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USB Audio to I²S Digital Audio Bridge CP2615 Data Sheet

The CP2615 device is designed to enable rapid development of USB-based audio applications.

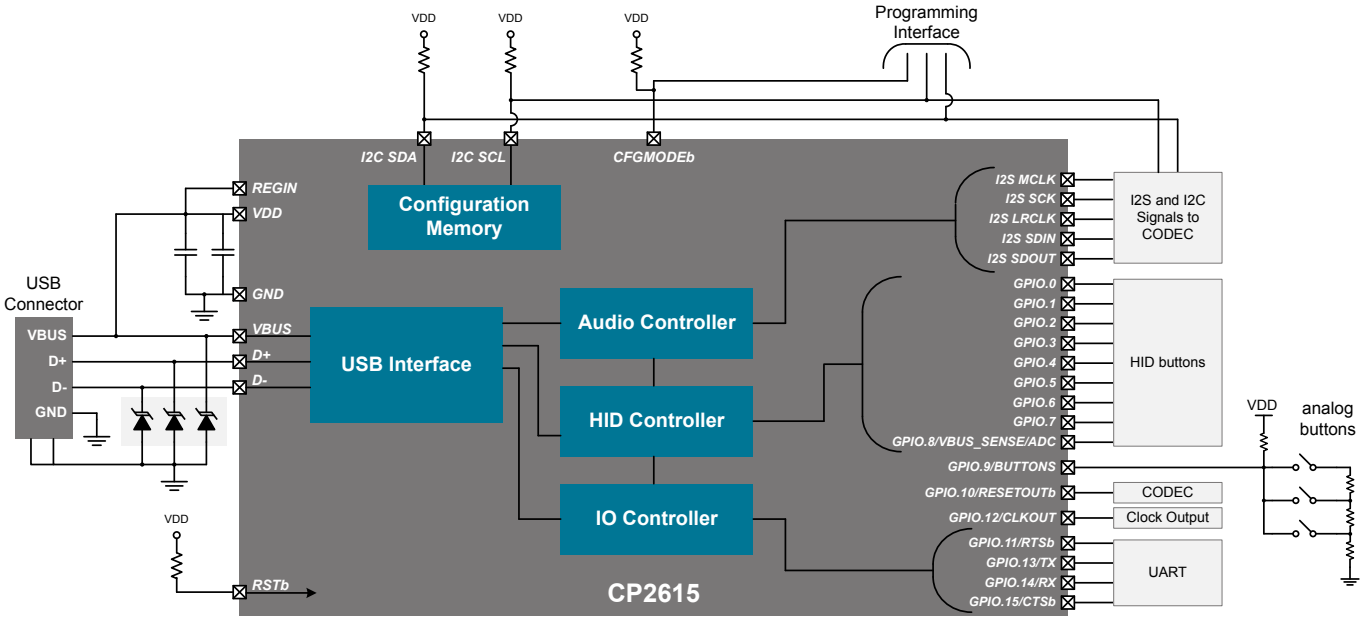
The CP2615 simplifies the process of transferring audio data from USB to I²S without any code development, speeding time to market for USB audio accessories such as USB speakers, USB headphones and USB music boxes, as well as VoIP systems. The CP2615 includes a USB 2.0 full-speed function controller, USB transceiver, oscillator, I²S (audio) interface, I²C (control) interface and UART interface in a compact 5 x 5 mm QFN-32 package ideal for space-constrained portable audio applications.

The CP2615 device is ideal for a wide range of USB Audio applications, including the following

- USB speakers
- MP3 accessories
- Navigation systems
- USB headphones/headsets
- Point of sale terminals
- Music boxes

KEY FEATURES

- USB Audio class 1.0
- Supports USB HID Consumer Controls for Audio and Media
- Includes USB-UART bridge function
- Supports 48 kHz,16-bit/ 24-bit stereo digital audio
- Integrated USB transceiver; no external resistors required
- Integrated clock; no external crystal required
- On-chip voltage regulator: 3.45 V output
- Self-powered or Bus-powered
- No firmware development



1. Feature List and Ordering Information

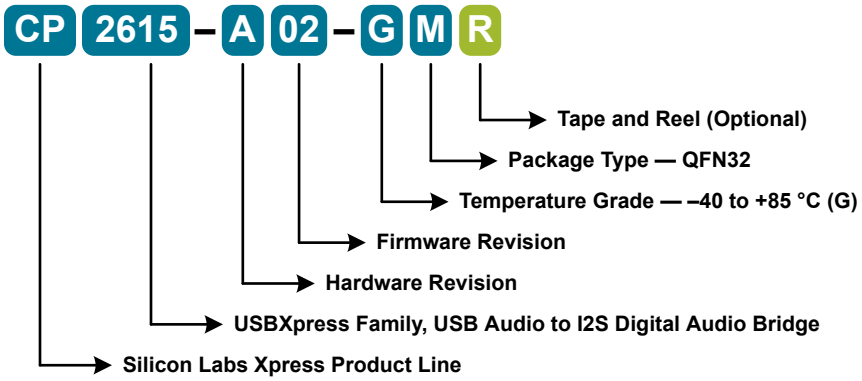


Figure 1.1. CP2615 Part Numbering

The CP2615 devices have the following features:

- **Single-Chip USB Audio to I²S Digital Audio Bridge**
  - Integrated USB transceiver; no external resistors required
  - Integrated clock; no external crystal required
  - On-chip voltage regulator: 3.3 V output
  - Integrated I²C to communicate with DACs/codecs
- **Digital Audio**
  - Compliant with USB Device Class Definition for Audio Devices Release 1.0
  - Natively supported (no custom driver required) on Windows/Android
  - Android USB Host Mode audio
  - 44.1 kHz and 48 kHz sampling rates
  - Synchronous and asynchronous endpoints
  - Simultaneous input and output audio streams when using 16-bit samples
  - Unidirectional input or output audio stream when using 24-bit samples
- **USB Peripheral Function Controller**
  - USB Specification 2.0 compliant; full-speed (12 Mbps)
  - USB Suspend states supported via SUSPEND pins
- **USB HID Consumer Controls**
  - Supports USB HID Consumer Controls for Volume and Mute Synchronization
- **Power**
  - Supports Self-powered and Bus powered modes
- **Other Features**
  - Optimized for low power in both USB active and idle modes, simplifying development of device-powered accessories
  - Highly-integrated SoC reduces external BOM cost and PCB footprint
  - Crystal-free USB operation means no external crystal is required
  - Embedded Flash memory stores device customization options, eliminating the need for any external EEPROM or flash storage
  - Pin compatible with CP2614 MFi Accessory Digital Audio Bridge

Table of Contents

2. Electrical Specifications

2.1 Electrical Characteristics

2.1.1 Recommended Operating Conditions

Table 2.1. Global DC Electrical Characteristics [1]

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
Digital Supply Voltage	V_{DD}		2.7	—	3.6	V
Supply Current – Active Mode		Sample rates: 44.1 kHz or 48 kHz Modes: • Play and Record (16-bit) • Play-only (24-bit or 16-bit) • Record-only (24-bit or 16-bit)	—	20.2	—	mA
Supply Current – Idle Mode		Audio Play and Record not active	—	7.2	—	mA
Supply Current - Suspend Mode			—	300	—	µA
Specified Operating Temperature Range			–40	—	+85	°C

Note:
1. V_{DD} = 2.7 to 3.6 V, –40 to +85 °C unless otherwise specified.

2.1.2 I²S, I²C, GPIO and Alternate Function Pins

Table 2.2. I²S, I²C, GPIO and Alternate Function Pins DC Electrical Characteristics [1]

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
Output High Voltage	V_{OH}	I_{OH} = –10 µA, Port I/O push-pull	V_{DD} – 0.1	—	—	V
		I_{OH} = –3 mA, Port I/O push-pull	V_{DD} – 0.7	—	—	
		I_{OH} = –10 mA, Port I/O push-pull	—	V_{DD} – 0.8	—	
Output Low Voltage	V_{OL}	I_{OL} = 10 µA	—	—	0.1	V
		I_{OL} = 8.5 mA	—	—	0.6	
		I_{OL} = 25 mA	—	1.0	—	
Input High Voltage	V_{IH}		2.0	—	—	V
Input Low Voltage	V_{IL}		—	—	0.8	V
Input Leakage Current		Weak Pull-Up Off	—	—	±1	µA
		Weak Pull-Up On, V_{IN} = 0 V	—	15	50	

Note:
1. V_{DD} = 2.7 to 3.6 V, –40 to +85 °C unless otherwise specified.

2.1.3 Reset

Table 2.3. Reset Electrical Characteristics [1]

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
RSTb Input High Voltage			0.7 x V_{DD}	—	—	V
RSTb Input Low Voltage			—	—	0.3 x V_{DD}	V
Minimum RSTb Low Time to Generate a System Reset			15	—	—	µs
RSTb Input Pullup Current		RSTb = 0.0 V	—	15	40	µA
V_{DD} Ramp Time for Power On			—	—	1	ms
I^2C Slave Mode delay after reset		RSTb high to first I^2C transaction	100	—	—	ms

Note:
1. –40 to +85 °C unless otherwise specified.

2.1.4 Voltage Regulator

Table 2.4. Voltage Regulator Electrical Specifications [1]

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
Input Voltage Range			2.7	—	5.25	V
Output Voltage		Output Current = 1 to 100 mA	3.0	3.3	3.6	V

Note:
1. –40 to +85 °C unless otherwise specified.

2.1.5 GPIO Output

Table 2.5. GPIO Output Specifications [1]

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
GPIO.12/CLKOUT frequency	f_{OUT} [2]		f_{OUT} x 0.985	f_{OUT}	f_{OUT} x 1.015	Hz

Note:
1. –40 to +85 °C unless otherwise specified.
2. f_{OUT} is the CLKOUT frequency programmed by configuration.

2.1.6 I²S Digital Audio Interface

Table 2.6. I²S Digital Audio Interface Specifications [1]

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
Resolution (output)			—	16	24	bits
Resolution (input)			—	16	24	bits
I2S_MCLK frequency			—	12	—	MHz
I2S_LRCLK frequency		Sample Rate = 48 kHz	—	48.0	—	kHz
		Sample Rate = 44.1 kHz	—	44.118	—	kHz
I2S_SCLK frequency			—	3.429	—	MHz
I2S_MCLK/I2S_LRCLK jitter		Asynchronous endpoint	—	140	—	ps RMS

Note:
1. V_{DD} = 2.7 to 3.6 V, –40 to +85 °C unless otherwise specified.

2.1.7 I²C

Table 2.7. I²C Specifications [1]

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
I2C_SCL frequency			—	100	—	kHz
Time to execute erase command		I²C slave mode	—	65	100	ms
Time to execute write command		I²C slave mode, 16-byte block	—	0.8	1.2	ms

Note:
1. V_{DD} = 2.7 to 3.6 V, –40 to +85 °C unless otherwise specified.

2.1.8 Analog Output/Input

Table 2.8. Analog Output/Input Characteristics

Parameter	Symbol	Test Condition[1]	Min	Typ	Max	Units
Analog Output						
THD + Noise		Playback resolution: 24 bits Asynchronous endpoint	—	-84	—	dB
		Playback resolution: 16 bits Asynchronous endpoint	—	-83	—	dB
Analog Input						
THD + Noise		Playback resolution: 24 bits Asynchronous endpoint	—	-75	—	dB
		Playback resolution: 16 bits Asynchronous endpoint	—	-74	—	dB

Note:

1. Common test conditions:
   - Sample rate — 48 kHz
   - Analog Output test signal — WAV file, 1 kHz, 0 dBFS
   - Analog Output measurement point — HEADPHONE jack (CP2615 Evaluation Board)
   - Analog Input test signal — 1 kHz, 1.0 VRMS
   - Analog Input stimulus point — LINE IN jack (CP2615 Evaluation Board)
   - Measurement bandwidth — 20 Hz – 20 kHz

2.2 Absolute Maximum Ratings

Stresses above those listed in 2.1.1 Recommended Operating Conditions may cause permanent damage to the device. This is a stress rating only and functional operation of the devices at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability. For more information on the available quality and reliability data, see the Quality and Reliability Monitor Report at http://www.silabs.com/support/quality/pages/default.aspx.

Table 2.9. Absolute Maximum Ratings

Parameter	Symbol	Test Condition	Min	Max	Units
Ambient Temperature Under Bias			–55	125	C
Storage Temperature			–65	150	C
Voltage on RSTb, GPIO, I^2S, I^2C, or VBUS Pins with respect to GND		V_{DD} ≥2.2 V V_{DD} < 2.2 V	–0.3 –0.3	5.8 V_{DD} + 3.6	V
Voltage on VBUS with respect to GND		V_{DD} ≥ 3.0 V V_{DD} not powered	–0.3 –0.3	5.8 V_{DD} + 3.6	V
Voltage on V_{DD} with respect to GND			–0.3	4.2	V
Maximum Total Current through V_{DD} or GND			—	500	mA
Maximum Output Current Sunk by RSTb or any I/O pin			—	100	mA

3. Functional Description

3.1 Audio Interfaces

3.1.1 Interface Signals

The CP2615 provides a Master Clock output and bidirectional I²S Master-mode interface for connection to an external converter. (For brevity, the term “converter” is used to represent a codec, DAC, or ADC.) The figure below shows the signals that comprise the audio interface.

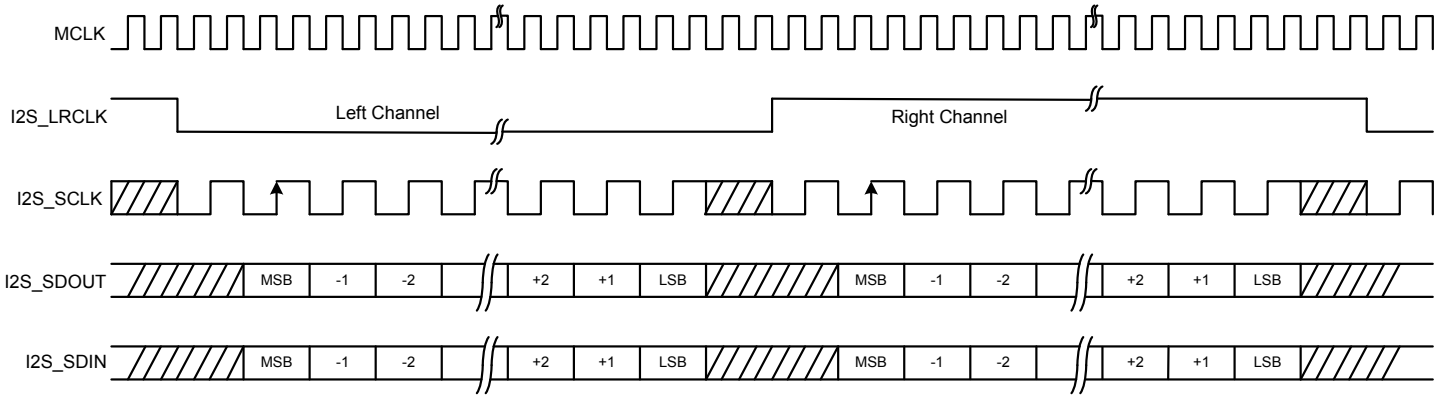


Figure 3.1. Audio Interface Signals

I2S_MCLK (output): The 12 MHz Master Clock output is typically used by oversampling audio converters to drive their internal analog-to-digital or digital-to-analog conversions.

I2S_LRCLK (output): The Left-Right Clock signal indicates which channel is currently being transferred on the interface. The I²S specification refers to this signal as WS (word select). The frequency of the I2S_LRCLK signal corresponds to the audio sample rate. The I2S_LRCLK and I2S_MCLK signals are derived from the same source, and I2S_LRCLK is an integer submultiple of I2S_MCLK. (Both of these attributes are typically required for proper codec operation.)

I2S_SCLK (output): The rising edge of Serial Clock indicates valid data on I2S_SDOUT and I2S_SDIN.

I2S_SDOUT (output): Serial Data Output from CP2615, typically connected to external DAC.

I2S_SDIN (input): Serial Data Input to CP2615, typically connected to external ADC.

The CP2615 operates in I²S Master Mode, and the I2S_LRCLK and I2S_SCLK signals are outputs from the CP2615. The external codec must operate in I²S Slave Mode. The I2S_LRCLK and I2S_SCLK signals are inputs for this mode.

3.1.2 Audio Sample Rates

The CP2615 supports audio sample rates of 44.1 kHz and 48 kHz. If both Playback and Record are used simultaneously, they must operate at the same sample rate. Table 3.1 I2S_MCLK and I2S_LRCLK Supported Sample Rates on page 10 describes the relationship of I2S_MCLK and I2S_LRCLK for the supported sample rates:

Table 3.1. I2S_MCLK and I2S_LRCLK Supported Sample Rates

I2S_MCLK Frequency	Nominal Sample Rate	I2S_MCLK/I2S_LRCLK Ratio	I2S_LRCLK Frequency
12.0 MHz	48 kHz	250	48000 Hz
	44.1 kHz	272	44,117.6 Hz

3.1.3 Audio Sample Resolutions

The CP2615 can be configured to support any one of the following stereo Playback/Record modes:

- Playback and Record: 16-bit resolution
- Playback only: 24-bit or 16-bit resolution
- Record only: 24-bit or 16-bit resolution

3.1.4 Audio Endpoint Synchronization

USB audio endpoint synchronization is defined in Table 5.12 Synchronization Characteristics of the *Universal Serial Bus Specification Revision 2.0*. The CP2615 supports the synchronous or asynchronous endpoint synchronization methods for all input and output streaming configurations. In synchronous mode, the CP2615 adjusts the frequency of I2S_MCLK and I2S_LRCLK to match the rate at which Start-of-Frame (SOF) packets are received from the USB host. In asynchronous mode, the CP2615 does not adjust the I^2S clocks and instead relies on the USB host to provide the synchronization based on implicit feedback from the input endpoint.

3.2 USB Function Controller and Transceiver

The Universal Serial Bus (USB) function controller in the CP2615 is a USB 2.0 compliant full-speed device with integrated transceiver and on-chip matching and pullup resistors. The USB function controller manages all control, audio, HID, and IO interface transfers between the USB host and the CP2615.

3.2.1 Endpoint Usage

The USB endpoints are allocated as follows:

Table 3.2. USB Endpoint Allocations

Endpoint	Function
0	USB control
1	HID interface
2	Serial I/O interface
3	Audio streaming (configurable)

3.2.1.1 USB Control Endpoint

The USB control endpoint is used for enumeration and normal USB control functions.

3.2.1.2 HID Interface Endpoint

The HID endpoint is an interrupt IN endpoint that is used to report Consumer Control (i.e. volume up, volume down, etc.) button presses.

3.2.1.3 Serial I/O Interface Endpoint

The Serial I/O endpoint is a bidirectional bulk interface that transfers either serial pass-through data with the CP2615 UART or I/O Protocol messages. A host application can use this interface to communicate with external devices or to interact with CP2615 general purpose I/O.

3.2.1.3.1 I/O Protocol

The CP2615 implements a simple messaging protocol that provides USB host applications a means for observing and controlling various I/O features. This custom protocol is named the I/O Protocol (IOP) and is implemented over the Serial I/O USB interface.

The I/O Protocol is a stateless, message based protocol that allows a USB host application to do the following:

- Query device identification information.
- Query GPIO configuration.
- Observe and control the GPIO.15-0 pins.
- Observe the analog pin GPIO.8/ADC.
- Receive autonomous notifications of GPIO/ADC changes.
- Perform small transfers on the I^2C bus.
- Query error status of the UART.

Any pin configured as a GPIO output can be controlled by the I/O Protocol. This allows a USB host application to control visual indicators or other hardware connected to the CP2615.

The I/O Protocol supports two methods for observing GPIO.15-0 digital values and GPIO.8/ADC analog values. The USB host application can poll the CP2615 by sending an appropriate IOP message and receiving the response. Alternatively, the USB host application can request that IOP notification messages be sent automatically whenever specific GPIO pins change value. All GPIO pins, including those assigned to alternate functions, may be monitored over the IOP.

For more information, see *Application Note AN1139: CP2614 I/O Protocol*.

3.2.1.4 Audio Streaming Endpoint

This is an isochronous unidirectional or bi-directional audio streaming endpoint that carries USB digital audio data between the USB host and the CP2615. The audio streaming interface has several possible configurations.

3.2.2 USB Suspend

The USB Suspend and Resume modes are supported for power management of the CP2615 device. There are two optional Suspend output signals that can be used to control power switching to external circuitry. These are SUSPEND (active high) and SUSPENDb (active low). The CP2615 will enter Suspend mode when Suspend signaling is detected on the bus. On entering Suspend mode, the configured Suspend output signals are asserted. The Suspend signals are also asserted after a CP2615 reset until device configuration during USB enumeration is complete. The SUSPEND signal is logic high when the device is in the Suspend state, and logic low when the device is in the normal mode. The SUSPENDb signal has the opposite logic value of SUSPEND.

The CP2615 exits Suspend mode when any of the following occur: Resume signaling is detected or generated, a USB Reset signal is detected, or a device reset occurs. SUSPEND and SUSPENDb are weakly pulled to VIO in a high impedance state during a CP2615 reset. If this behavior is undesirable, a strong pulldown (10 Ω) can be used to ensure SUSPEND remains low during reset.

The output mode (push-pull or open drain) of the optional suspend output signals is controlled by the CP2615 configuration. Refer to the Configuration section for more details.

3.3 Asynchronous Serial Data Bus (UART) Interface

The CP2615 provides an asynchronous serial (UART) interface whose function is determined by the device configuration. When enabled, the UART interface provides a full duplex communication channel with a USB host application.

The UART interface consists of the GPIO.13/TX (transmit) and GPIO.14/RX (receive) data signals as well as the GPIO.11/RTS (ready to send) and GPIO.15/CTS (clear to send) flow control signals. These signals are described in 3.4.1.1 GPIO.15, 11—UART Flow-Control Pins (RTS/CTS). Both the TX and RX signals must be configured to enable the UART interface. The use of RTS and CTS is optional depending on the use-case and baud rate.

The UART interface uses a fixed line configuration of 8 data bits, 1 stop bit and no parity (i.e., 8N1). Five common baud rates (115200, 57600, 38400, 19200 and 9600) are supported depending on the CP2615 functional configuration. Refer to the following sections for more information on the supported baud rates.

3.3.1 Serial Pass-Through Mode

When the CP2615 is configured for serial pass-through, the UART interface is used exclusively to provide a bi-directional data stream with a USB host application. The format and content of this communication stream is determined by the application and the CP2615 does not examine or interpret the data.

To ensure audio quality is not compromised, serial pass-through only supports low throughput communication. The table below summarizes the supported UART configurations for this mode. Communication over the serial pass-through may become unreliable if any other configuration is used.

Table 3.3. Supported Serial Pass-Through Configurations

Configuration	Baud Rate	GPIO.11 / RTS	GPIO.15 / CTS
Any audio mode	9600	Optional	Optional
No audio mode	All supported rates	Required above 19200	Optional

3.4 GPIO

The CP2615 supports sixteen user-configurable GPIO pins. Each of these GPIO pins can be used as an input, open-drain output or push-pull output. GPIO pins are observed and controlled through the CP2615 I/O Protocol (IOP) which is accessed through the Serial I/O interface. Alternately, GPIO pins can be assigned to various alternate functions that are directly controlled by the CP2615. The available alternate functions are described in the following sections.

The function, mode and initial state of the sixteen GPIO pins is determined by the device configuration. More information regarding the configuration and usage of these pins is available in *AN1044: CP2615 Customization User Guide*.

Alternate function outputs can be configured as open-drain or push-pull.

3.4.1 Fixed Alternate Pin Functions (GPIO.15-8)

GPIO.15-8 pins have fixed alternate functions that are listed in the table below. Each pin may be individually configured as either a GPIO or its assigned alternate function. Alternate function pins are controlled directly by the CP2615, but their state can be read by the IOP protocol.

Table 3.4. GPIO.15-8 Alternate Functions

Pin	Alternate Function
GPIO.15 / CTS	UART CTS Flow-control Input
GPIO.14 / RX	UART Receive Data Input
GPIO.13 / TX	UART Transmit Data Output
GPIO.12 / CLKOUT	Clock Output
GPIO.11 / RTS	UART RTS Flow-control Output
GPIO.10 / RESETOUTb	Codec Reset Output
GPIO.9 / BUTTONS	Pushbutton Ladder Input
GPIO.8 / ADC	ADC Analog Input

3.4.1.1 GPIO.15, 11—UART Flow-Control Pins (RTS/CTS)

The UART flow-control pins are used to prevent data loss by regulating the flow of UART data in either direction. These alternate functions are available when the CP2615 has been configured to enable the Serial I/O interface described in 3.3.1 Serial Pass-Through Mode. The pins are selected independently, so it is possible to have either or both configured.

GPIO.15/CTS, or Clear To Send, is an active-low input to the CP2615 and is driven logic low by an external UART device to signal that it can receive data. The CP2615 will halt transmitting data while CTS is pulled high.

GPIO.11/RTS, or Request To Send, is an active-low output from the CP2615, which indicates that the CP2615 is ready to accept data. The CP2615 will de-assert RTS whenever its internal buffers are nearly full. While RTS is high, the external UART device must stop transmitting to avoid data loss.

3.4.1.2 GPIO.14, 13—UART Data Pins (TX/RX)

The UART data pins should be selected whenever the CP2615 has been configured for serial pass-through. Both pins must be selected, even if only one direction is used.

GPIO.14/RX is the receive data pin for the CP2615 UART. Serial data received on this pin will be sent to the host if serial pass-through has been configured.

GPIO.13/TX is the transmit data pin for the CP2615 UART. Serial data from either the serial pass-through feature is transmitted on this pin.

3.4.1.3 GPIO.12—Programmable Clock Output (CLKOUT)

GPIO.12/CLKOUT is a configurable CMOS clock output. The clock output appears at the pin after the device enters High Power Mode. The clock output is removed from the pin when the device enters Low Power Mode or USB Suspend mode.

The output frequency is configurable through the use of a divider. When the divider is set to 0, the output frequency is 93.75 kHz. For divider values between 1 and 255, the output frequency is determined by the formula:

$$\text{CLKOUT}_{\text{freq}} = \frac{48\ \text{MHz}}{2 \times \text{divider}}$$

3.4.1.4 GPIO.10—Codec Reset Output (RESETOUTb)

GPIO.10/RESETOUTb is an active-low output that is typically used to drive the reset pin of the external codec. This pin is asserted (i.e. driven low) when the CP2615 enters Low Power mode, and can be controlled at other times via user-configurable I^2C command strings. For more information, see 3.6.1.1 I^2C Command Strings for Codec Configuration.

3.4.1.5 GPIO.9—Pushbutton Ladder Input (BUTTONS)

The CP2615 can be configured to report common consumer control buttons through the HID interface. When this feature is enabled, GPIO.9/BUTTONS can be used with a simple resistor ladder and up to fourteen pushbuttons to provide media button input to the CP2615. Additionally, HID media buttons can be connected as digital inputs to GPIO.7-0, which is described in 3.4.2.1 HID Media Buttons.

To sense button presses, the CP2615 periodically samples the input voltage on GPIO.9/BUTTONS. Once the input remains steady for a complete debounce period, the CP2615 converts the input value into a HID media button as determined by the device configuration. USB HID reports are then sent to the host as the button is pressed and when it is released.

The CP2615 divides the GPIO.9/BUTTONS input into sixteen equal sized (Vdd/16) slots numbered from 0 to 15. The center of each slot is given by the following equation, where n is the slot number.

$$V_n = \frac{V_{DD}}{32} \times (1 + 2 \times n)$$

Slots 1 through 14 can be assigned to any button listed in Table 3.6 GPIO.7-0 Selectable Alternate Input Functions on page 17, while slots 0 and 15 are reserved for the no button pressed condition. Slots can also be left unassigned, in which case they are ignored.

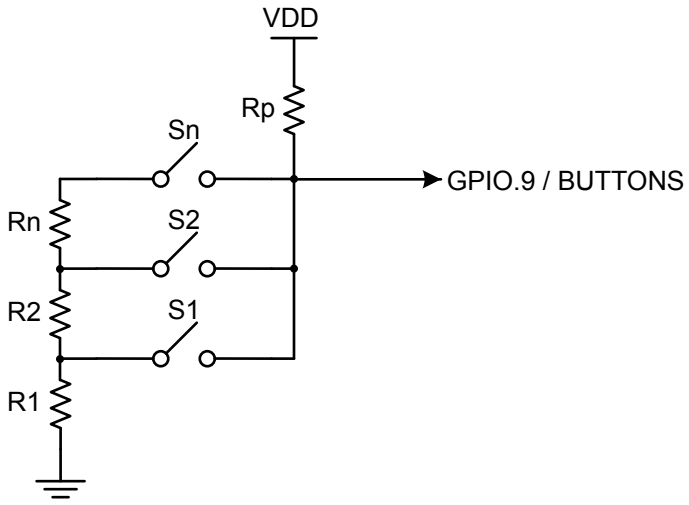


Figure 3.2. Example GPIO.9/BUTTONS Input Circuit

An example circuit for driving GPIO.9/BUTTONS is shown in the igure above. The circuit in the figure only shows three switches, but can easily be expanded by adding additional resistors and switches. While any switch is pressed a simple voltage divider of V_{DD} is formed and the voltage at GPIO.9/BUTTONS is easily calculated with the following equation.

$$V_{buttons} = V_{DD} \times \left(\frac{\sum_{1}^{n} Ri}{Rp + \sum_{1}^{n} Ri} \right)$$

The values of the resistor ladder should be selected so that the divider formed by each switch produces a voltage that is near the center of the switch's assigned slot. A set of resistor values for a fourteen button ladder are provided in the table, Table 3.5 Resistor Values for Example GPIO.9/BUTTONS Circuit on page 16. To guarantee proper operation, 1% tolerance resistors should be used.

The example circuit in the figure above has some features worth noting. First, with no button pressed Rp holds GPIO.9/BUTTONS in slot 15 and the resistor ladder draws no current. Also, when multiple switches are pressed, the lowest numbered switch is recognized while the others are ignored. This is because the lowest switch effectively shorts the resistor ladder of the higher switches.

Table 3.5. Resistor Values for Example GPIO.9/BUTTONS Circuit

Resistor	Value (kΩ)	Resistor	Value (kΩ)
Rp	100	—	—
R1	10.0	R8	24.9
R2	8.25	R9	33.2
R3	10.0	R10	44.2
R4	10.0	R11	64.9
R5	15.0	R12	100
R6	15.0	R13	182
R7	20.0	R14	432

3.4.1.6 GPIO.8—ADC Analog Input (ADC)

The ADC Analog Input alternate function provides a low-rate analog measurement channel that is reported through the I/O Protocol. The analog value can be polled or automatically reported whenever the value change exceeds a programmable threshold. The CP2615 samples GPIO.8/ADC at approximately 50 samples per second and provides 10-bit resolution referenced to V_{DD}. This pin can be used to track a slow moving sensor value such as temperature.

3.4.2 Selectable Alternate Pin Functions (GPIO.7-0)

GPIO.7-0 pins have selectable alternate functions that can be mapped to any pin. The selectable alternate input functions and the selectable alternate output functions are listed in the tables below. These predefined functions can be assigned to GPIO.7-0 in any order and combination. Additionally, all output functions can be assigned to more than one pin if desired, and can be configured as open-drain or push-pull. Alternate function pins are controlled directly by the CP2615, but their state can be read by the IOP protocol.

Table 3.6. GPIO.7-0 Selectable Alternate Input Functions

Alternate Input Name	Function
PLAY_PAUSE	HID Media Button – Play/Pause
FFWD	HID Media Button – Scan Next Track
REW	HID Media Button – Scan Previous Track
MUTE	HID Media Button – Playback Mute
VOL+	HID Media Button – Volume Increment
VOL–	HID Media Button – Volume Decrement
PLAY	HID Media Button – Play
STOP	HID Media Button – Stop
RECMUTE	Record Mute Toggle Button Input
PROFILE_SELECT	Cycle through audio profiles that have been configured or programmed by the host.
GESTURE	Implement multiple functions with one button.

Table 3.7. GPIO.7-0 Selectable Alternate Output Functions

Alternate Output Name	Function
SUSPEND	Suspend Mode (active high)
SUSPENDb	Suspend Mode (active low)
LOWPWR	Low Power Mode (active high)
LOWPWRb	Low Power Mode (active low)
RMUTE	Audio Record is Muted (active high)
RMUTEb	Audio Record is Muted (active low)
PBMUTE	Audio Playback is Muted (active high)
PBMUTEb	Audio Playback is Muted (active low)

3.4.2.1 HID Media Buttons

The CP2615 can be configured to report common consumer control buttons through the HID interface. These active low inputs are debounced by the CP2615 and are used to generate the HID reports on both the leading and trailing edges of a button push. The supported HID usages are indicated in Table 3.6 GPIO.7-0 Selectable Alternate Input Functions on page 17. These inputs should be connected to momentary pushbuttons through an external pull-up resistor. Note that buttons can also be connected to the CP2615 using GPIO.9/BUTTONS as described in 3.4.1.5 GPIO.9—Pushbutton Ladder Input (BUTTONS).

3.4.2.2 Record Mute Toggle Button

This active low input is debounced by the CP2615 and is used to toggle the internal audio record mute state. The CP2615 record mute state is toggled on a low-to-high transition. This input should be connected to a momentary pushbutton through an external pull-up resistor.

3.4.2.3 PROFILE_SELECT

Configuring a GPIO or buttons (resistor ladder) switch as a PROFILE_SELECT input allows the user to select between multiple profiles that are typically used to specify codec register writes that implement different equalization or audio effect settings. The CP2615 can be configured with up to three fixed audio profiles, and a fourth profile can be dynamically programmed by the host.

Each time the PROFILE_SELECT button is pressed, the next non-blank profile string is applied in round robin fashion ([**0**]>[**1**]>[**2**]>[**0**]). Blank profile strings (i.e. containing only the 00 terminator) are skipped. The currently-selected profile is saved to nonvolatile memory and persists across CP2615 reset and power-cycle events. The currently-selected profile will be applied when audio streaming starts.

3.4.2.4 GESTURE

The CP2615 recognizes four gestures (i.e. distinct types of GESTURE button press):

- Long press
- Single click
- Double click
- Triple click

Each of these four gestures can be assigned to the any of these Alternate Input Functions that are described in Table 3.6 GPIO.7-0 Selectable Alternate Input Functions on page 17:

- HID Media button functions (PLAY_PAUSE, FFWD, REW, MUTE, VOL+, VOL-, PLAY, STOP)
- RECMUTE
- PROFILE_SELECT

3.4.2.5 SUSPEND, SUSPENDb

These complimentary outputs are asserted while the CP2615 is in USB Suspend mode. The CP2615 enters USB Suspend mode when it is powered and USB is disconnected or USB activity is stopped by the connected USB host. This situation occurs if the CP2615 accessory is self-powered (such as with a battery) and a connected USB host goes into standby mode (powers down) or USB is disconnected. If the accessory is device powered, then USB Suspend mode will not be used. The CP2615 enters a very low power state while in USB Suspend mode, and the SUSPEND output signal(s) can be used to switch power to other circuitry in the accessory.

3.4.2.6 LOWPWR, LOWPWRb

These complimentary outputs are asserted whenever the CP2615 is in low power mode. The CP2615 enters low power mode when both the audio and serial I/O interfaces are idle. The LOWPWR output signal(s) can be used to switch power to other circuitry in the accessory in order to save power.

3.4.2.7 RMUTE, RMUTEb

The CP2615 asserts these complimentary outputs whenever it is muting the audio record channel. These signals reflect the state of the CP2615 audio record mute and can be used to drive a visual indicator for user feedback or drive the mute control of a microphone preamp.

3.4.2.8 PBMUTE, PBMUTEb

The CP2615 asserts these complimentary outputs whenever the host has commanded the CP2615 to mute the audio playback channel. These signals can be used to drive mute controls in the playback circuitry or to provide user feedback by driving a visual indicator.

3.5 Configuration

The CP2615 has an extensive set of configurable features and attributes. To streamline the product development process, the CP2615 Evaluation Kit provides tools that enable users to easily customize and program the CP2615 configuration parameters to meet the requirements of their system.

In the production environment, the CP2615 configuration can be programmed in-situ using an industry-standard I^2C EEPROM Programmer or equivalent. Customers can also order devices that are pre-programmed with their customized configuration.

Some of the configuration options of the CP2615 do not have a fixed length. For example, the manufacturer name and product name strings do not have a fixed length. Also, the codec configuration data can be variable length. While the CP2615 does not enforce any fixed length on these individual fields, the total configuration size can be a maximum of 2800 bytes. The baseline configuration length with no codec configuration and minimal identification strings is about 575 bytes. The CP2615 customization tool will show you the size of the configuration.

3.5.1 Configuration Parameters

The CP2615 configuration parameters can be grouped as follows:

- Device IDs and Strings
- Power Options
- Audio Options
- GPIO and Alternate Functions

The following sections provide an overview of each of these categories. For more information on CP2615 configuration parameters, refer to *AN1044: CP2615 Customization User Guide*.

3.5.1.1 Device IDs and strings

The following IDs and strings are configurable:

- USB Vendor and Product IDs
- USB Manufacturer, Product, and Serial Number strings

3.5.1.2 Power Options

The following power options are configurable:

- Power Mode (Bus-Powered or Self-Powered)
- Maximum Power Consumption

3.5.1.3 HID Consumer Control Buttons

- HID Consumer Control Buttons
  - Play
  - Stop
  - Scan Next Track (Transport Right)
  - Scan Previous Track (Transport Left)
  - Play/Pause
  - Mute
  - Volume Increment (Louder)
  - Volume Decrement (Softer)

3.5.1.4 Audio Options

The following audio playback and record options are selectable:

- No playback or record
- Playback only, 16-bit resolution
- Playback only, 24-bit resolution
- Playback only, 24-bit and 16-bit resolution
- Record only, 16-bit resolution
- Record only, 24-bit resolution
- Record only, 24-bit and 16-bit resolution
- Playback and record, 16-bit resolution
- Synchronization mode: synchronous or asynchronous

To facilitate using the CP2615 with various codecs devices, the configuration contains elements for specifying volume and mute behavior, as well as I^2C commands for initializing and dynamically configuring the codec.

3.5.1.5 GPIO and Alternate Functions

GPIO pins can be configured to have fixed or selectable functions, as as a general purpose input or output. For more information about fixed alternate pin functions, see 3.4.1 Fixed Alternate Pin Functions (GPIO.15-8) and for selectable pin functions see 3.4.2 Selectable Alternate Pin Functions (GPIO.7-0).

3.6 I²C Interface

The I²C (inter-integrated-circuit) bus is a de facto standard two-wire digital interface. For detailed information on the I²C standard, see the NXP I²C Bus Specification and User Manual.

The CP2615 operates in I²C Standard Mode at the nominal frequency of 100 kbits/s. For proper operation, the SCL (clock) and SDA (data) lines require external pullup resistors that are sized to ensure that the SCL/SDA rise times satisfy the requirements of all devices on the I²C bus. Improperly sized pullup resistors may cause data corruption or bus lockup.

The state of the CFGMODEb input pin when RSTb becomes deasserted determines whether the CP2615 operates in Normal Mode as an I²C Master (CFGMODEb = high), or in Configuration Mode as an I²C Slave (CFGMODEb = low).

3.6.1 CP2615 I²C Operation in Normal Mode

In Normal Mode the CP2615 provides the following I²C functionality:

- Execute pre-configured I²C write transactions in response to various system events (e.g. bootup, audio stream start/stop, volume/mute commands, audio profile switching, etc).
- Support I²C pass-through operation, enabling the host to initiate read or write transactions with I²C slave devices.

3.6.1.1 I²C Command Strings for Codec Configuration

The CP2615 supports a number of configurable I²C command strings that are typically used to initialize and configure the codec and other I²C slave devices in the system.

Table 3.8 Command Strings on page 21 lists the various I²C strings, describes when the strings are applied, and indicates if the given I²C string requires a zero-terminator byte (0x00) to identify the end of all subcommands.

Table 3.8. Command Strings

I²C Command String	Description	Requires Zero Terminator?
Codec Initialize	Executed on power mode transition from low to high.	Yes
Codec High To Low	Executed on power mode transition from high to low.	Yes
Audio Start	Executed when audio play/record streaming starts.	Yes
Audio Stop	Executed when audio play/record streaming stops.	Yes
Volume Set Prefix (Left) Volume Set Prefix (Right)	I²C bytes sent prior to writing the playback volume setting byte.	No
Volume Set Suffix (Left) Volume Set Suffix (Right)	I²C bytes sent after writing the playback volume setting byte.	Yes
Get Mute Prefix	I²C bytes sent prior to reading the playback mute setting byte.	Yes
Set Mute Prefix	I²C bytes sent prior to writing the playback mute setting byte.	No
Set Mute Suffix	I²C bytes sent after writing the playback mute setting byte.	Yes
Set Sample Rate (48 kHz) Set Sample Rate (44.1 kHz)	Executed when host sets the sample rate.	Yes
Profile (0, 1, 2)	Currently-selected profile is applied when audio streaming starts. Clicking PROFILE_SEL button selects and applies next profile.	Yes

Each I²C command string consists of a length byte followed by an array of bytes containing one or more subcommands. As indicated in Table 3.8 Command Strings on page 21, most I²C command strings must also be terminated with 0x00. The value of the length byte includes the size of the subcommand array and zero terminator, but not the length byte itself.

The maximum length of any one I²C command string is 2000 bytes, including the length byte and the zero terminator byte. The length byte should be set to the maximum value of 254 if the string is longer than 254 bytes. The maximum size of the entire CP2615 configuration (which includes all I²C command strings, USB descriptors and other device configuration info) is 4608 bytes.

The subcommands which comprise an I²C command string are composed of a one-byte ASCII-encoded subcommand token followed by the number of data bytes specific to that token. The ASCII-encoded tokens and their associated arguments are shown in Table 3.9 ASCII-encoded Tokens and Associated Arguments on page 21.

Table 3.9. ASCII-encoded Tokens and Associated Arguments

Token	Operation	Arguments (Binary)
“W” 0x57	I²C Write (Write one or more bytes)	U8: Number of bytes to write (size of array to be written) U8: Slave address U8[]: Bytes to be written
“R” 0x52	I²C Read (Read one or more bytes)	U8: Number of bytes to read U8: Slave address

Token	Operation	Arguments (Binary)
“P” 0x50	I²C Stop (Issue stop condition)	None
“C” 0x43	Assert codec reset output (RESE-TOUTb)	None
“c” 0x63	Deassert codec reset output (RESE-TOUTb)	None
“D” 0x44	Delay	U8: Delay in ms U8: Reserved
“B” 0x42	Perform CP2615 reboot	U8: waitForTransactionComplete If zero reboot immediately, else reboot when transaction is complete
“G” 0x47 (A02 only)	Set or clear GPIO pin(s)	U16: Mask (bitmapped, e.g. bit 0 = GPIO.0) Selects which GPIOs to write: • 0: GPIO state is unchanged • 1: GPIO written with corresponding Value bit U16: Value (bitmapped, e.g. bit 0 = GPIO.0) GPIO values to write if corresponding Mask bit is set.

The ‘W’ (write) and ‘R’ (read) operations always begin with an I²C start condition. The I²C stop condition must be explicitly specified for both read and write operations.

3.6.1.2 Example I²C Subcommands

This section contains examples of typical I²C subcommands. The examples use these conventions:

- Tokens are shown as ASCII characters, e.g. 'W'
- Binary data is shown as hex (e.g. 0x01)
- <SLA> represents the left-justified slave address

The following are examples typical I²C subcommands.

Write 0x44 to register 0x01 of slave device:

```
0x06 'W' 0x03 <SLA> 0x01 0x44 'P'
```

Read 2 bytes from register 0x55 of slave device, using stop/start between Write/Read transactions:

```
0x09 'W' 0x02 <SLA> 0x01 'P' 'R' 0x02 'SLA' 'P'
```

Read 2 bytes from register 0xAA of slave device, using repeated start between Write/Read transactions:

```
0x09 'W' 0x01 <SLA> 0xAA 'R' 0x02 'SLA' 'P'
```

Delay 20 ms (20 = 0x14):

```
0x06 'D' 0x14 0x00
```

(A02 only) Set GPIO.15 high, GPIO.8 high, GPIO.1 low. (For this operation, Mask = 1000 0001 0000 0010 and Value = 1xxx xxx1 xxxx xx0x). The un-masked bits can be written to any value, e.g.

```
0x06 'G' 0x81 0x02 0x81 0x00 'P'
                      .    .
                      .    .
0x06 'G' 0x81 0x02 0xFF 0xFD 'P'
```

3.6.1.3 I²C Pass-Through

The CP2615 I/O Protocol allows USB host applications to issue I²C write and read operations to I²C slave devices, and to the CP2615's internal user-accessible ROM. For more information on the I/O protocol, see 3.2.1.3.1 I/O Protocol.

Using pass-through mode, the host can also perform the following write and read operations which are recognized by the CP2615 and are not passed through to the physical I²C bus:

Table 3.10. Write/Read Operations in Pass-through Mode (A02 only)

CP2615 Slave Address (binary)	Register Address (hex)	Write Operation	Read Operation
1111 00x	FFFB	n/a	Read CP2615 firmware revision
1111 000	FFFC	Erase entire configuration area	n/a
1111 000	FFFD	Write Config lock	Read Config lock
1111 000	FFFE	Reset CP2615	n/a
1111 000	0000-17FF	Write (entire configuration area)	Read (entire configuration area)
1111 001	1400-17FF	Write (audio profile area only)	Read (audio profile area only)

3.6.2 CP2615 I²C Operation in Configuration Mode

The state of the CFGMODEb input pin at the conclusion of the device reset state determines whether the CP2615 operates normally (CFGMODEb = high) or enters Configuration Mode (CFGMODEb = low). In Configuration Mode, the CP2615 emulates an I²C flash EEPROM; all other device functionality is disabled. The CP2615 remains in Configuration Mode until it is reset or power-cycled. Refer to the following figure for typical configuration connections.

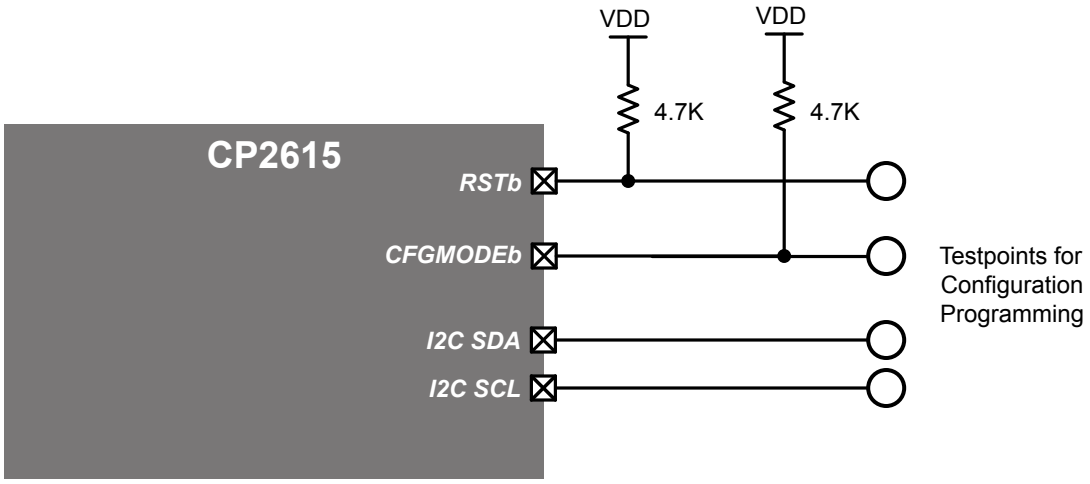


Figure 3.3. Typical I²C Configuration

The following sequence puts the CP2615 into Configuration Mode, after which an external I²C Master can be used to program the CP2615 configuration.

- Drive CFGMODEb and RSTb low (device power can be applied before or after this step)
- Delay at least 15 µs (the minimum RSTb low time)
- Drive RSTb high
- Delay at least 100 ms

The configuration block consists of 2048 bytes of non-volatile flash memory mapped to address range 0x0000-0x07FF. Two bytes are used in I²C Read and Write transactions to represent the address within the configuration block.

The CP2615 7-bit I²C Slave Address is 0011000. The corresponding 8-bit values for the CP2615 slave address plus the I²C Write/Read bit are 0x30 (Write) and 0x31 (Read).

CP2615 code execution is temporarily halted during the execution of memory erase and write operations. If the external I²C Master cannot tolerate NAKs or does not support retries, it must implement the appropriate delays after issuing I²C erase and write commands.

3.6.2.1 I²C Write Transactions

To prevent inadvertent flash erasure or corruption, each Write transaction must contain the flash keys (0xA5, 0xF1) between the address MSB/LSB and the block of data to be written. Write transactions with invalid flash keys will be ignored. The maximum number of data bytes that can be written per Write transaction is 62 bytes. The format of the Write transaction is:

Table 3.11. Write Transaction Format

Start	0x30 SLA+W	AddrMSB	AddrLSB	0xA5	0xF1	Data[0] … Data[n]	Stop

3.6.2.2 I²C Read Transactions

The entire configuration block can be read with a single Read transaction (if the external I²C Master is capable) or by using multiple Read transactions of smaller size. The format of the Read transaction is as follows:

Table 3.12. Read Transaction Format

Start	0x30 SLA+W	Address MSB	Address LSB	Stop	Start	0x31 SLA+R	Data[0] … Data[n]	Stop

3.6.2.3 Special Operations

In Configuration Mode, the CP2615 recognizes these addresses outside of the configuration block address range:

Table 3.13. Read CP2615 Firmware Revision

Start	0x30	0xFF	0xFB	Stop	Start	0x31	Firmware Version Number	Stop

Table 3.14. Erase the Configuration

Start	0x30	0xFF	0xFC	0xA5	0xF1	Stop

Table 3.15. Lock the Configuration

Start	0x30	0xFF	0xFD	0xA5	0xF1	Stop

Table 3.16. Read the Configuration Lock Byte

Start	0x30	0xFF	0xFD	Stop	Start	0x31	Config Lock Byte	Stop

Table 3.17. Reset CP2615

Start	0x30	0xFF	0xFE	Stop

3.6.2.4 Configuration Programming Example

The following sequence illustrates the actions required of an external I^2C Master when programming the CP2615 configuration. The sequence programs the new configuration data in blocks of 16 bytes, which is a typical size used by I^2C EEPROM programmers.

- Put the CP2615 into Configuration Mode.
- Read the Configuration Lock Byte to ensure it is 0xFF (i.e. unlocked).
- Erase the configuration.
- Delay while configuration is being erased (see 2.1.7 I^2C).
- Read the Configuration Block to ensure all bytes are 0xFF.
- For each block of 16 bytes to be written:
  - Execute Write transaction containing flash keys and 16 bytes of data.
  - Delay while configuration data is being written.
  - Execute 16-byte Read transaction to verify data.
- Lock the configuration. (optional).
- To return the CP2615 to normal operation, reset or power-cycle the device.

3.7 Voltage Regulator and Power

The CP2615 includes an internal voltage regulator that can be configured to operate in one of several modes. This allows it to be powered from an ordinary USB host or be self-powered.