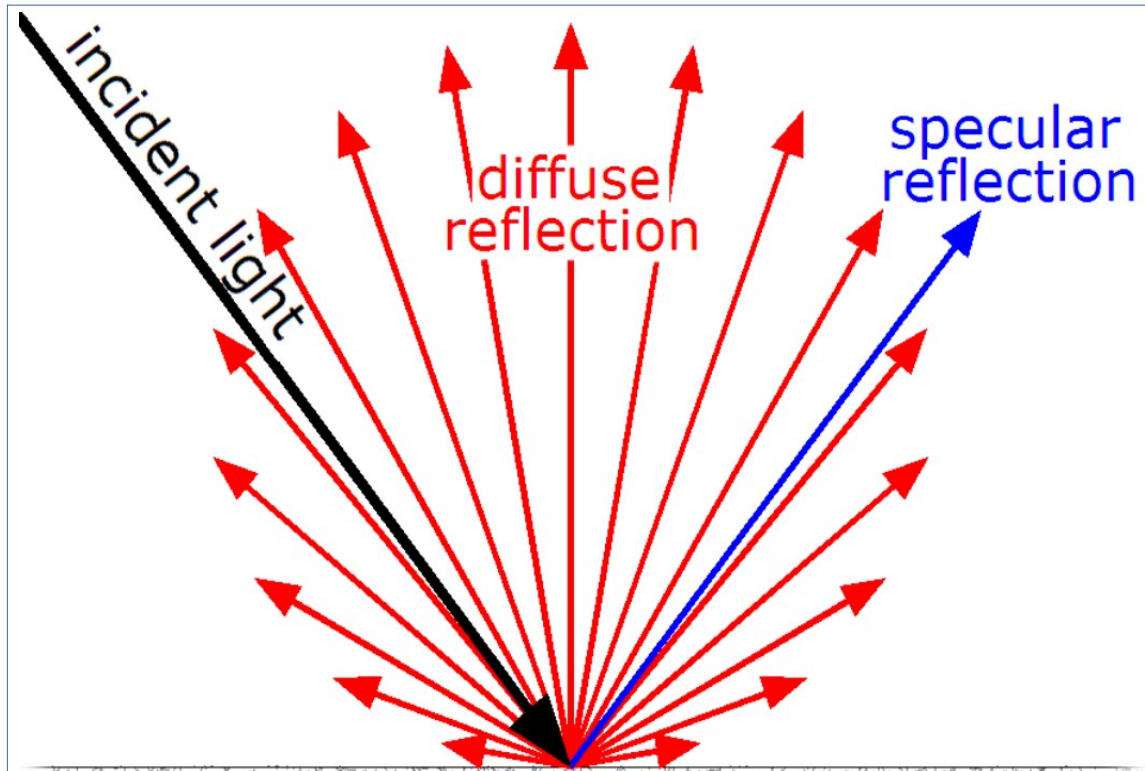


# Diffuse Reflection



Two Key Characteristics:

1. The surface with reflectivity as  $K_d = (k_r, k_g, k_b)$ , e.g., diffuse coefficients;

2. The decay of incident light is inverse proportional to its distance from the source to the surface point. e.g.,  $1/(r^2)$ , where  $r$  is being the distance from the light source to the surface.

Specular vs. diffuse reflection

[https://en.wikipedia.org/wiki/Diffuse\\_reflection](https://en.wikipedia.org/wiki/Diffuse_reflection)

Diffuse Reflection: the reflection of light uniformly in all different directions, the surface of this reflection exhibits Lambert reflection, e.g., equal luminance when viewed from all directions.

# Diffuse Reflection Formulation

Light source  $I_s(x,y)$  consists of r, g, b 3 primitive colors as follows, but let's simplify it as white color, so r, g, b all equal and have the highest value (if in graphics, they are 255)

$$\vec{I}_s(x,y,z) = (I_r(x,y,z), I_g(x,y,z), I_b(x,y,z)) \quad \dots (1)$$

Object surface consists of reflectivity, e.g., coefficient of reflection

$$\vec{K}_d = (K_r, K_g, K_b) \quad \dots (2)$$

$\vec{r}_d$  vector in Equation (1) is a ray equation, just like  $I_s(x,y,z)$  but has no r, g, b primitive color defined in it for the matter of simplicity.

# Diffuse Reflection Equation

Let's consider white color of the point light source, then each primitive color  $r$ ,  $g$ ,  $b$  of the object surface  $I(x,y,z)$  can be computed as follows:

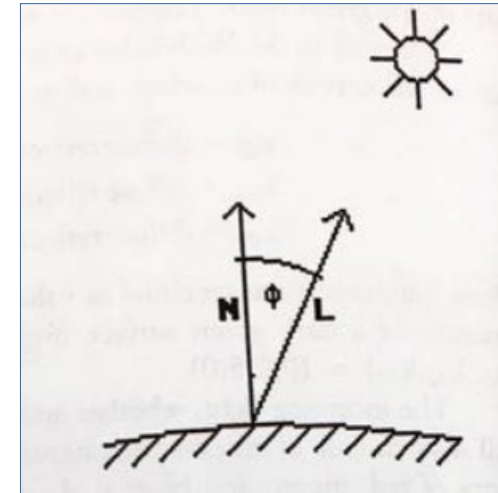
$$I_r = K_{dr} \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} \frac{1}{\|\vec{r}\|_2} \quad \dots (1.1)$$

where

$$\|\vec{r}\|_2^2 = x_r^2 + y_r^2 + z_r^2$$

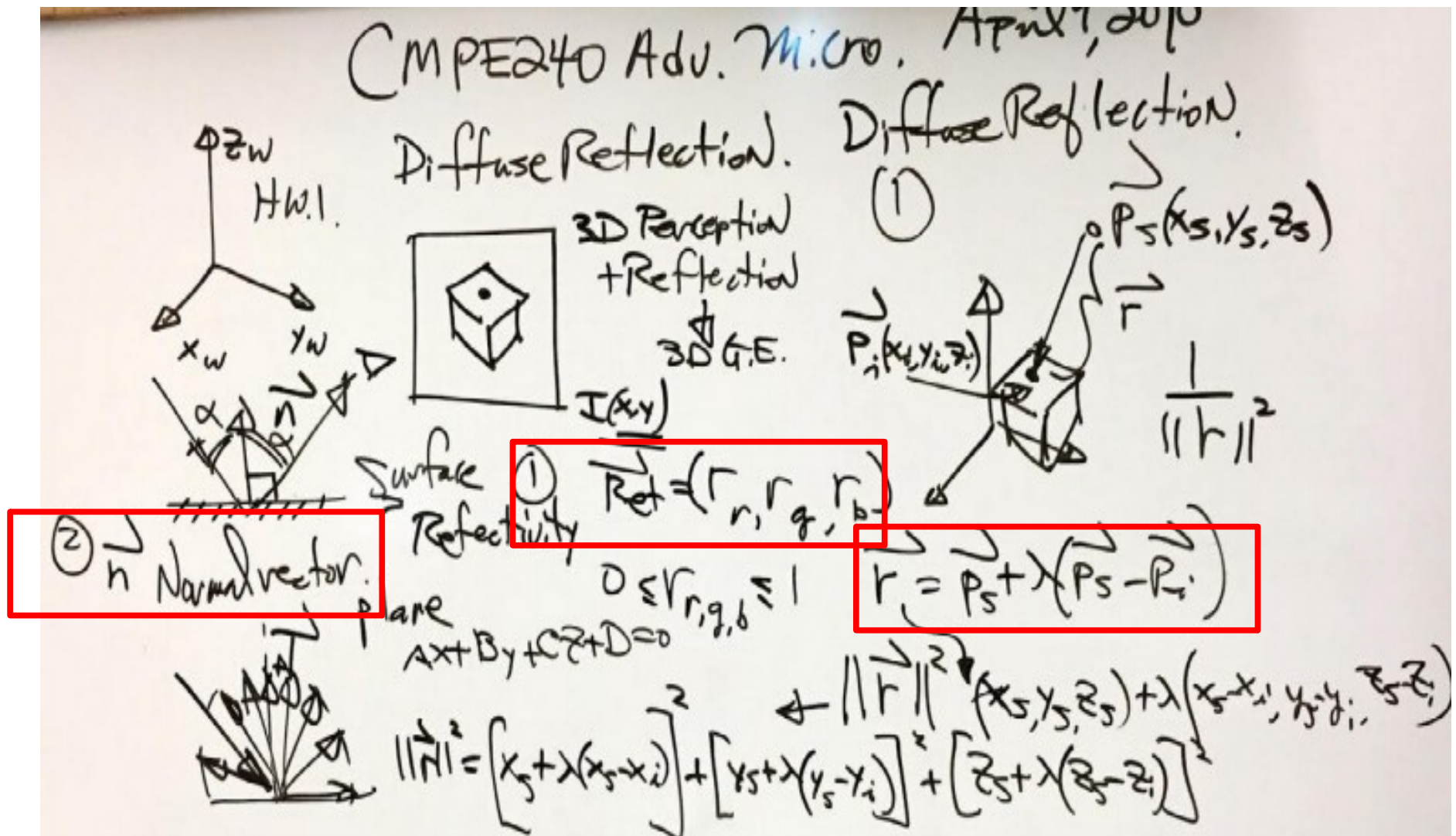
$$I_g = K_{dg} \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} \cdot \frac{1}{\|\vec{r}\|_2} \quad \dots (1.2)$$

$$I_b = K_{db} \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} \cdot \frac{1}{\|\vec{r}\|_2} \quad \dots (1.3)$$



Reference: Computer Graphics, C. K. Pokorny, C. F. Gerald, pp. 514

# Formulation Of Diffuse Reflection Equation





# Point Light Source And Incident Angle

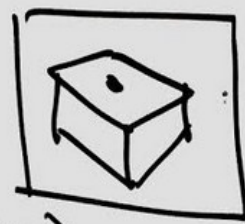
Point light source

CMPE240 Adv. Micro, April 9, 2018

②  $\vec{P}_S(x_s, y_s, z_s) = (r_{P_S}, g_{P_S}, b_{P_S})$

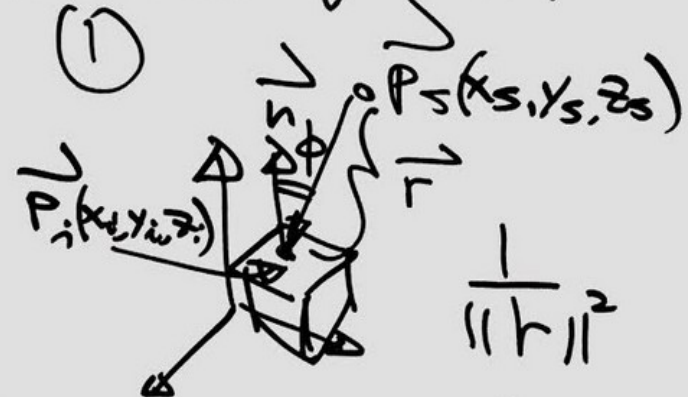


$0 \leq r, g, b \leq 1$   
16 bits / 24 bits.  
"The Sun"



Diffuse Reflection.

①



$$\frac{1}{||r||^2}$$

③

$$\vec{n} \cdot \vec{r} = ||\vec{n}|| ||\vec{r}|| \cos \phi$$

$$\cos \phi = \frac{\vec{n} \cdot \vec{r}}{||\vec{r}|| ||\vec{n}||}$$

$$I_{diff}(x, y, z) = k \frac{1}{||r||^2} \frac{\vec{n} \cdot \vec{r}}{||\vec{n}|| ||\vec{r}||} (r, g, b)$$

① ②

$$\vec{r} = \vec{P}_S + \lambda (\vec{P}_S - \vec{P}_i)$$

$$||\vec{r}||^2 = [x_s + \lambda(x_s - x_i)]^2 + [y_s + \lambda(y_s - y_i)]^2 + [z_s + \lambda(z_s - z_i)]^2$$

Angle of incident light

# Step 1-5 For Diffuse Reflection Computation

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Consider "Paint" Diff. Reflection

ONLY

Step 1.  $\{ \vec{P}_i(x_i, y_i, z_i) | i \in I \}$

Step 2.  $\vec{P}_S$  white, Step 3.

$\vec{R} = (r, g, b) = (1.0, 0.0, 0.0)$  "Red"

Step 4. Eq (1)

$$I_{\text{diff}}(x, y, z) = k \frac{1}{\|\vec{r}\|^2} \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} (r, g, b)$$

Compute Diff. Reflection ON Each Face (1) (2) ... (1)

"Visible"  $\vec{P}_i(x_i, y_i, z_i)$  (x<sub>w</sub>, y<sub>w</sub>, z<sub>w</sub>)  
World

Step 5. Transformation Pipeline (World-2-Viewer + Perspective projection)

$P_1 \rightarrow P_2 \rightarrow P_3 \rightarrow P_4$   
Counter Clockwise

Arrange vertex in contour clock wise direction when viewing from outside

# Step 6 For Diffuse Reflection Computation

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Consider "Paint" Diff. Reflection Diffuse Reflection.

ON LCD

Step 6. Compute Colour On Each Line (Linked by  $\vec{P}_i \neq \vec{P}_j$ )

Interpolation ( $B_i$  for  $x \neq y$ )

$I_{diff}(x,y,z) = k \frac{1}{\|r\|^2} \frac{n \cdot r}{\|n\| \|r\|} (r, g, b)$

Given  $\vec{P}_i, \vec{P}_j$ , Draw a line Linking  $\vec{P}_i \neq \vec{P}_j$  "GAPS"

D.D.A.  $y = ax + b$

Step 5. Transformation Pipeline

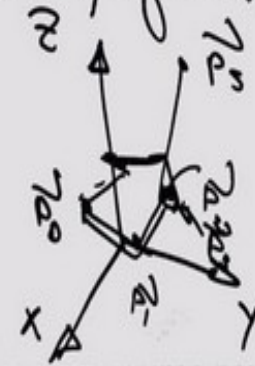


# Example On Diffuse Reflection Computation (1)

April 16, 2018 CMPE240 Adv. Micro HL 1/

- 1) Homework Submission via E-mail (Project w/ Source Code). the 2nd ONE ON SPI-Slave Due this Week; <sup>Exported.</sup>
- 2) Roadmap: Objective - 3D G.E. < 3D Diffuse Reflection  
- 2D G.E. S.P.I. (master/slave) I/P
- 3) INTER for Summer (2 pos). (Hardware I/P)  
ARM/CPU (Linux Device Driver.) LCD Driver\*  
Vision/Machine Learning

Example: Ray Equation. Continued from the Last Lecture.



$I_{diff, P_2}(x_2, y_2, z_2)$  in  $x_w, y_w, z_w$  World  
 $E(200, 200, 200)$ , Perspective Projection  
 Input (2D LCD)  $\rightarrow$  Viewer Coordinate System  $\dots (1)$

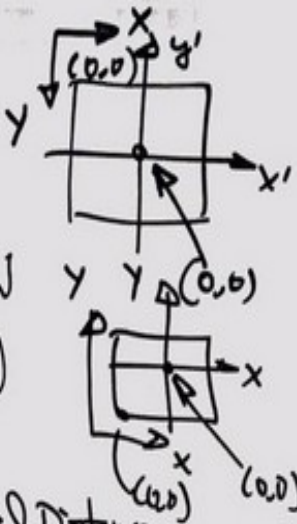
Focal Distance  $D = 100$  or  $20$

Input  $(x_i, y_i, z_i)$

Viewer Coordinate System  $\dots (1)$

Equations for projection:

$$X''_i = \frac{D}{z_i} \cdot x_i$$

$$Y''_i = \frac{D}{z_i} \cdot y_i$$


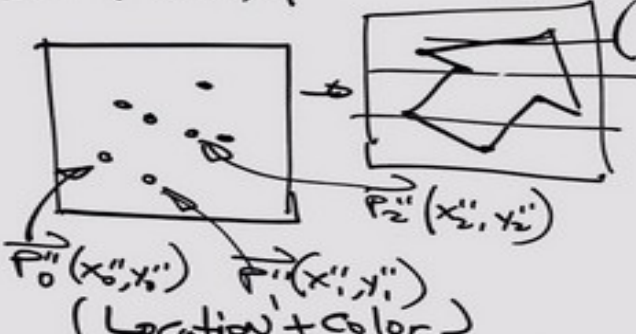


# Example On Diffuse Reflection Computation (2)

$\{\vec{P}_i(x_i, y_i, z_i) | i=0, 1, \dots, 6\}$   
 Hence, from P.P. (Eqn-1), we have  
 Suppose  $D=10$ , find  
 $\{\vec{P}_i(x_i, y_i) | i=0, 1, \dots, 6\}$

Example: Given  $(x_0, y_0) = (1, 1), (x_1, y_1) = (3, 5)$   
D.D.A. to Draw a Line  
 $Slope = a = \frac{y_1 - y_0}{x_1 - x_0} = \frac{5-1}{3-1} = 2$   
 (Note: if  $|a| < 1$ , then No GAP,  
 $y_{k+1} = a x_{k+1} + b, x_{k+1} = x_k$ )  
 Switch x and y.  
 $\frac{x - x_1}{x_2 - x_1} = \frac{y - y_1}{y_2 - y_1}$   
 $y = y_1 + \frac{y_2 - y_1}{x_2 - x_1}(x - x_1)$   
 $= \frac{y_2 - y_1}{x_2 - x_1}x + y_1 - \frac{y_2 - y_1}{x_2 - x_1}x_1$   
 $y = ax + b, \frac{1}{a}y = x + \frac{b}{a} (1,1)$   
 $\therefore x = \frac{1}{a}y - \frac{b}{a} \dots (2)$   
 $x = \frac{1}{2}y + \frac{1}{2} \begin{cases} x_{k+1} = x_k + 1 \\ x_{k+1} = \frac{1}{2}y_{k+1} + \frac{1}{2} \end{cases}$

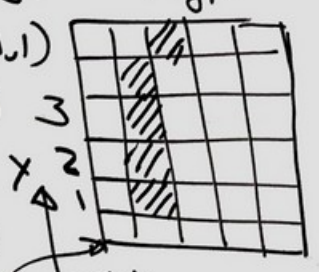
(Location + Color)  
Interpolation to find Color  
Find Boundaries?  
 Find Boundary:  $y = ax + b$  (GAPs)  
 $y_{k+1} = ax_{k+1} + b, x_{k+1} = x_k + 1$   
D.D.A. (Digital Differential Algorithm)




0 1 2 3 4 5 6

# Use DDA Algorithm To Find Boundary Points

Algorithm: 1° Given  $(x_0, y_0)$  Starting pt,  $(x_{N-1}, y_{N-1})$  Ending pt.  
 Find Slope  $a$ ;  
 2° if  $|a| < 1$ , then  $\begin{cases} x_{k+1} = x_k + 1 \\ y_{k+1} = a x_{k+1} + b \end{cases}$   
 3° Finish all pts till Reaching  $(x_{N-1}, y_{N-1})$  or  $x = \frac{1}{a}y - \frac{b}{a}$ , then  $\begin{cases} y_{k+1} = y_k + 1 \\ x_{k+1} = \frac{1}{a}y_{k+1} - \frac{b}{a} \end{cases}$   
 DDA Algorithm

Harry LI CMPE240 Adv. Micro April 18, 2018. y.  
 Diffuse Reflection Computation.  
 D.D.A (github/rualili)  
 Example: Fig. 1  
 Starting pt. (1,1)  
 Ending. (2,5)  
 Slope:  $\frac{y_2 - y_1}{x_2 - x_1} = \frac{5-1}{2-1} = 4$  (0,0)  
  
 $y = ax + b \rightarrow x = \frac{1}{a}y + \left(-\frac{b}{a}\right)$   
 For  $y_3 = y_2 + 1 = 2 + 1 = 3$   
 $x_3 = \frac{1}{a}y_3 + \left(-\frac{b}{a}\right) = \frac{1}{4} \cdot 3 + \frac{1}{4} = \frac{4}{4} = 1$   $a=4, b=-1$   
 For  $y_4 = y_3 + 1 = 3 + 1 = 4$   
 $x_4 = \frac{1}{a}y_4 + \left(-\frac{b}{a}\right) = \frac{4}{4} + \frac{1}{4} = \frac{5}{4}$   $a=4, b=-1$   
 Next. Diffuse Reflection ON Boundaries.  
 Index:  $y_{k+1} = y_k + 1 = 1 + 1 = 2$   
 $x_{k+1} = \frac{1}{a}y_{k+1} + \left(-\frac{b}{a}\right) = \frac{1}{4} \cdot 2 + \left(-\frac{-1}{4}\right) = \frac{3}{4}$   $y_k = 1$

① DDAP: Where pixels Locations are.

② Interpolation to find color (Diffuse Reflection)

From 3D illustration in Fig 2  $\rightarrow$  2D

Note:

1. Derive linear interpolation technique, equation (1) and (2), to find the boundary color along x-dimension and y-dimension respectively;
2. Then calculate average of the color from x-dimension and y-dimension as in Equation (3).

1. Derive linear interpolation technique, equation (1) and (2), to find the boundary color along x-dimension and y-dimension respectively;
2. Then calculate average of the color from x-dimension and y-dimension as in Equation (3).

$$I_{diff}(y) = \frac{I_{diff}(y_i) - I_{diff}(y_j)}{y_i - y_j} y - \frac{y_j (I_{diff}(y_i) - I_{diff}(y_j))}{y_i - y_j} + I_{diff}(y_j) \quad (2)$$

$$I_{diff}(x,y) = \frac{1}{2} (I_{diff}(x) + I_{diff}(y)) \quad \dots (3)$$

where  $(x,y) \in \Omega_{DDA}(DDA \neq 0)$







# Design LCD Drive Unit

## LPC Master SPI To LPC Slave SPI

Example: \* CMPE240 Adv. Micro, April 25, 2018 Harry Li 1/.

(0,0) Col. Row

(i,j)  $i=0,1,2,\dots,(No-Rows-1)$   
 $j=0,1,2,\dots,(No-Cols-1)$   
 $= (127, 256)$

Timing:  $255 \frac{1}{T_{CLKR}} + 126 \frac{1}{T_{CLKD}}$  (Right Before Starting @ this px)

1024.765

\* First Variable (col) 2nd Variable (Rows)

Example: Hardware Display Driver.

Sol: On the I/F to Master/Host LPC1769, Select SPI.

3+1 Signals { MOSI, MISO, SSEL, SCK } → Connect to Slave LPC1769. (the Same as Lab Assignment)

Second, LPC (Slave) I/F to LCD

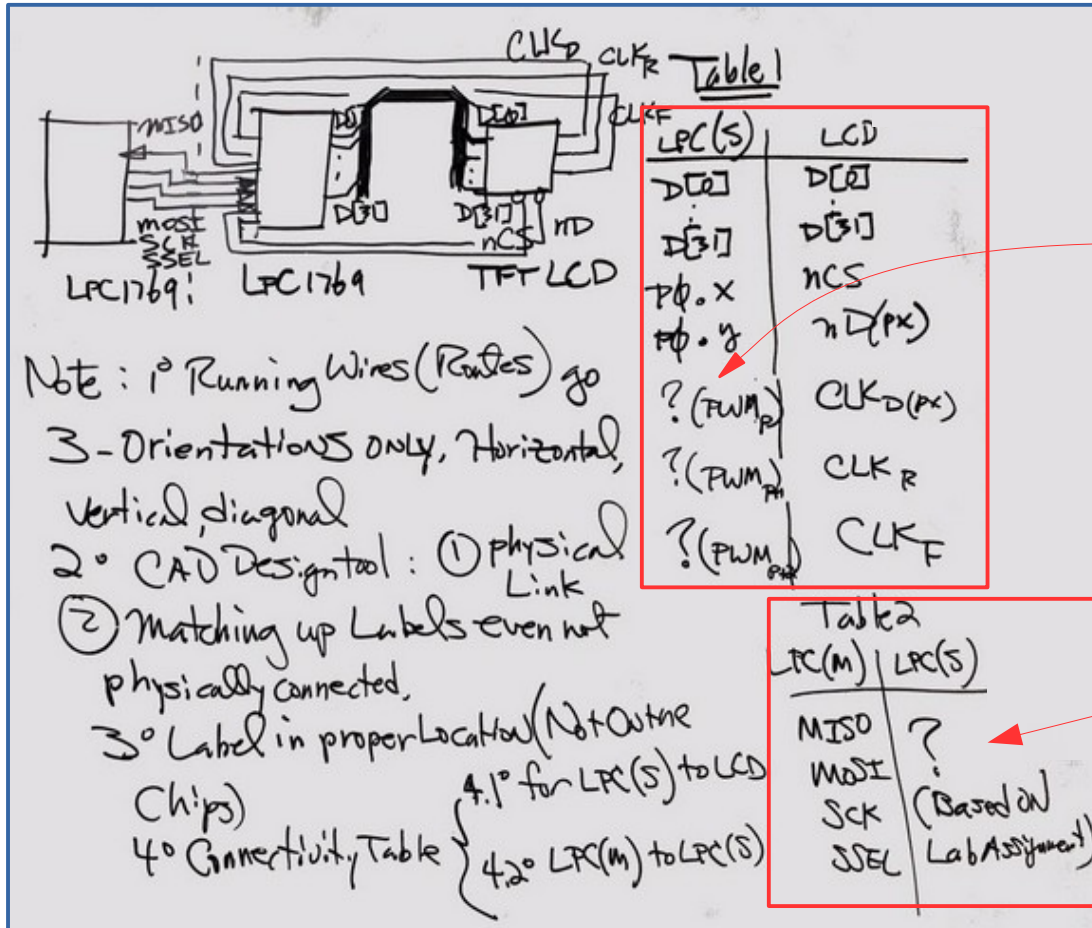
Slave LPC { OR UART/I2C SDA, SCK } →

the output

0x84 10001000 4

Addr

# Slave LPC I/F To LCD



Look up the SCH from the pdf doc of the LPC CPU module to finish the pin selection

Look up the SCH from the pdf doc of the LPC CPU module to finish the pin selection (as in the lab)

**Example:** 160 x 120 Resolution. For LCD Display, 30FPS, Pix Depth (color Depth) 24 bits. Design LPC Driver

Find (1) CLK<sub>D</sub>, (2) Software Driver for SPI

CLK<sub>F</sub> → CLK<sub>R</sub> → CLK<sub>D</sub> Clock on LPC (Master) - NonBlocking

(1/120) (x60) CLK<sub>D</sub>[15:8] = ? (CPSDUSR is given) 2-204