



DKAN0003A

Controlling the SmartDisplay with a SPI Peripheral

09 June 2009

Features

- IS01BFRGB LCD SmartDisplay from NKK Switches
- Simple implementation featuring the ATmega88PA from Atmel
- Complete software solution

Introduction

The IS01BFRGB SmartDisplay is NKK's standard LCD, used in every 36x24 LCD SmartSwitch. It features a 36x24 pixel monochrome LCD with red, green, and blue LED backlights. This application note describes the display's interface and provides an example implementation using a SPI peripheral. Complete C source code for Atmel's AVR ATmega88PA is provided.

Application

LCD

The IS01BFRGB LCD requires two supply voltages: 5VDC for logic (V_{DD}) and 7.3VDC typical for LCD contrast (V_{LC}).

Each LCD row requires that 40 data bits be serially clocked into the data-in (Din) pin on the falling edge of the serial clock pulse (SCP). The LCD only displays the last 36 data bits; the first 4 data bits are ignored. After a row of data is received, the latch pulse (LP) pin is pulsed to load the data. The LP-to-LP timing diagram in Figure 1 shows a row of data bits latched by an LP pulse.

Pulsing the LP while the first line marker (FLM) pin is high latches data into the first row. Each subsequent LP pulse latches the following row. Every 24th row, the FLM resets the display to the first row. The LP-to-LP timing determines the refresh rate. NKK recommends a maximum LP-to-LP timing of 1.2ms to avoid flicker*. The supplied code, with the ATmega88PA's 1MHz internal oscillator, achieves this. Figure 2 shows the timing diagram for a complete frame. Consult the datasheet for the timing specifications.

* It has been observed that a V_{LC} of more than 8VDC enables a slower refresh rate (approximately 1.8ms) without flicker. Since this requires fewer computational resources, a slower microcontroller can be used, or more tasks can be completed. Beyond 8VDC and 1.8ms, this relationship between V_{LC} and the refresh rate diminishes, and no advantage is gained.

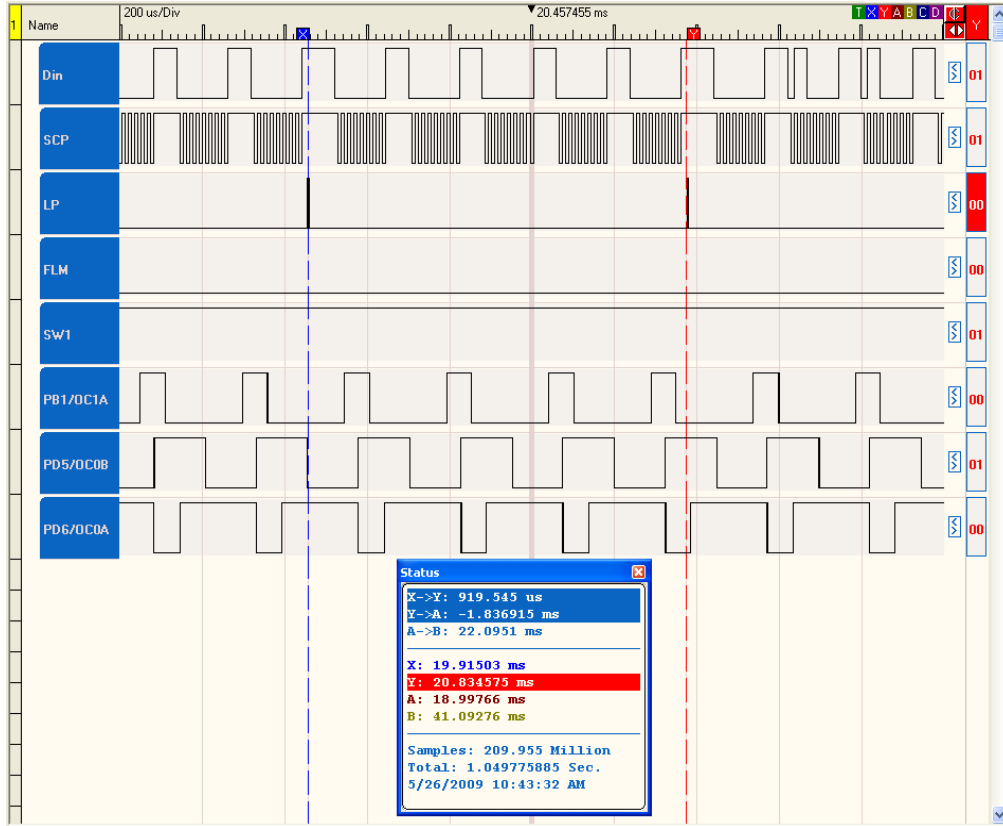


Figure 1. LP-to-LP Timing Diagram

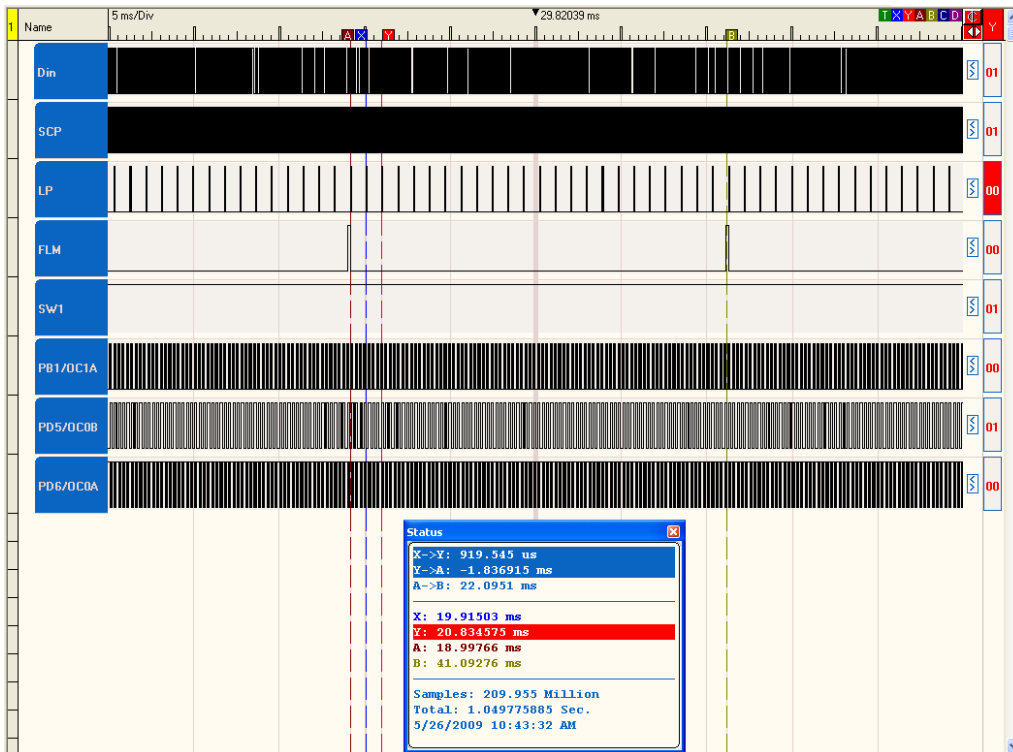


Figure 2. Frame Timing Diagram

Backlight

The LCD's backlight consists of red, green, and blue LEDs. Figure 3 shows an example circuit. The current-limiting resistors and duty cycle of each PWM on the ATmega88PA control the backlight LEDs' color and brightness. Refer to the datasheet for LED specifications.

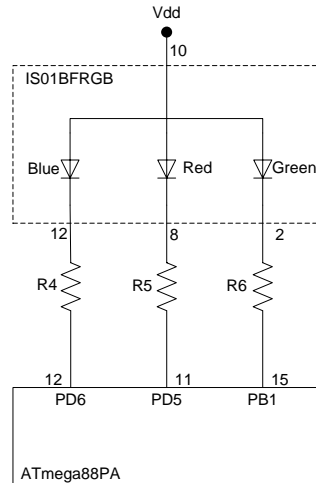


Figure 3. LED Backlight Circuit

Example Circuit

Figure 4 shows an example circuit using the ATmega88PA to control the NKK IS01BFRGB SmartDisplay. An LM2703 from National Semiconductor boosts V_{DD} to 7.3VDC for the LCD contrast (V_{LC}). The ATmega88PA controls the LM2703 shutdown pin, and the rheostat R_2 controls V_{LC} .

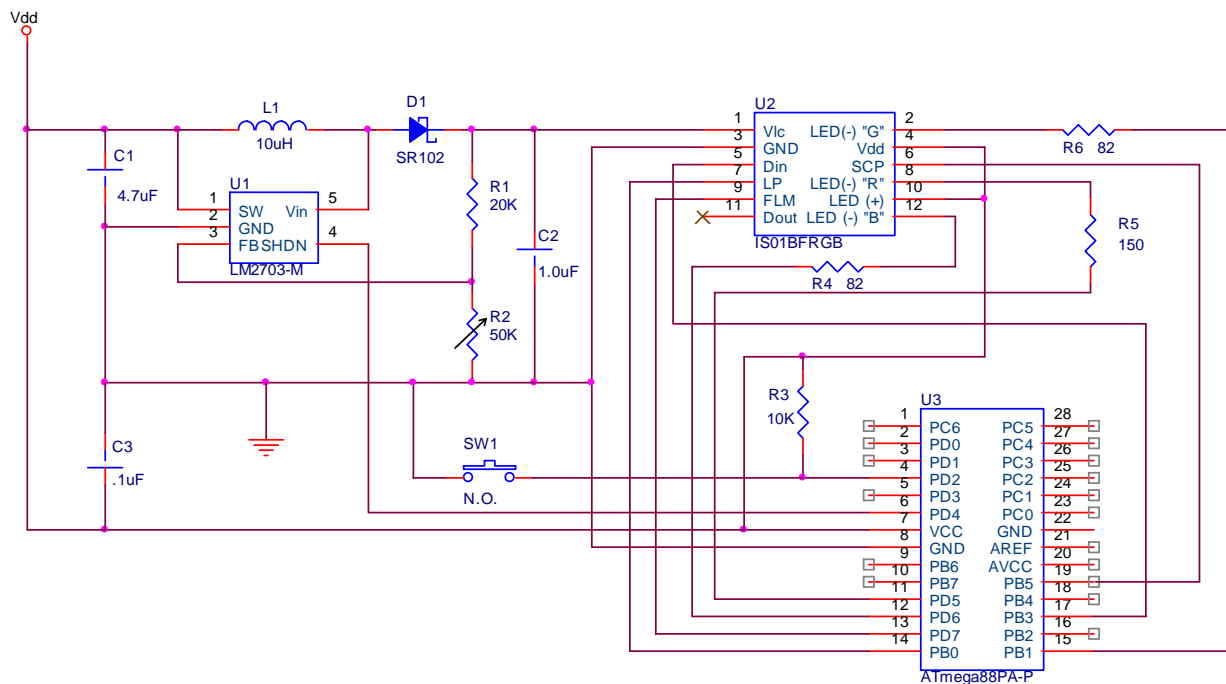


Figure 4. Example Circuit

Code

Figure 5 illustrates the program flow chart.

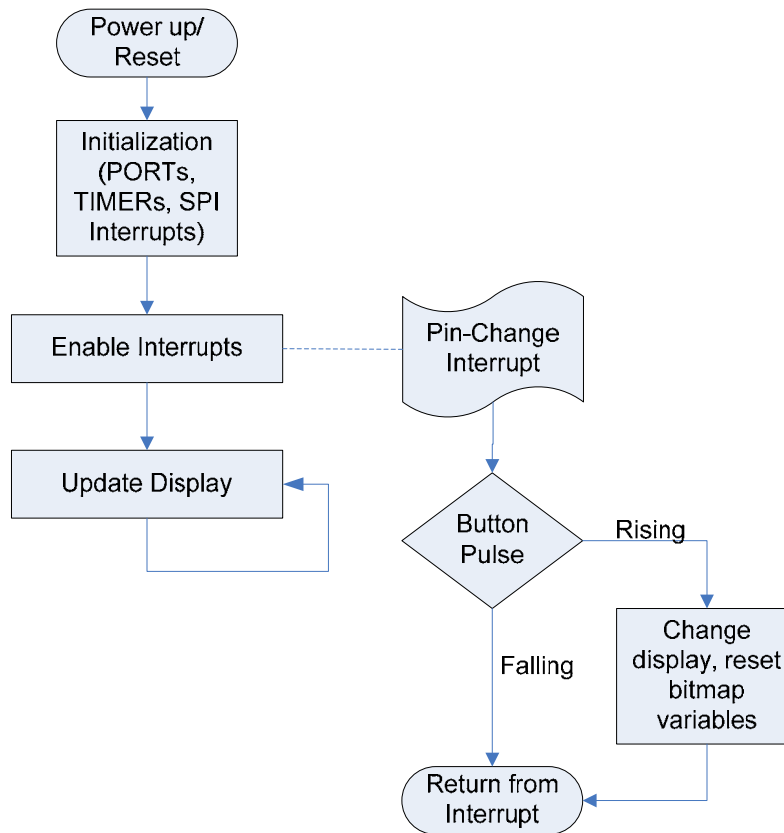


Figure 5. Program Flow Chart

Initialization

The program begins with the initialization of the GPIO pins, interrupts, Timer0, Timer1, and the SPI peripheral. A pin change interrupt is enabled on PD2, and the global interrupts are enabled. Timer0 and Timer1 are configured in a PWM mode to control the LED backlights. The SPI peripheral is configured for communication with the SmartDisplay.

Table 1. Port IO

| ATmega88PA | | IS01BFRGB | LM2703 |
|------------|-----------|------------|--------|
| Pin | Direction | | |
| PB0 | Output | LP | --- |
| PB1 | Output | LED(-) "G" | --- |
| PB3 | Output | Din | --- |
| PB5 | Output | SCP | --- |
| PD7 | Output | FLM | --- |
| PD6 | Output | LED(-) "B" | --- |
| PD5 | Output | LED(-) "R" | --- |
| PD4 | Output | --- | SHDN |
| PD2 | Input | SW1 | --- |

PWM

Timer0 and Timer1 control the LED backlight's brightness. Once the timers are configured as 8-bit inverted PWM outputs during initialization, each timer runs continuously. The timers have no pre-scaling, so they run at the same frequency as the CPU. Each PWM's duty cycle is set in the corresponding output compare register (OC0B, OC0A, or OC1A), providing individual LED control. Some PWM values are predefined in the code.

SPI Port

The SmartDisplay does not implement a standard SPI interface. However, a SPI port can communicate with it via its MOSI and SCK pins. The SPI peripheral is configured as a SPI Master in mode 2 (Clock Polarity = 1, Clock Phase = 0). It is set up to transmit the LSB first and run at 62.5kHz.

Pin Change Interrupt

An interrupt is generated on both a button press and a button release. After a button release, the interrupt service routine switches to the alternate bitmap and resets the bit, column, and row pointers to start a new image.

Bitmap

The display is a 36x24 pixel format, but the bitmaps have a 40x24 format to incorporate the ignored bits. Each bit sets a pixel state (1=on, 0=off). In this example, each 120-byte bitmap is stored in internal Flash. (Note: the program inverts the OFF bitmap for visual differentiation.) Figure 6 illustrates the bitmap format.

```

unsigned char IS01BFRGB_bitmap_1[24][5] PROGMEM =
{
  {0b00000000, 0b00000000, 0b00000000, 0b00000000, 0b00000000 } // Line #1
  {0b00000000, 0b00000000, 0b00000000, 0b00000000, 0b00000000 } // Line #2
  {0b00000000, 0b00000000, 0b00000000, 0b00000000, 0b00000000 } // Line #3
  {0b00000000, 0b01111000, 0b00000110, 0b00000110, 0b00000000 } // Line #4
  {0b00000000, 0b11111100, 0b00000110, 0b00000110, 0b00000000 } // Line #5
  {0b00000001, 0b10000110, 0b00000111, 0b00000110, 0b00000000 } // Line #6
  {0b00000011, 0b00000011, 0b00000111, 0b10000110, 0b00000000 } // Line #7
  {0b00000110, 0b00000001, 0b10000111, 0b10000110, 0b00000000 } // Line #8
  {0b00000110, 0b00000001, 0b10000111, 0b11000110, 0b00000000 } // Line #9
  {0b00000110, 0b00000001, 0b10000110, 0b11000110, 0b00000000 } // Line #10
  {0b00000110, 0b00000001, 0b10000110, 0b11100110, 0b00000000 } // Line #11
  {0b00000110, 0b00000001, 0b10000110, 0b01100110, 0b00000000 } // Line #12
  {0b00000110, 0b00000001, 0b10000110, 0b01110110, 0b00000000 } // Line #13
  {0b00000110, 0b00000001, 0b10000110, 0b00110110, 0b00000000 } // Line #14
  {0b00000110, 0b00000001, 0b10000110, 0b00111110, 0b00000000 } // Line #15
  {0b00000110, 0b00000001, 0b10000110, 0b00011110, 0b00000000 } // Line #16
  {0b00000011, 0b00000011, 0b00000110, 0b00011110, 0b00000000 } // Line #17
  {0b00000001, 0b10000110, 0b00000110, 0b00001110, 0b00000000 } // Line #18
  {0b00000000, 0b11111100, 0b00000110, 0b00000110, 0b00000000 } // Line #19
  {0b00000000, 0b01111000, 0b00000110, 0b00000110, 0b00000000 } // Line #20
  {0b00000000, 0b00000000, 0b00000000, 0b00000000, 0b00000000 } // Line #21
  {0b00000000, 0b00000000, 0b00000000, 0b00000000, 0b00000000 } // Line #22
  {0b00000000, 0b00000000, 0b00000000, 0b00000000, 0b00000000 } // Line #23
  {0b00000000, 0b00000000, 0b00000000, 0b00000000, 0b00000000 } // Line #24
};

```

Figure 6. Example Bitmap

Conclusion

This application note presents a method of using the SPI interface to control the NKK SmartDisplay. It provides a complete software solution utilizing an ATmega88PA, allowing a simple, effective implementation.

Additional Information

DKAN0002A: Bit-banging the SmartDisplay. Digi-Key Corporation. 09 June 2009.

Appendix: Parts List

| Part | DK Part Number | Description | Mfg Part Number |
|--------|-------------------|-----------------------------------|-------------------|
| R1 | 10KQBK-ND | RES 10K OHM 1/4W 5% CARBON FILM | CFR-25JB-10K |
| R2 | 3352H-503LF-ND | POT 50K OHM THUMBWHEEL CERM ST | 3352H-1-503LF |
| R3 | 20KQBK-ND | RES 20K OHM 1/4W 5% CARBON FILM | CFR-25JB-20K |
| R4 | 330QBK-ND | RES 330 OHM 1/4W 5% CARBON FILM | CFR-25JB-330R |
| R5 | 1.1KQBK-ND | RES 1.10K OHM 1/4W 5% CARBON FILM | CFR-25JB-1K1 |
| R6 | 330QBK-ND | RES 20K OHM 1/4W 5% CARBON FILM | CFR-25JB-330R |
| L1 | 811-1309-ND | INDUCTOR RADIAL 10UH 1.62A | 22R103C |
| C1 | 445-2867-ND | CAP CER 4.7UF 16V Y5V RAD | FK24Y5V1C475Z |
| C2 | 445-2852-ND | CAP CER 1UF 16V Y5V RAD | FK28Y5V1C105Z |
| C3 | 445-4802-ND | CAP CER .10UF 50V Y5V RAD | FK28Y5V1H104Z |
| D1 | SR102DICT-ND | DIODE SCHOTTKY 20V 1.0A DO-41 | SR102-T |
| U1 | LM2703MF-ADJCT-ND | IC CONV DC/DC MICPWR SOT23-5 | LM2703MF-ADJ/NOPB |
| U3 | ATMEGA88PA-PU-ND | MCU AVR 8K ISP FLASH MEM 28-DIP | ATmega88PA-PU |
| | | | |
| U2 | 360-2334-ND | SMARTDISPLAY RED/GREEN/BLUE | IS01BFRGB |
| SW1 | P8014S-ND | 6MM LIGHT TOUCH SW W/GND H=5 | EVQ-PBC05R |
| or | | | |
| SW1/U2 | 360-2332-ND | SMARTSWITCH STANDARD RGB | IS15ABFP4RGB |

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