NRC7292 Application Note

(FT232H_USB_SPI)

Ultra-low power & Long-range Wi-Fi

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NEWRACOM, Inc.

NRC7292 Application Note (FT232H_USB_SPI)
Ultra-low power & Long-range Wi-Fi

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1 Overview

NRC7292, a Wi-Fi Halow Chip, supports high speed SPI slave controller to communicate with a Host that supports SPI Master.

Alternatively, it can support USB interface with FTDI FT232H, which is a single channel USB 2.0 Hi-Speed (480Mb/s) to UART/FIFO IC. The FT232H can be configured in a variety of industry standard serial or parallel interfaces, such as MPSSE - JTAG, SPI, I2C.

The FT232H must be configured as SPI master to communicate with NRC7292. It is possible with the FT232H USB-SPI bridge driver described in this application note. Users can evaluate it with the NRC7292 EVK and FTDI C232HM MPSSE Cable.

Part No: C232HM-DDHSL-0

USB to Hi-Speed SPI/I2C/JTAG Serial Adapter Cable w/Embedded Electronics, LEDs, 3.3V

USB 2.0 Hi-Speed to MPSSE Cable (SPI/I2C/JTAG master) with +3.3V digital level signals.

- **Data Rates:** 30 Mbps
- **USB Speed:** High Speed (480MBps)
- **Interfaces:** MPSSE
- **USB Connector:** Type A
- **End Connector:** 10 way 0.1" female pin headers
- **Cable Length:** 0.5m
- **Cable Details:** 10 core, 6.5mm UL2464 24 AWG
- **Packages:** N/A
- **Channels:** 1
- **I/O Voltage:** 3.3V
- **USB Class:** FTDI Drivers
- **Virtual Com Port:** Yes
- **Max Power Output:** +3.3V / 250mA
- **FTDI Internal IC:** FT232H
- **Operating Temperature:** -40°C to +85°C

Figure 1.1 C232HM MPSSE Cable Overview

For more information on the FTDI C232MH MPSSE Cable, refer to the link (https://ftdichip.com/products/c232hm-ddhsl-0-2/) and related document in doc folder.

2 C232HM MPSSE Cable connection

Figure 2.1 and Table 2.1 show the wire colors and signal descriptions of the C232HM MPSSE Cable in MPSSE SPI mode.

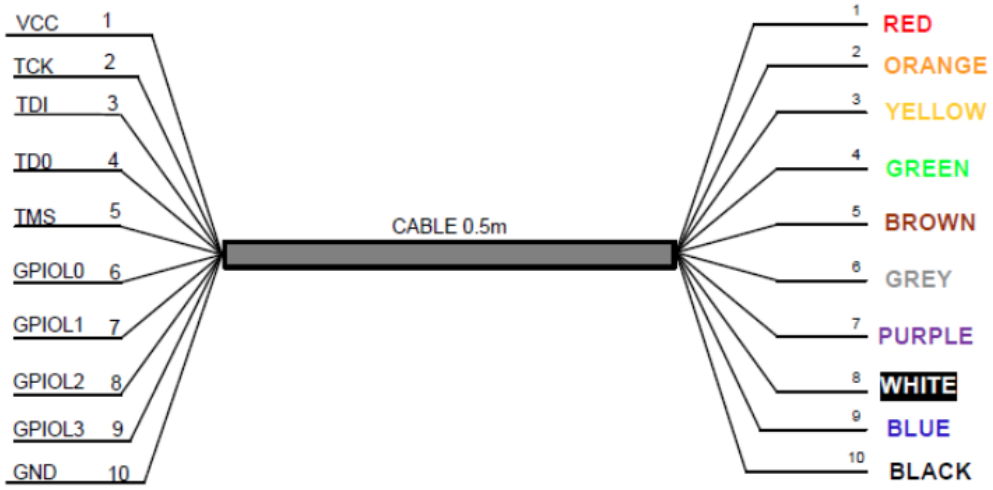


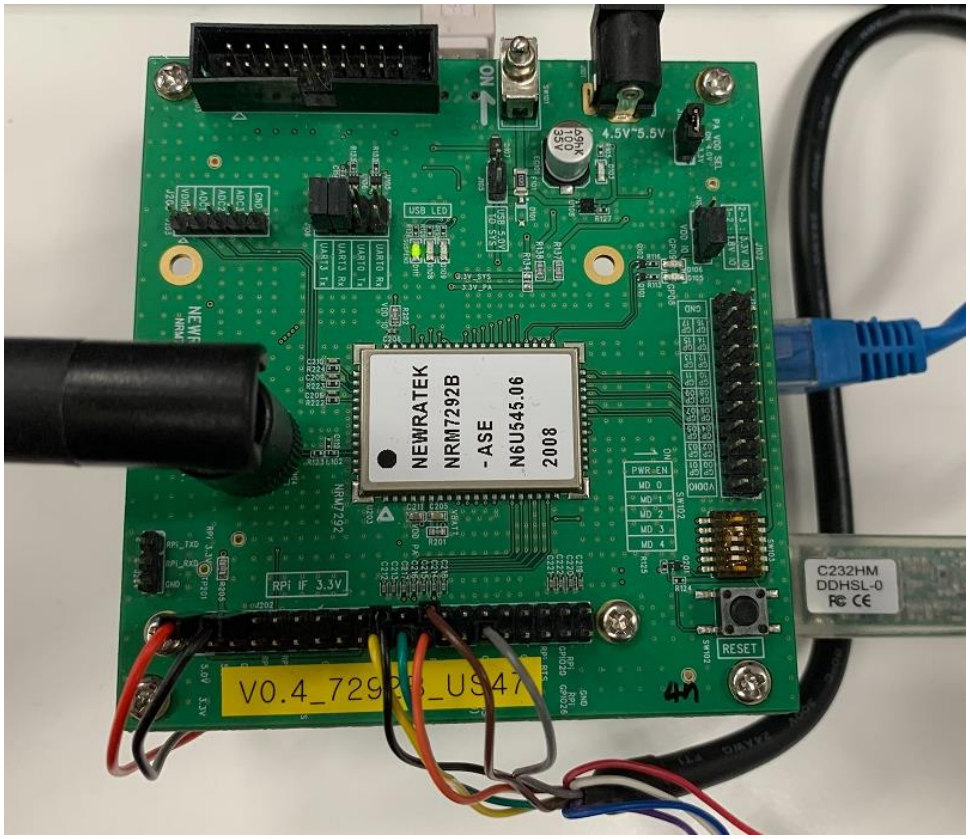
Figure 2.1 C232HM MPSSE Cable - Wire Colors

Colour	Pin Number	Name	Type	Description
Orange	2	SK	Output	Serial Clock
Yellow	3	DO	Output	Serial data output
Green	4	DI	Input	Serial Data Input
Brown	5	CS	Output	Serial Chip Select

Table 2.1 C232HM MPSSE Cable - SPI Signals

The FT232H supports only one chip select pin in MPSSE SPI mode. Therefore, it cannot communicate with more than one SPI slave device.

Figure 2.2 shows the wire connection between NRC7292 Evaluation Kit and C232HM MPSSE Cable.



Raspberry Pi 40 Pin Header		NRC7292 EVB 40 Pin Header		FTDI C232HM-DDHSL-0
Pin 2 (5V)	◄- - - - - - ►	Pin 2 (5V)		-
Pin 6 (GND)	◄- - - - - - ►	Pin 6 (GND)		-
-		-		-
-		Pin 19 (MOSI)	◄- - - - - - ►	YELLOW (DO)
-		Pin 20 (GND)	◄- - - - - - ►	BLACK (GND)
-		Pin 21 (MISO)	◄- - - - - - ►	GREEN (DI)
-		Pin 23 (CLK)	◄- - - - - - ►	ORANGE (SK)
-		Pin 24 (CS)	◄- - - - - - ►	BROWN (CS)
-		-		-
-		Pin 29 (EIRQ)	◄- - - - - - ►	GRAY (GPIOL0)

Figure 2.2 C232HM MPSSE Cable - Wire Connection with NRC7282 EVK

3 FT232H USB-SPI bridge driver

The FT232H USB-SPI bridge driver is based on the FTDI drivers implemented by DENX. The DENX FTDI drivers can be found at https://patchwork.kernel.org and is under the GNU Public License version 2 (**GPLv2**).

- FTDI FT232H Interface Driver
  : https://patchwork.kernel.org/project/spi-devel-general/patch/20190221202506.17744-2-agust@denx.de/
- FTDI MPSSE SPI Controller Driver
  : https://patchwork.kernel.org/project/spi-devel-general/patch/20190221202506.17744-3-agust@denx.de/

Figure 3.1 and Table 3.1 show the source tree and file descriptions for the FT232H USB-SPI bridge driver.

Source Path : nrc7292_sw_pkg/package/host/src/ft232h-usb-spi

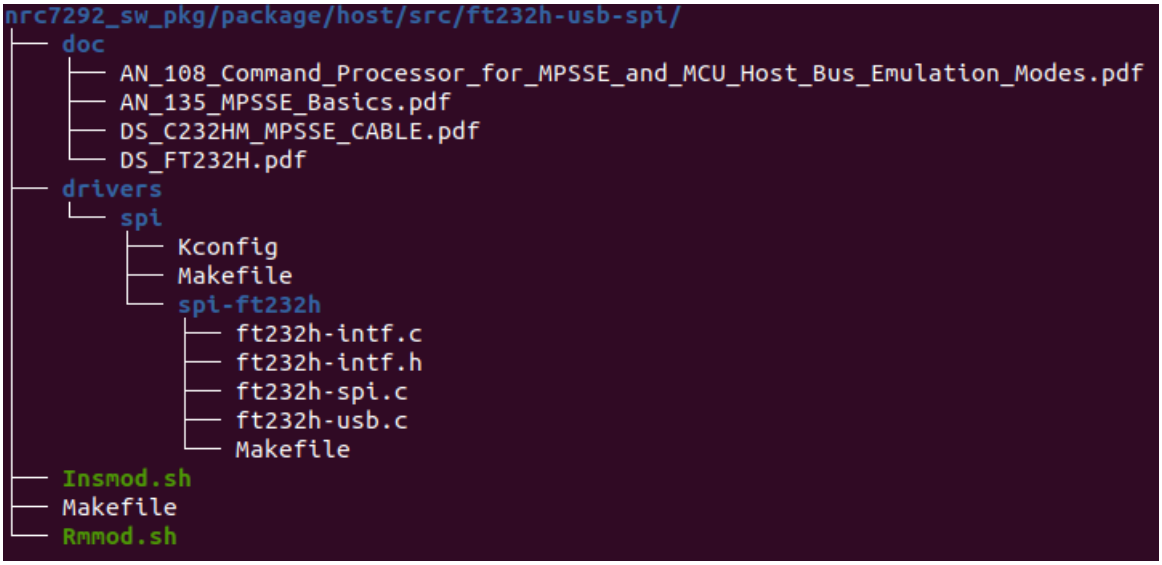


Figure 3.1 FT232H USB-SPI Bridge Driver - Source Tree

File Name	Description
doc/	Application Note, Datasheet, …
drivers/spi/Kconfig	Kconfig for kbuild
drivers/spi/Makefile	Makefile for kbuild

drivers/spi/spi-ft232h/ft232h-intf.[ch]	FT232H interface driver
drivers/spi/spi-ft232h/ft232h-spi.c	FT232H MPSSE SPI driver
drivers/spi/spi-ft232h/ft232h-usb.c	FT232H USB device driver
drivers/spi/spi-ft232h/Makefile	Makefile for kbuild
Makefile	Makefile to build as external module
Insmod.sh	Shell script to insert a module into the kernel
Rmmod.sh	Shell script to remove a module from the kernel

Table 3.1 FT232H USB-SPI Bridge Driver - File Descriptions

The FT232H USB-SPI bridge driver registers three types of drivers into the kernel as shown in Figure 3.2.

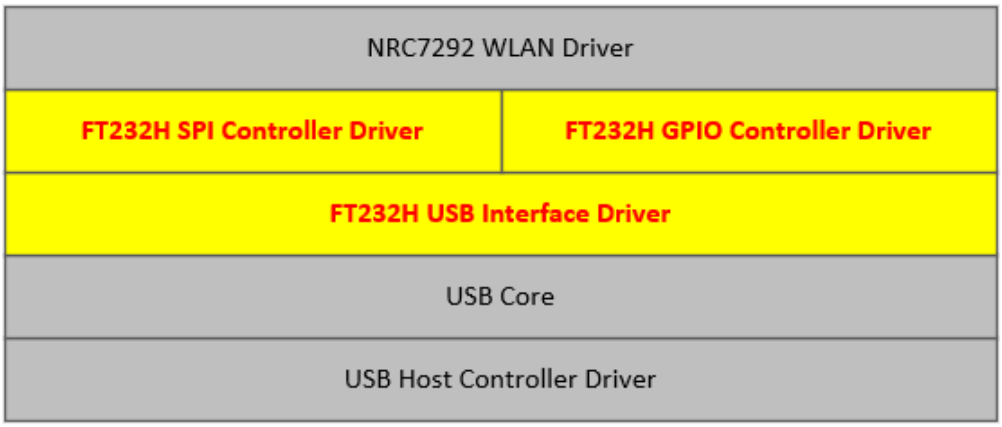


Figure 3.2 FT232H USB-SPI Bridge Driver - Layer Diagram

However, it is built as a single driver module. (spi-ft232h.ko)

4 Getting started

4.1 Building the spi-ft232h driver as an external module.

$ cd ${FT232H_USB_SPI_SOURCE_TOP}

$ make clean

```
pi@raspberrypi:~/ft232h-usb-spi $ make clean
make[1]: Entering directory '/usr/src/linux-headers-4.14.70-v7+'
  CLEAN   /home/pi/ft232h-usb-spi/drivers/spi/.tmp_versions
  CLEAN   /home/pi/ft232h-usb-spi/drivers/spi/Module.symvers
make[1]: Leaving directory '/usr/src/linux-headers-4.14.70-v7+'
```

$ make [debug]

```
pi@raspberrypi:~/ft232h-usb-spi $ make
make[1]: Entering directory '/usr/src/linux-headers-4.14.70-v7+'
  CC [M]  /home/pi/ft232h-usb-spi/drivers/spi/spi-ft232h/ft232h-intf.o
  CC [M]  /home/pi/ft232h-usb-spi/drivers/spi/spi-ft232h/ft232h-spi.o
  CC [M]  /home/pi/ft232h-usb-spi/drivers/spi/spi-ft232h/ft232h-usb.o
  LD [M]  /home/pi/ft232h-usb-spi/drivers/spi/spi-ft232h/spi-ft232h.o
  Building modules, stage 2.
  MODPOST 1 modules
  CC      /home/pi/ft232h-usb-spi/drivers/spi/spi-ft232h/spi-ft232h.mod.o
  LD [M]  /home/pi/ft232h-usb-spi/drivers/spi/spi-ft232h/spi-ft232h.ko
make[1]: Leaving directory '/usr/src/linux-headers-4.14.70-v7+'
```

If there are no errors, a spi-ft232h.ko file will be created under the "drivers/spi/spi-ft232h" directory.

$ modinfo ./drivers/spi/spi-ft232h/spi-ft232h.ko

```
pi@raspberrypi:~/ft232h-usb-spi $ modinfo ./drivers/spi/spi-ft232h/spi-ft232h.ko
filename:       /home/pi/ft232h-usb-spi/./drivers/spi/spi-ft232h/spi-ft232h.ko
license:        GPL v2
description:    FTDI FT232H USB-SPI bridge driver
author:         Anatolij Gustschin <agust@denx.de>
author:         Sangbeom Kim <sb.kim@newracom.com>
author:         Newracom, Inc. <www.newracom.com>
alias:          ft232h-usb-spi
srcversion:     F6D9C1D731B72C84B9CE82D
alias:          usb:v0403p6014d*dc*dsc*dp*ic*isc*ip*in*
depends:
name:           spi_ft232h
vermagic:       4.14.70-v7+ SMP mod_unload modversions ARMv7 p2v8
parm:           latency:latency timer value (1ms ~ 255ms, default 1ms) (int)
parm:           spi_bus_num:SPI controller bus number (if negative, dynamic allocation) (int)
parm:           gpio_base_num:GPIO controller base number (if negative, dynamic allocation) (int)
```

NOTE:

To integrate the spi-ft232h driver into the Linux kernel source:

i. Copy the drivers/spi/spi-ft232h directory to the kernel source.

$ cd ${FT232H_USB_SPI_SOURCE_TOP}

$ cp -a drivers/spi/spi-ft232h ${KERNEL_SOURCE_TOP}/drivers/spi

ii. Add the contents of Kconfig and Makefile under drivers/spi to the kernel source.

$ vim ${KERNEL_SOURCE_TOP}/drivers/spi/Kconfig

```
config SPI_MASTER
#   bool "SPI Master Support"
    bool
    default SPI
    help
      If your system has an master-capable SPI controller (which
      provides the clock and chipselect), you can enable that
      controller and the protocol drivers for the SPI slave chips
      that are connected.

if SPI_MASTER

comment "SPI Master Controller Drivers"

config SPI_FT232H
    tristate "FTDI FT232H SPI controller"
    depends on USB || GPIOLIB || COMPILE_TEST
    help
        FT232H supports SPI in MPSSE mode.
        This driver provides MPSSE SPI controller in master mode.
```

$ vim ${KERNEL_SOURCE_TOP}/drivers/spi/Makefile

```
# SPI slave protocol handlers
obj-$(CONFIG_SPI_SLAVE_TIME)        += spi-slave-time.o
obj-$(CONFIG_SPI_SLAVE_SYSTEM_CONTROL)  += spi-slave-system-control.o

obj-$(CONFIG_SPI_FT232H) += spi-ft232h/
```

iii. Execute Kernel Configuration Menu.

$ cd ${KERNEL_SOURCE_TOP}

$ make menuconfig

Kernel Configuration Menu : Device Drivers -> SPI support

```
--- SPI support
[ ]   Debug support for SPI drivers
      *** SPI Master Controller Drivers ***
< >   FTDI FT232H SPI controller (NEW)
```

4.2 Loading the spi-ft232h driver into the kernel.

$ cd ${FT232H_USB_SPI_SRC_TOP}

$ ./Insmod.sh -h

```
pi@raspberrypi:~/ft232h-usb-spi $ ./Insmod.sh -h
Usage: ./Insmod.sh [options]
Options:
  -l     set the latency time in msec (default : 1 msec)
  -s     set the SPI bus number (default : 3)
  -g     set the GPIO base number (default : 500)
  -h     print this help
```

The latency time is the amount of time to wait before sending an incomplete USB packet from the peripheral back to the host. For quick responses from the peripheral, it is set to 1 by default. 255 indicates the slowest responses.

$ ./Insmod.sh [options]

```
pi@raspberrypi:~/ft232h-usb-spi $ ./Insmod.sh
sudo insmod ./drivers/spi/spi-ft232h/spi-ft232h.ko latency=1 spi_bus_num=3 gpio_base_num=500
export  gpiochip0  gpiochip100  gpiochip128  gpiochip500  unexport
spi0  spi3
```

$ lsmod

```
pi@raspberrypi:~/ft232h-usb-spi $ lsmod
Module                  Size  Used by
spi_ft232h             20480  0
```

NOTE:

The USB PID of the C232HM MPSSE cable is 0x6014, so the FTDI SIO driver for the FT232H may be loaded into the kernel. It should be removed from the kernel.

$ dmesg

```
usb 1-1.5: new high-speed USB device number 6 using dwc_otg
usb 1-1.5: New USB device found, idVendor=0403, idProduct=6014
usb 1-1.5: New USB device strings: Mfr=1, Product=2, SerialNumber=3
usb 1-1.5: Product: C232HM-DDHSL-0
usb 1-1.5: Manufacturer: FTDI
usb 1-1.5: SerialNumber: FT4VTGE3
usbcore: registered new interface driver usbserial
usbcore: registered new interface driver usbserial_generic
usbserial: USB Serial support registered for generic
usbcore: registered new interface driver ftdi_sio
usbserial: USB Serial support registered for FTDI USB Serial Device
ftdi_sio 1-1.5:1.0: FTDI USB Serial Device converter detected
usb 1-1.5: Detected FT232H
usb 1-1.5: FTDI USB Serial Device converter now attached to ttyUSB0
```

$ lsmod

```
Module                  Size  Used by
ftdi_sio               45056  0
usbserial              36864  1 ftdi_sio
fuse                  114688  3
```

To blacklist the ftdi_sio module:

$ sudo vim /etc/modprobe.d/blacklist-ftdi.conf

```
1 blacklist ftdi_sio
```

4.3 Checking the SPI bus and GPIO base numbers.

If the spi_bus_num and gpio_base_num of module parameters are negative, the SPI bus and GPIO base numbers are assigned while the spi-ft232h driver is registered into the kernel.

```
pi@raspberrypi:~/ft232h-usb-spi $ ./Insmod.sh
sudo insmod ./drivers/spi/spi-ft232h/spi-ft232h.ko latency=1 spi_bus_num=-1 gpio_base_num=-1
export  gpiochip0  gpiochip100  gpiochip128  gpiochip500  unexport
spi0  spi3
```

So, the user should check these numbers before loading the nrc7292 driver into the kernel.

If the SPI bus number is 3 and the GPIO base number is 500, the device information can be found in the /sys/class/spi_master and /sys/class/gpio directories.

$ cat /sys/class/spi_master/spi3/device/modalias

$ cat /sys/class/gpio/gpiochip500/label

$ cat /sys/class/gpio/gpiochip500/base

$ cat /sys/class/gpio/gpiochip500/ngpio

```
pi@raspberrypi:~/ft232h-usb-spi $ cat /sys/class/spi_master/spi3/device/modalias
platform:ftdi-mpsse-spi
pi@raspberrypi:~/ft232h-usb-spi $ cat /sys/class/gpio/gpiochip500/label
ftdi-mpsse-gpio.0
pi@raspberrypi:~/ft232h-usb-spi $ cat /sys/class/gpio/gpiochip500/base
500
pi@raspberrypi:~/ft232h-usb-spi $ cat /sys/class/gpio/gpiochip500/ngpio
12
```

When the GPIO base number is 500, FT232H GPIO pins are assigned as in the following table.

GPIO Name	GPIO Index	GPIO Number
MPSSE_GPIOL0	0	500
MPSSE_GPIOL1	1	501
MPSSE_GPIOL2	2	502
MPSSE_GPIOL3	3	503
*MPSSE_GPIOH0	4	504
*MPSSE_GPIOH1	5	505
*MPSSE_GPIOH2	6	506
*MPSSE_GPIOH3	7	507
*MPSSE_GPIOH4	8	508
*MPSSE_GPIOH5	9	509
*MPSSE_GPIOH6	10	510
*MPSSE_GPIOH7	11	511

*) C232HM MPSSE Cable has no wires for MPSSE GPIOH.

Table 4.1 FT232H GPIO Pin Number

4.4 Loading the nrc7292 driver into the kernel.

Open the start.py file and set the following parameters.

```
################################################################################
# CSPI Conf.
hif_speed = 20000000    # SPI Master Clock Frequency
spi_bus_num = 0         # SPI Master Bus Number
spi_cs_num = 0          # SPI Master Chipselect Number
spi_gpio_irq = 5        # CSPI_EIRQ GPIO Number
spi_gpio_poll = -1      # CSPI_EIRQ GPIO Polling Interval (if negative, irq mode)
################################################################################
# FT232H USB-SPI Conf.
ft232h_usb_spi = 0      # FTDI FT232H USB-SPI bridge : 0(off) or 1(on)

if int(ft232h_usb_spi) == 1:
    spi_bus_num = 3
    spi_gpio_irq = 500
    if int(hif_speed) > 15000000:
        hif_speed = 15000000        # 15MHz / n (0 < n <= 65535)
    if int(spi_cs_num) != 0:         #
        spi_cs_num = 0              # one chipselect
    if int(spi_gpio_poll) < 0:      #
        spi_gpio_poll = 30          # 30 msec
################################################################################
```

ft232h_usb_spi	Parameter	Default Value
0 (off)	hif_speed	20,000,000 (Hz)
	spi_bus_num	0
	spi_cs_num	0
	spi_gpio_irq	5
	spi_gpio_poll	-1
1 (on)	hif_speed	15,000,000 (Hz)
	spi_bus_num	3
	spi_cs_num	0
	spi_gpio_irq	500
	spi_gpio_poll	30 (msec)

Table 4.2 FT232H and SPI related parameters

```
$ cd ~/nrc_pkg/script
$ vim start.py
```

Set ft232h_usb_spi to 1.

Change the following parameters if necessary.

- hif_speed
- spi_bus_num
- spi_gpio_irq.
- spi_gpio_poll

NOTE:

The SPI clock frequency supported by the FT232H is up 450KHz to 30MHz as (30MHz / n) division, while n is 1 to 65535. So, the supported SPI clock is 30, 15, 10, 7.5, 6, 4.29, 3.75MHz and so on. However, 30 MHz is not available for the NRC7292.

When running as an STA in open mode on US channel:

$ ./start.py 0 0 US

```
pi@raspberrypi:~/nrc_pkg/script $ ./start.py
Usage:
        start.py [sta_type] [security_mode] [country] [channel] [sniffer_mode]
Argument:
        sta_type      [0:STA   |  1:AP  |  2:SNIFFER  | 3:RELAY]
        security_mode [0:Open  |  1:WPA2-PSK  |  2:WPA3-OWE  |  3:WPA3-SAE]
        country       [US:USA  |  JP:Japan  |  TW:Taiwan  | KR:Korea | EU:EURO | CN:China]
        ------------------------------------------------------------
        channel       [S1G Channel Number]   * Only for Sniffer
        sniffer_mode  [0:Local | 1:Remote]   * Only for Sniffer
Example:
        OPEN mode STA for Korea                : ./start.py 0 0 KR
        Security mode AP for US                : ./start.py 1 1 US
        Local Sniffer mode on CH 40 for Japan  : ./start.py 2 0 JP 40 0
Note:
        sniffer_mode should be set as '1' when running sniffer on remote terminal
```

For more information, refer to the **UG-7292-001-EVK User Guide (Host Mode).pdf** file.

4.5 Removing the nrc7292 driver from the kernel.

$ cd ~/nrc_pkg/script

$ ./stop.py

4.6 Removing the spi-ft232h driver from the kernel.

$ cd ${FT232H_USB_SPI_SRC_TOP}

$ ./Rmmod.sh

```
pi@raspberrypi:~/ft232h-usb-spi $ ./Rmmod.sh
export  gpiochip0  gpiochip100  gpiochip128  unexport
spi0
```

5 Revision history

Revision No	Date	Comments
Ver 1.0	08/31/2021	Initial version