

# CS4803DGC Design and Programming of Game Console

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# Assignment #6

- An image controller
- What to learn
  - Graphics mode
  - Fixed operations
  - Sound
- No need to write assembly code. You can use any APIs



# Requirements

- UP/DOWN- move up/down
- LEFT/RIGHT- move left/right
- A- reset to original
- L/R- Rotate
- X/Y- Scale up/ scale down
- Touch- the background should move in the same direction as the stylus. It doesn't need to move as much as the stylus in magnitude- just the same direction.
- **Sound:** At every 10<sup>th</sup> degree rotation, generate sound
- Demo (4/15) Friday
- Report ( 5% of Lab #6): **Lab 6 will be 10% of the total grade.**
- **Final project will be 20% of the total grade**
  - Commented code and simple descriptions
  - Any problems encountered and solutions



# Graphics Mode

- Dual screen: Main screen, sub screen
- 8 Graphics Modes
- Background Type
  - Frame buffer: manipulate each pixel
  - 3D: OpenGL 3D feature
  - Text: aka tile background
  - Rotation: similar to text but rotation, scale
  - **Extended rotation:**
  - Large bitmap



# Extended Rotation Background

- A bitmap that can be displayed on the screen
- The bitmap could be larger than the physical size of the screen
- Hardware scrolling, rotation, scaling, shearing
- Register sets





# Graphics Modes

Main 2D Engine				
Mode	BG0	BG1	BG2	BG3
Mode 0	Text/3D	Text	Text	Text
Mode 1	Text/3D	Text	Text	Rotation
Mode 2	Text/3D	Text	Rotation	Rotation
Mode 3	Text/3D	Text	Text	Extended
Mode 4	Text/3D	Text	Rotation	Extended
<b>Mode 5</b>	Text/3D	Text	<b>Extended</b>	<b>Extended</b>
Mode 6	3D	-	Large Bitmap	-
Frame Buffer	Direct VRAM display as a bitmap			



# Graphics Modes

SUB 2D Engine				
Mode	BG0	BG1	BG2	BG3
Mode 0	Text/3D	Text	Text	Text
Mode 1	Text/3D	Text	Text	Rotation
Mode 2	Text/3D	Text	Rotation	Rotation
Mode 3	Text/3D	Text	Text	Extended
Mode 4	Text/3D	Text	Rotation	Extended
<b>Mode 5</b>	Text/3D	Text	Extended	<b>Extended</b>

- Frame buffer can be used by only one screen



# Initialization

- `initVideo`
- `initBackground`





# Mode 5 Set

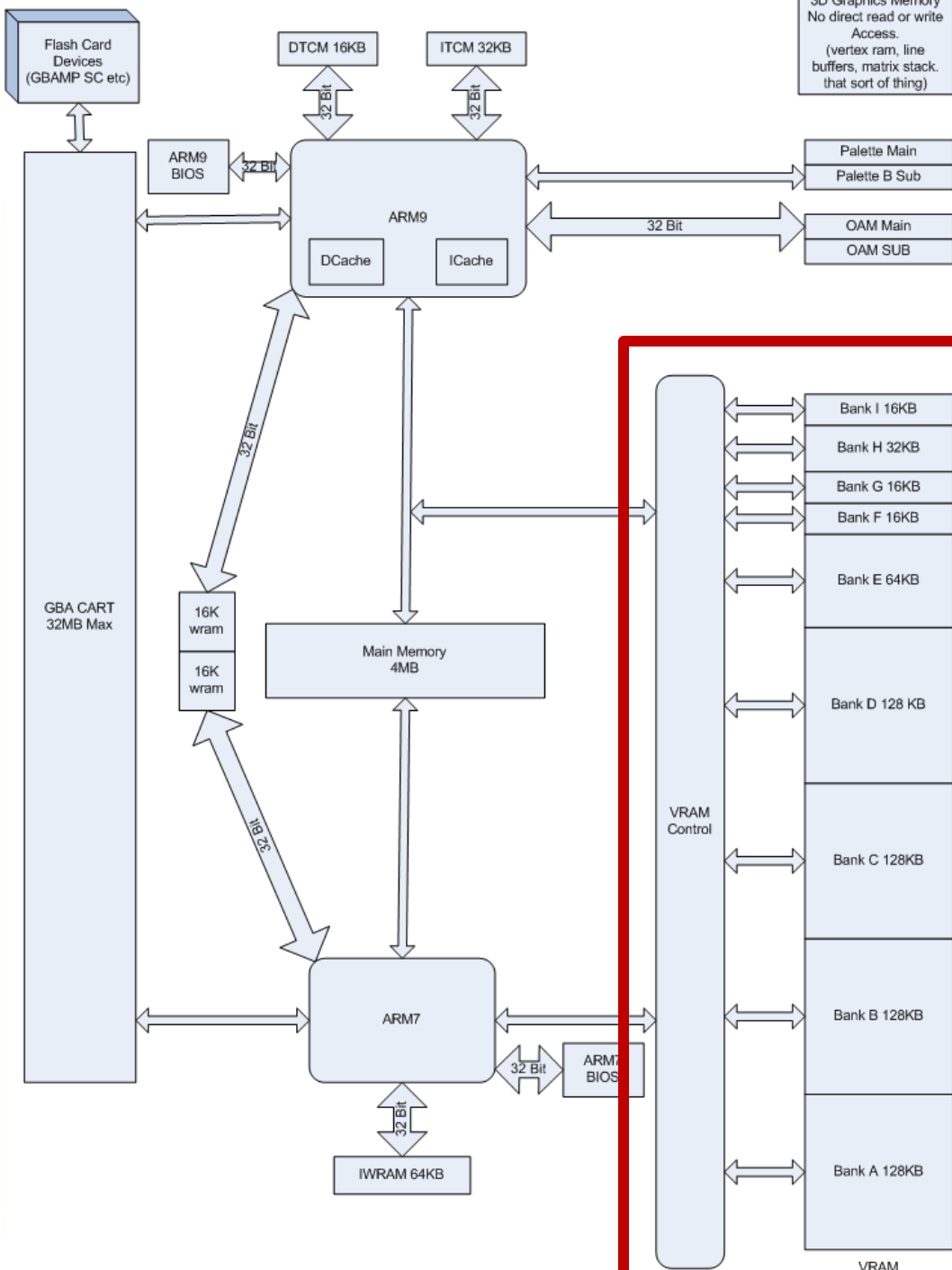
```
/* Set the video mode on the main screen. */
```

```
videoSetMode(MODE_5_2D | // Set the graphics mode to Mode 5  
  DISPLAY_BG2_ACTIVE | // Enable BG2 for display  
  DISPLAY_BG3_ACTIVE); //Enable BG3 for display
```

```
/* Set the video mode on the sub screen. */
```

```
videoSetModeSub(MODE_5_2D | // Set the graphics mode to Mode 5  
  DISPLAY_BG3_ACTIVE); // Enable BG3 for display
```

# Video RAM (VRAM)



VRAM works as working space for display. A certain memory space will be drawn depending on Mode 9 banks

Bank	Control Register	Size
VRAM_A	VRAM_A_CR	128KB
VRAM_B	VRAM_B_CR	128KB
VRAM_C	VRAM_C_CR	128KB
VRAM_D	VRAM_D_CR	128KB
VRAM_E	VRAM_E_CR	64KB
VRAM_F	VRAM_F_CR	16KB
VRAM_G	VRAM_G_CR	16KB
VRAM_H	VRAM_H_CR	32KB
VRAM_I	VRAM_I_CR	32KB



# VRAM allocation

- We need to allocate right amount of video memory to the correct memory address for a mode
  - Large enough to have the bitmap

```
void initVideo() {  
    /*  
    * Map VRAM to display a background on the main and sub screens.  
    * The vramSetMainBanks function takes four arguments, one for each of the  
    * major VRAM banks. We can use it as shorthand for assigning values to  
    * each of the VRAM bank's control registers.  
    * We map banks A and B to main screen background memory. This gives us  
    * 256KB, which is a healthy amount for 16-bit graphics.  
    * We map bank C to sub screen background memory.  
    * We map bank D to LCD. This setting is generally used for when we aren't  
    * using a particular bank.  
    */  
    vramSetMainBanks(VRAM_A_MAIN_BG_0x06000000,  
                    VRAM_B_MAIN_BG_0x06020000,  
                    VRAM_C_SUB_BG_0x06200000,  
                    VRAM_D_LCD);  
  
    // graphics mode setting (previous slide code)  
}
```



# Other Control Parameters

- BG\_{32x32|32x64|64x32|64x64}; used for text backgrounds
- BG\_RS\_{16x16|32x32|64x64|128x128}; used for rotation backgrounds
- BG\_BMP{8|16}\_{128x128|256x256|512x256|512x512}: extended rotation background variants, bit per pixel and resolution
- BG\_BMP8\_1024x512 and BG\_BMP8\_512x1024: is used only for MODE 6
- BG\_WRAP\_ON: if you scroll to the end of the image, it will wrap. This way, you can "scroll forever".
- BG\_PRIORITY(n) or BG\_PRIORITY\_n: the priority of the background: 0 is the highest priority, 3 the lowest. A background with a higher priority will be printed on top of backgrounds with lower priorities. If there is a sprite with the same priority, it will be printed on top of the background.
- BG\_MOSAIC\_ON: You have to set this flag if you want to use the mosaic effect (see below).
- BG\_TILE\_BASE(n): each tile-block is 16KB. This parameter selects, which block we want to use. For tile-based backgrounds only.
- BG\_MAP\_BASE(n): each map-block is 2KB. This parameter selects, which block we want to use. For tile-based backgrounds only.
- BG\_BMP\_BASE(n): each bitmap-block is 16KB. This parameter selects, which block we want to use. For bitmap backgrounds only.



# More Registers to Control BackGround

- **BGn\_X0**: this controls where the left origin of the screen maps to the background
- **BGn\_Y0**: this controls where the top of the screen maps to the background
- With  $n = 0, 1, 2$  or  $3$ . If we use an extended rotation background we have even more registers:
- **BGn\_XDX**: this controls the x-axis scaling, it's a 0.8.8 fixed point number. If you don't want to scale at all, set it to  $1.0$  (which is  $1 \ll 8$ ). Increase the value to "zoom out." For example,  $2.0$  ( $1 \ll 9$ ) will show the background at half its width.
- **BGn\_XDY**: this is for rotating and shearing
- **BGn\_YDX**: this is for rotating and shearing
- **BGn\_YDY**: this controls the y-axis scaling and works the same as **BGn\_XDX**.
- **BGn\_CX**: this controls where the left origin of the screen maps to the background (in 0.8.8 fixed point, too).
- **BGn\_CY**: this controls where the top of the screen maps to the background (in 0.8.8 fixed point, too).
- With  $n = 2$  or  $3$  and the same for the sub screen (**SUB\_BG2\_X0** etc.).
- When using a rotation background or extended rotation background the **BGn\_CX** and **BGn\_CY** registers replace **BGn\_X0** and **BGn\_Y0**.



# initBackgrounds()

```
/* Set up affine background 3 on main as a 16-bit color background. */  
    REG_BG3CNT = BG_BMP16_256x256 | BG_BMP_BASE(0) | // The starting  
    place in memory  
BG_PRIORITY(3); // A low priority /* Set the affine transformation matrix for the  
    main screen background 3 * to be the identity matrix. */  
REG_BG3PA = 1 << 8;  
REG_BG3PB = 0;  
REG_BG3PC = 0;  
REG_BG3PD = 1 << 8; /* Place main screen background 3 at the origin (upper  
    left of the * screen). */  
REG_BG3X = 0; REG_BG3Y = 0;
```

# Affine Transformation Matrix

- Each background is also transformed by its affine transformation matrix
- $X \rightarrow Ax+B$
- 4 registers [ABCD]
- A: REG\_BG3PA, B:REG\_BG3PB, C:REG\_BG3PC, D: REG\_BG3PD

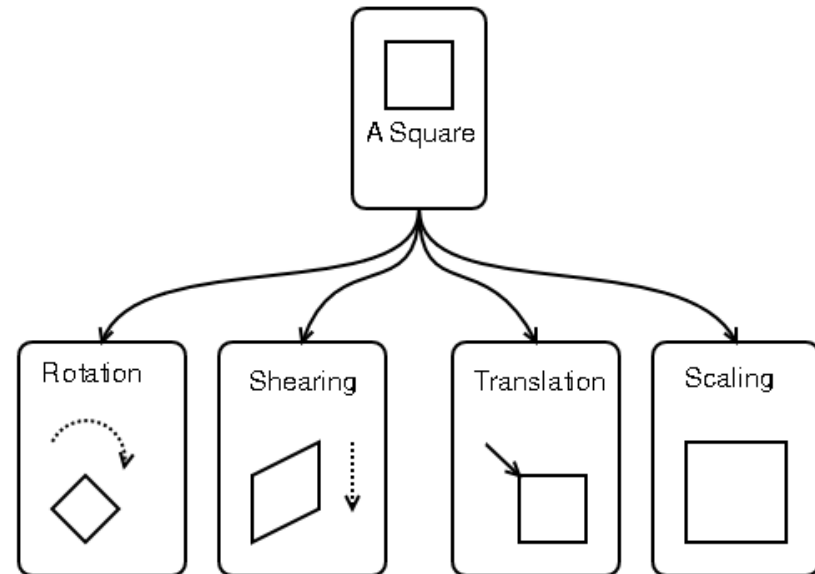


Figure 2. Affine transform Matrixes in Homogenous space

Rotation matrix

$\cos \theta$	$-\sin \theta$	0
$\sin \theta$	$\cos \theta$	0
0	0	1

Shear matrix

1	a	0
0	1	0
0	0	1

Scaling matrix

$S_x$	0	0
0	$S_y$	0
0	0	1

Translation matrix

1	0	dx
0	1	dy
0	0	1



# Fixed Point Operation

- Use integer operators to calculate floating point operations

- Fixed point integer

12.23	1223
+20.41	+ 2041

32.64

Fixed fraction

3264

12.23	1223
x 20.41	x 2041

249.61

2496143

- a 1.15.16 fixed point number: one bit sign, 15-bit integer, 16-bit fraction.  $1+15+16 = 32$





# Fixed Point Operation Types in DS

- v16 = 1.3.12 fixed point number (used for 3D)
- t16 = 1.11.4 fixed point number
- f32 = 1.19.12 fixed point number (used for matrices)
- v10 = 1.0.9 fixed point number (whoops! 10 bits don't fit into a normal integer? but 3 v10 numbers fit into a 32 bit integer, so this format is used for normals in 3D (it's also ok for normals to be between -1 and 1, so this is why these fixed point numbers have a long fraction but no integer part!))
- **0.8.8 fixed point number**: this format is used for the scaling of the extended rotation backgrounds and doesn't have a typedef in the NDSlib.



# 0.8.8 fixed Point Conversion

Fixed point number: 0x300

Value ?

3

Fixed point number: 0x104

Value?

$0x104 = b1\ 0000\ 0100 = 1 +$

$0 * 1/2 + 0 * 1/4 + 0 * 1/8 + 0 * 1/16 + 0 * 1/32 + 1 * 1/64 + 0 * 1/128 + 0 * 1/256$

Value 4.75 → Fixed point?

$4.75 = 4 + 0.5 + 0.25 \rightarrow (4 \ll 8 \mid 1 \ll 7 \mid 1 \ll 6)$

$= 0x4C0$



# Background Images

- Use hex array values: provided in the homepage
- Use DMA to read background images

```
/* Select a low priority DMA channel to perform our background *  
   copying. */
```

```
static const int DMA_CHANNEL = 3;
```

```
void displayStarField() {
```

```
  dmaCopyHalfWords(DMA_CHANNEL, starFieldBitmap, /* This variable  
    is generated for us by * grit. */
```

```
  (uint16 *)BG_BMP_RAM(0), /* Our address for main * background 3 */  
  starFieldBitmapLen); /* This length (in bytes) is generated * from grit.  
  */
```

```
}
```



# Sound

Only ARM 7 can play sound , but the library will handle this.

```
int main(int argc, char ** argv)
{
    [...]
    // Turn on Sound
    soundEnable ();
    ...
    soundChannelID=soundPlayNoise (10000, 100, 64); //frq can be
    changed here. Current frq is 10k Hz.
    swiDelay(10000000);
    soundKill (soundChannelID);
}
}
```



# ReadingKeys using APIs

```
If (keysHeld() & KEY_LEFT)
{
    // features for left key
}
If (keysHeld() & KEY_X)
{
    // features for left key
}
```



# Things to Know

- You might see two images
- Please start early. (This is longer than other assignments and 10% of the total grade !!)
- Download the startup code
- See more info for background setup
  - <http://patater.com/files/projects/manual/manual.html#id2612791>