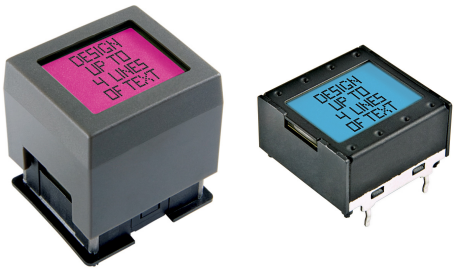
7850 East Gelding Drive • Scottsdale, AZ 85260-3420

# Application Notes for LCD 64x32 SmartSwitch/Display

Revision B




NKK Switches
7850 E. Gelding Drive
Scottsdale, AZ 85260

480- 991-0942
FAX (480) 998-1435
e-mail <hsajadi@nkkswitches.com>

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 is currently available as 64x32 pushbuttons, 64x32 compact pushbuttons, and 64x32 displays. For the purpose of the application notes these are referred to as SmartSwitch or switch. The switches and displays have 64 varieties of red/green/blue colors for backlighting. For prototyping it is recommended to use the relevant SmartSwitch socket accessory.

| Part number | Description |
|---|---|
| IS15DBFP4RGB | LCD 64x32 SmartSwitch |
| AT9704-085K | Socket for LCD 64x32 SmartSwitch |
| IS15DSBFP4RGB | Compact LCD 64x32 SmartSwitch |
| AT9704-085E | Socket for Compact LCD 64x32 SmartSwitch* |
| IS01DBFRGB | LCD 64x32 SmartDisplay |

* This socket is for compact SmartSwitch. Some pins had to be extracted to make it compatible with LCD 64x32 compact SmartSwitch.

Evaluation controllers and demonstration kits are also available.

## 3. Pin-outs

The switch, compact switch, and display have different pin-out configurations. All the functions are the same regardless of the pin-out configuration so for the purpose of the application notes the LCD 64x32 SmartSwitch will be used as the example. The following are the pin-outs for the LCD 64x32 SmartSwitch.

| Pins | Symbol | Pin Name | Function |
|---|---|---|---|
| 1 | SW | Switch Terminal | Normally open switch |
| 2 | SW | Switch Terminal | Normally open switch |
| 3 | GND | Ground | |
| 4 | VDD | Power | 5V power source for logic, LCD and LED |
| 5 | SDO | Data Out | Data output line of SPI |
| 6 | SDI | Data In | Data input line for SPI |
| 7 | SCK | Clock | SPI clock |
| 8 | $\overline{SS}$ | Slave Select | Chip select line of SPI |
| 9 | NC | | No Connection |

NKK Switches' LCD 64x32 SmartSwitch Pinout.


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

## 4. Pin Descriptions and Functions

**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. For a matrix of switches many different methods can be used for scanning.

**Ground**: The Ground for logic and 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. Fluctuations on VDD will affect the LCD's contrast.

**SDO:** Data out for SPI communication. This pin is not used for controlling the LCD display. It can be used for fault tolerance.

**SDI:** Data in for SPI communication.

**SCK:** Clock for SPI communication, maximum 8 MHZ.

$\overline{\text{SS}}$ **:** LCD 64X32 SmartSwitch Selector. This pin should be pulled down for the duration of the data/command package.

## 5. Controlling the LCD 64x32 SmartSwitch

The LCD 64X32 SmartSwitch can be controlled by SPI or by any serial clock and a data line. 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 are only four commands for communication. Three of them are 2 bytes long and one is 257 bytes long.

### a. 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.

### b. Using other types of serial communication

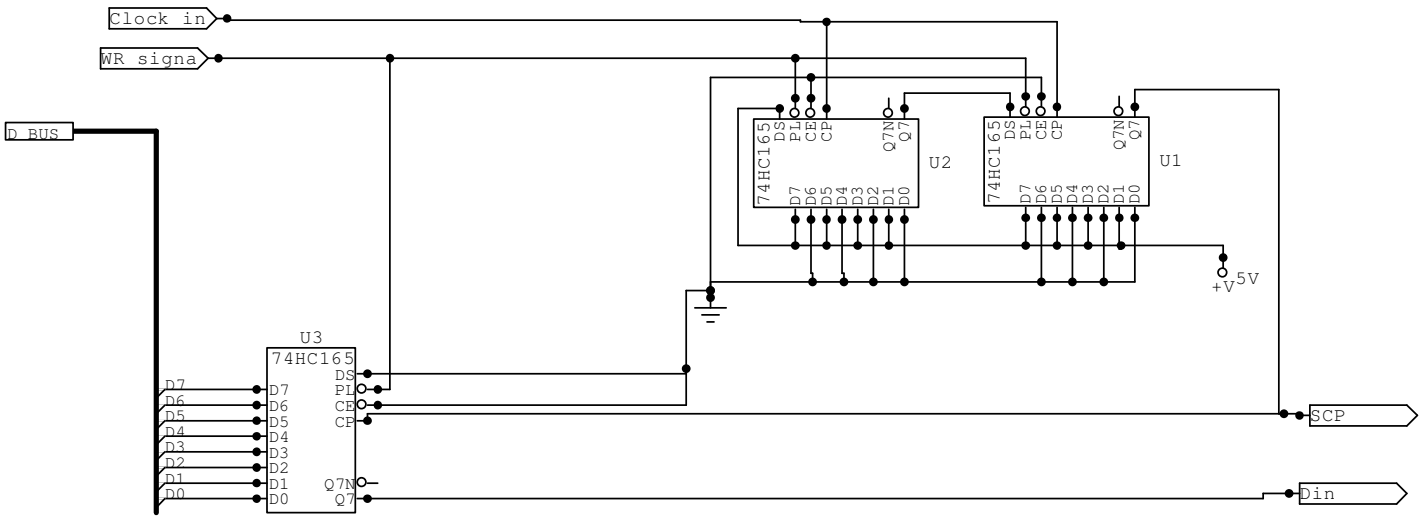
There are many ways to control the LCD 64X32 SmartSwitch such as; by UART in synchronous mode, by direct two pins of a microcontroller, or from a parallel-to-serial-converter. (See Figure 1 for parallel-to-serial-converter.)


**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

Figure 1, LCD 64X32 SmartSwitch Example Using Three Shift Registers

FIG. 1




**c. Transmitting the most significant bit first vs. the least significant bit first**

In SPI the most significant bit of the byte is transmitted first. In UART the least significant bit of the byte is transmitted first. Some SPI setups have the option to select the transmission order.
The LCD 64X32 SmartSwitch takes the first bit transmitted as the most significant bit of the byte.

**d. Transmitting the most significant bit first**

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

- **Command to Reset**

  This command is two bytes. Upon receiving this command the LCD 64X32 SmartSwitch 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 SmartSwitch 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 |


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

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 SmartSwitch 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 |

- **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 SmartSwitch 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 SmartSwitch**

| 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 |

**e. Transmitting the least significant bit first**

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

- **Command to Reset**

  This command is two bytes. Upon receiving this command the LCD 64X32 SmartSwitch 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.

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

This command is two bytes. Upon receiving this command the LCD 64X32 SmartSwitch will set 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 SmartSwitch will set 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 |

- **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 SmartSwitch 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


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

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 SmartSwitch**

| 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 unnecessary for least significant bit first transmission.

### f. Connection Options

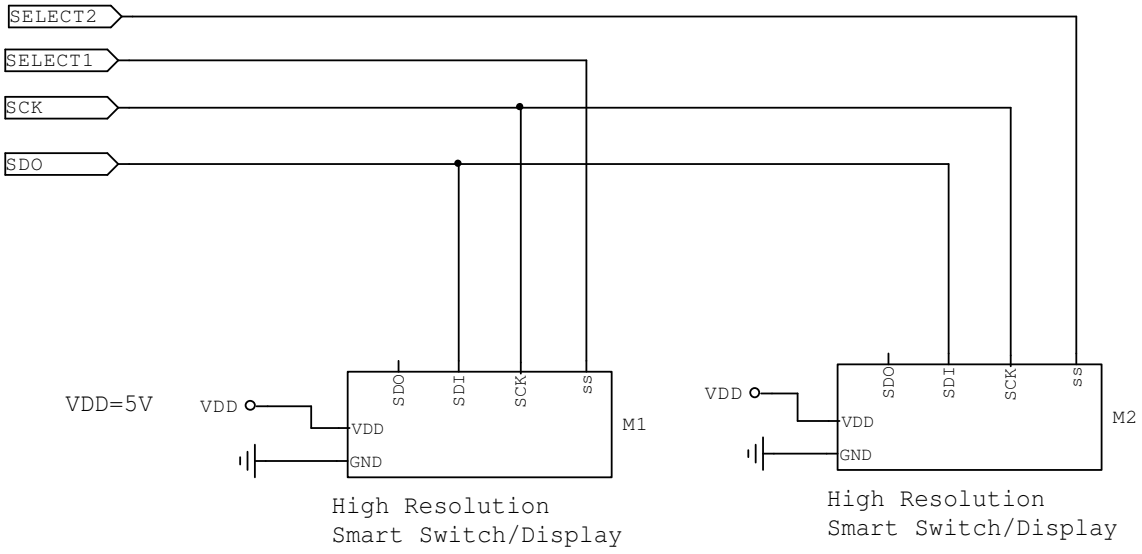
The LCD 64X32 SmartSwitches can be controlled by 3 pins (SCK, SDI, $\overline{SS}$ ) or by two pins (SCK, SDI).

### g. Controlling the LCD 64X32 SmartSwitches by 3 pins

Chip select ( $\overline{SS}$ ) is used for addressing individual LCD 64X32 SmartSwitches. The $\overline{SS}$ line should be pulled low then a command and its data is transmitted then the $\overline{SS}$ line should be pulled high. See figure 2.


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

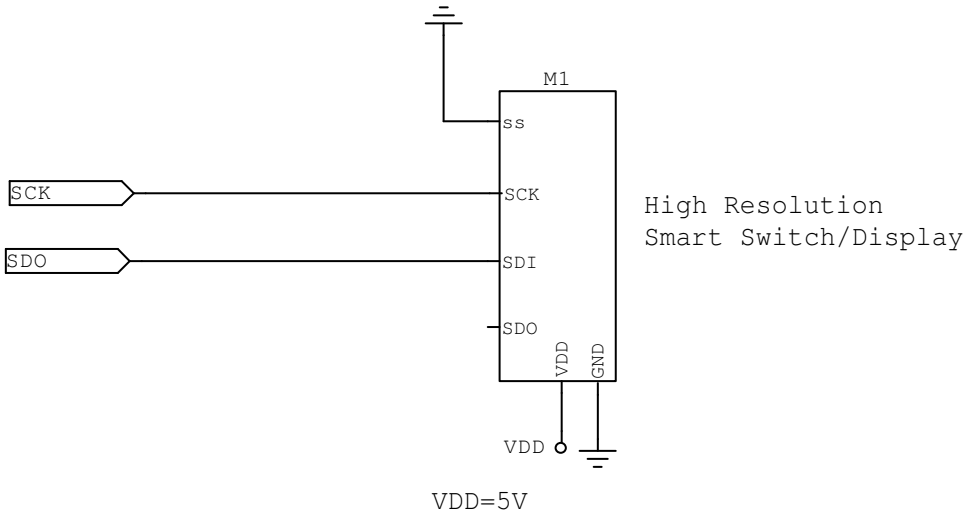
Figure 2, Two LCD 64X32 SmartSwitches with chip select ( $\overline{SS}$ ).




## h. Controlling the LCD 64X32 SmartSwitches by 2 pins

For controlling the LCD 64X32 SmartSwitch with two pins, the $\overline{SS}$ pin should be connected to GND and the SCK / SDI must be normally high. See figures 3 and 4.

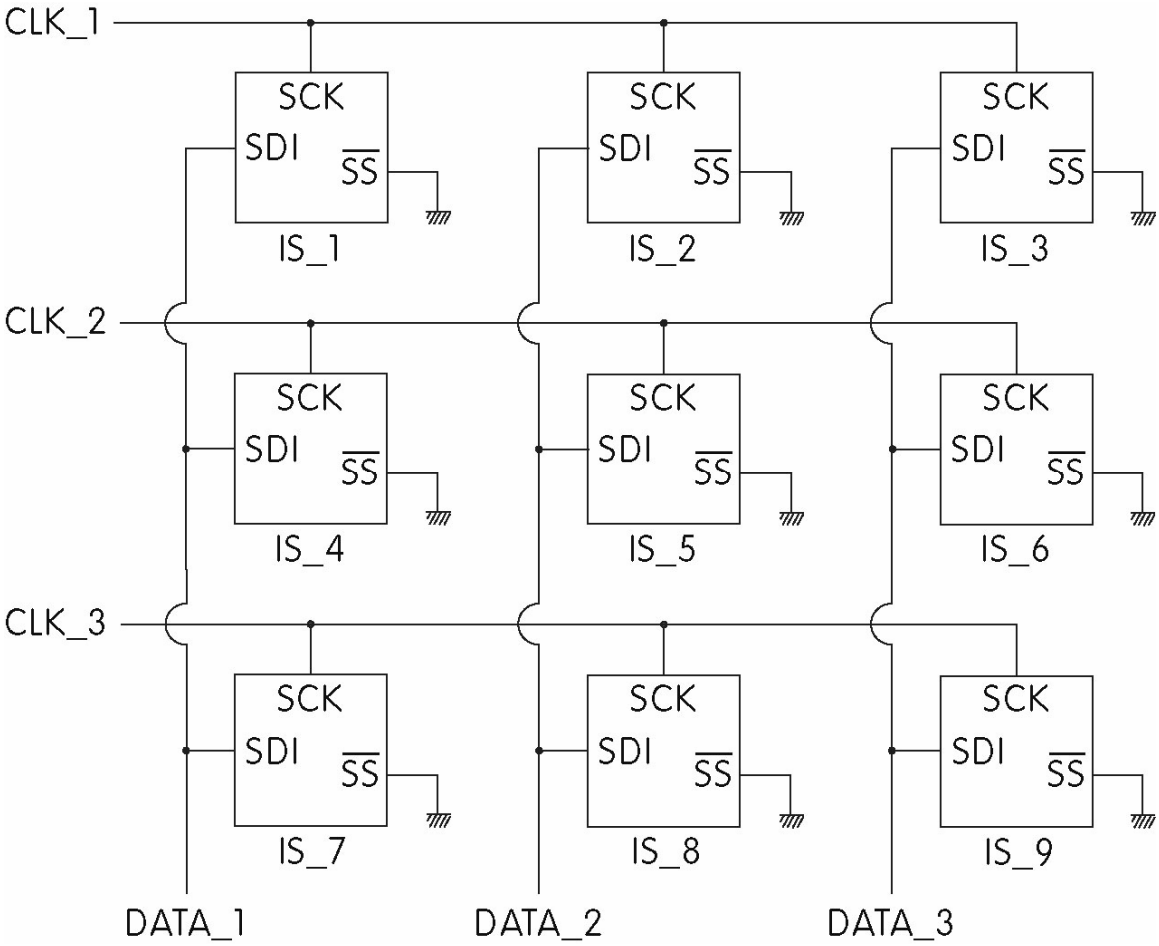
Figure 3, One LCD 64X32 SmartSwitch without chip select ( $\overline{SS}$ ).





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

Figure 4, Nine LCD 64X32 SmartSwitches without chip select ( $\overline{SS}$ ).




## 6. Operation

Upon power up, the LCD 64X32 SmartSwitch goes into the default state. The default state has display off, backlight off and master brightness at 1/20. Any command can be transmitted at any time. The command goes into effect and the current settings and display are maintained until the next command is received. Any transmission that is not a command is ignored.

## 7. Frequently asked questions

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

7850 East Gelding Drive • Scottsdale, AZ 85260-3420

**Why do the pixels not look sharp?**
The VDD is out of range. The VDD must be 5.0V. 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. However, NKK Switches does not have data for LCD 64X32 SmartSwitch behavior with VDD adjustment.

**My circuit only controls the LCD 64X32 SmartSwitch 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 oscilloscope capacitance makes the data stable.

**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 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, bright sunlight reflecting off the lens may cause problems with viewing.

**How many switches can be driven by one SPI?**
With an 8 MHZ clock with 10% overhead, it takes approximately 0.29 ms to transmit an image and backlighting data to one LCD 64X32 SmartSwitch.
(1/8000000 bit/s)*(259 bytes)*(8 bits/byte)*(1.10 overhead)=0.0002849 s

The limitation depends on how fast all the switches need to be updated at once in the application.
The number can be in 100s. However, the Fan out of the serial/driver 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 SmartSwitch 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.


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