CS 2261: Media Device Architecture - Week 3

HANSEN – Sep. 05, 2018 – Georgia Institute of Technology

Overview

- Quick “cuddling” note about function macro syntax
  - Also how-to “bake in” a dereference operation
- Basics of animation in Mode3
  - Vertical Synchronization (Vsync)
    - volatile keyword
  - Bouncing Robicular Rectangle
- Collision Detection
- Input Basics

Function Macros Addendum

- You there can be no space between the function macro name, and the argument list parentheses:

  -
    ```
    define ADD_V1(x, y) ((x) + (y))  // Good
    ```

  -
    ```
    define ADD_V2 (x, y) ((x) + (y))  // Bad!
    ```

  -
    ```
    int x = ADD_V1(2, 3);
          = ((2) + (3));  // looks good
    ```

  -
    ```
    int y = ADD_V2(3, 4);
          = (x, y) ((x) + (y))(3, 4);
          // syntax errors and unknown variables
    ```

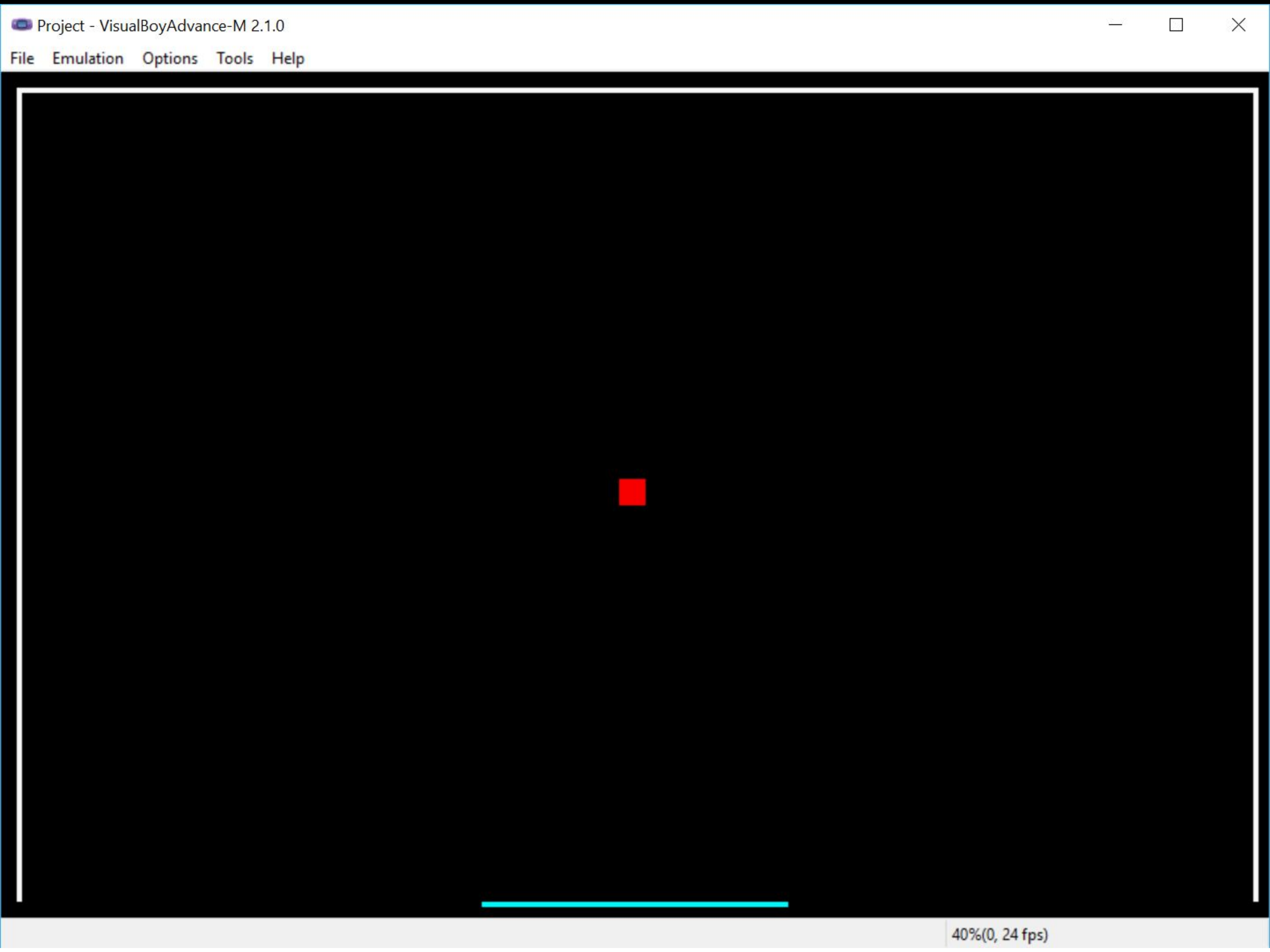
Baking in a Dereference Within a Macro

```
#define REG_DISPCTL (*(unsigned short *)0x4000000)
#define MODE3 3
#define BG2_ENABLE (1<<10)

int main() {
   REG_DISPCTL = MODE3 | BG2_ENABLE;
   // same as
   (*(unsigned short *)0x4000000) = 3 | 1024;

   //... do something else?

   while(1){}
   return;
)
```

We can almost make Brickless BreakOut/BrickOut?

- Graphics
  - 3 lines for walls -- we know how to do that!
  - bouncing square for ball -- we have the square part already!
  - paddle line that moves on input -- oh yes, input!

- Game loop logic
  - Move ball a bit, turn it around if it hits a wall or the paddle
  - Move paddle a bit up if up arrow is pressed, or down if down arrow is pressed
  - Lose if ball goes off bottom of screen


Project - VisualBoyAdvance-M 2.1.0
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40%(0, 24 fps)

What else does the “game” need?

- Constant update rate, so movement speed is predictable and stable

- Listen to User Input
  - Update state based on it

Vertical Synchronization (VSync) on the GBA -- The easiest way.

- The video controller is friendly, and lets us know what horizontal line it is currently working on drawing.
  - Each horizontal line is 240 pixels, and there are 160 of them.
  - When it is done drawing a line, it pretends to draw a few dozen more pixels (68px) on that line we can't see
    - This is called the HBlank period -- and it's pretty short
  - When it is done drawing the visible lines, it pretends to draw a few dozen more lines (68) past the bottom
    - This is called the VBlank period (and each fake line has the extra fake pixels to the right as well)

Vsync Continued

GBA Framerate:
59.73 Hz

- To prevent updating a line while it is being drawn (which can cause screen tearing), we need to only draw pixels during a VBlank
  - This is a decently useful amount of time (83k cpu cycles, per Tonc).
- To do this, we need to listen to the REG_VCOUNT (0x04000006).
  - This register stores the current line number being drawn to the screen (including the fake lines)

Wait for Vertical Blank

```
// holds the pixel row currently being drawn to the screen
volatile u16* scanlineCounter = (volatile u16*) 0x04000006;
// oddly 16 bits, but only uses 8 range: [0, 227]
```

- Why volatile?
  - Value in scanline counter is changed by hardware
  - The compiler tries to optimize your code by only re-checking the value in a variable if your code has changed it
  - The volatile keyword tells the compiler the value might change, so it always needs to check the value when your code tries to use it.

Aside about volatile syntax

```
volatile int foo;  // preferred syntax
int volatile foo;
```

- Both lead to a volatile int (this case is more common with multithreaded code).

```
volatile unsigned char* p_reg;  // preferred
unsigned char volatile* p_reg;
```

- Both lead to a pointer to a volatile value (usually a register your program does not control).

For completeness:

```
// the pointer itself can change at any time
   short* volatile volatilePtr;
// volatile pointer to a volatile value
   short volatile * volatile crazyPointer
```

Aside to the aside about pointer syntax

```
int* foo;
int * foo;  // looks like multiplication -- boo!
int *foo;
```

These are all the same from the compiler's perspective!

Generally, just pick one and *try* to stick with it.

void waitForVBlank()

```
// scanlineCounter stores the current row being drawn
// 0-159 is onscreen, 160-227 is the vertical blank
volatile u16* scanlineCounter = (u16*) 0x04000006;

void waitForVBlank() {
  while (*scanlineCounter >= 160);  // stall until current VBlank ends
  while (*scanlineCounter < 160);   // stall until next VBlank begins
}

int main() {
  // initialize game state here
  while (1) {
    doGameLogic();    // update and move all mobile game objects
    waitForVBlank();  // wait for current screen to finish drawing
    drawGameData();   // draw the world -- and be fast about it!
  }
  return 0;
}
```

This is a fairly crude (but effective) VSync

- We’re wasting a lot of the CPU here doing nothing at all, just waiting until we catch the start of the next VBlank.

- Better VSync involves interrupts, which we’ll cover much later.

Bouncing Square

- Basic Algorithm:
    - Draw the square
    - Move it to a new location (in game state)
    - Erase the old square
    - Draw the new square

```
// notQuiteBouncingRectangle.c
#define RGB(R, G, B) ((R) | (G) << 5 | (B) << 10)
#define REG_DISPCNT (*(unsigned short *)0x04000000)
#define MODE3 3
#define BG2_ENABLE (1<<10)
#define VIDEO_BUFFER ((u16*)0x06000000)

typedef unsigned short u16;
typedef unsigned char u8;

#define SetPixel(x, y, val) (VIDEO_BUFFER[(x) + (y)*240] = val)

int time = 0;
u8 ballSize, ballX, ballY, ball_Vx, ball_Vy;
u8 padding, screenWidth, screenHeight;
volatile u16* scanlineCounter = (u16*) 0x04000006;

void drawSquare(u8 x, u8 y, u8 size, u16 color){
  for (u8 i=0; i<size; i++){
    for (u8 j=0; j<size; j++){
      SetPixel(x+i, y+j, color);
    }
  }
}

void waitForVBlank() {
  while (*scanlineCounter >= 160);  // wait until current VBlank ends
  while (*scanlineCounter < 160);  // wait until next VBlank starts
}
```

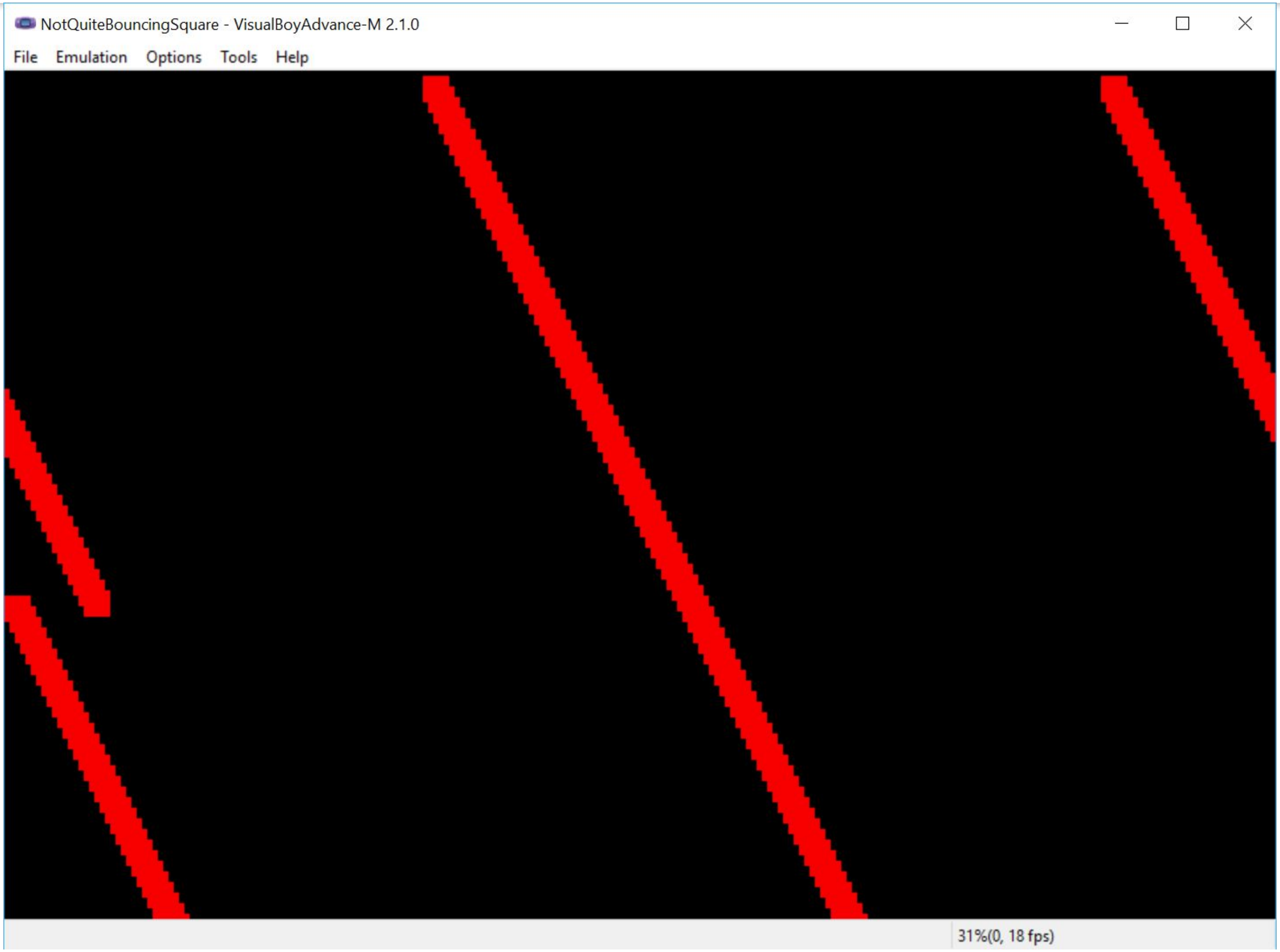
```
void updateBallPosition() {
    ballX += ball_Vx;
    ballY += ball_Vy;
}

int main() {
  REG_DISPCNT = MODE3 | BG2_ENABLE;

  time = 0;
  padding = 3;
  ballSize = 5;
  screenWidth = 240 - 2*padding;
  screenHeight = 160 - 2*padding;
  ballX = screenWidth / 2;
  ballY = screenHeight / 2;
  ball_Vx = 1;
  ball_Vy = 2;

  while (1) {
    updateBallPosition();
    drawSquare(ballX, ballY, ballSize, RGB(31, 0, 0));
    time++;
  }
  return 0;
}
```

Sad Demo



NotQuiteBouncingSquare - VisualBoyAdvance-M 2.1.0
File
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Help
31%(0, 18 fps)

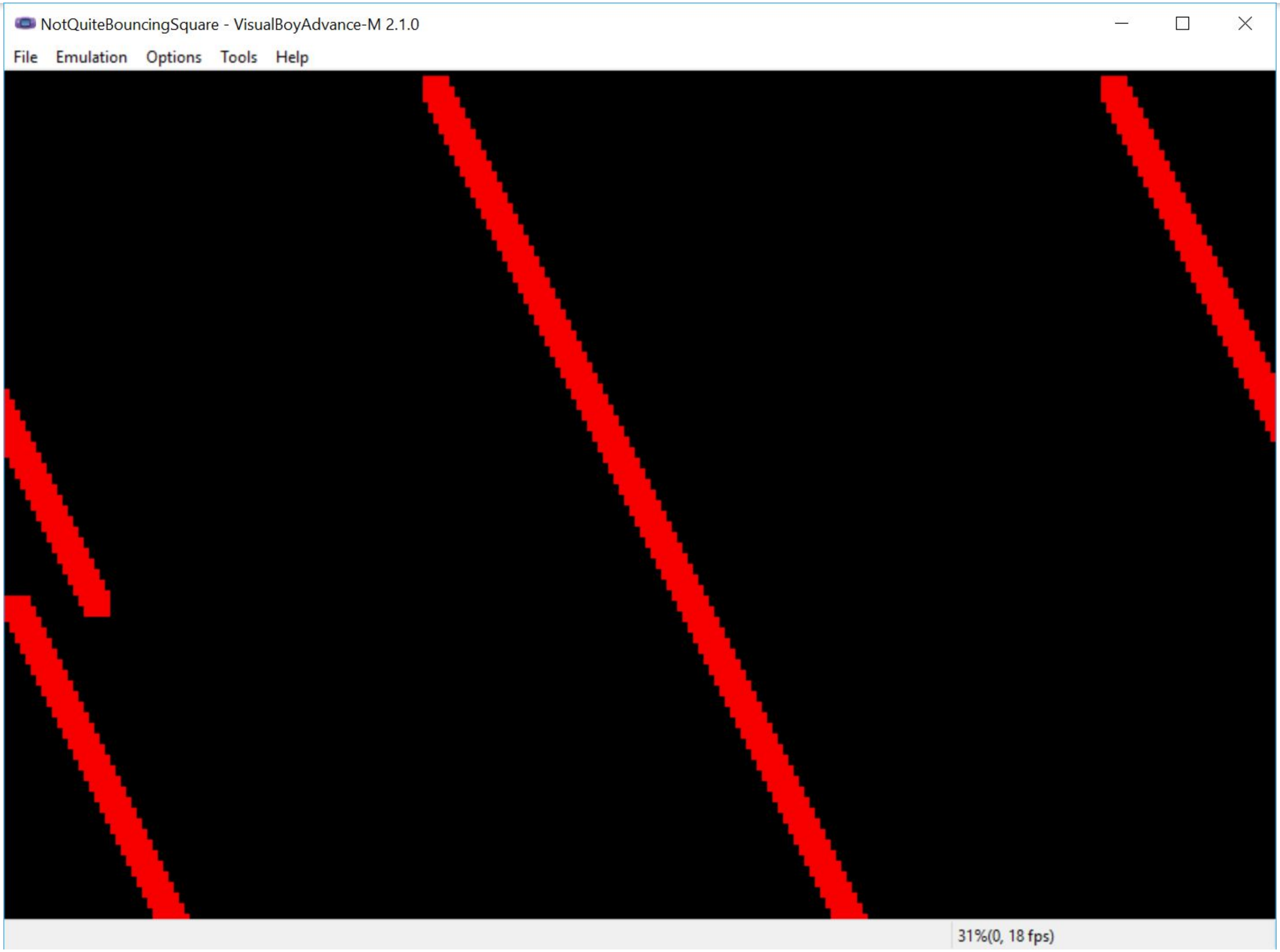
```
void updateBallPosition() {
    ballX += ball_Vx;
    ballY += ball_Vy;
}

int main() {
  REG_DISPCNT = MODE3 | BG2_ENABLE;

  time = 0;
  padding = 3;
  ballSize = 5;
  screenWidth = 240 - 2*padding;
  screenHeight = 160 - 2*padding;
  ballX = screenWidth / 2;
  ballY = screenHeight / 2;
  ball_Vx = 1;
  ball_Vy = 2;

  while (1) {
    updateBallPosition();
    waitForVBlank();
    drawSquare(ballX, ballY, ballSize, RGB(31, 0, 0));
    time++;
  }
  return 0;
}
```

Added VSync Demo

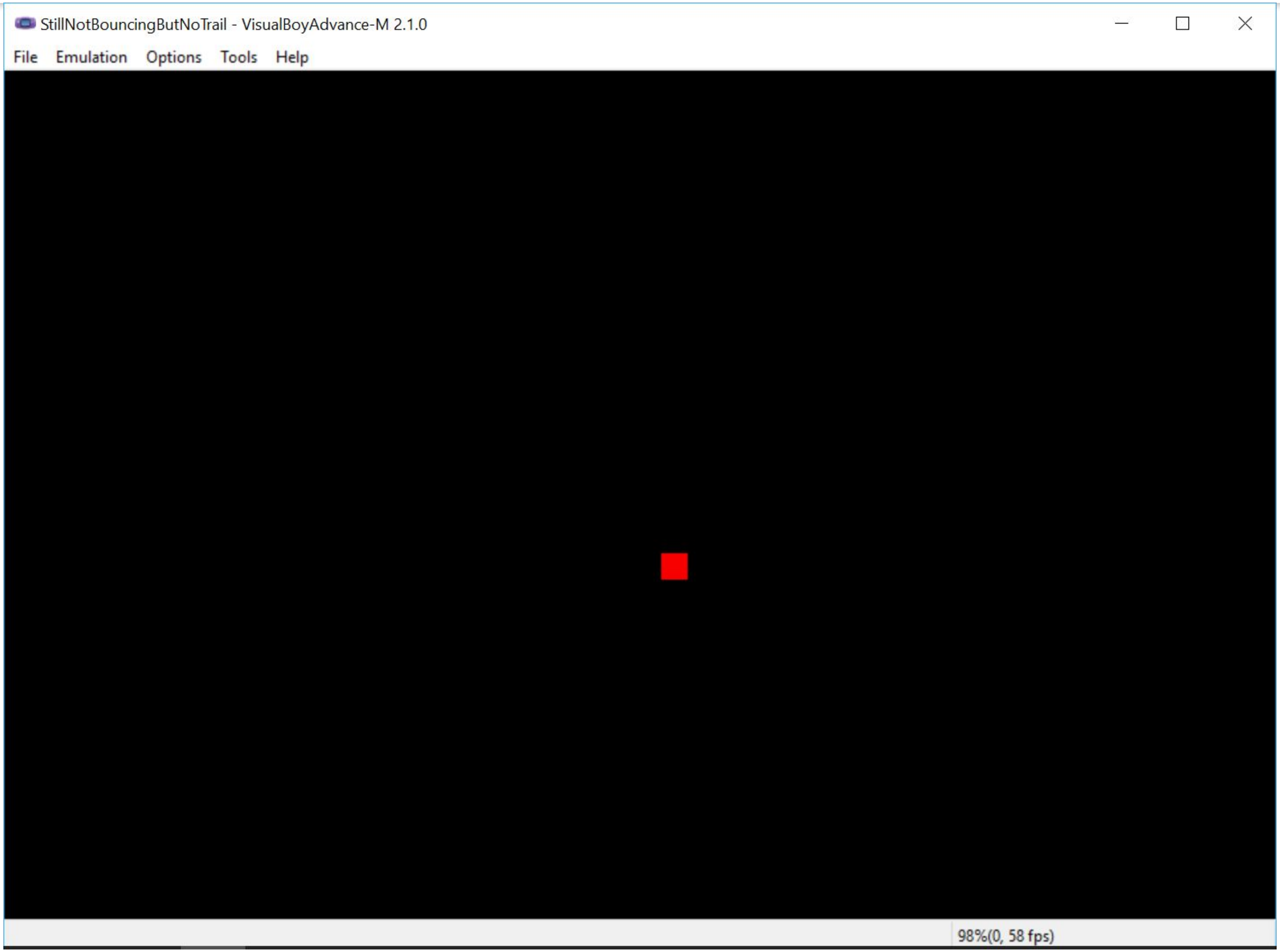


NotQuiteBouncingSquare - VisualBoyAdvance-M 2.1.0
File Emulation Options Tools Help
31%(0, 18 fps)

Improvement: Erase the Previous Square

```
while (1) {
  updateBallPosition(time);
  waitForVBlank();
  drawSquare(ballX - ball_Vx, ballY - ball_Vy, ballSize, RGB(0, 0, 0));
  drawSquare(ballX, ballY, ballSize, RGB(31, 0, 0));
  time++;
}
```

Demo again -- one square this time! #progress



Maybe slow it down a little?

```
 while (1) {
  updateBallPosition();
  waitForVBlank();
  for(int i=0; i<30000; i++) { /* waste some time */ }
  drawSquare(ballX - ball_Vx, ballY - ball_Vy, ballSize, RGB(0, 0, 0));
  drawSquare(ballX, ballY, ballSize, RGB(31, 0, 0));
  time++;
 }

Another (better, IMO) option:
void updateBallPosition(int time) {
 int timestep = 3;  // only do things ever so many frames
 if (time % timestep == 0 && time != 0) {
  ballX += ball_Vx;
  ballY += ball_Vy;
 }
}
/* … */
 while (1) {
  updateBallPosition(time);
  waitForVBlank();
  drawSquare(ballX - ball_Vx, ballY - ball_Vy, ballSize, RGB(0, 0, 0));
  drawSquare(ballX, ballY, ballSize, RGB(31, 0, 0));
  time++;
 }
```

Demo Again

Maybe it should *Bounce*?

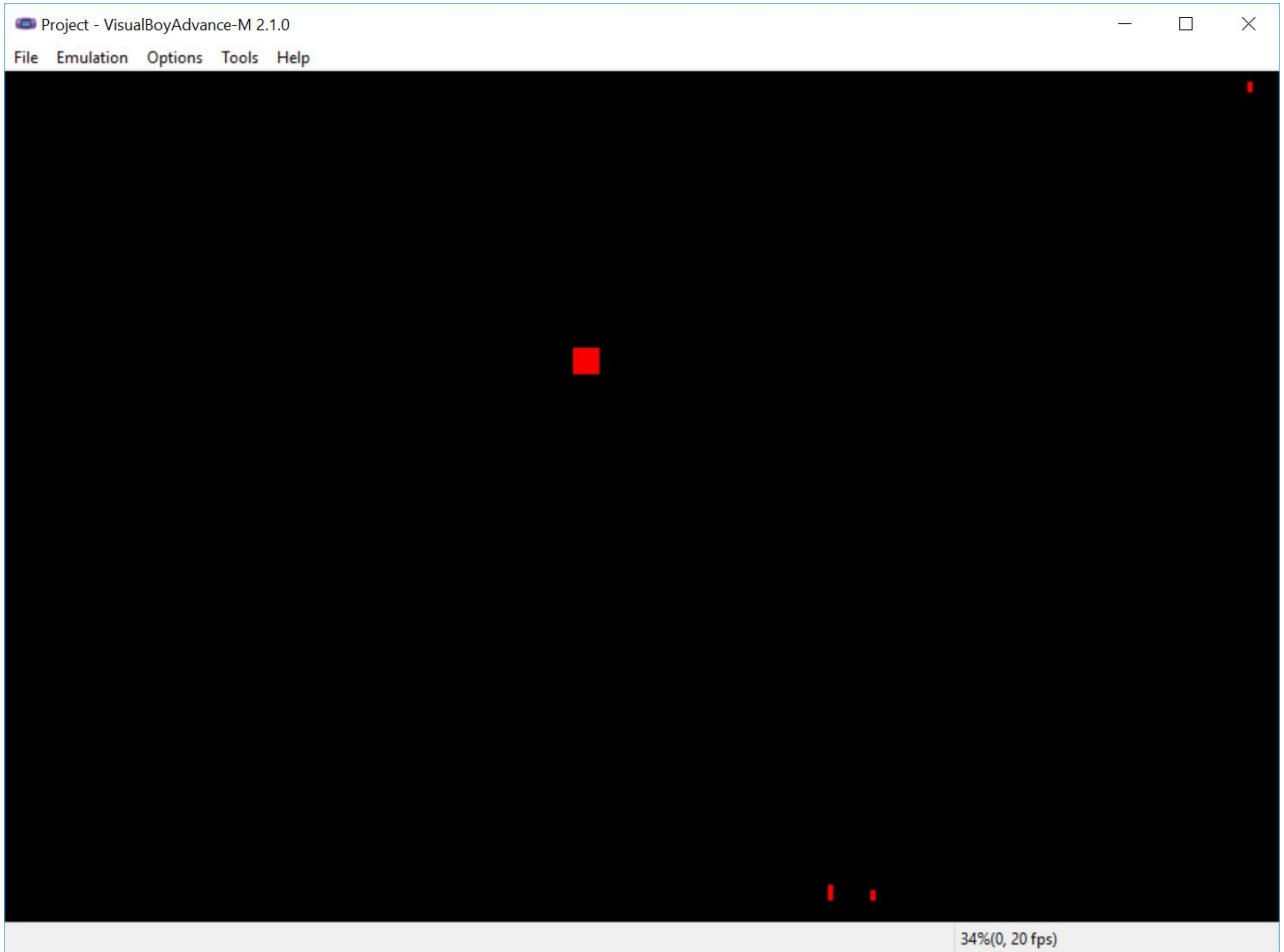
```
void updateBallPosition(int time) {
  int timestep = 3;
  if (time % timestep == 0 && time != 0) {
    ballX += ball_Vx;
    ballY += ball_Vy;

    if (ballX < 0){  // we should have to switch everything back to ints!
      ballX = -ballX;
      ball_Vx = -ball_Vx;
    }
    if (ballY < 0){
      ballY = -ballY;
      ball_Vy = -ball_Vy;
    }
    if (ballX + ballSize >= 240) {
      ballX -= ballX + ballSize - 240;
      ball_Vx = -ball_Vx;
    }
    if (ballY + ballSize >= 160) {
      ballY -= ballY + ballSize - 160;
      ball_Vy = -ball_Vy;
    }
  }
}
```

Maybe it should *Bounce*?

```
int ballSize, ballX, ballY, ball_Vx, ball_Vy;
int padding, screenWidth, screenHeight;
```

Almost!



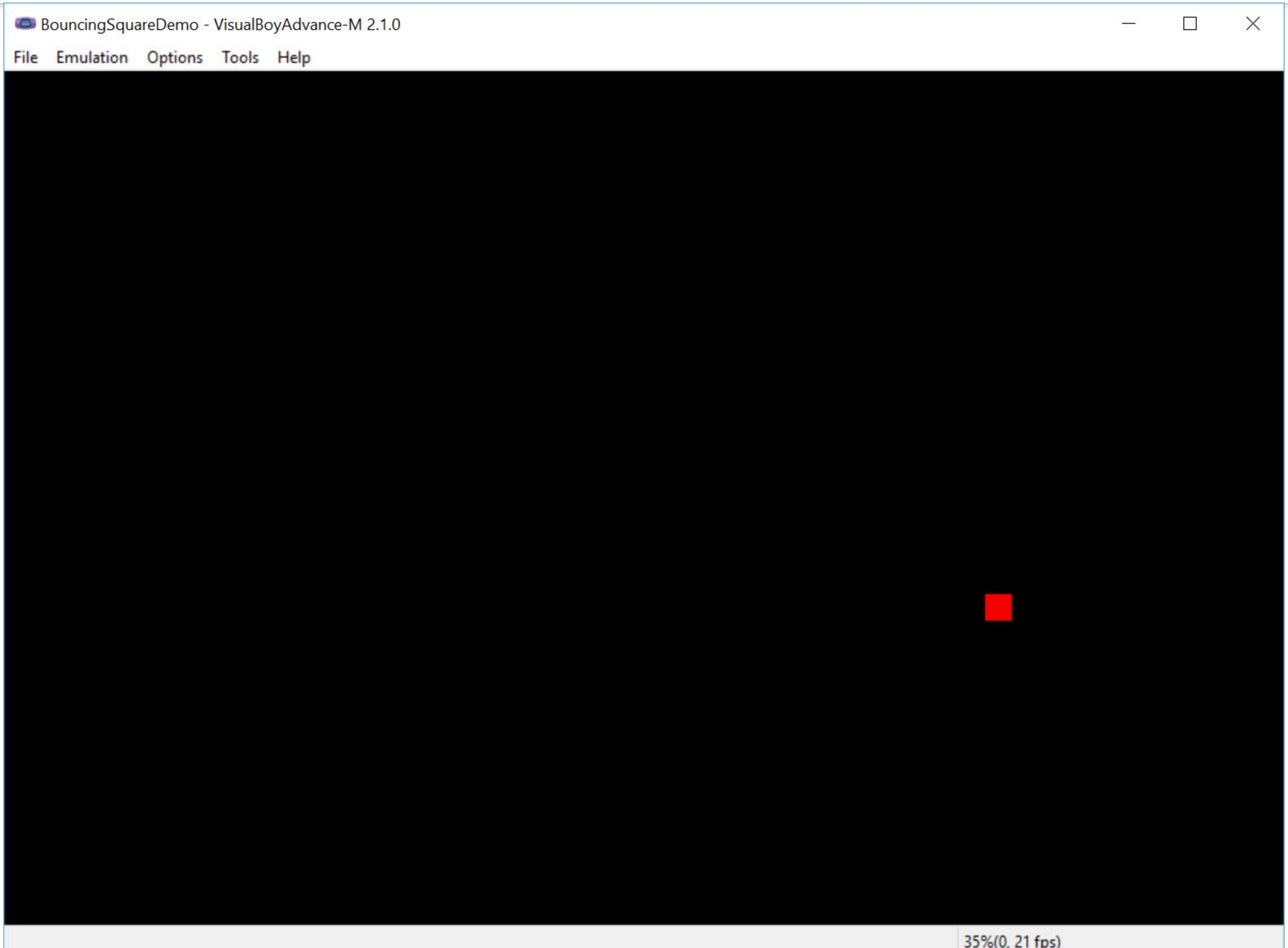
Be a little less clever

```
int padding, screenWidth, screenHeight;
int prevBallX, prevBallY;


void updateBallPosition(int time) {
  int timestep = 3;
  prevBallX = ballX;
  prevBallY = ballY;
  if (time % timestep == 0 && time != 0) {
 /* … */
}

  while (1) {
    updateBallPosition(time);
    waitForVBlank();
    drawSquare(prevBallX, prevBallY, ballSize, RGB(0, 0, 0));
    drawSquare(ballX, ballY, ballSize, RGB(31, 0, 0));
    time++;
  }
```

Real Bouncing Demo



Basics of Collision Detection

- We handled colliding with a barrier (simple out of bounds checking)

- How do we detect a collision with another square, for example?

  -
    ```
    x1 + s1 > x2 && x1 < x2 + s2 &&
    y1 + s1 > y2 && y1 < y2 + s2
    ```
  - Pretty straightforward

What about Collisions with the paddle?

- Y check is degenerate, same as checking hitting the bottom.
  - `ballY + ballSize >= paddleY`

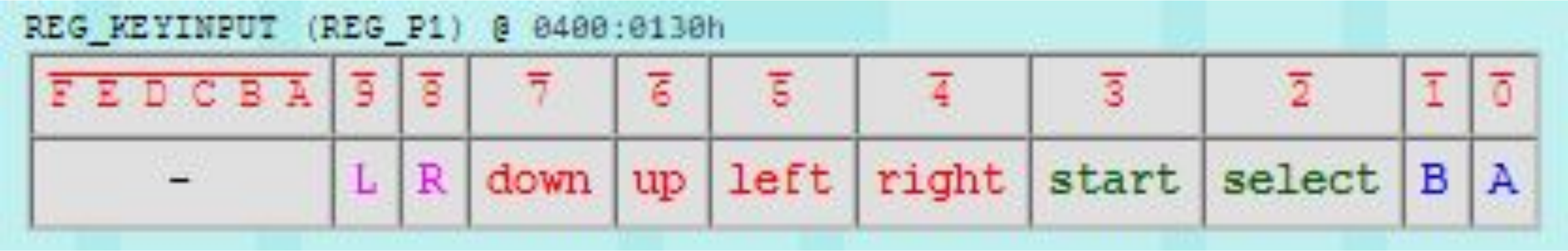
- X check is only slightly more interesting
  - `ballX + ballSize >= paddleX && ballX < paddleX + paddleWidth`

- When X and Y checks are both true, collision!
  - Note: you could also allow for side collisions like real brick games do as well

Input Basics

- 10 buttons
  - Start
  - Select
  - A
  - B
  - Left
  - Right
  - Up
  - Down
  - Left shoulder
  - Right shoulder

Button Register REG_KEYINPUT 0x04000130



REG_KEYINPUT (REG_P1) @ 0400:0130h

F E D C B A	9	8	7	6	5	4	3	2	1	0
-	L	R	down	up	left	right	start	select	B	A

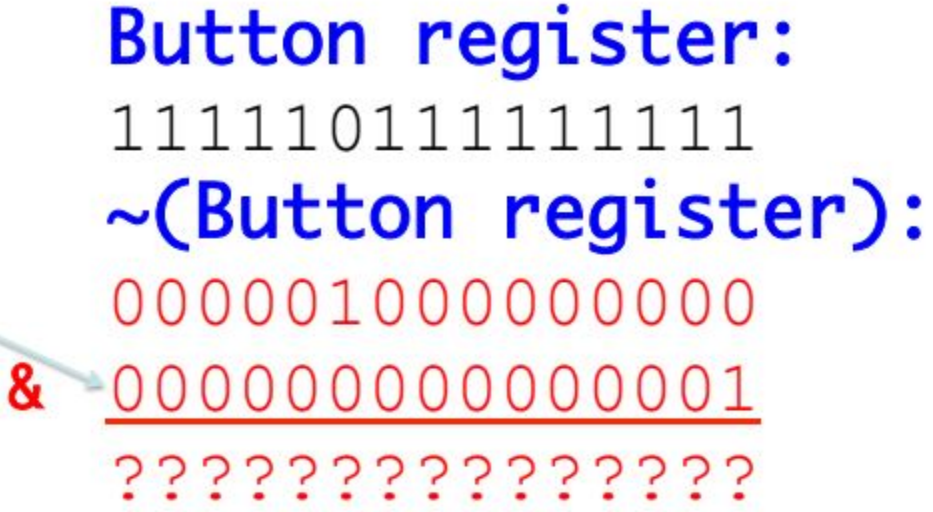
- Only bits 0-9 are used here.
  - 1 is not pressed
  - 0 is pressed ???
    - It’s a trick of the wiring that zeros out the bit when you ground it by completing the circuit.
- When nothing is pressed, all the bits are 1
  - To make things more intuitive, flip them before checking

```
#define REG_KEYINPUT (*(volatile u16*)0x04000130)

#define KEY_A        0x0001
#define KEY_B        0x0002
#define KEY_SELECT   0x0004
#define KEY_START    0x0008
#define KEY_RIGHT    0x0010
#define KEY_LEFT     0x0020
#define KEY_UP       0x0040
#define KEY_DOWN     0x0080
#define KEY_R        0x0100
#define KEY_L        0x0200

// is KEY_A pressed?
KEY_A & ~REG_KEYINPUT
```

What we expect if A is pressed



Button register:

1111101111111111

~(Button register):

0000010000000000

& 0000000000000001

????????????????

```
#define KEY_DOWN_NOW(key) (~(REG_KEYINPUT) & key)
```