RX Family

RSPI Module Using Firmware Integration Technology

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Introduction

The RX family MCUs supported by this module have up to three channels of Serial Peripheral Interface (RSPI). RSPI is capable of high-speed, full-duplex synchronous serial communications with multiple processors and peripheral devices

This document covers the RSPI Module Using Firmware Integration Technology (FIT) for the supported RX family MCUs. Details are provided that describe the RSPI driver's architecture, integration of the FIT module into a user's application, and how to use the API.

Target Device

The following is a list of devices that are currently supported by this API:

- **RX110 Group**
- **RX111 Group**
- **RX210 Group**
- **RX63N Group**

When using this application note with other Renesas MCUs, careful evaluation is recommended after making modifications to comply with the alternate MCU.

Related Documents

- Firmware Integration Technology User's Manual (R01AN1833EU0100)
- Board Support Package Module Using Firmware Integration Technology (R01AN1685EU0250)
- Adding Firmware Integration Technology Modules to Projects (R01AN1723EU0110)

Contents

1. Overview

This software provides an applications programing interface (API) to prepare the RSPI peripheral for operation and for performing data transfers over the SPI bus.

The RSPI Driver module fits between the user application and the physical hardware to take care of the low-level hardware control tasks that manage the RSPI peripheral.

It is recommended to review the RSPI peripheral chapter in the RX MCU hardware user's manual before using this software.

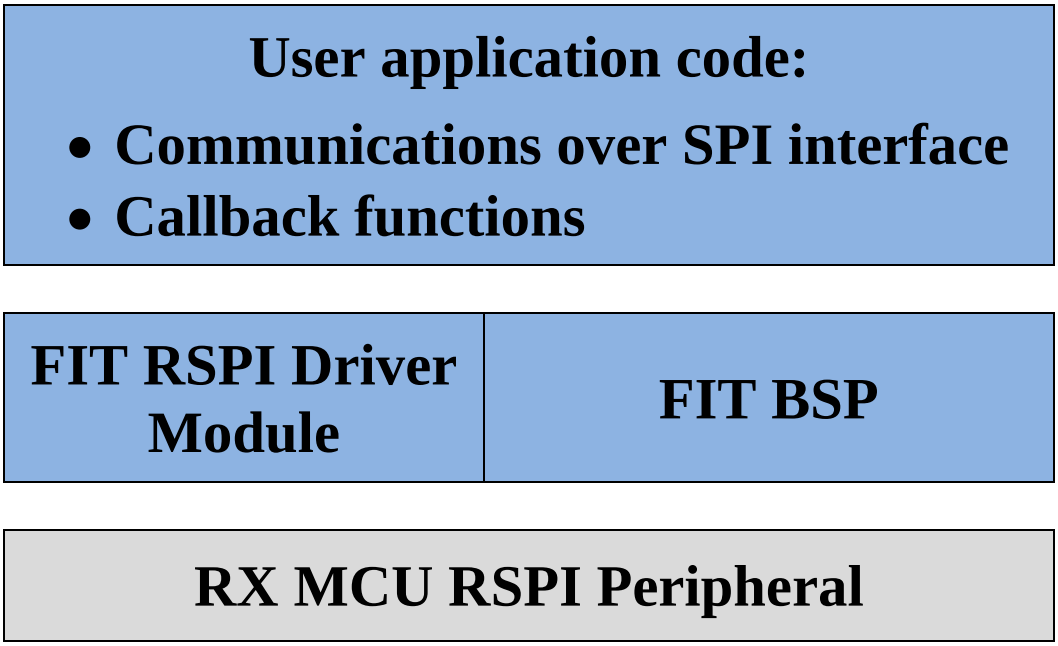

Figure 1 : Example Figure Showing Project Layers

1.1 Using the FIT RSPI Driver module

After adding the RSPI driver module to your project you will need to modify the *r_rspi_rx_config.h* file to configure the software for your installation. See Section 2.9 for details on configuration options.

Control registers for input and output signal pins to be used for RSPI must be correctly set up before the RSPI peripheral can operate with them. The RSPI module does not provide any means to initialize the pin registers--that needs to be done externally prior to calling RSPI API functions. Typically this would be accomplished at system startup time as part of a general pin initialization routine.

With the I/O ports having been set up previously, the first step in using an RSPI channel at run time is to call the R_RSPI_Open() function, passing the required settings and parameters. On completion, the RSPI channel will be active and ready to perform all other functions available in this API. SPI Data transfer operations may be used at this time, or various control operations may be performed to change settings.

The most commonly used settings are applied at the call to R_RSPI_Open(). Default settings are applied that satisfy most requirements. For some of these settings to be changed later during run-time, the R_RSPI_Close() function must be called so that R_RSPI_Open() can be called again with new settings.

Three commands are provided in the R_RSPI_Control() function:

- Change the base bit-clock rate.
- Immediately abort a transfer operation.
- Set various registers in the RSPI in a single command.

When data transfers are performed over the SPI bus the driver informs the user’s application of the completion status by calling the user-provided callback function.

Most of the RSPI API functions will require a 'handle' argument. This is used to identify the RSPI channel number that is selected for the operation. A handle is obtained by first calling the R_RSPI_Open() function. You must provide the address of a location where you will store the handle to R_RSPI_Open(), and on completion the handle will be available for use. Thereafter, simply pass the provided handle value for that RSPI channel number to the other API functions when calling them. In your application you will need to keep track of which handle belongs to a given channel, as each channel will be assigned its own handle.

2. API Information

This Driver API follows the Renesas API naming standards.

2.1 Hardware Requirements

This driver requires your MCU support the following features:

- One or more available RSPI peripheral channels.

2.2 Hardware Resource Requirements

This section details the hardware peripherals that this driver requires. Unless explicitly stated, these resources must be reserved for the driver and the user cannot use them independently.

RSPI.

2.3 Software Requirements

This driver is dependent upon the support from the following software:

- This software depends on a FIT compliant BSP module being present. It assumes that the related I/O ports have been correctly initialized elsewhere prior to calling this software's API functions.
- This software requires that the peripheral clock (PCLKB) has been initialized by the BSP prior to calling the APIs of this module. The r_bsp macro ‘BSP_PCLKB_HZ’ is used by the driver for calculating bit-rate register settings. If the user modifies the PCLKB setting outside of the r_bsp module or the r_cgc module, then calculations on the bit rate will be invalid.

2.4 RSPI features Supported by Driver

This driver supports the following subset of the features available with the RSPI peripheral.

RSPI transfer functions:

- Use of MOSI (master out/slave in), MISO (master in/slave out), SSL (slave select), and RSPCK (RSPI clock) signals allows serial communications through SPI operation (four-wire method) or clock synchronous operation (three-wire method).
- Capable of serial communications in master/slave mode
- Switching of the polarity of the serial transfer clock
- Switching of the phase of the serial transfer clock

Data format:

- MSB-first/LSB-first selectable
- Transfer bit length is selectable as 8, 9, 10, 11, 12, 13, 14, 15, 16, 20, 24, or 32 bits.

Bit rate:

- In master mode, the on-chip baud rate generator generates RSPCK by frequency-dividing PCLK (Division ratio: 2 to 4096).
- In slave mode, the externally input clock is used as the serial clock (the maximum frequency is that of PCLK divided by 8).

Error detection:

- Mode fault error detection

- Overrun error detection
- Parity error detection

SSL control function:

- Four SSL signals (SSLn0 to SSLn3) for each channel
- In single-master mode: SSLn0 to SSLn3 signals are output.
- In slave mode: SSLn0 signal for input, selects the RSPI slave. SSLn1 to SSLn3 signals are unused.
- Controllable delay from SSL output assertion to RSPCK operation (RSPCK delay)

  Range: 1 to 8 RSPCK cycles (set in RSPCK-cycle units)
- Controllable delay from RSPCK stop to SSL output negation (SSL negation delay)

  Range: 1 to 8 RSPCK cycles (set in RSPCK-cycle units)
- Controllable wait for next-access SSL output assertion (next-access delay)

  Range: 1 to 8 RSPCK cycles (set in RSPCK-cycle units)
- Able to change SSL polarity

Control in master transfer:

- For each transfer operation, the following can be set:

  Slave select number, further division of base bit rate, SPI clock polarity/phase, transfer data bit-length, MSB/LSB-first, burst (holding SSL), SPI clock delay, slave select negation delay, and next-access delay

Interrupt sources:

- RSPI receive interrupt (receive buffer full)
- RSPI transmit interrupt (transmit buffer empty)
- RSPI error interrupt (mode fault, overrun, parity error)

2.5 RSPI Features not supported

- Due to 16-bit or 32-bit data register access restrictions of the RSPI peripheral, DTC support is fairly complicated for other size data. DTC transfers are not be supported by this driver.
- To conserve limited RAM resources of smaller memory MCUs, like the RX111, this driver requires that data buffers are not statically allocated by the driver, but rather must be allocated by the user application at a higher level. This gives the application the control of how to allocate RAM.
- Only single-sequence data transfers are supported. The multi-command-sequence data transfer features of the RSPI peripheral are not supported by this driver.
- Only single-frame data transfers are supported by this driver. The multi-frame features of the RSPI peripheral are not supported. This means that the maximum supported data frame size is 32-bits.
- Multi-master mode is not supported.

2.6 Supported Toolchains

This driver is tested and working with the following toolchains:

- Renesas RX Compiler Toolchain v1.02

2.7 Header Files

All API calls are accessed by including a single file "r_rspi_rx_if.h" which is supplied with this software's project code.

Build-time configuration options are selected or defined in the file "r_rspi_rx_config.h"

2.8 Integer Types

If your toolchain supports C99 then *stdint.h* should be described as shown below. If not, then there should be *typedefs.h* file that is included with your project as defined by the Renesas Coding Standards document.

This project uses ANSI C99 "Exact width integer types" in order to make the code clearer and more portable. These types are defined in *stdint.h*.

2.9 Configuration Overview

Some features or behavior of the software are determined at build-time by configuration options that the user must select.

Configuration options in *r_irq_rx_config.h*	
RSPI_CFG_REQUIRE_LOCK	If this is set to (1) then the RSPI driver will attempt to obtain the lock for the channel when performing certain operations to prevent concurrent access conflicts. .
RSPI_CFG_PARAM_CHECKING_ENABLE	Checking of arguments passed to RSPI API functions can be enabled or disabled. Disabling argument checking is provided for systems that absolutely require faster and smaller code. By default the module is configured to use the setting of the system-wide BSP_CFG_PARAM_CHECKING_ENABLE macro. This can be locally overridden for the RSPI module by redefining RSPI_CFG_PARAM_CHECKING_ENABLE. To control parameter checking locally, set RSPI_CFG_PARAM_CHECKING_ENABLE to 1 to enable it, otherwise set to 0 skip checking.
RSPI_CFG_DUMMY_TXDATA	The user-specified Dummy Data to be transmitted during receive-only operations.
RSPI_CFG_USE_CHANn	Enable the RSPI channels to use at build-time. (0) = not used. (1) = used.
RSPI_CFG_IR_PRIORITY_CHANn	Sets the shared interrupt priority for the channel. This is provided as a convenience. Priority can still be changed outside of this module at run time *after* a call to R_RSPI_Open has been made to a channel. However the next call to R_RSPI_Open for that channel will change it back to this configuration value.
RSPI_CFG_USE_RX63_ERROR_INTERRUPT	For RX63 Group MCUs the RSPI error interrupt is a group interrupt shared with the SCI peripheral. So the error interrupt is disabled by default for RX63 Group to prevent conflict with SCI FIT module. However, If not using the SCI FIT module, this may be enabled by setting RSPI_CFG_USE_RX63_ERROR_INTERRUPT to (1).
RSPI_CFG_MASK_UNUSED_BITS	When reading the RSPI received data register for data frame bit lengths that are not 8, 16, or 32-bits the unused upper bit will contain residual values from the transmit data. As a convenience, these unused upper bits may be optionally masked off (cleared to 0) by the driver when the data is transferred to the user-data buffer. Since this takes additional processing time in the data transfer interrupt handler it will cause a reduction in performance for the highest bit rate settings. This is not needed for 8, 16, or 32-bit transfers. So only enable this option when using data frame bit lengths that are not 8, 16, or 32-bits. (0) = do not clear. (1) = clear unused upper bits.

Table 1 : List of RSPI driver module configuration options

2.10 API Data Structures

This section details the data structures that are used with the driver's API functions.

2.10.1 Special Data Types

To provide strong type checking and reduce errors, many parameters used in API functions require arguments to be passed using the provided type definitions. Allowable values are defined in the public interface file *r_rspi_rx_if.h*. The following special types have been defined:

Enumeration of SPI bus interface modes

Type: rspi_interface_mode_t

Values: RSPI_IF_MODE_3WIRE // Use GPIO for slave select.

RSPI_IF_MODE_4WIRE // Use slave select signals controlled by RSPI.

Enumeration of master or slave operating mode configuration settings

Type: rspi_master_slave_mode_t

Values: RSPI_MS_MODE_MASTER // Channel operates as SPI master.

RSPI_MS_MODE_SLAVE // Channel operates as SPI slave

RSPI control command codes

Type: irq_cmd_t

Values: RSPI_CMD_SET_BAUD // Use to set the base SPI clock bit-rate

RSPI_CMD_ABORT // Stop the current read or write operation immediately.

RSPI_CMD_SETREGS // Set additional RSPI regs in one operation. (Advanced use)

RSPI control command data structures

See R_RSPI_ Control() chapter.

Handle

Type: rspi_handle_t

Values: User allocates storage for this type for a handle. The address of this location must be passed in the call to the R_RSPI_Open function. The handle value is automatically assigned by R_RSPI_Open function and returned in the location specified.

Channel Settings structure for Open

The R_RSPI_Open() function requires a pointer to an initialized instance of this structure to set certain operating modes at the channel open.

Type: rspi_chnl_settings_t

Members: rspi_interface_mode_t gpio_ssl; // Specify the interface mode.

rspi_master_slave_mode_t master_slave_mode; // Specify master or slave mode operation.

uint32_t bps_target; // The target bits per second setting for the channel.

Callback function data structure

The channel number and the procedure result code are passed in this data structure to the user defined callback function.

Type: rspi_callback_data_t

Members: rspi_handle_t handle; // The channel handle.

rspi_evt_t event_code; // The event code.

2.11 Typedef enumerations used for the command settings word

This list contains the enumerated types available for specific settings of the command word for write and read operations. The command word is a 16-bit value that is a collection of bitfields. This word will get copied to the SPCMD register for each call to one of the read or write functions. To build a complete command word select one and only one member from each type and assign it to the corresponding member in the rspi_command_word_t structure.

Clock phase

The combination of the CPHA (clock phase) and CPOL (clock resting polarity) determine the "SPI mode setting"

Note: For slave-mode operation RSPI only supports sampling on even edge. This corresponds to what is sometimes referred to as SPI Mode-1, or Mode-3.

Type: rspi_spcmd_cpha_t

Members:
- RSPI_SPCMD_CPHA_SAMPLE_ODD // Data sampling on odd edge, data variation on even edge.
- RSPI_SPCMD_CPHA_SAMPLE_EVEN // Data variation on odd edge, data sampling on even edge.

Clock polarity

Type: rspi_spcmd_cpol_t

Members:
- RSPI_SPCMD_CPOL_IDLE_LO // RSPCK is low when idle.
- RSPI_SPCMD_CPOL_IDLE_HI // RSPCK is high when idle.

Clock base rate division

The SPI clock base bit rate setting will be further divided by this.

Type: rspi_spcmd_br_div_t

Members:
- RSPI_SPCMD_BR_DIV_1 // Select the base bit rate
- RSPI_SPCMD_BR_DIV_2 // Select the base bit rate divided by 2
- RSPI_SPCMD_BR_DIV_4 // Select the base bit rate divided by 4
- RSPI_SPCMD_BR_DIV_8 // Select the base bit rate divided by 8

Slave select to be asserted during transfer operation.

Type: rspi_spcmd_ssl_assert_t

Members:
- RSPI_SPCMD_ASSERT_SSL0 // Select SSL0
- RSPI_SPCMD_ASSERT_SSL1 // Select SSL1
- RSPI_SPCMD_ASSERT_SSL2 // Select SSL2
- RSPI_SPCMD_ASSERT_SSL3 // Select SSL3

Slave select negation.

This bit determines whether the RSPI will deassert the slave select signal after each frame, or keep it asserted.

Type: rspi_spcmd_ssl_negation_t

Members:
- RSPI_SPCMD_SSL_NEGATE // Negates all SSL signals upon completion of transfer.
- RSPI_SSPCMD_SL_KEEP // Keep SSL signal level from end of transfer until start of next.

Frame data length

The number of bits in each SPI data frame.

Type: rspi_spcmd_bit_length_t

Members:
- RSPI_SPCMD_BIT_LENGTH_8 // 8 bits data length
- RSPI_SPCMD_BIT_LENGTH_9 // 9 bits data length
- RSPI_SPCMD_BIT_LENGTH_10 // 10 bits data length
- RSPI_SPCMD_BIT_LENGTH_11 // 11 bits data length
- RSPI_SPCMD_BIT_LENGTH_12 // 12 bits data length
- RSPI_SPCMD_BIT_LENGTH_13 // 13 bits data length
- RSPI_SPCMD_BIT_LENGTH_14 // 14 bits data length
- RSPI_SPCMD_BIT_LENGTH_15 // 15 bits data length
- RSPI_SPCMD_BIT_LENGTH_16 // 16 bits data length
- RSPI_SPCMD_BIT_LENGTH_20 // 20 bits data length
- RSPI_SPCMD_BIT_LENGTH_24 // 24 bits data length
- RSPI_SPCMD_BIT_LENGTH_32 // 32 bits data length

Data transfer bit order.

Type: rspi_spcmd_bit_order_t

Members:		
	RSPI_SPCMD_ORDER_MSB_FIRST	// MSB first.
	RSPI_SPCMD_ORDER_LSB_FIRST	// LSB first.

RSPI signal delays

Type: rspi_spcmd_spnden_t

Members:		
	RSPI_SPCMD_NEXT_DLY_1	// A next-access delay of 1 RSPCK +2 PCLK.
	RSPI_SPCMD_NEXT_DLY_SSLND	// Next-access delay = next access delay register (SPND)

Type: rspi_spcmd_slnden_t

Members:		
	RSPI_SPCMD_SSL_NEG_DLY_1	// An SSL negation delay of 1 RSPCK.
	RSPI_SPCMD_SSL_NEG_DLY_SSLND	// Delay = SSL negation delay register (SSLND)

Type: rspi_spcmd_sckden_t

Members:		
	RSPI_SPCMD_CLK_DLY_1	// An RSPCK delay of 1 RSPCK.
	RSPI_SPCMD_CLK_DLY_SPCKD	// Delay = setting of RSPI clock delay register (SPCKD).

2.11.1 Complete command word data structure.

This contains one of each of the above types in the correct order to set all the bits of the SPCMD register.

```
#pragma bit_order right      // Match the order of description in the hardware manual.
typedef struct rspi_command_word_s
{
    union {
        struct{
            rspi_spcmd_cpha_t          cpha          :1;
            rspi_spcmd_cpol_t          cpol          :1;
            rspi_spcmd_br_div_t        br_div        :2;
            rspi_spcmd_ssl_assert_t    ssl_assert    :3;
            rspi_spcmd_ssl_negation_t  ssl_negate    :1;
            rspi_spcmd_bit_length_t    bit_length    :4;
            rspi_spcmd_bit_order_t     bit_order     :1;
            rspi_spcmd_spnden_t        next_delay    :1;
            rspi_spcmd_slnden_t        ssl_neg_delay :1;
            rspi_spcmd_sckden_t        clock_delay   :1;
        };
        uint16_t word;
    };
} rspi_command_word_t;
```

Example instance of command word initialization

```
static const rspi_command_word_t my_command_reg_word = {
        RSPI_SPCMD_CPHA_SAMPLE_ODD,
        RSPI_SPCMD_CPOL_IDLE_LO,
        RSPI_SPCMD_BR_DIV_1,
        RSPI_SPCMD_ASSERT_SSL0,
        RSPI_SPCMD_SSL_KEEP,
        RSPI_SPCMD_BIT_LENGTH_8,
        RSPI_SPCMD_ORDER_MSB_FIRST,
        RSPI_SPCMD_NEXT_DLY_SSLND,
        RSPI_SPCMD_SSL_NEG_DLY_SSLND,
        RSPI_SPCMD_CLK_DLY_SPCKD,
};
```

2.12 Return Values

The different values API functions can return.

Return Type: rspi_err_t

Values:	Cause
RSPI_SUCCESS	Function completed without errors
RSPI_ERR_BAD_CHAN	Invalid channel number
RSPI_ERR_CH_NOT_OPENED	Channel not yet opened. Function can not be completed.
RSPI_ERR_CH_NOT_CLOSED	Channel still open from previous open.
RSPI_ERR_UNKNOWN_CMD	Control command is not recognized.
RSPI_ERR_INVALID_ARG	Argument is not valid for parameter.
RSPI_ERR_ARG_RANGE	Argument is out of range for parameter.
RSPI_ERR_NULL_PTR	Received null pointer; missing required argument.
RSPI_ERR_LOCK	A lock procedure failed
RSPI_ERR_UNDEF	Undefined/unknown error

2.13 Event Codes

The different codes returned by API events.

Return Type: rspi_evt_t

Values:	Cause
RSPI_EVT_TRANSFER_COMPLETE	The data transfer completed.
RSPI_EVT_TRANSFER_ABORTED	The data transfer was aborted.
RSPI_EVT_ERR_MODE_FAULT	Mode fault error.
RSPI_EVT_ERR_READ_OVF	Read overflow.
RSPI_EVT_ERR_PARITY	Parity error.
RSPI_EVT_ERR_UNDEF	Undefined/unknown error event.

2.14 Adding the RSPI Driver FIT Module to Your Project

The driver must be added to an existing e2Studio project. It is best to use the e2Studio FIT plugin to add the driver to your project as that will automatically update the include file paths for you. Alternatively, the driver can be imported from the archive that accompanies this application note and manually added by following these steps:

1. This application note is distributed with a zip file package that includes the FIT RSPI driver module in its own folder *r_rspi_rx*.
2. Unzip the package into the location of your choice.
3. In a file browser window, browse to the directory where you unzipped the distribution package and locate the *r_rspi_rx* folder
4. Open your e2Studio workspace.
5. In the e2Studio project explorer window, select the project that you want to add the RSPI module to.
6. Drag and drop the *r_rspi_rx* folder from the browser window (or copy/paste) into your e2Studio project at the top level of the project.
7. Update the source search/include paths for your project by adding the paths to the module files:
    a. Navigate to the "Add directory path" control:

        'project name'->properties->C/C++ Build->Settings->Compiler->Source -Add (green + icon)

    b. Add the following paths:

        "${workspace_loc:/${ProjName}/r_rspi_rx}"

"${workspace_loc:/${ProjName}/r_rspi_rx/src}"

8. Locate the *r_rspi_rx_config_reference.h* file in the *r_rspi_rx/ref/* source folder in your project and copy it to your project's *r_config* folder.
9. Change the name of the copy in the r_config folder to *r_rspi_rx_config.h*

10. Whether you used the plug-in or manually added the package to your project, it is necessary to configure the driver for your application.
    a. Make the required configuration settings by editing the copied *r_rspi_rx_config.h* file. See Configuration Overview.

The RSPI driver module uses the *r_bsp* package for certain MCU information and support functions The r_bsp package is easily configured through the *platform.h* header file which is located in the r_bsp folder. To configure the r_bsp package, open up *platform.h* and uncomment the #include for the board you are using.

3. Port Configuration

3.1 System Initialization

RSPI I/O signals may be optionally assigned to different I/O ports. The initialization of the Multi-function Pin Controller (MPC) and the PORT registers must be handled by the application, either through calls to the FIT MPC module, or directly. This initialization must be performed before a call is made to the driver Open function. A sample of direct initialization for the RSK-RX111 channel 0 is provided here:

```
/* Using GPIO to control the slave select signal (Synchronous 3-wire mode). */
PORTA.PODR.BIT.B4  = 1;    /* Set GPIO slave select pin to de-selected level. */
PORTA.PDR.BIT.B4   = 1;    /* Set as output. */

/* Set pins that will be used for RSPI to a safe state before switching over */
PORTA.PODR.BYTE &= 0xB7 ;  /* Clear data for RSPI port bits */
PORTB.PODR.BYTE &= 0xFE ;
PORTA.PMR.BYTE  &= 0xB7 ;  /* RSPI port bits GPIO for now */
PORTB.PMR.BYTE  &= 0xFE ;

/* Use BSP function to enable writing to MPC registers. */
R_BSP_RegisterProtectDisable(BSP_REG_PROTECT_MPC);

/* Make the RSPI peripheral signal assignment selections in the MPC registers. */
MPC.PB0PFS.BYTE = 0x0D ;   /* PB0 is RSPCKA */
MPC.PA6PFS.BYTE = 0x0D ;   /* PA6 is MOSIA */
MPC.PA3PFS.BYTE = 0x0D ;   /* PC7 is MISOA */

/* Use BSP function to prevent writing to MPC registers. */
R_BSP_RegisterProtectEnable(BSP_REG_PROTECT_MPC);

/* Switch over pin control to the RSPI peripheral. */
PORTA.PMR.BYTE  |= 0x48 ;    /* PA3, PA6 assigned to SPI peripheral */
PORTB.PMR.BYTE  |= 0x01 ;    /* PB0 assigned to SPI peripheral */
```

4. Driver Architecture

4.1 System Examples

The driver supports single-master/multi-slave mode operation, or slave-mode operation. Each RSPI channel controls one SPI bus. Multiple-master operation on the same bus is not supported in this driver. An example of a single master connected to multiple slaves on one SPI bus is shown.

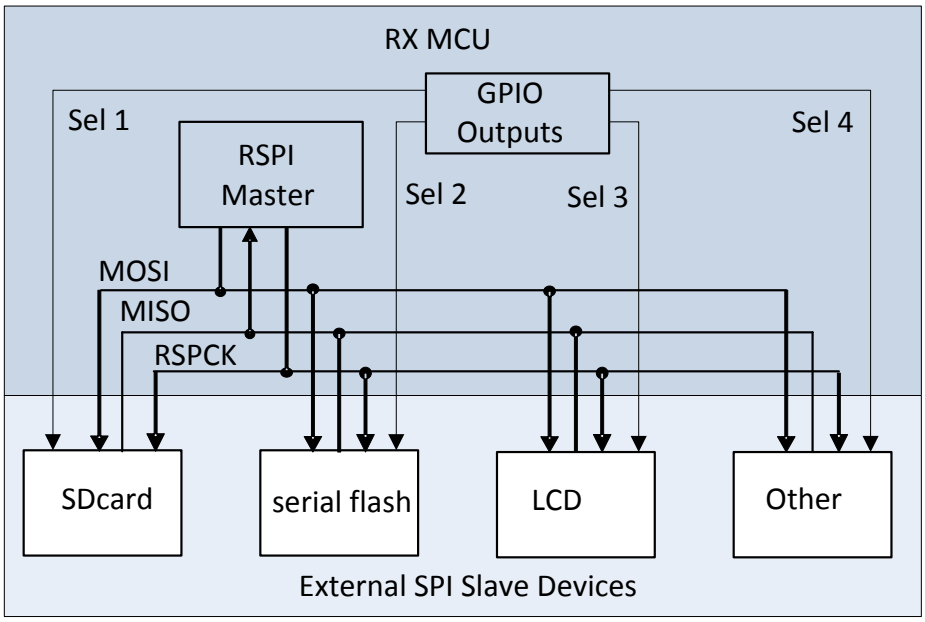

Figure 2. This example shows the use of GPIO ports to serve as the slave select signals (3-Wire mode).

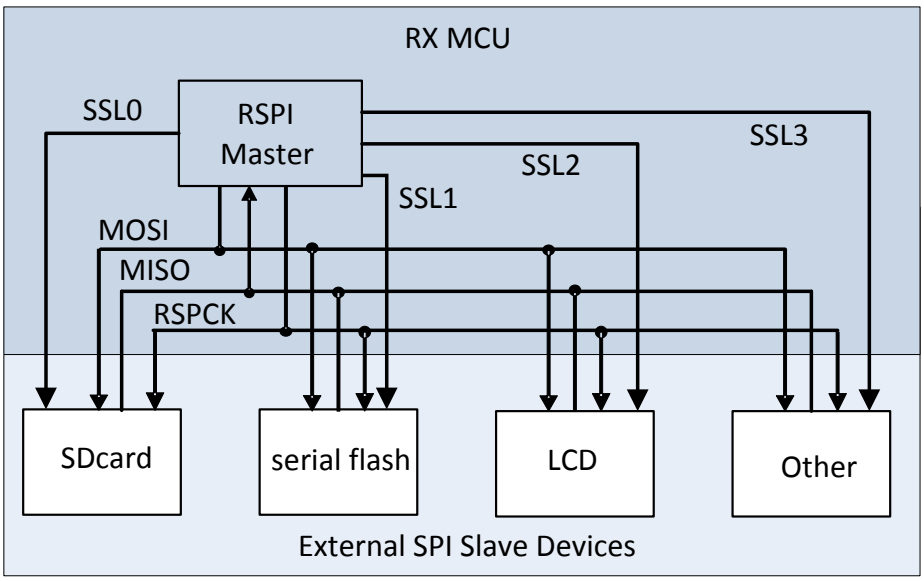

Figure 3. The built-in RSPI peripheral slave select hardware (SSL) may be used to generate the signals (SPI 4-Wire mode).

4.2 Multi-Channel RSPI Support

For supported RX family MCUs that have multiple channels of RSPI available, this driver will operate all available channels on an individually selectable basis with the same body of code. Each channel can be configured with its own setup independently of the other channels in use.

5. Data transfer operations

The RSPI driver provides three data transfer functions available for both master and slave mode operation; Write, Read, Write/Read (full duplex). All write and read operations are performed with the RSPI configured for full-duplex mode. All write and read operations are done in a non-blocking fashion where the call to the write or read function sets up the transfer then returns. The function returns as soon as the operation has been successfully initialized, or there is an error.

If locking has been enabled by the configuration option, the RSPI channel will be locked for the duration of the operation. After that, the remainder of the transfer operation is performed within RSPI interrupt handler routines.

An RSPI Transmit buffer empty interrupt (SPTI) ISR is implemented to perform the first transmit operation. When the first one or two SPTI interrupts occur (depending on Master-mode or Slave-mode respectively), the SPTI ISR disables further SPTI interrupts. After that the remaining transfer operation is processed through the receive buffer full interrupt (SPRI). This interrupt indicates that a complete frame of data has been received by RSPI, and that a complete frame has been clocked out.

SPTI and SPRI interrupts both call a common handler routine for all channels. The first time through, receive data can never be valid because nothing has been clocked out yet – it is just placing the first data into the transmit buffer. So, the receive data buffer is read to clear it and the data is discarded. Additionally, slave mode double buffers the slave transmit data so that back-to-back frames clocked by the master will not starve the slave's transmit shift register. In this case the SPTI interrupt will be entered twice before the SPRI interrupt takes over. The transfer process ends when the SPRI ISR is entered after the final data has been transferred.

When the specified number of frames has been transferred, the ISR terminates the operation, disables the RSPI channel and its interrupts, then calls the user-defined callback function to alert the application that it is done. If locking has been enabled then the channel is unlocked at this time.

5.1.1 Transmitting data from RSPI

In Master mode, data is written by the RSPI Master on the MOSI (master out, slave in) line. In Slave mode, data is written by the RSPI Slave on the MISO (master in, slave out) line. Since all data transfer operations are internally performed in full duplex mode, when only transmitting the RSPI driver will read the receive data register to clear it, but will discard the result. Data to be transmitted is be read from a buffer location pointed to by the user application, and it is copied to the RSPI transmit data register after being type-casted for the data type specified by the current operation.

5.1.2 RSPI Master receiving data from a SPI Slave

Data is received by the RSPI Master on the MISO (master in, slave out) line. With the RSPI peripheral configured as SPI bus Master, it is set for full-duplex operation in order to receive data from a slave device on the SPI bus. This requires the RSPI Master to output clocks to the Slave. Clocks are output only when the RSPI Master is sending data. Therefore, in order to read data from the SPI bus, the master must also simultaneously write data. This can either be actual data that needs to be transmitted (if the slave is capable of full-duplex communication), or it can be dummy data that is ignored by the slave. In this driver implementation the read data is clocked by dummy writes of a user definable data pattern.

5.1.3 RSPI Slave write to SPI Master

The Slave-mode write operation is nearly the same as the master-mode except that, after setting up for transmission, the slave waits for clocks from a master SPI device. Additionally, slave mode double buffers the slave transmit data so that back-to-back frames clocked by the master will not starve the slave's transmit shift register.

If not reading while writing, the read data register is cleared after every frame is transmitted. The transmit operation will terminate when the requested number of frames has been transmitted, or until aborted by user command.

5.1.4 RSPI Slave read from SPI Master

The Slave-mode read operation is exactly the same as the master-mode except that, after setting up for reception, the slave waits for clocks from a master SPI device. If not also transmitting valid data while receiving, the transmit data register is filled with a user definable dummy data pattern. The read operation will terminate when the requested number of frames has been received, or until aborted by user command.

5.2 Interrupts

5.2.1 Data transfer interrupts

The RSPI driver transmit and receive operations are performed in a non-blocking fashion; data transfer operations are carried out on an event driven basis with interrupt service routines. The RSPI Transmit Buffer Empty (SPTI), and Receive Buffer Full (SPRI) interrupts are used to call a common read/write function that performs a single frame receive and/or transmit procedure, depending on the state.

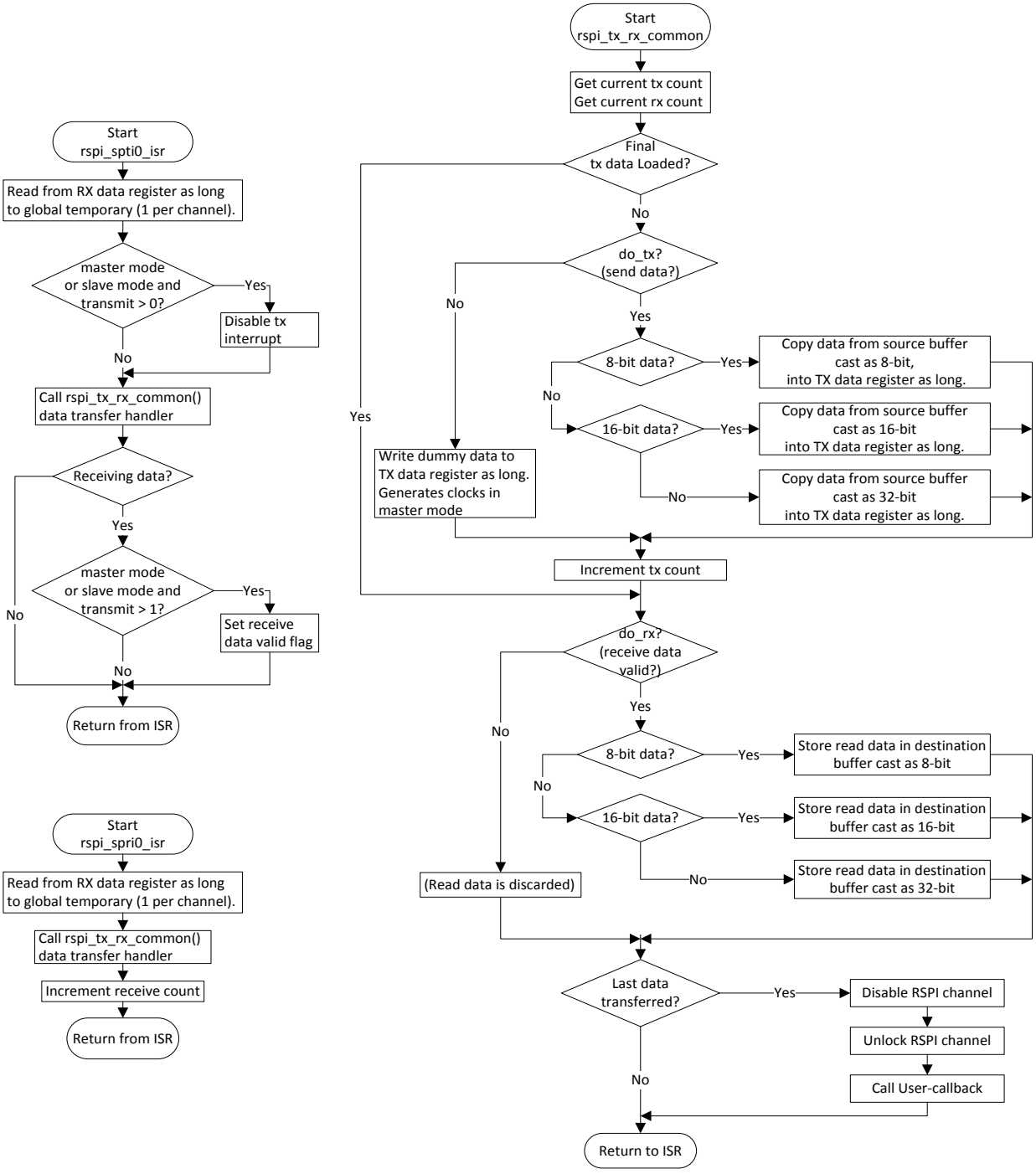

Figure 4. Common data transfer interrupt handler algorithm.

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5.2.2 Error interrupts

The RSPI Error interrupts (SPEI) are used to call a common handler function that reads the status register to determine the interrupt cause. Further processing of the data transfer operation is halted and the callback function is called.

5.3 Callback Functions

The definition of callbacks follows the FIT 1.0 specification rules:

a. Callback functions take one argument. This argument is 'void * pdata'.

b. Before calling a callback function the function pointer is be checked to be valid. At a minimum the pointer is be checked to be:

i. Non-null

ii. Not equal to FIT_NO_FUNC macro.

5.3.1 Example callback function prototype declaration.

```
void callback(void * pdata)
```

5.3.2 Invocation of Callback functions

At the conclusion of every transfer operation the user defined callback will be called. This will occur within the context of the interrupt handler that processed the transfer operation. Any error condition that generates an interrupt, most typically the receive-overrun error, will also call the callback. A pointer to a data structure containing the channel number and result code of the interrupt that calls the callback are be passed as the only argument. It is up to the user application to process the provided information appropriately. Since callbacks are being processed within the context of the interrupt, and interrupts are disabled at this time, it is strongly recommended that the user-defined callback function complete as quickly as possible to avoid missing further system interrupts.

The most typical use of the callback function is to inform the application that the data transfer has completed. This may be done by setting a "busy" flag just before starting the transfer, and then clearing the busy flag within the callback. When used in RTOS environments, then a semophore or other flag or message service provided by the OS may be used within the callback.

Example transfer start:

```
/* Conditions: Channel currently open. */
g_transfer_complete = false;
rspi_result = R_RSPI_WriteRead(handle, my_command_word, source, dest, length);
if (RSPI_SUCCESS != rspi_result)
{
    return error;
}

while (!g_transfer_complete) // Poll for interrupt callback to set this.
{
    nop();// Do something useful while waiting for the transfer to complete.
}
```

Example callback function:

```
void my_callback(void * pdata)
{
    /* Examine the event to check for abnormal termination of transfer. */
    g_test_callback_event = (*(rspi_callback_data_t *)pdata).event_code;

    g_transfer_complete = true;
}
```

6. API Functions

6.1 Summary

The following functions are included in this design:

Function	Description
R_RSPI_Open ()	Initializes the associated registers required for to prepare the specified RSPI channel for use, provides the handle for use with other API functions. Takes a callback function pointer for responding to interrupt events.
R_ RSPI_Close()	Disables the specified RSPI channel.
R_RSPI_Control()	Handles special hardware or software operations for the RSPI channel .
R_RSPI_Write()	The Write function transmits data to a SPI master or slave device..
R_RSPI_Read()	The Read function receives data from a SPI master or slave device.
R_RSPI_WriteRead()	The Write Read function simultaneously transmits data to a SPI master or slave device while receiving data from that device (full duplex).
R_RSPI_GetVersion()	Returns the driver version number.

6.2 R_RSPI_Open()

This function applies power to the RSPI channel, initializes the associated registers, enables interrupts, and provides the channel handle for use with other API functions.

Format

```
rspi_err_t   R_RSPI_Open(uint8_t                channel,
                         rspi_chnl_settings_t  *pconfig,
                         void                 (*pcallback)(void *pcbdat),
                         rspi_handle_t         *phandle);
```

Parameters

channel

Number of the RSPI channel to be initialized

pconfig

Pointer to RSPI channel configuration data structure.

pcallback

Pointer to user defined function called from interrupt.

phandle

Pointer to a handle for channel. Handle value will be set by this function

Return Values

RSPI_SUCCESS:	*Successful; channel initialized*
RSPI_ERR_BAD_CHAN:	*Channel number is not available*
RSPI_ERR_CH_NOT_CLOSED:	*Channel currently in operation; Perform R_RSPI_Close() first*
RSPI_ERR_NULL_PTR:	*pconfig pointer or phandle pointer is NULL*
RSPI_ERR_INVALID_ARG:	*An element of the pconfig structure contains an invalid value.*
RSPI_ERR_LOCK:	*The lock could not be acquired.*

Properties

Prototyped in file “r_rspi_rx_if.h”

Description

The Open function is responsible for preparing an RSPI channel for operation. This function must be called once prior to calling any other RSPI API functions (except R_RSPI_GetVersion). Once successfully completed, the status of the selected RSPI will be set to "open". After that this function should not be called again for the same RSPI channel without first performing a "close" by calling R_RSPI_Close().

Reentrant

Yes. Reentrance for different channel OK. Reentrance for the same channel will result in a ‘Lock error’ return.

Example

```
/* Conditions: Channel not yet open. */
uint8_t chan = 0;
rspi_handle_t handle;
rspi_chnl_settings_t my_config;
rspi_cmd_baud_t my_setbaud_struct;
rspi_err_t rspi_result;

my_config.gpio_ssl          = RSPI_4WIRE_MODE;
my_config.master_slave_mode = RSPI_MASTER_MODE;
my_config.bps_target        = 4000000; // Bit rate in bits-per-second.

rspi_result = R_RSPI_Open(chan, &my_config, &test_callback, &handle );

if (RSPI_SUCCESS != rspi_result)
{
    return rspi_result;
}
```

6.3 R_RSPI_ Control()

The Control function is responsible for handling special hardware or software operations for the RSPI channel.

Format

```
rspi_err_t     R_RSPI_Control(rspi_handle_t  handle,
                              rspi_cmd_t     cmd,
                              void          *pcmd_data);
```

Parameters

handle

Handle for the channel

cmd

Enumerated command code.

Available command codes:

RSPI_CMD_SET_BAUD // Change the base bit rate setting without reinitializing the RSPI channel.

RSPI_CMD_ABORT, // Stop the current read or write operation immediately.

RSPI_CMD_SETREGS, // Set all supported RSPI regs in one operation. Expert use only!

pcmd_data

Pointer to the command-data structure parameter of type void that is used to reference the location of any data specific to the command that is needed for its completion. Commands that do not require supporting data must use the FIT_NO_PTR

Return Values

RSPI_SUCCESS:	*Command successfully completed.*
RSPI_ERR_CH_NOT_OPEN:	*The channel has not been opened. Perform R_RSPI_Open() first*
RSPI_ERR_BAD_CHAN:	*Channel number is not available*
RSPI_ERR_UNKNOWN_CMD:	*Control command is not recognized.*
RSPI_ERR_NULL_PTR:	*pcmd_data pointer or phandle pointer is NULL*
RSPI_ERR_INVALID_ARG:	*An element of the pcmd_data structure contains an invalid value.*
RSPI_ERR_LOCK:	*The lock could not be acquired*

Properties

Prototyped in file “r_rspi_rx_if.h”

Description

This function is responsible for handling special hardware or software operations for the RSPI channel. It takes an RSPI handle to identify the selected RSPI, an enumerated command value to select the operation to be performed, and a void pointer to a location that contains information or data required to complete the operation. This pointer must point to storage that has been type-cast by the caller for the particular command using the appropriate type provided in "r_rspi_rx_if.h" .

Reentrant

Yes if locking is enabled. Reentrancy to operate on the same RSPI is rejected by BSP lock. If locking is disabled then reentrancy is only safe for operating on a different RSPI. If locking is enabled special care should be taken to prevent deadlock. Caller should check return value and should handle a locked return status by permitting the process owning the lock to complete.

Example

```
my_setbaud_struct.bps_target = 12000000; // Set for 12 Mbps
rspi_result = R_RSPI_Control(handle, RSPI_CMD_SET_BAUD,  &my_setbaud_struct);
if (RSPI_SUCCESS != rspi_result)
{
    return error;
}
/* This is taking too long, stop the current transfer now! */
rspi_result = R_RSPI_Control(handle, RSPI_CMD_ABORT,  FIT_NO_PTR);
```

Type defines used with the R_RSPI_Control function.

Control function command codes.

```
typedef enum rspi_cmd_e
{
    RSPI_CMD_SET_BAUD = 1,
    RSPI_CMD_ABORT,     // Stop the current read or write operation immediately.
    RSPI_CMD_SETREGS,   // Set all supported RSPI regs in one operation.
} rspi_cmd_t;
```

Data structure for the Set Baud command. This command sets the base-bit rate for the specified channel. The value specified in 'bps_target' may not be what actually gets set. The function will try to find a setting to match, but if the requested bit rate is not possible based on the divisor ratios available, then the function will set the next lower available bit-rate.

```
typedef struct rspi_cmd_baud_s
{
    uint32_t    bps_target;   // The target bits-per-second setting for the channel.
} rspi_cmd_baud_t;
```

Advanced use! Entries for use in setting RSPI registers that control operation. To be used with the R_RSPI_Control()-RSPI_CMD_SETREGS command. Values will be copied directly into the associated register when used. To use this with the RSPI_CMD_SETREGS command, user creates an instance of this with settings as required, and passes a pointer to it as an argument in the call to R_RSPI_Control().

```
typedef struct rspi_cmd_setregs_s
{
    uint8_t sslp_val;   // RSPI Slave Select Polarity Register (SSLP)
    uint8_t sppcr_val;  // RSPI Pin Control Register (SPPCR)
    uint8_t spckd_val;  // RSPI Clock Delay Register (SPCKD)
    uint8_t sslnd_val;  // RSPI Slave Select Negation Delay Register (SSLND)
    uint8_t spnd_val;   // RSPI Next-Access Delay Register (SPND)
    uint8_t spcr2_val;  // RSPI Control Register 2 (SPCR2)
} rspi_cmd_setregs_t;
```

Special Notes:

The RSPI_CMD_ABORT command requires no supporting data, so `FIT_NO_PTR` is used as the pcmd_data argument.

6.4 R_RSPI_Close()

Fully disables the RSPI channel designated by the handle.

Format

```
RSPI_err_t      R_RSPI_Close(rspi_handle_t handle);
```

Parameters

handle

Handle for the channel

Return Values

RSPI_SUCCESS:	*Successful; channel closed*
RSPI_ERR_CH_NOT_OPEN:	*The channel has not been opened so closing has no effect.*
RSPI_ERR_BAD_CHAN:	*Channel number is not available*
RSPI_ERR_NULL_PTR:	*A required pointer argument is NULL*

Properties

Prototyped in file “r_rspi_rx_if.h”

Description

This disables the RSPI channel designated by the handle.. The RSPI handle is modified to indicate that it is no longer in the 'open' state. The RSPI channel cannot be used again until it has been reopened with the R_RSPI_Open function. If this function is called for an RSPI that is not in the open state then an error code is returned.

Reentrant

Yes, however unintentional reentrancy for same RSPI channel may result in an unexpected RSPI_ERR_ NOT_OPEN return code.

Example

```
RSPI_err_t  rspi_result;

rspi_result = R_RSPI_Close(handle);

if (RSPI_SUCCESS != rspi_result)
{
    return rspi_result;
}
```

6.5 R_RSPI_ Write()

The Write function transmits data to the selected SPI device

Format

```
rspi_err_t     R_RSPI_Write(rspi_handle_t       handle,
                            rspi_command_word_t spcmd_command_word,
                            void               *psrc,
                            uint16_t            length);
```

Parameters

handle

Handle for the channel

command_word

Bitfield data consisting of all the RSPI command register settings for SPCMD for this operation. See: 2.11 Typedef enumerations used for the command settings word

psrc

Void type pointer to a source data buffer from which data will be transmitted to a SPI device. Based on the data frame bit-length specified in the command_word, the psrc pointer will be type cast to the corresponding data type during the transfer. So, for example, if the bit-length is set to 16-bits, then the source buffer data will be accessed as a block of 16-bit data, and so on for each bit-length setting. Bit-length settings that are not 8, 16 or 32 will use the data type that they can be contained within. For example, 24-bit frames will be stored in 32-bit storage, 11-bit frames will be stored in 16-bit storage, etc.

length

Transfer length variable to indicate the number of data frames to be transferred. The size of the data word is determined from settings in the command_word argument. Be sure that the length argument matches the storage type of the source data; this is a count of the number of frames, not the number of bytes.

Return Values

RSPI_SUCCESS:	*Write operation successfully completed.*
RSPI_ERR_CH_NOT_OPEN:	*The channel has not been opened. Perform R_RSPI_Open() first*
RSPI_ERR_BAD_CHAN:	*Channel number is not available*
RSPI_ERR_NULL_PTR:	*A required pointer argument is NULL*
RSPI_ERR_LOCK:	*The lock could not be acquired. The channel is busy.*

Properties

Prototyped in file “r_rspi_rx_if.h”

Description

Reentrant

Yes. Reentrance for different channel OK. Reentrance for the same channel will result in a ‘Lock error’ return.

Example

```
/* Conditions: Channel currently open. */
g_transfer_complete = false;

rspi_result = R_RSPI_Write(handle, my_command_word, source, length);
if (RSPI_SUCCESS != rspi_result)
{
   if (RSPI_ERR_LOCK == rspi_result)
   {
       // Channel must be busy. Try again later.
   }
   return error;
}
```

```
while (!g_transfer_complete) // Poll for interrupt callback to set this.
{
    nop(); // Do something useful while waiting for the transfer to complete.
}
```

6.6 R_RSPI_ Read()

The Read function receives data from the selected SPI device.

Format

```
rspi_err_t     R_RSPI_Read(rspi_handle_t        handle,
                           rspi_command_word_t  spcmd_command_word,
                           void                *pdest,
                           uint16_t             length);
```

Parameters

handle

Handle for the channel

command_word

Bitfield data consisting of all the RSPI command register settings for SPCMD for this operation. See: 2.11 Typedef enumerations used for the command settings word

pdest

Void type pointer to a destination buffer into which data will be copied that has been received from a SPI device. It is the responsibility of the caller to insure that adequate space is available to hold the requested data count. The argument must not be NULL. Based on the data frame bit-length specified in the command_word, the pdest pointer will be type cast to the corresponding data type during the transfer. So, for example, if the bit-length is set to 16-bits, then the data will be stored in the destination buffer as a 16-bit value, and so on for each bit-length setting. Bit-length settings that are not 8, 16 or 32 will use the smallest data type that they can be contained within. For example, 24-bit frames will be stored in 32-bit storage, 11-bit frames will be stored in 16-bit storage, etc.

length

Transfer length variable to indicate the number of data frames to be transferred. The size of the data word is determined from settings in the command_word argument. Be sure that the length argument matches the storage type of the source data; this is a count of the number of frames, not the number of bytes.

Return Values

RSPI_SUCCESS:	*Read operation successfully completed.*
RSPI_ERR_CH_NOT_OPEN:	*The channel has not been opened. Perform R_RSPI_Open() first*
RSPI_ERR_BAD_CHAN:	*Channel number is not available*
RSPI_ERR_NULL_PTR:	*A required pointer argument is NULL*
RSPI_ERR_LOCK:	*The lock could not be acquired. The channel is busy.*

Properties

Prototyped in file “r_rspi_rx_if.h”

Description

Reentrant

Yes. Reentrance for different channel OK. Reentrance for the same channel will result in a ‘Lock error’ return.

Example

```
/* Conditions: Channel currently open. */
g_transfer_complete = false;

rspi_result = R_RSPI_Read(handle, my_command_word, dest, length);
if (RSPI_SUCCESS != rspi_result)
{
   return error;
}

while (!g_transfer_complete) // Poll for interrupt callback to set this.
{
    nop(); // Do something useful while waiting for the transfer to complete.
}
```

6.7 R_RSPI_ WriteRead()

The Write Read function simultaneously transmits data to a SPI device while receiving data from a SPI device.

Format

```
rspi_err_t     R_RSPI_WriteRead(rspi_handle_t        handle,
                                rspi_command_word_t  spcmd_command_word,
                                void                *psrc,
                                void                *pdest,
                                uint16_t             length);
```

Parameters

handle

Handle for the channel

command_word

Bitfield data consisting of all the RSPI settings for the command register (SPCMD) for this operation. See: 2.11 Typedef enumerations used for the command settings word

psrc

Void type pointer to a source data buffer from which data will be transmitted to a SPI device. Based on the data frame bit-length specified in the command_word, the psrc pointer will be type cast to the corresponding data type during the transfer. So, for example, if the bit-length is set to 16-bits, then the source buffer data will be accessed as a block of 16-bit data, and so on for each bit-length setting. Bit-length settings that are not 8, 16 or 32 will use the data type that they can be contained within. For example, 24-bit frames will be stored in 32-bit storage, 11-bit frames will be stored in 16-bit storage, etc.

pdest

Void type pointer to a destination buffer into which data will be copied that has been received from a SPI device. It is the responsibility of the caller to insure that adequate space is available to hold the requested data count. The argument must not be NULL. Based on the data frame bit-length specified in the command_word, the pdest pointer will be type cast to the corresponding data type during the transfer. So, for example, if the bit-length is set to 16-bits, then the data will be stored in the destination buffer as a 16-bit value, and so on for each bit-length setting. Bit-length settings that are not 8, 16 or 32 will use the smallest data type that they can be contained within. For example, 24-bit frames will be stored in 32-bit storage, 11-bit frames will be stored in 16-bit storage, etc.

length

Transfer length variable to indicate the number of data frames to be transferred. The size of the data word is determined from settings in the command_word argument. Be sure that the length argument matches the storage type of the source data; this is a count of the number of frames, not the number of bytes. The same number of frames will be both written and read.

Return Values

RSPI_SUCCESS:	*Read operation successfully completed.*
RSPI_ERR_CH_NOT_OPEN:	*The channel has not been opened. Perform R_RSPI_Open() first*
RSPI_ERR_BAD_CHAN:	*Channel number is not available*
RSPI_ERR_NULL_PTR:	*A required pointer argument is NULL*
RSPI_ERR_LOCK:	*The lock could not be acquired. The channel is busy.*

Properties

Prototyped in file “r_rspi_rx_if.h”

Description

Reentrant

Yes. Reentrance for different channel OK. Reentrance for the same channel will result in a ‘Lock error’ return.

Example

```
/* Conditions: Channel currently open. */
g_transfer_complete = false;
rspi_result = R_RSPI_WriteRead(handle, my_command_word, source, dest, length);
if (RSPI_SUCCESS != rspi_result)
{
    return error;
}

while (!g_transfer_complete) // Poll for interrupt callback to set this.
{
    nop();// Do something useful while waiting for the transfer to complete.
}
```

6.8 R_RSPI_ GetVersion()

This function returns the driver version number at runtime.

Format

```
uint32_t  R_RSPI_GetVersion(void);
```

Parameters

None

Return Values

Version number with major and minor version digits packed into a single 32-bit value.

Properties

Prototyped in file “r_rspi_rx_if.h”

Description

The function returns the version of this module. The version number is encoded such that the top two bytes are the major version number and the bottom two bytes are the minor version number

Reentrant

Example

Example showing this function being used.

```
/* Retrieve the version number and convert it to a string. */

uint32_t   version, version_high, version_low;
char       version_str[9];

version = R_RSPI_GetVersion();

version_high = (version >> 16)&0xf;
version_low  =  version & 0xff;

sprintf(version_str, "RSPIv%1.1hu.%2.2hu", version_high, version_low);
```

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Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	Nov 15, 2013	--	First edition issued
1.20	April 3, 2014	--	Updated list of supported/tested MCUs
			Updated colophon to 4.0

General Precautions in the Handling of MPU/MCU Products

The following usage notes are applicable to all MPU/MCU products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Handling of Unused Pins

   Handle unused pins in accordance with the directions given under Handling of Unused Pins in the manual.

   — The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible. Unused pins should be handled as described under Handling of Unused Pins in the manual.

2. Processing at Power-on

   The state of the product is undefined at the moment when power is supplied.

   — The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the moment when power is supplied.
   In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the moment when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the moment when power is supplied until the power reaches the level at which resetting has been specified.

3. Prohibition of Access to Reserved Addresses

   Access to reserved addresses is prohibited.

   — The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.

4. Clock Signals

   After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has stabilized.

   — When the clock signal is generated with an external resonator (or from an external oscillator) during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Moreover, when switching to a clock signal produced with an external resonator (or by an external oscillator) while program execution is in progress, wait until the target clock signal is stable.

5. Differences between Products

   Before changing from one product to another, i.e. to a product with a different part number, confirm that the change will not lead to problems.

   — The characteristics of an MPU or MCU in the same group but having a different part number may differ in terms of the internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

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