

# **SUB-20**

## **User Manual**

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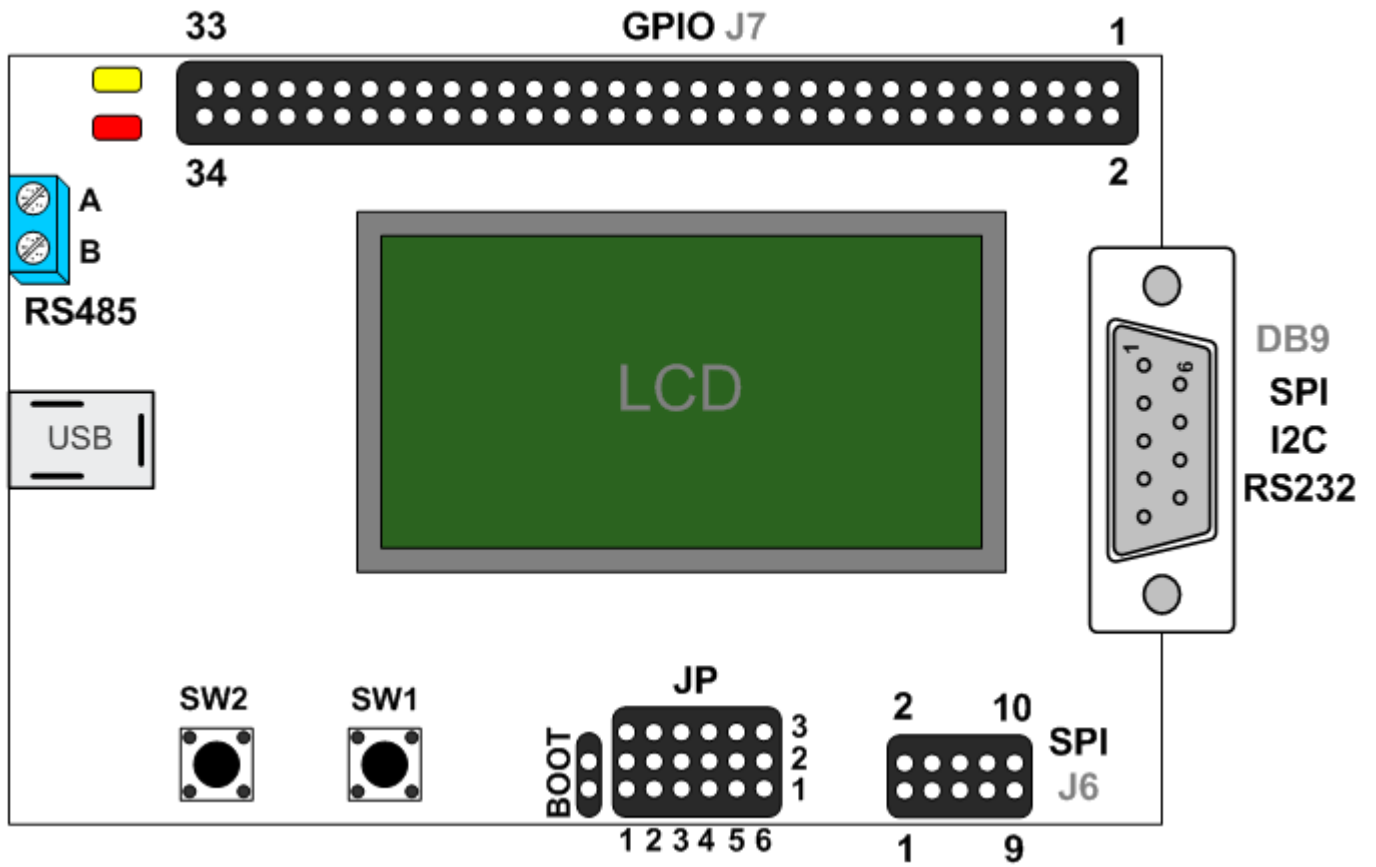
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# 1 Document Revision History

- 2.9
  1. sub\_spi\_transfer\_ess
  
- 2.8
  1. GPIOB
  2. FIFO\_READ\_FULL
  3. MDIO1
  
- 2.7
  1. Bit-bang I2C Masters
  2. Updated GPIO Header for I2Cx, SPIx, UARTx

## 2 SUB-20 Layout

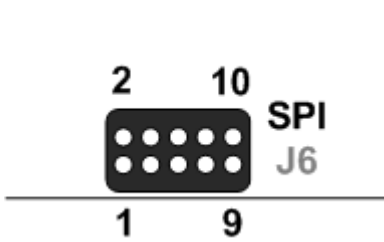


## 2.1 GPIO Header

Header Pin	GPIO	Alternative Function	Notes
1	GPIO8	I2C_SCL	Pulled up 1.5KOhm DB9.8
2	GPIO9	I2C_SDA	Pulled up 1.5KOhm DB9.6
3	GPIO10	RS232_RXD_TTL	For Configurations with RS232 or RS485
4	GPIO11	RS232_TXD_TTL	
5	GPIO12		
6	GPIO13		
7	GPIO14	MDC	
8	GPIO15	MDIO	
9	GPIO24	PWM_0, SCLx0, MIS0x0 <sup>1</sup>	
10	GPIO25	PWM_1, SDAx0, MOSIx0 <sup>1</sup>	
11	GPIO26	PWM_2, SCLx1, SCKx0 <sup>1</sup>	
12	GPIO27	PWM_3, SDAx1, SSx0 <sup>1</sup>	
13	GPIO28	PWM_4, SCLx2, MIS0x1 <sup>1</sup> , UARTx0_RX <sup>1</sup>	
14	GPIO29	PWM_5, SDAx2, MOSIx1 <sup>1</sup> , UARTx0_TX <sup>1</sup>	
15	GPIO30	PWM_6, SCLx3, SCKx1 <sup>1</sup> , UARTx1_RX <sup>1</sup>	
16	GPIO31	PWM_7, SDAx3, SSx1 <sup>1</sup> , UARTx1_TX <sup>1</sup>	
17	GPIO0	LCD_D0	For Configurations with LCD
18	GPIO1	LCD_D1	
19	GPIO2	LCD_D2	
20	GPIO3	LCD_D3	
21	GPIO4	IR_TX	For Configurations with IR
22	GPIO5		
23	GPIO6	LCD_En	For Configurations with LCD
24	GPIO7	LCD_RS	
25	GPIO23	ADC7	
26	GPIO22	ADC6	
27	GPIO21	ADC5	
28	GPIO20	ADC4	
29	GPIO19	ADC3	
30	GPIO18	ADC2	
31	GPIO17	ADC1	
32	GPIO16	ADC0	
33		VCC	
34		GND	

<sup>1</sup> - Under development

## 2.2 SPI Header

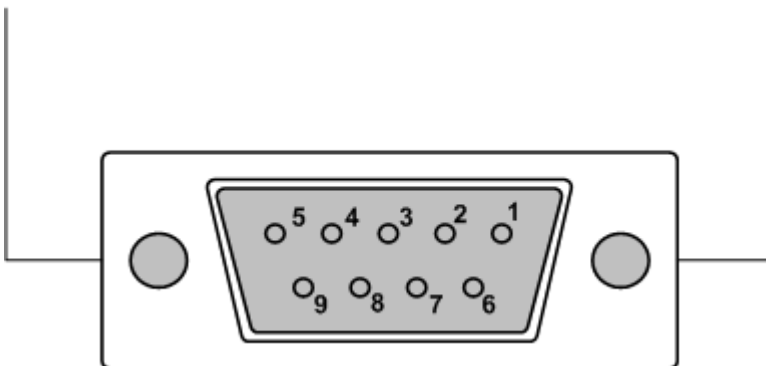


Header Pin	SPI Function	Fast PWM	GPIOB	MDIO1	Notes
1	MOSI - Master Out Slave In		GPIOB1	MDC1	Optional Level Converter*
2	SS1		GPIOB0		GPIO Voltage**
3	MISO - Master In Slave Out		GPIOB3		Optional Level Converter*
4	SS2	FPWM_0	GPIOB2		GPIO Voltage**
5	SS0		GPIOB5		Output, Optional Level Converter*
6	SS3	FPWM_1	GPIOB4		GPIO Voltage**
7	SCK - Master Clock		GPIOB7	MDIO1	Optional Level Converter*
8	SS4	FPWM_2	GPIOB6		GPIO Voltage**
9	SPI_EXT_PWR - External SPI Power		EXT_PWR		
10	GND		GND		

Level Converter\* - Adjustable operating voltage in configurations with Level Converters (see [Jumpers](#) and [Ordering Information](#)).

GPIO Voltage\*\* - Operates at the same voltage as GPIO according to SUB-20 configuration (see [Ordering Information](#)).

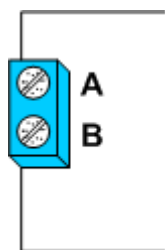
## 2.3 DB9 Connector



Pin	Function	Configuration
1	SPI SS0	
2	I2C_EXT_PWR	
	RS232 PC_RX	Serial2
3	SPI_EXT_PWR	Lxxx

	RS232 PC_TX	Serial2
4	SPI SCK	
5	GND	
6	I2C SDA	
7	SPI MISO	
8	I2C SCL	
9	SPI MOSI	

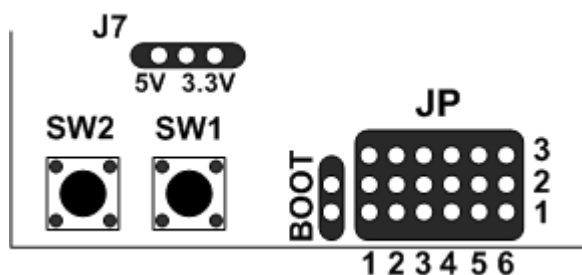
## 2.4 RS485 Connector



RS485 Connector is installed only in Serial4 configuration.

Pin	Function
A	inverting or '-' pin
B	non-inverting or '+' pin

## 2.5 Jumpers, SW1,SW2





JP1	I2C Pull-ups Voltage when JP2 1-2 closed	1-2	3.3V	Should not be used with 3.3V configurations
		2-3	5V	
JP2	I2C Pull-ups Voltage	1-2	Internal	Can not be used in Serial configurations
		2-3	External DB9.2	
JP3	SCL Pull-up	1-2	On	
		2-3	Off	
JP4	SDA Pull-up	1-2	On	
		2-3	Off	
JP5	SPI Voltage when JP6 1-2 closed	1-2	3.3V	
		2-3	5V	
JP6	SPI Voltage	1-2	Internal	Only for Lxxx configurations. DB9.3 Can not be used as SPI Voltage in Serial configurations
		2-3	External J6.9 or DB9.3	
J7	GPIO Voltage	left	5V	
		right	3.3V	
BOOT, SW1	Force Bootloader on Power Reset	Closed or Pressed		
SW2	Force Monitor on Power Reset	Pressed		Only for Serial2 configurations

For additional information about SUB-20 configurations please see [Ordering Information](#).

### 3 SUB-20 API

#### **API Function List**

[sub\\_find\\_devices](#)  
[sub\\_open](#)  
[sub\\_get\\_serial\\_number](#)  
[sub\\_get\\_product\\_id](#)  
[sub\\_get\\_version](#)

[sub\\_i2c\\_freq](#)  
[sub\\_i2c\\_config](#)  
[sub\\_i2c\\_start](#)  
[sub\\_i2c\\_stop](#)  
[sub\\_i2c\\_scan](#)  
[sub\\_i2c\\_read](#)  
[sub\\_i2c\\_write](#)

[sub\\_bb\\_i2c\\_config](#)  
[sub\\_bb\\_i2c\\_scan](#)  
[sub\\_bb\\_i2c\\_read](#)  
[sub\\_bb\\_i2c\\_write](#)

[sub\\_spi\\_config](#)  
[sub\\_spi\\_transfer](#)

[sub\\_gpio\\_config](#)  
[sub\\_gpio\\_read](#)  
[sub\\_gpio\\_write](#)

[sub\\_fpwm\\_config](#)  
[sub\\_fpwm\\_set](#)

[sub\\_adc\\_config](#)  
[sub\\_adc\\_read](#)  
[sub\\_adc\\_single](#)

[sub\\_lcd\\_write](#)

[sub\\_rs\\_set\\_config](#)  
[sub\\_rs\\_get\\_config](#)  
[sub\\_rs\\_timing](#)  
[sub\\_rs\\_xfer](#)

[sub\\_fifo\\_config](#)  
[sub\\_fifo\\_read](#)  
[sub\\_fifo\\_write](#)

## 3.1 Device Initialization

### Functions

[sub\\_find\\_devices](#)

[sub\\_open](#)

[sub\\_get\\_serial\\_number](#)

[sub\\_get\\_product\\_id](#)

### 3.1.1 sub\_find\_devices

#### Synopsis

```
sub_device sub_find_devices( sub_device first )
```

Function scans USB devices currently connected to the host looking for SUB-20 device(s). If parameter **first** is NULL function will initiate new search, otherwise it will continue to search from the place it finished during last call.

#### Return value

Function returns next found SUB-20 device descriptor or NULL if no more devices were found. Returned value can be used as parameter for [sub\\_open](#). Device descriptor is not a device handle required by API calls. Handle is returned by [sub\\_open](#).

#### Example

```
sub_device dev=0;
while( dev = sub_find_devices(dev) )
{
    /* Check device serial number */
}
```

### 3.1.2 sub\_open

#### Synopsis

```
sub_handle sub_open( sub_device dev )
```

Open SUB-20 device. If parameter **dev** is NULL function will try to open first available SUB-20 device. In this case it will call internally [sub\\_find\\_devices\(0\)](#). Otherwise function will try to open SUB-20 device referenced by **dev**. If your application intended to work with single SUB-20 device you can always call `sub_open` with **dev** =NULL.

#### Return value

On success function returns non zero handler that should be used in all subsequent calls to SUB-20 API functions. In case of error function returns NULL and set [sub\\_errno](#)

#### Example

```
handle = sub_open( 0 );
if( !handle )
{
    printf("sub_open: %s\n", sub_strerror(sub_errno));
    return -1;
}
```

### 3.1.3 sub\_get\_serial\_number

#### Synopsis

```
int sub_get_serial_number( sub_handle hndl, char *buf, int sz)
```

Get serial number string descriptor

#### Parameters

- \*buf - buffer to store descriptor
- sz - buffer size

#### Return value

On success function returns string descriptor size. Otherwise negative number.

#### Example

```
if( sub_get_serial_number(hndl, buf, sizeof(buf)) >= 0 )
    printf( "Serial Number : %s\n", buf );
else
{
    /* Error */
}
```

### 3.1.4 sub\_get\_product\_id

#### Synopsis

```
int sub_get_product_id( sub_handle hndl, char *buf, int sz);
```

Get product ID string descriptor

#### Parameters

- \*buf - buffer to store descriptor
- sz - buffer size

#### Return value

On success function returns string descriptor size. Otherwise negative number.

#### Example

```
if( sub_get_product_id(hndl, buf, sizeof(buf)) >= 0 )
    printf( "Product ID : %s\n", buf );
else
{
    /* Error */
}
```

### 3.1.5 sub\_get\_version

#### Synopsis

```
const struct sub_version* sub_get_version( sub_handle hndl );
```

Get version of shared (DLL) or static library, driver, SUB-20 device and bootloader.

#### Return value

Function fills internal structure with gathered versions and returns pointer to this structure.

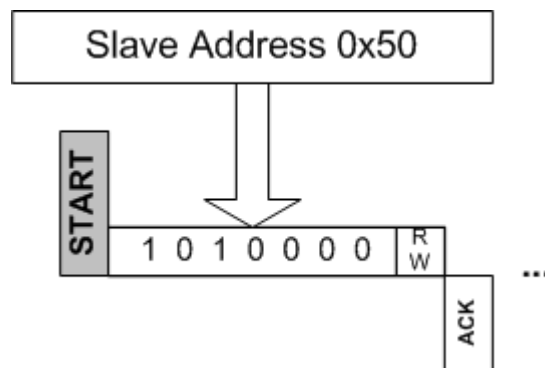
**Example**

```
const struct sub_version* sub_ver;  
sub_ver = sub_get_version( hndl );
```

## 3.2 I2C functions

**Slave Address Convention**

Slave address parameter referenced in I2C related functions is 7 bit number representing I2C slave device address without R/W bit. For example with slave address parameter equal 0x50 slave address stage of the I2C transaction will look like:

**Acknowledge Polling**

I2C EEPROM slave devices may enter internal memory write cycle. Once the internally-timed write cycle has started EEPROM inputs are disabled, acknowledge polling can be initiated. This involves sending a start condition followed by the device slave address and R/W bit. Only if the internal write cycle has completed will the EEPROM respond with an ACK, allowing the read or write sequence to continue. Acknowledge polling should be performed on application level. SUB-20 knows nothing about nature of I2C slave device it is connected to.

**EEPROM Page Write**

I2C EEPROMs are usually capable of no more than 64-byte page writes. The internal EEPROM data address lower 6 bits are internally incremented following the receipt of each data byte. The higher data address bits are not incremented, retaining the memory page row location. When the data address, internally generated, reaches the page boundary, the following byte is placed at the beginning of the same page. If more than 64 data bytes are transmitted to the EEPROM, the data address will "roll over" and previous data will be overwritten. The address "roll over" during write is from the last byte of the current page to the first byte of the same page.

**Functions**

[sub\\_i2c\\_freq](#)  
[sub\\_i2c\\_config](#)  
[sub\\_i2c\\_start](#)  
[sub\\_i2c\\_stop](#)  
[sub\\_i2c\\_read](#)  
[sub\\_i2c\\_write](#)

SUB-20 can work in both I2C master and I2C slave modes. Detailed description of I2C slave mode can be found here: [SUB-20 as I2C Slave](#).

### 3.2.1 sub\_i2c\_freq

#### Synopsis

```
int sub_i2c_freq( sub_handle hndl, int* freq )
```

Set and get SUB-20 I2C master clock frequency. If **\*freq** is non zero I2C clock frequency will be set to value equal or close to **\*freq**. SUB-20 has I2C frequency generator that can generate clock frequencies in range from 444,444 KHz down to 489 Hz. Function will calculate close possible frequency from the available range. If function succeed **\*freq** will reflect the resulting I2C clock frequency. Some of available I2C clock frequencies are listed below

```
444444 Hz (Maximal)
421052 Hz
400000 Hz
...
100000 Hz
...
491 Hz
489 Hz (Minimal)
```

#### Parameters

- **\*freq** - Desired frequency or zero. On return will be filled with resulting frequency

#### Return value

On success function returns 0. Otherwise [error code](#).

### 3.2.2 sub\_i2c\_config

#### Synopsis

```
int sub_i2c_config( sub_handle hndl, int sa, int flags )
```

Configure SUB-20 I2C module.

#### Parameters

- **sa** - slave address for SUB-20 in I2C slave mode. See [I2C Slave Address Convention](#) and [I2C Slave](#)
  - **flags** - set of below flags
- [I2C\\_GCE](#)                      Enable general call address (0x00) detection in I2C slave mode

#### Return Value

On success function returns 0. Otherwise [error code](#).

### 3.2.3 sub\_i2c\_start

#### Synopsis

```
int sub_i2c_start( sub_handle hndl )
```

Generate I2C start condition.

#### Return value

On success function returns 0. Otherwise [error code](#).

#### See also

[Error Codes](#), [I2C Status](#)

### 3.2.4 sub\_i2c\_stop

#### Synopsis

```
int sub_i2c_stop( sub_handle hndl )
```

Generate I2C stop condition.

#### Return value

On success function returns 0. Otherwise [error code](#).

#### See also

[Error Codes](#), [I2C Status](#)

### 3.2.5 sub\_i2c\_scan

#### Synopsis

```
int sub_i2c_scan( sub_handle hndl, int* slave_cnt, char* slave_buf )
```

Scan I2C bus looking for connected slave devices.

#### Parameters

- *slave\_cnt* - Buffer to store number of found slave devices
- *slave\_buf* - Buffer to store found [slave device addresses](#)

#### Return value

On success function returns 0. Otherwise [error code](#).

#### See also

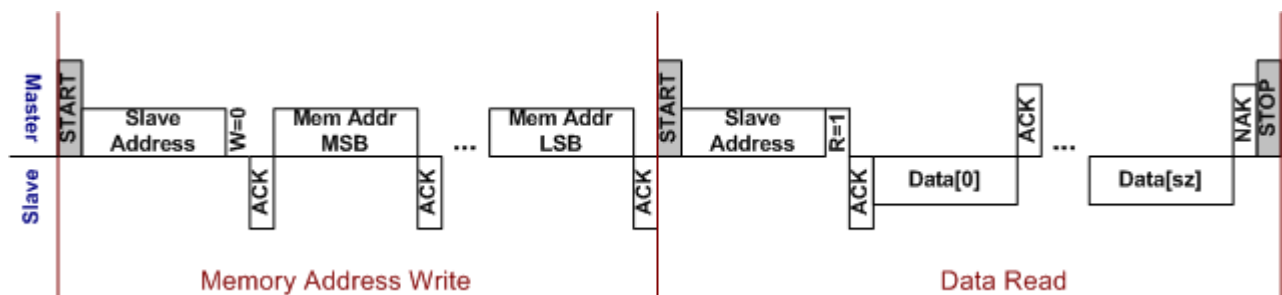
[Error Codes](#), [I2C Status](#)

### 3.2.6 sub\_i2c\_read

#### Synopsis

```
int sub_i2c_read( sub_handle hndl, int sa, int ma, int ma_sz,
                  char* buf, int sz )
```

Perform complete I2C master read transaction with optional memory address write. Transaction will have following format:



If *ma\_sz* is zero "Memory Address Write" stage will be skipped.

Function has no limitation of the read data size - *sz* parameter. However internal organization of the I2C slave

device being read should be considered.

#### Parameters

- sa - [Slave Address](#)
- ma - Memory Address. Will be shifted out in "Memory Address Write" stage MSB first
- ma\_sz - Memory Address size bytes
- buf - Buffer to store read data
- sz - Read data size bytes.

#### Return value

On success function returns 0. Otherwise [error code](#).

#### See also

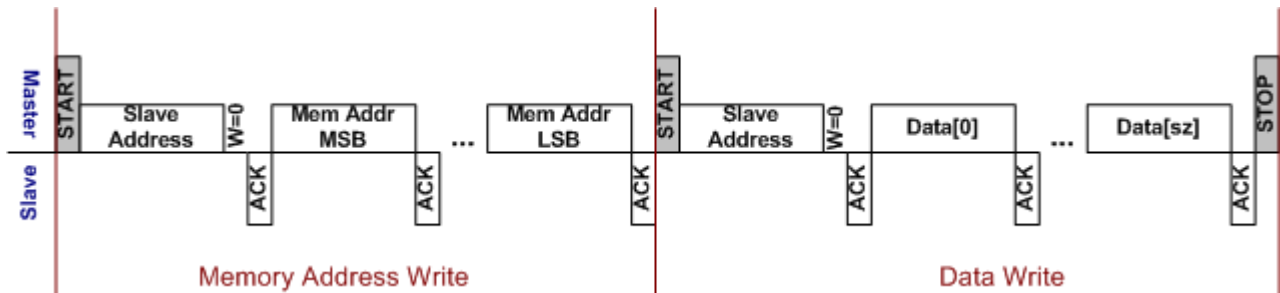
[Error Codes](#), [I2C Status](#)

### 3.2.7 sub\_i2c\_write

#### Synopsis

```
int sub_i2c_write( sub_handle hndl, int sa, int ma, int ma_sz,
                  char* buf, int sz )
```

Perform complete I2C master write transaction with optional memory address write. Transaction will have following format:



If **ma\_sz** is zero "Memory Address Write" stage will be skipped.

Function has no limitation of the write data size - **sz** parameter. However internal organization of the I2C slave device being written should be considered especially [Acknowledge Polling](#) and [EEPROM Page Write](#).

#### Parameters

- sa - [Slave Address](#)
- ma - Memory Address. Will be shifted out in "Memory Address Write" stage MSB first
- ma\_sz - Memory Address size bytes
- buf - Buffer for data to be written
- sz - Write data size bytes

#### Return value

On success function returns 0. Otherwise [error code](#).

#### See also

[Error Codes](#), [I2C Status](#)



### 3.2.8 I2C Status

The status of last I2C operation successful or not successful is stored in **sub\_i2c\_status** global variable defined in *libsub.h* as

```
extern int    sub_i2c_status;
```

Following statuses are available:

0x00	No errors
0x08	START condition transmitted
0x10	Repeated START condition transmitted
0x18	SLA+W transmitted; ACK received
0x20	SLA+W transmitted; NAK received
0x28	Data byte transmitted; ACK received
0x30	Data byte transmitted; NAK received
0x38	Arbitration lost in SLA; or NAK received
0x40	SLA+R transmitted; ACK received
0x48	SLA+R transmitted; NAK received
0x50	Data received; ACK has been returned
0x58	Data received; NAK has been returned
0xE0	Arbitration lost
0xE1	Arbitration lost in START
0xE2	Arbitration lost in STOP
0xE3	Arbitration lost in read ACK
0xE4	Arbitration lost in read NAK
0xE5	Arbitration lost in write
0xF8	Unknown error
0xFF	Illegal START or STOP condition

### 3.3 Bit-bang I2C Masters

Beginning from the FW version 0.2.6 and library version 0.1.12.16, SUB-20 provides additional four independent I2C master channels on GPIO24..31 compatible with I2C specification 3.0.

Header Pin	GPIO	Alternative I2C Master Function
9	GPIO24	SCLx0
10	GPIO25	SDAx0
11	GPIO26	SCLx1
12	GPIO27	SDAx1
13	GPIO28	SCLx2
14	GPIO29	SDAx2
15	GPIO30	SCLx3
16	GPIO31	SDAx3

Each channel can operate in Fast Plus (1000KHz), Fast (400KHz) and Standard (100KHz) modes. In Fast and Standard modes I2C masters support clock stretching.

#### **SDAx, SCLx Pull-ups**

Considering the fact that bit-bang I2C channels share the GPIO pins with other SUB-20 modules, there are no internal (mounted on SUB-20 board) pull-ups on these channels. **Pull-ups must be provided on target board.**

#### **Clock Stretching**

In Fast and Standard modes bit-bang I2C masters support clock stretching. Clock stretching pauses a transaction by holding the SCL line LOW. The transaction cannot continue until the line is released HIGH again. Slaves can hold the SCL line LOW to force the master into a wait state until the slave is ready.

**Functions**

[sub\\_bb\\_i2c\\_config](#)  
[sub\\_bb\\_i2c\\_scan](#)  
[sub\\_bb\\_i2c\\_read](#)  
[sub\\_bb\\_i2c\\_write](#)

### 3.3.1 sub\_bb\_i2c\_config

**Synopsis**

```
int sub_bb_i2c_config( sub_handle hndl, int mode, int stretch_ms )
```

Configure SUB-20 Bit-bang I2C Masters module. Configuration is common for all Bit-bang I2C channels.

**Parameters**

- mode - Bit-bang I2C Master mode. One of the following flags:

<a href="#">BB_I2C_FAST_P</a>	Fast Plus mode 1000KHz
<a href="#">BB_I2C_FAST</a>	Fast mode 400KHz
<a href="#">BB_I2C_STD</a>	Standard mode 100KHz

- stretch\_ms - Clock stretching timeout up to 4194ms. Clock stretching feature is available in Fast and Standard modes. If SCL line is hold LOW by I2C slave device longer than **stretch\_ms** timeout, Bit-bang I2C function will fail and [I2C Status](#) will be set to 0xE0.

**Return Value**

On success function returns 0. Otherwise [error code](#).

**Compatibility**

FW version	0.2.6 or grater
Library version	0.1.12.16 or grater

### 3.3.2 sub\_bb\_i2c\_scan

**Synopsis**

```
int sub_bb_i2c_scan( sub_handle hndl, int channel, int* slave_cnt,  
                    char* slave_buf )
```

Scan I2C bus looking for connected slave devices.

**Parameters**

- channel - Bit-bang I2C Master channel 0..3
- \*slave\_cnt - Buffer to store number of found slave devices
- slave\_buf - Buffer to store found [slave device addresses](#)

**Return value**

On success function returns 0. Otherwise [error code](#).

**See also**

[Error Codes](#), [I2C Status](#)

**Compatibility**

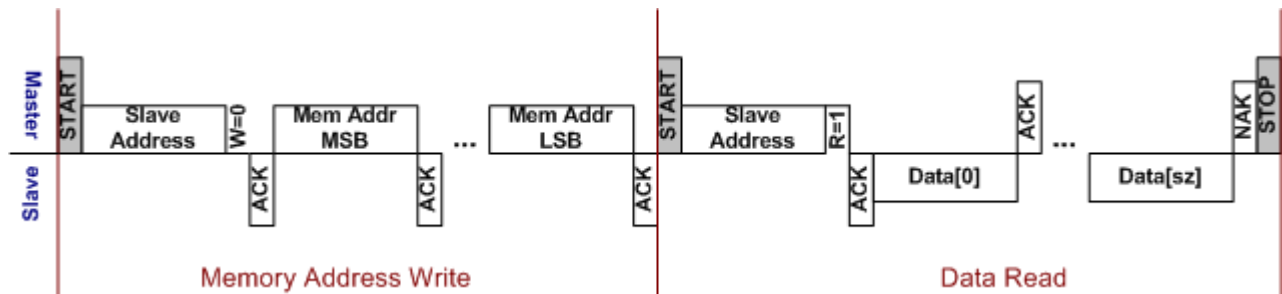
FW version	0.2.6 or grater
Library version	0.1.12.16 or grater

### 3.3.3 sub\_bb\_i2c\_read

#### Synopsis

```
int sub_bb_i2c_read( sub_handle hndl, int channel, int sa, int ma, int ma_sz,
                    char* buf, int sz )
```

Perform complete I2C master read transaction with optional memory address write. Transaction will have following format:



If **ma\_sz** is zero "Memory Address Write" stage will be skipped.

Function has no limitation of the read data size - **sz** parameter. However internal organization of the I2C slave device being read should be considered.

#### Parameters

- channel - Bit-bang I2C Master channel 0..3
- sa - [Slave Address](#)
- ma - Memory Address. Will be shifted out in "Memory Address Write" stage MSB first
- ma\_sz - Memory Address size bytes
- buf - Buffer to store read data
- sz - Read data size bytes.

#### Return value

On success function returns 0. Otherwise [error code](#).

#### See also

[Error Codes](#), [I2C Status](#)

#### Compatibility

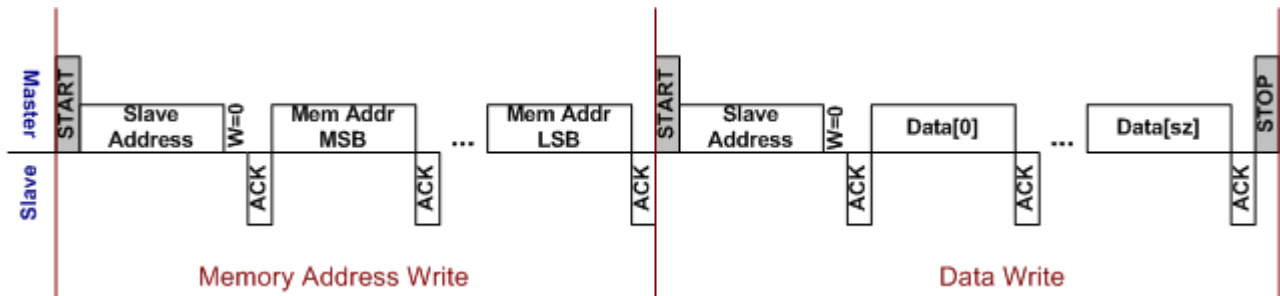
FW version      0.2.6 or grater  
Library version   0.1.12.16 or grater

### 3.3.4 sub\_bb\_i2c\_write

#### Synopsis

```
int sub_bb_i2c_write( sub_handle hndl, int channel, int sa, int ma, int ma_sz,
                     char* buf, int sz )
```

Perform complete I2C master write transaction with optional memory address write. Transaction will have following format:



If **ma\_sz** is zero "Memory Address Write" stage will be skipped.

Function has no limitation of the write data size - **sz** parameter. However internal organization of the I2C slave device being written should be considered especially [Acknowledge Polling](#) and [EEPROM Page Write](#).

#### Parameters

- channel - Bit-bang I2C Master channel 0..3
- sa - [Slave Address](#)
- ma - Memory Address. Will be shifted out in "Memory Address Write" stage MSB first
- ma\_sz - Memory Address size bytes
- buf - Buffer for data to be written
- sz - Write data size bytes

#### Return value

On success function returns 0. Otherwise [error code](#).

#### See also

[Error Codes](#), [I2C Status](#)

#### Compatibility

FW version        0.2.6 or grater  
Library version   0.1.12.16 or grater

## 3.4 SPI Functions

### SPI Pins Configuration

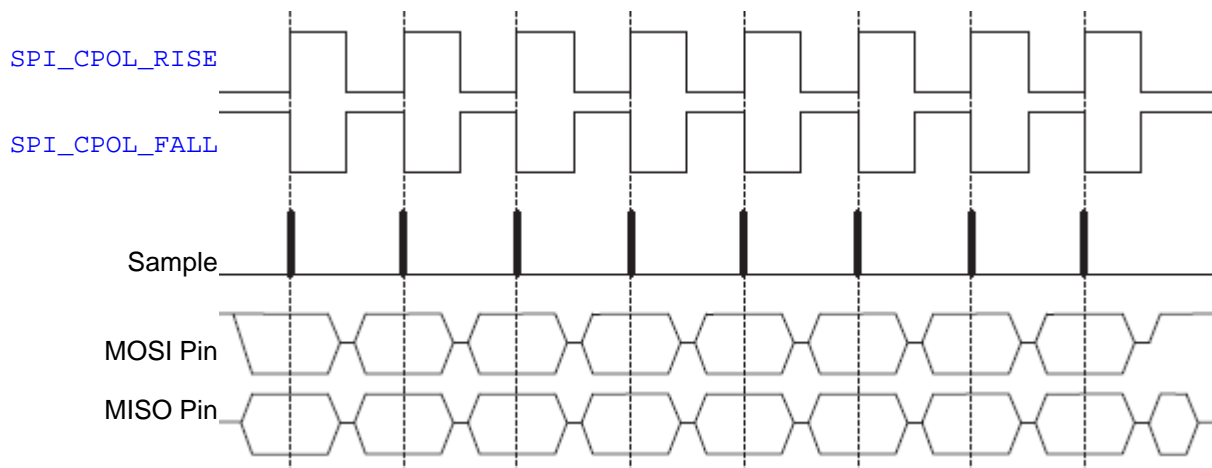
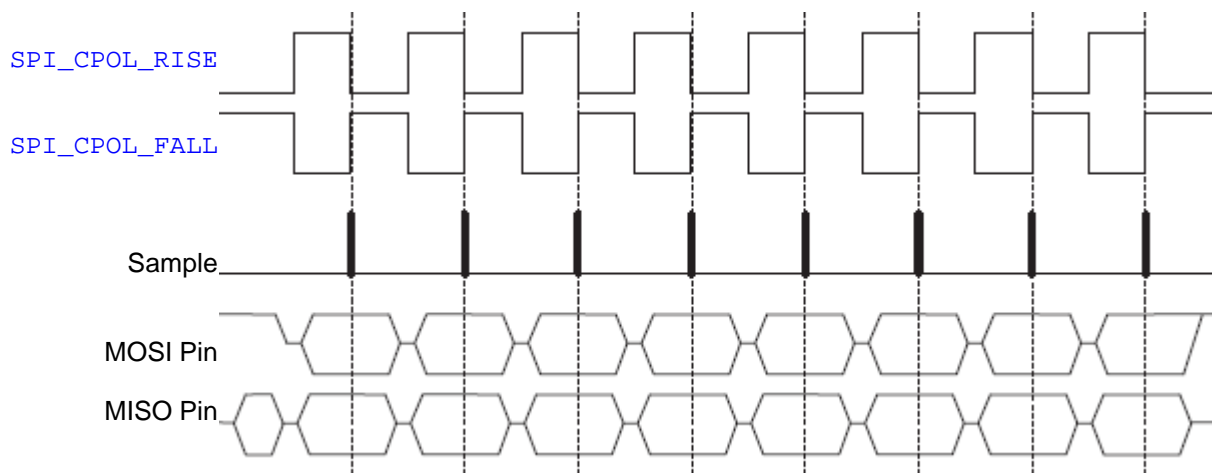
After SPI is enabled SUB-20 SPI module will take control over SPI pins.

Pin	Function	Master mode	Slave mode	Disabled
SCK	SPI Master Clock	Output	Input	HiZ
MOSI	Master Out Slave In	Output	Input	
MISO	Master In Slave Out	Input	Output**	
SS0	Slave Select 0	Output Hi (Configurable by <a href="#">sub_spi transfer</a> )	Input	
SS1 SS2 SS3 SS4	Slave Select 1..4	HiZ (Configurable by <a href="#">sub_spi transfer</a> )	Not in use	

\*If SPI is disabled all SPI pins are in HiZ.

\*\* In SPI slave mode MISO is output only when SS0 is low

### SPI SCK Polarity and Phase explanations

SPI Transfer format with `SPI_SMPL_SETUP`SPI Transfer format with `SPI_SETUP_SMPL`**Functions**

[sub\\_spi\\_config](#)  
[sub\\_spi\\_transfer](#)  
[sub\\_sdio\\_transfer](#)

**3.4.1 sub\_spi\_config****Synopsis**

```
int sub_spi_config( sub_handle hndl, int cfg_set, int* cfg_get )
```

Configure SUB-20 SPI module or read current configuration. If `*cfg_get` is NULL function will configure SPI according to the `cfg_set` parameter. Otherwise it will read current SPI configuration into `*cfg_get`

**Parameters**

- `cfg_set` - Desired SPI configuration. This parameter is effective only if `*cfg_get` is NULL. `cfg_set` should be assembled as a combination of below flags

<code>SPI_ENABLE</code>	Enable SUB-20 SPI module.
<code>SPI_SLAVE</code>	SPI module is in Slave mode. <a href="#">sub_spi_transfer</a> can work only when SPI module is in Master mode
<code>SPI_CPOL_RISE</code>	SCK is low when idle. See <a href="#">SPI Polarity and Phase explanations</a>
<code>SPI_CPOL_FALL</code>	SCK is high when idle. See <a href="#">SPI Polarity and Phase explanations</a>
<code>SPI_SMPL_SETUP</code>	Sample data on leading SCK edge, setup on trailing. See <a href="#">SPI Polarity and Phase explanations</a>
<code>SPI_SETUP_SMPL</code>	Setup data on leading SCK edge, sample on trailing. See <a href="#">SPI Polarity and Phase explanations</a>

Below flags are relevant only for SPI master mode (`SPI_SLAVE` not set)

<code>SPI_LSB_FIRST</code>	Transmit LSB first
<code>SPI_MSB_FIRST</code>	Transmit MSB first
<code>SPI_CLK_8MHZ</code>	SPI SCK frequency 8 MHz
<code>SPI_CLK_4MHZ</code>	SPI SCK frequency 4 MHz
<code>SPI_CLK_2MHZ</code>	SPI SCK frequency 2 MHz
<code>SPI_CLK_1MHZ</code>	SPI SCK frequency 1 MHz
<code>SPI_CLK_500KHZ</code>	SPI SCK frequency 500 KHz
<code>SPI_CLK_250KHZ</code>	SPI SCK frequency 250 KHz
<code>SPI_CLK_125KHZ</code>	SPI SCK frequency 125 KHz

- `*cfg_get` - Pointer to store current configuration read from SUB-20 device or NULL

#### **Return value**

On success function returns 0. Otherwise [error code](#).

#### **Example**

```
/* Read current SPI configuration */
sub_spi_config( hndl, 0, &spi_config );

/* Configure SPI */
sub_spi_config( hndl,
SPI_ENABLE | SPI_CPOL_RISE | SPI_SMPL_SETUP | SPI_MSB_FIRST | SPI_CLK_4MHZ, 0 );

/* Disable SPI */
sub_spi_config( hndl, 0, 0 );
```

### 3.4.2 sub\_spi\_transfer

#### Synopsis

```
int sub_spi_transfer( sub_handle hndl, char* out_buf, char* in_buf,
                    int sz, int ss_config )
```

Perform SPI master transaction. Depending on **out\_buf** and **in\_buf** parameters transaction can be either read ( **out\_buf==0**), write ( **in\_buf==0**) or read-write ( both **in\_buf** and **out\_buf** are non zero).

#### Parameters

- **out\_buf** - Output data buffer or NULL. If NULL there will be no write transaction and MOSI pin will stay unchanged.
- **in\_buf** - Input buffer to store read data or NULL. If NULL there will be no read transaction and data on MISO pin will be ignored.
- **sz** - Transaction size
- **ss\_config** - Determines selection and operation of SS pin. **ss\_config** value must be created with macro **SS\_CONF(SS\_N,SS\_MODE)**,

where **SS\_N** is SS pin number and **SS\_MODE** is one of the following flags:

<b>SS_H</b>	SS goes high and stays high during and after transaction
<b>SS_HL</b>	SS goes high and stays high during first byte transfer, after that it goes low
<b>SS_HHL</b>	SS goes high and stays high during first 2 bytes transfer, after that it goes low
<b>SS_HHHL</b>	SS goes high and stays high during first 3 bytes transfer, after that it goes low
<b>SS_HHHHL</b>	SS goes high and stays high during first 4 bytes transfer, after that it goes low
<b>SS_HI</b>	SS goes high and stays high during entire transfer, after that it goes low
<b>SS_L</b>	SS goes low and stays low during and after transaction
<b>SS_LH</b>	SS goes low and stays low during first byte transfer, after that it goes high
<b>SS_LHL</b>	SS goes low and stays low during first 2 bytes transfer, after that it goes high
<b>SS_LLLH</b>	SS goes low and stays low during first 3 bytes transfer, after that it goes high
<b>SS_LLLHL</b>	SS goes low and stays low during first 4 bytes transfer, after that it goes high
<b>SS_LO</b>	SS goes low and stays low during entire transfer, after that it goes high

**SS\_HiZ** SS stays in HiZ mode (Except SS0)

If **ss\_config** is zero there will be no SS activity (changes).

#### Return value

On success function returns 0. Otherwise [error code](#).

#### Example

```
/* Write 10 bytes. Use SS0 low */
rc = sub_spi_transfer( hndl, out, 0, 10, SS_CONF(0,SS_LO) );

/* Transfer 10 bytes out and 10 bytes in. Use SS2 high */
rc = sub_spi_transfer( hndl, out, in, 10, SS_CONF(2,SS_HI) );

/* Read 10 bytes. No SS */
rc = sub_spi_transfer( hndl, 0, in, 10, 0 );
```

### 3.4.3 sub\_spi\_transfer\_ess

#### Synopsis

```
int sub_spi_transfer_ess( sub_handle hndl, char* out_buf, char* in_buf,
                        int sz, char* ess_str )
```

Perform SPI master transaction with Extended Slave Select control (ESS). Depending on **out\_buf** and **in\_buf** parameters transaction can be either read (**out\_buf**==0), write (**in\_buf**==0) or read-write ( both **in\_buf** and **out\_buf** are non zero).

#### Parameters

- out\_buf - Output data buffer or NULL. If NULL there will be no write transaction and MOSI pin will stay unchanged.
- in\_buf - Input buffer to store read data or NULL. If NULL there will be no read transaction and data on MISO pin will be ignored.
- sz - Transaction size
- ess\_str - string defining SS selection and activity during SPI transfer. Characters of the **ess\_str** have following meaning

0	Select SS0	
1	Select SS1	
2	Select SS2	
3	Select SS3	
4	Select SS4	
H	SS High	Byte Transfer
L	SS Low	Byte Transfer
^	SS High	No Byte Transfer
v	SS Low	No Byte Transfer
-	Small delay without SS changes	No Byte Transfer

#### Return value

On success function returns 0. Otherwise [error code](#).

#### Example

```
/* Write 5 bytes with SS0 Low. Make SS0 High to Low pulse after each byte */
rc = sub_spi_transfer( hndl, out, 0, 5, "0L^-vL^-vL^-vL^-v" );

/* Transfer 10 bytes with SS High. Use SS1 for first 5 bytes and SS2 for last */
rc = sub_spi_transfer( hndl, out, in, 10, "1HHHHHv-2HHHHHv" );

/* Read 10 bytes. SS0 High for first 2 bytes and low after that */
rc = sub_spi_transfer( hndl, 0, in, 10, "0HHv" );
```

#### Compatibility

FW version        0.2.9 or grater  
Library version   0.1.12.19 or grater

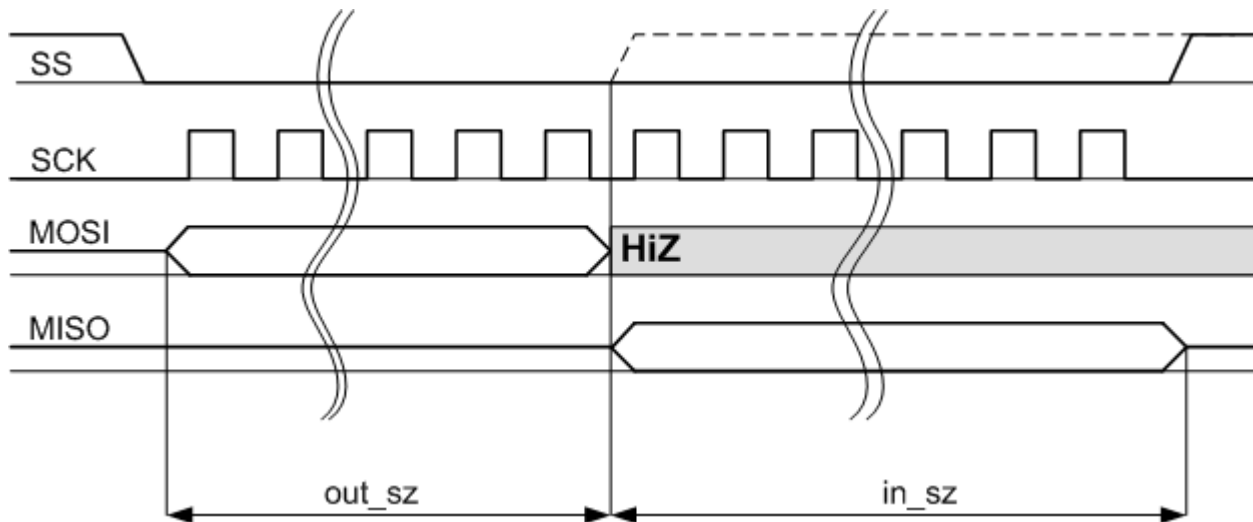
### 3.4.4 sub\_sdio\_transfer

#### Synopsis

```
int sub_sdio_transfer( sub_handle hndl, char* out_buf, char* in_buf,
                    int out_sz, int in_sz, int ss_config )
```



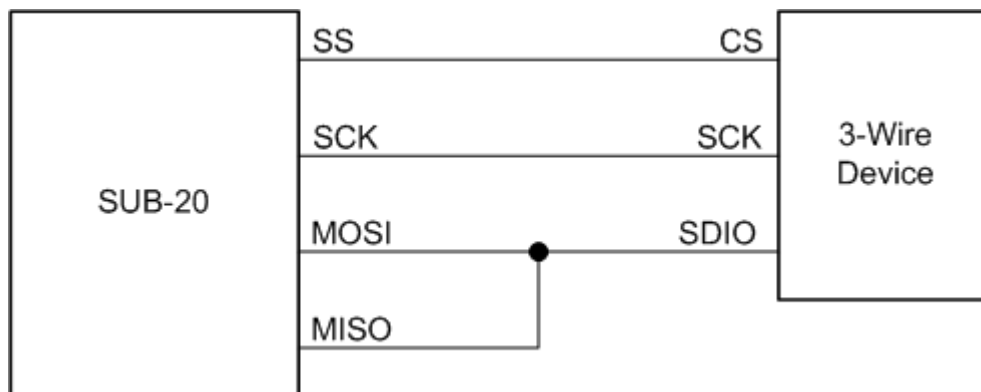
Perform 3-Wire compatible SPI master transaction like one shown below.



1. SS changes according to **ss\_config** parameter.
2. **out\_sz** bytes are transmitted via MOSI. MOSI will be in output state during transfer.
3. MOSI state is changed to HiZ after last bit transmitted. If required SS changes.
4. **in\_sz** bytes received from MISO input. MOSI left in HiZ state.
5. SS changes according to **ss\_config** parameter

SPI Clock - SCK phase and polarity can be configured with [sub\\_spi\\_config](#).

Above implementation of SPI transaction allows using of the SUB-20 as 3-Wire SPI master. In this case connection to 3-Wire device should be as following:



#### Parameters

- out\_buf - Output data buffer.
- in\_buf - Input buffer to store read data.
- out\_sz - Number of bytes to transmit in range 0..60.
- in\_sz - Number of bytes to receive in range 0..60.
- ss\_config - Determines selection and operation of SS pin. **ss\_config** value must be created with macro **SS\_CONF(SS\_N,SS\_MODE)**, where **SS\_N** is SS pin number and **SS\_MODE** is one of the following flags:

**SS\_HL** SS goes high and stays high during transmit stage, after that it goes low

**SS\_HI** SS goes high and stays high during entire transaction (transmit and receive), after that it goes low

**SS\_LH** SS goes low and stays low during transmit stage, after that it goes high  
**SS\_LO** SS goes low and stays low during entire transaction (transmit and receive), after that it goes high

**SS\_HiZ** SS stays in HiZ mode (Except SS0)  
 If **ss\_config** is zero there will be no SS activity (changes).

#### Return value

On success function returns 0. Otherwise [error code](#).

#### Example

```
/* Transmit one byte and receive 3 bytes */
/* SS1 goes low during transaction */
sub_sdio_transfer( hndl, out_buf, in_buf, 1, 3, SS_CONF(1,SS_LO) );
```

#### Compatibility

FW version        0.1.9 or grater  
 Library version    0.1.12.11 or grater

## 3.5 MDIO Functions

MDIO is a Management Data Input/Output Interface defined in IEEE 802.3 Clause 22 and extended in Clause 45. It is two signal based interface between Station Management (SUB-20 in our case) and a Physical Layer device (PHY). Where a PHY, or grouping of PHY's, is an individually manageable entity, known as an MDIO Manageable Device (MMD).

#### Signals

- MDC - management data clock. MDC is sourced by SUB-20 to the PHY as the timing reference for transfer of information on the MDIO signal.
- MDIO - management data input/output. MDIO is a bidirectional signal between PHY and the SUB-20. It is used to transfer control information and status between the PHY and the SUB-20. Control information is driven by the SUB-20 synchronously with respect to MDC and is sampled synchronously by the PHY. Status information is driven by the PHY synchronously with respect to MDC and is sampled synchronously by the SUB-20.

#### Frame Format

SUB-20 supports both MDIO frame formats defined in IEEE 802.3 Clause 22 and Clause 45.

- Clause 22 MDIO frame format

	PREAMBLE	ST	OP	PHYAD	REGAD	TA	DATA
<b>READ</b>	111...111	01	10	AAAAA	RRRRR	Z0	DDDDDDDDDDDDDDDDDD
<b>WRITE</b>	111...111	01	01	AAAAA	RRRRR	10	DDDDDDDDDDDDDDDDDD

- Clause 45 MDIO frame format

	PREAMBLE	ST	OP	PRTAD	DEVAD	TA	ADDRESS / DATA
Address	111...111	00	00	PPPPP	EEEE	10	AAAAAAAAAAAAAAAA
Write	111...111	00	01	PPPPP	EEEE	10	DDDDDDDDDDDDDDDD
Read	111...111	00	11	PPPPP	EEEE	Z0	DDDDDDDDDDDDDDDD
Post-read-increment-address	111...111	00	10	PPPPP	EEEE	Z0	DDDDDDDDDDDDDDDD

### Channels

Beginning from FW version 0.2.8 and library version 0.1.12.18 additional MDIO1 channel is available on SPI header ( see [SPI Header](#) ). To access MDIO1 channel use [sub\\_mdio\\_xfer\\_ex](#) function with **channel=1**.

### Functions

[sub\\_mdio22](#)

[sub\\_mdio45](#)

[sub\\_mdio\\_xfer](#), [sub\\_mdio\\_xfer\\_ex](#)

## 3.5.1 sub\_mdio22

### Synopsis

```
int sub_mdio22( sub_handle hndl, int op, int phyad, int regad,
                int data, int* content )
```

Generate IEEE 802.3 Clause 22 MDIO READ or WRITE frame. Frame format is shown here: [Clause 22 MDIO frame](#).

### Parameters

- op - operation code

SUB\_MDIO22\_READ                READ operation  
SUB\_MDIO22\_WRITE              WRITE operation

- phyad - 5 bit PHY address
- regad - 5 bit register address
- data - 16 bit data for WRITE operation
- \*content - 16 bit register content placeholder for READ operation

### Return value

On success function returns 0. Otherwise [error code](#).

### Example

```
/* Read register 0x12 in PHY 1 */
rc = sub_mdio22( hndl, SUB_MDIO22_READ, 0x01, 0x12, 0, &content );
/* Write register 0x5 in PHY 2 */
rc = sub_mdio22( hndl, SUB_MDIO22_WRITE, 0x02, 0x05, 0x55AA, 0 );
```

### Compatibility

FW version        0.2.1 or grater  
Library version   0.1.12.12 or grater

### 3.5.2 sub\_mdio45

#### Synopsis

```
int sub_mdio45( sub_handle hndl, int op, int prtad, int devad,
                int data, int* content )
```

Generate IEEE 802.3 Clause 45 MDIO frame. Frame format is shown here: [Clause 45 MDIO frame](#).

#### Parameters

- op - operation code

SUB_MDIO45_ADDR	ADDRESS operation
SUB_MDIO45_WRITE	WRITE operation
SUB_MDIO45_PRIA	POST-READ-INCREMENT-ADDRESS operation
SUB_MDIO45_READ	READ operation

- prtad - 5 bit port address
- devad - 5 bit device address
- data - 16 bit address or data for ADDRESS or WRITE operation
- \*content - 16 bit register content placeholder for READ or POST-READ-INCREMENT-ADDRESS operation

#### Return value

On success function returns 0. Otherwise [error code](#).

#### Compatibility

FW version      0.2.1 or grater  
Library version   0.1.12.12 or grater

### 3.5.3 sub\_mdio\_xfer, sub\_mdio\_xfer\_ex

#### Synopsis

```
int sub_mdio_xfer( sub_handle hndl, int count, union sub_mdio_frame* mdios )
int sub_mdio_xfer_ex( sub_handle hndl, int channel, int count,
                     union sub_mdio_frame* mdios )
```

Generate a sequence of independent MDIO frames. Frames in sequence can be Clause 22 or Clause 45 format with different operations and addresses.

#### Parameters

- channel - mdio channel (see [MDIO Channels](#) )
- count - number of frames to generate (currently up to 15).
- \*mdios - array of **count** sub\_mdio\_frame unions

```
union sub_mdio_frame
{
    struct
    {
        int      op;
        int      phyad;
        int      regad;
        int      data;
    } clause22;
    struct
```

```

    {
        int      op;
        int      prtad;
        int      devad;
        int      data;
    }clause45;
};

```

Frame operation is defined by **op** field value.

**clause22.op** can be

<code>SUB_MDIO22_READ</code>	READ operation
<code>SUB_MDIO22_WRITE</code>	WRITE operation

**clause45.op** can be

<code>SUB_MDIO45_ADDR</code>	ADDRESS operation
<code>SUB_MDIO45_WRITE</code>	WRITE operation
<code>SUB_MDIO45_PRI</code>	POST-READ-INCREMENT-ADDRESS operation
<code>SUB_MDIO45_READ</code>	READ operation

For READ and POST-READ-INCREMENT-ADDRESS operations **clause22.data** or **clause45.data** will be filled with data read from PHY.

#### Return value

On success function returns 0. Otherwise [error code](#).

#### Example

```

union sub_mdio_frame mdios[2];

mdios[0].clause22.op = SUB_MDIO22_READ;
mdios[0].clause22.phyad = 0x01;
mdios[0].clause22.regad = 0x12;

mdios[1].clause45.op = SUB_MDIO45_ADDR;
mdios[1].clause45.prtad = 0x04;
mdios[1].clause45.devad = 0x02;
mdios[1].clause45.data = 0x55AA;

rc = sub_mdio_xfer( hndl, 2, mdios );

```

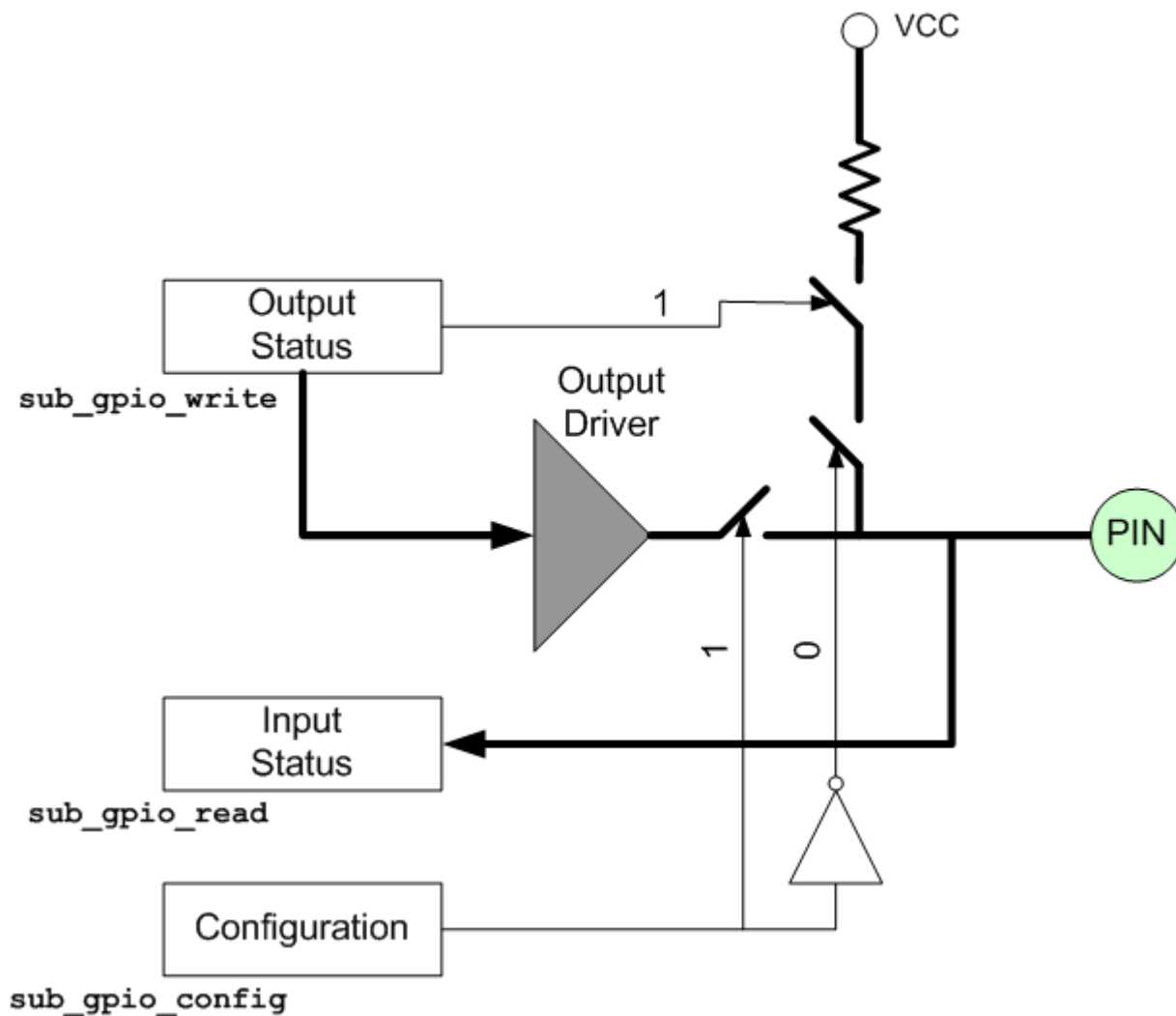
#### Compatibility

<b>sub_mdio_xfer</b>	
FW version	0.2.1 or grater
Library version	0.1.12.12 or grater
<b>sub_mdio_xfer_ex</b>	
FW version	0.2.8 or grater
Library version	0.1.12.18 or grater

## 3.6 GPIO Functions

### GPIO Functional Description

SUB-20 GPIO can be in input or output state. GPIO state is defined by configuration bit. In output state GPIO will drive high or low level depending on output status. In input state GPIO can be pulled high by internal weak pull-up resistor.



GPIO Pin configuration

Configuration	State	Output Status	
		"0"	"1"
"0"	Input state	HiZ	pull-up
"1"	Output state	LOW	HIGH

**GPIOB**

GPIOB are located on SPI header (see [SPI Header](#)). GPIOB module shares I/O pins with SPI module. If SPI is enabled MISO, MOSI, SCK and SS0 pins are partially controlled by SPI module, although they can be accessed by GPIOB functions with restrictions.

Special care should be taken for SUB-Lxxx models where SPI Level Converters are installed. In this case **GPIOB pins direction should respect direction of the corresponding Level Converter** to prevent short circuit on this pins.

**Functions**

[sub\\_gpio\\_config](#)

[sub\\_gpio\\_read](#)

[sub\\_gpio\\_write](#)

[sub\\_gpio\\_config](#)

[sub\\_gpiob\\_read](#)  
[sub\\_gpiob\\_write](#)

### 3.6.1 sub\_gpio\_config

#### Synopsis

```
int sub_gpio_config( sub_handle hndl, int set, int* get, int mask )
```

Configure GPIO state (direction) as input or output.

#### Parameters

- set - Bits 0..31 of **set** parameter correspond to GPIO0..GPIO31 configuration bits. If GPIO*n* configuration bit is "1" then GPIO*n* direction is output, otherwise it is input.
- \*get - Pointer to store current GPIO configuration read from SUB-20.
- mask - Bit in **set** parameter will take effect only if corresponding **mask** bit is "1". With **mask**=0 function will only read current GPIO configuration.

#### Return value

On success function returns 0. Otherwise [error code](#).

#### Example

```
/* gpio0..6 - input, gpio7 - output */  
rc = sub_gpio_config( hndl, 0x00000080, &config, 0x000000FF );  
  
/* read gpio configuration */  
rc = sub_gpio_config( hndl, 0, &config, 0 );
```

#### See also

[Error Codes](#)

### 3.6.2 sub\_gpio\_read

#### Synopsis

```
int sub_gpio_read( sub_handle hndl, int* get )
```

Read GPIO input status. Function reads logic value "1"-high, "0"-low directly from GPIO pin.

#### Parameters

- \*get - Pointer to store received GPIO input status. Bits 0..31 of \***get** correspond to GPIO0..GPIO31 input statuses.

#### Return value

On success function returns 0. Otherwise [error code](#).

#### See also

[Error Codes](#)

### 3.6.3 sub\_gpio\_write

#### Synopsis

```
int sub_gpio_write( sub_handle hndl, int set, int* get, int mask )
```

Set GPIO output status. For GPIO in output state function will set output driver to drive "1"-high, "0"-low. For

GPIO in input state function will "1"-enable, "0"-disable weak pull-up on corresponding GPIO pin.

#### **Parameters**

- set - Bits 0..31 of **set** parameter correspond to GPIO0..GPIO31 output statuses.
- \*get - Pointer to store current GPIO output status read from SUB-20.
- mask - Bit in **set** parameter will take effect only if corresponding **mask** bit is "1". With **mask=0** function will only read current GPIO output status.

#### **Return value**

On success function returns 0. Otherwise [error code](#).

#### **See also**

[Error Codes](#)

### 3.6.4 sub\_gpiob\_config

#### **Synopsis**

```
int sub_gpiob_config( sub_handle hndl, int set, int* get, int mask )
```

Configure GPIOB state (direction) as input or output.

#### **Parameters**

- set - Bits 0..7 of **set** parameter correspond to GPIOB0..GPIOB7 configuration bits. If GPIOBn configuration bit is "1" then GPIOBn direction is output, otherwise it is input.
- \*get - Pointer to store current GPIOB configuration read from SUB-20.
- mask - Bit in **set** parameter will take effect only if corresponding **mask** bit is "1". With **mask=0** function will only read current GPIOB configuration.

#### **Return value**

On success function returns 0. Otherwise [error code](#).

#### **See also**

[Error Codes](#)

#### **Compatibility**

FW version        0.2.7 or grater  
Library version   0.1.12.17 or grater

### 3.6.5 sub\_gpiob\_read

#### **Synopsis**

```
int sub_gpiob_read( sub_handle hndl, int* get )
```

Read GPIOB input status. Function reads logic value "1"-high, "0"-low directly from GPIOB pin.

#### **Parameters**

- \*get - Pointer to store received GPIOB input status. Bits 0..7 of **\*get** correspond to GPIOB0..GPIOB7 input statuses.

#### **Return value**

On success function returns 0. Otherwise [error code](#).

#### **See also**

[Error Codes](#)



**Compatibility**

FW version      0.2.7 or grater  
 Library version   0.1.12.17 or grater

**3.6.6 sub\_gpiob\_write****Synopsis**

```
int sub_gpiob_write( sub_handle hndl, int set, int* get, int mask )
```

Set GPIOB output status. For GPIOB in output state function will set output driver to drive "1"-high, "0"-low. For GPIO in input state function will "1"-enable, "0"-disable weak pull-up on corresponding GPIOB pin.

**Parameters**

- set - Bits 0..7 of **set** parameter correspond to GPIOB0..GPIOB7 output statuses.
- \*get - Pointer to store current GPIOB output status read from SUB-20.
- mask - Bit in **set** parameter will take effect only if corresponding **mask** bit is "1". With **mask**=0 function will only read current GPIOB output status.

**Return value**

On success function returns 0. Otherwise [error code](#).

**See also**

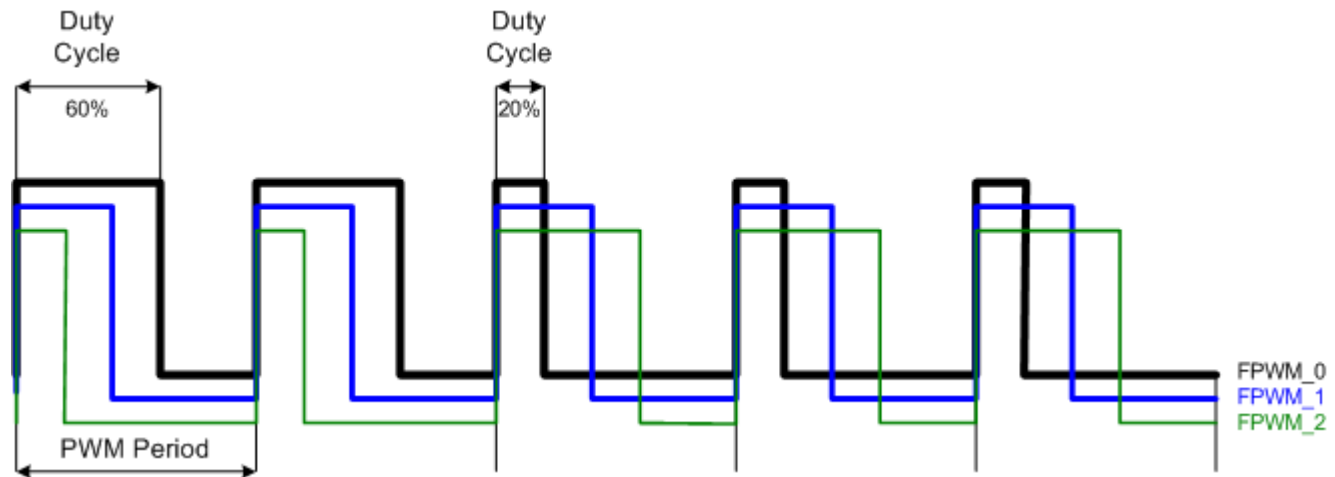
[Error Codes](#)

**Compatibility**

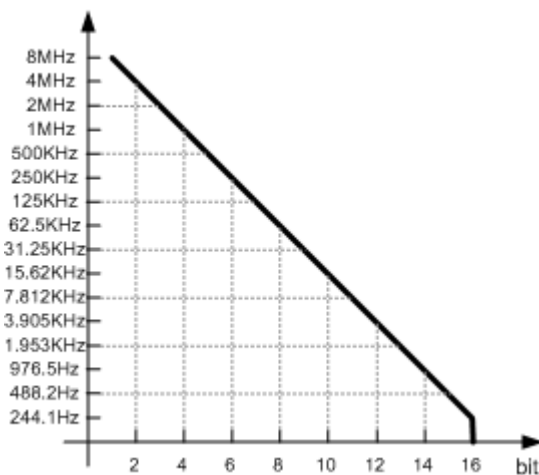
FW version      0.2.7 or grater  
 Library version   0.1.12.17 or grater

**3.6.7 Fast PWM**

Fast PWM outputs are available on SPI header pins 4,6,8 (see [SPI Header](#)). Outputs are referenced as FPWM\_0, FPWM\_1 and FPWM\_2. All three outputs share the same PWM generation module in SUB-20 and have the same PWM frequency but separate duty cycle configuration.



Fast PWM frequency range is 8Mhz .. 0.238Hz. Duty cycle precision is 2..16 bits depending on the PWM frequency.



### Functions

[sub\\_fpwm\\_config](#)

[sub\\_fpwm\\_set](#)

#### 3.6.7.1 sub\_fpwm\_config

##### Synopsis

```
int sub_fpwm_config( sub_handle hndl, double freq_hz, int flags )
```

Configure fast PWM module.

##### Parameters

- freq\_hz - Desired fast PWM frequency in Hz. Frequency can be in a range 8MHz .. 0.238Hz
- flags - Set of configuration flags listed below

<b>FPWM_ENABLE</b>	General fast PWM enable. If this flag is not set fast PWM module will be disabled and FPWM outputs will go to HiZ.
<b>FPWM_EN0</b>	Enable FPWM_0 output. Otherwise FPWM_0 will stay low.
<b>FPWM_EN1</b>	Enable FPWM_1 output. Otherwise FPWM_1 will stay low.
<b>FPWM_EN2</b>	Enable FPWM_2 output. Otherwise FPWM_2 will stay low.

##### Return value

On success function returns 0. Otherwise [error code](#).

##### Example

```
/*
 * Enable fast PWM module with FPWM_0 and FPWM_2 outputs.
 * PWM frequency 10.6Hz
 */
sub_fpwm_config( hndl, 10.6, FPWM_ENABLE|FPWM_EN0FPWM_EN2 );
```

##### See also

[sub\\_fpwm\\_set](#)

[Error Codes](#)

### 3.6.7.2 sub\_fpwm\_set

#### Synopsis

```
int sub_fpwm_set( sub_handle hndl, int pwm_n, double duty )
```

Configure specific fast PWM output.

#### Parameters

- pwm\_n - number of FPWM output to configure. Can be 0,1,2
- duty - desired duty cycle % in range 0..100. Can be not integer.

#### Return value

On success function returns 0. Otherwise [error code](#).

#### Example

```
sub_fpwm_set( hndl, 0, 20 );  
sub_fpwm_set( hndl, 1, 30.5 );  
sub_fpwm_set( hndl, 2, 12.25 );
```

#### See also

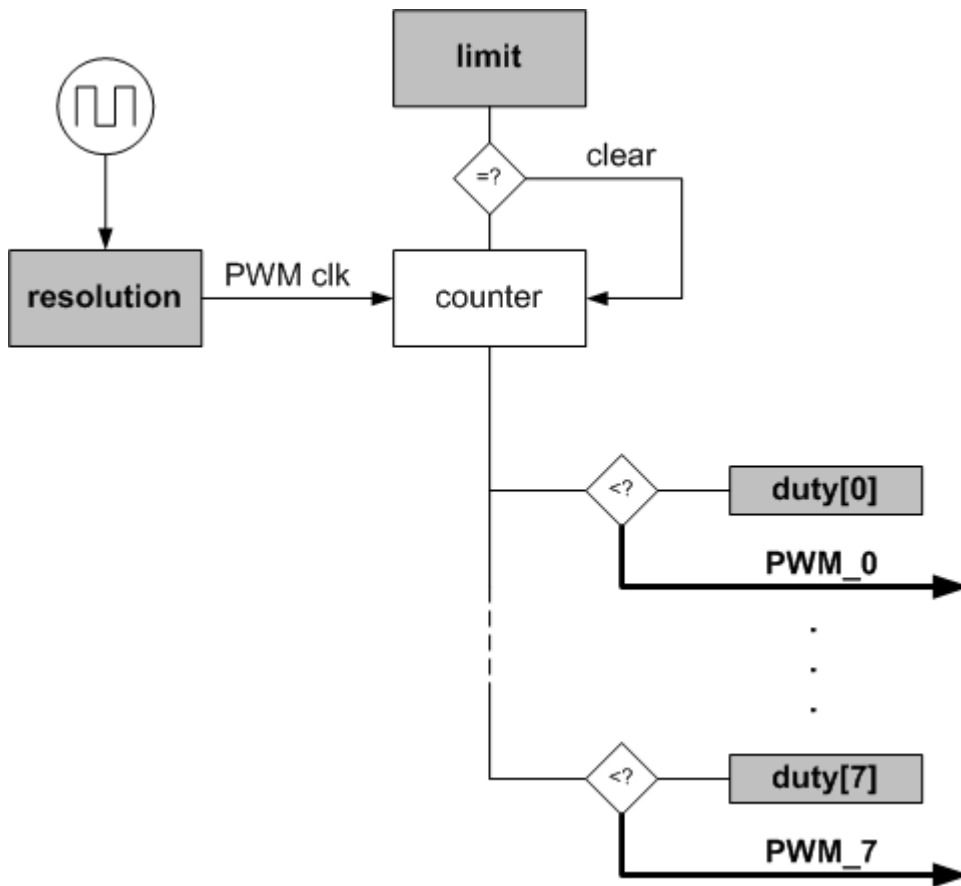
[sub\\_fpwm\\_config](#)

[Error Codes](#)

## 3.6.8 PWM

PWM outputs are available on GPIO24..GPIO31 pins (see [GPIO Header](#)). Outputs are referenced as PWM\_0 .. PWM\_7.

PWM generation module shown below has configurable source clock, counter limit and separate comparator for each PWM output.



PWM module resolution and limit are configured with [sub\\_pwm\\_config](#). Duty cycle of each PWM output can be set with [sub\\_pwm\\_set](#).

PWM module output signal controls output driver of the corresponding GPIO (see [GPIO Functions](#)). **To get high/low transition of the GPIO pin it should be configured to output state with [sub\\_gpio\\_config](#).** Otherwise PWM module will enable/disable internal pull-up.

#### Functions

[sub\\_fpwm\\_config](#)

[sub\\_pwm\\_set](#)

#### 3.6.8.1 sub\_pwm\_config

##### Synopsis

```
int sub_pwm_config( sub_handle hndl, int res_us, int limit )
```

Configure PWM module.

##### Parameters

- res\_us - PWM module clock resolution in  $\mu\text{s}$ . Resolution range is 20 $\mu\text{s}$  - 16384 $\mu\text{s}$ .
- limit - PWM module counter limit in range 0-255. If **limit** is 0 PWM module will be turned off.

##### PWM frequency

Resolution and limit define PWM module frequency

$$F_{\text{pwm}} = 1000000 / (\text{res\_us} * \text{limit}) \text{ Hz}$$

PWM frequency range is

$$F_{pwm\_min} = 1000000 / (20 * 2) = 25000 \text{ Hz} = 25\text{KHz}$$
$$F_{pwm\_max} = 1000000 / (16384 * 255) = 0.238 \text{ Hz}$$

#### **Return value**

On success function returns 0. Otherwise [error code](#).

#### **See also**

[sub\\_pwm\\_set](#)  
[Error Codes](#)

#### **Compatibility**

FW version        0.1.8 or grater  
Library version   0.1.12.10 or grater

### **3.6.8.2        sub\_pwm\_set**

#### **Synopsis**

```
int sub_pwm_set( sub_handle hndl, int pwm_n, int duty )
```

Configure specific PWM output.

#### **Parameters**

- pwm\_n - number of PWM output to configure. Can be 0..7.
- duty - Duty cycle in range 0..255

#### **Duty cycle**

- If duty cycle is 0, PWM output will be constantly low
- If duty cycle is grater or equal to the limit set by [sub\\_pwm\\_config](#), PWM output will be constantly high

Effective duty cycle in percent can be calculated as

$$\text{DUTY\%} = \text{duty} / \text{limit} * 100\%$$

Duty cycle resolution in bits depends on limit. It can be in range of 1 bit for limit=2 up to 8 bit for limit=255

#### **Return value**

On success function returns 0. Otherwise [error code](#).

#### **Example**

```
/* Set PWM resolution=10ms, limit=100, frequency=1Hz */  
sub_pwm_config( hndl, 10000, 100 );  
  
/* Set PWM_0 pin (GPIO24) to output state */  
sub_gpio_config( hndl, 0x01000000, &config, 0x01000000 );  
  
/* Output 50% duty cycle on PWM_0 pin */  
sub_pwm_set( hndl, 0, 50 );
```

#### **See also**

[sub\\_pwm\\_config](#)  
[Error Codes](#)

#### **Compatibility**

FW version        0.1.8 or grater

Library version 0.1.12.10 or grater

## 3.7 Analog to Digital Converter - ADC

SUB-20 has 8 single ended and a 16 differential analog input combinations with x1 x10 or x200 input gain amplifier. Analog inputs are referenced as ADC0..ADC7 see [GPIO Header](#). The SUB-20 ADC module features a 10-bit successive approximation ADC. The ADC contains a Sample and Hold circuit which ensures that the input voltage to the ADC is held at a constant level during conversion.

### Functions

[sub\\_adc\\_config](#)

[sub\\_adc\\_single](#)

[sub\\_adc\\_read](#)

### 3.7.1 sub\_adc\_config

#### Synopsis

```
int sub_adc_config( sub_handle hndl, int flags )
```

Configure SUB-20 ADC module.

#### Parameters

- flags - set of below flags

<a href="#">ADC_ENABLE</a>	Enable ADC module. If this flag is not set ADC module will be disabled
<a href="#">ADC_REF_VCC</a>	Use VCC as ADC reference
<a href="#">ADC_REF_2_56</a>	Use internal 2.56V reference

#### Return value

On success function returns 0. Otherwise [error code](#).

### 3.7.2 sub\_adc\_single

See [sub\\_adc\\_read](#).

### 3.7.3 sub\_adc\_read

#### Synopsis

```
int sub_adc_single( sub_handle hndl, int* data, int mux );
int sub_adc_read( sub_handle hndl, int* data, int* mux, int reads );
```

Read single or multiple ADC conversion result(s)

#### Parameters

- data - buffer to store conversion result(s)
- mux - ADC input channel multiplexer control code(s). See table below.
- reads - number of results to read

ADC mux code	Single Ended	Differential Positive	Differential Negative	Gain
--------------	--------------	-----------------------	-----------------------	------

ADC_S0	ADC0	N.A.			
ADC_S1	ADC1				
ADC_S2	ADC2				
ADC_S3	ADC3				
ADC_S4	ADC4				
ADC_S5	ADC5				
ADC_S6	ADC6				
ADC_S7	ADC7				
ADC_D10_10X	N.A.	ADC1	ADC0	10	
ADC_D10_200X		ADC1	ADC0	200	
ADC_D32_10X		ADC3	ADC2	10	
ADC_D32_200X		ADC3	ADC2	200	
ADC_D01		ADC0	ADC1	N.A.	
ADC_D21		ADC2	ADC1		
ADC_D31		ADC3	ADC1		
ADC_D41		ADC4	ADC1		
ADC_D51		ADC5	ADC1		
ADC_D61		ADC6	ADC1		
ADC_D71		ADC7	ADC1		
ADC_D02		ADC0	ADC2		
ADC_D12		ADC2	ADC2		
ADC_D32		ADC3	ADC2		
ADC_D42		ADC4	ADC2		
ADC_D52		ADC5	ADC2		
ADC_1_1V	Internal 1.1V	N.A.			
ADC_GND	Analog GND				

**ADC Result**

For single ended conversion:

$$ADC = \frac{V_{IN} \cdot 1023}{V_{REF}}$$

For differential:

$$ADC = \frac{(V_{POS} - V_{NEG}) \cdot GAIN \cdot 512}{V_{REF}}$$

ADC is a result of conversion. Note that the result of differential conversion is signed and can be negative.

**Return value**

On success function returns 0. Otherwise [error code](#).

**Example**

```
int adc, adc_buf[3], adc_mux[3];

sub_adc_single( fd, &adc, ADC_S0 );    /* Read ADC on ADC0 input */

adc_mux[0] = ADC_S0;
adc_mux[1] = ADC_S2;
adc_mux[2] = ADC_S3;
sub_adc_read( fd, adc_buf, adc_mux, 3 ); /* Read ADC on ADC0,2,3 inputs */
```

## 3.8 LCD Functions

### Functions

- [sub\\_lcd\\_write](#)

### 3.8.1 sub\_lcd\_write

#### Synopsis

```
int sub_lcd_write( sub_handle hndl, char* str );
```

This function will work only on [SUB-20 configurations](#) with LCD.

Characters from **\*str** are written to the LCD beginning from the current LCD position. Special characters and sequences listed below are used to format LCD output and control current position.

ANSI C notation	Hex value	Description	Example
\f	0x0C	Clear LCD and go to first position	"\fHello"
\r	0x0D	Go to first position	"\r0123"
\n	0x0A	Go to next string	"\rHello\nWorld"
\eXY	0x1B X Y	Go to position X,Y	"\e00Hello\e01World"

Every string written to LCD will be space padded till the end of the string.

#### Parameters

- \*str - LCD string


#### Return value

On success function returns 0. If LCD is not supported function will return ["Feature not supported"](#).

#### Example

```
sub_lcd_write( hndl,
"\fHello\nWorld" );
sub_lcd_write( hndl,
"\f\e20Hello\e21World" );
sub_lcd_write( hndl, "\r1\n2" );

sub_lcd_write( hndl, "\fT:\nR:" );
sub_lcd_write( hndl,
"\e20abc\e21def" );
```



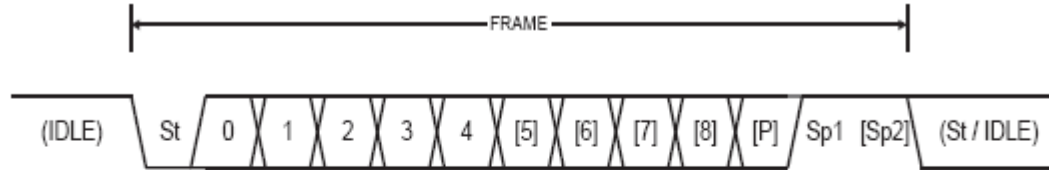
#### Compatibility

- Required firmware version > 0.0.4
- Required DLL version > 0.1.12.2



### 3.9 RS232 RS485 Functions

#### RS232 RS485 Frame format



<b>St</b>	Start bit, always low.
<b>(n)</b>	Data bits (0 to 8).
<b>P</b>	Parity bit. Can be odd or even.
<b>Sp</b>	Stop bit, always high.

#### Functions

[sub\\_rs\\_set\\_config](#)  
[sub\\_rs\\_get\\_config](#)  
[sub\\_rs\\_timing](#)  
[sub\\_rx\\_xfer](#)

#### 3.9.1 sub\_rs\_set\_config

##### Synopsis

```
int sub_rs_set_config( sub_handle hndl, int config, int baud)
```

Configure SUB-20 UART (Universal Asynchronous Receiver Transmitter).

##### Parameters

- config - UART configuration. Config should be assembled as a combination of the following flags

<a href="#">RS_RX_ENABLE</a>	Enable UART receiver
<a href="#">RS_TX_ENABLE</a>	Enable UART transmitter
<a href="#">RS_CHAR_5</a>	Data Bits
<a href="#">RS_CHAR_6</a>	
<a href="#">RS_CHAR_7</a>	
<a href="#">RS_CHAR_8</a>	
<a href="#">RS_CHAR_9</a>	Parity
<a href="#">RS_PARITY_NONE</a>	
<a href="#">RS_PARITY_EVEN</a>	
<a href="#">RS_PARITY_ODD</a>	Stop Bits
<a href="#">RS_STOP_1</a>	
<a href="#">RS_STOP_2</a>	

To disable UART provide configuration without [RS\\_RX\\_ENABLE](#) and [RS\\_TX\\_ENABLE](#).

- baud - Desired baudrate. Maximum baudrate is 2Mbps. The actual baudrate may slightly differ from the desired as actual baudrate is an integer quotient from dividing the 16MHz reference clock.

**Return value**

On success function returns 0. Otherwise [error code](#).

**Example**

```
/* Set 9660 bps, 8 data bits, no parity, 1 stop bit */
sub_rs_set_config( hndl,
RS_RX_ENABLE|RS_TX_ENABLE|RS_CHAR_8|RS_PARITY_NONE|RS_STOP_1, 9600 );
```

**3.9.2 sub\_rs\_get\_config****Synopsis**

```
int sub_rs_get_config( sub_handle hndl, int* config, int* baud)
```

Read current SUB-20 UART configuration.

**Parameters**

- \*config - will be filled with UART configuration see [sub\\_rs\\_set\\_config](#) for details
- \*baud - will be filled with actual UART baudrate

**Return value**

On success function returns 0. Otherwise [error code](#).

**3.9.3 sub\_rs\_timing****Synopsis**

```
int sub_rs_timing( sub_handle hndl, int flags, int tx_space_us,
                  int rx_msg_us, int rx_byte_us )
```

Configure UART transfer timing and order of transmit and receive operations. Actual transfer is initiated by [sub\\_rx\\_xfer](#) function.

**Parameters**

- flags - one or none of the below flags:

RS_RX_BEFORE_TX	Receive message and after that transmit message
RS_RX_AFTER_TX	Transmit message and after that receive message
none	Receive and transmit simultaneously

- tx\_space\_us - delay in  $\mu$ s between subsequent byte transmit
- rx\_msg\_us - message reception timeout in  $\mu$ s
- rx\_byte\_us - byte to byte reception timeout in  $\mu$ s

Delay and timeouts precision is  $\pm 64 \mu$ s. They should not exceed  $4.000.000 \mu$ s = 4s.

Following table explains relation between **rx\_msg\_us** and **rx\_byte\_us** parameters

rx_msg_us=0	rx_byte_us=0	Message reception will last no more then 4s
rx_msg_us=0	rx_byte_us>0	First byte reception will last no more then 4s. Every next byte should be received in rx_byte_us time
rx_msg_us>0	rx_byte_us=0	Message reception will last no more then rx_msg_us time
rx_msg_us>0	rx_byte_us>0	First byte reception will last no more then rx_msg_us time. Every next byte should be received in rx_byte_us time

**Return value**

On success function returns 0. Otherwise [error code](#).

**Example**

```
/* Request message transmit and after that receipt */
/* No space between transmitted bytes */
/* Message should be received in 1s */
sub_rs_timing( hndl, RS_RX_AFTER_TX, 0, 1000000, 0 );
```

**3.9.4 sub\_rs\_xfer****Synopsis**

```
int sub_rs_xfer( sub_handle hndl, char* tx_buf, int tx_sz,
                char* rx_buf, int rx_sz )
```

Transmit and/or receive message(s) via UART configured with [sub\\_rs\\_set\\_config](#) and in accordance with transfer timing set with [sub\\_rs\\_timing](#).

**Parameters**

- tx\_buf - buffer with data to be transmitted
- tx\_sz - number of bytes to transmit (can be 0 if transmit not required)
- rx\_buf - buffer to store received data
- rx\_sz - maximal number of bytes to receive (can be 0 if reception is not required)

**rx\_sz** and **tx\_sz** should not be greater than 62 bytes.

Function will terminate after following conditions fulfilled: **tx\_sz** bytes transmitted and either **rx\_sz** bytes received or one of the timeouts occurs (see [sub\\_rs\\_timing](#))

For 9bit transfer data in **tx\_buf** and **rx\_buf** has following format

byte 0	byte 1	...	byte n	byte n+1
bit ..8 LSB	bits 7..0	...	bit ..8 LSB	bits 7..0

Even bytes (0,2,4,...) contain 8'th bit in LSB. Odd bytes (1,3,5,...) contain bits 7..0. Data is shifted out beginning from bit 0 (see [RS232 RS485 Frame format](#)). Parameters **tx\_sz** and **rx\_sz** should correspond to total number of bytes in **tx\_buf** and **rx\_buf**.

**Return value**

On success function returns non negative value that denotes number of received bytes. It can be less than **rx\_sz** if timeout occurs.

Otherwise -1 will be returned and [sub\\_errno](#) will contain [error code](#).

**Example**

```
/* Set timing */
sub_rs_timing( hndl, RS_RX_AFTER_TX, 0, 1000000, 200000 );

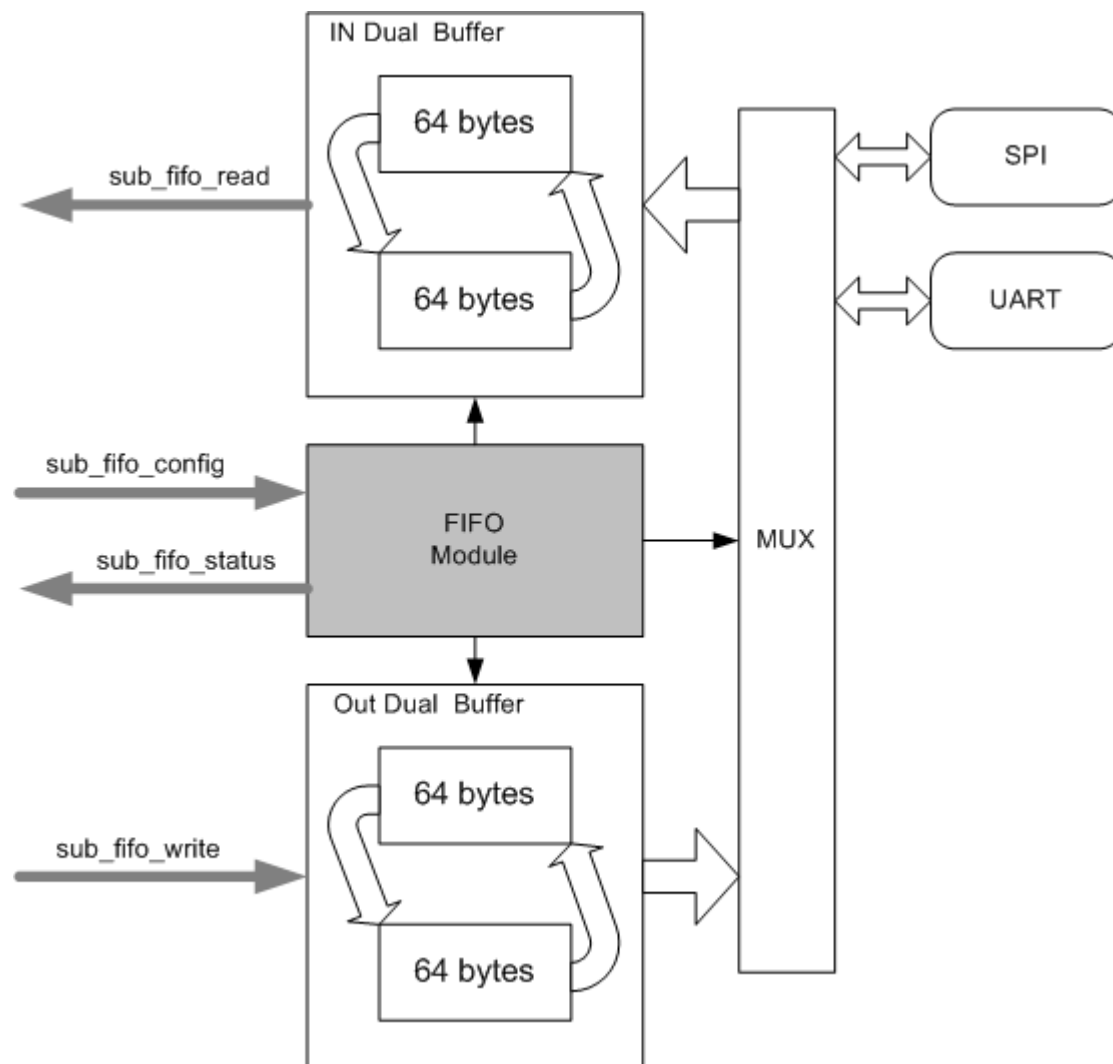
/*
Transmit 3 bytes and try to receive up to 5 bytes
in 1s with 200ms byte to byte timeout
*/
sub_rs_xfer( hndl, "at\r", 3, rx_buf, 5 );
```

**Compatibility**

FW version 9-bit transfer support - 0.2.2 or grater

### 3.10 FIFO, Streaming, Slave Modes

FIFO is used for implementation of streaming data transfer and slave modes functionality such as SPI slave, I2C slave. Below is simplified block diagram of the SUB-20 FIFO module.



#### 3.10.1 FIFO Functions

[sub\\_fifo\\_config](#)  
[sub\\_fifo\\_read](#)  
[sub\\_fifo\\_write](#)

### 3.10.1.1 sub\_fifo\_config

#### Synopsis

```
int sub_fifo_config( sub_handle hndl, int config )
```

Configure FIFO.

#### Parameters

- config - set of FIFO configuration flags listed below
 

<a href="#">FIFO_SELECT_SPI</a>	Connect SPI module to FIFO
<a href="#">FIFO_SELECT_I2C</a>	Connect I2C slave module to FIFO
<a href="#">FIFO_SELECT_UART</a>	Connect UART to FIFO
<a href="#">FIFO_CLEAR</a>	Clear IN and OUT FIFO buffers
<a href="#">FIFO_READ_FULL</a>	Read only full 64 byte FIFO buffers

#### Return value

On success function returns 0. Otherwise [error code](#).

#### Compatibility

FW version	<a href="#">FIFO_CLEAR</a> - 0.1.3 or grater
	<a href="#">FIFO_SELECT_UART</a> - 0.2.0 or grater
Library version	0.1.12.10 or grater

### 3.10.1.2 sub\_fifo\_write

#### Synopsis

```
int sub_fifo_write( sub_handle hndl, char* buf, int sz, int to_ms )
```

Function attempts to transfer **sz** bytes from buffer into OUT FIFO in no more then **to\_ms** time.

#### Parameters

- buf - source buffer
- sz - buffer size
- to\_ms - timeout in milliseconds

#### Return Value

On success a non negative number of actually written bytes is returned. It can be less then or equal to **sz**. In case of error negative error code (defined in `errno.h`) will be returned and if applicable [sub\\_errno](#) will be set to the corresponding value. Possible error codes are

-ENOENT (-2)	USB failure
-EIO (-5)	USB failure
-ENOMEM (-12)	Memory failure
-EINVAL (-22)	Invalid parameter
-EFBIG (-27)	Buffer overflow
-ETIMEDOUT (-116)	Timeout

### 3.10.1.3 sub\_fifo\_read

#### Synopsis

```
int sub_fifo_read( sub_handle hndl, char* buf, int sz, int to_ms )
```

Function attempts to read **sz** bytes from IN FIFO into buffer in no more then **to\_ms** time.

#### Parameters

- buf - destination buffer

- **sz** - buffer size. Considering internal FIFO structure it is highly recommended to use only 64 divisible **sz** values and corresponding buffer size. It will guarantee better performance and no buffer overflow error (-EFBIG).
- **to\_ms** - timeout in milliseconds

#### **Return Value**

On success a non negative number of actually read bytes is returned. It can be less then or equal to **sz**. In case of error negative error code (defined in `errno.h`) will be returned and if applicable [sub\\_errno](#) will be set to the corresponding value. Possible error codes are

-ENOENT (-2)	USB failure
-EIO (-5)	USB failure
-ENOMEM (-12)	Memory failure
-EINVAL (-22)	Invalid parameter
-EFBIG (-27)	Buffer overflow. To prevent this error use 64 divisible <b>sz</b>
-ETIMEDOUT (-116)	Timeout

#### **Known Issue**

If IN FIFO contains exactly 64 or 128 bytes, attempt to read more then 64 or 128 bytes correspondingly with `sub_fifo_read` will cause to timeout (-116). As a workaround always call `sub_fifo_read` with `sz=64`.

### **3.10.2 SPI Slave**

#### **Configuration**

To use SUB-20 in SPI slave mode following should be done:

- Configure SPI module with [sub\\_spi\\_config](#). Make sure to set **SPI\_SLAVE** flag.
- Connect SPI module to FIFO with [sub\\_fifo\\_config](#). **FIFO\_SELECT\_SPI** must be set.
- If required, write data to FIFO with [sub\\_fifo\\_write](#). This data will be read by external SPI master.
- If required, read data from FIFO with [sub\\_fifo\\_read](#). This will be data written by external SPI master.

#### **Example**

Below is an example to exchange 12 bytes with SPI master:

```
sub_spi_config( hndl, SPI_ENABLE | SPI_SLAVE | SPI_CPOL_RISE | SPI_SMPL_SETUP, 0 );
sub_fifo_config( hndl, FIFO_SELECT_SPI );
sub_fifo_write( hndl, "Hello Master", 12, 100 );
read_sz=0;
while( read_sz < 12 )
{
    rc = sub_fifo_read( hndl, in_buff, 64, 10000 ); /* wait 10 sec */
    if( rc < 0 )
        return rc; /* error */
    read_sz += rc;
}
```

#### **Slave Select**

SUB-20 SPI Slave module use SS0 pin as slave select. SS0 must be pulled low by external SPI master to enable SUB-20 SPI module functionality. When SS0 is held low, the SPI is activated, and MISO becomes an output. All other pins are inputs. When SS is driven high, all pins are inputs, and the SPI is passive.

### 3.10.3 I2C Slave

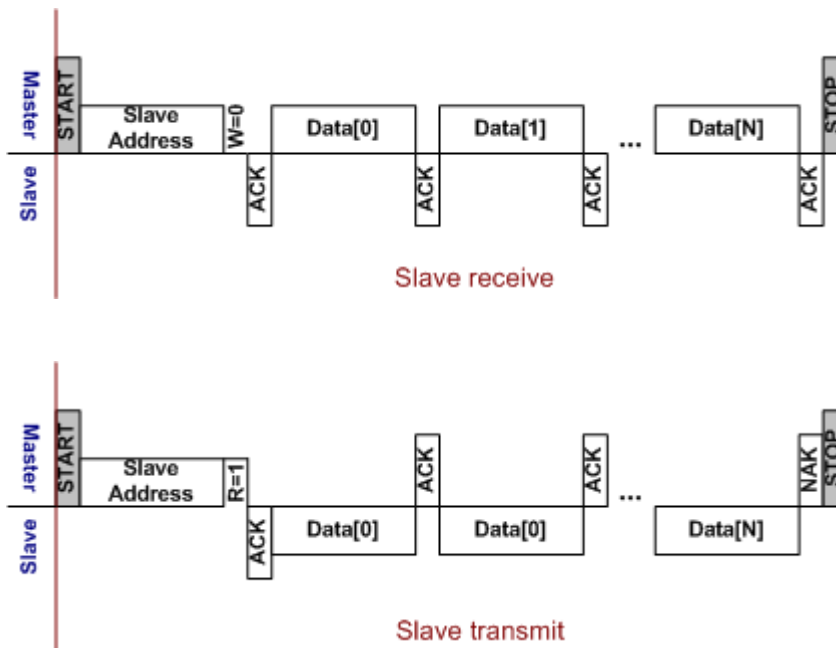
#### Configuration

To use SUB-20 in I2C slave mode following should be done:

- Configure I2C Slave module with [sub\\_i2c\\_config](#). Set desired I2C slave address and optional flag(s).
- Connect I2C Slave module to FIFO with [sub\\_fifo\\_config](#). Set [FIFO\\_SELECT\\_I2C](#) flag.
- If required write data to FIFO with [sub\\_fifo\\_write](#). This data will be read by external I2C master.
- If required read data from FIFO with [sub\\_fifo\\_read](#). This will be data written by external I2C master.

#### Transactions

SUB-20 I2C slave module acts as zero address I2C slave device. Below are diagrams of receive and transmit transactions.



## 3.11 Error Codes

API functions may return error code and/or set global variable [sub\\_errno](#) to provide information about completion of requested operation. The string describing error code can be received with [sub\\_strerror](#) function call.

### 3.11.1 sub\_errno

Global variable **sub\_errno** contains status of last SUB-20 API call. Variable **sub\_errno** defined in *libsub.h*.

Following error codes are available:

- |   |                         |
|---|-------------------------|
| 0 | OK                      |
| 1 | SUB Device not found    |
| 2 | Can't open SUB device   |
| 3 | Can't set configuration |

4	Can't claim interface
5	Failed to setup async transaction
6	Failed to submit async transaction
7	Bulk write failed
8	Bulk read failed
9	Bulk read incomplete
10	Out buffer overflow
11	I2C error
12	Wrong tag code in response
13	Wrong tag size in response
14	Wrong parameters
15	SPI Disabled
16	Feature not supported

### 3.11.2 sub\_strerror

#### Synopsis

```
char* sub_strerror( int errnum )
```

Return string describing error number. This function is similar to strerror().

#### Parameters

- errnum - error number

#### Return Value

Function returns pointer to string with error description. If error number is unknown function will return pointer to string "Unrecognized error <error\_number>".



## 4 Electrical Characteristics

### 4.1 Absolute Maximum Ratings

Operating Temperature	-20°C to +65°C
Voltage on any Pin with respect to Ground	-0.5V to VCC+0.5V
Maximum Operating Voltage	+6V
DC Current per I/O Pin	40mA
DC Current Vcc and GND Pins	200mA

### 4.2 DC Characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Units
V <sub>IL</sub>	Input Low Voltage	V <sub>CC</sub> = 3.3V - 5.5V	0.5		0.2V <sub>CC</sub>	V
V <sub>IH</sub>	Input High Voltage	V <sub>CC</sub> = 3.3V - 5.5V	0.6V <sub>CC</sub>		V <sub>CC</sub> + 0.5	V
V <sub>OL</sub>	Output Low Voltage	I <sub>OL</sub> = 10mA, V <sub>CC</sub> = 5V I <sub>OL</sub> = 5mA, V <sub>CC</sub> = 3.3V		0.3 0.2	0.7 0.5	V
V <sub>OH</sub>	Output High Voltage	I <sub>OH</sub> = -20mA, V <sub>CC</sub> = 5V I <sub>OH</sub> = -10mA, V <sub>CC</sub> = 3.3V	4.2 2.3	4.5 2.6		V
I <sub>IL</sub>	Input Leakage Current I/O Pin	V <sub>CC</sub> = 5.5V, pin low			1	μA
I <sub>IH</sub>	Input Leakage Current I/O Pin	V <sub>CC</sub> = 5.5V, pin high			1	μA
I <sub>CC</sub>	Power Consumption Current	V <sub>CC</sub> = 5V		19	30	mA

Although each I/O port can sink or source more than the test conditions under steady state conditions (non-transient), the following must be observed:

1. The sum of all I<sub>OL</sub>, for GPIO4-GPIO7 should not exceed 100 mA.
2. The sum of all I<sub>OL</sub>, for GPIO0-GPIO3, GPIO8-GPIO15 should not exceed 100 mA.
3. The sum of all I<sub>OL</sub>, for GPIO24-GPIO31 should not exceed 100 mA.
4. The sum of all I<sub>OL</sub>, for GPIO16-GPIO23 should not exceed 100 mA.
5. If I<sub>OL</sub> exceeds the test condition, V<sub>OL</sub> may exceed the related specification. Pins are not guaranteed to sink current greater than the listed test condition.
6. The sum of all I<sub>OH</sub>, for GPIO4-GPIO7 should not exceed 100 mA.
7. The sum of all I<sub>OH</sub>, for GPIO0-GPIO3, GPIO8-GPIO15 should not exceed 100 mA.
8. The sum of all I<sub>OH</sub>, for GPIO24-GPIO31 should not exceed 100 mA.
9. The sum of all I<sub>OH</sub>, for GPIO16-GPIO23 should not exceed 100 mA.

### 4.3 AC Characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Units
SPI						
F <sub>SPI</sub>	SPI Master frequency		0.125		8	MHz
F <sub>SPI_SLAVE</sub>	SPI Slave frequency				2	MHz
MDIO						
F <sub>MDC</sub>	MDC frequency			1		MHz

## 5 Ordering Information

Ordering Code	I2C	SPI Master	SPI Slave	GPIO	LCD	RS232	RS485	SW1/2	IR	Notes
SUB-20-B <b>Basic</b>	V	V	V	V						
SUB-20-EB <b>Basic Enclosure</b>	V	V	V							Heavy duty enclosure with <a href="#">DB9 Connector</a>
SUB-20-V <b>Visual</b>	V	V	V	V	V					
SUB-20-R25 <b>Serial2</b>	V	V	V	V	V	V		V		
SUB-20-R45 <b>Serial4</b>	V	V	V	V	V		V	V		
SUB-20-I5 <b>Infra5</b>	V	V	V	V	V			V	V	
SUB-20-Lxxx	V	V		V	x	x	x	x	x	SPI Level Converters
SUB-20-Cxxx	Custom Configuration									

For SUB-20-Lxxx, 'xxx' - can be any of the above configuration with addition of SPI Level Converters and without SPI Slave option. For example SUB-20-LV is SUB-20-V board with SPI Level Converters.

**SUB-20-EB**

