



Power Amplifier Serial Interface

Version 1.62

Requirements Specification

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## **1. Introduction**

### **1.1 Version Control**

| Date     | Author   | Revision | Comment                                                                                                                                   |
|----------|----------|----------|-------------------------------------------------------------------------------------------------------------------------------------------|
| 12/20/00 | Welte    | 1.00     | Initial Revision                                                                                                                          |
| 12/21/00 | Welte    | 1.10     | Added more clarity to section 2.4 and changed Figure 2-1 to specify host as Master and size of transaction.                               |
| 1/4/01   | Welte    | 1.20     | Redefined chip select, device ID mechanism. Made some changes to timing diagrams.                                                         |
| 1/9/01   | Welte    | 1.30     | Changes made in accordance to design review, namely remove the –RackEnable signal, specify backplane values, make some error corrections. |
| 1/10/01  | JS       | 1.40     | Elaborated on hardware issues.                                                                                                            |
| 3/30/01  | G. Nakao | 1.41     |                                                                                                                                           |
| 6/6/01   | G. Nakao | 1.42     | SPI Refinements                                                                                                                           |
| 6/7/01   | RMS      | 1.61     | Further clarifications                                                                                                                    |
| 9/12/01  | J.Briggs | 1.62     | SPI Timing changes                                                                                                                        |

### **1.2 Scope**

This document is a technical description of the RF Power Amplifier Serial Peripheral Interface (SPI) requirements.

### **1.3 Overview**

The Power Amplifiers operate at approximately 133 watts average power, and will be combined in parallel to achieve 400 watts average power, or 1200 watts peak power. Amplifier status and configuration is done via the SPI interface. The amplifier section is comprised of 3 modules. Two SPI interface connectors are to be located on the rear of each amplifier module. The SPI interface is routed to each individual amplifier within the amplifier by daisy chain wiring.

In the event of an amplifier failure, the remaining amplifiers continue to operate, providing continuous performance and soft fail operation. Failed amplifiers indicate their status via the SPI interface.

The Power Amplifier must be capable of collecting and sending over the serial bus amplifier status including:

- temperature**
- forward power**
- reflected power**
- attenuator level**
- phase setting**

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**DC supply voltage**  
**DC supply current**  
**fan status**  
**internal self- test result**  
**amplifier model number**

## **2. Power Amplifier**

### ***2.1 Status & Control***

The Power Amplifier has status & control information as defined in Table 2.1:

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| <b>Description</b>           | <b>No. of Bits</b> | <b>Definition</b>                                                                             | <b>Read/Write</b> |
|------------------------------|--------------------|-----------------------------------------------------------------------------------------------|-------------------|
| Temperature                  | 8                  | 0 = 0C<br>255 = -1C<br>206 = -50C<br>100 = +100C                                              | Read only         |
| Forward Power                | 8                  | 0 = 0 Watts<br>1 = 1 Watts<br>255 = 255 Watts                                                 | Read only         |
| Reflected Power              | 8                  | 0 = 0 Watts<br>1 = 1 Watts<br>255 = 255 Watts                                                 | Read only         |
| DC Supply Voltage            | 8                  | 0 = 0 Volts<br>255 = 30V                                                                      | Read only         |
| DC Supply Current            | 8                  | 0 = 0 Amps<br>255 = 40 amps                                                                   | Read only         |
| Fan Fail Alarm               | 1                  | 0 = Normal, 1 = Alarm Occurred                                                                | Read only         |
| Amplifier Online             | 1                  | 0= offline, 1=enabled                                                                         | Read/Write        |
| Amplifier Reset              | 1                  | 0 = Normal, 1 = Reset Occurred                                                                | Read/Write        |
| Reverse Power Shutdown       | 1                  | 0 = Normal, 1 = Shutdown Occurred                                                             | Read/Write        |
| Amplifier Overdrive Alarm    | 1                  | 0 = Normal, 1 = Alarm Occurred                                                                | Read/Write        |
| Thermal Alarm                | 1                  | 0 = Normal, 1 = Alarm Occurred                                                                | Read/Write        |
| Amplifier Overdrive Shutdown | 1                  | 0 = Normal, 1 = Shutdown Occurred                                                             | Read/Write        |
| Thermal Alarm Shutdown       | 1                  | 0 = Normal, 1 = Shutdown Occurred                                                             | Read/Write        |
| Phase Control                | 8                  | -128 = -20 degrees min (in 40 steps)<br>0 = 0 degrees<br>+127 = +20 degrees min (in 40 steps) | Write Only        |
| Attenuation Level            | 8                  | 0 = -2 dB min (in 40 steps)<br>63 = No attenuation<br>127 = +2 dB min (in 40 steps)           | Write Only        |
| Serial Number                | 256                |                                                                                               | Read only         |

**Table 2-1****2.2 Non-volatile read/write**

In addition, the Power Amplifier contains 256 bytes of non-volatile read/write memory for storing phase control and attenuation levels for various channel frequencies. The manufacturer will be responsible for initializing correct attenuation & phase values for all frequencies, as well as model and version numbers.

The memory content and locations are defined in Table 2-2:

| <b>Relative Offset</b> | <b>Page Address</b> | <b>Description</b>                        |
|------------------------|---------------------|-------------------------------------------|
| 0                      | 0                   | 940 MHz Attenuation Value                 |
| 1                      |                     | 940 MHz Phase Value                       |
| 2                      |                     | Unused                                    |
| 3                      |                     | Unused                                    |
| 4                      | 1                   | 930 MHz Attenuation Value                 |
| 5                      |                     | 930 MHz Phase Value                       |
| .                      |                     | Unused                                    |
| .                      |                     | Unused                                    |
| .                      | 2                   | Unused                                    |
| .                      |                     | Unused                                    |
| 216                    | 0x36                | Serial Number (32 bytes starting at 0xD8) |
| .                      |                     | “                                         |
| .                      |                     | “                                         |
| .                      |                     | “                                         |
| 247                    |                     | Serial Number                             |
| 248                    | 0x3E                | Model Number                              |
| 249                    |                     | Version Number                            |
| 250                    |                     | Unused                                    |
| 251                    |                     | Unused                                    |
| 252                    | 0x3F                | Unused                                    |
| 253                    |                     | Unused                                    |
| 254                    |                     | Unused                                    |
| 255                    |                     | Checksum                                  |
|                        |                     |                                           |
|                        |                     |                                           |

*Table 2-2*

### 3. Microprocessor Interface

The microprocessor interface provides serial communication between the Power Amplifier and external microprocessor/microcontroller (host). Through this interface, the Power Amplifier will send information to the host and the host will send information to the Power Amplifier. The SPI interface is a standard CPU interface, common on PIC and Motorola CPUs. As a point of reference, the 68HC11 CPU is the classic implementation of the SPI, and is the reference used at Sonik for the operation of the SPI bus.

Along with the SPI signals, there are 6 address lines on the SPI interface connector. These address lines are used to determine which device on the SPI bus is being addressed, as well as which information within the device is being addressed. The 6 address lines are split into 3 device select lines (device ID 0-7), and 3 register select lines.

#### 3.1 SPI BUS ID

Each module on the SPI BUS will have an ID value as described in Table 3.1. When the address lines associated with the device ID match the module's ID, the module is to respond.

| <b>System Devices</b> | <b>ID<br/>(A5, A4, A3)</b> |
|-----------------------|----------------------------|
| Reserved              | 0 0 0                      |
| Power Amplifier #1    | 0 0 1                      |
| Power Amplifier #2    | 0 1 0                      |
| Power Amplifier #3    | 0 1 1                      |
| Power Amplifier #4    | 1 0 0                      |
| Power Supply #1       | 1 0 1                      |
| Power Supply #2       | 1 1 0                      |
| Reserved              | 1 1 1                      |

**Table 3-1**

### **3.2 Serial Communication Description**

The Power Amplifier and host will communicate synchronously via a Serial Peripheral Interface (SPI) Bus with the master located on the host and the Power Amplifier functioning as one of up to 8 slave devices.

### **3.3 SPI Bus Interface**

The SPI interface on the PA shall use a DB15 male connector as the primary interface (designated SPI1), and a DB15 female connector (designated SPI2) as a daisy-chain interface. All pins on both connectors will be wired in parallel. All pins will be RF bypassed, and all input pins will have 10kΩ resistive pull-ups to +5V internal to the amplifier. The capacitive loading on each pin shall not exceed 100pF.

The connector cable between the SPI control unit and first PA, and the daisy chain cables used to connect between the 4 PAs will have wires only for pins 1-10. Pins 11 and 12 will be tied to pin 15 or left open inside each SPI1 input connector shell, in order to select the PA number. Pin 14 may be used for DC power to other SPI devices. No more than 25mA should be drawn from pin 14 by any SPI device. The DC power on pin 14 comes from the SCM board in the controller.

The SPI bus interface connector pin outs are described in Table 3-2:

| <b>Pin</b> | <b>Description</b> | <b>Pin</b> | <b>Description</b>         |
|------------|--------------------|------------|----------------------------|
| 1          | Shield GND         | 9          | SPI MOSI                   |
| 2          | SPI A5             | 10         | SPI MISO                   |
| 3          | SPI A4             | 11         | Backplane ID0              |
| 4          | SPI A3             | 12         | Backplane ID1              |
| 5          | SPI A2             | 13         | Reset                      |
| 6          | SPI A1             | 14         | +10-15VDC from controller. |
| 7          | SPI A0             | 15         | GND                        |
| 8          | SPI CLK            |            |                            |

**Table 3-2**

Note: Pins 11 and 12 will indicate to the amplifier its slot location in the rack.

| Pin 11 | Pin 12 | Amplifier |
|--------|--------|-----------|
| Ground | Ground | 1         |
| Ground | Open   | 2         |
| Open   | Ground | 3         |
| Open   | Open   | 4         |

Pins 13, 14, and 15 should be left open in the Sonik rack.  
These pins will be used by the manufacturer for test purposes.

SPI bits A5-A3 are used to select the Power Amplifier module on the SPI BUS. SPI bits A2-A0 are used to select the register/device within the selected Power Amplifier module.

### 3.4 Power Amplifier Device ID

The Power Amplifier shall have SPI “devices” associated with SPI A2-A0 defined in Table 3-3:

| Device ID | Definition                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                      |                             |                                |                    |                                   |                       | Device Size (in bytes) |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|----------------------|-----------------------------|--------------------------------|--------------------|-----------------------------------|-----------------------|------------------------|
| 0         | Temperature (read only)<br>Forward Power (read only)<br>Reflected Power (read only)<br>DC supply voltage (read only)<br>DC supply current (read only)                                                                                                                                                                                                                                                                                                                                                                 |            |                      |                             |                                |                    |                                   |                       | 5                      |
| 1         | Status word (Read Only) For all bits except bit 6, the amplifier sets the bit when the relevant condition occurs. The bit will stay set until cleared by a write of a 1 to the corresponding bit in the control register. Bit 6 indicates whether the amplifier is active or shut down. The amplifier may only be brought online by writing a 1 to bit 6 of the control register, but shutdown may occur either by writing a 0 to bit 6 of the control register, or by one of the shutdown conditions being detected. |            |                      |                             |                                |                    |                                   |                       | 1                      |
|           | 7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 6          | 5                    | 4                           | 3                              | 2                  | 1                                 | 0                     |                        |
|           | Fan Fail Flag                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Amp Online | Amplifier Reset Flag | Reverse Power Shutdown Flag | Amplifier Overdrive Alarm Flag | Thermal Alarm Flag | Amplifier Overdrive Shutdown Flag | Thermal Shutdown Flag |                        |
| 2         | Phase Control (write only)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                      |                             |                                |                    |                                   |                       | 1                      |
| 3         | Attenuation Level (write only)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                      |                             |                                |                    |                                   |                       | 1                      |
| 4         | EEPROM (read/write)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                      |                             |                                |                    |                                   |                       | 4                      |
| 5         | Control word (write only)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |                      |                             |                                |                    |                                   |                       | 1                      |
|           | 7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 6          | 5                    | 4                           | 3                              | 2                  | 1                                 | 0                     |                        |

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|   | Fan Fail Flag Clear   | Amp Online | Amplifier Reset Flag Clear | Reverse Power Shutdown Flag Clear | Amplifier Overdrive Alarm Flag Clear | Thermal Alarm Flag Clear | Amplifier Overdrive Shutdown Flag Clear | Thermal Shutdown Flag Clear |  |
|---|-----------------------|------------|----------------------------|-----------------------------------|--------------------------------------|--------------------------|-----------------------------------------|-----------------------------|--|
| 6 | Reserved              |            |                            |                                   |                                      |                          |                                         |                             |  |
| 7 | Factory Communication |            |                            |                                   |                                      |                          |                                         |                             |  |
|   |                       |            |                            |                                   |                                      |                          |                                         |                             |  |

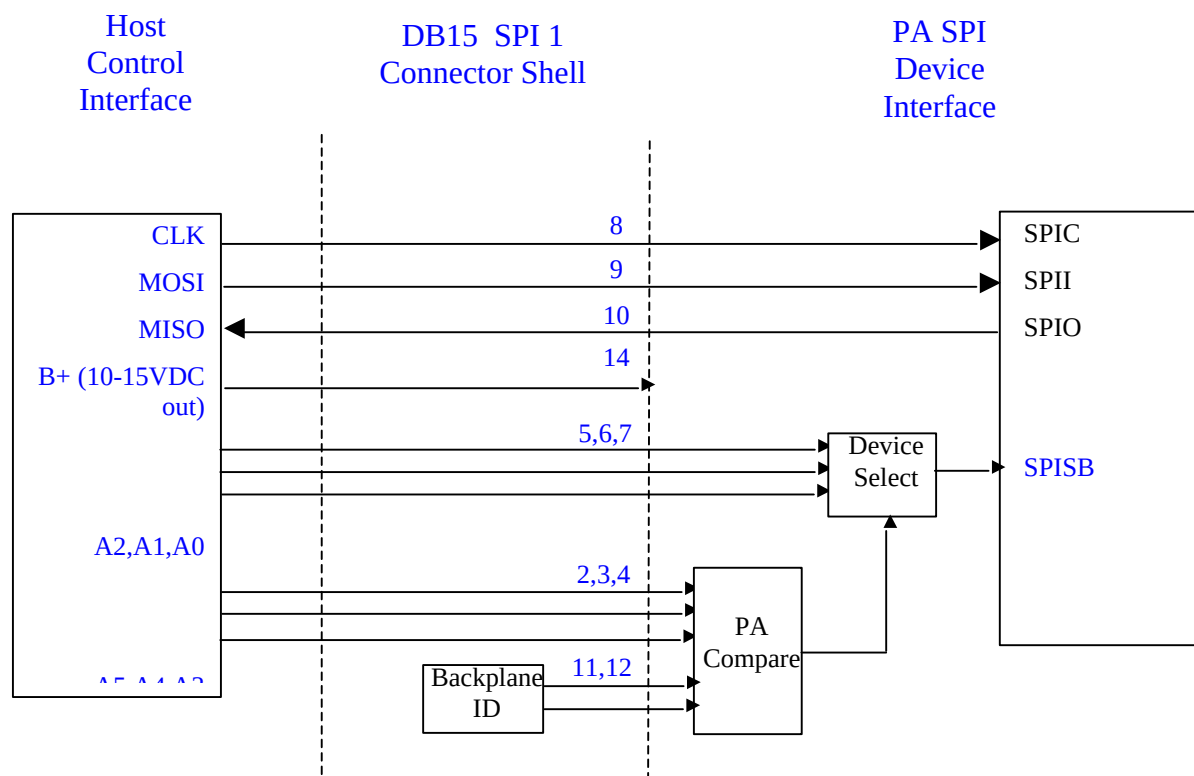
Table 3-3

### 3.5 SPI Electrical Considerations

All signals are CMOS levels with 30%/70% thresholds. Devices driving the SPI bus must be able to drive a load of 500 ohms // 2200pF with a rise-time of less than 1uS. The SN65176B transceiver from TI is a recommended I/O device. It is differential, but can be used in a single-ended mode.

### 3.6 Serial Communication Format

Figure 3-1 below shows the connection between the host and the Power Amplifier:



**Figure 3-1**

Note that the Host is the Master Device and therefore is the only device on the SPI bus to drive the CLK signal.

The host changes its MOSI output on the falling edge of the SPI clock while the SPISB (chip selected) is driven active low. The Power Amplifier is expected to sample data (SPII) on the rising edge of the clock signal.

The host samples the MISO input on the rising edge of the SPI clock while the SPISB (chip selected) is driven active low. The Power Amplifier is expected to change its output (SPIO) on the falling edge of the SPI clock.

SPI transfers are variable length depending on the SPI device (refer to Table 3-3). During an SPI transfer, data is transmitted and received simultaneously.

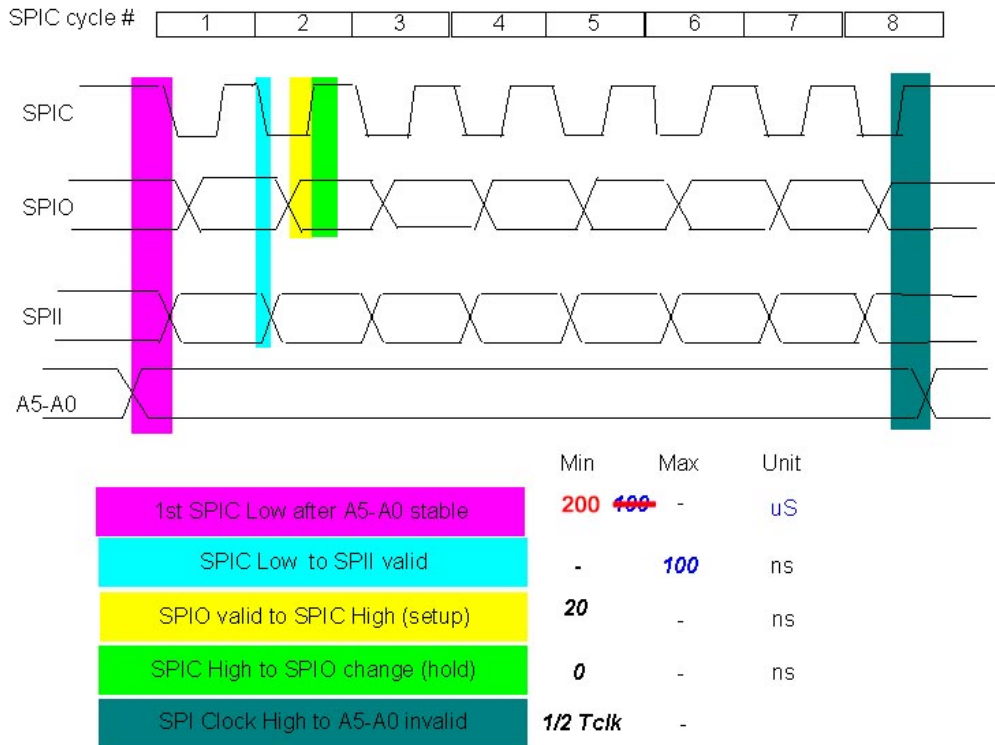
### **3.7 SPI Session Protocol**

All SPI transfers are started and controlled by the host. A SPI transfer is started after the Power Amplifier device address A5..A0 is selected and is complete when the address changes. The address will always return to an inactive state (ie no SPI device within the system is selected).

SPI transfers in packets of 8 bits, with the most significant bit (bit 7) as the first bit.

The transfer waveform is shown in Figure 3-2:

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Tclk refers to the SPIC cycle. If SPIC cycle is 500kHz, 1/2 Tclk is equal to 1 us

Figure 3-2

The Power Amplifier must be able to support a SPIC cycle of between 0kHz and 800kHz. The design of the interface should not assume that the time intervals between edges of signals during a transfer will necessarily be regular, i.e. there may be some jitter and delay during clocking, although all maximum and minimum timings given above will be adhered to.

Minimum time interval between SPI transfers to an individual PA is 500uS.

Whenever the SPI address does not match a device's SPI ID, the SPIO line must go high-impedance (<20uA output current).

### 3.7.1 Power Amplifier DeviceID 0 transfer protocol

DeviceID 0 is a 5 byte transfer with the following order:

Byte 1: Temperature

Byte 2: Forward Power

Byte 3: Reflected Power

Byte 4: DC Supply Voltage

Byte 5: DC Supply Current

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During the 5 byte transfer, A5-A0 will not normally change.

If prior to the completion of the 5 byte transfer, the SPI address A5..A0 changes, for example due to a host reset or error, the transfer will be halted by the PA. The next time the device ID on the addressed PA is active, the transfer begins again starting with byte 1.

The timing diagram is shown in Figure 3-3:

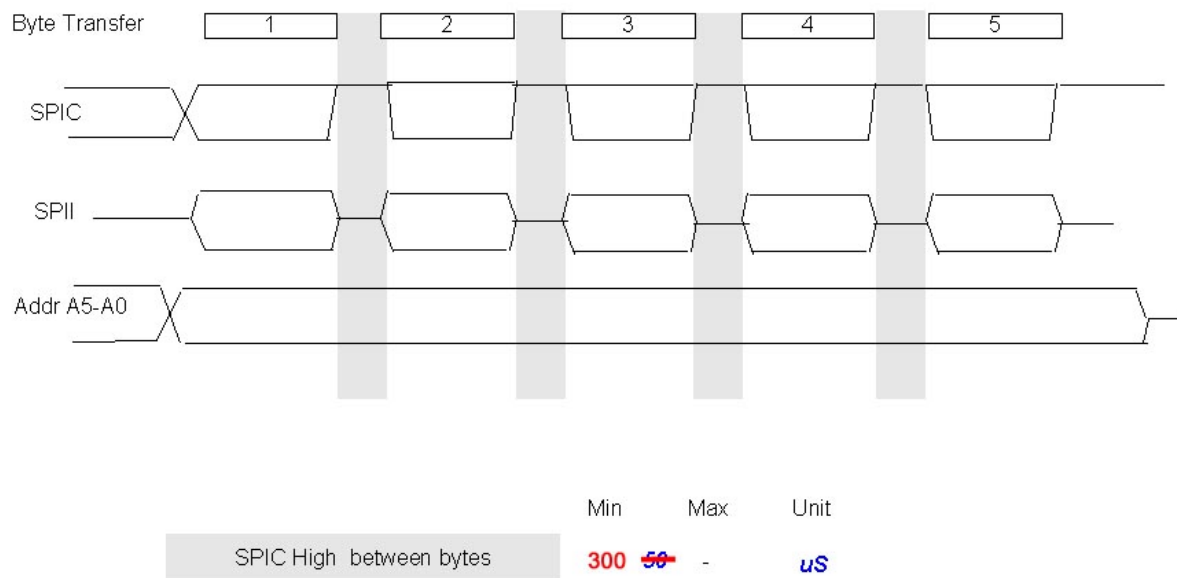


Figure 3-3

#### 3.7.2 Power Amplifier DeviceID 1 transfer protocol

DeviceID 1 is a 1 byte transfer. The timing diagram for this transfer is shown in Figure 3-2.

#### 3.7.3 Power Amplifier DeviceID 2 transfer protocol

DeviceID 2 is a 1 byte transfer. The timing diagram for this transfer is shown in Figure 3-2.

#### 3.7.4 Power Amplifier DeviceID 3 transfer protocol

DeviceID 3 is a 1 byte transfer. The timing diagram for this transfer is shown in Figure 3-2.

#### 3.7.5 Power Amplifier DeviceID 4 transfer protocol

##### 3.7.5.1 Read

A read of DeviceID 4 is a 6 byte transfer with the following order:

Byte 1: 0x03 (this is the READ instruction byte for the EEPROM)

Byte 2: target EEPROM page number (0-63) shifted left two bits (e.g page 3 = 00001100b)

Byte 3: byte 1

Byte 4: byte 2

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Byte 5: byte 3

Byte 6: byte 4

The timing diagram for this transfer is approximately shown in Figure 3-3, with the addition of a byte.

#### **3.7.5.2 Write**

A write to DeviceID 4 is an 8 byte transfer with the following order:

Byte 1: 0x06 (this is the WRITE ENABLE instruction byte for the EEPROM)

Byte 2: 0x02 (this is the WRITE instruction byte for the EEPROM)

Byte 3: target EEPROM page number (0-63) shifted left two bits (e.g page 63 = 11111100b)

Byte 4: byte 1

Byte 5: byte 2

Byte 6: byte 3

Byte 7: byte 4

Byte 8: 0x04 (this is the WRITE DISABLE instruction byte for the EEPROM)

The timing diagram for this transfer is approximately shown in Figure 3-3, with the addition of 3 bytes.