ZL38090 Preliminary Data Sheet
Designed for USB Headsets and Microphones

Description

The ZL38090 is part of Microsemi's Timberwolf audio processor family of products that features Microsemi's innovative *AcuEdge*™ firmware, which uses a set of highly-complex and integrated algorithms designed for audio enhancement. These algorithms are incorporated into a powerful DSP platform that allows the user to extract intelligible information from adverse audio environments.

The Microsemi *AcuEdge* Firmware for the ZL38090 device is specifically designed for USB headset and USB microphones. The ZLS38090 *AcuEdge* firmware is royalty-free and provides an advanced audio feature set including beam forming (BF), noise reduction (NR), equalizers (EQ), and a compressor, limiter and expander (CLE) to improve both the intelligibility and subjective quality of voice in harsh acoustic environments.

Microsemi offers additional tools to speed up the product development cycle. The *MiTuner*™ ZLS38508 or ZLS38508LITE GUI software packages allow a user to interactively configure the ZL38090 device. The optional ZLE38470BADA Automatic Tuning Kit provides automatic tuning and easy control for manual fine tuning adjustments.

Ordering Information

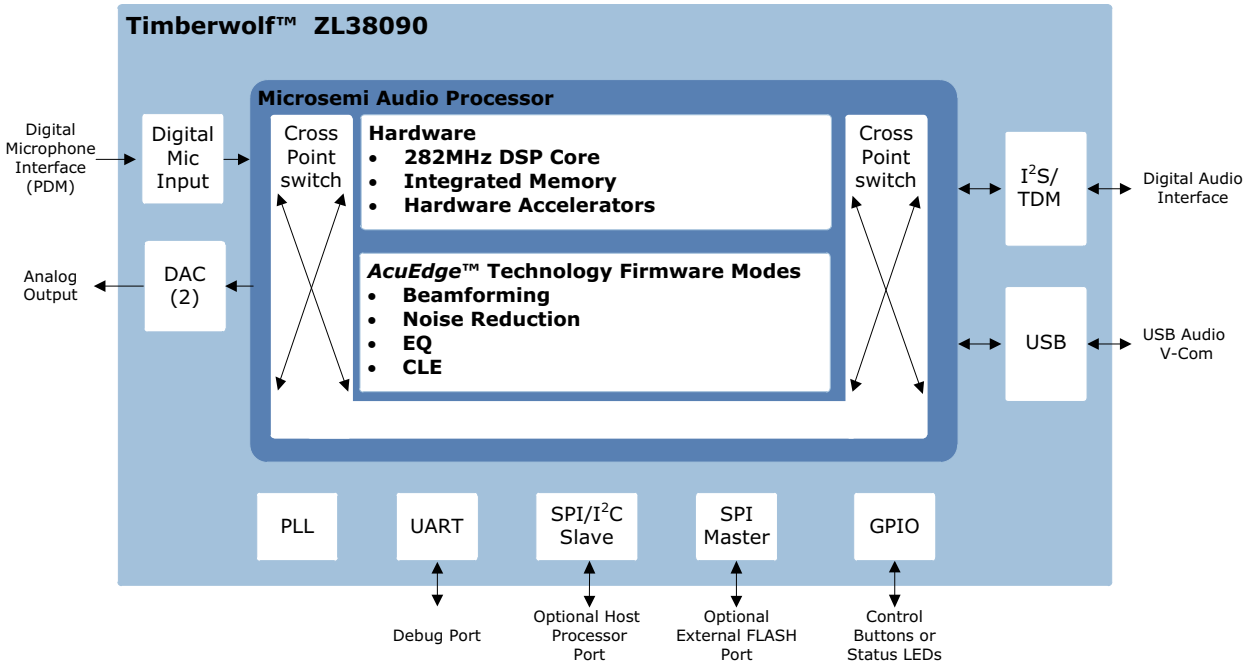
- ZL38090LDF1: 64-pin QFN (9×9) Package (Tape & Reel)
- ZL38090LDG1: 64-pin QFN (9×9) Package (Tray)
- ZL38090UGB2: 56-ball WLCSP (3.1×3.1) Package (Tape & Reel)

Note: These packages meet RoHS 2 Directive 2011/65/EU of the European Council to minimize the environmental impact of electrical equipment.

Applications

- USB Beamforming Microphones
- USB to analog bridge/ USB to I^2S bridge
- USB Headsets/headset dongles
- USB Speakerphones
- USB Speakers

Figure 1 • ZL38090 Block Diagram



Microsemi *AcuEdge*™ Technology ZL38090 Firmware

- Supports 1 stereo headset with play and record or playback-only functions
- Microphone Beamforming (2 microphones)
- Advanced Microphone noise reduction
- Standard Dynamic Range Compressor
- Limiter
- Expander
- Send and receive path 8-band parametric equalizers
- 8 kHz/16 kHz/24 kHz/48 kHz audio streaming
- 4 Defined Function GPIOs for Volume Up/Down, Mute Mic, and Hook-Switch On/Off
- 4 Defined Function PWM outputs for LED control
- 4 additional GPIOs capable of key input and PWM LED control
- USB Audio Class Device v1.0 compliant
- Adaptive mode for playback, Asynchronous mode for record
- USB Audio Class clock modes
- Common HID controls for volume, hookswitch control and mute
- USB port that enumerates with:
  - EP0 (Control)
  - 2 endpoints for Microphones and Speakers (both stereo)
  - 1 interrupt endpoint (for HID Status Reporting)
  - 2 optional endpoints for Virtual Com support
- Skype/Lync Compatible
- Standalone USB device (additional host processor not required for headphone applications)

Hardware Features

- DSP with Voice Hardware Accelerators
- Dual ΔΣ 16-bit digital-to-analog converters (DAC)
  - Sampling up to 48 kHz and internal output drivers
  - Headphone amplifiers capable of 32mW output drive power into 16 ohms
- 2 Digital Microphone input supporting up to 4 Microphones
- 1 TDM / Inter-IC Sound (I^2S) port
- SPI or I^2C Slave port for host processor interface
- Master SPI port for optional serial Flash interface
  - Device boots from either Flash or SPI
- General Purpose Input/Output pins (GPIOs)
- General purpose UART port for debug

The *MiTuner*™ Automatic Tuning Kit and ZLS38508 MiTuner GUI

Microsemi's Automatic Tuning Kit option includes:

- Audio Interface Box hardware
- Microphone and Speaker
- ZLS38508 *MiTuner* GUI software
  - Allows tuning of Microsemi's *AcuEdge* Technology Audio Processor

The ZLS38508 software features:

- Auto Tuning and Subjective Tuning support
- Provides visual representations of the audio paths with drop-down menus to program parameters, allowing:
  - Control of the audio routing configuration
  - Programming of key blocks in the transmit (Tx) and receive (Rx) audio paths
  - Setting analog and digital gains
- Configuration parameters allow users to “fine tune” the overall performance

Tools

- ZLK38000 Evaluation Kit
- *MiTuner*™ ZLS38508 and ZLS38508LITE GUI
- *MiTuner*™ ZLE38470BADA Automatic Tuning Kit

Contents

Figures

Tables

1 Revision History

The revision history describes the changes that were implemented in the document. The changes are listed by revision, starting with the most current publication.

1.1 Revision 2.0

The following is a summary of the changes in revision 2 of this document.

- Migration to new document format; no other changes to technical details or content besides those listed here
- Added USB interface schematic and recommendation for protection device
- Added second digital microphone input pin
- Removed reference to second TDM port
- Updated verbiage on front page to better delineate and describe features
- Minor text corrections
- Headers applied to aid in documentation navigation
- Updated typical power consumption numbers and updated descriptions of operating power states
- Added more detailed block diagram on front page
- Section 2 Overview, page 2 and Section 3 AcuEdge Firmware, page 4 rewritten to provide clarification on applications and firmware operational modes: no changes to technical details or specification
- Type 3 and Type 4 flash devices are supported, but not recommended; specific devices previously recommended have been removed from Table 3, page 20
- Removed remote wake up bullet from firmware feature highlights

2 Overview

2.1 Introduction

The Microsemi ZL38090 Audio Processor powered by ZLS38090 *AcuEdge*™ Firmware is ideal for providing high definition audio for USB headsets, USB Microphones and for USB audio bridging devices (USB to I^2S/TDM).

The ZL38090 provides Two-way Audio Communication using sophisticated audio processing. This includes beam forming (BF), noise reduction (NR), equalizers (EQ), and a compressor, limiter and expander (CLE) to improve both the intelligibility and subjective quality of voice in harsh acoustic environments.

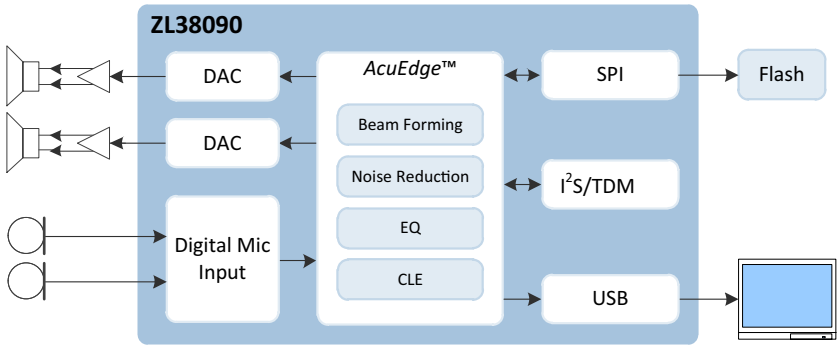
2.2 Applications

Applications for the ZL38090 device include any design that requires USB to analog or USB to I^2S/TDM bridging. In addition to this basic function, the ZL38090 also offers audio enhancement for audio recording and two-way audio. Typical applications include:

- USB Beamforming Microphones
- USB to analog bridge/ USB to I^2S bridge
- USB Headsets/ headset dongles
- USB Speakerphone
- USB Speakers

The following application block diagram shows the ZL38090 used in an USB headset utilizing the 2-microphone beam forming to remove interfering noise.The USB headset does not need a host processor to control the device. The ZL38090 is a self-contained processor that provide basic functions for 2-way audio communications, including GPIO functions for Volume Up/Down, Mute Mic, and Hook-Switch On/Off. The ZL38090 is Skype/Lync compatible allowing the user to control Skype/Lync through the GPIO. The ZL38090 incorporates a virtual com port to allow the developer/user to modify various audio processing settings. An external FLASH is used to hold the PID and VID of the end device.

Figure 1 • **USB Headset**



2.3 Hardware Peripherals

The main peripherals of the ZL38090 device are shown in Figure 1, page i, and a description of each follows.

The ZL38090 device provides the following peripheral interfaces:

- USB Audio Class Device v1.0 compliant
  - Adaptive mode for playback, Asynchronous mode for record
  - USB Audio Class clock modes
  - Remote wake-up via fixed function GPIO
  - Common HID controls for volume, hookswitch control and mute

- USB port that enumerates with EP0 (Control), 2 endpoints for Microphones and Speakers, (both stereo), and 1 interrupt endpoint (for Status Reporting)
- Skype/Lync Compatible
- Standalone USB device (additional host processor not required for headphone applications)

- 1 digital Microphone interface allowing sampling of 1 or 2 digital microphones
- 2 independent headphone drivers
  - Dual 16-bit digital-to-analog converters (DACs)
  - 16 ohms single-ended or differential drive capability
  - 32 mW output drive power into 16 ohms
- 2 Time-Division Multiplexing (TDM) buses
  - The ports can be configured for Inter-IC Sound (I^2S) or Pulse-Code Modulation (PCM) operation
  - PCM operation supports PCM and GCI timing, I^2S operation supports normal and left justified transmission
  - Each port can be a clock master or a slave
  - Each port supports up to four bi-directional streams when configured in PCM mode or two bi-directional streams when configured for I^2S mode at data rates from 128 kb/s to 8 Mb/s
  - Sample rate conversions are automatically done when data is sent/received at different rates than is processed internally. Only integer conversions are allowed.
- SPI – The device provides two Serial Peripheral Interface (SPI) ports
  - The SPI Slave port is recommended as the main communication port with a host processor. The port provides the fastest means to Host Boot and configures the device's firmware and configuration record[1].
  - The Master SPI port is used to load the device's firmware and configuration record from external Flash memory (Auto Boot).
- I^2C - The device provides one Inter-Integrated Circuit (I^2C) port. (Pins are shared with the SPI Slave port)
  - The I^2C port can be used as the main communication port with a host processor, and can be used to Host Boot and configure the device's firmware and configuration record.
- UART – The device provides one Universal Asynchronous Receiver/Transmitter (UART) port
  - The UART port can be used as a debug tool and is used for tuning purposes.
- GPIO – The device provides 14 General Purpose Input/Output (GPIO) ports.
  - GPIO ports can be used for interrupt and event reporting, fixed function control, bootstrap options, as well as being used for general purpose I/O for communication and controlling external devices.
  - The 56 pin WLCSP package is limited to 11 GPIOs.

2.4 Audio Design Considerations

The acoustic design consists of the microphone, speaker, speaker driver and the industrial design of the enclosure. For optimal performance, care must be taken with the device speaker, speaker driver, microphone selection, and the industrial design to insure maximum acoustic isolation and minimize distortion.

Microsemi offers various tools and guides to assist in developing the end system. Consult the *Microsemi AcuEdge™ Firmware Manual* and the *Microphone Speaker and Amplifier Design Note* for more information.

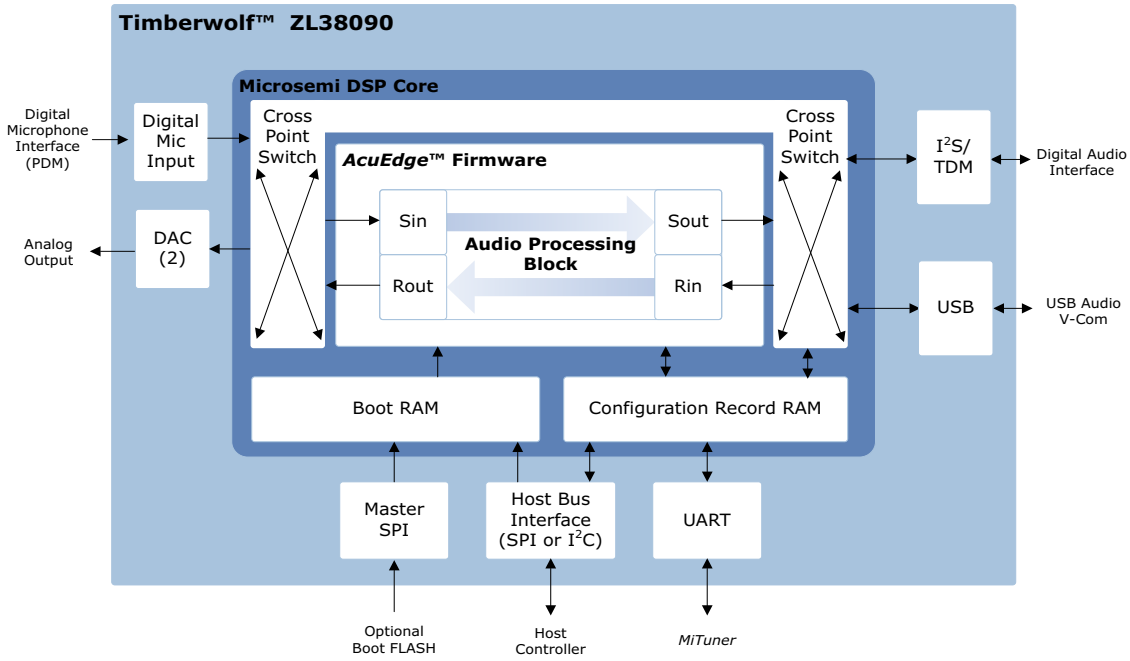
1. The configuration record is a set of register values that are customizable by the application developer to configure and tune the ZL38090 for a particular design. Refer to the *Microsemi AcuEdge™ Firmware Manual* for firmware and configuration record information

3 *AcuEdge* Firmware

Firmware-implemented algorithms, configuration options, and performance can vary based on the loaded firmware image. The description here of firmware modes and features represents a summary of the options available at the time of publication, and should not be considered part of the hardware datasheet specification. The *Microsemi AcuEdge™ Firmware Manual* for the appropriate firmware image should be referenced for more detailed information and specification about each of the firmware modes.

Figure 1 depicts many of the typical interfaces available in an *AcuEdge* firmware image. The desired firmware image may be loaded at startup or swapped during runtime via the host processor or via an optional external flash device (see Device Booting and Firmware Swapping, page 26, for more information). Once running, the *AcuEdge* firmware and Cross Point Switch share configuration registers, which may be accessed via the Host Bus Interface. The *MiTuner* GUI Application can be used during development to tune the various registers via the UART debug interface. *MiTuner* can save the complete set of configuration registers to a file, called the Configuration Record. The set and definition of configuration registers is defined by the firmware, and can vary based on the loaded image. The specification of these registers is documented in the *Microsemi AcuEdge™ Firmware Manual*.

Figure 2 • **ZL38090 *AcuEdge* Firmware Typical Interfaces**



The Microsemi *AcuEdge* Firmware implements various signal processing algorithms, such as Equalization, Noise Reduction, beam forming and CLE. These algorithms execute in the Audio Processing Block. The send path is processed at 16 kHz sampling rate while the receive path is processed at full band. All audio is presented at the USB at full band sampling rates. The Audio Processing Block has between one and four audio IO (input/output) ports which can be routed to/from the various audio interfaces via the Cross Point Switch. The firmware automatically decimates audio inputs down to the Audio Processing sampling rate (16 kHz), and interpolates audio outputs up to the rate appropriate for the given output peripheral. Refer to the corresponding Audio Interface-specific documentation in Audio Interfaces, page 6, for details and audio rates for each audio peripheral.

The following section highlights some key features of the firmware. Consult the *Microsemi AcuEdge™ Firmware Manual* for more details.

3.1 Main Application Configurations

The configuration of the ZL38090 is determined depending on which firmware block is enabled. The firmware image and configuration is initially loaded at power-on-reset, either from external serial Flash or from a host controller (see Device Booting and Firmware Swapping, page 26).

There are two main configurations, headset configuration and USB/I^2S bridge configuration. The sections that follow highlight the primary features and operation of the various configurations.

3.1.1 Headset Configuration

In this configuration, the ZL38090 can use either a single mic or dual microphones. In both configurations, the following features are available:

- Noise Reduction – Analyses the spectral density of the background noise. This information is used to remove noise while minimizing signal distortion.
- CLE – A sophisticated audio compressor/limiter/expander with adjustable attack and decay time. This feature along with Beamforming and advanced Noise Reduction allows for Far Field Microphone pick-up.
- 8 band parametric equalizer – Equalizers are available on the Rin/Rout path, and the Sin/Sout path. Each path contains eight programmable equalization filters. These equalization filters allow the application developer to adjust and tune the audio signal to meet certain design requirements

When using dual microphones, Beam Forming (BF) can be implemented to form a steerable beam in from of the 2-microphone array. The beamformer accepts those sources that it determines are in the direction of interest and attenuates those that are deemed to be coming from other directions. The beam former setting can be programmed to allow the beam angle and aggressiveness of the off-beam attenuation to be modified. This can allow multiple setting corresponding to a "low/med/high" setting for noise reduction and beamforming. If a single mic is used, beamforming is not available but all other functions are available.

3.1.2 USB Bridge Configuration

In this configuration, the ZL38090 is used as a simple I^2S/TDM/Audio to USB bridge. All audio processes are bypassed.

4 Audio Interfaces

4.1 Digital Microphone Interface

The ZL38090 supports up to four digital microphones using the DMIC_CLK, DMIC_IN1, and DMIC_IN2 interface pins.The ZL38090 digital microphone clock output (DMIC_CLK) is either 1.024 MHz or 3.072 MHz depending on the selected TDM-A sample rate. Selecting an 8 kHz or 16 kHz TDM-A sample rate corresponds to a 1.024 MHz digital microphone clock and selecting a 48 kHz sample rate corresponds to a 3.072 MHz digital microphone clock. Microphone data is decimated and filtered to operate at the 16 kHz sampling rate of the Audio Processing block. When there is no TDM-A bus to set the sample rate, the ZL38090 will operate from the crystal and will pass digital audio from the microphones operating at a 48 kHz sampling rate.

A stereo digital microphone, or two separate mono digital microphones, send two microphone channels on one pin by sending the data for one channel on the rising edge and one channel on the falling edge. The selection as to which clock edge is used to clock in the microphone data (rising/falling) is done via a firmware configuration record register. Various digital microphone interfaces are presented in Figures 3–5.

Figure 3 • **Single Mono Digital Microphone Interface**

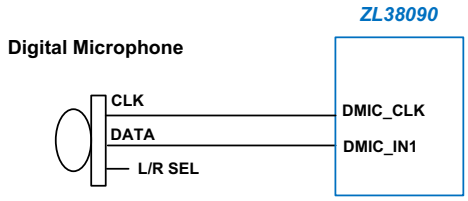


Figure 4 • **Dual Microphone or Stereo Digital Microphone Interface**

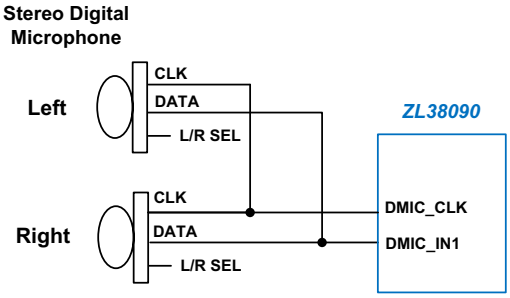
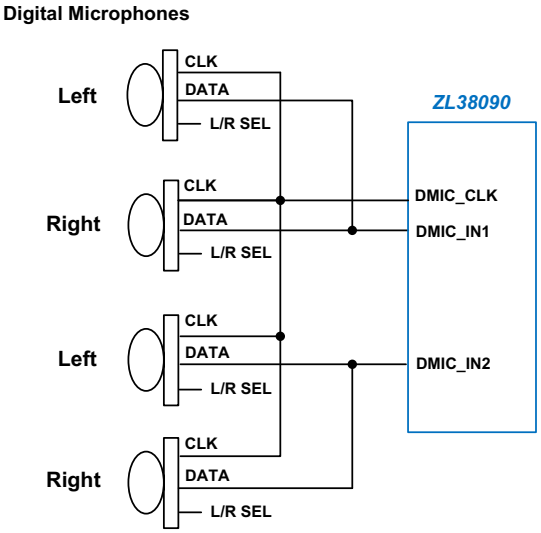


Figure 5 • **Four Digital Microphone Interfaces**

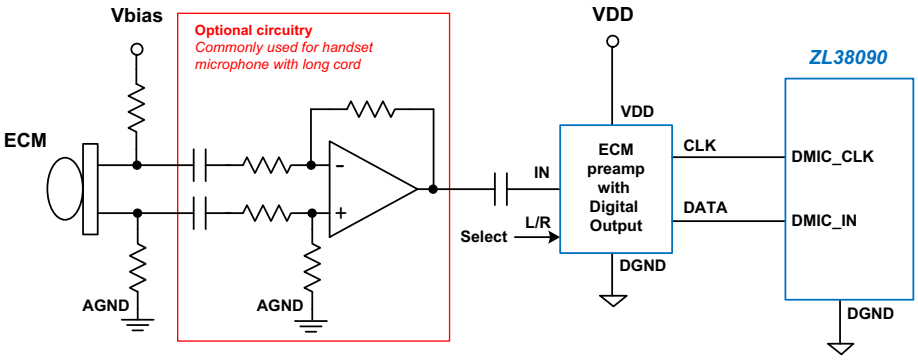


4.1.1 Analog Microphone Use

Electret condenser microphones (ECM) can be used with the digital microphone interface by using a Digital Electret Microphone Pre-Amplifier device as shown in Figure 6. External Codecs can also be used to connect to analog microphones. The external Codecs would interface to the ZL38090 via the TDM buses.

The analog microphone is wired to an optional differential amplifier which can provide filtering and gain and converts the microphone signal to single-ended. The microphone signals are then further amplified and digitized through the Digital Electret Microphone Pre-Amplifiers and applied to the ZL38090 digital microphone input. The ZL38090 provides the clock to activate the Digital Electret Microphone Pre-Amplifier.

Figure 6 • **ECM Circuit**



When using an analog microphone, operation in the Low Power state is not recommended. For more information, see Device Power States, page 38.

4.2 DAC Output

The ZL38090 supports two 16-bit fully differential delta-sigma digital-to-analog converters. The two output DACs independently drive an analog output subsystem. Each subsystem is able to drive two output pins, representing four independent single-ended headphone outputs that can be driven by two independent data streams. The pins can be independently configured. Four analog gains on each headphone output are provided and can be set to: 1x, 0.5x, 0.333x, or 0.25x.

Note: Only the positive DAC outputs are available with the 56-ball WLCSP package. The 56-ball WLCSP package provides two independent single-ended headphone outputs that can be driven by two independent data streams.

The headphone amplifiers are self-protecting so that a direct short from the output to ground or a direct short across the terminals does not damage the device.

The ZL38090 provides audible pop suppression which reduces pop noise in the headphone earpiece when the device is powered on/off or when the device channel configurations are changed. This is especially important when driving a headphone single-ended through an external capacitor (see Output Driver Configurations, page 8, configuration C).

The DACs and headphone amplifiers can be powered down if they are not required for a given application. To fully power down the DACs, disable both the positive and negative outputs.

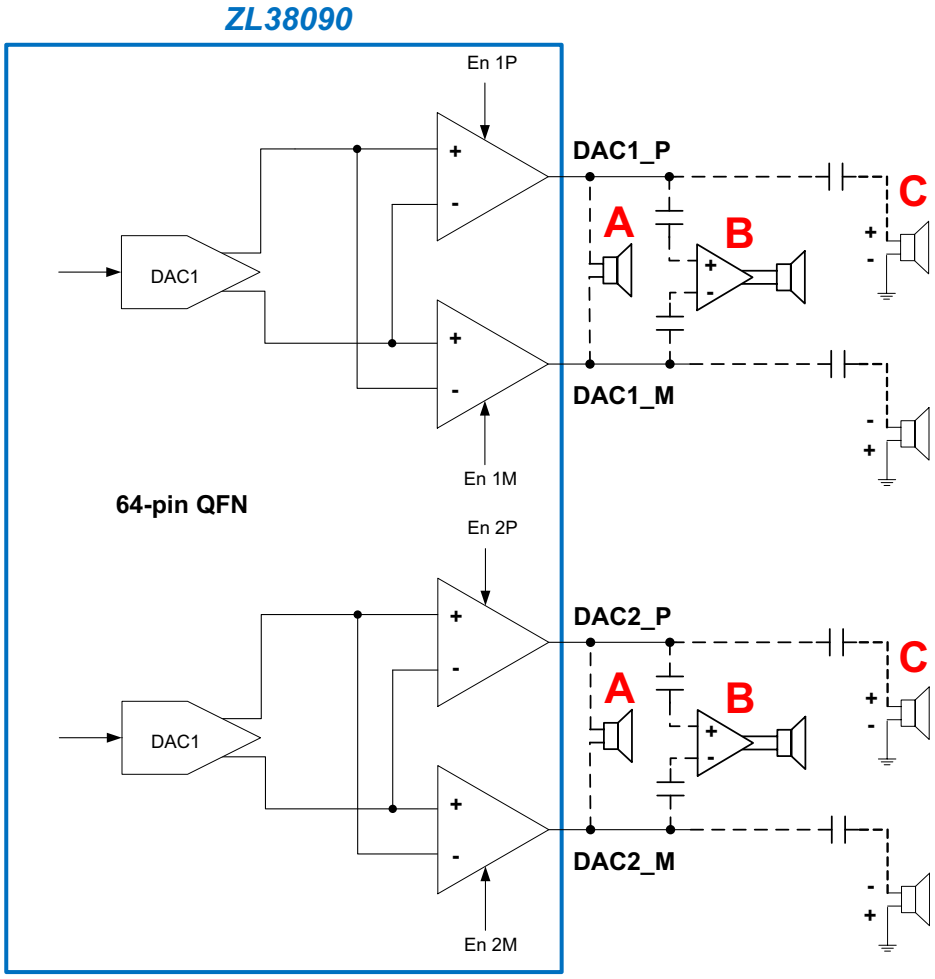
4.2.1 Output Driver Configurations

Figure 7, page 9 shows the different possible output driver configurations for the 64-pin QFN package. When using the 56-ball WLCSP package, only the positive single ended outputs DAC1_P and DAC2_P are provided.

The two output DACs independently drive positive and negative headphone driver amplifiers. The output pins can be independently configured in the following ways:

A. Direct differential drive of a speaker as low as 32 ohms. For this configuration an analog gain of 1x is commonly used. (Differentially driving a 16 ohm speaker is possible, but only with the same amount of power as in the single-ended case. The signal level must be reduced to not exceed ½ scale in this case.) This configuration is not available in the 56-ball WLCSP package.
B. Direct differential drive of a high impedance power amplifier. A Class D amplifier is recommended for this speaker driver. A 1 µF coupling capacitor is generally used with the Class D amplifier. The analog gain setting depends on the gain of the Class D amplifier, analog gain settings of 0.25x or 0.5x are commonly used. This configuration is not available in the 56-ball WLCSP package.
C. Driving either a high impedance or a capacitively coupled speaker as low as 16 ohms single-ended. For this configuration an analog gain of 1x is commonly used. The coupling capacitor value can vary from 10 µF to 100 µF depending on the type of earpiece used and the frequency response desired.

Figure 7 • **Audio Output Configurations**



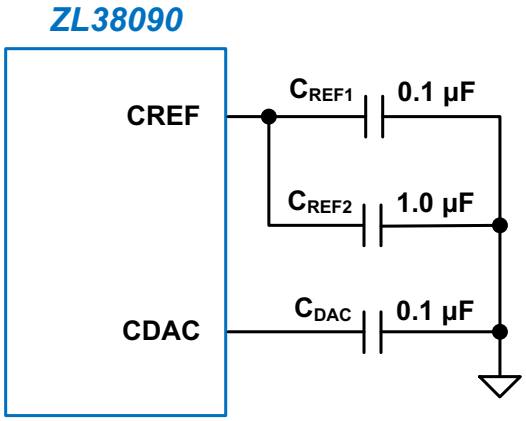
4.2.2 DAC Bias Circuit

The common mode bias voltage output signal (CREF) must be decoupled through a 0.1 µF (C_{REF1}) and a 1.0 µF (C_{REF2}) ceramic capacitor to VSS.

The positive DAC reference voltage output (CDAC) must be decoupled through a 0.1 µF (C_{DAC}) ceramic capacitor to VSS as shown in Figure 8.

All capacitors can have a 20% tolerance and should have a minimum voltage rating of 6.3 V.

Figure 8 • **ZL38090 Bias Circuit**



4.3 TDM Interface

The ZL38090 supports a generic TDM interface that consists of four signals:

- Data clock (PCLK/I^{2}S_SCK)
- Data rate sync (FS/I^{2}S_WS)
- Serial data input (DR/I^{2}S_SDI)
- Serial data output (DX/I^{2}S_SDO)

The TDM port can be configured for Inter-IC Sound (I^{2}S) or Pulse-Code Modulation (PCM) operation.

The TDM block is capable of being a master or a slave.

While a TDM bus configuration may carry many encoded audio streams, the ZL38090 device Cross Point Switch can only address a maximum of 4 bi-directional audio streams per TDM bus. These four audio streams are referred to as channels #1 through #4, and each of these channels can be independently configured to decode any of the TDM bus's audio streams.

Once the TDM bus is configured for a data sample rate and encoding, all data rates and encoding on that bus will be the same. 16-bit linear data will be sent on consecutive 8-bit timeslots (e.g., if timeslot N is programmed in the timeslot registers, the consecutive timeslot is N+1).

The TDM interface supports bit reversal (LSB first <- -> MSB first) and loopbacks within the TDM interface and from one interface to another.

The generic TDM interface supports the following mode and timing options.

4.3.1 I^{2}S Mode

In I^{2}S mode, the 4-wire TDM port conforms to the I^{2}S protocol and the port pins become I2S_SCK, I2S_WS, I2S_SDI, and I2S_SDO (refer to Table 9, page 31 for pin definitions).

An I^{2}S bus supports two bi-directional data streams with left and right channels, by using the send and receive data pins utilizing the common clock and word signals. The send data is transmitted on the I2S_SDO line and the receive data is received on the I2S_SDI line.

The I^{2}S port can be used to connect external analog-to-digital converters or Codecs. The port can operate in master mode where the ZL38090 is the source of the port clocks, or slave mode where the word select and serial clocks are inputs to the ZL38090.

The word select (I2S_WS) defines the I^{2}S data rate and sets the frame period when data is transmitted for the left and right channels. A frame consists of one left and one right audio channel. The I^{2}S ports operate at 8, 16, and 48 kHz data rates as slave or master. Per the I^{2}S standard, the word select is output using a 50% duty cycle.

The serial clock (I2S_SCK) rate sets the number of bits per word select frame period and defines the frequency of I2S_CLK. I^{2}S data is input and output at the serial clock rate. Input data bits are received on I2S_SDI and output data bits are transmitted on I2S_SDO. Data bits are always MSB first. The number

of clock and data bits per frame can be programmed as 8, 16, 32, 64, 96, 128, 192, 256, 384, 512, or 1024. Any input data bits that are received after the LSB are ignored.

The I^2S port operates in two frame alignment modes (I^2S and Left justified) which determine the data start in relation to the word select.

Figure 9 illustrates the I^2S mode, which is left channel first with I2S_WS (Left/Right Clock signal) low, followed by the right channel with I2S_WS high. The MSB of the data is clocked out starting on the second falling edge of I2S_SCK following the I2S_WS transition and clocked in starting on the second rising edge of I2S_SCK following the I2S_WS transition. Figure 9 shows I^2S operation with 32 bits per frame.

Figure 9 • **I^2S Mode**

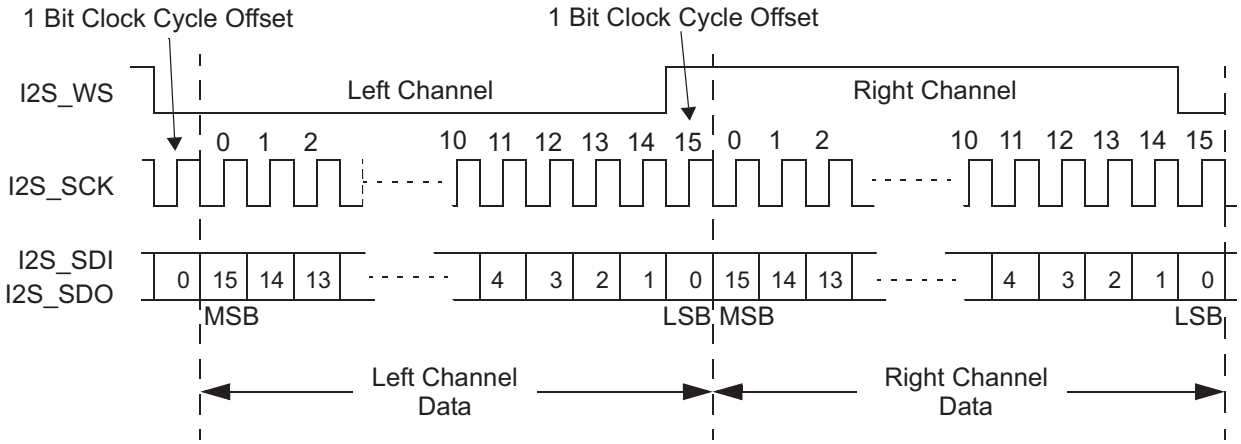
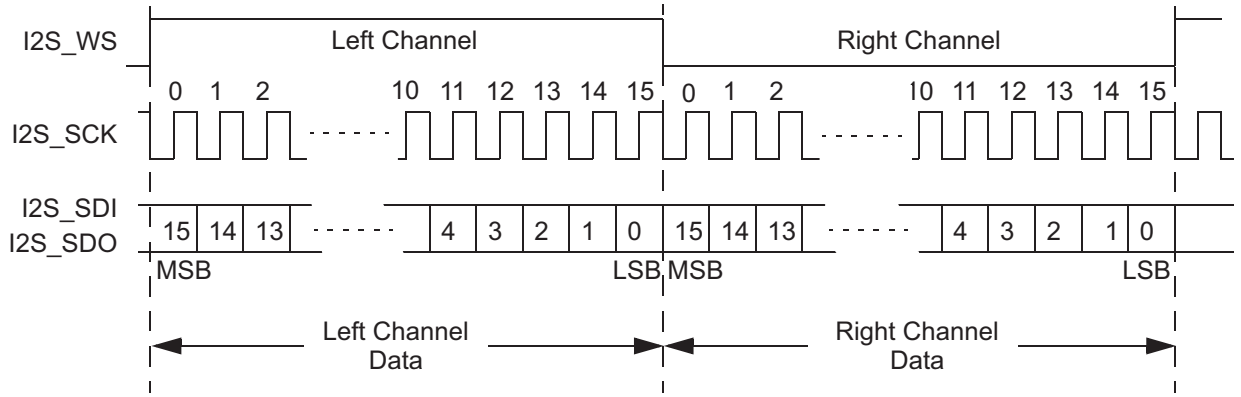


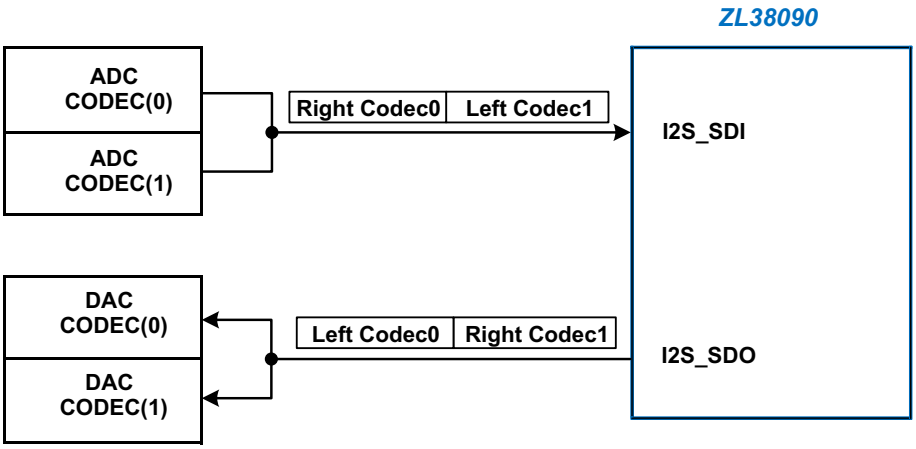
Figure 10 illustrates the left justified mode, which is left channel first associated with I2S_WS (Left/Right Clock signal) high, followed by the right channel associated with I2S_WS low. The MSB of the data is clocked out starting on the falling edge of I2S_SCK associated with the I2S_WS transition, and clocked in starting on the first rising edge of I2S_SCK following the I2S_WS transition.

Figure 10 • **Left Justified Mode**



Each I^2S interface can support one dual channel Codec (Figure 11) through the Codec's I^2S interface. The four 16- bit channel processing capacity of the DSP is spread across the two input channels from the ADCs of Codec(0) and Codec(1), and the two output channels to the DACs of Codec(0) and Codec(1).

Figure 11 • **Dual Codec Configuration**



Both I^2S bus modes can support full bi-directional stereo communication. The device supports I^2S loopback.

See the *Microsemi AcuEdge™ Firmware Manual* for I^2S port registers.

4.3.2 PCM Mode

Each of the PCM channels can be assigned an independent timeslot. The timeslots can be any 8-bit timeslot up to the maximum supported by the PCLK being used.

The PCM ports can be configured for Narrowband G.711 A-law/μ-Law or Linear PCM or Wideband G.722 encoding. For a given TDM bus, once it is configured for a data sample rate and encoding, all data rates and encoding on that bus will be the same. 16-bit linear PCM will be sent on consecutive 8-bit timeslots (e.g., if timeslot N is programmed in the timeslot registers, the consecutive timeslot is N+1). The PCM interface can transmit/receive 8-bit compressed or 16-bit linear data with 8 kHz sampling (Narrowband), or 16-bit linear data with 16 kHz sampling (Wideband). Although the firmware allows it, 44.1 and 48 kHz sampling are not commonly used with PCM.

Wideband audio usually means that the TDM bus is operating at a 16 kHz FS, but there are two other operating modes that support wideband audio using an 8 kHz FS:

- G.722 supports wideband audio with an 8 kHz FS. This uses a single 8-bit timeslot on the TDM bus.
- “Half-FS Mode” supports wideband audio with an 8 kHz FS signal. In this mode, 16-bit linear audio is received on two timeslot pairs; the first at the specified timeslot (N, N+1) and the second a half-frame later. In total, four 8-bit timeslots are used per frame, timeslots (N, N+1) and ((N + ((bits_per_frame)/16)), (N + 1 + ((bits_per_frame)/16))). The user programs the first timeslot and the second grouping is generated automatically 125/2 μs from the first timeslot.

The PCM voice/data bytes can occupy any of the available timeslots, except for PCM clock rates that have extra clocks in the last timeslot. If there is more than one extra clock in the last timeslot, the timeslot data will be corrupted, do not use the last timeslot for these clock frequencies (e.g., 3.088 MHz etc.).

The PCM block can be configured as a master or a slave and is compatible with the Texas Instruments Inc. McBSP mode timing format.

Figure 12 and Figure 13 illustrate the PCM format with slave timing, FS and PCLK are provided by the host. Slave mode accommodates frame sync pulses with various widths (see GCI and PCM Timing Parameters, page 45).

Figure 12 • **TDM – PCM Slave Functional Timing Diagram (8-bit, xeDX = 0)**

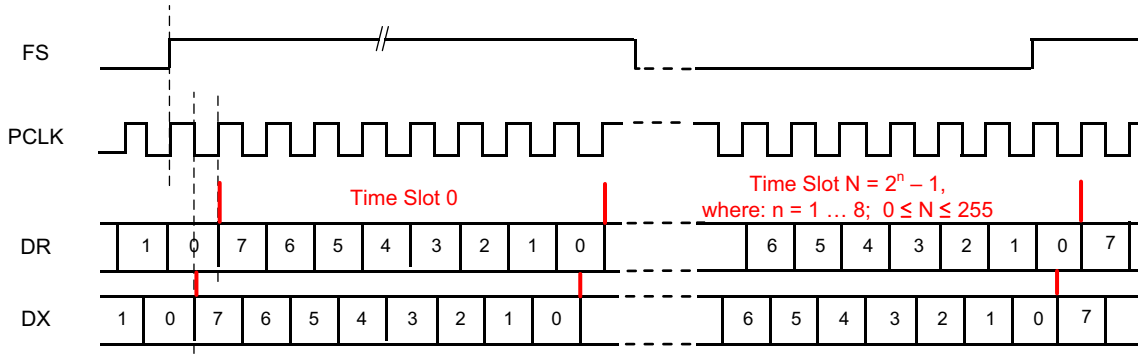


Figure 13 • **TDM – PCM Slave Functional Timing Diagram (8-bit, xeDX = 1)**

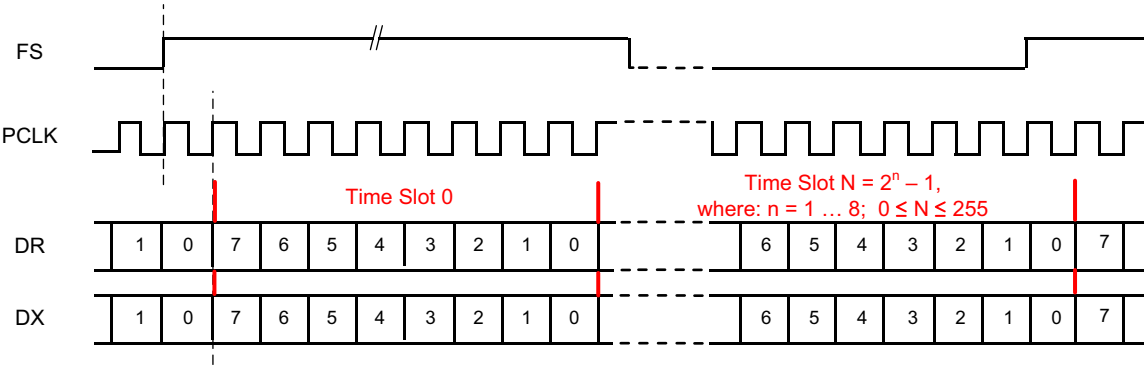


Figure 14 and Figure 15 illustrate the PCM format with master timing, FS and PCLK are provided by the ZL38090. Master mode outputs a frame sync pulse equal to one PCLK cycle.

Diagrams for PCM transmit on negative edge (xeDX = 0) and PCM transmit on positive edge (xeDX = 1) are shown for both slave and master timing.

Figure 14 • **TDM – PCM Master Functional Timing Diagram (8-bit, xeDX = 0)**

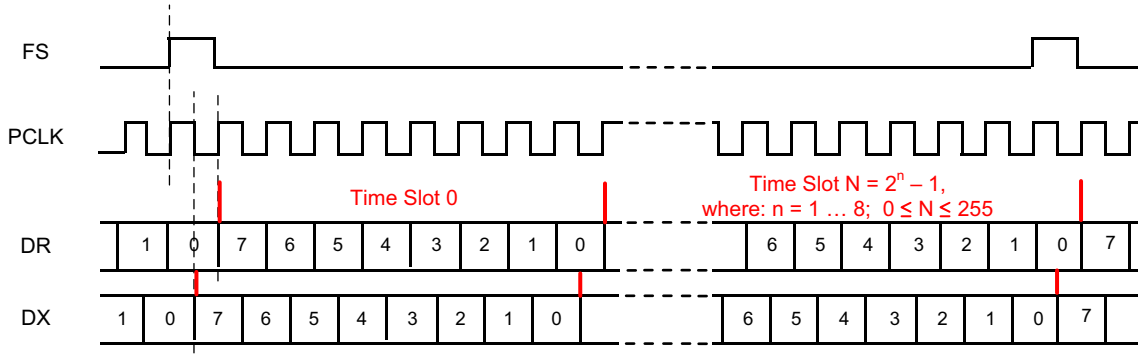
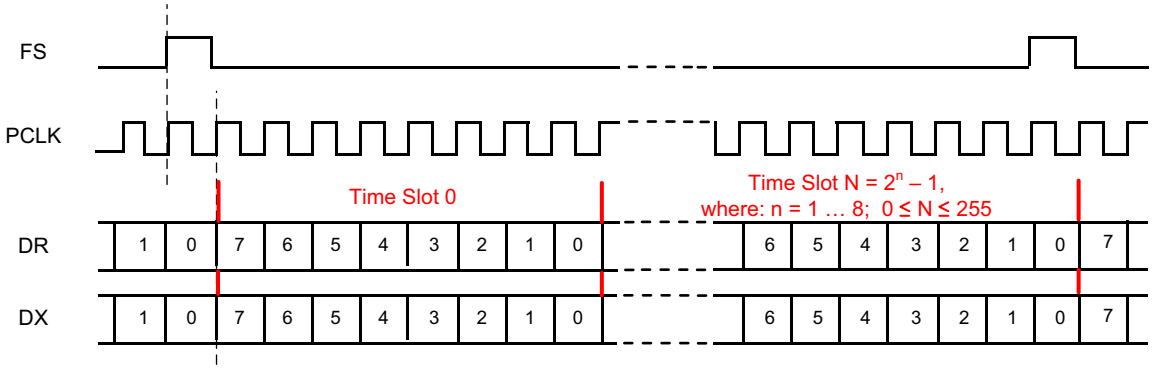


Figure 15 • **TDM – PCM Master Functional Timing Diagram (8-bit, xeDX = 1)**



4.3.3 GCI Mode

The GCI voice/data bytes can occupy any of the available timeslots. The GCI block can be configured as a master or a slave and supports a clock that has the same frequency as the data rate.

Note: Traditional GCI Monitor, Signaling, and Control channel bytes and double data rate are not supported.

Figure 16 illustrates the GCI format with slave timing, FS and PCLK are provided by the host. Slave mode accommodates frame sync pulses with various widths (see GCI and PCM Timing Parameters, page 45).

Figure 17 illustrates the GCI format with master timing, FS and PCLK are provided by the ZL38090. Master mode outputs a frame sync pulse equal to one PCLK cycle.

For both, first data bits are aligned with the rising edge of the frame sync pulse.

Figure 16 • **TDM – GCI Slave Functional Timing Diagram**

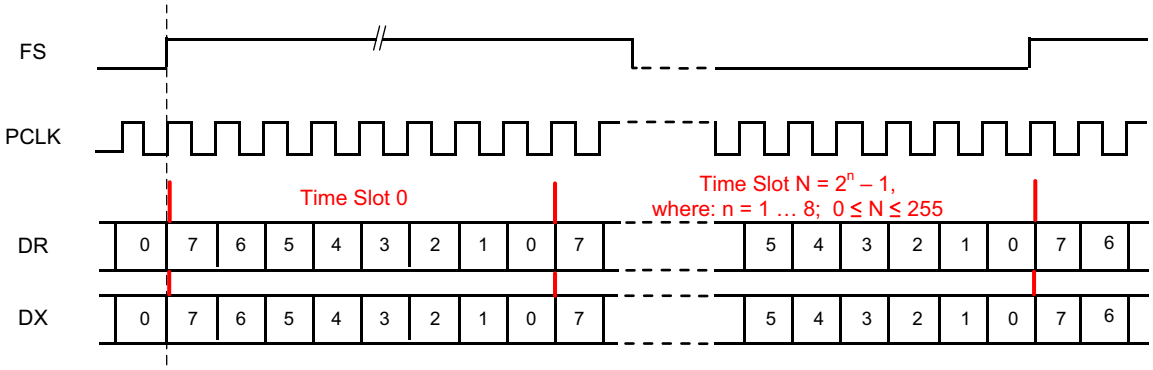
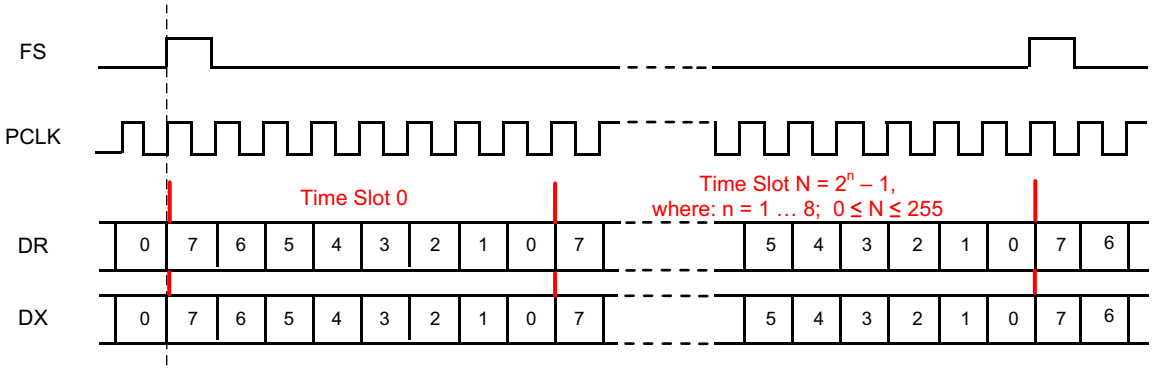


Figure 17 • **TDM – GCI Master Functional Timing Diagram**

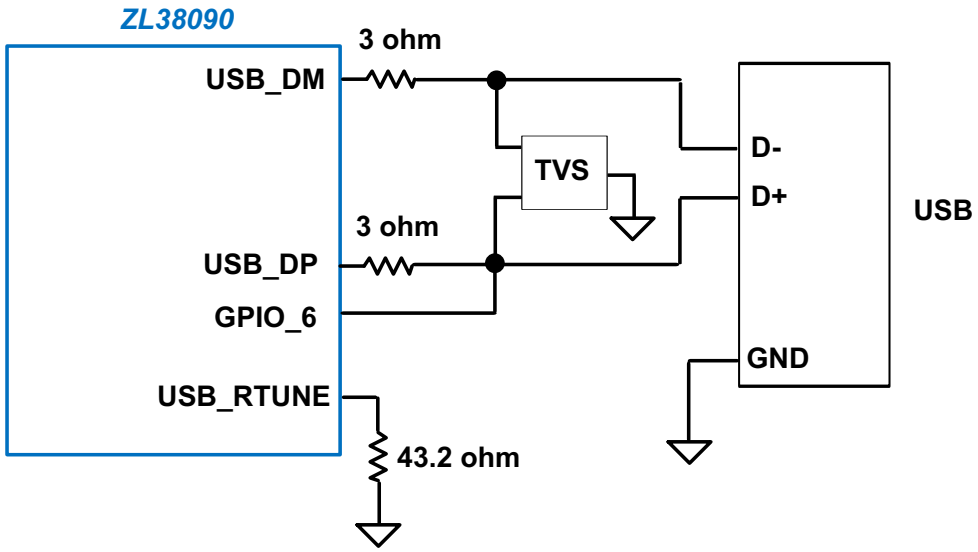


4.4 USB Interface

The ZL38090 will enumerate as an USB Audio Class v1.0 Device. Windows, Macintosh, and Linux PCs will all identify the ZLS38090 as an audio class device without requiring additional driver installation. The ZL38090 is USB 2.0 compliant. It will send and receive at the full speed rate of 12 Mbps. The device will enumerate with one control endpoint, and two endpoints for Microphone input and Speaker output (both are Stereo) with one interrupt endpoint for Status Reporting. Configuration settings allows for either stereo play/record or just stereo playback.

Figure 18 illustrates the connection of the USB interface to the ZL38090. A USB protection device (transient voltage suppressor) is recommended. The ZL38090 uses GPIO_6 for USB Resume.

Figure 18 • **USB Interface Circuit**



5 Control Interfaces

5.1 Host Bus Interface

The host bus interface (HBI) is the main communication port from a host processor to the ZL38090. It can be configured to be either a SPI Slave or an I^2C Slave port, either of which can be used to program or query the device.

The ZL38090 allows for automatic configuration between SPI and I^2C operation. For the HBI port, if the HCLK toggles for two cycles, the HBI will default to the SPI Slave, otherwise it will remain configured as I^2C (see Table 1, page 16). The HBI comes up listening in both SPI and I^2C modes, but with I^2C inputs selected. If HCLK is present, it switches the data selection before the first byte is complete so that no bits are lost. Once the port is determined to be SPI, a hardware reset is needed to change back to I^2C.

This port can read and write all of the memory and registers on the ZL38090. The port can also be used to boot the device, refer to Device Booting and Firmware Swapping, page 26.

Table 1 • **HBI Slave Interface Selection**

Description	Condition	Operating Mode	Notes
HBI Slave interface selection.	HCLK toggling	Host SPI bus	
	HDIN tied to VSS	Host I^2C bus. Slave address 45h (7-bit).	1
	HDIN tied to DVDD33	Host I^2C bus. Slave address 52h (7-bit).	

1. By default, the HBI comes up as an I^2C interface. Toggling the HCLK pin will cause the host interface to switch to a SPI interface. If an I^2C interface is desired, HCLK needs to be tied to ground.

5.1.1 SPI Slave

The physical layer is a 4-wire SPI interface. Chip select and clock are both inputs.

The SPI Slave port can support byte, word, or command framing. Write and read diagrams for these framing modes are shown in Figures 19 – 24. The SPI Slave chip select polarity, clock polarity, and sampling phase are fixed.

The ZL38090 command protocol is half duplex, allowing the serial in and serial out to be shorted together for a 3- wire connection. The chip select is active low. The data is output on the falling edge of the clock and sampled on the rising edge of the clock.

The SPI Slave supports access rates up to 25 MHz. The outbound interrupt is always active low.

Figure 19 • **SPI Slave Byte Framing Mode – Write**

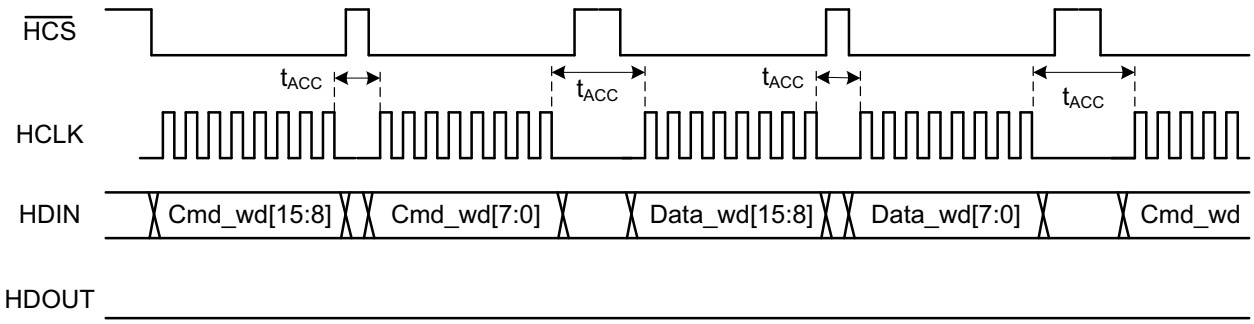


Figure 20 • **SPI Slave Byte Framing Mode – Read**

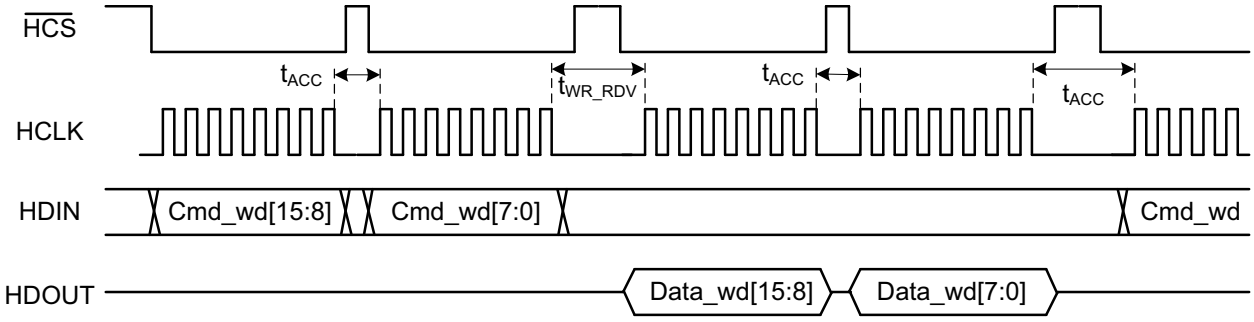


Figure 21 • **SPI Slave Word Framing Mode – Write, Multiple Data Words**

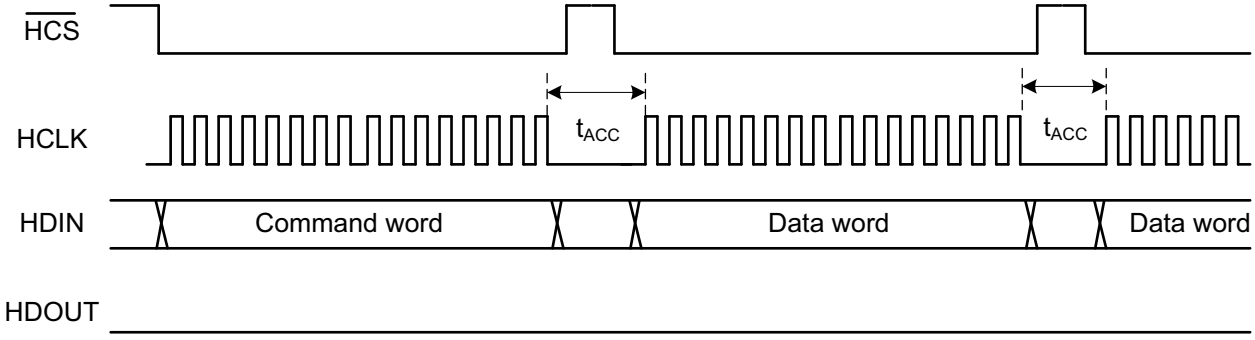


Figure 22 • **SPI Slave Word Framing Mode – Read, Multiple Data Words**

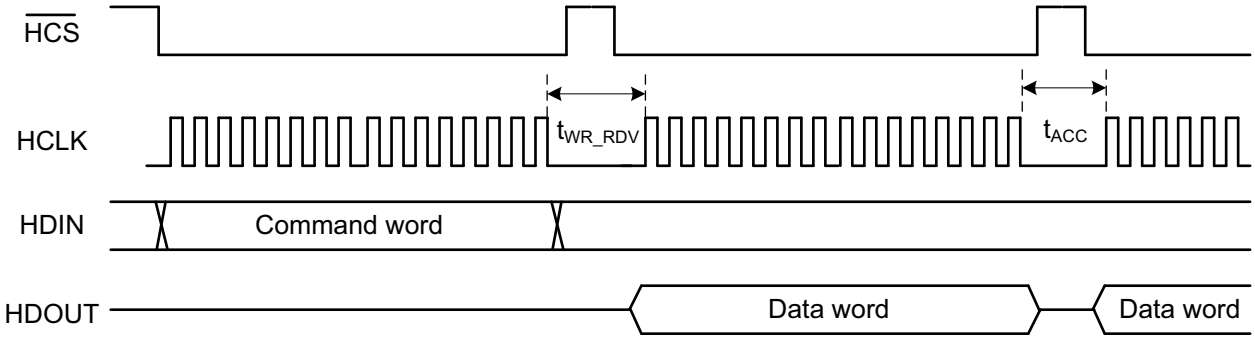


Figure 23 • **SPI Slave Command Framing Mode – Write**

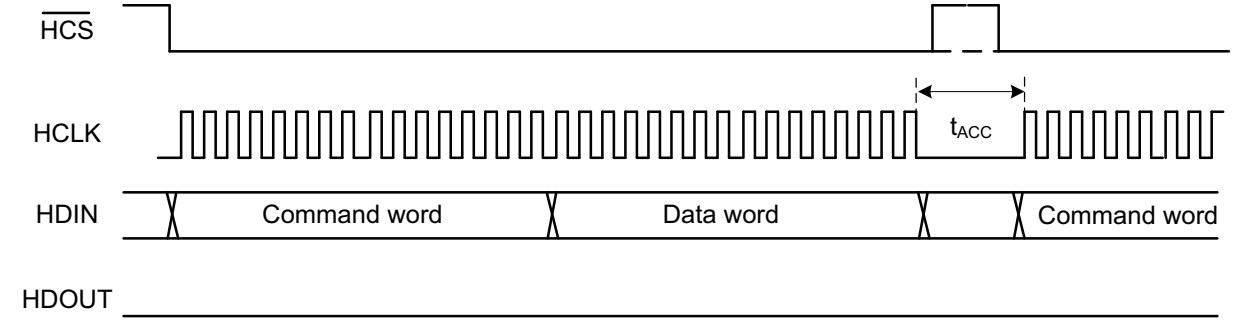
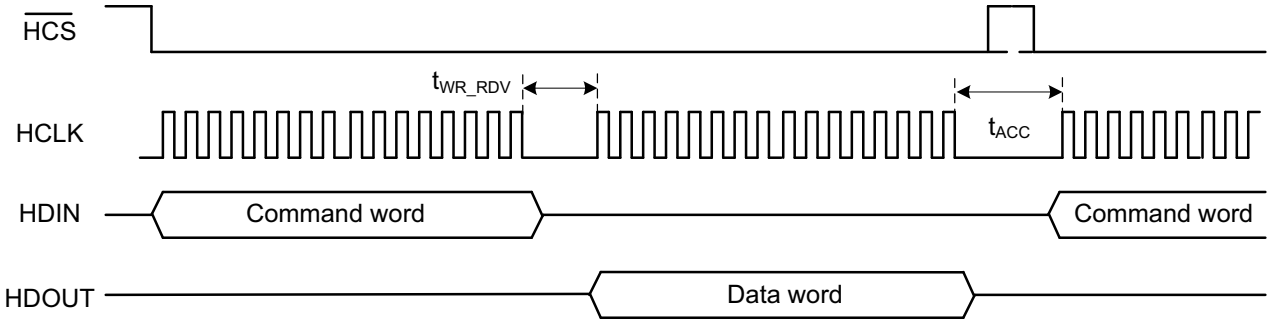


Figure 24 • **SPI Slave Command Framing Mode – Read**



5.1.2 I²C Slave

The I²C bus is similar to the Philips Semiconductor (NXP) 1998 Version 2.0, I²C standard. The ZL38090 I²C bus supports 7-bit addressing and transfer rates up to 400 kHz. External pull-up resistors are required on the I²C serial clock input ($\overline{HCS}$) and the I²C serial data input/output (HDOUT) when operating in this mode (note, the I²C slave pins are 3.3 V pins and are not 5 V tolerant).

The selection of the I²C slave address is performed at bootup by the strapping of the HDIN and HCLK pins, see Table 1, page 16.

5.1.3 Host Interrupt Pin

An internal host interrupt controller controls the active low interrupt pin which is part of the host bus interface. Associated with the interrupt controller is an event queue which reports status information about which event caused the interrupts.

Upon sensing the interrupt, the host can read the event queue to determine which event caused the interrupt. Specific events are enabled by the host processor, and are typically not used with a standalone (controllerless) design.

Refer to Events in the *Microsemi AcuEdge™ Firmware Manual* for Event ID Enumerations.

5.2 UART

The ZL38090 device incorporates a two-wire UART (Universal Asynchronous Receiver Transmitter) interface with a fixed 115.2 K baud transfer rate, 8 data bits, 1 stop and no parity. TX and RX pins allow bi-directional communication with a host PC. The UART pins must be made accessible on the PCB for debug and tuning purposes.

5.3 Master SPI

Like the HBI SPI Slave, the physical layer of the Master SPI is a 4-wire SPI interface supporting half duplex communication.It supports only one chip select which is multiplexed with GPIO_9.

The Master SPI is only used by the built-in boot ROM to bootload from an external serial Flash. The ZL38090 can automatically read the Flash data (program code and configuration record) through this interface upon the release of reset (Auto Boot), depending on the value of the bootstrap options.

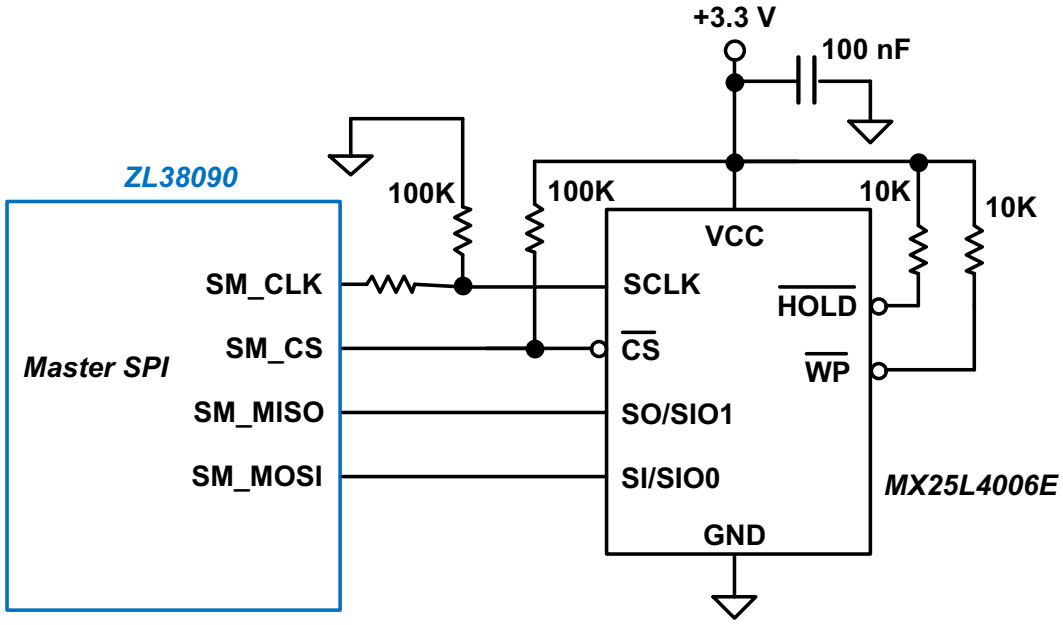
Note: An alternative to Auto Boot is to perform a Host Boot through the HBI port. Refer to Device Booting and Firmware Swapping, page 26.

5.3.1 Flash Interface

After power-up the ZL38090 will run its resident boot code, which establishes the initial setup of the Master SPI port and then downloads the firmware from external Flash memory when configured for auto boot mode. This Flash firmware establishes the resident application and sets the configuration of all the ZL38090 ports.

Figure 25 illustrates the connection of Flash memory to the ZL38090 Master SPI port. Figure 25 and the ZLE38000 demonstration hardware uses the Macronix™ MX25L4006E 4 Mbit CMOS Serial Flash device.

Figure 25 • **Flash Interface Circuit**



5.3.1.1 Flash Selection

The ZL38090 Boot ROM is designed to work with a wide variety of Flash devices. There are numerous Flash devices that the ZL38090 Boot ROM can recognize and program without host intervention other than a command to initialize the Flash. Other unrecognized devices may be utilized if they conform to certain characteristics of known devices and the host informs the ZL38090 Boot ROM of their type and size.

The ZL38090 identifies Flash devices (with a single binary image) with the ZL38090 boot ROM auto-sensing the Flash type. The ZL38090 complies with *JEDEC Manufacturer and Device ID Read Methodology for SPI Compatible Serial Interface Memory Devices*. The ZL38090 is compatible with the *Serial Flash Discoverable Parameters JEDEC* standard JESD216B and the *Common Flash Interface* JESD68.01 JEDEC standard. The ZL38090 can identify devices by their JEDEC standard JEP106-K *Standard Manufacturer's Identification Code*.

Select a Flash size that is adequate to store all the firmware images required of the application. The image sizes can be obtained from the specific firmware releases.

A list of Flash devices that are identifiable by the ZL38090 Boot ROM are shown in Table 2. The size of these devices are all 2 Mbit or 4 Mbit, the Boot ROM will also recognize the size of 8 Mbit parts that are Type 1 or Type 2 devices (as defined in Table 3).

Table 2 • **Flash Devices Tested with the ZL38090**

Manufacturer	Part Number	Description
Macronix™	MX25V4006EM1I-13G	4 Mbit Flash.
Winbond™	W25X40CLSNIG-ND	4 Mbit Flash.
	W25X20CLSNIG-ND	2 Mbit Flash.
Micron®	M25P20-VMN6PB	Large 512 Kbit sectors limit the usefulness of this device. Holds only 1 application image.
	M25P40-VMN6PB	4 Mbit Flash. Large 512 Kbit sectors limit the usefulness of this device. Holds only 2 or 3 application images.
Spansion™	S25FL204K0TMF1010	4 Mbit Flash.

Table 2 • **Flash Devices Tested with the ZL38090**

Manufacturer	Part Number	Description
AMIC Technology	A25L020O-F	2 Mbit Flash.

Flash devices whose JEDEC ID or size (usually a size of 16 Mbit or larger) that are not recognized by the ZL38090 Boot ROM can be made to work if they fit the characteristics of one of the four Flash types listed in Table 3. By writing the type (1, 2, 3, or 4) to ZL38090 address 0x118 and the number of sectors to ZL38090 address 0x116 prior to initializing the Flash device, the Boot ROM will treat it as a known device of known size even though the manufacturer ID or size field are not recognized.

Table 3 • **Supported Flash Types**

Characteristic	Type 1	Type 2	Type 3[1]	Type 4[1]
Sector Size	512 Kbit (64 KB)	32 Kbit (4 KB)	32 Kbit (4 KB)	16 Kbit (2 KB)
Read Status Reg Cmd	0x05	0x05	0x05	0xD7
Status Reg	Busy bit = 0x01	Busy bit = 0x01	Busy bit = 0x01	Done bit = 0x80
Data Read Cmd	0x03	0x03	0x03	0x03
Write Enable Cmd	0x06	0x06	0x06	N/A
Page Write Cmd	0x02	0x02	N/A Uses AAI to program word or byte. Uses Write Disable command to terminate AAI.	N/A Uses write from buffer command.
4-Byte Bulk Erase Cmd	N/A	N/A	N/A	0xC794809A
Examples	**Micron®** M25P20-VMN6PB M25P40-VMN6PB	**Winbond™** W25X40CLSNIG-ND W25X20CLSNIG-ND **Macronix™** MX25V4006EM1I-13G **AMIC Technology** A25L020O-F **Spansion™** S25FL204K0TMF1010 **Atmel®** AT25DF041A		

1. While Type 3 and Type 4 flash devices are supported, they are not recommended due to the time and complexity required to program these devices.

5.4 GPIO

The ZL38090 64-pin QFN package has 14 GPIO (General Purpose Input/Output) pins; the ZL38090 56-ball WLCSP package has 11 GPIO pins.

The GPIO pins can be individually configured as either inputs or outputs, and have associated maskable interrupts reported to the host processor through the interrupt controller and event queue. The GPIO pins are intended for low frequency signaling.

When a GPIO pin is defined as an input, the state of that pin is sampled and latched into the GPIO Read Register. A transition on a GPIO input can cause an interrupt and event to be passed to the host processor.

GPIO pins 7, 8, and 10–13 have special predefined functions, such as volume up/down, associated with these pins. This functionality is designed to support the features of a headset designed for Skype, Lync,

or other VoIP communication system. See Fixed Function I/O in the *Microsemi AcuEdge™ Firmware Manual*.

Immediately after any power-on or hardware reset the GPIO pins are defined as inputs and their state is captured in the GPIO Configuration Register. The state of this register is used to determine which options are selected for the device. The GPIO pin status is then redefined as specified in the configuration record that is loaded from the Flash or host.

In addition to the predefined fixed functions and the general functionality of the GPIO pins, the GPIO pins also support the bootstrap functions listed in Table 5, page 26.

5.5 USB Interface

In addition to the USB Audio outlined in USB Interface, page 15, the ZL38090 has the option of enumerating 2 endpoints for bi-directional Virtual Com support over USB. This optional USB Virtual Com interface can be used for code load and debug control from any connected PC. This Virtual Com interface is available over the same USB connection that carries audio and can be enabled or disabled via the configuration record. See USB Endpoints in the *Microsemi AcuEdge™ Firmware Manual*.

5.5.1 USB Audio Function Topology

The USB Audio Class Descriptors allow the host to discover and control the USB devices' audio controls, commonly called the Audio Function. See USB Audio Function in the *Microsemi AcuEdge™ Firmware Manual*.

6 Reset

The device has a hardware reset pin ($\overline{\text{RESET}}$) that places the entire device into a known low power state. When the reset pin is brought low for a duration of at least 10µs, both a digital and analog reset will occur. The digital reset will reset all device states and registers. The analog reset will deactivate the internal PLL and drive the VDD12_CTRL pin low, disabling the +1.2V supply.

When the reset pin is driven high, the device will go though its boot process and the firmware will be reloaded. GPIO pins will be re-sensed when the reset pin is brought high.

A 10 KΩ pull-up resistor is required on the $\overline{\text{RESET}}$ pin to DVDD33 if this pin is not continuously driven.

7 Power Supply

7.1 Power Supply Sequencing/Power up

No special power supply sequencing is required. The +3.3 V or +1.2 V power rails can be applied in either order.

Upon power-up, the ZL38090 begins to boot and senses the external resistors on the GPIO to determine the bootstrap settings. After 3 ms, the boot process begins and the ZL38090 takes less than 1 second to become fully operational (for Auto Boot from Flash, including the time it takes to load the firmware).

In order to properly boot, the clocks (and power supplies) to the device must be stable. This requires either the 12.000 MHz crystal or clock oscillator to be active and stable before the ZL38090's reset is released.

7.1.1 Power Supply Considerations

The 5V USB supply is typically used to power the ZL38090.

The ZL38090 requires +1.2 V to power its core DSP power supply (DVDD12). To achieve optimum noise and power performance, supply DVDD12 from an external source. Use a DC-DC switching power converter like the Microsemi LX7186A to achieve high efficiency and load regulation. The ZL38090 is designed to minimize power in its active states when DVDD12 is supplied externally.

Figure 26, page 24 shows DVDD33 and DVDD12 powered from the +5V USB supply. The Microsemi LX8213-33ISE 300mA Low Drop Out Voltage Regulator is shown supplying DVDD33. The Microsemi LX7186A 1.4MHz fixed frequency, current mode, synchronous PWM buck (step-down) DC-DC converter is shown supplying DVDD12.

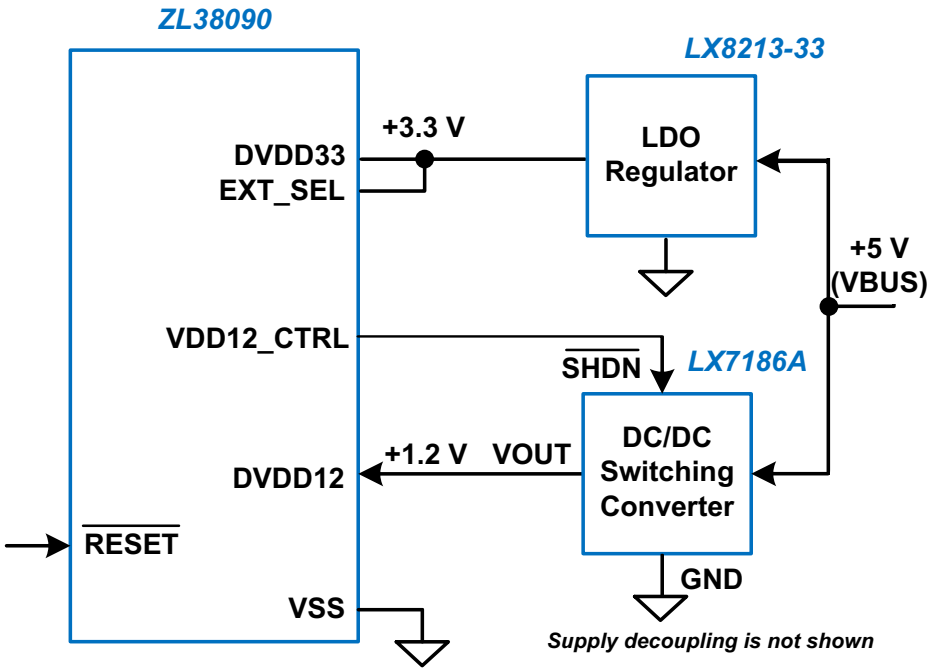
External +1.2 V supply use is selected when the EXT_SEL pin is tied to +3.3 V. The EXT_SEL pin can be pulled high or simply hard-wired to DVDD33. This is the typical use case.

VDD12_CTRL is a CMOS output which can be used to control the shutdown of the external +1.2 V supply. VDD12_CTRL will provide a steady +3.3 V output (with up to 4 mA of source current) for the external supply to be enabled and 0 V for the supply to be disabled.

For power savings when the ZL38090 does not need to be operational, the external voltage regulator can be turned off by pulling the $\overline{\text{RESET}}$ pin low for longer than 10 µS (Reset mode). This action will force the VDD12_CTRL pin low, shutting off the external LDO and allowing the +1.2 V supply to collapse to 0 V.

If shutdown of the external +1.2 V supply is not desired, simply leave the VDD12_CTRL output pin floating.

Figure 26 • **Typical Power Supply Configuration**



7.1.1.1 Internal +1.2 V Power

Note: The internal +1.2 V power option is only available with the 64-pin QFN package. The VDD12_CTRL pin is not available on the 56-ball WLCSP package.

An alternative supply configuration takes advantage of the ZL38090 built-in voltage regulator as the DVDD12 source. The internal voltage regulator requires an external N-channel FET device and a parallel 470 ohm resistor. Figure 27, page 25 shows DVDD12 powered from the internal supply. Power dissipation is higher with internal regulator use due to the internal control circuitry and functional blocks being active.

Note: When using the internal regulator, the ZL38090 will not meet the 12.5 mW USB suspend power specification.

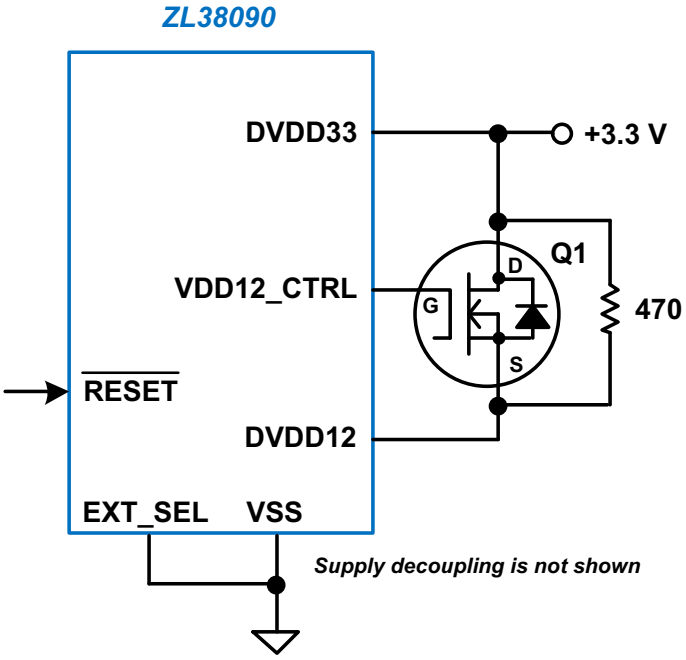
Internal supply use is selected when the EXT_SEL pin is tied to VSS. With the built-in voltage regulator enabled, VDD12_CTRL will drive Q1 and generate +1.2 V at DVDD12. The parallel 470 ohm resistor is required to ensure supply start-up. Q1 can be any of the high power FETs shown in Table 4, page 24, or an equivalent.

Table 4 • **Q1 Component Options**

Manufacturer	Part Number
Vishay®	Si1422DH
International Rectifier	IRLMS2002
Diodes Inc.®	ZXMN2B03E6

For power savings when the ZL38090 does not need to be operational, the internal voltage regulator can be turned off by pulling the RESET pin low for longer than 10 µS (Reset mode). This action will force the VDD12_CTRL pin low, shutting off the FET and allowing the +1.2 V supply to collapse to 0 V.

Figure 27 • **Internal +1.2 V Power Supply Configuration**



8 Device Booting and Firmware Swapping

8.1 Bootloader

The ZL38090 device contains a built-in bootloader that gets executed after a hardware reset, when power is initially applied to the part, and during the firmware Swap process. The bootloader performs the following actions:

- Reads the GPIO bootstrap information and stores it in the Boot Sense registers
- Determinant on the bootstrap setting, it loads external serial Flash device contents (firmware and configuration record) into Program RAM (Auto Boot), or waits for the host to load Program RAM (Host Boot and Firmware Swap)
- If Auto Boot is selected, the bootloader then programs the ZL38090 configuration registers to their proper default values, and jumps to Program RAM to execute the firmware

8.2 Bootstrap Modes

Table 5 lists the different boot options that can be selected by using an external resistor. GPIOs have internal pull-down resistors, thereby defaulting to a 0 setting. A resistor to DVDD33 is required to select a 1 option. An external pull-up resistor must have a value of 3.3 KΩ. A GPIO with a bootstrap pull-up can be used for other functionality following the power-up boot sense process.

Table 5 • **Bootstrap Modes**

GPIO_2	GPIO_1	GPIO_0	Operating Mode	Description	Notes
X	0	0	12.000 MHz Crystal (default)	Clock source selection	
X	1	1	Reserved		
0	X	X	Host Boot over HBI or USB Virtual Com Port (default)	Boot source selection	
1	X	X	Auto Boot from external Flash		1

1. Apply a 3.3 KΩ resistor from GPIO_2 to DVDD33. Note, when external Flash is selected, GPIO_9 = SM_CS.

8.3 Loadable Device Code

In order for the ZL38090 to operate, it must be loaded with code that resides externally. This code can be Auto Booted from an external Flash memory through the Master SPI, loaded into the ZL38090 by the host processor through the HBI port, or loaded from the USB host over the USB Virtual Com port. An external resistor pull-up or an internal resistor pull-down determines which boot mode will be used (see Table 5).

The external code consists of two logical segments, the firmware code itself and the configuration record. The firmware is a binary image which contains all of the executable code allowing the ZL38090 to perform voice processing and establishes the user command set. The configuration record contains settings for all of the user registers and defines the power-up operation of the device.

The configuration record is set up so that the registers are initialized to their desired values for normal operation.

A GUI development tool (*MiTuner*™ ZLS38508) is provided to create and modify a configuration record and create a bootable Flash image which can then be duplicated for production of the end product. This tool requires access to the UART for tuning.

8.3.1 Boot Speed

When performing an Auto Boot from a Flash device, the boot sequence lasts <1 second (for a typical firmware image and configuration record of size 400 kB).

8.4 Bootup Procedure

Valid clocks (crystal or clock oscillator) must be present before the ZL38090 device can exit its reset state. After the reset line is released, the ZL38090's internal voltage regulator will be enabled (if the EXT_SEL pin is strapped low). Once the +1.2 V supply is established, the PLL will be also be enabled. Based on the GPIO bootstrap options, the ZL38090 will select the system parameters and the PLL will lock to the desired operating frequency.

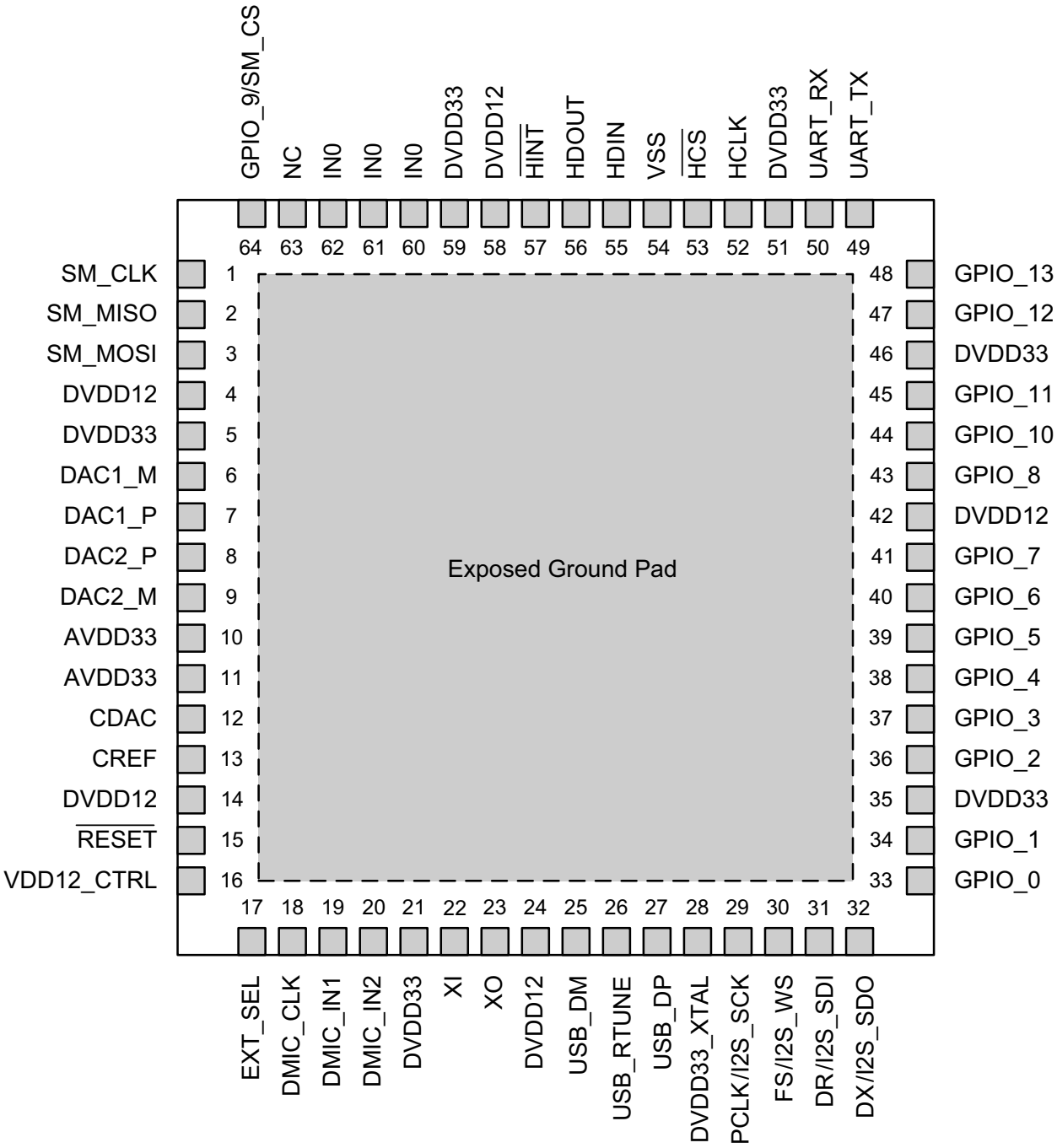
Next, if the GPIO strapping pins indicate that the ZL38090 will Auto Boot, it will begin reading data from the external Flash. Refer to the *Microsemi AcuEdge™ Firmware Manual* for a listing of the complete Boot Sequence.

If the GPIO strapping pins indicate that the ZL38090 will Host Boot, the SPI or I^2C port that initiates the loading process becomes the boot master. The ZL38090 allows for automatic configuration between SPI and I^2C operation.

9 Device Pinouts

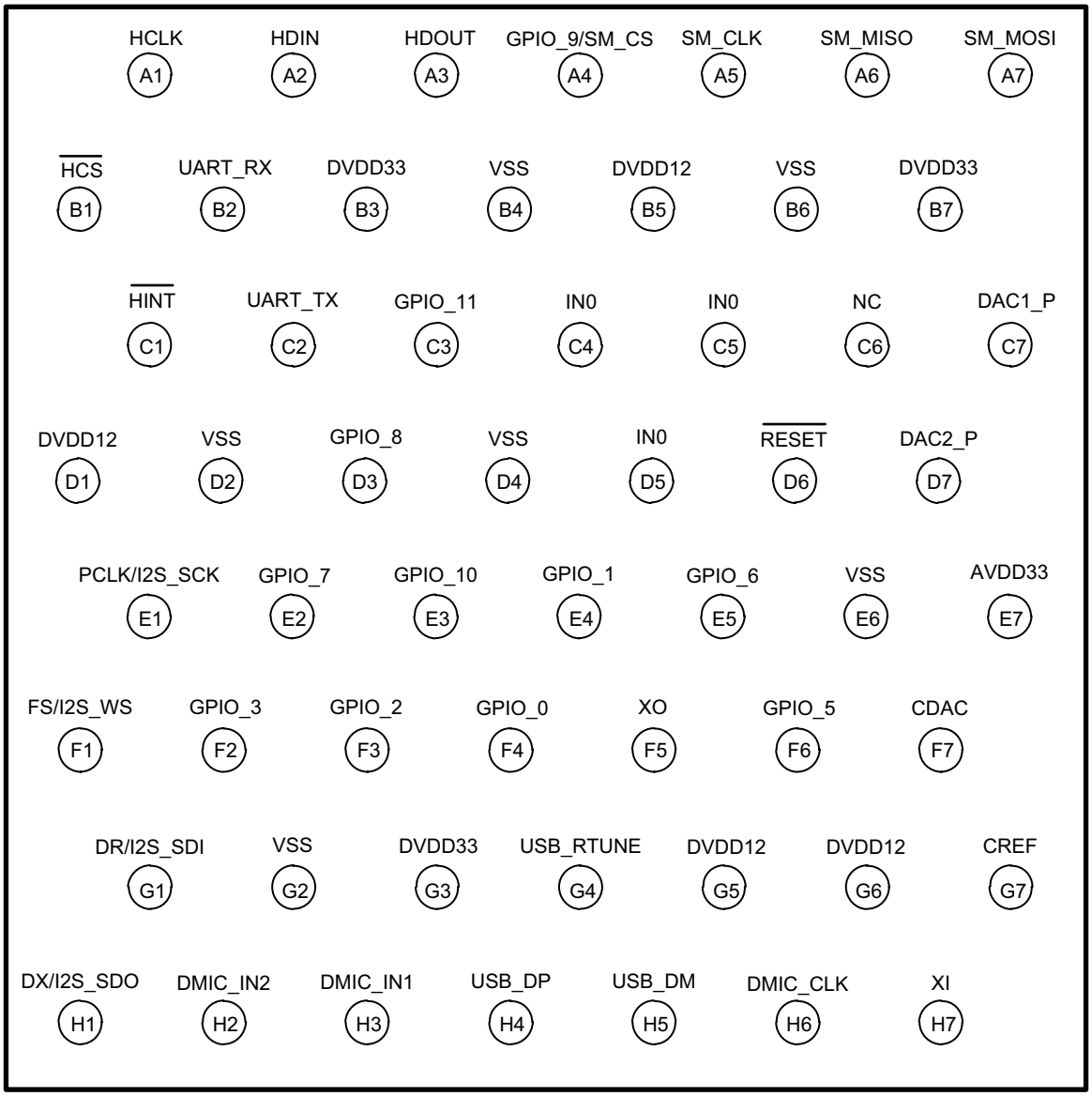
9.1 64-Pin QFN

Figure 28 • **ZL38090 64-Pin QFN – Top View**



9.2 56-Ball WLCSP

Figure 29 • **ZL38090 56-Ball WLCSP – Top View**



10 Pin Descriptions

10.1 Reset Pin

Table 6 • **Reset Pin Description**

QFN Pin #	WLCSP Ball	Name	Type	Description
15	D6	$\overline{\text{RESET}}$	Input	**Reset.** When low the device is in its reset state and all tristate outputs will be in a high impedance state. This input must be high for normal device operation. *A 10 KΩ pull-up resistor is required on this pin to DVDD33 if this pin is not continuously driven.* Refer to Reset, page 22 for an explanation of the various reset states and their timing.

10.2 DAC Pins

Table 7 • **DAC Pin Description**

QFN Pin #	WLCSP Ball	Name	Type	Description
6	–	DAC1_M	Output	**DAC 1 Minus Output.** This is the negative output signal of the differential amplifier of DAC 1. Pin functionality is firmware dependent. *Not available on the WLCSP package.*
7	C7	DAC1_P	Output	**DAC 1 Plus Output.** This is the positive output signal of the differential amplifier of DAC 1. Pin functionality is firmware dependent.
9	–	DAC2_M	Output	**DAC 2 Minus Output.** This is the negative output signal of the differential amplifier of DAC 2. Pin functionality is firmware dependent. *Not available on the WLCSP package.*
8	D7	DAC2_P	Output	**DAC 2 Plus Output.** This is the positive output signal of the differential amplifier of DAC 2. Pin functionality is firmware dependent.
12	F7	CDAC	Output	**DAC Reference.** This pin may require capacitive decoupling. Refer to DAC Output, page 7.
13	G7	CREF	Output	**Common Mode Reference.** This pin requires capacitive decoupling. Refer to DAC Output, page 7.

10.3 Microphone Pins

Table 8 • **Microphone Pin Description**

QFN Pin #	WLCSP Ball	Name	Type	Description
18	H6	DMIC_CLK	Output	**Digital Microphone Clock Output.** Clock output for digital microphones and digital electret microphone pre-amplifier devices.
19	H3	DMIC_IN1	Input	**Digital Microphone Input 1.** Stereo or mono digital microphone input. *Tie to VSS if unused.*
20	H2	DMIC_IN2	Input	**Digital Microphone Input 2.** Stereo or mono digital microphone input. *Tie to VSS if unused.*

10.4 TDM and I^2S Port Pins

The firmware supports a single TDM interface. The TDM block is capable of being a master or a slave. The ports can be configured for Pulse-Code Modulation (PCM) or Inter-IC Sound (I^2S) operation. The ports conform to PCM, GCI, and I^2S timing protocols.

Table 9 • **TDM and I^2S Ports Pin Descriptions**

QFN Pin #	WLCSP Ball	Name	Type	Description
29	E1	PCLK/ I2S_SCK	Input/ Output	**PCM Clock (Input/Tristate Output).** PCLK is equal to the bit rate of signals DR/DX. In TDM master mode this clock is an output and in TDM slave mode this clock is an input. **I^2S Serial Clock (Input/Tristate Output).** This is the I^2S bit clock. In I^2S master mode this clock is an output and drives the bit clock input of the external slave device's peripheral converters. In I^2S slave mode this clock is an input and is driven from a converter operating in master mode. After power-up, this signal defaults to be an input in I^2S slave mode. *A 100 KΩ pull-down resistor is required on this pin to VSS. If this pin is unused, tie the pin to VSS.* *When driving PCLK/I2S_SCK from a host, one of the following conditions must be satisfied:* *1. Host drives PCLK low during reset, or* *2. Host tri-states PCLK during reset (the 100 KΩ resistor will keep PCLK low), or* *3. Host drives PCLK at its normal frequency*

Table 9 • **TDM and I²S Ports Pin Descriptions *(continued)***

QFN Pin #	WLCSP Ball	Name	Type	Description
30	F1	FS/I2S_WS	Input/ Output	**PCM Frame Sync (Input/Tristate Output).** This is the TDM frame alignment reference. This signal is an input for applications where the PCM bus is frame aligned to an external frame signal (slave mode). In master mode this signal is a frame pulse output. **I²S Word Select (Left/Right) (Input/Tristate Output).** This is the I²S left or right word select. In I²S master mode word select is an output which drives the left/right input of the external slave device's peripheral converters. In I²S slave mode this pin is an input which is driven from a converter operating in master mode. After power-up, this signal defaults to be an input in I²S slave mode. *Tie this pin to VSS if unused.*
31	G1	DR/I2S_SDI	Input	**PCM Serial Data Stream Input.** This serial data stream operates at PCLK data rates. **I²S Serial Data Input.** This is the I²S port serial data input. *Tie this pin to VSS if unused.*
32	H1	DX/I2S_SDO	Output	**PCM Serial Data Stream Output.** This serial data stream operates at PCLK data rates. **I²S Serial Data Output.** This is the I²S port serial data output.

10.5 Headset Control/Indicator Pins

These pins are used for headset control functions and LED indicators.

Table 10 • **Headset Control/Indicator Pin Descriptions**

QFN Pin #	WLCSP Ball	Name	Type	Description
41	E2	GPIO_7	Input/ Output	**Hook Switch/Volume Down.** Fixed function used to control the hook state and volume down with GPIO[10:13].
43	D3	GPIO_8	Input/ Output	**Microphone/Volume Up.** Fixed function used to control the hook state and volume down with GPIO[10:13].
44	E3	GPIO_10	Input/ Output	**Volume Control/Call State.** Fixed function used to control the volume and indicate the call state with GPIO[7:8].
45	C3	GPIO_11	Input/ Output	**Call Control/Volume State 1.** Fixed function used to control the hook switch (on/off) and control multicolor LEDs for volume indication with GPIO[7:8].
47	–	GPIO_12	Input/ Output	**Volume State 2.** Fixed function used to control multicolor LEDs for volume indication with GPIO[7:8]. *GPIO_12 is not available on the WLCSP package.*
48	–	GPIO_13	Input/ Output	**Volume State 3.** Fixed function used to control multicolor LEDs for volume indication with GPIO[7:8]. *GPIO_13 is not available on the WLCSP package.*

10.6 USB Pins

These pins are used for USB functions.

Table 11 • **USB Pin Descriptions**

QFN Pin #	WLCSP Ball	Name	Type	Description
25	H5	USB_DM	Input/ Output	**USB Data D- Signal.** Carries USB data to/from USB 2.0.
26	G4	USB_RTUNE	Input/ Output	**Tx Resistor Tune.** Connect to external 43.2 Ω resistor to VSS.
27	H4	USB_DP	Input/ Output	**USB Data D+ Signal.** Carries USB data to/from USB 2.0.
40	E5	GPIO_6	Input/ Output	**USB Resume.** This pin is used to sense activity on USB Data D+ to resume from sleep or perform a USB reset. It can be configured as an input or output and is intended for low-frequency signaling.

10.7 HBI – SPI Slave Port Pins

This port functions as a peripheral interface for an external controller, and supports access to the internal registers and memory of the device.

Table 12 • **HBI – SPI Slave Port Pin Descriptions**

QFN Pin #	WLCSP Ball	Name	Type	Description
52	A1	HCLK	Input	**HBI SPI Slave Port Clock Input.** Clock input for the SPI Slave port. Maximum frequency = 25 MHz. This input should be tied to VSS in I2C mode, refer to Table 1, page 16 *Tie this pin to VSS if unused.*
53	B1	$\overline{\text{HCS}}$	Input	**HBI SPI Slave Chip Select Input.** This active low chip select signal activates the SPI Slave port. **HBI I^2C Serial Clock Input.** This pin functions as the I2C_SCLK input in I^2C mode. *A pull-up resistor is required on this node for I^2C* operation. *Tie this pin to VSS if unused.*
55	A2	HDIN	Input	**HBI SPI Slave Port Data Input.** Data input signal for the SPI Slave port. This input selects the slave address in I^2C mode, refer to Table 1, page 16 *Tie this pin to VSS if unused.*
56	A3	HDOUT	Input/ Output	**HBI SPI Slave Port Data Output (Tristate Output).** Data output signal for the SPI Slave port. **HBI I^2C Serial Data (Input/Output).** This pin functions as the I^2C_SDA I/O in I^2C mode. *A pull-up resistor is required on this node for I^2C operation.*
57	C1	$\overline{\text{HINT}}$	Output	**HBI Interrupt Output.** This output can be configured as either CMOS or open drain by the host.

10.8 Master SPI Port Pins

This port functions as the interface to an external Flash device used to optionally Auto Boot and load the device's firmware and configuration record from external Flash memory.

Table 13 • **Master SPI Port Pin Descriptions**

QFN Pin #	WLCSP Ball	Name	Type	Description
1	A5	SM_CLK	Output	**Master SPI Port Clock (Tristate Output).** Clock output for the Master SPI port. Maximum frequency = 8 MHz.
2	A6	SM_MISO	Input	**Master SPI Port Data Input.** Data input signal for the Master SPI port.
3	A7	SM_MOSI	Output	**Master SPI Port Data Output (Tristate Output).** Data output signal for the Master SPI port.
64	A4	GPIO_9/ SM_CS	Input/ Output	**Master SPI Port Chip Select (Input Internal Pull-Up/Tristate Output).** Chip select output for the Master SPI port. Shared with GPIO_9, see Table 16, page 35.

10.9 Oscillator Pins

These pins are connected to a 12.000 MHz crystal or clock oscillator which drives the device's internal PLL.

Table 14 • **Oscillator Pin Descriptions**

QFN Pin #	WLCSP Ball	Name	Type	Description
22	H7	XI	Input	**Crystal Oscillator Input.** Refer to External Clock Requirements, page 42.
23	F5	XO	Output	**Crystal Oscillator Output.** Refer to External Clock Requirements, page 42.

10.10 UART Pins

The ZL38090 device incorporates a two-wire UART (Universal Asynchronous Receiver Transmitter) interface with a fixed 115.2 K baud transfer rate, 8 data bits, 1 stop and no parity. The UART port can be used as a debug tool and is used for tuning purposes.

Table 15 • **UART Pin Descriptions**

QFN Pin #	WLCSP Ball	Name	Type	Description
50	B2	UART_RX	Input	**UART (Input).** Receive serial data in. This port functions as a peripheral interface for an external controller and supports access to the internal registers and memory of the device.
49	C2	UART_TX	Output	**UART (Tristate Output).** Transmit serial data out. This port functions as a peripheral interface for an external controller and supports access to the internal registers and memory of the device.

10.11 GPIO Pins

GPIO ports can be used for interrupt and event reporting, fixed function control, bootstrap options, as well as being used for general purpose I/O for communication and controlling external devices. Pin functionality is firmware dependent.

Table 16 • **GPIO Pin Descriptions**

QFN Pin #	WLCSP Ball	Name	Type	Description
33, 34, 36	F4, E4, F3	GPIO_[0:2]	Input/ Output	**General Purpose I/O (Input Internal Pull-Down/Tristate Output).** These pins can be configured as an input or output and are intended for low-frequency signaling. Refer to Table 5, page 26 for bootstrap functionality.
37, 38, 39	F2, –, F6	GPIO_[3:5]	Input/ Output	**General Purpose I/O (Input Internal Pull-Down/Tristate Output).** These pins can be configured as an input or output and are intended for low-frequency signaling. *GPIO_4 is not available on the WLCSP package.*
64	A4	GPIO_9/ SM_CS	Input/ Output	**General Purpose I/O (Input Internal Pull-Down/Tristate Output).** This pin can be configured as an input or output and is intended for low-frequency signaling. Alternate functionality with SM_CS, see Table 13, page 34.

10.12 Supply and Ground Pins

Table 17 • **Supply and Ground Pin Descriptions**

QFN Pin #	WLCSP Ball	Name	Type	Description
17	–	EXT_SEL	Input	**VDD +1.2 V Select.** Select external +1.2 V supply. Tie to DVDD33 if the +1.2 V supply is to be provided externally. Tie to VSS (0 V) if the +1.2 V supply is to be generated internally. Refer to Power Supply Considerations, page 23 for more information. *Not available on the WLCSP package.*
16	–	VDD12_CTRL	Output	**VDD +1.2 V Control.** Analog control line for the voltage regulator external FET when EXT_SEL is tied to VSS. When EXT_SEL is tied to DVDD33, the VDD12_CTRL pin becomes a CMOS output which can drive the shutdown input of an external LDO. Refer to Power Supply Considerations, page 23 for more information. *Not available on the WLCSP package.*
4, 14, 24, 42, 58	B5, D1, G5, G6	DVDD12	Power	**Core Supply.** Connect to a +1.2 V ±5% supply. *Place a 100 nF, 20%, 10 V, ceramic capacitor on each pin decoupled to the VSS plane.* Refer to Power Supply Considerations, page 23 for more information.
5, 21, 35, 46, 51, 59	B3, B7, G3	DVDD33	Power	**Digital Supply.** Connect to a +3.3 V ±5% supply. *Place a 100 nF, 20%, 10 V, ceramic capacitor on each pin decoupled to the VSS plane.*
28	–	DVDD33_ XTAL	Power	**Crystal Digital Supply.** This pin must be connected to a +3.3 V supply source capable of delivering 10 mA. *Not available on the WLCSP package.*

Table 17 • **Supply and Ground Pin Descriptions *(continued)***

QFN Pin #	WLCSP Ball	Name	Type	Description
10, 11	E7	AVDD33	Power	**Analog Supply.** Connect to a +3.3 V ±5% supply. *Place a 100 nF, 20%, 10 V, ceramic capacitor on each pin decoupled to the VSS plane.*
54	B4, B6, D2, D4, E6, G2	VSS	Ground	**Ground.** Connect to digital ground plane.
	–	Exposed Ground Pad	Ground	**Exposed Pad Substrate Connection.** Connect to VSS. This pad is at ground potential and must be soldered to the printed circuit board and connected via multiple vias to a heatsink area on the bottom of the board and to the internal ground plane. *Not available on the WLCSP package.*

10.13 No Connect Pins

Table 18 • **No Connect Pin Description**

QFN Pin #	WLCSP Ball	Name	Type	Description
63	C6			**No Connection.** This pins is to be left unconnected, do not use as a tie point.

10.14 IN0 Pins

These pins are to be tied to Ground only.

Table 19 • **IN0 Pin Descriptions**

QFN Pin #	WLCSP Ball	Name	Type	Description
60, 61, 62	C4, C5, D5	IN0	Input	**IN0.** Tie these pins to Ground.

11 Electrical Characteristics

11.1 Absolute Maximum Ratings

Stresses above those listed under *Absolute Maximum Ratings* can cause permanent device failure. Functionality at or above these limits is not implied. Exposure to absolute maximum ratings for extended periods may affect device reliability.

Table 20 • **Absolute Maximum Ratings**

Supply voltage (DVDD33, AVDD33)	−0.5 to +4.0 V
Core supply voltage (DVDD12)	−0.5 to +1.32 V
Input voltage	−0.5 to +4.0 V
Continuous current at digital outputs	15 mA
Reflow temperature, 10 sec., MSL3, per *JEDEC J-STD-020*	260 °C
Storage temperature	−55 to +125 °C
ESD immunity (Human Body Model)	JS-001-2014 Class 1C compliant

11.2 Thermal Resistance

Table 21 • **Thermal Resistance**

Junction to ambient thermal resistance[1], θ_{JA}	64-pin QFN	22.1 °C/W
	56-ball WLCSP	33.8 °C/W
Junction to board thermal resistance[1],<Footnote> θ_{JB}	64-pin QFN	6.1 °C/W
	56-ball WLCSP	3.9 °C/W
Junction to exposed pad thermal resistance[1], θ_{JC}	64-pin QFN	2.0 °C/W
Junction to case thermal resistance[1], θ_{JC}	56-ball WLCSP	5.2 °C/W
Junction to top characterization parameter, Ψ_{JT}	64-pin QFN	0.1 °C/W
	56-ball WLCSP	0.3 °C/W

1. The thermal specifications assume that the device is mounted on an effective thermal conductivity test board (4 layers, 2s2p) per JEDEC JESD51-7 and JESD51-5

11.3 Operating Ranges

Microsemi guarantees the performance of this device over the industrial (−40 °C to 85 °C) temperature range by conducting electrical characterization over each range and by conducting a production test with single insertion coupled to periodic sampling. These characterization and test procedures comply with the *Telcordia GR-357-CORE Generic Requirements for Assuring the Reliability of Components Used in Telecommunications Equipment*.

Table 22 • **Operating Ranges**

Parameter	Symbol	Min.	Typ.	Max.	Units
Ambient temperature	T_A	−40		+85	°C

Table 22 • **Operating Ranges *(continued)***

Parameter	Symbol	Min.	Typ.	Max.	Units
Analog supply voltage	V_{AVDD33}	3.135	3.3	3.465	V
Digital supply voltage	V_{AVDD33}				
Crystal Digital supply voltage	V_{DVDD33_XTAL}				
Crystal I/O voltage	V_{XI}		2.5	2.625	V
Core supply voltage	V_{DVDD12}	1.14	1.2	1.26	V

11.4 Device Power States

The ZL38090 operates in one of four hardware power states. These power states are defined as Working, Sleep, Reset, and USB Suspend. The current consumed by the ZL38090 is dependent upon the power state and the active firmware mode. Typical current consumption for all firmware modes and hardware states are shown in Table 23, page 39. Refer to the *Microsemi AcuEdge™ Firmware Manual* for programming and additional information on the firmware modes.

11.4.1 Working State

In the Working state, the ZL38090 is awake and running. In simple terms, the device is “on”. Device features are enabled and supported depending on the firmware and configuration settings.

There are two modes of operation in the ZLS38090firmwareNormal Mode and Power Saving Mode. Both modes support the full complement of firmware audio processing features.

Normal Mode is recommended for applications that use the internal voltage regulator with analog microphones. Normal Mode keeps the Audio Processor always on, thereby minimizing +1.2 V power supply noise that could be injected into sensitive analog microphone circuitry via the board layout.

Power Saving Mode can be enabled by setting register 0x206 (System Control Flags) bit 0, or it can be selected from the ZLS38508 *MiTuner™* GUI in the AEC Control window (Enable Power Saving Mode). This mode disables the audio processor block when idle, reducing the average current drawn from the +1.2 V power supply. The resulting trade-off is switching noise on this supply. Because of this, Power Saving Mode is not recommended for applications that use the internal voltage regulator with analog microphones.

11.4.2 USB Suspend State

USB Suspend is used to conserve power when a quick response is required. The Audio Processor is made inactive and the internal clocks are shut down. The ZL38090 will respond to no other inputs until it awakens from USB Suspend mode. In accordance with the USB specification, the ZL38090 will respond to activity on the USB bus to wake from USB Suspend state. The firmware and configuration records loaded into the device RAM are retained and no re-boot is required.

11.4.3 Reset State

Reset is a hardware state used to further conserve power. The +1.2V supply can be removed. The firmware and configuration records loaded into the device RAM are not retained in Reset and must be reloaded when the device is brought out of Reset. See Reset, page 22 for more information and refer to Power Supply, page 23 for information on +1.2 V removal.

11.4.4 Current Consumption

Device current consumption can vary with the firmware load. Common values are listed here using an external +1.2 V supply for the core power supply with a 12.000 MHz crystal and a 3.3 KΩ resistor from GPIO_2 to DVDD33 (external Flash selected), unless otherwise noted.

Table 23 • **Current Consumption**

	+3.3 V[1]		+1.2 V[2]			
Device Power State	**Typ.**	**Max.**	**Typ.**	**Max.**	**Units**	**Notes / Conditions**
Working state, Normal Mode	21		115		mA	Firmware active, Power Saving off, 1 DAC active[3], 2 MICs active[4].
Working state, Power Saving Mode	21		85			Firmware active, Power Saving on, 1 DAC active[3], 2 MICs active[4].
USB Suspend state	0.68		3.4			Firmware inactive (firmware and configuration record are retained), DACs and MICs are powered down.
Reset state	100		0		µA	Device in reset (reset > 10 µS), DVDD12 removed[5].

1. Table values include all current entering DVDD33, AVDD33, and DVDD33_XTAL pins. Add 1.0 mA to Normal, Power Saving, and USB Suspend modes if the internal voltage regulator is used (EXT_SEL = VSS).
2. Core supply voltage. Table values include all current entering DVDD12 pins.
3. DAC in differential mode, for 2 DACs active in differential mode, add 3.6 mA to +3.3 V current.
4. DMIC_IN active.
5. DVDD12 is removed if the internal regulator is used for +1.2 V generation or if the VDD12_CTRL pin is used to shutdown an external +1.2 V LDO that provides DVDD12 to the ZL38090.

11.5 DC Specifications

Typical values are for T_A = 25 ºC and nominal supply voltage. Minimum and maximum values are over the industrial −40 ºC to 85 ºC temperature range and supply voltage range as shown in Operating Ranges, page 37, except as noted. A 12.000 MHz clock oscillator is active.

Table 24 • **DC Specifications**

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes / Conditions
Input high voltage	V_{IH}	0.7 × V_{DVDD33}		V_{DVDD33} + 0.3	V	All digital inputs
Input low voltage	V_{IL}	V_{VSS} − 0.3		0.3 × V_{DVDD33}	V	All digital inputs
Input hysteresis voltage	V_{HYS}	0.4			V	
Input leakage (input pins)	I_{IL}			5	µA	0 to +3.3 V
Input leakage (bi-directional pins)	I_{BL}			5	µA	0 to +3.3 V
Weak pull-up current	I_{PU}	38	63	101	µA	Input at 0 V
Weak pull-down current	I_{PD}	19	41	158	µA	Input at +3.3 V
Input pin capacitance	C_I		5		pF	
Output high voltage	V_{OH}	2.4			V	At 12 mA
Output low voltage	V_{OL}			0.4	V	At 12 mA
Output high impedance leakage	I_{OZ}			5	µA	0 to +3.3 V
Pin capacitance (output & input/tristate pins)	C_O		5		pF	

Table 24 • **DC Specifications *(continued)***

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes / Conditions
Output rise time	t_{RT}		1.25		ns	10% to 90%, C_{LOAD} = 20 pF
Output fall time	t_{FT}		1.25		ns	90% to 10%, C_{LOAD} = 20 pF

11.6 AC Specifications

For all AC specifications, typical values are for T_A = 25 °C and nominal supply voltage. Minimum and maximum values are over the industrial −40 °C to 85 °C temperature range and supply voltage ranges as shown in Operating Ranges, page 37, except as noted. A 12.000 MHz clock oscillator is active with Two-Way Voice Communication firmware in Normal, Wideband operational mode.

11.6.1 Microphone Interface

AC specifications for microphone interface.

Table 25 • **Microphone Interface**

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes / Conditions
Microphone clock output (DMIC_CLK),						
8 kHz, 16 kHz sample rate			1.024		MHz	
48 kHz sample rate			3.072		MHz	
DMIC_CLK, Output high current	I_{OH}		20		mA	$V_{OH} = D_{VDD33} - 0.4$ V
DMIC_CLK, Output low current	I_{OL}		30		mA	V_{OL} = 0.4 V
DMIC_CLK, Output rise and fall time	t_R, t_F		5		nS	C_{LOAD} = 100 pF

11.6.2 DAC

Measurements taken using PCM mode. THD+N versus output power for speaker drive applications presented in Figure 30, page 41; THD+N versus output voltage for amplifier drive applications presented in Figure 31, page 42.

Table 26 • **DAC**

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes / Conditions
DAC output level:						DAC gain = 1, 1 KΩ load.
Full scale: Differential	V_{DACFS}		4.8		V_{PP}	
Single-ended			2.4			
0 dBm0: Differential			2.8			
Single-ended			1.4			
PCM full scale level (V_{ppd} value)			9		dBm0	DAC gain = 1, 600 Ω load
DAC output power:						[1], Single-ended loads driven capacitively to ground
Single-ended, 32 ohm load			20.6	24	mW	
Single-ended, 16 ohm load			37.5	47		
Differential, 32 ohm load			86.0	94		

Table 26 • **DAC *(continued)***

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes / Conditions
Frequency response: Sample rate = 48 kS/s	f_R	20		20000	Hz	[1],3 dB cutoff includes external AC coupling, without AC coupling the response is low pass.
Dynamic range: Sample rate = 48 kS/s			92		dBFS	20 Hz – 20 kHz
Total harmonic distortion plus noise	THD + N		−82		dBFS	[2], Input = −3 dBFS.
Signal to Noise Ratio	SNR		85		dB	[2],1004 Hz, C-message weighted
Allowable capacitive load to ground	C_L			100	pF	[1], At each DAC output.
Power supply rejection ratio	PSRR		70		dB	[1], 20 Hz - 100 kHz, 100 mVpp supply noise.
Crosstalk			−85	−70	dB	[1], Between DAC outputs.

1. Guaranteed by design, not tested in production.
2. Single-ended or differential output.

Figure 30 • **THD+N Ratio versus Output Power – Driving Low Impedance**

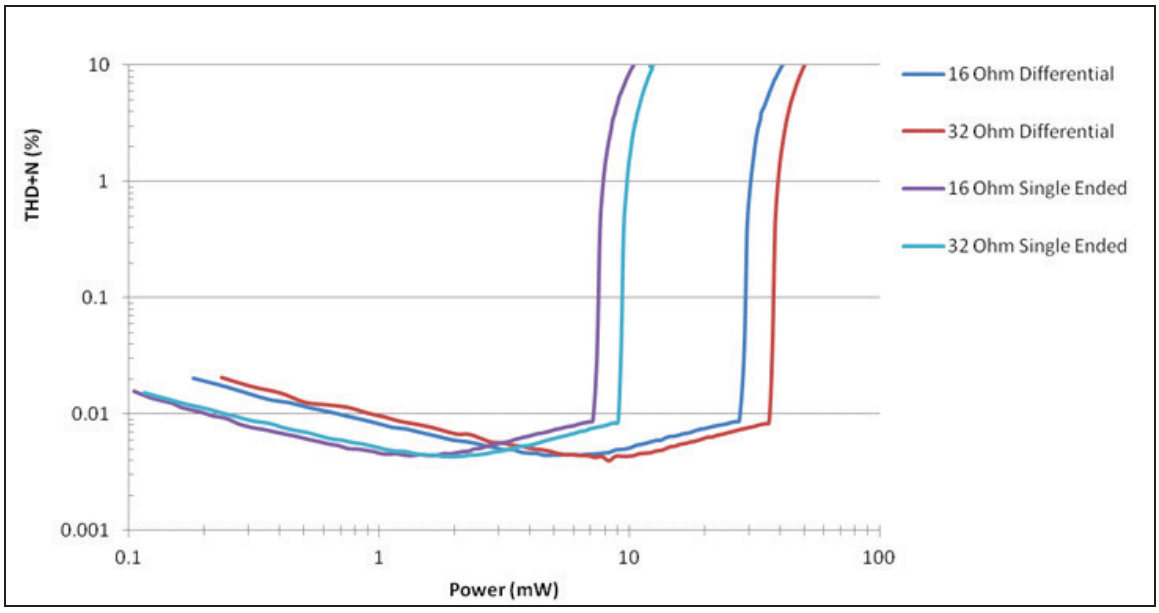
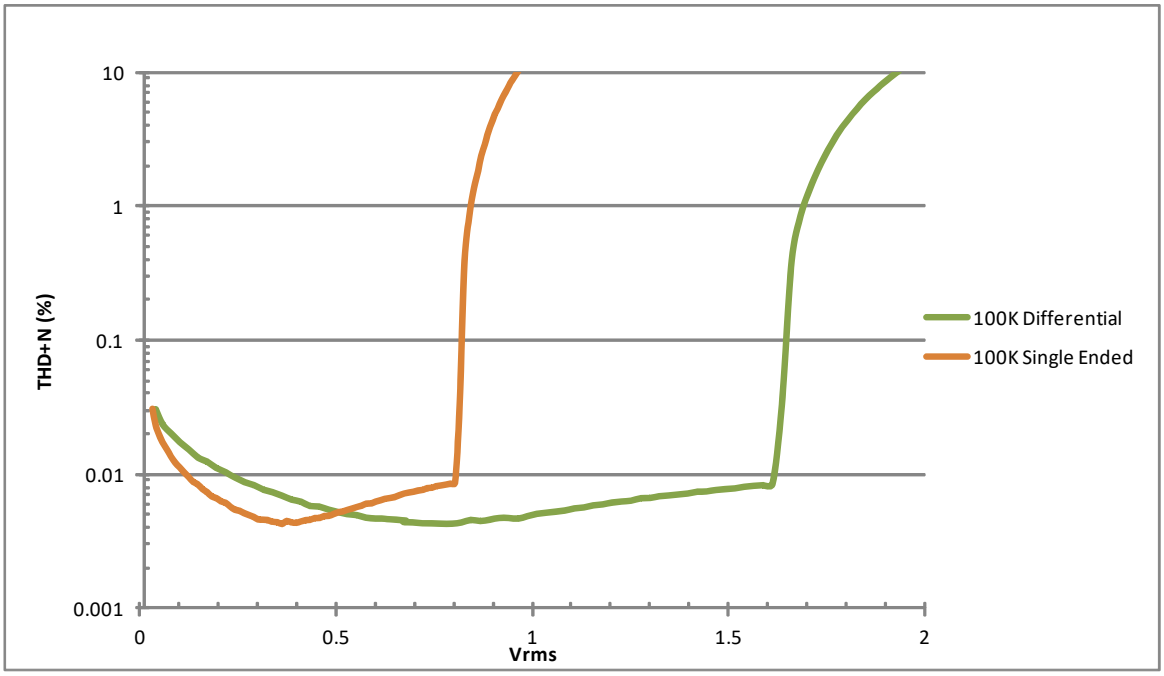


Figure 31 • **THD+N Ratio versus V_{RMS} – Driving High Impedance**



11.7 External Clock Requirements

In all modes of operation the ZL38090 requires an external clock source. The external clock drives the device's internal PLL which is the source for the internal timing signals.

The external clock source can either be:

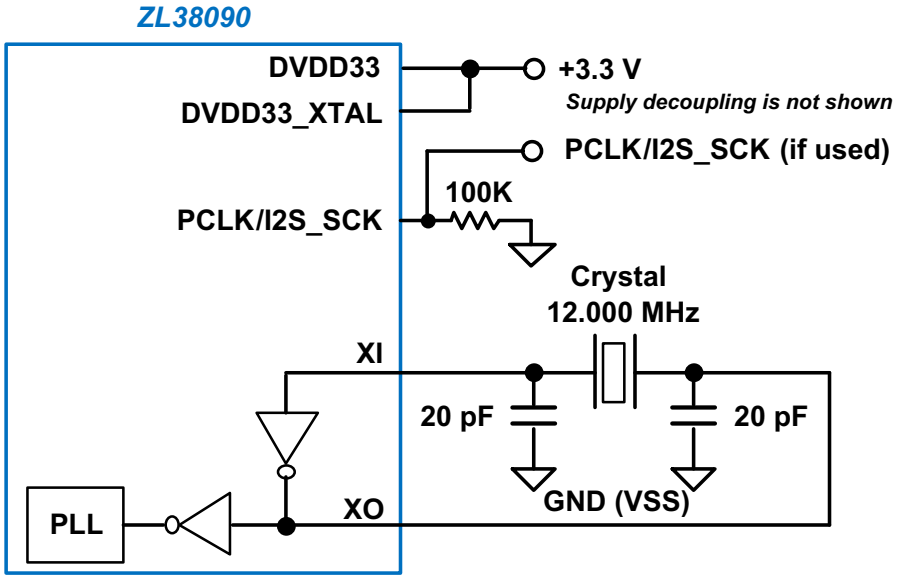
- 12.000 MHz crystal, or
- 12.000 MHz clock oscillator with a 2.5 V output

The following sections discuss these options.

11.7.1 Crystal Application

The oscillator circuit that is created across pins XI and XO requires an external fundamental mode crystal that has a specified parallel resonance (f_P) at 12.000 MHz.

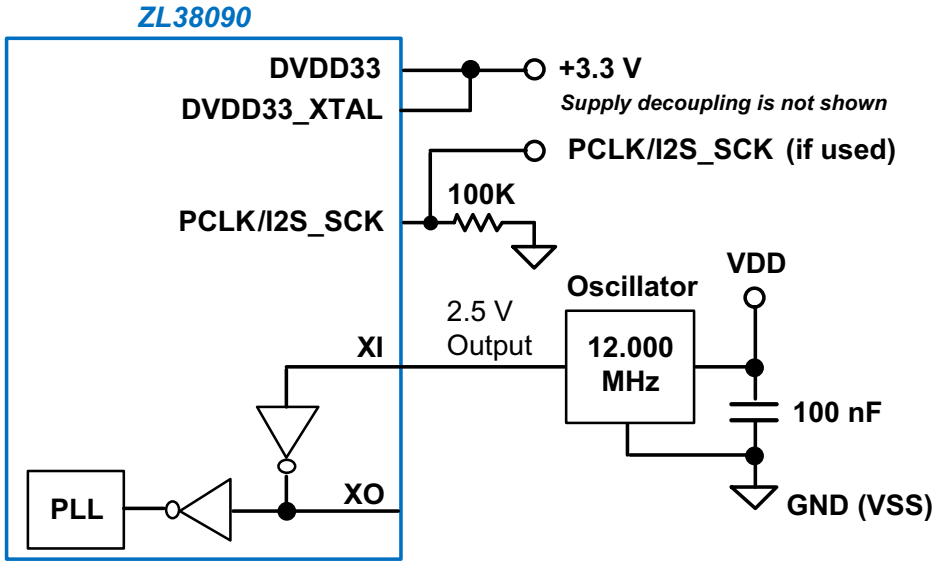
Figure 32 • **Crystal Application Circuit**



11.7.2 Clock Oscillator Application

Figure 33, page 43 illustrates the circuit that is used when the ZL38090 external clock source is a clock oscillator. The oscillator pins are 2.5 V compliant and should not be driven from 3.3 V CMOS without a level shifter or voltage attenuator.

Figure 33 • **Clock Oscillator Application Circuit**



11.7.3 AC Specifications - External Clocking Requirements

These specifications apply to crystal and clock oscillator external clocking.

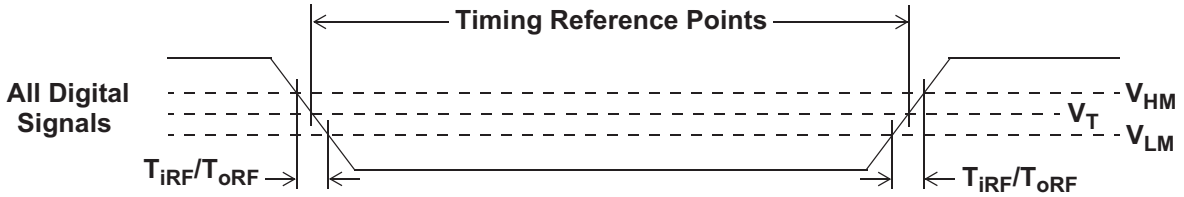
Table 27 • **AC Specifications – External Clocking Requirement**

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes / Conditions
External clocking frequency accuracy	A_{OSC}	−50		50	ppm	Not tested in production.
External clocking duty cycle	DC_{OSC}	40		60	%	
PCLK input jitter				1	ns_{pp}	
PCLK output jitter (master mode)				0.75	ns_{pp}	
PCLK input jitter			200		µs	
Holdover accuracy				50	ppm	

12 Timing Characteristics

Figure 34 depicts the timing reference points that apply to the timing diagrams shown in this section. For all timing characteristics, typical values are for T_A = 25 °C and nominal supply voltage. Minimum and maximum values are over the industrial −40 °C to 85 °C temperature range and supply voltage ranges as shown in Operating Ranges, page 37, except as noted.

Figure 34 • **Timing Parameter Measurement Digital Voltage Levels**



12.1 TDM Interface Timing Parameters

12.1.1 GCI and PCM Timing Parameters

Specifications for GCI and PCM timing modes are presented in the following table. The specifications apply to both port A and port B in slave operation.

A timing diagram that applies to GCI timing of the TDM interface is illustrated in Figure 35, page 46.

Timing diagrams that apply to PCM timing of the TDM interface are illustrated in Figure 36, page 46 and Figure 37, page 47.

Table 28 • **GCI and PCM Timing Parameters**

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes / Conditions
PCLK period	t_{PCY}	122		7812.5	ns	1, 2
PCLK High pulse width	t_{PCH}	48				2
PCLK Low pulse width	t_{PCL}	48				2
Fall time of clock	t_{PCF}			8		
Rise time of clock	t_{PCR}			8		
FS delay (output rising or falling)	t_{FSD}	2		15		2
		2		25		3
FS setup time (input)	t_{FSS}	5				4
FS hold time (input)	t_{FSH}	0.5		125000 − $2t_{PCY}$		4
Data output delay	t_{DOD}	2		15		2
		2		25		5
Data output delay to High-Z	t_{DOZ}	0		10		5
Data input setup time	t_{DIS}	5				4
Data input hold time	t_{DIH}	0				4
Allowed PCLK jitter time	t_{PCT}			20		Peak-to-peak
Allowed Frame Sync jitter time	t_{FST}			20		Peak-to-peak

1. PCLK frequency must be within 100 ppm.
2. C_{LOAD} = 40 pF

3. C_{LOAD} = 150 pF
4. Setup times based on 2 ns PCLK rise and fall times; hold times based on 0 ns PCLK rise and fall times.
5. Guaranteed by design, not tested in production.

Figure 35 • **GCI Timing, 8-bit**

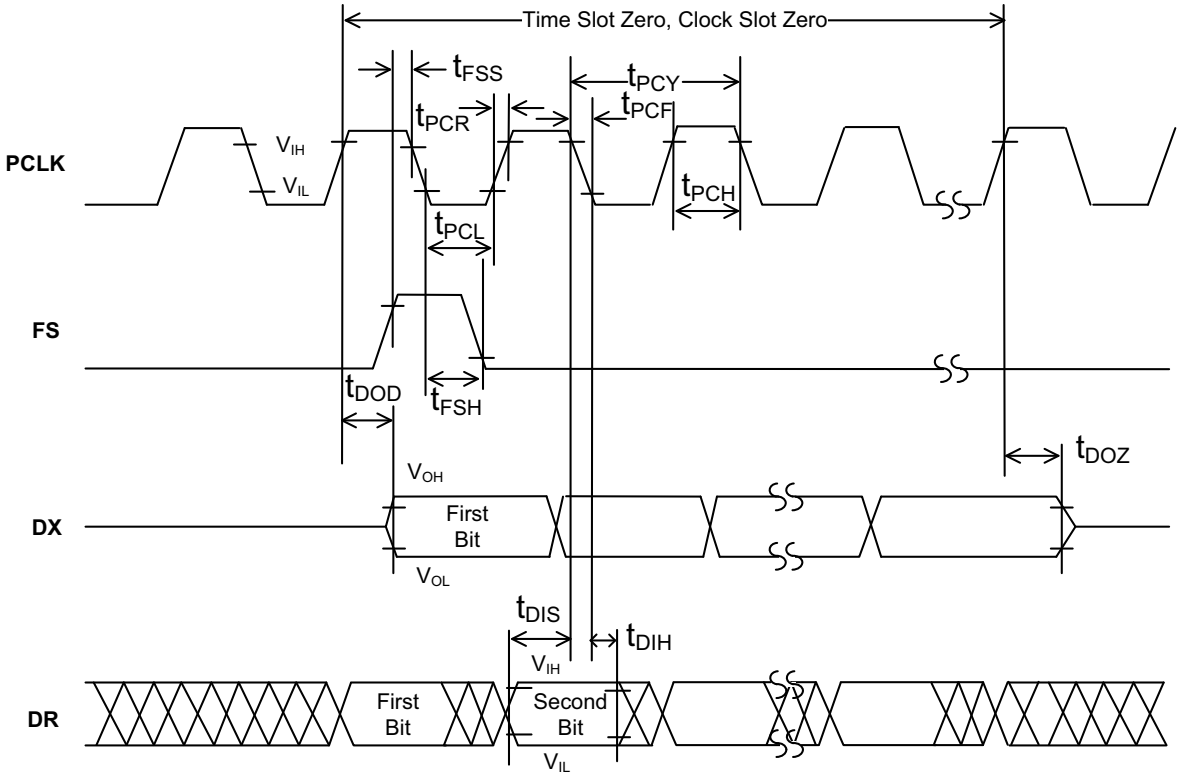


Figure 36 • **PCM Timing, 8-bit with xeDX = 0 (Transmit on Negative PCLK Edge)**

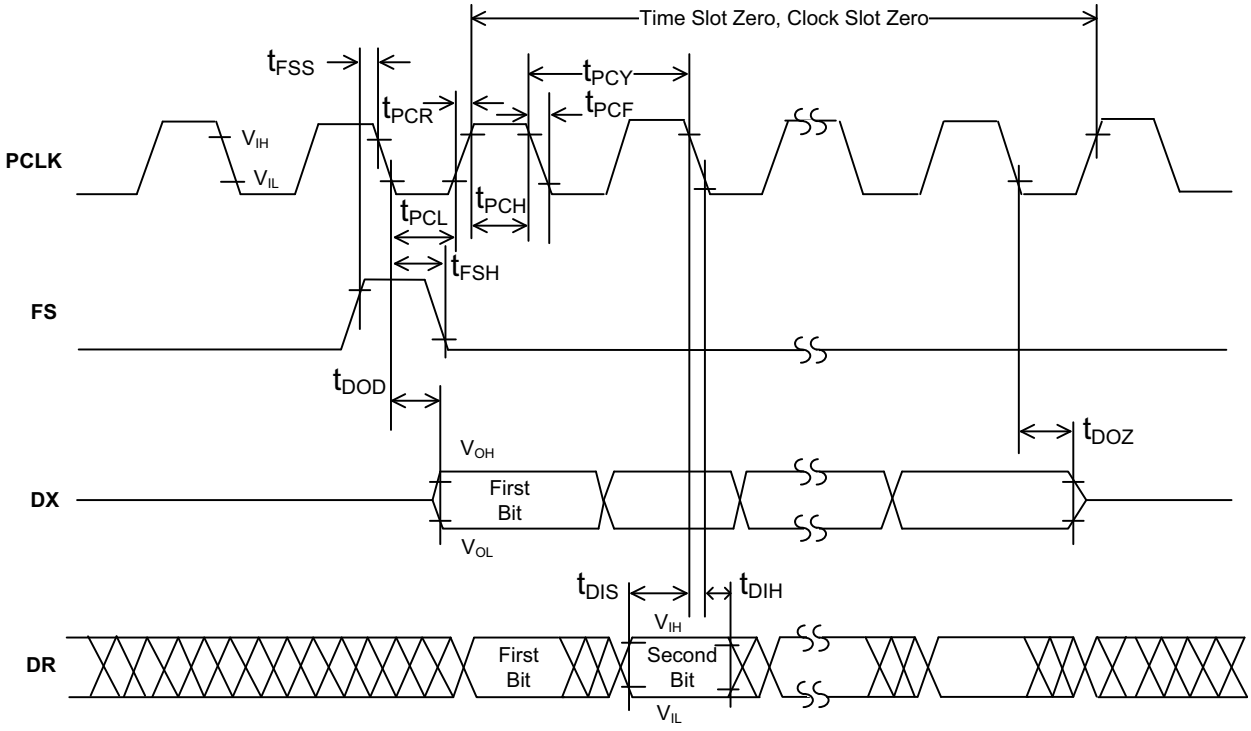
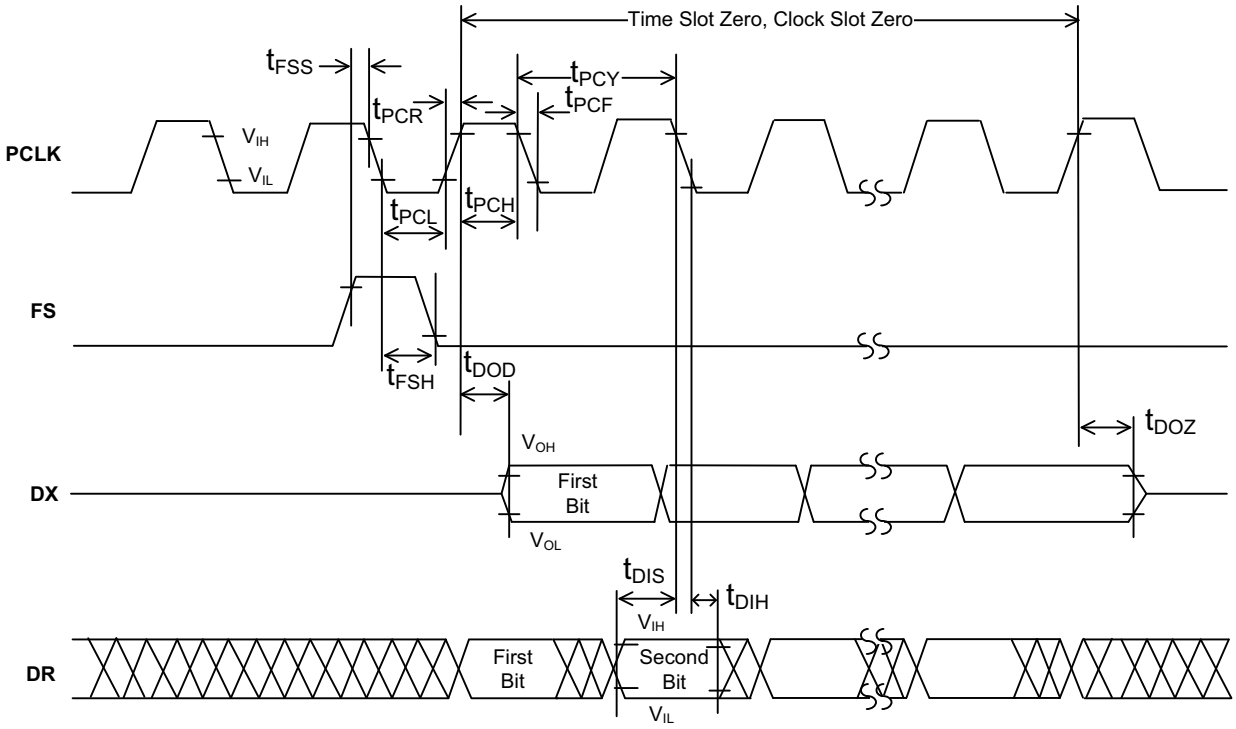


Figure 37 • **PCM Timing, 8-bit with xeDX = 1 (Transmit on Positive PCLK Edge)**



12.1.2 I²S Timing Parameters

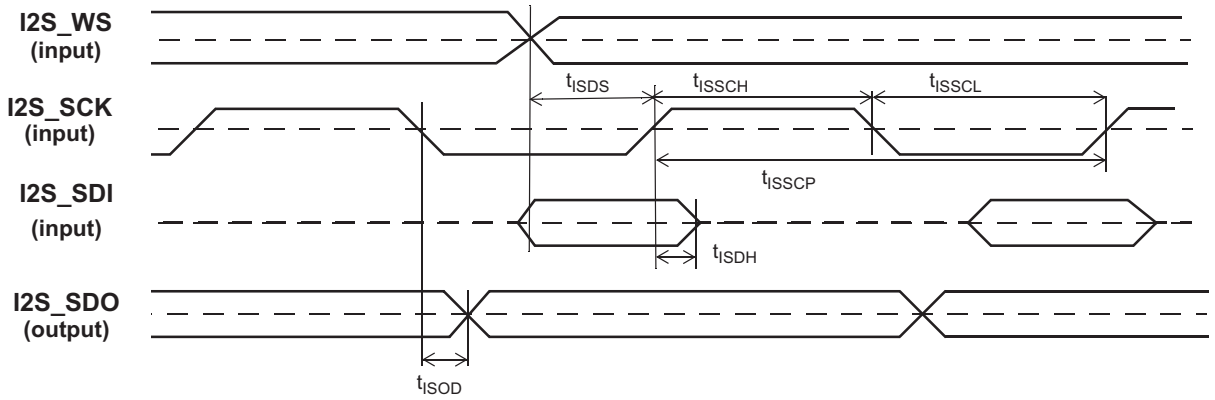
12.1.2.1 I²S Slave

Specifications for I²S Slave timing are presented in the following table. The specifications apply to both port A and port B. A timing diagram for the I²S Slave timing parameters is illustrated in Figure 38, page 48.

Table 29 • **I²S Slave Timing Specifications**

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes / Conditions
I2S_SCK Clock Period						
f_s = 48 kHz	t_{ISSCP}		651.04		ns	
f_s = 8 kHz			3.91		µs	
I2S_SCK Pulse Width High						
f_s = 48 kHz	t_{ISSCH}	292.97		358.07	ns	
f_s = 8 kHz		1.76		2.15	µs	
I2S_SCK Pulse Width Low						
f_s = 48 kHz	t_{ISSCL}	292.97		358.07	ns	
f_s = 8 kHz		1.76		2.15	µs	
I2S_SDI Setup Time	t_{ISDS}	5			ns	
I2S_WS Setup Time	t_{ISDS}	5			ns	
I2S_SDI Hold Time	t_{ISDH}	0			ns	
I2S_WS Hold Time	t_{ISDH}	0.5			ns	
I2S_SCK Falling Edge to I2S_SDO Valid	t_{ISOD}	2		15	ns	C_{LOAD} = 40 pF

Figure 38 • **Slave I²S Timing**



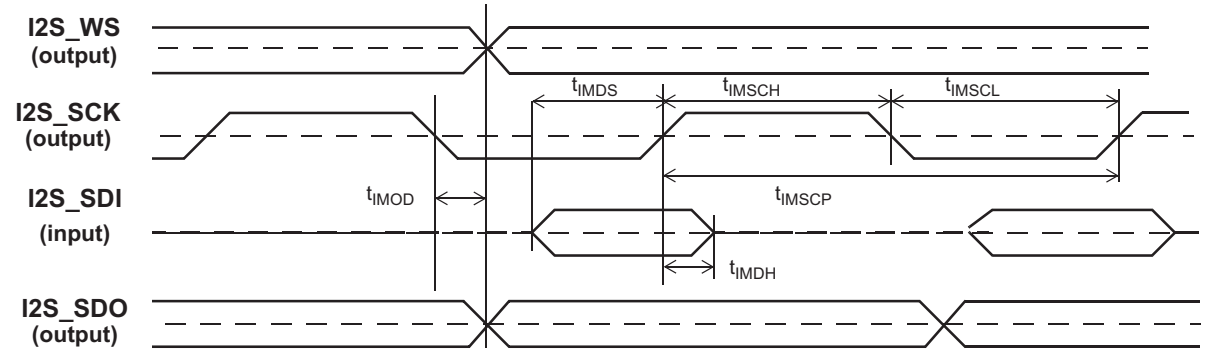
12.1.2.2 I²S Master

Specifications for I²S Master timing are presented in the following table. The specifications apply to both port A and port B. A timing diagram for the I²S Master timing parameters is illustrated in Figure 39.

Table 30 • **I²S Master Timing Specifications**

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes / Conditions
I2S_SCK Clock Period						
f_s = 48 kHz	t_{IMSCP}		651.04		ns	
f_s = 8 kHz			3.91		µs	
I2S_SCK Pulse Width High						
f_s = 48 kHz	t_{IMSCH}	318.0		333.0	ns	
f_s = 8 kHz		1.95		1.96	µs	
I2S_SCK Pulse Width Low						
f_s = 48 kHz	t_{IMSCL}	318.0		333.0	ns	
f_s = 8 kHz		1.95		1.96	µs	
I2S_SDI Setup Time	t_{IMDS}	5			ns	
I2S_SDI Hold Time	t_{IMDH}	0			ns	
I2S_SCK Falling Edge to I2S_WS	t_{IMOD}	2		15	ns	C_{LOAD} = 40 pF
I2S_SCK Falling Edge to I2S_SDO Valid	t_{IMOD}	2		15	ns	C_{LOAD} = 40 pF

Figure 39 • **Master I²S Timing**



12.2 Host Bus Interface Timing Parameters

The HBI is the main communication port from the host processor to the , this port can read and write all of the memory and registers on the . The port can be configured as SPI Slave or I^2C Slave.

For fastest command and control operation, use the SPI Slave configuration. The SPI Slave can be operated with HCLK speeds up to 25 MHz; the I^2C Slave will operate with HCLK speeds up to 400 kHz.

12.2.1 SPI Slave Port Timing Parameters

The following table describes timing specific to the device. A timing diagram for the SPI Slave timing parameters is illustrated in Figure 40, page 50.

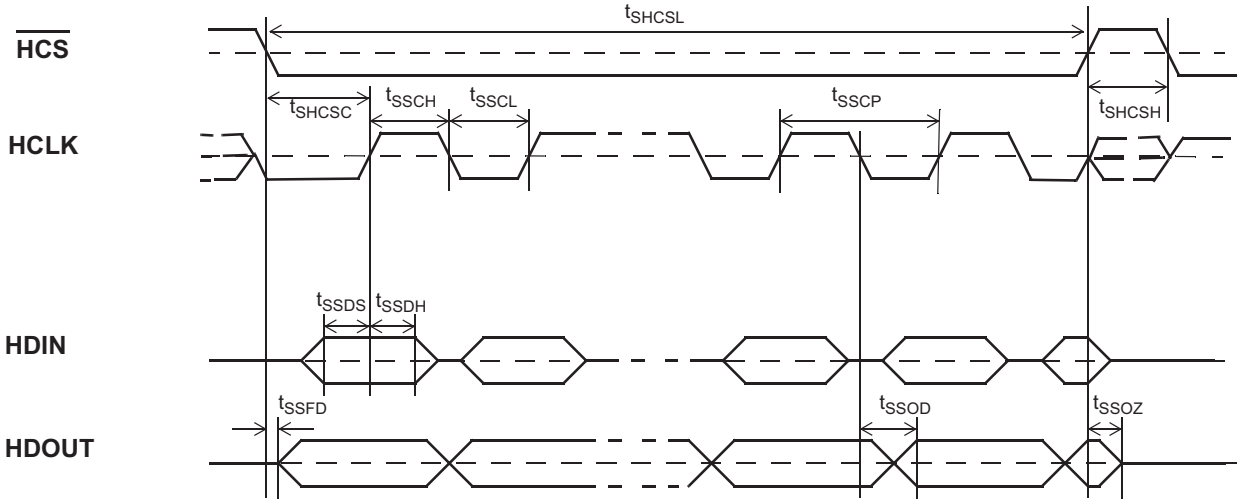
For seamless control operation, both the SPI Slave timing and the system timing need to be considered when operating the SPI Slave at high speeds. System timing includes host set-up and delay times and board delay times.

Table 31 • **SPI Slave Port Timing Parameters**

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes / Conditions
HCLK Clock Period	t_{SSCP}	40			ns	
HCLK Pulse Width High	t_{SSCH}	16	$t_{SSCP}/2$			[1]
HCLK Pulse Width Low	t_{SSCL}	16	$t_{SSCP}/2$			[1]
HDIN Setup Time	t_{SSDS}	5				
HDIN Hold Time	t_{SSDH}	0				
$\overline{HCS}$ Asserted to HCLK Rising Edge:						
Write	t_{SHCSC}	5	$t_{SSCP}/2$			
Read if host samples on falling edge		5	$t_{SSCP}/2$			
Read if host samples on rising edge		t_{SSFD} + host HDOUT setup time to HCLK	t_{SSFD} + $t_{SSCP}/2$			
HCLK Driving Edge to HDOUT Valid	t_{SSOD}	2		15		C_{LOAD} = 40 pF
$\overline{HCS}$ Falling Edge to HDOUT Valid	t_{SSFD}	0		15		[2], C_{LOAD} = 40 pF
$\overline{HCS}$ De-asserted to HDOUT Tristate	t_{SSOZ}	0		10		[5], C_{LOAD} = 40 pF
$\overline{HCS}$ Pulse High	t_{SHCSH}	20	$t_{SSCP}/2$			[1, 3]
$\overline{HCS}$ Pulse low	t_{SHCSL}					[4]

1. HCLK may be stopped in the high or low state indefinitely without loss of information. When $\overline{HCS}$ is at low state, every 16 HCLK cycles, the 16-bit received data will be interpreted by the SPI interface logic.
2. The first data bit is enabled on the falling edge of $\overline{HCS}$ or on the falling edge of HCLK, whichever occurs last.
3. The SPI Slave requires 61 ns $\overline{HCS}$ off time just to make the transition of $\overline{HCS}$ synchronized with HCLK clock. In the command framing mode, there is no $\overline{HCS}$ off time between each 16-bit command/data, and $\overline{HCS}$ is held low until the end of command.
4. If $\overline{HCS}$ is not held low for 8 or 16 HCLK cycles exactly, the SPI Slave will reset. During byte or word framing mode, $\overline{HCS}$ is held low for the whole duration of the command. Multiple commands can be transferred with $\overline{HCS}$ low for the whole duration of the multiple commands. The rising edge of the $\overline{HCS}$ indicates the end of the command sequence and resets the SPI Slave.
5. Guaranteed by design, not tested in production.

Figure 40 • **SPI Slave Timing**



12.2.2 I²C Slave Interface Timing Parameters

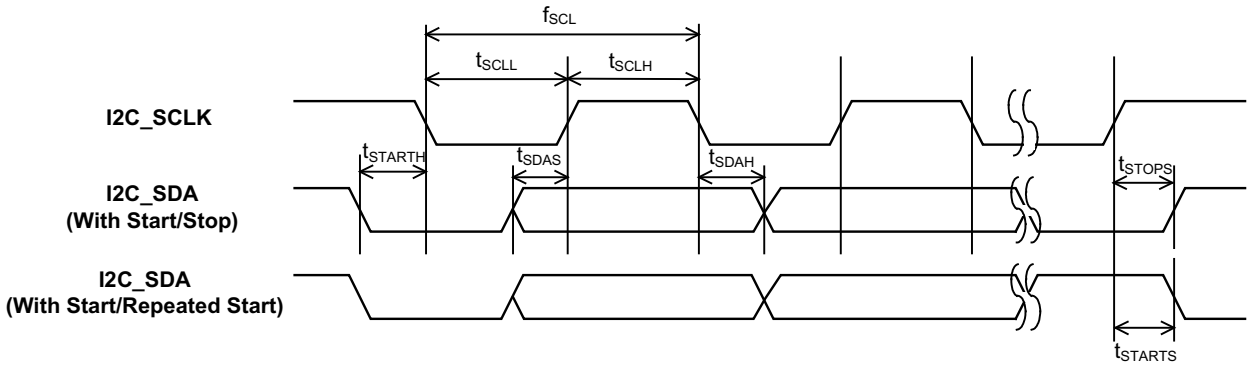
The I²C interface uses the SPI Slave interface pins.

Specifications for I²C interface timing are presented in the following table. A timing diagram for the I²C timing parameters is illustrated in Figure 41, page 51.

Table 32 • **I²S Slave Timing Specifications**

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes / Conditions
SCLK Clock Frequency	f_{SCL}	0		400	kHz	
START Condition Hold Time	t_{STARTH}	0.6			µs	
SDA data setup time	t_{SDAS}	100			ns	
SDA Hold Time Input	t_{SDAH}	100			ns	
SDA Hold Time Output	t_{SDAH}	300			ns	
High period of SCLK	t_{SCLH}	0.6			µs	
Low period of SCLK	t_{SCLL}	1.3			µs	
STOP Condition Setup Time	t_{STOPS}	0.6			µs	
Repeated Start Condition Setup Time	t_{STARTS}	0.6			µs	
Pulse Width Spike Suppression, glitches ignored by input filter	t_{SP}	50			ns	

Figure 41 • **I²C Timing Parameter Definitions**



12.3 UART Timing Parameters

Specifications for UART timing are presented in the following table. Timing diagrams for the UART timing parameters are illustrated in Figure 42 and Figure 43.

Table 33 • **UART Timing Specifications**

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes / Conditions
UART_RX and UART_TX bit width Baud rate = 115.2 kbps	t_{UP}		8.68		µs	
Allowed baud rate deviation 8 bits with no parity				4.86	%	Guaranteed by design, not tested in production.

Figure 42 • **UART_RX Timing**

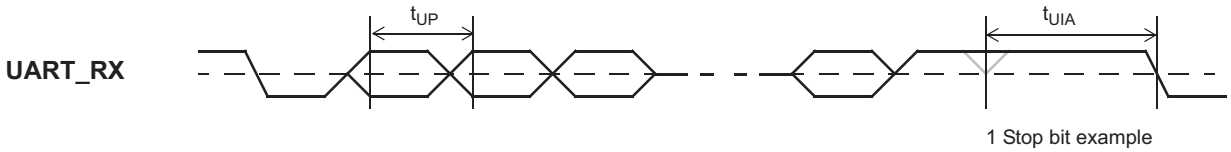
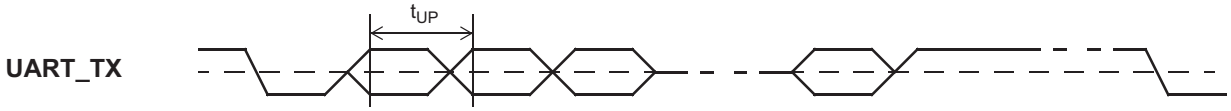


Figure 43 • **UART_TX Timing**



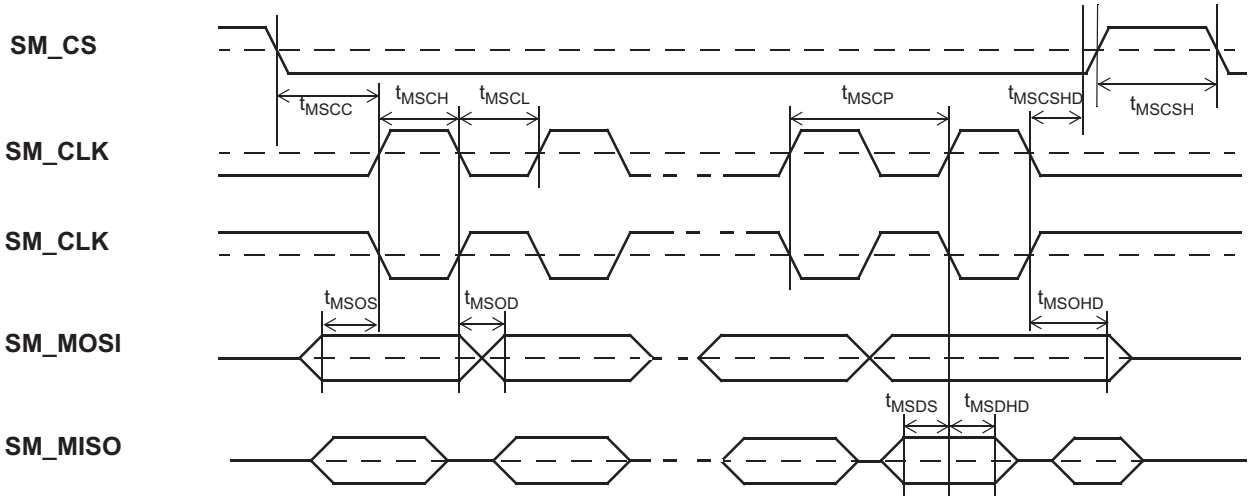
12.4 Master SPI Timing Parameters

Specifications for Master SPI timing are presented in the following table. A timing diagram for the Master SPI timing parameters is illustrated in Figure 44.

Table 34 • **Master SPI Timing Specifications**

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes / Conditions
SM_CLK Clock Period	t_{MSCP}	40		320	ns	Max. 25.0 MHz
SM_CLK Pulse Width High	t_{MSCH}	$(t_{MSCP}/2) - 2$		160		
SM_CLK Pulse Width Low	t_{MSCL}	$(t_{MSCP}/2) - 2$		160		
SM_MISO Setup Time	t_{MSDS}	3				
SM_MISO Hold Time	t_{MSDHD}	0				
SM_CS Asserted to SM_CLK Sampling Edge	t_{MSCC}	$(t_{MSCP}/2) - 4$				
SM_CLK Driving Edge to SM_MOSI Valid	t_{MSOD}	−1		2		C_{LOAD} = 40 pF
SM_MOSI Setup to SM_CLK Sampling Edge	t_{MSOS}	$(t_{MSCP}/2) - 4$				C_{LOAD} = 40 pF
SM_MOSI Hold Time to SM_CLK Sampling Edge	t_{MSOHD}	$(t_{MSCP}/2) - 4$				C_{LOAD} = 40 pF
SM_CS Hold Time after last SM_CLK Sampling Edge	t_{MSCSHD}	$(t_{MSCP}/2) - 4$				
SM_CS Pulse High	t_{MSCSH}	$(t_{MSCP}/2) - 2$				

Figure 44 • **Master SPI Timing**



13 Package Outline Drawings

13.1 Package Drawings

Figure 45 • **64-Pin QFN**

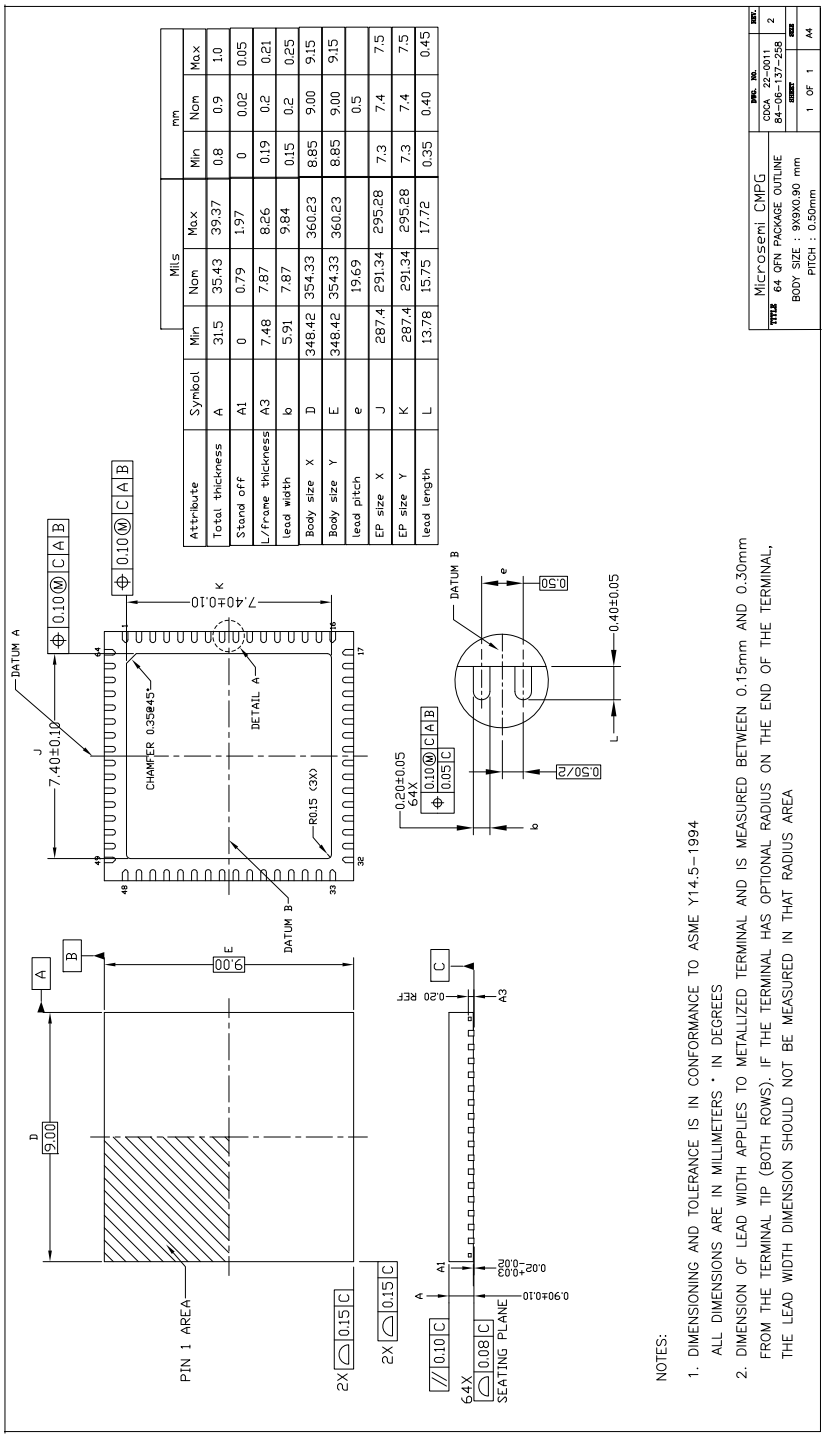
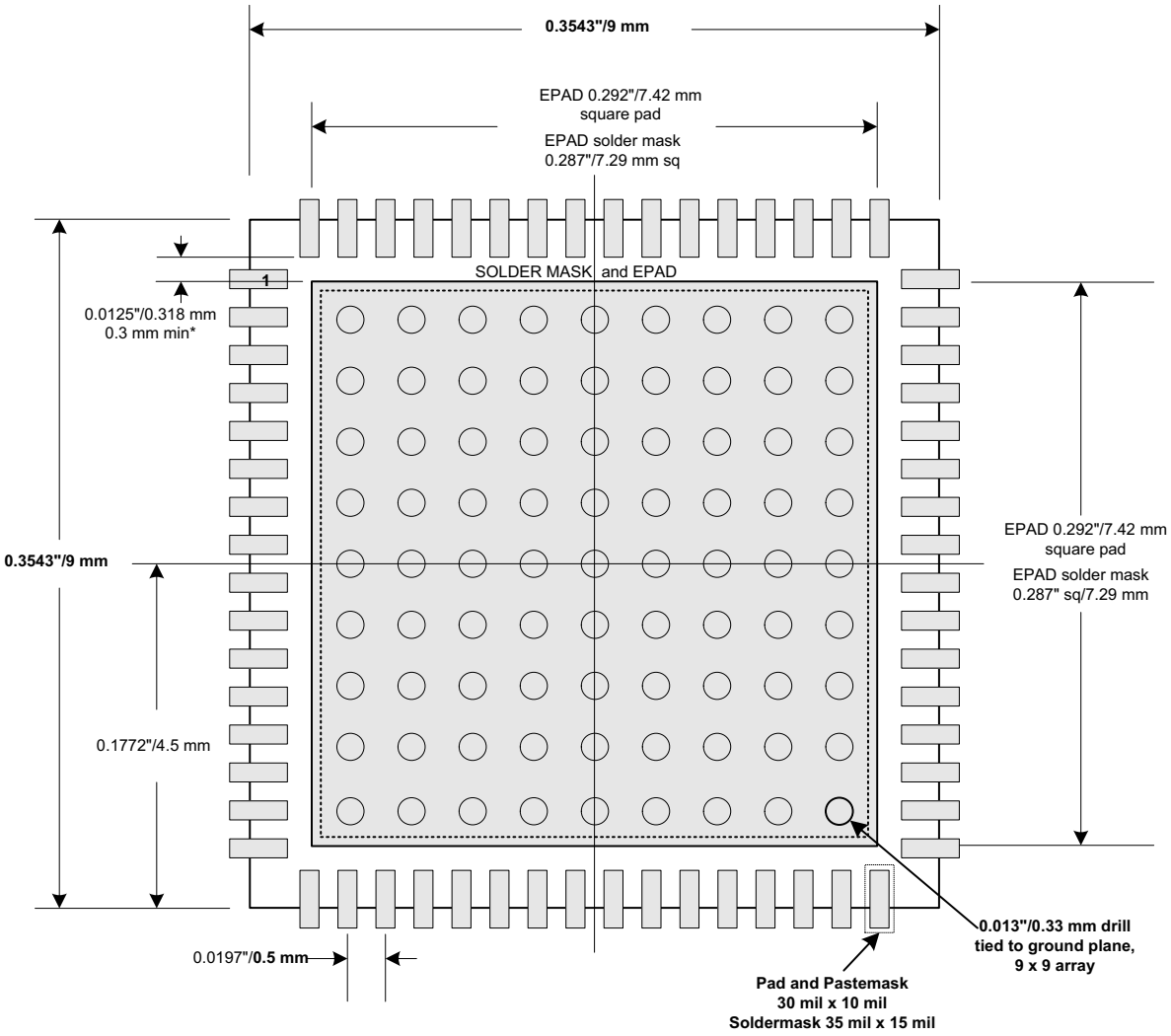


Figure 46 • **Recommended 64-Pin QFN Land Pattern – Top View**

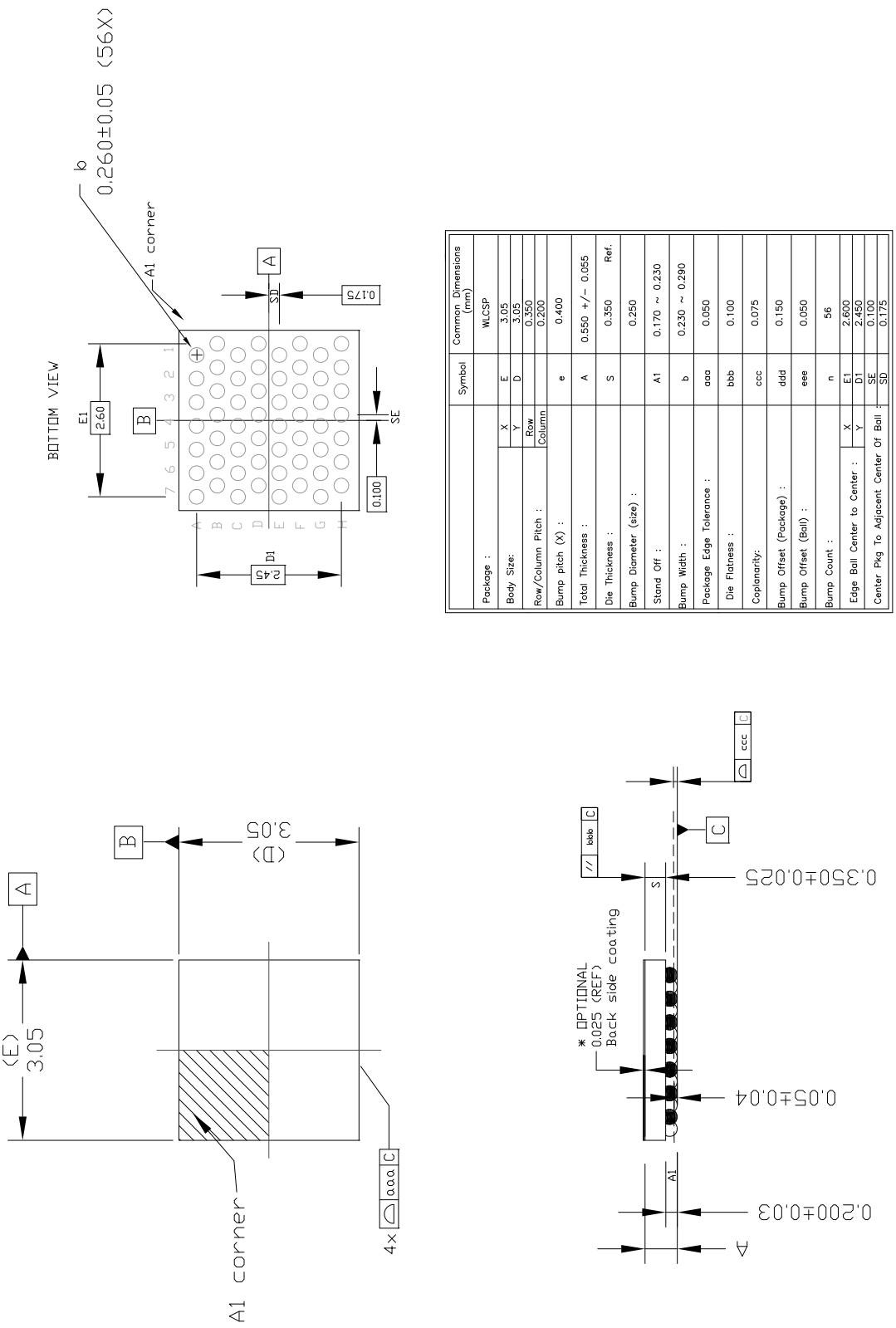


64-QFN
9 mm x 9 mm, 0.5 mm pitch

* Minimum spacing between pins and epad must be 0.3 mm

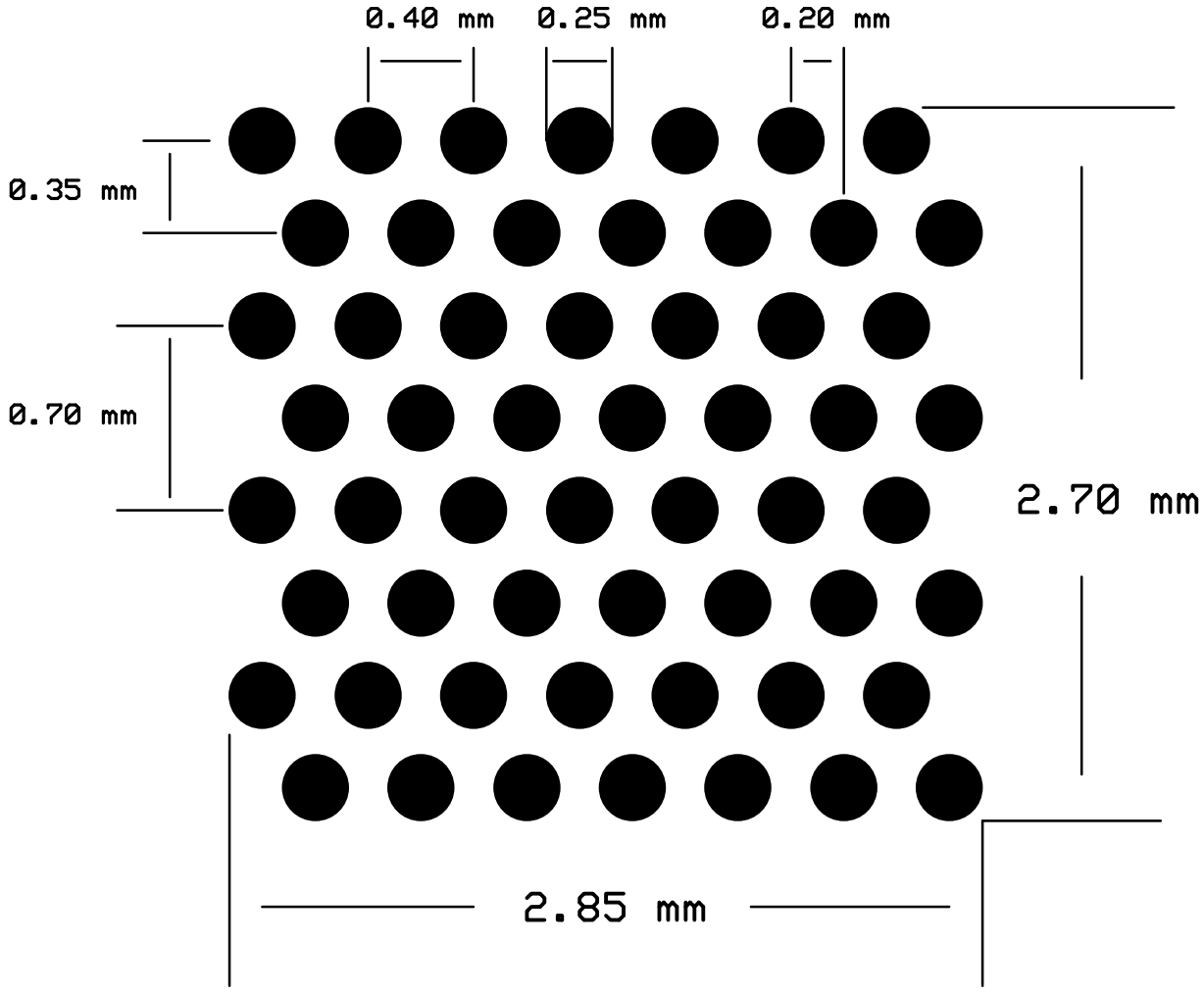
Recommended EPAD configuration uses 0.292"/7.42 mm square pad tied to a ground plane with a 9 x 9 array of 0.013"/0.33 mm vias. This is necessary for good thermal performance.

Figure 47 • **56-Ball WLCSP**



			Symbol	Common Dimensions (mm)
Package :				WLCSP
Body Size:		X	E	3.05
		Y	D	3.05
Row/Column Pitch :		Row		0.350
		Column		0.200
Bump pitch (X) :			e	0.400
Total Thickness :			A	0.550 +/- 0.055
Die Thickness :			S	0.350 Ref.
Bump Diameter (size) :				0.250
Stand Off :			A1	0.170 ~ 0.230
Bump Width :			b	0.230 ~ 0.290
Package Edge Tolerance :			aaa	0.050
Die Flatness :			bbb	0.100
Coplanarity:			ccc	0.075
Bump Offset (Package) :			ddd	0.150
Bump Offset (Ball) :			eee	0.050
Bump Count :			n	56
Edge Ball Center to Center :		X	E1	2.600
		Y	D1	2.450
Center Pkg To Adjacent Center Of Ball :			SE	0.100
			SD	0.175

Figure 48 • **56-Ball WLCSP Staggered Balls Expanded Bottom View**



Ball Diameter -- 0.25 mm

Pitch:

Horizontal -- 0.40 mm

Vertical -- 0.35 mm