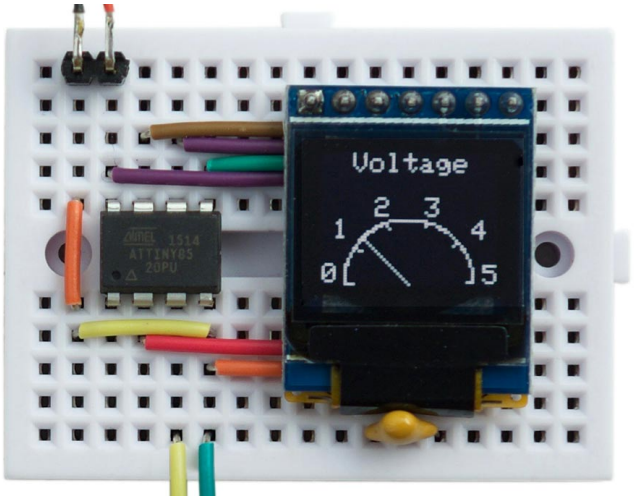
ATtiny85 Graphics Display

27th April 2017

This article describes a 64x48 monochrome OLED display based on an ATtiny85. I've included three sample applications: a simple oscilloscope, a wireframe animation, and an analogue voltmeter:



Analogue voltmeter using a 64x48 OLED graphics display based on an ATtiny85.

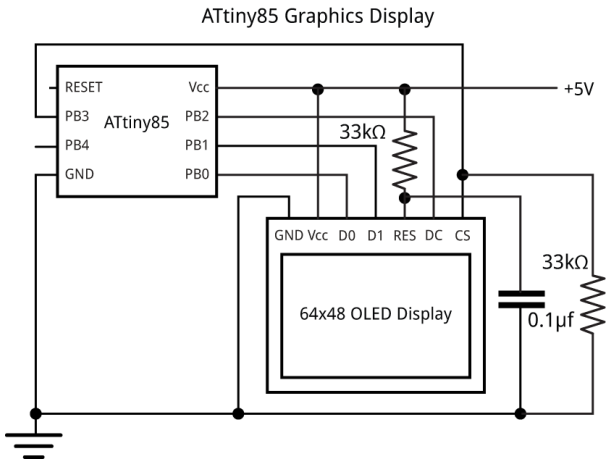
It should be relatively straightforward to redesign the code to work with any other AVR processor.

Introduction

I recently wanted a flexible way of displaying information from a project, and found this small monochrome 64x48 OLED display on Aliexpress [1]. A similar one is available from Sparkfun [2]. Although both SPI and I2C versions are available, I chose the SPI version because the display update is faster.

The display needs 4 pins to drive it, just within the capabilities of the ATtiny85 and leaving one pin available for another application. You can't read the display memory, so to do graphics you need to write into a buffer in RAM, and then copy this to the display. Because the display is 64x48 pixels it requires 68x48/8 or 384 bytes of memory for the graphics buffer, again just within the capabilities of the ATtiny85.

Here's the circuit:



Circuit of the 64x48 OLED graphics display based on an ATtiny85.

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The resistor from the display's CS pin holds the chip select low to prevent the display from being affected by the ISP signals while programming the ATtiny85.

Driving the display

The display uses the SSD1306 driver chip [3] which divides up the display into columns one pixel wide, and horizontal bands eight pixels high which are referred to as pages.

The graphics commands to plot points, draw lines, and draw text, all edit a buffer, which stores one bit for each pixel on the display. This is defined as follows:

```
// Screen buffer
const int Buffersize = 64*6;
unsigned char Buffer[Buffersize];
```

The **DisplayBuffer()** routine display the contents of the buffer by copying the bytes to the display. For this application we're using the display's Horizontal Addressing mode, which copies bytes to the display memory from left to right and top to bottom. To use this mode you just specify the column and page ranges with the commands 0x21 and 0x22, and then send the 384 bytes.

The SSD1306 is designed to handle displays up to 128x64, and the 64x48 display is positioned in the centre of this area, so to address it you need to select columns 32 to 95 (inclusive) and pages 2 to 7 (inclusive):

```
void DisplayBuffer() {
  PINB = 1<<cs; // cs low
  // Set column address range
  Command(0x21); Command(32); Command(95);
  // Set page address range
  Command(0x22); Command(2); Command(7);
  for (int i = 0 ; i < Buffersize; i++) Data(Buffer[i]);
  PINB = 1<<cs; // cs high
}
```

This calls **Data()** which writes a byte to the display:

```
void Data(uint8_t d) {
  uint8_t changes = d ^ (d>>1);
  PORTB = PORTB & ~(1<<data);
  for (uint8_t bit = 0x80; bit; bit >>= 1) {
    PINB = 1<<clk; // clk low
    if (changes & bit) PINB = 1<<data;
    PINB = 1<<clk; // clk high
  }
}
```

I spent a bit of time optimising the **Data()** routine, to make the display update as fast as possible. This version uses a variable **changes** to determine whether the data pin, PB1, should be changed for each bit to be output. This allows us to write to the PINB port to toggle the bit. With an 8 MHz ATtiny85 this routine updates the display in about 5.4 msec. This implies that we can update the display about 180 times a second, fast enough for simple animations.

Commands are identified by taking the dc pin low:

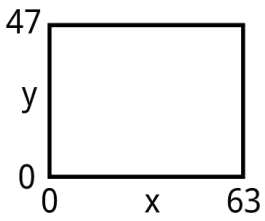
```
void Command(uint8_t c) {
  PINB = 1<<dc; // dc low
  Data(c);
  PINB = 1<<dc; // dc high
}
```

Finally, **InitDisplay()** reads the display setup parameters from program memory, and writes them to the display:

```
void InitDisplay () {
  PINB = 1<<cs; // cs low
  for (uint8_t c=0; c<InitLen; c++) Command(pgm_read_byte(&Init[c]));
  PINB = 1<<cs; // cs high
}
```

Plotting points

I wrote some basic graphics routines for plotting points and drawing lines. These work on a conventional coordinate system with the origin at lower left:



You can move the origin by changing **xOrigin** and **yOrigin**; for example, to have the origin in the centre do:

```
xOrigin = 32; yOrigin = 24;
```

First the routine that plots a point:

```
void PlotPoint(int x, int y) {
  int row = 47 - y - yOrigin;
  int col = x + xOrigin;
  int page = row>>3;
  int bit = row & 0x07;
  // Set correct bit in slice buffer
  Buffer[page*64 + col] |= 1<<bit;
}
```

Note that this doesn't do any checking, so either make sure you don't plot points outside the display area, or add a line to check the x and y values.

Drawing lines

The line plotting is performed by the **DrawTo()** line-drawing routine, which uses Bresenham's line algorithm to draw the best line between two points without needing any divisions or multiplications [4]

```
void DrawTo(int x1, int y1) {
  int sx, sy, e2, err;
  int dx = abs(x1 - x0);
  int dy = abs(y1 - y0);
  if (x0 < x1) sx = 1; else sx = -1;
  if (y0 < y1) sy = 1; else sy = -1;
  err = dx - dy;
  for (;;) {
    PlotPoint(x0, y0);
    if (x0==x1 && y0==y1) return;
    e2 = err<<1;
    if (e2 > -dy) {
      err = err - dy;
      x0 = x0 + sx;
    }
    if (e2 < dx) {
      err = err + dx;
      y0 = y0 + sy;
    }
  }
}
```

Drawing text

For simplicity the routine to draw text ignores the bottom three bits of the y coordinate, and plots the characters in a single page. The routine accesses the character set from program memory. An abbreviated version of the character map is as follows:

```
const uint32_t CharMap[96][6] PROGMEM = {
{ 0x00, 0x00, 0x00, 0x00, 0x00, 0x00 },
{ 0x00, 0x00, 0x5F, 0x00, 0x00, 0x00 },
...
{ 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0x00 }
};
```

The first row defines the bit pattern for ASCII character 32, space, and so on up to character 127.

Because of the limited RAM available on the ATtiny85, the text to be plotted is also specified in program memory, and the **PlotText()** routine reads the characters using **pgm_read_byte()**:

```
void PlotText(int x, int y, const __FlashStringHelper *s) {
  int p = (int)s;
  int page = (47 - y - yOrigin)>>3;
  while (1) {
    char c = pgm_read_byte(p++);
    if (c == 0) return;
    for (uint8_t col = 0 ; col < 6; col++) {
      Buffer[page*64 + x + xOrigin] = pgm_read_byte(&CharMap[c-32][col]);
      x++;
    }
  }
}
```

To define the text to be plotted as being in program memory use the **F()** macro (F for Flash). For example, to plot "ATtiny85" centred on the second line of the display, write:

```
PlotText(6, 16, F("ATtiny85"));
```

Applications

Analogue voltmeter

The first application is an analogue voltmeter that reads the voltage on the analogue input A2 (PB4), and displays it as a pointer on an analogue display:

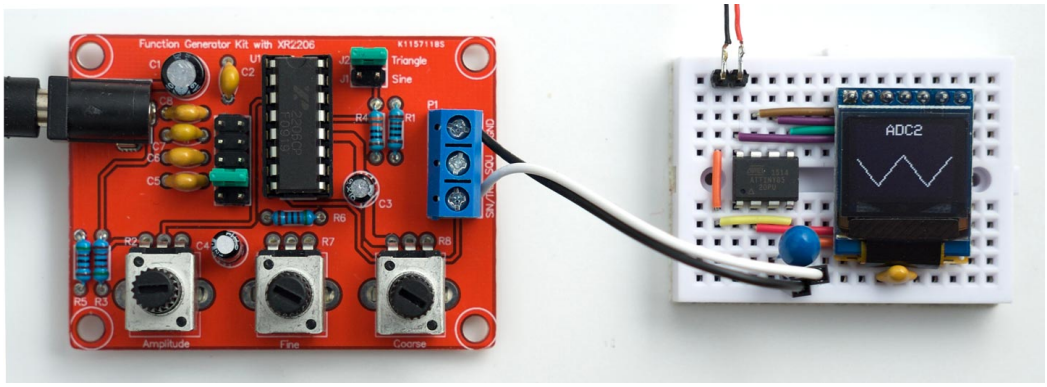
```
void AnalogueMeter () {
  xOrigin = 32; yOrigin = 0;
  const int Delta2 = 16;
  int x = -(23<<9), y = 0;
  ClearBuffer();
  PlotText(-20, 40, F("Voltage"));
  for (int i = 0; i<=100; i++) {
    if (i%20 == 0) {
      MoveTo(x>>9, (y>>9));
      DrawTo((x>>9) - (x>>12), (y>>9) - (y>>12));
    }
    if (i == (analogRead(A2)*25 + 25)>>8) {
      MoveTo(x>>9, y>>9);
      DrawTo(0, 0);
    }
    MoveTo(x>>9, y>>9);
    x = x + ((y>>9) * Delta2);
    y = y - ((x>>9) * Delta2);
```

```
    if (i != 100) DrawTo(x>>9, y>>9);
  }
  PlotText(-31, 0, F("0")); PlotText(27, 0, F("5"));
  PlotText(-27, 16, F("1")); PlotText(23, 16, F("4"));
  PlotText(-12, 24, F("2  3"));
  DisplayBuffer();
}
```

Simple oscilloscope

The second application reads the analogue signal on the analogue input A2 (PB4) and displays it as a waveform on the display.

For example, here it is displaying the triangular waveform from a waveform generator kit I bought on Banggood [5]:



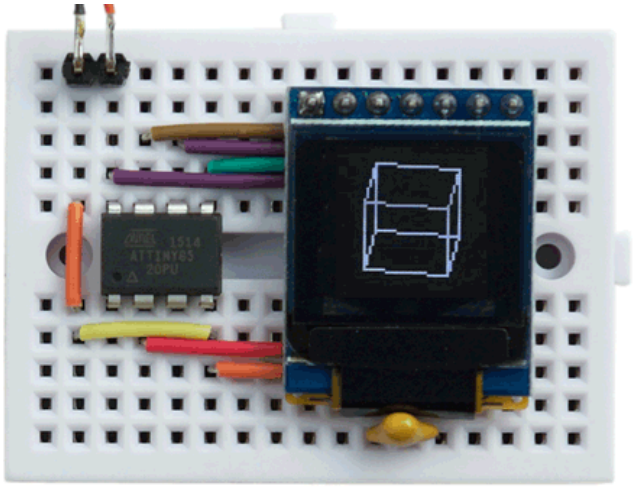
Simple oscilloscope displaying a triangle wave, using the ATtiny85-based graphics display.

Here's the program:

```
void Oscilloscope () {
  xOrigin = 0; yOrigin = 0;
  ClearBuffer();
  PlotText(20, 40, F("ADC2"));
  for (int x=1; x<63; x++) {
    int y = analogRead(A2)>>5;
    if (x == 1) MoveTo(x, y); else DrawTo(x, y);
  }
  DisplayBuffer();
}
```

Animated cube

The final application generates an animated rotating wireframe cube:



Animated wireframe cube using the ATtiny85-based graphics display.

Here's the program:

```
void RotatingCube () {
  const int Delta = 9; // Approximation to 1 degree in radians * 2^9
  xOrigin = 32; yOrigin = 24;
  int x = 0, y = 22<<9;
  for (;;) {
    ClearBuffer();
    int x9 = x>>9, y9 = y>>9, x10 = x>>10, y10 = y>>10;
    // Top
    MoveTo(x9, y10 + 12); DrawTo(y9, -x10 + 12);
    DrawTo(-x9, -y10 + 12); DrawTo(-y9, x10 + 12);
    DrawTo(x9, y10 + 12); DrawTo(x9, y10 - 12);
    // Bottom
    DrawTo(y9, -x10 - 12); DrawTo(-x9, -y10 - 12);
    DrawTo(-y9, x10 - 12); DrawTo(x9, y10 - 12);
    // Sides
    MoveTo(y9, -x10 + 12); DrawTo(y9, -x10 - 12);
    MoveTo(-x9, -y10 + 12); DrawTo(-x9, -y10 - 12);
    MoveTo(-y9, x10 + 12); DrawTo(-y9, x10 - 12);
    // Rotate cube
    x = x + (y9 * Delta);
    y = y - ((x>>9) * Delta);
    DisplayBuffer();
  }
}
```

To run any of the examples put the appropriate call inside **loop()**; for example:

```
void loop () {
  RotatingCube();
}
```

Here's the whole ATtiny85 Graphics Display program with the examples: ATtiny85 Graphics Display Program.

---

1. ^ White 0.66 inch OLED Display Module 64x48 from e_goto Processors on Aliexpress.
2. ^ SparkFun Micro OLED Breakout on Sparkfun.
3. ^ SSD1306 Datasheet on Adafruit.
4. ^ Bresenham's line algorithm on Wikipedia.
5. ^ Geekcreit XR2206 Function Signal Generator DIY Kit on Banggood.

This comment was deleted.

johnsondavies Mod Guest • 16 days ago

You mean using I2C? No, sorry, but you could probably modify this code to use an I2C library.

Reply • Share ›

JOHN VERBAN johnsondavies • 5 days ago

I have tried but cant get code to work, volt meter to ssd1306 128x64 4pin.Can you code for me? I can pay for your time.....please jverban@hotmail.com

Reply • Share ›

johnsondavies Mod JOHN VERBAN • 5 days ago

Hi John, wouldn't it be cheaper to order an SPI version of the OLED display, the same as the one I used in the article?

Reply • Share ›

JOHN VERBAN johnsondavies • 5 days ago

I have a fair few I2C oled on hand and would like to use them

Reply • Share ›

This comment was deleted.

johnsondavies Mod Guest • 16 days ago

There is no hardware I2C support in the ATtiny85. The USI can be used to provide I2C support using the TinyWireM or TinyWireS library.

Reply • Share ›

This comment was deleted.

johnsondavies Mod Guest • 15 days ago

No, sorry, I've never run it with an I2C display.

Reply • Share ›

Phil-S • a month ago

Very nice.
Do you think this could be a battery powered project?
I'm looking to do some temperature, clock displays, self-contained, maybe display on button press?
Or will there be a pin shortage with the 85?

Reply • Share ›

johnsondavies Mod Phil-S • a month ago

I can't see why it shouldn't be battery-powered. You could make it go to sleep a short delay after displaying the temperature, and use a button on the Reset pin to wake it.

Reply • Share ›

Phil-S johnsondavies • a month ago

Thanks for that. I seem to recall you using reset for ATtiny85 wakeup somewhere else.
These projects are little gems. I particularly like the use of the small MCU's to run complex displays and the innovative way you use the limited number of pins.

Reply • Share ›

johnsondavies Mod ➚ Phil-S • a month ago

Here's an example of Reset used to wake up:

http://www.technoblogy.com/...

Reply • Share ›

Stephane Come • a month ago

Amazing project David! Way to go to fit this into an ATtiny85... Wow...
Would it be possible to display the voltage measured up the title? I'm trying to display the variable containing the analog value converted, but I'm not getting how to use plotText() and a variable. Any insight would be much appreciated.
Excellent project!!

Reply • Share ›

johnsondavies Mod ➚ Stephane Come • a month ago

Thanks for your feedback!

Yes, **PlotText()** only plots a fixed string from program memory. You'd have to write a version of it to convert an integer variable to characters and plot them. I'll have a go if I get time.

Reply • Share ›

Stephane Come ➚ johnsondavies • a month ago

Thank you... So I could write an overloaded function getting a long value, converting it to a String and then send that to the OLED. Will try. Disclaimer - I'm not a C programmer. ;-) I love all your projects. So insightful and I'm able to learn a lot. one of the best blogs on the subject.

Reply • Share ›

johnsondavies Mod ➚ Stephane Come • a month ago

Try it, and if you can't get it to work I'll try and help.

Reply • Share ›

Stephen Denne • 3 months ago

I love your projects, and have built a couple of them. I was trying to create a similar project, but made quite different decisions. I went with an I2C 128x32 OLED, addressing the speed and memory problems by writing to the unused SSD1306 memory, and double buffering. The trade-off is that I can't gradually build up an image, but can still display text and generate graphs.
https://github.com/datacute...

Reply • Share ›

johnsondavies Mod ➚ Stephen Denne • 3 months ago

Glad you like them - and thanks for the link!

Reply • Share ›

JOHN VERBAN ➚ Stephen Denne • 7 days ago

Can you help with code for I2C 128x64 OLED?

Reply • Share ›

Musashi • 4 months ago

What an interesting little oled and seems pretty nifty in use. Learning so much from reading your posts, always clearly explained with detailed images, code and links for further information. Thanks for sharing!

Reply • Share ›

johnsondavies Mod ➚ Musashi • 4 months ago

Thank you! I'm also working on a new feature which I'll post in a couple of days.

Reply • Share ›

Miles Treacher • 4 months ago

Uber cool, really like this project.

Reply • Share ›