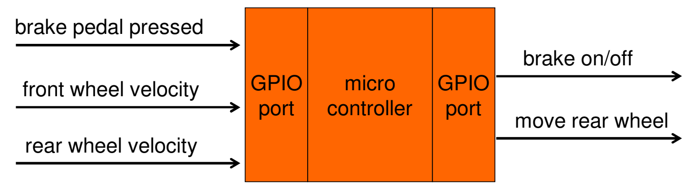
- Rear wheel controller/anti-lock brake system
  - Normal operation
    - Regulate velocity of rear wheel
  - Brake pressed
    - Gradually increase amount of breaking
    - If skidding (front wheel is moving much faster than rear wheel) then temporarily reduce amount of breaking
- Inputs
  - Brake pedal
  - Front wheel speed
  - Rear wheel speed
- Outputs
  - Pulse-width modulation rear wheel velocity
  - Pulse-width modulation brake on/off

Rear wheel controller/anti-lock brake system



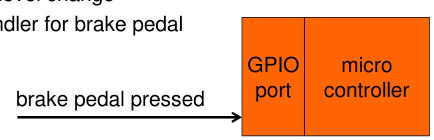
Basic I/O ports (brakes)

- Check if brake pedal pressed – or interrupt
  - brakePressed = read (brakePedalPort)
- Turn brake on/off
  - write (brakePort, onOff)
- Move rear wheel
  - write (rearWheel, onOff)



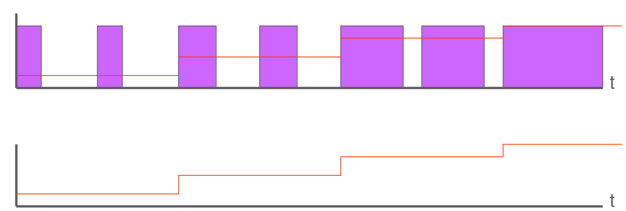
Polling vs. interrupts

- Software must repeatedly check
  - Brake pedal port
  - How often?
  - Need to make sure not to forget to do so (use timer)
- Use automatic detection capability of processor
  - Connect brake pedal to input capture or external interrupt pin
  - Interrupt on level change
  - Interrupt handler for brake pedal



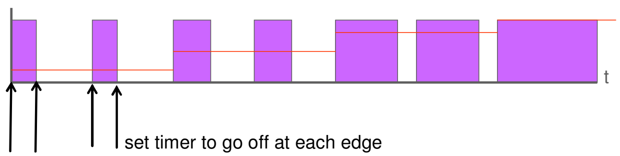
Pulse-width modulation for brakes

- To pump the brakes gradually increase the duty-cycle (t_{on}) until car stops



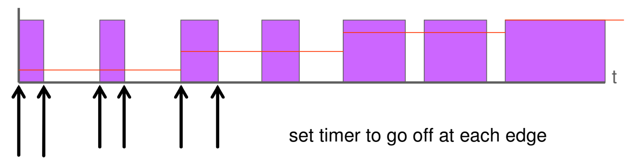
Brake pump setup

- Use timer to turn brake on and off
  - Apply brake
  - Set timer to interrupt after “on” time
  - Disengage brake
  - Set time to interrupt after “off” time
  - Repeat
- How do we tell which interrupt is which?



Brake pump setup (cont’d)

- Change value of “on” time to change analog average
  - average output = (on + off) / (period)
- How do we decide on the period of the pulses?
- Using two timers
  - One to set period (auto-reload)
  - One to turn it off at the right duty cycle



Bright LED

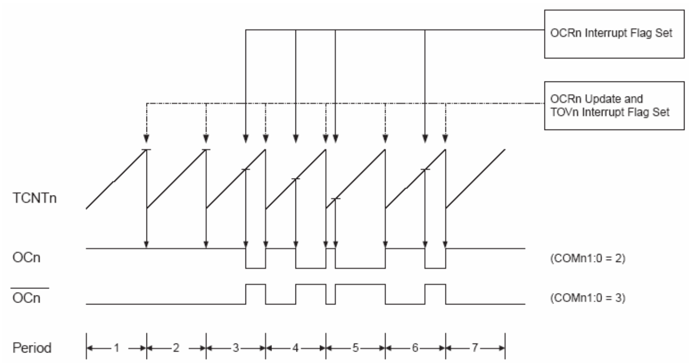
- Easy to control intensity of light through pulse-width modulation
- Duty-cycle is averaged by human eye
  - Light is really turning on and off each period
  - Too quickly for human retina (or most video cameras)
  - Period must be short enough (< 1ms is a sure bet)
- LED output is low to turn on light, high to turn it off
  - Active low output

Sample code for LED

- Varying PWM output

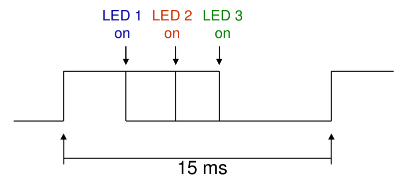
```
volatile uint8_t width; /* positive pusle width */
volatile uint8_t delay; /* used to slow the pulse width changing */

SIGNAL (SIG_OVERFLOW2)
{
    if(delay++ == 20) { OCR2 = width++; delay = 0; }
}

int main (void)
{
    /* must make OC2 pin an output for the PWM to visible */
    DDRD = _BV(DDD7);
    /* use Timer 2 FastPWM and the overflow interrupt to update duty-cycle */
    TCCR2 = _BV (WGM21) | _BV (WGM20) | _BV (COM21) | _BV(COM20) | _BV(CS21) | _BV(CS20);
    TIMSK = _BV (TOIE2);
    /* setup initial conditions */
    delay = 0;
    /* enable interrupts */
    sei ();
    for (;;)
    { ; /* LOOP FOREVER as the interrupt will make necessary adjustment */ }
    return (0);
}
```

Fast PWM

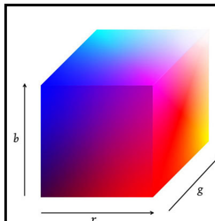


LED PWM control

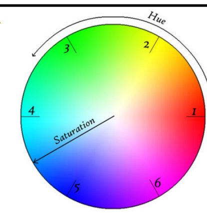
- Control three LEDs: Red, Green, and Blue
- Active Low, 15 ms period, 256 possible values for LED
- Timer 0 interrupt 15ms/256
- Each interrupt, dec. count and decide if each LED is on
  - if count is 0, count is 255 and all LEDs are off



III. Color



Color

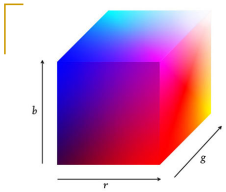


- Color perception usually involves three quantities:
  - *Hue*: Distinguishes between colors like red, green, blue, etc
  - *Saturation*: How far the color is from a gray of equal intensity
  - *Lightness*: The perceived intensity of a reflecting object
- Sometimes lightness is called *brightness* if the object is emitting light instead of reflecting it.
- In order to use color precisely in computer graphics, we need to be able to specify and measure colors.

Color Spaces

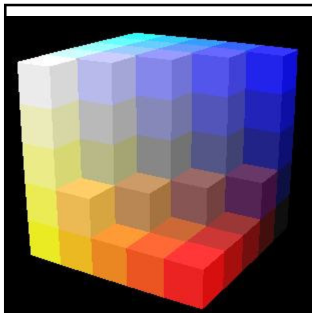
- Definition: A mapping of color components onto a Cartesian coordinate system in three or more dimensions.
- RGB, CMY, XYZ, HSV, HLS, Lab, UVW, YUV, YCrCb, Luv, $L^* u^* v^*$, ..
- Different Purposes: display, editing, computation, compression, ..
- Equally distant colors may not be equally perceivable

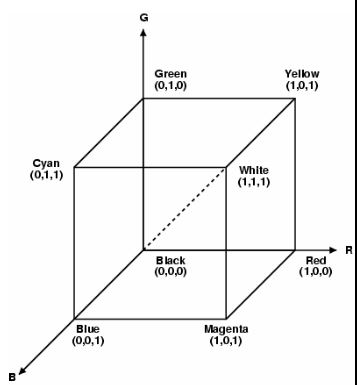
Additive Model: (RGB System)



- R, G, B normalized on orthogonal axes
- All representable colors inside the unit cube
- Color Monitors mix R, G and B
- Video cameras pick up R, G and B
- CIE (Commission Internationale de l'Eclairage) standardized in 1931: B: 435.8 nm, G: 546.1 nm, R: 700 nm.
- 3 fixed components acting alone can't generate all spectrum colors.

RGB Color space



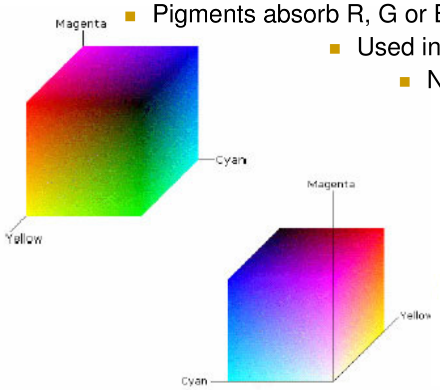


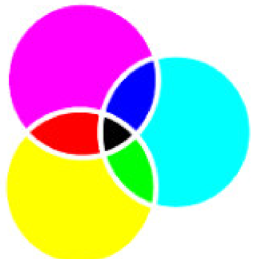
Problems with RGB

- Only a small range of potential perceivable colors (particularly for monitor RGB)
- It isn't easy for humans to say how much of RGB to use to get a given color
  - How much R, G and B is there in "brown"?
- Perceptually non-linear
  - Two points, a certain distance apart, may be perceptually different in one part of the space, but could be same in another part of the space.

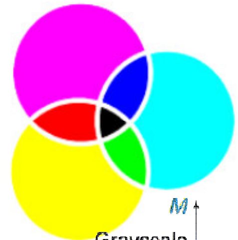
Subtractive model (CMY System)

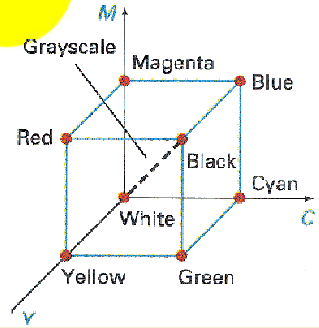
- Color results from removal of light from the illumination source
- Pigments absorb R, G or B and so give C, M or Y
- Used in deskjet/ inkjet printers.
- No ink (pigment) = white



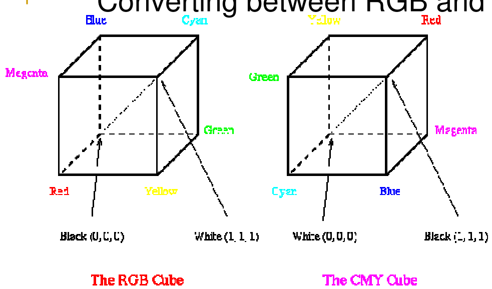


CMY Color space



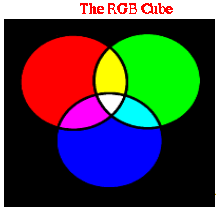


Converting between RGB and CMY



$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} C \\ M \\ Y \end{bmatrix}$$



Specifying Color

- Color perception usually involves three quantities:
  - *Hue*: Distinguishes between colors like red, green, blue, etc
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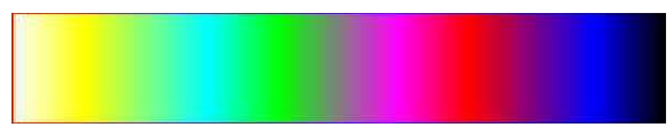
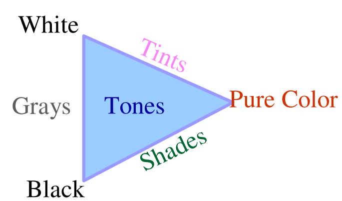


How Do Artists Do It?

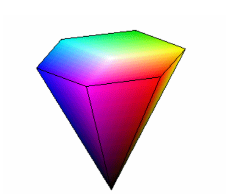
- Artists often specify color as tints, shades, and tones of saturated (pure) pigments
- *Tint*: Gotten by adding white to a pure pigment, decreasing saturation
- *Shade*: Gotten by adding black to a pure pigment, decreasing lightness
- *Tone*: Gotten by adding white and black to a pure pigment

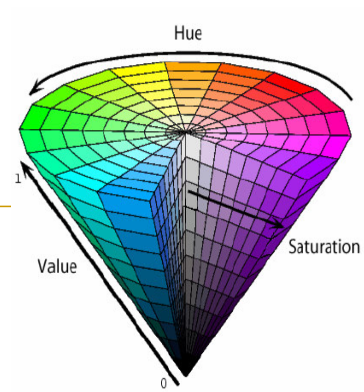


HSV Color Space

- Computer scientists frequently use an intuitive color space that corresponds to tint, shade, and tone:
  - Hue - The color we see (red, green, purple)
  - Saturation - How far is the color from gray (pink is less saturated than red, sky blue is less saturated than royal blue)
  - Brightness (Luminance) - How bright is the color (how bright are the lights illuminating the object?)

HSV Color space



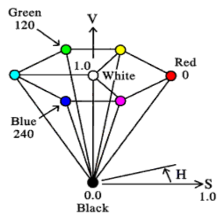


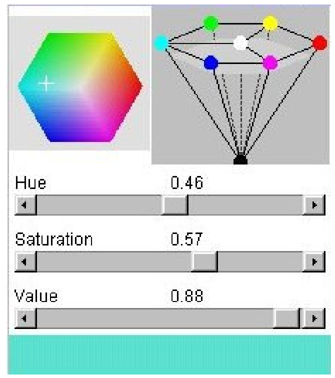
HSV Color Model

- Hue (H) is the angle around the vertical axis
- Saturation (S) is a value from 0 to 1 indicating how far from the vertical axis the color lies
- Value (V) is the height of the hexcone"

HSV Color Space

- A more intuitive color space
  - H = Hue
  - S = Saturation
  - V = Value (or brightness)



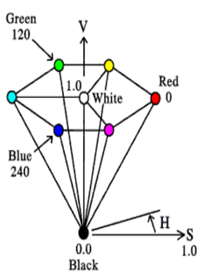


http://www.cs.rit.edu/~ncs/color/a_spaces.html

HSV System

- Normally represented as a cone or *hexcone*
- Hue is the angle around the circle or the regular hexagon; $0 \le H \le 360$
- Saturation is the distance from the center; $0 \le S \le 1$
- Value is the position along the axis of the cone or hexcone; $0 \le V \le 1$
- Value is not perceptually-based, so colors of the same value may have slightly different brightness
- Main axis is grey scale

HSV to RGB Conversion




```
if ( S == 0 )                       //HSV values = From 0 to 1
{
   R = V * 255                      //RGB results = From 0 to 255
   G = V * 255
   B = V * 255
}
else
{
   var_h = H * 6
   var_i = int( var_h )             //Or ... var_i = floor( var_h )
   var_1 = V * ( 1 - S )
   var_2 = V * ( 1 - S * ( var_h - var_i ) )
   var_3 = V * ( 1 - S * ( 1 - ( var_h - var_i ) ) )

   if       ( var_i == 0 ) { var_r = V     ; var_g = var_3 ; var_b = var_1 }
   else if ( var_i == 1 ) { var_r = var_2 ; var_g = V     ; var_b = var_1 }
   else if ( var_i == 2 ) { var_r = var_1 ; var_g = V     ; var_b = var_3 }
   else if ( var_i == 3 ) { var_r = var_1 ; var_g = var_2 ; var_b = V     }
   else if ( var_i == 4 ) { var_r = var_3 ; var_g = var_1 ; var_b = V     }
   else                    { var_r = V     ; var_g = var_1 ; var_b = var_2 }

   R = var_r * 255                  //RGB results = From 0 to 255
   G = var_g * 255
   B = var_b * 255
   }
}
```