

Using the Siemens S65 – Display

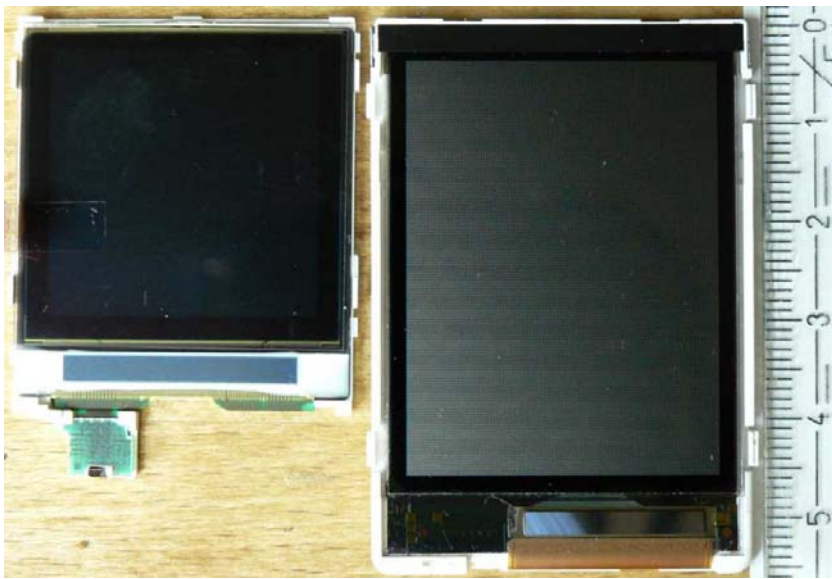
by **Christian Kranz**, October 2005 (http://www.superkranz.de/christian/S65_Display/DisplayIndex.html)

(PDF by **Benjamin Metz**, 10th October 2005)

About the Display:

Siemens used for the mobile phones S65, M65, CX65 and SK65 a 16-bit color TFT display with 132x176 pixel. This display has integrated white backlight LED's and an attractive screen size.

The display is available for less than 20 EUR in phone part shops and ebay. The following picture compares the well known Nokia 6100 display with the S65 - display.



The following pages describe how to use this display in own applications. Actually it is focused on the Atmel AVR processor but from the description it should be possible to use it with other controller also.

Info: Actually there are known three different types of the display. The picture below shows two versions. Luckily they are compatible from hardware and software point of view. An incompatible display is actually not known.



Hardware:

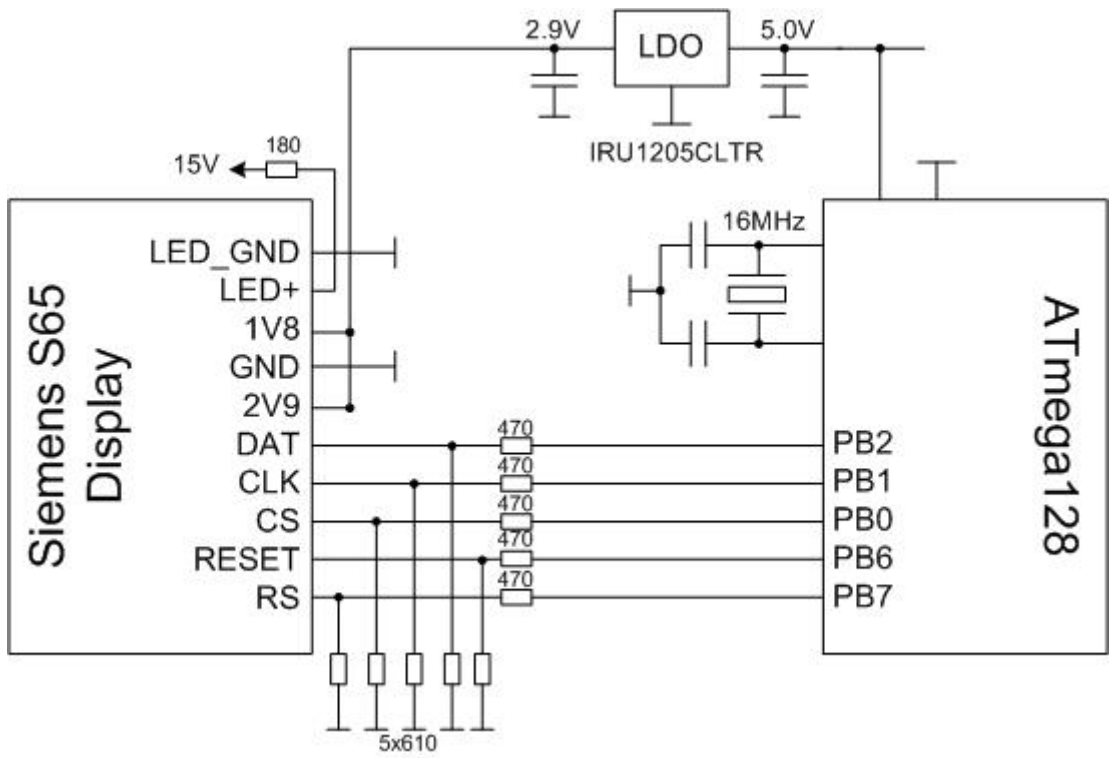
The Display pin description can be found on this Picture:



Schematic:

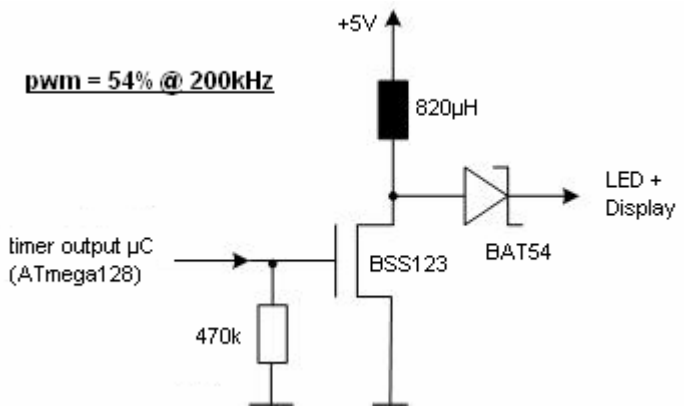
The schematic of the testboard is shown in the picture below. Both display supplies are connected to a 2.9V supply that is generated out of an LDO from the 5.0V supply of the Atmel AVR μ C. I used the IRU1205CLTR LDO because I will later need the power on/off feature of this LDO. The Atmel AVR μ C is running with 16MHz.

The five interface lines between the display and the μ C are level-shifted from the 5V domain of the μ C to the 2.9V domain of the display. Because the interface will run with 8MHz the impedance has to be low to get stable signals. It might be a good idea to go to active level shifter in future to save power, especially for the RESET line because this line has to be high as long as the display is used. On the other hand you can use a higher impedance level shifter here because speed is not important.



Display Backlight:

The display forward voltage was measured to be 10.4V at 20mA current. That means a relative large voltage is needed. This voltage can be easily generated with a PWM signal generator of the μC . (Do not forget to switch on the current limitation of your power supply until the PWM generator is running correct. If you drive the n-channel gate high for a longer time you will have a short circuit.) For the circuit below you need a pulse width (high/period) of 54% at a period frequency of 200kHz to generate the required voltage with 20mA LED current. A block capacitor is already implemented on the display and is not needed.



Software - (Commands and Data):

Data and commands to the display controller are distinguished by the RS line. If RS is high, the controller expects commands, if the RS line is low it expects data.

RS = high	Command
RS = low	Data

Initialization Commands:

A LCD TFT display is programmed in three steps. To switch on the display a initialization sequence is needed to program the power chip of the display. That is needed because of the high multiplex rate of the display a relative high voltage is used for driving the glass. The glass voltage can be in the 10V to 20V range and is usually generated by charge pumps.

After switching on the power usually the display parameter are programmed. In some cases also the boost circuit has to be reprogrammed from startup to active.

After startup the display can be used for displaying...

The originally measured seven initialization sequences from the S65 display can luckily be reduced to two sequences. In addition we do not need the very long time intervals Siemens used in here approach. The first (of the two) used initialization sequence is:

INIT1:

```
0xFDFD, 0xFDFD
0xEF00
0xEE04, 0x1B04
0xFEFE, 0xFEFE
0xEF90, 0x4A04, 0x7F3F, 0xEE04, 0x4306
```

After that we need to wait for the display internal voltage settling.

This wait time is very sensitive. **If the time is too short or too long the display will not work!** It was measured to be 7ms and this value shall also be used to drive the display with the sequences shown here.

The second sequence follows directly and is:

INIT2:

```
0xEF90, 0x0983, 0x0800, 0x0BAF, 0x0A00, 0x0500, 0x0600, 0x0700
0xEF00
0xEE0C
0xEF90, 0x0080
0xEF00, 0x4902
0xEF00
0x7F01, 0xE181
0xE202
0xE276
0xE183
0x8001
```

After the initialization sequence the display is ready to use. An immediate clear screen is recommended because the display shows random content after first power on.

Power Down Commands:

For a regular shutdown a display needs normally a power down sequence to discharge the glass voltage in a controlled manner. Otherwise the lifetime of the display might be reduced. Currently the power down sequence is not known. Therefore we only have the possibility to reset the display and switch off the power supply.

Writing Full-Screen and Screen Sections:

After the initialization the display is ready to use. Usually the first thing to do is to clear the display. That can be perfectly done with the following memory write command.

MEMWR:

0xEF90, 0x05**OR**, 0x06**YS**, 0x07**XS**

After this command the display data can be written pixel by pixel, each pixel 16-bit.

The parameter **XS** and **YS** are defining subsections of the display memory. It is not required to write the complete memory. If only a part of the display should be written the data write can be stoppend and the next **MEMWR** command resets the write pointer to the given coordinates.

The complete screen is written with **XS = 0** and **YS = 0**. In that case it is not required to repeat the command for each screen write. It is sufficient to write simple the data again and again. The display memory is organized according the picture on the right side. The total number of bytes is 132x176x2, that means in total 0xB580 pixel. The memory is written first in X - direction and second in Y - direction. The parameter **OR** defines the display orientation.

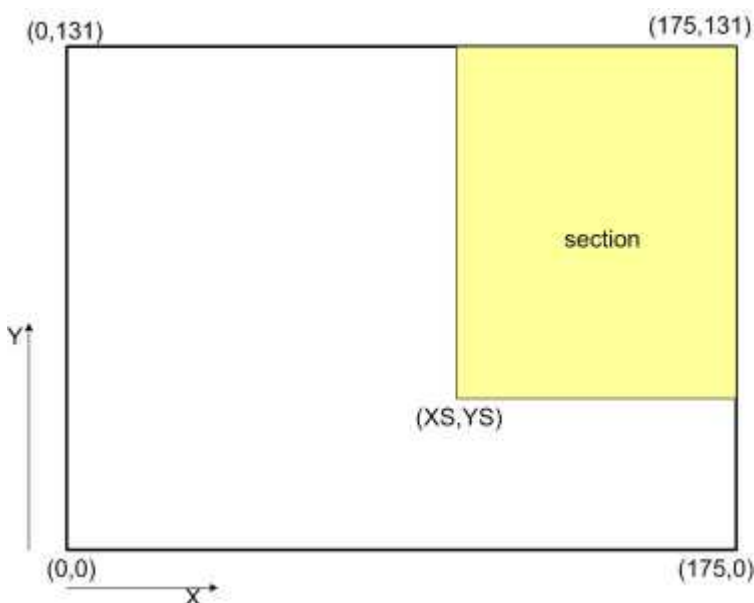
OR = 0x04 sets the **0 degree** orientation shown in the picture below.

OR = 0x00 defines the **90 degree** orientation.

For details see the section [partial screen write](#).

With **OR = 0x04** the memory is written in x-direction, that means line by line in x-direction from left (low x-number) to right (high x-number).

With **OR = 0x00** the display memory is written in y-direction, that means from column by column from **YS** to **131**.

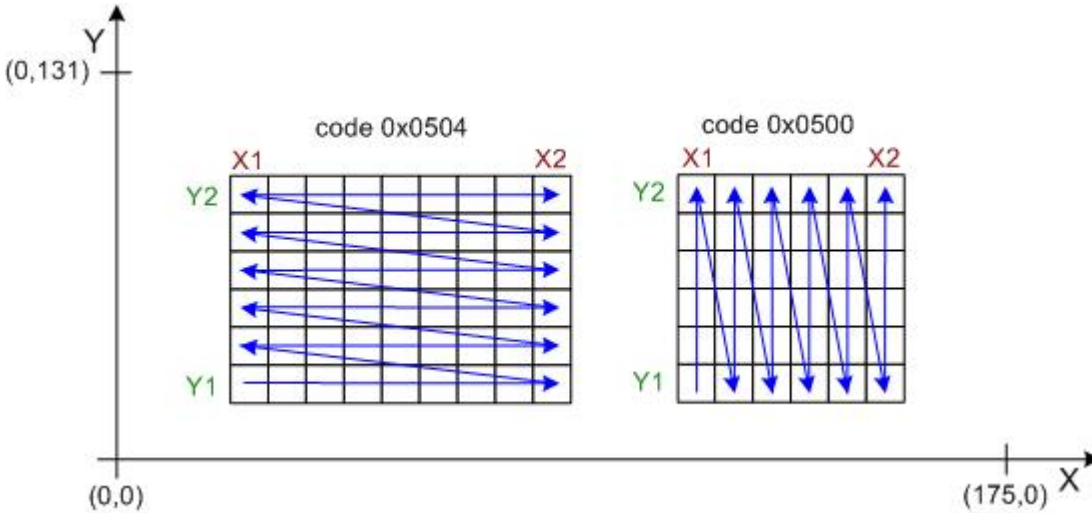


Pixel Color Coding:

The display memory is initialized to work according the -5-6-5- color coding (-R-G-B-) scheme. That means the first (MSB first) 5-bits are coding the intensity of red, the following 6-bits are coding the intensity of green and the last 5-bits the intensity of blue. (0xFFFF is white, 0x0000 is black)

Partial Screen Write:

The display memory is organized in a matrix form with x- and y coordinates. At each matrix coordinate one 16-bit color value (pixel) is stored. (Advanced techniques like PET (sub-pixel addressing) seems not to be supported.) The following picture shows the principle:



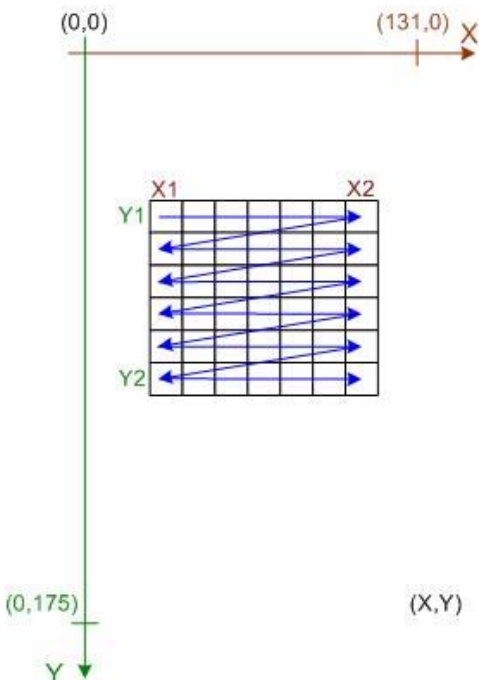
For partial writing to the memory the commands below are used. The start corner (X1,Y1) and the end corner (X2,Y2) have to be defined. X2 has to be larger or equal X1, Y2 has to be larger or equal Y1.

PMEMWRX: (X-direction)

0xEF90, 0x0504, 0x08X1, 0x09X2, 0x0AY1, 0x0BY2

PMEMWRY: (Y-direction)

0xEF90, 0x0500, 0x08X1, 0x09X2, 0x0AY1, 0x0BY2



The display memory can be written in X- or Y-direction. Other advanced memory access modes are not supported. Writing in Y-direction is usually preferred if the display is used 90-degree rotated. If than the X- and Y-values in the PMEMWRY command are exchanged, the coordination system - shown in the left picture is obtained. In this case bitmaps are drawn from the upper left corner down to the lower right corner.

Reengineering the S65 Display:

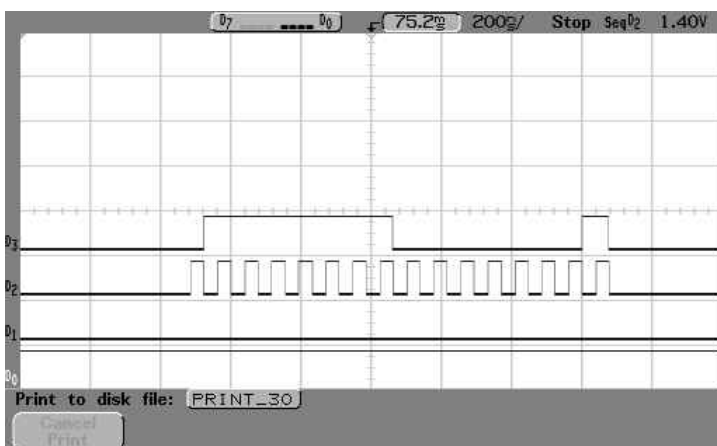
The Siemens S65 display is a special manufacturing for the Siemens AG (now Siemens/BenQ). Because of that it is very difficult to get data sheets for the used display controller. The display is a product of Seiko-Epson but does not response to the known Epson display commands (also not to the commands of relative new epon 16-bit controller). Because of that i decided to do a re-engineering of the display interface using a S65 mobile phone.

It was easy to figure out that Siemens uses a serial two wire interface with additional chip select, a command/data signal (usually called RS) and a reset signal. The clock frequency of the serial interface is 13MHz. Supply voltages are 2.9V for the display driver and 1.8V for the digital interface. In addition there are two supply pins for the four white backlight LED's. The LED's are serial connected and buffered with a capacitance on the display board. The serial connection ensures a very constant light intensity distribution. That is because each LED is driven by the same current. The disadvantage is that a relative high voltage is needed for driving the LEDs. The LED voltage was measured to 10.4V at 20mA for one display. But in the hardware section you can see that it is not very difficult to generate the voltage with a PWM signal generated by the μC . The display pin out can be seen on the figure on the left side. CS is the chip select line, CLK the clock line, DAT the data line, RS the command/data identification, 2V9 the 2.9V supply, 1V8 the 1.8V supply, LED+ the positive LED supply and LED_GND the negative LED supply.



The display interface was measured using a HP (Agilent) 16-channel digital oscilloscope. (unfortunately a logic analyser was not available)

The display commands and data are written in a 16-bit format like the example on the picture. A data bit is latched with the rising edge of the clock signal by the display controller.



Start Up Sequence:

The following sequences for starting the display could be identified:

Sequence 1: (time 0ms)

0xFDFD, 0xFDFD

Sequence 2: (time 68ms after start)

0xEF00, 0xEE04, 0x1B04, 0xFEFE, 0xFEFE
0xEF90, 0x4A04, 0x7F3F, 0xEE04, 0x4306

Sequence 3: (time 75ms after start)

0xEF90, 0x0983, 0x0800, 0x0BAF, 0x0A00, 0x0500, 0x0600, 0x0700
0xEF00
0xEE0C
0xEF90, 0x0080,
0xEFB0, 0x4902
0xEF00
0x7F01, 0xE181

Sequence 4: (time 182ms after start)

0xE202

Sequence 5: (time 297ms after start)

0xE276

Sequence 6: (time 401ms after start)

0xE183

Sequence 7: (time 460ms after start)

0x8001

In addition it could be measured, that Siemens always refreshes the screen at once. That means also if only parts of the screen are changed the complete display memory is refreshed. Reason for that is, that Siemens uses an display graphic controller like the s1d13732. This controller holds the display memory and writes the display content via hardware.

Only the commands are generated by the μC . The sequence used by Siemens for writing the complete display is:

write complete display memory:

0xEF90, 0x0500, 0x0600, 0x0700

After that the display data follows (with RS line low). Writing the display data takes 28.59ms which corresponds to $(132 \cdot 176 \cdot 16 = 371712 \text{ bits})$ with 13MHz clock frequency.

Power Down Sequence:

Unfortunately the power down sequence could not be measured with the used equipment. It was not possible to find a proper trigger condition to get a reliable repeatable measurement of the power down sequence.

Triggering to the backlight was possible but the memory of the digital scope was too small to catch the sequences. Unfortunately the backlight is switched off after the display is powered down. Spending more effort it might be possible to catch the power down sequence but that is not done up to now. The proposed sequence so far is reset of display and switching off the supply.