KSDK SPI Master-Slave with FRDM-K64F

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1 Introduction

The Kinetis software development kit (SDK) is an extensive suite of robust peripheral drivers, stacks, middleware and example applications designed to simplify and accelerate application development on any Kinetis MCU.

This document describes the use of the dSPI module, present on most Kinetis devices, using the KSDK drivers. It is based on a simple SPI Master-Slave configuration example.

For more information about KSDK visit:
www.freescale.com/KSDK

freescale semiconductor

2 Serial Peripheral Interface.

The serial peripheral interface (SPI) module provides a synchronous serial bus for communication between an MCU and an external peripheral device.

The module supports different configurations for instance changing the polarity or the state of the lines when the bus is idle among others. For a better understanding of the characteristics and operation of the module please refer to the specific Kinetis device reference manual.

2.1 SPI signals.

The SPI peripheral has different signals that are connected when using either Master or Slave mode, the next table presents such signals.

Signal	Master mode	Slave mode	I/O
PCS0/$\overline{SS}$	Peripheral Chip Select 0 (O)	Slave Select (I)	I/O
PCS[1:3]	Peripheral Chip Selects 1–3	(Unused)	O
PCS4	Peripheral Chip Select 4	(Unused)	O
PCS5/ $\overline{PCSS}$	Peripheral Chip Select 5 /Peripheral Chip Select Strobe	(Unused)	O
SCK	Serial Clock (O)	Serial Clock (I)	I/O
SIN	Serial Data In	Serial Data In	I
SOUT	Serial Data Out	Serial Data Out	O

Table 1. SPI signals

3 SPI configuration example.

This section considers SPI configuration examples "FRDM-K64_SPI_MASTER_KSDK_example" and "FRDM-K64_SPI_SLAVE_KSDK_example" developed in KDS IDE. The next sections will discuss the philosophy of the examples showing the configuration code.

3.1 Configure SPI pins.

The KSDK includes board support files for each supported hardware platform. These files are located in the *<install_dir>/boards*, look for the board folder; each folder contains similar information related to the specific board. The pin_mux folder contains functions to configure the pins present on the board for each peripheral.

The **`configure_spi_pins`** function initializes the pin signal for the peripheral instances present on the board. In the example the SPI0 is being used by calling:

```
configure_spi_pins(HW_SPI0);
```

The next signals are configured:

SPI0	Alternative 2
PTD0	SPI0_PCS0 (Chip Select)

PTD1	SPI0_SCK (Serial Clock)
PTD2	SPI0_SOUT (Serial Data Out)
PTD3	SPI0_SIN (Serial Data In)

The same SPI configuration is used for the master and slave modes.

3.2 SPI IRQ Handler.

The SPI KSDK driver implements just one ISR callback for master and slave modes. The IRQ handler is included in the fsl_dspi_irq.c file; it can be found in: *<install_dir> \KSDK_1.1.0\platform\drivers\src\dspi.*

The handler implements a different algorithm depending on the mode that is being used (master or slave).

3.3 SPI Master Configuration.

Here the SPI master configuration is discussed: the necessary structure configurations and the drivers needed.

NOTE:

The notation RM in implies that more information about the register can be found in the device specific reference manual

- **Driver Support**: Including the SPI support header file is necessary whenever using the drivers. Include the file:

  ```
  #include "fsl_dspi_master_driver.h"
  ```

- **Master User Configuration structure**: Creating a user configuration structure allows the user to set the common parameters for the SPI peripheral. This structure is passed to the `DSPI_DRV_MasterInit` function. A basic user configuration includes:
  - `dspi_master_user_config_t userConfig;`

    Create a structure for the user configuration.
  - `userConfig.isChipSelectContinuous = false;`

    Select if the PCSn (Chip Select) signal is returned to their inactive state between transfers or if it keeps asserted. (SPIx_PUSHR[CONT] RM)
  - `userConfig.isSckContinuous = false;`

    It disables or enables the continuous operations of the SCK (Serial Clock) signal. (SPIx_MCR[CONT_SCKE] RM)
  - `userConfig.pcsPolarity = kDspiPcs_ActiveLow;`

    Select if the Active value of the PCSx is low or high. (SPIx_MCR[PCSIS] RM)
  - `userConfig.whichCtar = kDspiCtar0;`

    Select which SPI CTARx is being used. For master opration it can be CTAR0 or CTAR1. (Search “Number of CTARs” in RM).

- `userConfig.whichPcs = kDspiPcs0;`

  Select the device specific chip select. In this case the PCS0 (PTD0) is used. (SPIx_PUSHR[PCS] RM).

- **Master Bus Configuration structure**: Creating a data structure for the bus configuration allows the user to properly set the parameters to allow the communication.

  - `dspi_device_t spiDevice;`

    Create a structure for the SPI device bus settings.

  - `spiDevice.dataBusConfig.bitsPerFrame = 8;`

    Configure the bits sent per frame through the bus. It allows a max number of 16 for master mode and 32 for slave mode. (SPIx_CTARn[FMSZ] RM).

  - `spiDevice.dataBusConfig.clkPhase = kDspiClockPhase_SecondEdge;`

    Select when the data is captured, if leading edge or the second edge. (SPIx_CTARn[CPHA] RM).

  - `spiDevice.dataBusConfig.clkPolarity = kDspiClockPolarity_ActiveHigh;`

    Select the inactive values of the SCK line selecting low or high state. (SPIx_CTARn[CPOL] RM).

  - `spiDevice.dataBusConfig.direction = kDspiMsbFirst;`

    Select whether the LSB or MSB of the frame is transferred first. (SPIx_CTARn[LSBFE] RM).

  - `spiDevice.bitsPerSec = 50000;`

    Select the bits per seconds transmitted. This selection sets the proper baudrate value for the peripheral.

- **Master Configuration Drivers:** As seen above there are two configurations done by the master: configuration of the peripheral and configuration of the bus. Next are listed the two driver functions needed to complete the process.

  - `DSPI_DRV_MasterInit(HW_SPI0, &dspiMasterState, &userConfig);`

    The driver sets the SPI module with the parameters configured in the user configuration structure.

    Parameters:

    Instance →select the SPI instance, in this case SPI0 is used.

    dSPIstate →pointer to a data state structure. It needs to be created by the user to allocate memory for it.

    userConfig →pointer to the user configuration structure mentioned before.

  - `DSPI_DRV_MasterConfigureBus(HW_SPI0, &spiDevice, &calculatedBaudRate);`

    Configure the SPI port physical parameters to access a device on the bus.

Parameters:

Instance →select the SPI instance, in this case SPI0 is used.

device →pointer to the bus configuration structure.

calculatedBaudRate →pointer to the variable where the Calculated Baud Rate value will be stored. The user can check the value to determine if the desired value is close enough to the one set by the driver.

3.4 SPI Master Transfer.

The SPI KSDK driver includes blocking and non blocking functions to implement the data transfers. In this example the blocking function was used.

- ```
  DSPI_DRV_MasterTransferBlocking(HW_SPI0,
                                  NULL,
                                  &spiSourceBuffer,
                                  &spiSinkBuffer,
                                  1,
                                  1000);
  ```

  Sends the data contained in the source buffer and stores the incoming data in the sink buffer returning a specific error value.

  Parameters:

  Instance →select the SPI instance, in this case SPI0 is used.

  device →pointer to the bus configuration structure. It can be set to NULL if the bus configuration was done before.

  sendBuffer →Pointer to the source buffer.

  receiveBuffer →Pointer to the sink buffer

  transferByteCount →Number of bytes that will be transmitted.

  timeout → Value handled by the OSA that determines how long the function will block the continuity of the code. It can be set to OSA_WAIT_FOREVER to indicate that function will be blocking until a returned error code.

3.5 SPI Slave Configuration.

The SPI Slave configuration is very similar to the master configuration.

- **Slave User Configuration structure:** For the SPI Slave configuration it is only necessary to set the user configuration structure using the same parameters as in master configuration.
  - ```
    dspi_slave_user_config_t slaveUserConfig;
    ```

Create a structure for the user configuration.

An extra parameter in the user configuration for the slave can be set:

- `slaveUserConfig.dummyPattern = DSPI_DEFAULT_DUMMY_PATTERN;`

  Select the value that will be send by the slave when the transmit buffer does not have any data.

- **Slave Configuration Driver**: The slave user configuration has to be passed to the initialization driver to complete the process.

  - `DSPI_DRV_SlaveInit(HW_SPI0, &dspiSlaveState, &slaveUserConfig);`

    The driver sets the SPI module with the parameters configured in the user configuration structure.

    Parameters:

    Instance →select the SPI instance, in this case SPI0 is used.

    dSPIstate →pointer to a data state structure. It needs to be created by the user to allocate memory for it.

    slaveConfig →pointer to the user configuration structure mentioned before.

3.6 SPI Slave Transfer.

As in master mode the slave mode drivers include blocking and non blocking transfer functions. The structure of the function is very similar to the master transfer function.

- ```
  DSPI_DRV_SlaveTransferBlocking( HW_SPI0,
                                  NULL,
                                  &spiSourceBuffer,
                                  &spiSinkBuffer,
                                  1,
                                  OSA_WAIT_FOREVER);
  ```

  Stores the incoming data in the sink buffer and sends the data contained in the source buffer returning a specific error value.

  Parameters:

  Instance →select the SPI instance, in this case SPI0 is used.

  sendBuffer →Pointer to the source buffer.

  receiveBuffer →Pointer to the sink buffer

  transferByteCount →Number of bytes that will be transmitted.
  ```

timeout → Value handled by the OSA that determinates how long the function will block the continuity of the code. It can be set to OSA_WAIT_FOREVER to indicate that function will be blocking until a returned error code.

4 SPI Master-Slave example.

To test the code two FRDM-K64Fs are used. The philosophy of the example is the next:

*The **Master** board is configured to send one of three possible messages to the slave device every time SW2 is pressed, confirming the master is calling the transfer function the blue led is toggled. The possible values are 0x52 (R), 0x47 (G) or 0x42 (B) and are sent in that order.*

*The **Slave** board is receiving the data from the master; if it receives R it will turn on the red led and is the same process for G or B. Every time the slave receives data it writes to the data buffer a byte that will be sent in the next transfer.*

The Boards configuration is showed in the image below.

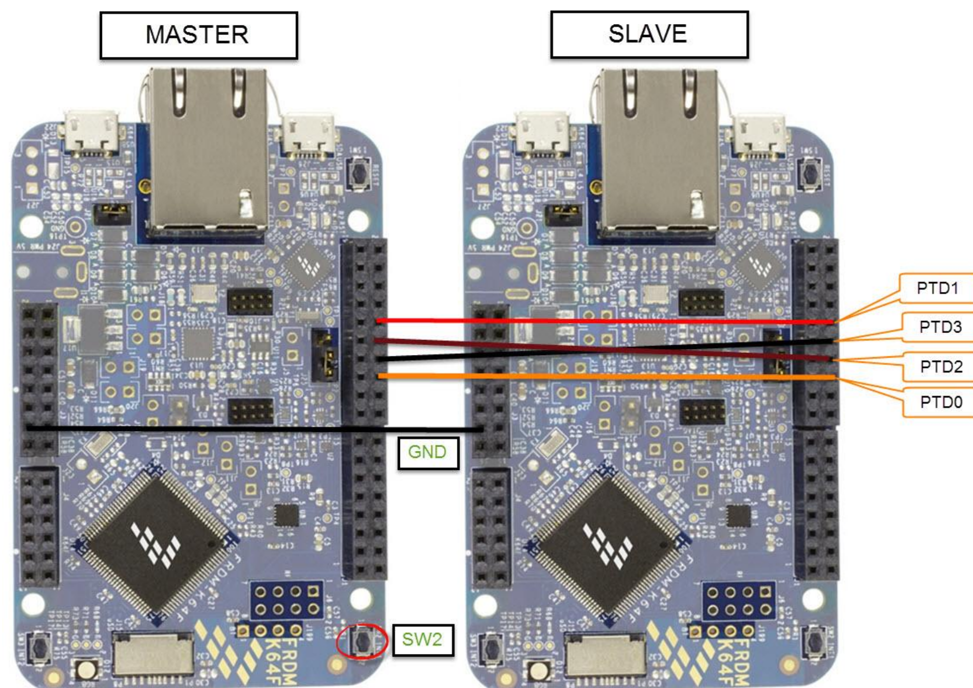
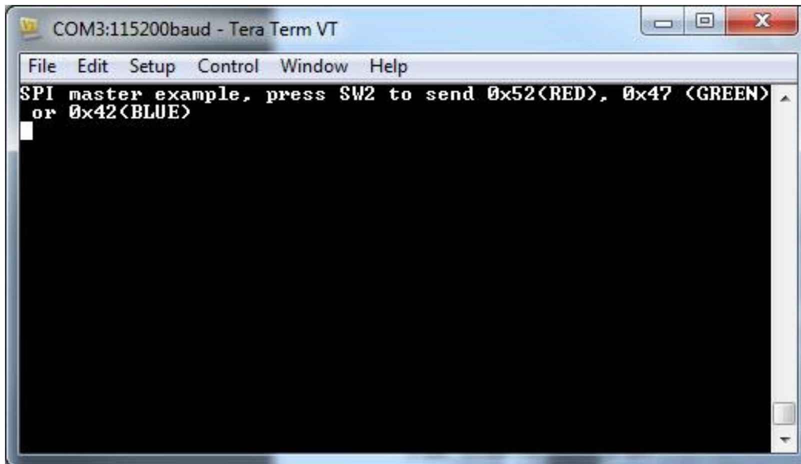


Figure 1. Boards Configuration

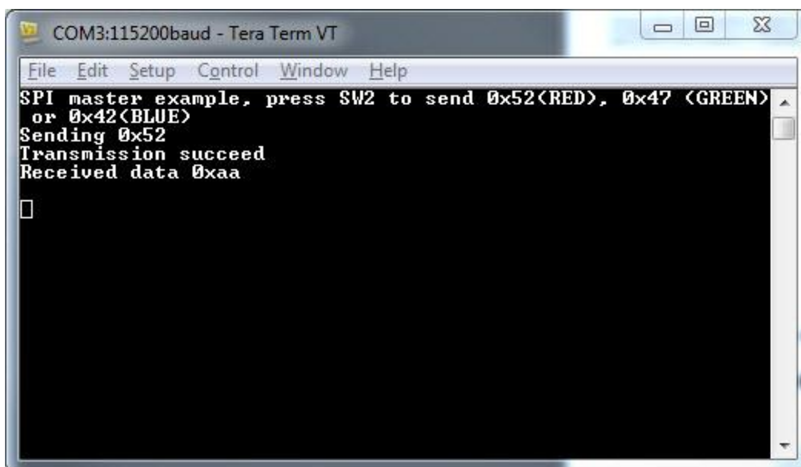
4.1 Running the Example.

Once one board is running the master code and the other one is running the slave code and both of them are correctly wired the procedure is the following:

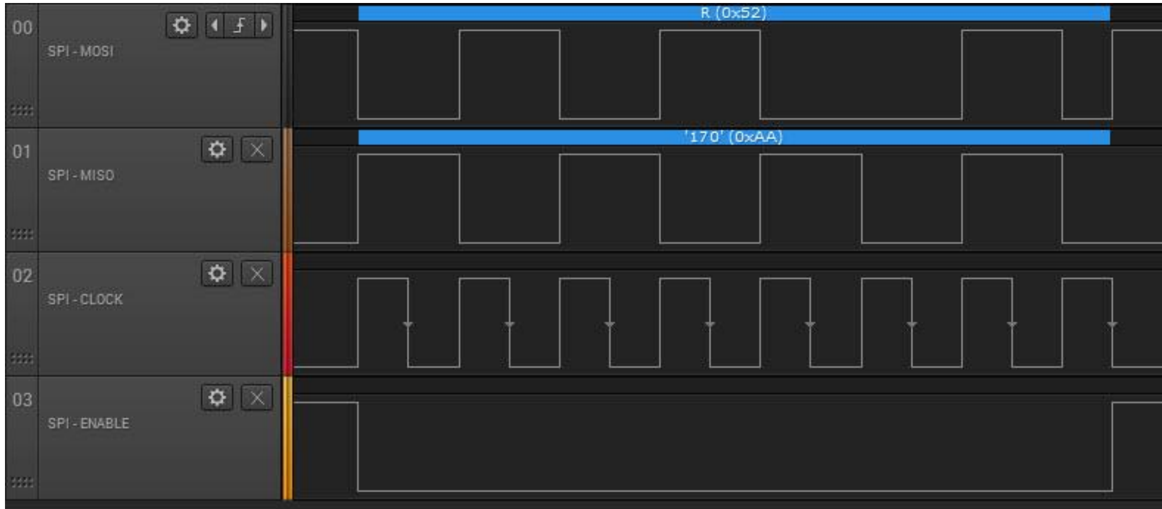
1. Open a Terminal software (e.g Teraterm) enabling the communication with the COMx port of the master board and set the communication properties to:
    - 115200 buadrate.
    - 8 bit data.
    - No parity.
    - 1 stop bit.
2. Run **master** board and run the **slave** board, the next is shown in the terminal (COMx port of Master board):



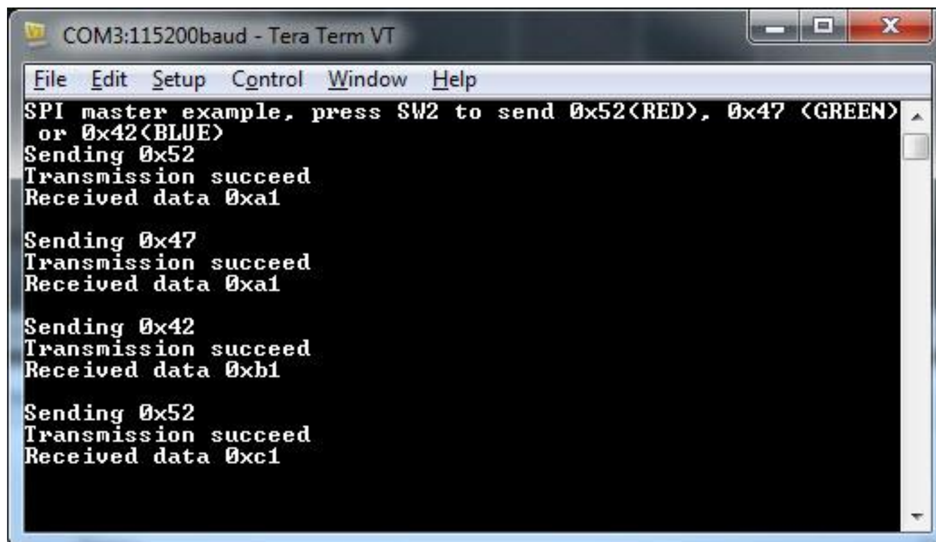
3. Run the slave board, you will see all the RGB led on for a second and then off. It indicates the program is running.
4. Press SW2 in master board and see the blue led of master board being toggled. The slave board will receive the message and turn the corresponding led. This is the message of the terminal of the master board.



The terminal shows the sent message and the received data. Here is image of the signals viewed on a logic analyzer.



5. Press again the SW2 and a different message will be sent.



6. See the RGB led of the slave board changing de color according to the received message

5 References.

- K64 Reference Manual
- Getting Started with Kinetis SDK (KSDK): <install_dir>\KSDK_1.1.0\doc
- Writing my first KSDK Application in KDS – Hello World and Toggle LED with Interrupt.

6 Example Main Code.

6.1 Master main code

```
#include "fsl_device_registers.h"
#include "fsl_os_abstraction.h"
#include "fsl_dspi_master_driver.h"
#include "board.h"

#define RED    0x52
#define GREEN  0x47
#define BLUE   0x42

bool pushflag = false;
uint8_t spiSourceBuffer = RED;
uint8_t spiSinkBuffer;

uint8_t RGBdataOut[3] = {RED, GREEN, BLUE};
uint8_t RGBcount = 0;
int main(void)
{
    /* Write your code here */
       hardware_init();
       dbg_uart_init();
       OSA_Init();

       GPIO_DRV_Init(switchPins, ledPins);

       printf("SPI master example, press SW2 to send 0x52(RED), 0x47 (GREEN) or 0x42(BLUE)
\n\r");

       configure_spi_pins(HW_SPI0);
       dspi_master_state_t dspiMasterState; // simply allocate memory for this
       // configure the members of the user config //
       dspi_master_user_config_t userConfig;
       userConfig.isChipSelectContinuous = false;
       userConfig.isSckContinuous = false;
       userConfig.pcsPolarity = kDspiPcs_ActiveLow;
       userConfig.whichCtar = kDspiCtar0;
       userConfig.whichPcs = kDspiPcs0;  //Selects the Chip select
       // init the DSPI module //
       DSPI_DRV_MasterInit(HW_SPI0, &dspiMasterState, &userConfig);

       // Define bus configuration.
       uint32_t calculatedBaudRate;
       dspi_device_t spiDevice;
       spiDevice.dataBusConfig.bitsPerFrame = 8;
       spiDevice.dataBusConfig.clkPhase = kDspiClockPhase_SecondEdge;
       spiDevice.dataBusConfig.clkPolarity = kDspiClockPolarity_ActiveHigh;
       spiDevice.dataBusConfig.direction = kDspiMsbFirst;
       spiDevice.bitsPerSec = 50000;
       // configure the SPI bus //
       DSPI_DRV_MasterConfigureBus(HW_SPI0, &spiDevice, &calculatedBaudRate);
```

```
    for (;;) {

        if(GPIO_DRV_ReadPinInput(kGpioSW1) == 0)    //is switch pressed?
        {
                pushflag = true;
        }
        OSA_TimeDelay(250);
        if(pushflag)
        {
                pushflag = false;
                GPIO_DRV_TogglePinOutput(BOARD_GPIO_LED_BLUE);
                printf ("Sending 0x%x \n\r",spiSourceBuffer & 0xFF);
                //SEND DATA
             dspi_status_t Error = DSPI_DRV_MasterTransferBlocking(HW_SPI0,
                                                                        NULL,
                                                                        &spiSourceBuffer,
                                                                        &spiSinkBuffer,
                                                                        1,
                                                                        1000);
             if (Error == kStatus_DSPI_Success)
             {
                printf ("Transmission succeed  \n\r");
                printf ("Received data 0x%x \n\n\r",spiSinkBuffer & 0xFF);
                RGBcount++;
                if(RGBcount > 2 ){RGBcount = 0;}
                spiSourceBuffer = RGBdataOut[RGBcount];
             }
        }
    }
    return 0;
}
```

6.2 Slave main code

```
#include "fsl_device_registers.h"
#include "fsl_os_abstraction.h"
#include "fsl_dspi_slave_driver.h"
#include "fsl_dspi_hal.h"
#include "board.h"

/*RGB values*/
#define RED    0x52
#define GREEN  0x47
#define BLUE   0x42

#define RED_LED                     0
#define GREEN_LED            1
#define BLUE_LED             2
#define ALL_ON               3
#define ALL_OFF                     4

void Turn_Led (uint8_t Led);

uint8_t spiSourceBuffer = 0xAA;
uint8_t spiSinkBuffer;
```

```
int main(void)
{

    /* Write your code here */
      // declare which module instance you want to use
      hardware_init();
      dbg_uart_init();
      OSA_Init();

      GPIO_DRV_Init(switchPins, ledPins);

      Turn_Led (ALL_ON);
      OSA_TimeDelay(1000);
      Turn_Led (ALL_OFF);

      configure_spi_pins(HW_SPI0);

      dspi_slave_state_t dspiSlaveState;
      dspi_slave_user_config_t slaveUserConfig;
      slaveUserConfig.dataConfig.clkPhase = kDspiClockPhase_SecondEdge;
      slaveUserConfig.dataConfig.clkPolarity = kDspiClockPolarity_ActiveHigh;
      slaveUserConfig.dataConfig.bitsPerFrame = 8;
      slaveUserConfig.dataConfig.direction = kDspiMsbFirst;
      slaveUserConfig.dummyPattern = DSPI_DEFAULT_DUMMY_PATTERN;

      DSPI_DRV_SlaveInit(HW_SPI0, &dspiSlaveState, &slaveUserConfig);

    for (;;) {

      dspi_status_t Error = DSPI_DRV_SlaveTransferBlocking(HW_SPI0,
                                                           &spiSourceBuffer,
                                                           &spiSinkBuffer,
                                                           1,
                                                           OSA_WAIT_FOREVER);
      if (Error == kStatus_DSPI_Success)
              {
                      switch(spiSinkBuffer)
                      {
                              case((uint8_t)RED):
                                      Turn_Led (RED_LED);
                                      spiSourceBuffer = 0xA1;
                                      break;
                              case((uint8_t)GREEN):
                                      Turn_Led (GREEN_LED);
                                      spiSourceBuffer = 0xB1;
                                      break;
                              case((uint8_t)BLUE):
                                      Turn_Led (BLUE_LED);
                                      spiSourceBuffer = 0xC1;
                                      break;
                              case((uint8_t)0xFF):
                                      Turn_Led (ALL_ON);
                                      break;
                      }
              }

    }
    return 0;
}
```

```
void Turn_Led (uint8_t Led)
{
	switch(Led)
	{
		case 0:
			GPIO_DRV_ClearPinOutput(BOARD_GPIO_LED_RED);
			GPIO_DRV_SetPinOutput(BOARD_GPIO_LED_GREEN);
			GPIO_DRV_SetPinOutput(BOARD_GPIO_LED_BLUE);
			break;
		case 1:
			GPIO_DRV_SetPinOutput(BOARD_GPIO_LED_RED);
			GPIO_DRV_ClearPinOutput(BOARD_GPIO_LED_GREEN);
			GPIO_DRV_SetPinOutput(BOARD_GPIO_LED_BLUE);
			break;
		case 2:
			GPIO_DRV_SetPinOutput(BOARD_GPIO_LED_RED);
			GPIO_DRV_SetPinOutput(BOARD_GPIO_LED_GREEN);
			GPIO_DRV_ClearPinOutput(BOARD_GPIO_LED_BLUE);
			break;
		case 3:
			GPIO_DRV_ClearPinOutput(BOARD_GPIO_LED_RED);
			GPIO_DRV_ClearPinOutput(BOARD_GPIO_LED_GREEN);
			GPIO_DRV_ClearPinOutput(BOARD_GPIO_LED_BLUE);
			break;
		case 4:
			GPIO_DRV_SetPinOutput(BOARD_GPIO_LED_RED);
			GPIO_DRV_SetPinOutput(BOARD_GPIO_LED_GREEN);
			GPIO_DRV_SetPinOutput(BOARD_GPIO_LED_BLUE);
			break;
	}
}
```