$SSOLFDWLRQ 1RWH IRU WKH /&' [6PDUW'LVSOD\

5HYLVLRQ &

7850 East Gelding Drive • Scottsdale, AZ 85260-3420

TABLE OF CONTENTS

Toll Free 1.877.2BUYNKK (877.228.9655) • **Phone** 480.991.0942 • **Fax** 480.998.1435
www.nkksmartswitch.com • **Email** engineering@nkkswitches.com

7850 East Gelding Drive • Scottsdale, AZ 85260-3420

1. General Information

The application notes should be used in conjunction with the LCD 64x32 data sheet which has the LED, LCD, and other specifications as well as the timing diagram for the communication.

2. Part Numbers

The LCD 64x32 family currently has four products (Two standard size pushbuttons, a compact pushbutton, and a display). NKK has introduced a new version of the four products called widescreen. The widescreen versions are 100% compatible with the current products. The only difference is that the size of pixels are enlarged resulting in bigger display and smaller border. For prototyping it is recommended to use the relevant SmartDisplay socket accessory.

Part numbers

Current PN	New Widescreen PN	Socket	Description
IS15DBFP4RGB	IS15EBFP4RGB	AT9704-085K	LCD64x32 Standard size, long travel switch
IS15DBFP4RGB-09YN	IS15EBFP4RGB-09YN	AT9704-085F	LCD64x32 Standard size, short travel switch
IS15DSBFP4RGB	IS15ESBFP4RGB	AT9704-085F	LCD64x32 Compact size, short travel switch
IS01DBFRGB	IS01EBFRGB	Industry standard 2mmx2mm	LCD64x32 Display

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

Development kits

Part Number	Switches/Displays
IS-DEV KIT-6	IS15DBFP4RGB
IS-DEV KIT-6HB	IS15DBFP4RGB-09YN
IS-DEV KIT-6C	IS15DSBFP4RGB
IS-DEV KIT-6D	IS01DBFRGB

IS-C1603H can control up to 40 LCD64x32 SmartDisplays. Logic Boards are required. Please refer to IS-C1603H user manual for further information.

Toll Free 1.877.2BUYNKK (877.228.9655) • **Phone** 480.991.0942 • **Fax** 480.998.1435
www.nkksmartswitch.com • **Email** engineering@nkkswitches.com

3. Pin-outs

The footprint of IS15DSBFP4RGB and IS15DBFP4RGB-09YN are the same even though IS15DBFP4RGB-09YN has an extra NC pin. However IS15DBFP4RGB and IS01DBFRGB have different footprints. Controlling all the LCD64x32 products are the same.

Pin Symbol	Pin Name	Function
SW	Switch Terminal	Normally open switch
SW	Switch Terminal	Normally open switch
GND	Ground	
VDD	Power	5V power source for logic, LCD and LED
SDO	Data Out	Data output line of SPI
SDI	Data In	Data input line for SPI
SCK	Clock	SPI clock
$\overline{SS}$	Slave Select	Chip select line of SPI
NC	NC	No Connection

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: The Ground for logic, LCD and LED.

VDD: Power source for logic, LCD and LED. The voltage must be 5V. The voltage for LCD is produced from this voltage. Deviation of VDD beyond stated range in the data sheet will affect the LCD's contrast. The tight voltage range is to assure acceptable LCD display contrast for the entire operating temperature range.

SDO: Data out for communication. The SDO status lags 16 clock cycles from SDI status. This pin is not used for controlling the LCD display. It can be used for fault tolerance. However it does not go to high impedance when the LCD64x32 is not selected so SDO of the switches must not be connected together. For most application this pin is not connected.

SDI: Data in for serial communication. This pin has a 50K ohm internal pull up resistor to VDD.

SCK: Clock for serial communication, maximum 8 MHZ. This pin has a 50K ohm internal pull up resistor to VDD. The data is taken on the falling edge of clock.

$\overline{SS}$: LCD 64X32 SmartDisplay Selector. This pin has a 50K ohm pull up resistor to VDD. The ss pin must be pulled low for the duration of the command/data package. If the ss line pulled high before the command and its associated data are finished the command will be ignored. Multiple commands can be transmitted while the ss line is low. When ss is high the clock and data line are ignored.

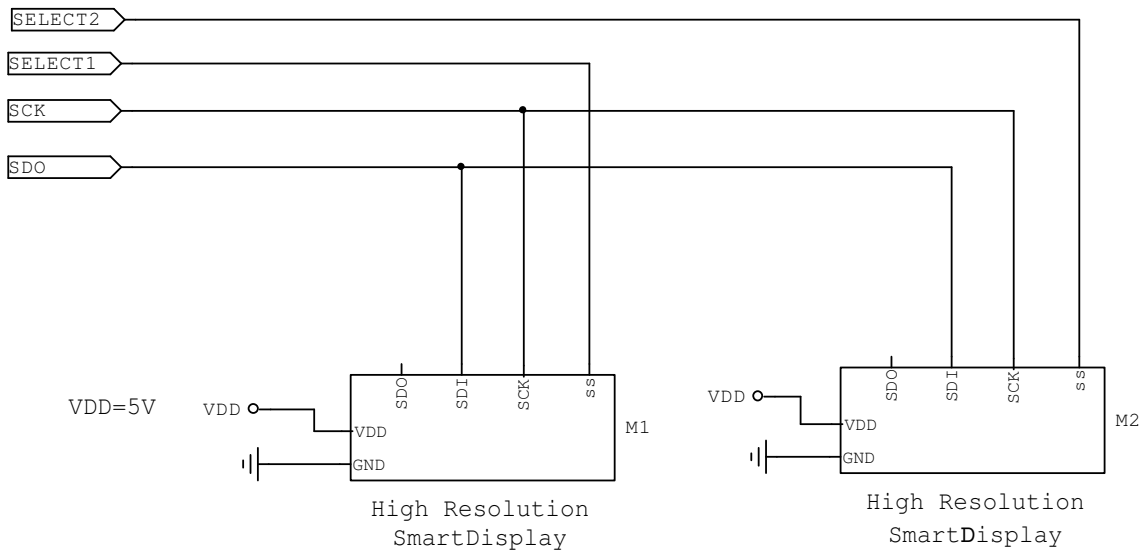
4. Connection Options

The LCD 64X32 SmartDisplays can be controlled with 3 pins (SCK, SDI, $\overline{SS}$) or with two pins (SCK, SDI).

a. Controlling the LCD 64X32 SmartDisplays with 3 pins

Chip select ($\overline{SS}$) is used for addressing individual LCD 64X32 SmartDisplays. For each session the $\overline{SS}$ line should be pulled low then a command and its associated data is transmitted then the $\overline{SS}$ line should be pulled high. Many commands can be transmitted in one session. See figure 2.

Figure 2, Two LCD 64X32 SmartDisplays with chip select ($\overline{SS}$).

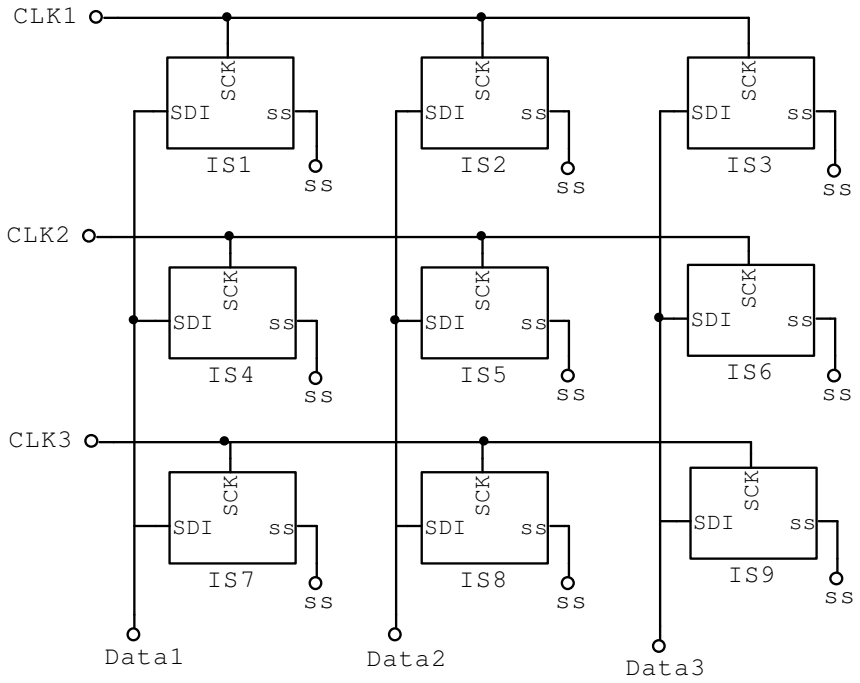


Toll Free 1.877.2BUYNKK (877.228.9655) • **Phone** 480.991.0942 • **Fax** 480.998.1435
www.nkksmartswitch.com • **Email** engineering@nkkswitches.com

b. Controlling the LCD 64X32 SmartDisplays with 2 pins

For controlling the LCD 64X32 SmartDisplay with two pins, SCK / SDI must be normally high and the $\overline{SS}$ pin is low all the time. For most application $\overline{SS}$ can be connected to ground. However one customer had an FPGA controlling the switches and when FPGA got reset sometimes it send a clock bit causing the switches to fall out of sync with FPGA. It is recommended to connect all $\overline{SS}$ to a control pin so the communication can be reset if needed.

Figure 4, Nine LCD 64X32 SmartDisplays controlled with two pins without chip select ($\overline{SS}$).



All the clock and data lines remain high (or float) except one active clock and one active data. The addressed switch is at the intersection of the active clock and active data. Since the clock is high, there is no effect for other switches of the active data. Other switches of the active clock row receive 0xFF data which is ignored.

Toll Free 1.877.2BUYNKK (877.228.9655) • **Phone** 480.991.0942 • **Fax** 480.998.1435
www.nkksmartswitch.com • **Email** engineering@nkkswitches.com

7850 East Gelding Drive • Scottsdale, AZ 85260-3420

5. Controlling the LCD 64x32 SmartDisplays

Upon power up the LCD64x32 has the following initial state and is ready for commands from host.
LCD display: OFF
LED colors: OFF
Brightness level: Lowest level

The host has the following command options:

a. Transmit a new image
b. Transmit to select 1 of 64 available backlight options
c. Transmit to select 1 of 8 backlight brightness level options

Any command can be transmitted at any time. The command goes into effect and the settings and display are maintained until they are changed via another command from host. Any transmission that is not a command is ignored. There is no delay required between the commands.

SPI, UART in synchronous mode or two pins of microcontroller can be used to control the LCD 64X32 SmartDisplays. The data bits are taken on the falling edge of each clock. The communication is byte oriented. The first bit transmitted is taken as most significant bit of the byte (B7) the second bit transmitted is B6…the eighth bit is taken as B0.

There is no time limit to finish a byte. If $\overline{SS}$ line is pulled high before completion of a command or its associated data, that command is ignored and communication get reset.

The commands for serial communication with most significant bit first (SPI) are explained in section 6. Please note the image bytes must be manipulated from bitmap format.

The commands for serial communication with least significant bit first (UART) are explained in section 7. Please note that no manipulation is needed for the image bytes from bitmap format.

Toll Free 1.877.2BUYNKK (877.228.9655) • **Phone** 480.991.0942 • **Fax** 480.998.1435
www.nkksmartswitch.com • **Email** engineering@nkkswitches.com

6. Communication with most significant bit transmitted first (SPI)

SPI Set Up

The data is taken on the falling edge of the clock so SPI should be set up accordingly.
For a PIC microcontroller the following setup will work:

- CKP=1, CKE=1, SMP=0/1

- CKP=0, CKE=0, SMP=0/1

Please note in some types of microcontrollers when the SPI transmit is set for the rising edge the switches might seem to work, but the circuit will be very sensitive since the data line will be marginally stable on the falling edge.

There are four commands for controlling the LCD 64x32 SmartDisplay.

Command		Data	Function	Remark
HEX	**Binary**			
0x55	01010101	256 Bytes (64x32=2,048 bits)	Graphic data	See below for bitmap data
0x40	01000000	One byte (RRGGBB11)	LED colors	64 color options for backlight. 2 bit per color
0x41	01000001	One byte(***11111)	Brightness level	8 brightness level
0x5E	01011110	One byte (00000011)	Reset	Reset

- **Command to Reset**

This command is two bytes. Upon receiving this command the LCD 64X32 SmartDisplay returns to the default state.
The default state is: LCD display off, brightness 1/20 and LED's off.
The first byte is 0x5E.
The second byte is 0x03.

- **Command to set the LED backlight master brightness**

This command is two bytes. Upon receiving this command the LCD 64X32 SmartDisplay will set the LED backlight master brightness according to the value of the second byte.
The first byte is 0x41.
The second byte is as follows:

B7	B6	B5	B4	B3	B2	B1	B0
L2	L1	L0	1	1	1	1	1

The B0 to B4 must be 1. B5, B6, B7 determine the brightness as follows:

L2	L1	L0	Brightness level
0	0	0	1/20 of brightness
0	0	1	1/10 of brightness
0	1	0	1/7 of brightness
0	1	1	1/5 of brightness
1	0	0	1/3 of brightness
1	0	1	1/2 of brightness
1	1	0	2/3 of brightness
1	1	1	Full brightness

- **Command to set the LED backlight colors**

This command is two bytes. Upon receiving this command the LCD 64X32 SmartDisplay will set LED backlight color according to the value of the second byte.
The first byte is 0x40.
The second byte is as follow:

B7	B6	B5	B4	B3	B2	B1	B0
R1	R0	G1	G0	BU1	BU0	1	1

The B0 and B1 must be 1. B2 to B7 determine the colors. BU0 and BU1 determine the blue level. G0 and G1 determine the green level. R0 and R1 determine the red level.

R1/G1/BU1	R0/G0/BU0	Color brightness
0	0	off
0	1	¼ brightness
1	0	½ brightness
1	1	Full brightness

There are 64 backlight color options available.

Toll Free 1.877.2BUYNKK (877.228.9655) • **Phone** 480.991.0942 • **Fax** 480.998.1435
www.nkksmartswitch.com • **Email** engineering@nkkswitches.com

- **Command to download an image**

This command is 257 bytes. The first byte is the command and the following 256 bytes are the data for the image. The LCD 64X32 SmartDisplay has two memory locations that are interchangeable. While one is being used to refresh the displayed image the other is free for receiving a new image. Upon completion of the download the memory location that just received an image is used for refreshing the display while the other location is now free to receive another image. The advantage is the downloading is hidden from the switch user and the new image is only displayed when fully received.

The first byte is 0x55.
The following 256 bytes will be displayed according to table below:

Bitmap format for LCD 64X32 SmartDisplay

Byte 8	Byte 7	…	Byte2	Byte 1
D0D1D2D3D4D5D6D7	D0D1…D6D7	…	D0D1…D6D7	D0D1D2D3D4D5D6D7
Byte 16		…		Byte 9
D0D1D2D3D4D5D6D7		…		D0D1D2D3D4D5D6D7
.	.	…	.	.
.	.	…	.	.
.	.	…	.	.
.	.	…	.	.
Byte 256		…		Byte 249
D0D1D2D3D4D5D6D7	D0D1…D6D7	…	D0D1…D6D7	D0D1D2D3D4D5D6D7

The monochrome bitmap images created in graphic programs have the following formats:

Bitmap format for an image:

Byte 8	Byte 7	…	Byte2	Byte 1
D7D6D5D4D3D2D1D0	D7D6…D1D0	…	D7D6…D1D0	D7D6D5D4D3D2D1D0
Byte 16		…		Byte 9
D7D6D5D4D3D2D1D0		…		D7D6D5D4D3D2D1D0
.	.	…	.	.
.	.	…	.	.
.	.	…	.	.
.	.	…	.	.
Byte 256		…		Byte 249
D7D6D5D4D3D2D1D0	D7D6…D1D0	…	D7D6…D1D0	D7D6D5D4D3D2D1D0

Each byte has to be reformatted according to the table below to have proper picture display.

Image file byte	B7	B6	B5	B4	B3	B2	B1	B0
Converted byte for transmission	B0	B1	B2	B3	B4	B5	B6	B7

Toll Free 1.877.2BUYNKK (877.228.9655) • **Phone** 480.991.0942 • **Fax** 480.998.1435
www.nkksmartswitch.com • **Email** engineering@nkkswitches.com

7. Communication with least significant bit transmitted first

.

There are four commands for controlling the LCD 64x32 SmartDisplay.

Command		Data	Function	Remark
HEX	Binary			
0xAA	10101010	256 Bytes (64x32=2,048 bits)	Graphic data	See below for bitmap data
0x02	00000010	One byte (11BBGGRR)	LED colors	64 color options for backlight. 2 bit per color
0x82	10000010	One byte(11111***)	Brightness level	8 brightness level
0x7A	01111010	One byte (11000000)	Reset	Reset

- **Command to Reset**

This command is two bytes. Upon receiving this command the LCD 64X32 SmartDisplay returns to the default state.
The default state is: LCD display off, brightness 1/20 and LED's off.
The first byte is 0x7A.
The second byte is 0xC0.

Toll Free 1.877.2BUYNKK (877.228.9655) • **Phone** 480.991.0942 • **Fax** 480.998.1435
www.nkksmartswitch.com • **Email** engineering@nkkswitches.com

- **Command to set the LED backlight master brightness**

This command is two bytes. Upon receiving this command the LCD 64X32 SmartDisplay will set the LED backlight master brightness according to the value of the second byte.
The first byte is 0x82.
The second byte is as follows:

B7	B6	B5	B4	B3	B2	B1	B0
1	1	1	1	1	L0	L1	L2

The B3 to B7 must be 1. B0, B1, B2 determine the brightness as follows:

L2	L1	L0	Brightness level
0	0	0	1/20 of brightness
0	0	1	1/10 of brightness
0	1	0	1/7 of brightness
0	1	1	1/5 of brightness
1	0	0	1/3 of brightness
1	0	1	1/2 of brightness
1	1	0	2/3 of brightness
1	1	1	Full brightness

- **Command to set the LED backlight colors**

This command is two bytes. Upon receiving this command the LCD 64X32 SmartDisplay will set the LED backlight color according to the value of the second byte.
The first byte is 0x02.
The second byte is as follow:

B7	B6	B5	B4	B3	B2	B1	B0
1	1	BU0	BU1	G0	G1	R0	R1

The B6 and B7 must be 1. B0 to B5 determine the colors. BU0 and BU1 determine the blue level. G0 and G1 determine the green level. R0 and R1 determine the red level.

R1/G1/BU1	R0/G0/BU0	Color brightness
0	0	off
0	1	¼ brightness
1	0	½ brightness
1	1	Full brightness

Toll Free 1.877.2BUYNKK (877.228.9655) • **Phone** 480.991.0942 • **Fax** 480.998.1435
www.nkksmartswitch.com • **Email** engineering@nkkswitches.com

- **Command to download an image**

This command is 257 bytes. The first byte is the command and the following 256 bytes are the data for the image. The LCD 64X32 SmartDisplay has two memory locations that are interchangeable. While one is being used to refresh the displayed image the other is free for receiving a new image. Upon completion of the download the memory location that just received an image is used for refreshing the display while the other location is now free to receive another image. The advantage is the downloading is hidden from the switch user and the new image is only displayed when fully received.

The first byte is 0xAA.
The following 256 bytes will be displayed according to table below:

Bitmap format for LCD 64X32 SmartDisplay

Byte 8	Byte 7	…	Byte2	Byte 1
D0D1D2D3D4D5D6D7	D0D1…D6D7	…	D0D1…D6D7	D0D1D2D3D4D5D6D7
Byte 16		…		Byte 9
D0D1D2D3D4D5D6D7		…		D0D1D2D3D4D5D6D7
.	.	…	.	.
.	.	…	.	.
.	.	…	.	.
.	.	…	.	.
Byte 256		…		Byte 249
D0D1D2D3D4D5D6D7	D0D1…D6D7	…	D0D1…D6D7	D0D1D2D3D4D5D6D7

The images created in graphic programs have the following formats:

Bitmap format for an image:

Byte 8	Byte 7	…	Byte2	Byte 1
D7D6D5D4D3D2D1D0	D7D6…D1D0	…	D7D6…D1D0	D7D6D5D4D3D2D1D0
Byte 16		…		Byte 9
D7D6D5D4D3D2D1D0		…		D7D6D5D4D3D2D1D0
.	.	…	.	.
.	.	…	.	.
.	.	…	.	.
.	.	…	.	.
Byte 256		…		Byte 249
D7D6D5D4D3D2D1D0	D7D6…D1D0	…	D7D6…D1D0	D7D6D5D4D3D2D1D0

Byte reformatting is not needed for least significant bit first transmission.

Toll Free 1.877.2BUYNKK (877.228.9655) • **Phone** 480.991.0942 • **Fax** 480.998.1435
www.nkksmartswitch.com • **Email** engineering@nkkswitches.com

7850 East Gelding Drive • Scottsdale, AZ 85260-3420

8. Frequently asked questions

Does the display have to be refreshed?
No. the LCD 64X32 SmartDisplay automatically refreshes the display with the current image until a new image is fully received.

Does a delay required between the commands?
NO. The commands can be sent continuously.

Why do the pixels not look sharp?
The VDD is out of range. The LCD voltage is produced from VDD.
If the voltage is low the pixels will not be at maximum darkness and the contrast will be reduced.
If the voltage is high the background will be darker which will also cause a reduction in contrast.

Is it possible to extend the operating temperature by adjusting VDD?
The display requires no adjustment for use in the specified operating temperature range. It should be possible to extend the temperature range by adjusting the VDD or at least improve the contrast at the extreme temperature. However, NKK Switches does not have data for LCD 64X32 SmartDisplay behaviors with VDD adjustment. Additionally the maximum voltage for logic is 5.5V that should not be exceeded.

My circuit only controls the LCD 64X32 SmartDisplay intermittently; however it works fine when I probe the SCK or SDI pins with the oscilloscope. What is going on?
The serial communication of the circuit is set for transmitting on rising edge of the clock hence the data is not stable on the falling edge of clock. The added oscilloscope capacitance makes the data more stable.

I check the signals with oscilloscope. They all look correct. Why the switch does not accept the commands?
Most likely your controller does not wait for the transmit buffer to finish before putting ss signal to high. If the ss signal is pulled high before the command and its associated data are received, the command is ignored.

Does the micro-controller have to have external memory?
External memory is not required. The picture data can be retrieved from storage or the images can be made on the fly using ASCII code and look-up tables placed on the microcontroller program memory without using external memory.

Is the display visible without the backlighting?
Yes. The LCD in the switch is transflective so it can be seen with sufficient ambient lighting. The negative LCD option requires backlighting.

Is the display sunlight readable?
Since the LCD is transflective, it is sunlight readable. However, the backlight will be difficult to see.

Toll Free 1.877.2BUYNKK (877.228.9655) • **Phone** 480.991.0942 • **Fax** 480.998.1435
www.nkksmartswitch.com • **Email** engineering@nkkswitches.com

7850 East Gelding Drive • Scottsdale, AZ 85260-3420

How many switches can be driven by one SPI?
With an 8 MHZ clock, it takes approximately 0.26 ms to transmit an image and backlighting data to one LCD 64X32 SmartDisplay.
(1/8,000,000 bit/s)*(259 bytes)*(8 bits/byte) =0.000259 s

The limitation depends on how fast all the switches need to be updated at once in the application. For example 193 switches can be controlled and all 193 switches can receive new image LED data in 50ms. However, the signals Fan out should be considered. A driver can be used to put the switches in many groups. NKK Switches' uses a 74HC4050 chip with 16 switches to a group.

Can the switches be controlled with low voltage?
The VDD must be 5.0V. The LCD 64X32 SmartDisplay specifications do not support low voltage signals. The switches have been tested down to 2.8V signals without any issues however the customer should have due diligence and test the switches within the application environment. The microcontroller signal pins need to handle current from the switches signals internal 50K pull up to 5V.

Toll Free 1.877.2BUYNKK (877.228.9655) • **Phone** 480.991.0942 • **Fax** 480.998.1435
www.nkksmartswitch.com • **Email** engineering@nkkswitches.com