Fundamentals of Computer Systems

Bresenham's Line Algorithm in Hardware

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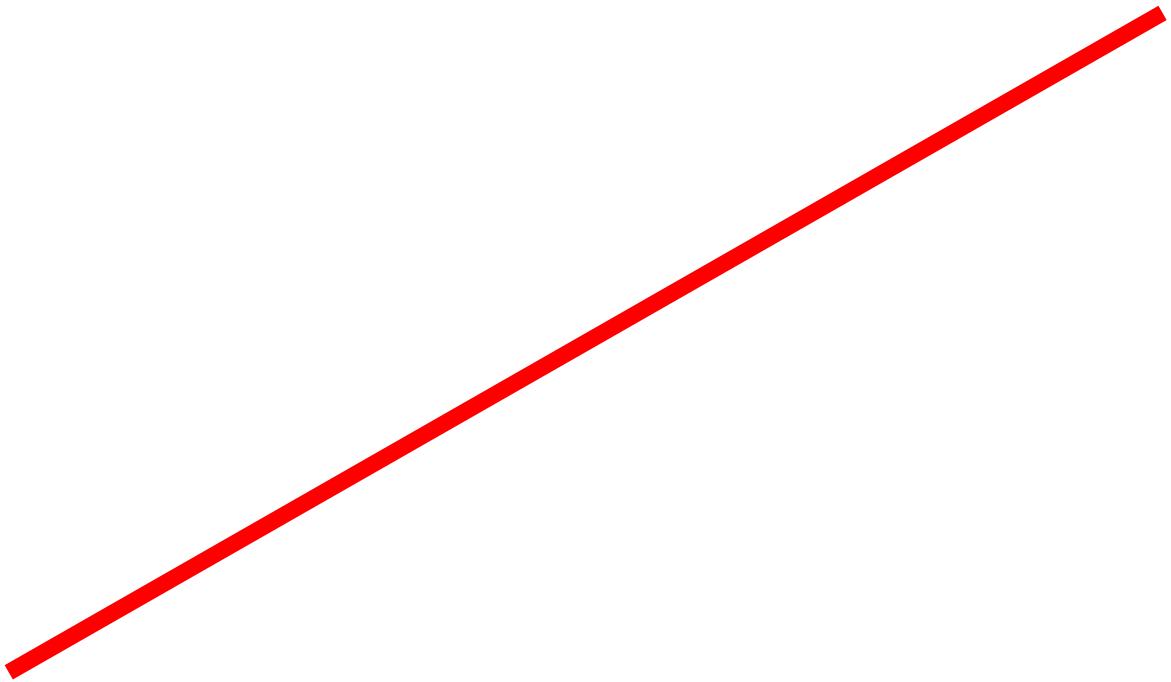
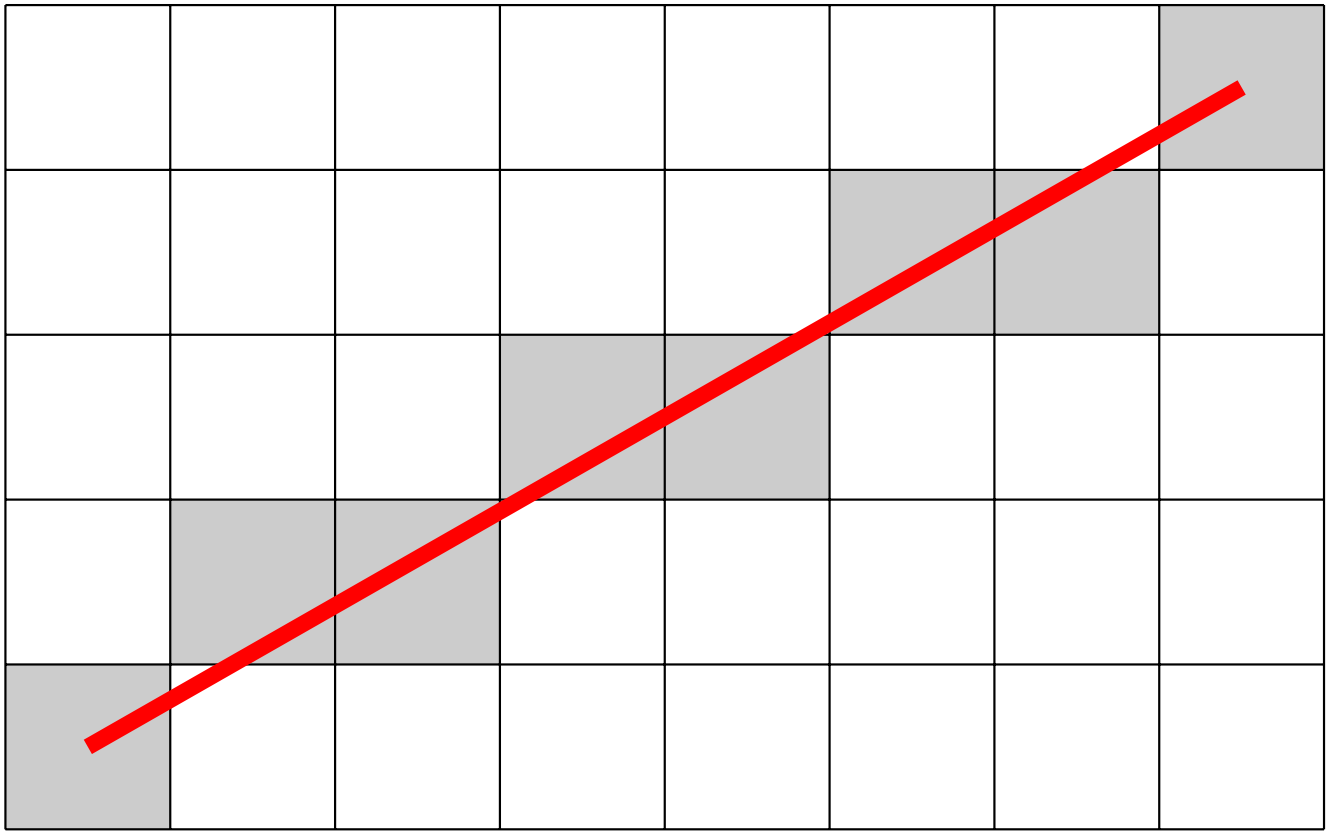
Bresenham’s Line Algorithm

Objective:Draw a line...



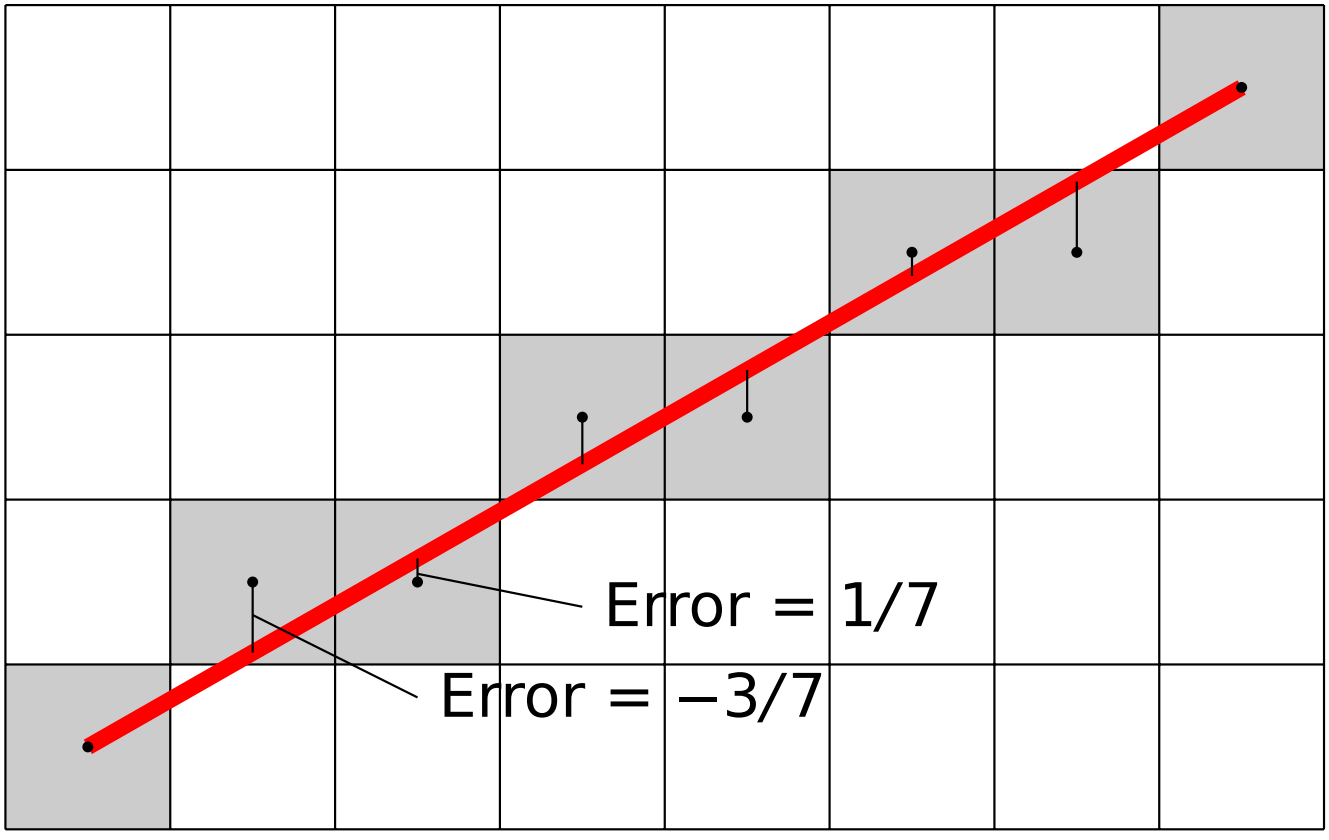
Bresenham’s Line Algorithm

...with well-approximating pixels...



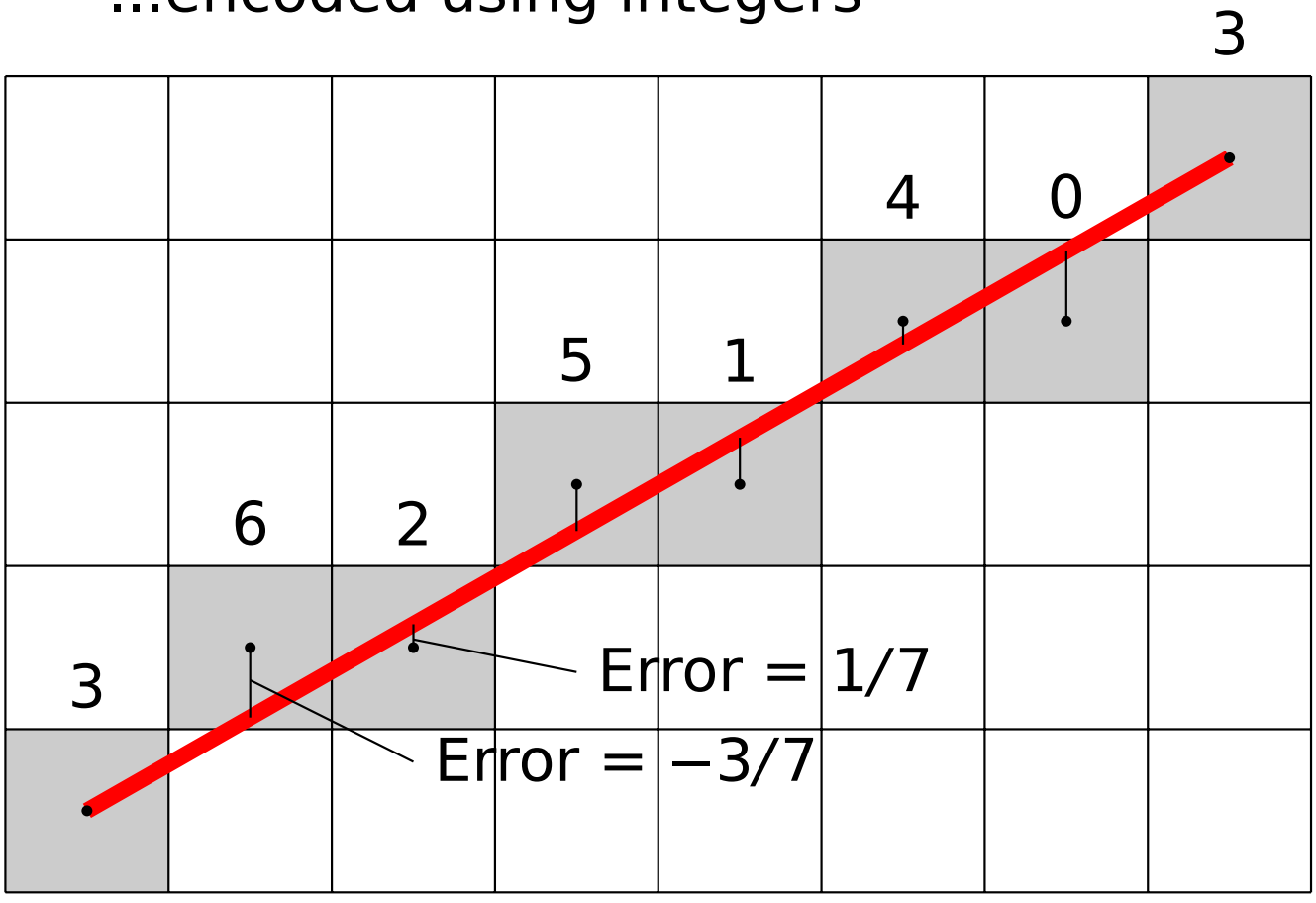
Bresenham’s Line Algorithm

...by maintaining error information..



Bresenham’s Line Algorithm

...encoded using integers



The Pseudocode from Wikipedia

```
function line(x0, y0, x1, y1)
    dx := abs(x1-x0)
    dy := abs(y1-y0)
    if x0 < x1 then sx := 1 else sx := -1
    if y0 < y1 then sy := 1 else sy := -1
    err := dx-dy

    loop
      setPixel(x0,y0)
      if x0 = x1 and y0 = y1 exit loop
      e2 := 2*err
      if e2 > -dy then
        err := err - dy
        x0 := x0 + sx
      end if
      if e2 <  dx then
        err := err + dx
        y0 := y0 + sy
      end if
    end loop
```

My C Code

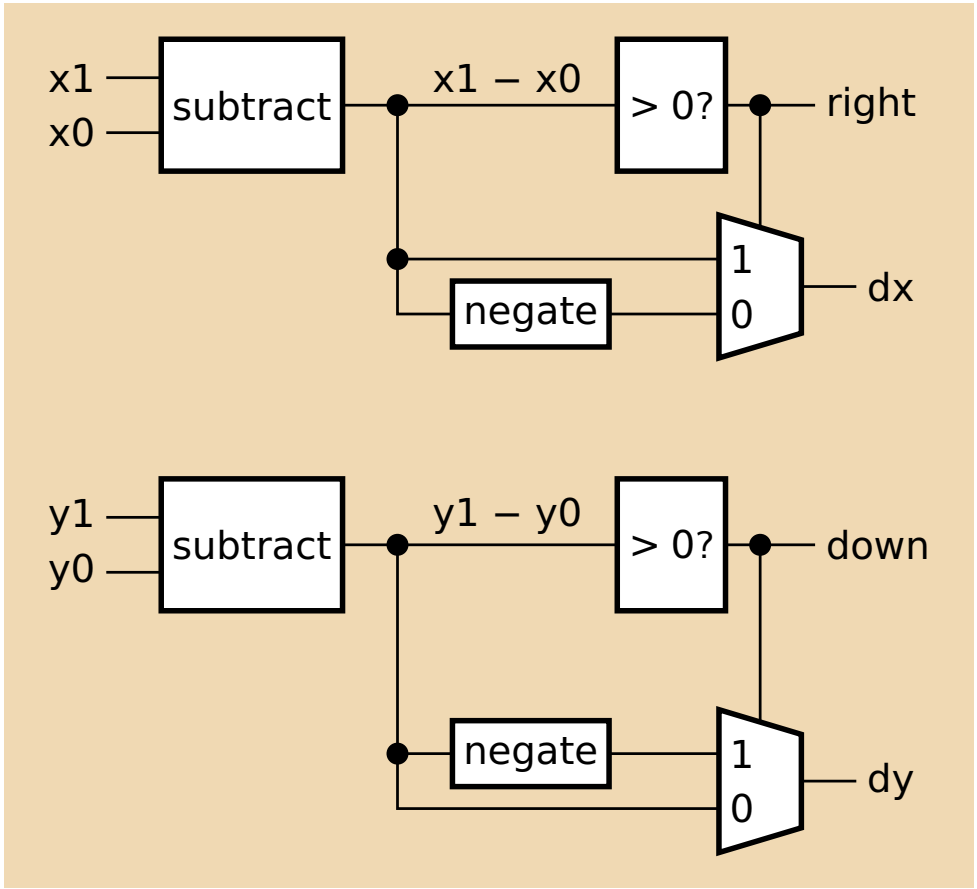
```
void line(Uint16 x0, Uint16 y0, Uint16 x1, Uint16 y1)
{
  Sint16 dx, dy;  // Width and height of bounding box
  Uint16 x, y;    // Current point
  Sint8 sx, sy;   // -1 or 1
  Sint16 err;     // Loop-carried value
  Sint16 e2;      // Temporary variable
  int right, down;// Boolean

  dx = x1 - x0; right = dx > 0;  if (!right) dx = -dx;
  dy = y1 - y0; down = dy > 0;   if (down) dy = -dy;
  err = dx + dy; x = x0; y = y0;
  for (;;) {
    plot(x, y);
    if (x == x1 && y == y1) break; // Reached the end
    e2 = err << 1; // err * 2
    if (e2 > dy) { err += dy; if (right) x++; else x--;}
    if (e2 < dx) { err += dx; if (down)  y++; else y--;}
  }
}
```

Datapath for *dx*, *dy*, *right*, and *down*

```
void line(Uint16 x0, Uint16 y0,
          Uint16 x1, Uint16 y1)
{
  Sint16 dx;   // Width of bounding box
  Sint16 dy;   // Height of BB (neg)
  Uint16 x, y; // Current point
  Sint8 sx, sy;// -1 or 1
  Sint16 err;  // Loop-carried value
  Sint16 e2;   // Temporary variable
  int right;   // Boolean
  int down;    // Boolean
```

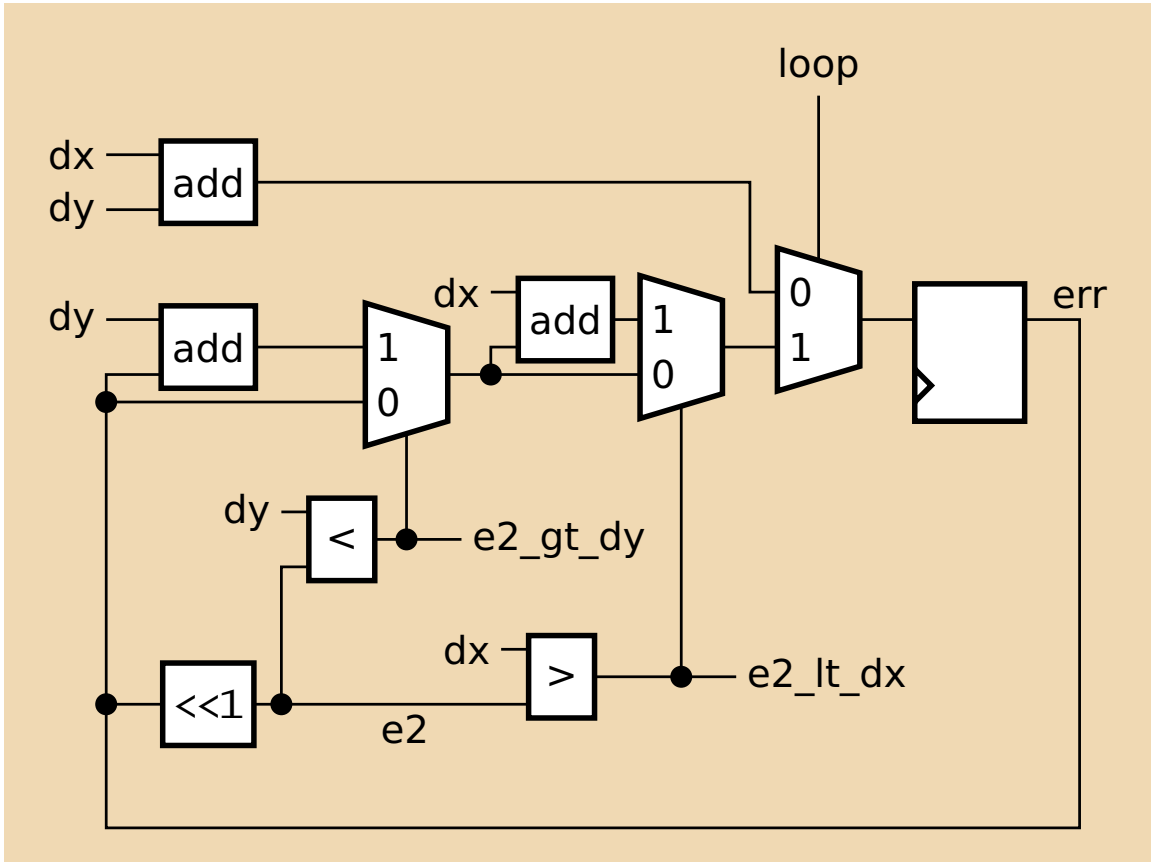
```
dx = x1 - x0;
right = dx > 0;
if (!right) dx = -dx;
dy = y1 - y0;
down = dy > 0;
if (down) dy = -dy;

err = dx + dy;
x = x0; y = y0;

for (;;) {
  plot(x, y);
  if (x == x1 && y == y1)
    break;
  e2 = err << 1;
  if (e2 > dy) {
    err += dy;
    if (right) x++;
    else x--;
  }
  if (e2 < dx) {
    err += dx;
    if (down)  y++;
    else y--;
  }
}
```

Datapath for *dx*, *dy*, *right*, and *down*



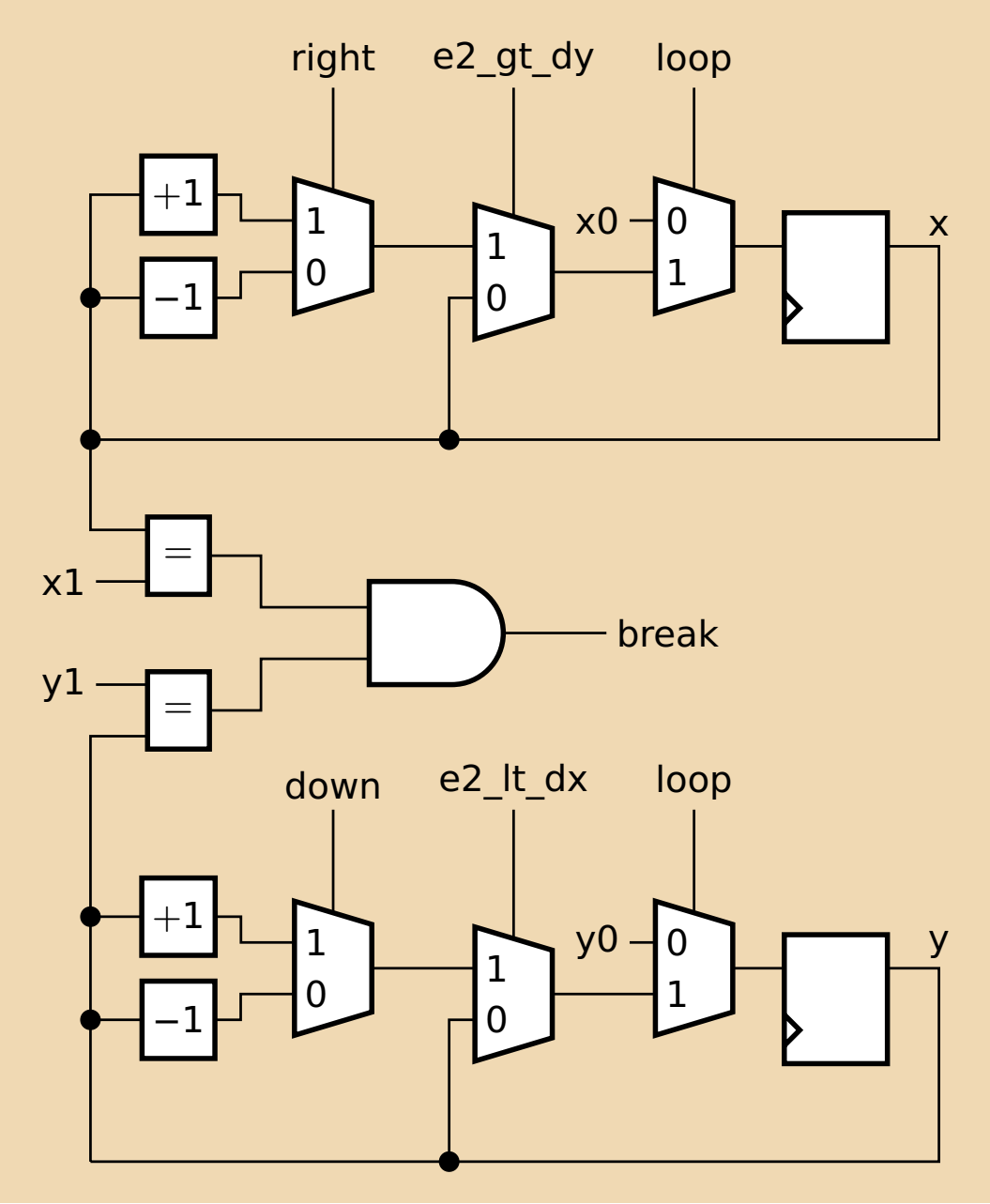

```
dx = x1 - x0;
right = dx > 0;
if (!right) dx = -dx;
dy = y1 - y0;
down = dy > 0;
if (down) dy = -dy;

err = dx + dy;
x = x0; y = y0;

for (;;) {
  plot(x, y);
  if (x == x1 && y == y1)
    break;
  e2 = err << 1;
  if (e2 > dy) {
    err += dy;
    if (right) x++;
    else x--;
  }
  if (e2 < dx) {
    err += dx;
    if (down)  y++;
    else y--;
  }
}
```

Datapath for *err*



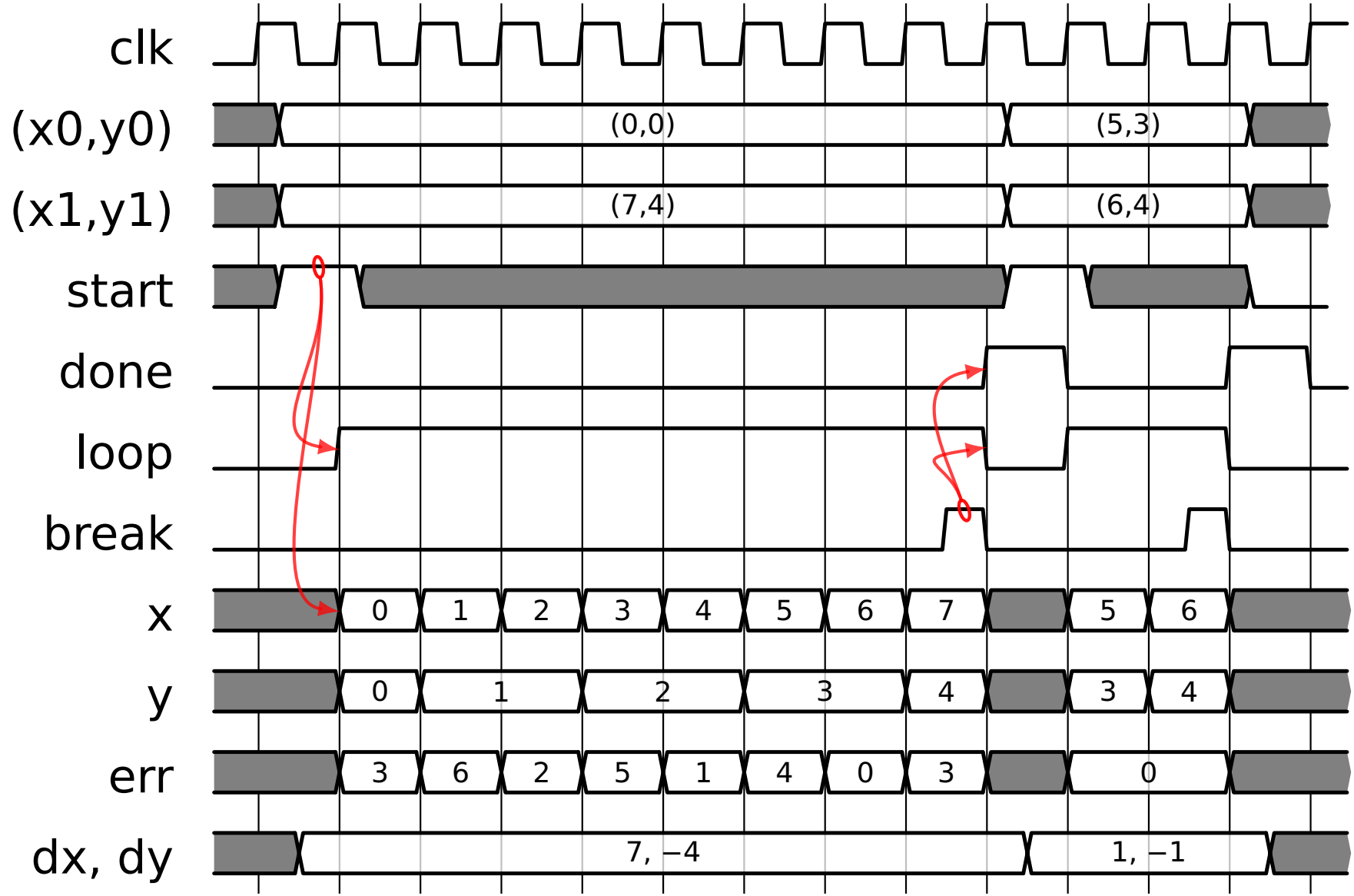

```
dx = x1 - x0;
right = dx > 0;
if (!right) dx = -dx;
dy = y1 - y0;
down = dy > 0;
if (down) dy = -dy;

err = dx + dy;
x = x0; y = y0;

for (;;) {
  plot(x, y);
  if (x == x1 && y == y1)
    break;
  e2 = err << 1;
  if (e2 > dy) {
    err += dy;
    if (right) x++;
    else x--;
  }
  if (e2 < dx) {
    err += dx;
    if (down)  y++;
    else y--;
  }
}
```

Datapath for *x* and *y*

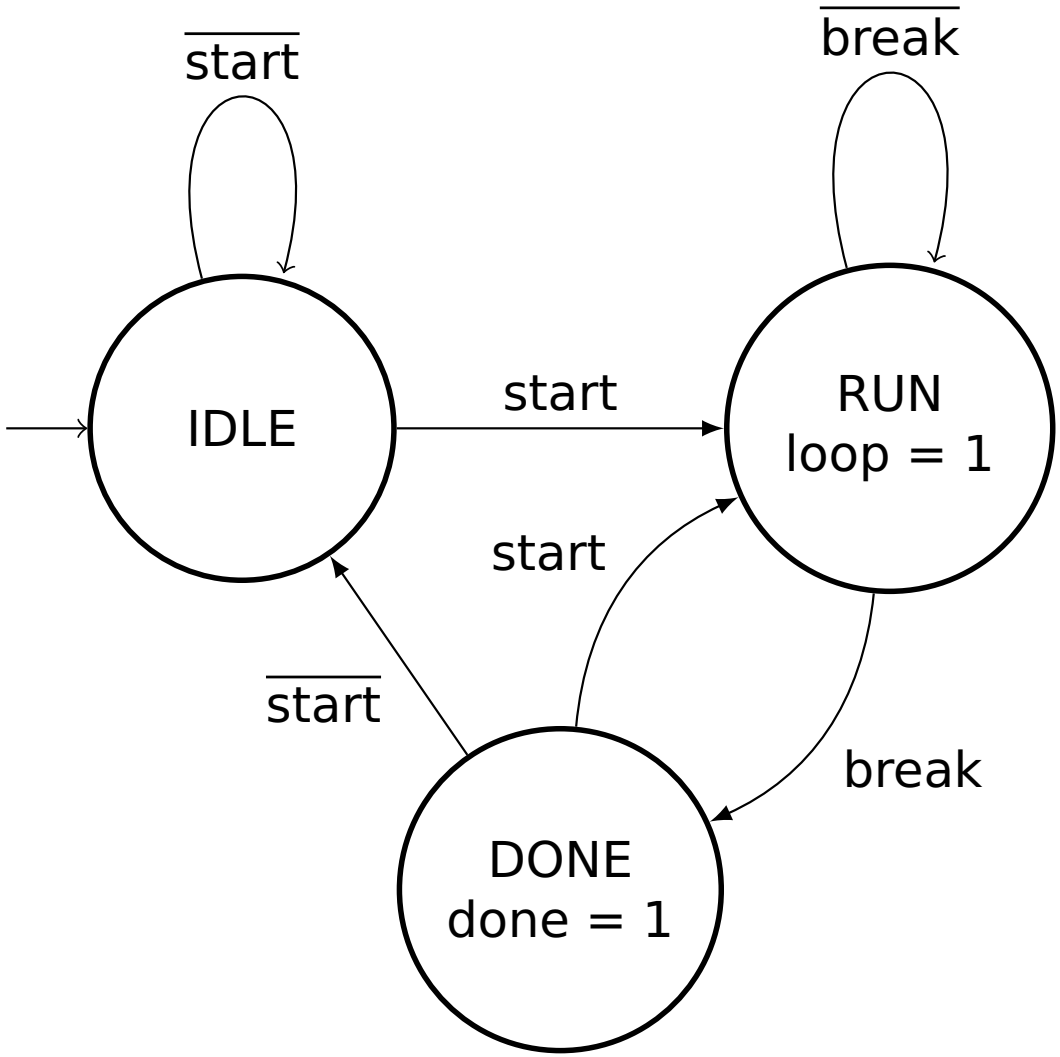



```
dx = x1 - x0;
right = dx > 0;
if (!right) dx = -dx;
dy = y1 - y0;
down = dy > 0;
if (down) dy = -dy;

err = dx + dy;
x = x0; y = y0;

for (;;) {
  plot(x, y);
  if (x == x1 && y == y1)
    break;
  e2 = err << 1;
  if (e2 > dy) {
    err += dy;
    if (right) x++;
    else x--;
  }
  if (e2 < dx) {
    err += dx;
    if (down)  y++;
    else y--;
  }
}
```

Timing


clk
(x0,y0)
(x1,y1)
start
done
loop
break
x
y
err
dx, dy
(0,0)
(5,3)
(7,4)
(6,4)
0 1 2 3 4 5 6 7 5 6
0 1 2 3 4 3 4
3 6 2 5 1 4 0 3 0
7, −4
1, −1

Control FSM


start
break
IDLE
start
RUN
loop = 1
start
start
break
DONE
done = 1