

# Application Note for the OLED Color SmartSwitches and Displays

Revision G

**SMARTSWITCH**™



NKK Switches  
7850 E. Gelding Drive  
Scottsdale, AZ 85260

480- 991-0942  
FAX (480) 998-1435  
Email: [engineering@nkkswitches.com](mailto:engineering@nkkswitches.com)

**All Rights Reserved Worldwide**

NKK Switches makes no warranty for the use of these products and assumes no responsibility for any errors, which may appear in this document, nor does it make a commitment to update the information contained herein.  
SmartSwitch is trademark of NKK Switches.

TABLE OF CONTENTS

Table of Contents .....2

1. General Information .....3

2. Pin-out .....4

3. Design Consideration.....5

4. Initialization.....8

5. Memory Format .....11

6. Specifying a Memory Window for Downloading.....12

7. Pixels and Image Format .....14

8. Display Commands Available .....16

9. Additional Commands Available.....17

10. Scrolling (Screensaver) .....18

11. Graphic Command .....20

12. Initialization Options.....22

13. Sample Schematic for Multi-switch Controller .....23

14. Frequently Asked Questions .....24

## 1. General Information

This application note should be used in conjunction with the OLED data sheets which have the timing diagrams for communication. The Frameless OLED switch is rated for 50,000 hours of screen life. The OLED switch and OLED display are rated for 30,000 hours of screen life. The same OLED controller is used for all the three OLEDs. The initialization values are different for each product: OLED switch (Table 1); OLED display (Table 2); and Frameless OLED switch (Table 3). The rest of this application note applies to all OLED modules. The footprint and physical dimensions of the OLED switch and the Frameless OLED switch are the same.

### Part Numbers

The following is the list of the OLED switch and display part numbers and their associated accessories. The OLED is currently available as 96 x 64 pixel switch, a 64 x 48 pixel switch, and a 52 x 36 pixel display. All OLED modules incorporate the same OLED controller (SSD1331).

Part Number	Pixels	Socket	Charge Pump (21 mA)	Charge Pump (100 mA)	Description
ISF15ACP4	96 RGB x 64	AT9704-085L	IS-CHPMP	IS-CHPMPHP	Frameless OLED SmartSwitch with 65,000 colors per pixel
ISC15ANP4	64 RGB x 48	AT9704-085L	IS-CHPMP	IS-CHPMPHP	OLED SmartSwitch with 65,000 colors per pixel
ISC01P	52 RGB x 36	AT9704-085M	IS-CHPMP	IS-CHPMPHP	OLED display with 65,000 colors per pixel

For prototyping, it is recommended to use the sockets and charge pump. The charge pump produces 16 V from the logic level voltage and has an enable pin. When the charge pump is disabled, the 16 V is floating. The IS-CHPMP has up to 21 mA current capability. The IS-CHPMPHP has up to 100 mA current capability.

### Development Kits

Development kits are available for all OLED products. The development kits include a power supply, RS232 cable, controller and two switches or two displays on the socket. The development kits can operate from a 9V battery as well.

Development kits Part Number	Switch/Display
IS-DEV KIT-9	ISF15ACP4
IS-DEV KIT-7	ISC15ANP4
IS-DEV KIT-7D	ISC01P

## 2. Pin-out

The pin functions are the same for all OLED switches. The OLED display does not have switch pins.

Symbol	Pin Name	Function
SW	Switch terminal	Normally open switch
SW	Switch terminal	Normally open switch
V <sub>DD</sub>	Power	Power source for the logic circuit
$\overline{SS}$	Slave select	Select the OLED module
RES	Reset	Reset the OLED module
D/C	Data/Command	Indicates image data or command and the associated data transmission
SCK	Clock	SPI clock
SDI	Data	SPI data
V <sub>CC</sub>	Power	Power source for the OLED
GND	Ground	

**Switch terminals (SW, SW):** The switch is normally open. The switch can be scanned by connecting one pin to ground and the other pin to a micro-controller pin with a pull up resistor. For a matrix of switches, many different methods can be used for switch scanning.

**Ground:** Ground for the logic circuit and OLED

**V<sub>DD</sub>:** Power source for the logic circuit (2.4 V to 3.5 V)

**V<sub>CC</sub>:** Supply voltage for the OLED (15 V to 17 V)

**SCK:** Clock for the serial communication. Maximum is 6.66 MHz

**SDI:** Data for serial communication

**D/C:** Data/command select. When this pin is pulled low, the transmitted bytes are treated as command along with the associated data. When this pin is pulled high, the transmitted bytes are treated as image data.

**RES:** Reset.

**$\overline{SS}$  :** Select the OLED module. This pin should be pulled down for the duration of the data/command communication.

### 3. Design Considerations

#### 3.1 Power Requirements $V_{CC}$ (16 V)

There are two voltages required for controlling the OLED switch or display. The internal controller has to be ready before the  $V_{CC}$  (16 V) is supplied. This means the  $V_{CC}$  has to be supplied with a delay after  $V_{DD}$  (please refer to datasheet on power up timing). Additionally,  $V_{CC}$  cannot be less than  $V_{DD}$  at any time due to the internal ESD circuit. You can assume the ESD circuit connects  $V_{DD}$  to  $V_{CC}$  via a diode. These requirements leave two options for the designer of a controller:

- 3.1.1 When  $V_{CC}$  is disabled, its voltage to be the same as  $V_{DD}$ .
- 3.1.2 When  $V_{CC}$  is disabled, it is float.

Many manufacturers have introduced a charge pump IC chip for the OLED. The charge pumps produces the required voltage (16V) for the OLED from 2.4 to 5.5 V input and the SHTDN pin for the voltage output to be float. Charge pump manufacturers should provide the schematic, parts list and suggested layout to be incorporated in the design.

For your convenience in the prototype stages NKK has made two charge pumps that can provide up to 21 mA/100 mA at 16 V output from 2.4 to 5.5 V input. They have a shut-down pin to activate/float the output voltage. The charge pump part numbers are IS-CHPMP and IS-CHPMPHP.

Care must be taken in the design so  $V_{CC}$  is disabled upon power up.

While power up is completely under the designers control, powering off can happen at any time when the user does not follow the turn off procedure. The designer should have  $V_{CC}$  capacitance less than  $V_{DD}$  capacitance or have a pull down resistor for  $V_{CC}$  so  $V_{CC}$  is not present after  $V_{DD}$  when powering off.

The OLED current consumption is proportional to the number of pixels ON. The maximum current consumption is all the pixels ON at full brightness (white image).

#### 3.2 Communication

The OLEDs accept serial communication. There are four control lines (Clock, Data, C/D and  $\overline{SS}$ ). The communication is byte oriented and the first bit is taken as the highest bit of the byte. A data bit is taken on the rising edge of each clock. The two pins of microcontroller I/O with output capabilities, SPI pins MOSI and SCLK, or any other serial pins that can comply with clock and data requirements can be used.

C/D determines whether the received transmissions is image data or command along with associated data. Please note, there is no command for image data. Any bytes received while C/D is high will be considered image data. Once the image data for a pixel is received, the cursor address increments to the next pixel. Once it reaches the end of a specified window it starts from the beginning. The reason for this feature is so no command is required when displaying video. It is a good practice to have C/D normally high so any mistake in firmware effects only the image rather than the setup, which could possibly damage the OLED. Any microcontroller I/O with output capability can be used as C/D.

$\overline{SS}$  determines if the OLED accepts the transmission from the clock and data lines or ignores them. When  $\overline{SS}$  is high, all activity from the clock or data lines are ignored. A command and its associated data have to be completed in one session when  $\overline{SS}$  is pulled low. If  $\overline{SS}$  is pulled high before a command, and its associated data are completed, that command is ignored. If  $\overline{SS}$  is pulled high in the middle of a byte, that byte is ignored and in the next session when  $\overline{SS}$  is pulled down, a new byte is started. Multiple commands can be transmitted in one session. A common mistake is not waiting for SPI transmission to finish before pulling  $\overline{SS}$  high. Any microcontroller I/O with output capability can be used as  $\overline{SS}$ .

### 3.3 Hardware and Layout

To avoid noise on the display, these steps are recommended:

- 3.3.1 Add a serial resistor (22 ohm to 27 ohm) in series close to OLED pin for the SCK line.
- 3.3.2 Add a 0.1  $\mu$ F capacitor close to  $V_{DD}$  pin.
- 3.3.3 Ensure good ground routing to avoid potential ground differences on the board.
- 3.3.4 Add a serial resistor for each of any other signal.

### 3.4 Controlling Many OLED Switches or Displays

When controlling many OLED switches, it is suggested to divide the signals via a driver. Example: NKK designed a 16-switch logic board which connects to the controller via a ribbon cable. Using 74HC4050, we split the SCK signal to four signals and all other signals were split to two signals. The result: each four switches share one clock signal and each eight switches share all the other signals. NKK tested the 16-switch logic board with various cable lengths getting up to 180 inches (the longest cable we had) without any problem.

### 3.5 SCK Frequency

The specification states the maximum frequency is 6.6 MHz. However, the development kit SCK is 8 MHz. Some customers have reported SCK as high as 16 MHz. Possibly there is two byte buffer in the OLED communication, and throughput maximum is 6.6 MHz. Since it takes time for a microcontroller to retrieve/convert the data, the throughput is always less than SCK frequency. If a higher frequency is used, NKK recommends experimenting with the timing between bytes or calculating so 6.6 MHz throughput is not exceeded.

### 3.6 Running Video

Displaying video is achieved by sequentially sending video frames at the desired speed. The theoretical maximum frames per second for the Frameless OLED is about 67. If multiple OLEDs need to run video at the same time, the design may need to have multiple clocks and data lines.

### 3.7 Operating Life

The OLED life for the standard switch and display is rated for 30,000 hours (40% pixels on). The OLED life for the Frameless switch and display is rated for 50,000 hours (40% pixels on). This means the white color will be at half brightness after 30,000/50,000 hours. The OLED life rating is based on displaying moving images such as videos. It is determined that when a display is showing a video, on average, each pixel of the display is on 40 percent of the time.

The brightness has an inverse effect on life. For example, using a 30,000 hour rated OLED at half brightness increases the life of the display to 60,000 hours.

When a still image or text is used for an extended time, the pixels used for the image will get dimmer than the surrounding pixels that have not been used. For example, if a blue color is used in one area most the time, when white is displayed in that area, the white will have a tint of yellow. The yellow is because red and green is now stronger than the blue. However, by properly designing the image colors and by anticipating the amount of time they will be displayed, this problem can be avoided.

For still images, longer life can be achieved if all the colors are used and the still images are alternated.

As a reference for the 30,000 hour rated OLED, the half-life of individual colors at 100 percent brightness are as follows:

- Green is over 20,000 hours.
- Blue is over 10,000 hours.
- Red is over 10,000 hours.

The creativity of the software engineer can drastically improve the life expectancy of the OLED switch or display. It is possible to get a much higher than indicated 30,000/50,000 hours of life through image positioning, incorporating dimming or using screen savers and/or moving images.

## 4. Initialization

The initialization procedure upon power up for the Frameless OLED (96 x 64), OLED switch (64 x 48) and OLED display (52 x 36) are stated in tables 1, 2 and 3.

1. By design, V<sub>CC</sub> should be disabled upon power up.
2. The Reset pin should be set to low for minimum of 3 μs and then set to high.
3. V<sub>CC</sub> can be enabled any time from this point to before the display is turned ON at the end of initialization.
4. Initialize the OLED controller by transmitting the commands and data from the appropriate table below. Each command is one byte and has 0 to 10 associated data bytes. The D/C pin should be set low for the entire command and its associated data. To transmit each command, set the select pin to low, transmit the command and its associated data, and then set the select pin to high.

Table 1 Initialization for the OLED switch (64 x 48) 30,000 hour life  
Commands Function

			Commands	Function
*1	4.1	Transmit	81H 15H	Contrast for color A
*1	4.2	Transmit	82H 1AH	Contrast for color B
*1	4.3	Transmit	83H 17H	Contrast for color C
	4.4	Transmit	87H 0FH	Master current control
	4.5	Transmit	A0H 70H	Remap and color depth setting
	4.6	Transmit	A1H 00H	Set display start line
*1	4.7	Transmit	A2H 10H	Set display offset
	4.8	Transmit	A4H	Normal display
*1	4.9	Transmit	A8H 2FH	Multiplex ratio
	4.10	Transmit	ABH 00H 12H 0CH 14H 12H	Dim mode setting for color A, B and C
*1	4.11	Transmit	ADH 8EH	Master configuration
	4.12	Transmit	B0H 0BH	Power save mode
*1	4.13	Transmit	B1H 44H	Phase 1 and 2 period adjustment
*1	4.14	Transmit	B3H A0H	Display clock divider/oscillator frequency
*1	4.15	Transmit	B9H	Enable linear gray scale
*1	4.16	Transmit	BBH 12H	Pre-charge level
*1	4.17	Transmit	BEH 3EH	Set V <sub>comh</sub>
	4.18	Transmit	AFH	Display on in normal mode

\*1: Changing the set up values may cause damage to the OLED modules.

Table 2 Initialization for OLED Display (52 x 36) 30,000 hour life  
Commands Function

		Commands	Function
*1	4.1	Transmit 81H 0EH	Contrast for color A
*1	4.2	Transmit 82H 13H	Contrast for color B
*1	4.3	Transmit 83H 12H	Contrast for color C
	4.4	Transmit 87H 0FH	Master current control
	4.5	Transmit A0H 70H	Remap and color depth setting
	4.6	Transmit A1H 00H	Set display start line
*1	4.7	Transmit A2H 1CH	Set display offset
	4.8	Transmit A4H	Normal display
*1	4.9	Transmit A8H 23H	Multiplex ratio
	4.10	Transmit ABH 00H 07H 0AH 09H 12H	Dim mode setting for color A, B and C
*1	4.11	Transmit ADH 8EH	Master configuration
	4.12	Transmit B0H 0BH	Power save mode
*1	4.13	Transmit B1H 44H	Phase 1 and 2 period adjustment
*1	4.14	Transmit B3H 30H	Display clock divider/oscillator frequency
*1	4.15	Transmit B9H	Enable linear gray scale
*1	4.16	Transmit BBH 12H	Pre-charge level
*1	4.17	Transmit BEH 3CH	Set Vcomh
	4.18	Transmit AFH	Display on

\*1: Changing the set up values may cause damage to the OLED modules.

Table 3 Initialization for Frameless OLED switch (96 x 64) 50,000 hour life  
Commands Function

	Commands	Function
*1	4.1 Transmit 81H 1CH	Contrast for color A
*1	4.2 Transmit 82H 2EH	Contrast for color B
*1	4.3 Transmit 83H 2CH	Contrast for color C
*2	4.31 Transmit 8A 4F	Second pre charge speed for color A
*2	4.32 Transmit 8B 74	Second pre charge speed for color B
*2	4.33 Transmit 8C 88	Second pre charge speed for color C
	4.4 Transmit 87H 0FH	Master current control
	4.5 Transmit A0H 68H	Remap and color depth setting
	4.6 Transmit A1H 00H	Set display start line
*1	4.7 Transmit A2H 00H	Set display offset
	4.8 Transmit A4H	Normal display
*1	4.9 Transmit A8H 3FH	Multiplex ratio
	4.10 Transmit ABH 00H 0EH 17H 16H 12H	Dim mode setting for color A, B and C
*1	4.11 Transmit ADH 8EH	Master configuration
	4.12 Transmit B0H 0BH	Power save mode
*1	4.13 Transmit B1H 17H	Phase 1 and 2 period adjustment
*1	4.14 Transmit B3H F0H	Display clock divider/ oscillator frequency
*1	4.15 Transmit B9H	Enable linear gray scale
*1	4.16 Transmit BBH 1DH	Pre-charge level
*1	4.17 Transmit BEH 20H	Set Vcomh
	4.18 Transmit AFH	Display on in normal mode

\*1: Changing the set up values may cause damage to the OLED modules.

\*2: All three commands must be transmitted in one session.

Upon finishing initialization, the OLED module displays the content of whatever is in the memory.

### 5. Memory Format

The onboard OLED controller can control up to 96 x 64 pixels. The controller memory size is 96 x 2 bytes per pixel x 64.

	0H 0D	10H 16D	16H 22D					49H 73D	4FH 79D	5FH 95D
0H/0D	Green	Blue	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Blue	Green
	Green	Blue	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Blue	Green
	Green	Blue	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Blue	Green
	Green	Blue	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Blue	Green
	Green	Blue	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Blue	Green
	Green	Blue	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Blue	Green
	Green	Blue	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Blue	Green
23H/35D	Green	Blue	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Blue	Green
	Green	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Green
	Green	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Green
2FH/47D	Green	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Green
	Green	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Green
	Green	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Green
3FH/63D	Green	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Green
	Green	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Green
	Green	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Green

Picture 1 OLED on-board memory map

The memory data specified by yellow will be displayed on the OLED display (52 X 36).  
 The memory data specified by yellow and blue will be displayed on the OLED switch (64 x 48).  
 All the 96 x 64 memory (specified by yellow, blue and green) gets displayed on the Frameless OLED switch (96 x 64).

## 6. Specifying a Memory Window for Downloading

A memory window is specified by a beginning and end column and a beginning and end row. These boundaries are set by commands 15H and 75H.

The two bytes following the 15H command specify the beginning and end columns (Range 00H to 5FH) and the cursor moves to the beginning column.

The two bytes following the 75H command specify the beginning and end rows. (Range 00H to 3FH) and the cursor moves to the beginning row.

The boundaries of the memory window can be changed at any time to any size and location of the memory.

Table 5 shows the commands to specify the size and location of memory corresponding to the OLED switch (64 x 48).

Table 6 shows the commands to specify the size and location of memory corresponding to the OLED display (52 x 36).

Table 7 shows the commands to specify the size and location of memory corresponding to Frameless OLED switch (96 x 64).

Table 5 Setting the columns and rows and putting the cursor at top left OLED display (64 x 48)

	Commands	Function
Transmit	15H 10H 4FH	Set the column range
Transmit	75H 00H 2FH	Set the row range

Table 6 Setting the columns and rows and putting the cursor at top left OLED display (52 x 36)

	Commands	Function
Transmit	15H 16H 49H	Set the columns range
Transmit	75H 00H 23H	Set the rows range

Table 7 Setting the columns and rows and putting the cursor at top left Frameless OLED display (96 x 64)

	Commands	Function
Transmit	15H 00H 5FH	Set the column range
Transmit	75H 00H 3FH	Set the row range

With the suggested initialization of tables 1, 2 and 3, the cursor starts at the upper left hand pixel of the specified memory window. The cursor increments to the next pixel to the right after two bytes of data for a pixel are received. After receiving data for the right most pixel of a row, the cursor moves to the left hand pixel of the next row. Once the last row is completed, the cursor returns to left hand pixel of the first row. There are other cursor movement option explained in section 12.

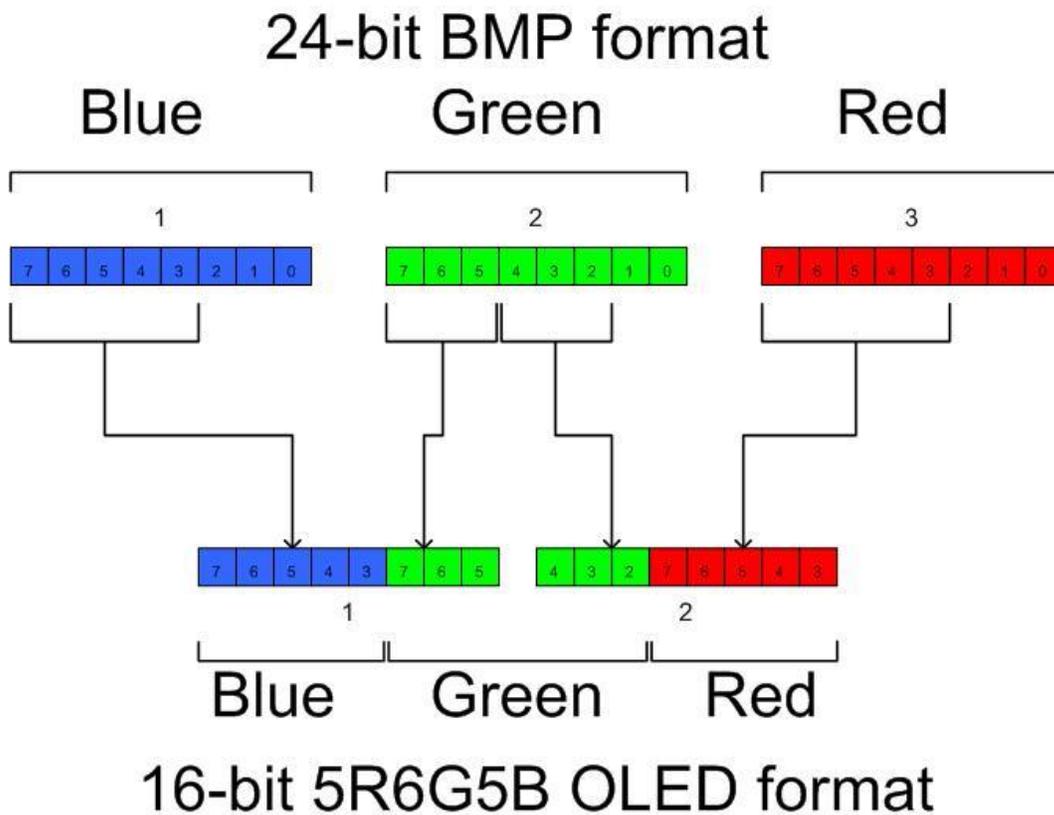
Any data transmitted when the D/C pin is high is considered as image data. The OLED onboard controller continuously refreshes the OLED from the memory. Any changes to the memory will be displayed immediately.

## 7. Pixels and Image Format

Each pixel requires two bytes in the 565 format as shown below:

B	B	B	B	B	G	G	G	G	G	G	R	R	R	R	R
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0

It may be best to create the images in a computer as 24-bit bitmap (.bmp) images, which is standard, then extract the 16 bits from the three bytes of the 24-bit bitmap. The Universal Communicator converts the three bytes to two bytes as shown in the image below:



When resizing an image to fit the size of the OLED switch or display, consider compressing the image in order to compensate for the fact that the pixels are not square. It is best to compress before resizing.

		Vertical compression	Horizontal compression
ISF15ACP4	96 x 54	75%	None
ISC15ANP4	64 x 48	None	5%
ISC01P	52 x 36	5%	None

**Image size for the 64 x 48 (6144 bytes) OLED switch**

<b>Byte</b>	<b>Description</b>
1-128	First line of image
129-256	Second line of image
•	
•	
•	
5889-6016	47th line of image
6017-6144	48 <sup>th</sup> line of image

**Image size for the 52 x 36 (3744 bytes) OLED display**

<b>Byte</b>	<b>Description</b>
1-104	First line of image
105-208	Second line of image
•	
•	
•	
3537-3640	35th line of image
3641-3744	36 <sup>th</sup> line of image

**Image size for the 96 x 64 (12288 bytes) Frameless OLED switch**

<b>Byte</b>	<b>Description</b>
1-192	First line of image
193-384	Second line of image
•	
•	
•	
11905-12096	63rd line of image
12097-12288	64 <sup>th</sup> line of image

## 8. Display Commands Available

### Display On/Off

The following three commands can be used at any time. They do not affect the content of the memory:

1	Transmit	ACH	Dim display
2	Transmit	AEH	Display off (sleep mode)
3	Transmit	AFH	Display on

Transmitting the AEH command turns the display off. Transmitting the AFH command turns the display on in normal mode.

Transmitting the ACH command turns the display on in dim mode. The dim mode level corresponds to initialization step 4.10. The last three bytes are the contrast for colors A, B and C. The values can not exceed the maximum level for each color of initialization as noted in steps 4.1, 4.2 and 4.3, respectively.

### Powering Down Sequences

The following procedure is recommended to be followed for turning the OLED switch or display off:

1. Transmit the command to turn the OLED display off.

Transmit	AEH	Display off
----------	-----	-------------

2. Disable the  $V_{CC}$ .
3. Turn off the  $V_{DD}$  power.

**9. Additional Commands Available**

**No Operation**

Transmit	E3H	NOP
Transmit	BCH	NOP
Transmit	BDH	NOP

**Display Mode**

These are one byte commands. They do not affect memory data.

Transmit	A4H	Normal operation
Transmit	A5H	All pixels on at the highest brightness
Transmit	A6H	All pixels on at lowest brightness
Transmit	A7H	Inverse display

Command A4H is for normal operation. Commands A5H/A6H forces all pixels to their highest/lowest intensity regardless of the contents of the memory. The A7H command causes the complement of the pixels’ data from memory to be displayed.

**Master Current Control**

Transmit	87H 0FH	Master current control
----------	---------	------------------------

This command should be used while the display is off (after command AEH). There are 16 steps for the current level (00H to 0FH). 0FH is the maximum brightness and 00H is the minimum brightness. The OLED life of 30,000/50,000 hours is based on 0FH brightness. The dimmer the OLEDs are while in use, the longer their life expectancy.

## 10. Scrolling (Screensaver)

Command 27H is used to set up the parameter for scrolling. This command can only be transmitted during initialization or when the display is off and scrolling is deactivated (commands AEH and 2EH). The sequence of use is as follows: First, turn off the display and deactivate scrolling and send data for an image. Second, send the command 27H. Finally, turn the display on and activate the scrolling (commands AFH and 2FH).

Command 27H has five bytes of data; A, B, C, D and E.

Byte A sets the number of columns shifted horizontally to the right each time. For example, the value 01H will make the image appear to be shifting from the right to left. The value 5FH will make the image appear to be shifting from the left to right. Byte A should not be set to 00H or it will deactivate the scrolling for the rest of the session. Scrolling cannot be reactivated. Therefore, the Byte A value should be set between 01H and 5FH.

Byte B sets the offset or starting row.

Byte C sets the number of rows that get shifted horizontally.

Byte D sets the number of rows that are vertically shifted up each time. For example the value 01H will make the image appear to be shifting from the bottom to top. The value 3FH will make the image appear to be shifting from the top to bottom. A zero value for byte D indicates no vertical shift.

Byte E sets the interval between each shift.

The horizontal speed of scrolling is determined by the value of bytes A and E.

The vertical speed of scrolling is determined by the value of bytes D and E.

The portion of the image that is horizontally shifted is determined by the values of bytes B and C.

For the horizontal scroll, rows selected will shift using the 96 columns.

For vertical scroll, all 96 columns will be shifted using all 64 rows.

After deactivation, the position of the contents of the memory has been changed due to the shifts. To restore the original image, the image data should be downloaded again. Refer to Table 5.

**Table 5 Scrolling Commands**

Hex	D7	D6	D5	D4	D3	D2	D1	D0	Command	Description
27	0	0	1	0	0	1	1	1	Continuous Horizontal and Vertical Scrolling Setup	A[6:0]: Sets number of columns as horizontal scroll offset Range: 0D-95D (0 equals no horizontal scroll) B[5:0]: Sets start row address C[6:0]: Sets number of rows to be horizontally scrolled $B[5:0]+C[6:0] \leq 64$ D[5:0]: Sets number of rows as vertical scroll offset Range: 0D-63D (0 equals no vertical scroll) E[1:0]: Sets time interval between each scroll step 00B 6 frames 01B 10 frames 10B 100 frames 11B 200 frames  <b>Note:</b> (1) Vertical scroll is run with 64MUX setting only (2) The parameters should not be changed after scrolling is activated
A[6:0]	*	A6	A5	A4	A3	A2	A1	A0		
B[5:0]	*	*	B5	B4	B3	B2	B1	B0		
C[6:0]	*	C6	C5	C4	C3	C2	C1	C0		
D[5:0]	*	*	D5	D4	D3	D2	D1	D0		
E[1:0]	*	*	*	*	*	*	E1	E0		
2E	0	0	1	0	1	1	1	0	Deactivate scrolling	This command deactivates the scrolling action  <b>Note:</b> (1) After sending 2EH command to deactivate the scrolling action, the RAM data needs to be rewritten.
2F	0	0	1	0	1	1	1	1	Activate scrolling	This command activates the scrolling function according to the setting done by Continuous Horizontal and Vertical Scrolling Setup command 27H.

## 11. Graphic Commands

Table 6 and table 7 have the graphic commands. Please note the command 26H is the set up which effect the operation of commands 22H and 23H. Note: Graphic commands modify the content of memory.

Table 6 Graphic Commands

Hex	D7	D6	D5	D4	D3	D2	D1	D0	Command	Description
21	0	0	1	0	0	0	0	1	Draw Line	A[6:0]: Column address of start B[5:0]: Row address of start
A[6:0]	*	A6	A5	A4	A3	A2	A1	A0		C[6:0]: Column address of end
B[5:0]	*	*	B5	B4	B3	B2	B1	B0		D[5:0]: Row address of end
C[6:0]	*	C6	C5	C4	C3	C2	C1	C0		E[5:1]: Color C of the line
D[5:0]	*	*	D5	D4	D3	D2	D1	D0		F[5:0]: Color B of the line
E[5:1]	*	*	E5	E4	E3	E2	E1	*		G[5:1]: Color A of the line
F[5:0]	*	*	F5	F4	F3	F2	F1	F0		
G[5:1]	*	*	G5	G4	G3	G2	G1	*		
24	0	0	1	0	0	1	0	0	Dim Window	A[6:0]: Column address of start B[5:0]: Row address of start
A[6:0]	*	A6	A5	A4	A3	A2	A1	A0		C[6:0]: Column address of end
B[5:0]	*	*	B5	B4	B3	B2	B1	B0		D[5:0]: Row address of end
C[6:0]	*	C6	C5	C4	C3	C2	C1	C0		The effect of dim window: GS15~GS0 no change GS19~GS16 become GS4 GS23~GS20 become GS5
D[5:0]	*	*	D5	D4	D3	D2	D1	D0		... GS62~GS60 become GS15
25	0	0	1	0	0	1	0	1	Clear Window	A[6:0]: Column address of start B[5:0]: Row address of start
A[6:0]	*	A6	A5	A4	A3	A2	A1	A0		C[6:0]: Column address of end
B[5:0]	*	*	B5	B4	B3	B2	B1	B0		D[5:0]: Row address of end
C[6:0]	*	C6	C5	C4	C3	C2	C1	C0		
D[5:0]	*	*	D5	D4	D3	D2	D1	D0		

**Table 7 Graphic Commands and Set Up**

Hex	D7	D6	D5	D4	D3	D2	D1	D0	Command	Description
22	0	0	1	0	0	0	1	0	Drawing Rectangle	A[6:0]: Column address of start
A[6:0]	*	A6	A5	A4	A3	A2	A1	A0		B[5:0]: Row address of start
B[5:0]	*	*	B5	B4	B3	B2	B1	B0		C[6:0]: Column address of end
C[6:0]	*	C6	C5	C4	C3	C2	C1	C0		D[5:0]: Row address of end
D[5:0]	*	*	D5	D4	D3	D2	D1	D0		E[5:1]: Color C of the line
E[5:1]	*	*	E5	E4	E3	E2	E1	*		F[5:0]: Color B of the line
F[5:0]	*	*	F5	F4	F3	F2	F1	F0		G[5:1]: Color A of the line
G[5:1]	*	*	G5	G4	G3	G2	G1	*		H[5:1]: Color C of the fill area
H[5:1]	*	*	H5	H4	H3	H2	H1	*		I [5:0]: Color B of the fill area
I[5:0]	*	*	I5	I4	I3	I2	I1	I0		J[5:1]: Color A of the fill area
J[5:1]	*	*	J5	J4	J3	J2	J1	*		
23	0	0	1	0	0	0	1	1	Copy	A[6:0]: Column address of start
A[6:0]	*	A6	A5	A4	A3	A2	A1	A0		B[5:0]: Row address of start
B[5:0]	*	*	B5	B4	B3	B2	B1	B0		C[6:0]: Column address of end
C[6:0]	*	C6	C5	C4	C3	C2	C1	C0		D[5:0]: Row address of end
D[5:0]	*	*	D5	D4	D3	D2	D1	D0		E[6:0]: Column address of new start
E[6:0]	*	E6	E5	E4	E3	E2	E1	E0		F[5:0]: Row address of new start
F[5:0]	*	*	F5	F4	F3	F2	F1	F0		
26	0	0	1	0	0	1	1	0	Fill Enable / Disable	A0 0 : Disable fill for draw rectangle command (RESET)
A[4:0]	*	*	*	A4	0	0	0	A0		1 : Enable fill for draw rectangle command
										A[3:1] 000: Reserved values
										A4 0 : Disable reverse copy (RESET)
										1 : Enable reverse during copy command

## 12. Initialization Options

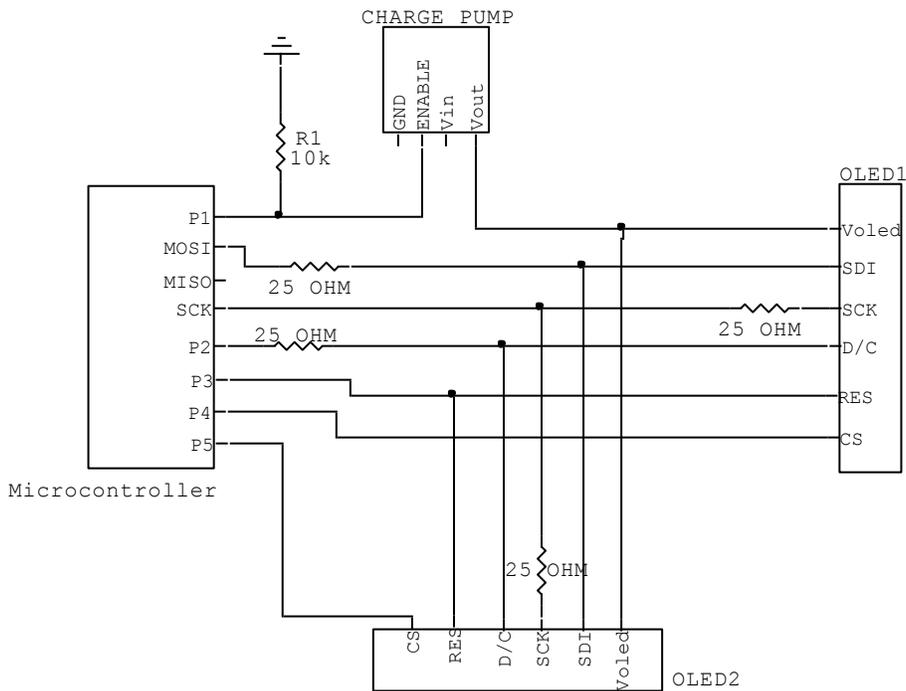
This command is the step 4.5 of initialization. There are many options for format of the image data as well as selecting the 256 color instead of 65K. For 256 colors each pixels has one byte of data in the format of BBBGGGRR. However the on-board controller translates it to two bytes upon receiving the byte.

Hex	D7	D6	D5	D4	D3	D2	D1	D0	Command	Description
A0	1	0	1	0	0	0	0	0		A[0]= 0 : Horizontal address increment
A[7:0]	A7	A6	A5	A4	A3	A2	A1	A0		Remap and color / Depth setting

### 13. Sample Schematic for a Multi-switch Controller

Below is a sample schematic to control two OLED modules. With the theoretical maximum clock frequency of 6.6 MHz, 134 images per second can be transmitted via SPI. However, realistically, 84 images per second is possible. There are 6144 bytes for each image in the 65k color mode. One image takes 6144 bytes \* 8 bits/byte = 49152 bits. Dividing the SPI frequency by 49152 provides the maximum number of images that can be transmitted per second. The preceding calculation does not consider overhead and data retrieving time.

Illustration 1: Sample schematic for control of two OLED modules



## 14. Frequently Asked Questions

### **How many different colors can each pixel display?**

65,536 different colors. OLEDs have the most vivid and sharp display among all the technologies.

### **Is the OLED SmartSwitch/Display capable of displaying movies?**

Yes. The OLED response time is 0.2 ms, which is the best among all the display technologies. The bottle neck is normally the communication speed. Over 100 frames per second (60 fps for the Frameless OLED) of data can be transmitted to the OLED SmartSwitch or display. Most videos are 24 to 30 frames per second.

### **Can the OLED SmartSwitch/Display capable of displaying live video?**

Yes. However, the controller has to be fast enough to resize and transmit the data in the right format to the OLED SmartSwitch/Display.

### **What is aging?**

Aging for the OLED refers to the reduction in brightness over time. Specifically, the OLED life is defined as the time it takes for the brightness to reach half the original state. Since the OLED is intended to display movies or frequently changing images, it is assumed that each pixels will be on the equivalent of 40% of the time at full brightness.

### **How does aging affect the colors?**

When displaying movies, the OLED colors pixels age proportionally and the combined colors stay relatively consistent. However when a still image or text is used for an extended period of time, the pixels used for the image/text will get dimmer than surrounding pixels that have not been used. For example, if a blue color is used in one area most the time, when white is displayed in that area, the white will have a tint of yellow. The yellow is because red and green is now stronger than the blue. However, by properly designing the image colors and by anticipating the amount of time they will be displayed, this problem can be avoided.

### **Does the power up/down sequence have to be followed?**

Yes. The power up sequence must be observed. If  $V_{CC}$  powers the circuit before  $V_{DD}$  is activated, the circuit could latch and damage the OLED.

For the power down sequence,  $V_{CC}$  cannot be present after  $V_{DD}$  is off. Simultaneous turn off is possible as long as  $V_{CC}$  is examined to confirm that it does not have too much capacitance charge after turn off.

### **Are subassemblies of SmartSwitches available?**

Yes. NKK Switches has many development kits and also supports custom designs.

### **Is NKK Switches planning to develop other sizes of the OLED SmartSwitch?**

NKK Switches continuously improves existing product as well as develops new products. Customer feedback is considered when deciding what new products to develop. Feedback and/or application requirements is welcomed.