Q4413

ECHO CANCELLER/ VARIABLE RATE VOCODER

GENERAL DESCRIPTION

The QUALCOMM Q4413 Variable Rate Vocoder/Echo Canceller is a full-duplex speech encoder and decoder that produces toll-quality speech at compressed data rates of under 13.3 kilobits per second (kbps). The Q4413 provides a single-chip solution to the speech compression requirements for digital telephone, wireless communications, voice storage, and speech synthesis systems. It also contains an optional network echo canceller which meets CCITT Recommendation G.165. The Q4413 uses the latest version of the proprietary QUALCOMM Codebook Excited Linear Predictive (QCELP) speech coding algorithm called PureVoice™ to achieve the quality of a wired phone at low data rates.

The Q4413 can encode speech at fixed or variable data rates. In Fixed Rate Mode, the Q4413 can code speech at rates of 13.3 kbps or 6.2 kbps. In Variable Rate Mode, the Q4413 automatically adjusts the data rate from 1 kbps to 13.3 kbps every 20 milliseconds (ms). When in Variable Rate Mode, the Q4413 codes speech at under 10 kbps in continuous speech applications and at under 5 kbps in typical two-way telephone conversations, without degrading the speech quality.

A Rate Reduction Mode is also available to lower the average data rate below that of normal variable rate operation while maintaining high speech quality. QUALCOMM's rate reduction algorithm, SmartRate™, is the key to this intelligent coding technique.

The Q4413 is a masked ROM version of a digital signal processor (DSP) device. Digitized speech is transferred to and from the Q4413 via a digital serial interface that connects to a 64 kbps μ-law, A-law or linear speech codec. Compressed speech packets are transferred to and from the Q4413 via an 8-bit parallel data bus interface that connects to standard microprocessor buses. The Q4413 is also controlled via this processor interface.

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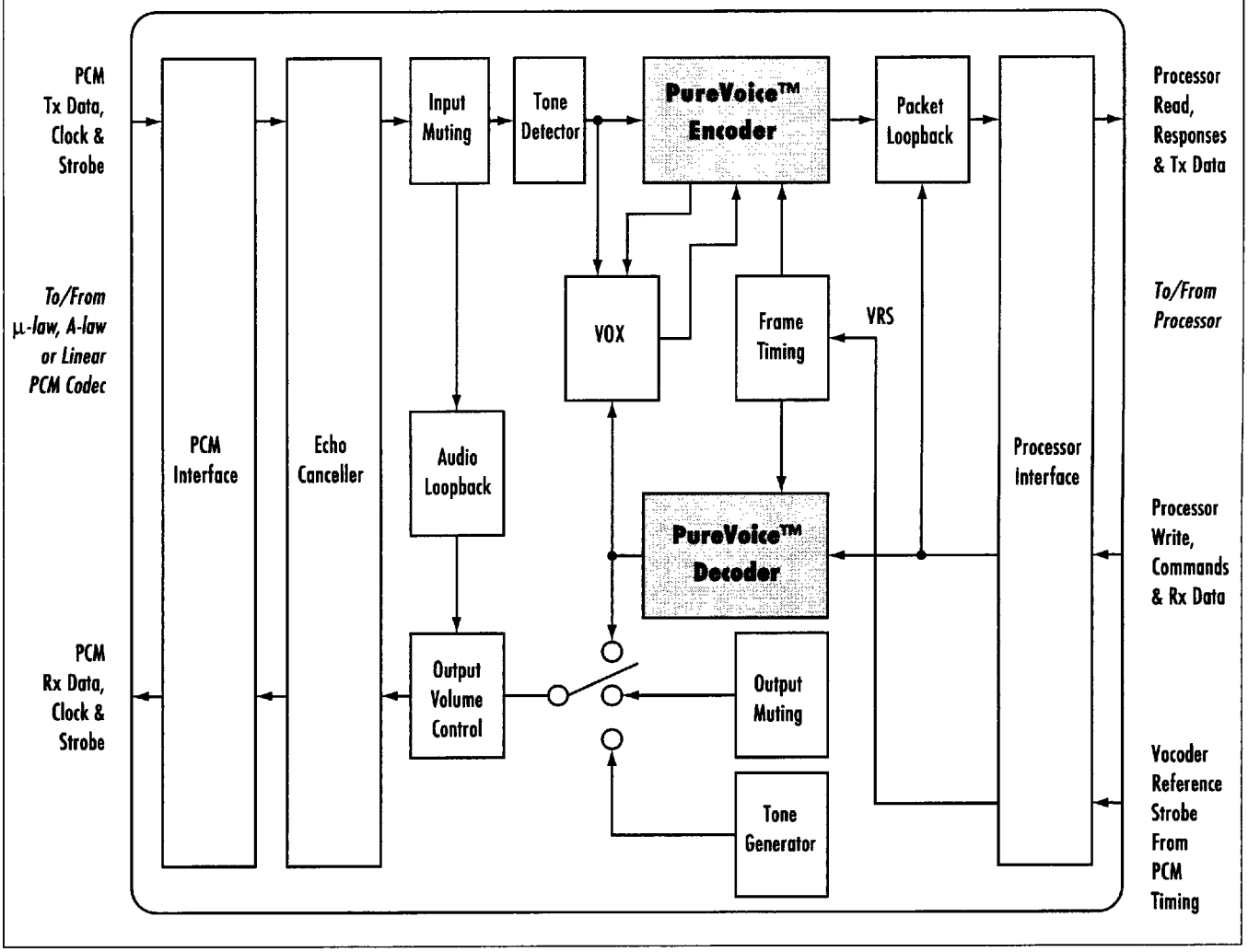
FUNCTIONAL OVERVIEW

The operation of the Q4413 Vocoder/Echo Canceller is controlled through an 8-bit parallel processor interface using a set of pre-defined vocoder commands. Digitized speech samples are transferred to and from the Q4413 via a standard serial interface that is compatible with standard μ-law, a-law or linear PCM codecs. Compressed packets of speech data are transferred to and from the Q4413 via the same 8-bit parallel processor interface used for controlling the Q4413. Figure 1 shows how the Q4413 interfaces to the other system components.

The Q4413 includes many functions in addition to the basic vocoder operation, making it a full-featured speech compression system. Figure 1 shows the functional block diagram of the Q4413. The PureVoice encoder and decoder, along with the frame timing section, make up the core of the Q4413. The echo canceller removes the echo caused by connecting to the telephone network. The PCM interface sends and receives μ-law, A-law or linear PCM data to and from the codec. The processor interface sends and receives commands and compressed data to and from the system processor. The Input Muting feature allows muting of the input speech, and the Output Muting feature allows muting of the output speech. The Output Volume Control feature adjusts the output volume. The Tone Detector is capable of detecting any of the sixteen possible DTMF tones as well as two different FAX tones. The Tone Generator feature creates single or dual frequency tones, including DTMF tones. The Voice-Activated Switch (VOX) feature may be used for hands-free telephone operation (for example, a speaker phone). The Audio Loop Back function allows testing

Figure 1. Q4413 Vocoder/Echo Canceller Block Diagram



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of the PCM interface, and the Packet Loop Back function allows testing of the microprocessor interface. Each of the functions in this diagram is explained in detail in the following sections.

PUREVOICE™ ENCODER

The PureVoice Encoder is the most complex function of the Q4413 Variable Rate Vocoder/Echo Canceller. The Encoder operates on one 20 ms frame at a time. Each frame contains 160 PCM samples. The encoding process includes measurement of the speech energy, data rate determination, dynamic adjustment of the rate thresholds, and encoding the speech into packets of compressed data. The Encoder provides a packet of data to the processor every 20 ms. Each encoded packet contains one byte that represents the data rate and a varying number of data bytes that represent the speech in each frame. The length of the packet depends on the data rate that has been chosen either by the user or by the rate decision algorithm in Variable Rate Mode. The four possible packet lengths can be seen in Figure 13. Any extra bits in the last byte of a packet are set to zero. The processor formats the valid data bits contained in the packet from the Q4413 for storage or transmission.

The Encoder operates in three compression modes: Fixed Rate, Variable Rate or Reduced Rate. The Fixed Rate Mode compresses the speech at fixed data rates of 6200 or 13300 bits per second (bps). Variable Rate Mode compresses the speech at data rates of 1000, 6200 or 13300 bps based on speech energy. The Reduced Rate Mode is a subset of Variable Rate Mode. The encoded data rates are the same as those mentioned for Variable Rate Mode with the addition of Quarter Rate which is 2700 bps. In Reduced Rate Mode, some of the frames which would normally be encoded at Full Rate (13.3 kbps) are encoded at lower data rates. The Q4413 achieves toll-quality speech with Variable Rate Mode, levels 0,1 and 2 of Reduced Rate Mode, and a fixed data rate of 13.3 kbps. Levels 3 and 4 of Reduced Rate Mode and the 6.2 kbps fixed rate produce near toll-quality speech.

PUREVOICE™ DECODER

The PureVoice Decoder receives packets of compressed speech from the processor every 20 ms. Each packet contains one byte that represents the data rate and a varying number of compressed data bytes needed for reconstructing the speech. The Decoder provides a reconstructed speech output of 160 8-bit μ-law, A-law or 16-bit linear companded speech samples every 20 ms to the PCM interface. The packets input to the Decoder contain a varying number of valid data bits depending on the data rate used to encode the frame. The processor must properly format the data from the transmission channel or storage device into the packet structure used by the Decoder.

NETWORK ECHO CANCELLER

Network echo cancellers are used in the land-based telephone network to eliminate echos caused by impedance mismatches at the hybrids. Every land-based telephone is connected to a central office by a two-wire line which supports transmission in both directions. However, for calls longer than about 35 miles, the two directions of transmission must be physically separated resulting in a four-wire line. The device that interfaces between the two-wire and four-wire segments is called a hybrid. The echo is modeled using adaptive filtering techniques. The echo is then subtracted from the incoming speech and it becomes imperceptible to the user. The Q4413 contains an Echo Canceller which meets CCITT Recommendation G.165. The Echo Canceller cancels an echo path delay of 32 ms on far-end echo, and provides at least 35 dB of Echo Return Loss Enhancement (ERLE). ERLE is the amount of energy removed from the echo after it has passed through the Echo Canceller.

FRAME TIMING

The Frame Timing section of the Q4413 Variable Rate Vocoder/Echo Canceller determines the beginning of each 20 ms frame for the Encoder and Decoder. A single input signal, Vocoder Reference Strobe (VRS), provides the basis for this 20 ms timing. The Encoder Frame Timing and Decoder Frame Timing are independently set by the Tx Offset and Rx Offset from

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the VRS. These offsets are programmed through the Initialize command described in the *Q4413 Vocoder/ Echo Canceller Commands* section. The frame timing is initiated by providing a single strobe (or a repetitive 20 ms signal) to the VRS input pin or by issuing a Software VRS command to the Q4413. The initial VRS typically occurs at initialization or when the system configuration is changed.

PCM INTERFACE

The PCM interface of the Q4413 Variable Rate Vocoder/Echo Canceller interfaces to a μ-law, A-law or linear PCM codec. This interface receives and transmits 64 kbps μ-law, A-law or linear companded speech samples. μ-law and A-law samples are transferred as 8-bit serial words every 125 μs. Linear samples are transferred as 16-bit serial words every 125 μs. Three of the bits are used for volume control. The PCM interface is shown in Figure 2. All data is transferred synchronously with externally sourced clocks and strobes. For additional information, refer to the *Operational Interfaces* section. Two optional PCM interface handshake signals, Tx Buffer Full (TXBF) and Rx Buffer Empty (RXBE), are provided to facilitate PCM data transfer for applications that do not require the use of a codec.

The codec interface format (μ-law, A-law or linear) may be selected by the Configuration command. For more information, refer to the *Configuration Command* in the *Q4413 Vocoder/Echo Canceller Commands* section.

PROCESSOR INTERFACE

The Q4413 is controlled by a processor via the 8-bit parallel processor interface. The packets of compressed data are also transmitted and received over the processor interface. Communication between the Q4413 and the processor is governed by a protocol that defines the Q4413 commands and responses (described in the *Q4413 Variable Rate Vocoder/Echo Canceller Commands* section). The Q4413 acts as a slave peripheral to the processor. Therefore, the processor always initiates communication.

Commands sent to the Q4413 from the processor are called command packets. Responses sent from the Q4413 to the processor are called response packets. There are only three commands which result in a response packet from the Q4413. These are the Tx Frame command, the Diagnostic Test command and the Test Result command. Data is transferred via the 8-bit data bus using the read and write signals from the processor. The processor interface is shown in Figure 3.

The Q4413 features two self-diagnostic tests: a RAM Test and an ALU Test. The RAM Test verifies that the RAM locations can be written to and read from properly. The ALU Test verifies that the DSP core is functioning properly.

MUTING

The Muting Control command controls both input and output muting.

The Input Muting function suppresses the input speech so that it is not encoded. Comfort noise is the

Figure 2. Q4413 Variable Rate Vocoder/Echo Canceller to PCM Codec Interface

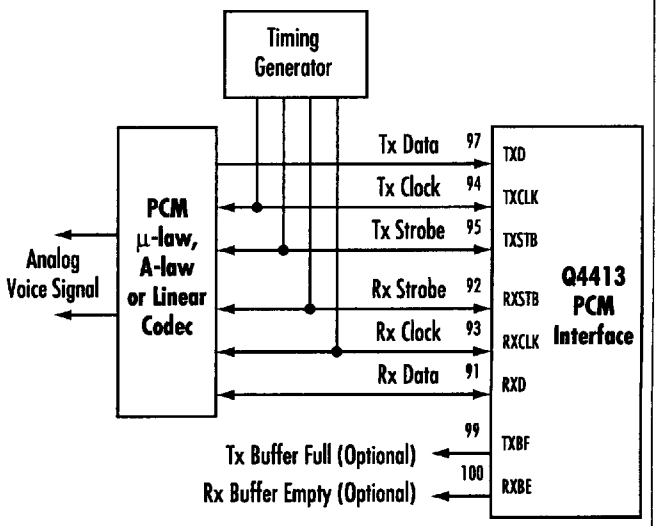
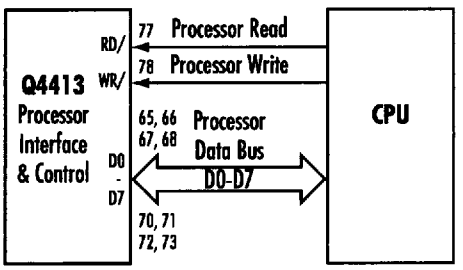


Figure 3. Vocoder to Processor Interface



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only data that is encoded. The reconstructed signal at the Decoder contains only comfort noise. In Variable Rate Mode, the Encoder processes the input speech at the low, 1000 bps data rate.

The Output Muting function replaces the reconstructed speech samples with comfort noise before the samples are sent to the PCM interface. Output muting is often used to eliminate pops and glitches that may be caused by the switching of processing paths or data sources. When the processor is aware of any system configuration changes that might cause errors to be heard, the Output Muting feature should be enabled and then disabled after the event.

For more information, refer to the *Muting Control Command* in the *Q4413 Variable Rate Vocoder/Echo Canceller Commands* section.

INPUT VOLUME CONTROL

The Input Volume Control function controls the gain of the PCM samples going into the vocoder. The 16-bit value is completely programmable from the processor. The input volume can be varied between 42 dB of gain, 42 dB of attenuation, and muting (i.e. no output). Use caution when applying gain. Large gain increases can cause clipping of the speech samples which may result in a degradation of voice quality when the compressed speech packets are eventually decoded. For more information, refer to the *Input Volume Control Command* in the *Q4413 Variable Rate Vocoder/Echo Canceller Commands* section.

OUTPUT VOLUME CONTROL

The Output Volume Control function controls the gain of the reconstructed speech samples out of the Decoder. The 16-bit value is completely programmable from the processor. The output volume can be varied between 42 dB of gain, 42 dB of attenuation, and muting (i.e. no output). Use caution when applying gain. Large gain increases can cause clipping of the speech samples sent to the codec, resulting in distortion. Some unavoidable quantization noise will be added when gain is applied. For more information, refer to the *Output Volume Control Command* in the *Q4413 Variable Rate Vocoder/Echo Canceller Commands* section.

TONE GENERATOR

The Tone Generator synthesizes single or dual frequency tones at the RXD output of the Q4413. The frequency, volume and duration of the tones are completely programmable. Tone generation overrides the voice output to the PCM interface. However, the Q4413 continues to operate during tone generation. Therefore, received packets must continue to be passed to the Q4413 Decoder to ensure that the speech is reconstructed properly when the tones are discontinued. Standard DTMF signals can be generated using this tone generator. For more information, see *Tone Generation Command* in the *Q4413 Variable Rate Vocoder/Echo Canceller Commands* section.

TONE DETECTOR

The Tone Detector is capable of detecting DTMF and FAX modem tones as PCM samples at the Vocoder Encoder input. It operates after the Echo Canceller to prevent echoed tones from being detected. The Tone Detector can be enabled or disabled using the Configuration command. If tone detection is enabled, the Q4413 will append two tone detection result bytes to the response packet of the TX Frame command. The first byte shows any standard DTMF tones that are present in the current frame. The second byte shows any FAX tones that are present in the current frame. Tone Muting can also be enabled or disabled using the Configuration command. If it is enabled, the Q4413 will mute the PCM samples going into the Vocoder Encoder when a DTMF tone is detected. The samples will be replaced with background noise. If it is disabled, tones will be encoded and passed through the vocoder. FAX tones will always be encoded and passed through the vocoder. For more information, refer to the *Configuration Command* and the *TX Frame Command* in the *Q4413 Variable Rate Vocoder/Echo Canceller Commands* section.

VOX - VOICE ACTIVATED SWITCH

The VOX function is used in real-time, full-duplex applications where hands-free telephone operation is required. In hands-free operation, the microphone is typically near the speaker output, which can result in

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feedback between the speaker output and the microphone. This phenomenon, coupled with the inherent processing delay of the Q4413 Variable Rate Vocoder/Echo Canceller, will result in an echo heard by users at the far end as they speak. ("Far end" refers to the other end of the link; "near end" refers to the end with VOX Mode enabled.) VOX Mode will allow only one side of the full-duplex link to be transmitted when there is voice activity, thus removing the return path for possible echo. VOX Mode operational parameters are completely programmable and are described in the *Operating Modes* section. Also, refer to the *VOX Command* in the *Q4413 Variable Rate Vocoder/Echo Canceller Commands* section.

LOOP BACK

The Loop Back command controls both the Audio and Packet Loop Back functions.

The Audio Loop Back function causes the digitized speech samples provided to the Q4413 PCM input to be looped back to the PCM output without being processed by the Encoder. This is useful for verifying the correct operation of the PCM interface. The output PCM samples will not match the input PCM samples on a bit-by-bit basis due to the DC block implemented by the Q4413. The speech output will still sound identical to the input.

The Packet Loop Back function loops back unchanged Rx packets to the processor as Tx packets. This is useful for verifying the correct operation of the processor interface.

For more information, refer to the *Loop Back Command* in the *Q4413 Variable Rate Vocoder/Echo Canceller Commands* section.

OPERATING MODES

The Q4413 Variable Rate Vocoder/Echo Canceller operates in a variety of modes to provide maximum performance in a wide range of applications. The three main operating modes are Fixed Rate, Variable Rate and Reduced Rate Modes. The two selectable data rates in Fixed Rate Mode are 6200 and 13300 bps. The Variable Rate Mode dynamically adjusts the speech data rate for each frame based on the speech signal energy. Variable Rate Mode varies the data rate between 1000, 6200 and 13300 bps. Reduced Rate Mode analyzes the characteristics of the input speech to determine whether the current frame can be encoded at a reduced rate without affecting voice quality. The average data rate in Reduced Rate Mode is even lower than that of Variable Rate Mode. In addition to these three main operating modes, the Q4413 provides other operating modes to enhance speech compression operation. The Initialize command configures the Q4413 timing, and the Configuration command allows the user to turn on various features within the Q4413. The Average Rate Limit command is used with Variable Rate Mode to limit the maximum average data rate to between 6200 and 13300 bps. The VOX Mode is used for hands-free operation similar to a speaker phone. Sleep Mode saves power when the Q4413 is not in use at a given time. Sample Slipping is a mechanism that adjusts for timing differences between the PCM interface and the transmission channel. The following sections describe these modes.

Q4413 VARIABLE RATE VOCODER/ECHO CANCELLER INITIALIZATION

The Q4413 must be initialized at power-up, after a reset condition, or when new system parameters are required, such as when a new two-way voice connection is made. The initialization process specifies the Tx and Rx timing parameters, starts the 20 ms frame timing, and establishes the background noise estimate for the current environment.

Initialization typically starts after the assertion of the hardware RESET signal. The Configuration command may be issued by the processor 1 ms after the reset is complete to turn on desired modes or features of the Q4413. The Initialize command can then be issued to configure the Tx Offset and Rx Offset timing parameters. Tx Offset and Rx Offset determine the timing relationships between the VRS and the Tx Tick and Rx Tick, respectively. These special timing considerations align the processor timing with the vocoder timing and ensure that the most current frame of data is being processed. The Initialize command also causes the Q4413 to look for the VRS, which starts the

internal frame timing. The External Hardware VRS signal may be asserted any time after the Initialize command has been issued. Alternatively, the Software VRS command may be issued from the processor 250 micro seconds (μs) after the Initialize command has been issued. Once the VRS occurs, the Reinitialize Background Noise Estimate command should be issued to initialize the data rate thresholds. After the initialization process is complete the Q4413 will be ready to perform speech compression via the Tx Frame and Rx Frame commands. The following is a summary of the initialization procedure:

- Reset the Q4413 Variable Rate Vocoder/Echo Canceller (Hardware Reset or Software Reset via the Software Reset command) and wait 1 ms.
- Issue the Configuration command.
- Select Tx Offset and Rx Offset via the Initialize command.
- Issue an External Hardware VRS or the Software VRS command 250 μs after the Initialize command.
- Initialize background noise by issuing the Initialize Background Noise Estimate command.
- Start data transfer using the Tx Frame and Rx Frame commands.

After initialization, the first encoded frame will be a "Blanked" frame (i.e. no valid data will be present). Each frame following the "Blanked" frame will be encoded and decoded based on the parameters defined by the Tx Frame and Rx Frame commands.

SPEECH ENCODING AND DECODING

After the initialization sequence is complete, speech encoding and decoding may begin. PCM data samples at the TXD input are internally grouped together into 20 ms frames (160 PCM samples per 20 ms frame). These frames are encoded into packets and output to the processor every 20 ms via the Tx Frame command. The Decoder path of the Q4413 receives packets of compressed speech data from the processor every 20 ms via the Rx Frame command. Each frame of compressed speech information is decoded and provided to the RXD output as PCM samples.

For the encoding operation, the processor receives an encoded packet of compressed speech data every 20 ms by issuing a Tx Frame command to the Q4413. The Tx Frame command must be issued within a 19 ms window after the Tx Frame Tick. (This is discussed in detail in the *Processor Interface* section.) Each packet of compressed speech data is transferred to the processor in the Tx Frame response packet. Due to double buffering of the packets in the Q4413, the data contained in the Tx Frame response packet corresponds to the speech encoded during the previous 20 ms frame. The Tx Frame response packet contains the data rate for the frame as well as the valid data bits. The Tx Frame command contains the maximum and minimum data rate limits for the next 20 ms frame to be processed. Alternatively, the processor can also provide only data rate parameters for the current frame being processed using the Tx Frame Rate Only command, which is discussed in the *Operational Interfaces* section. Each packet of compressed speech data received by the processor is then formatted for transmission over a digital communications channel or for sending to a storage medium. The processing delay between the arrival of the first PCM sample in a 20 ms frame and the completion of the encoding process for that frame is approximately 47.5 ms.

The decoding process begins when the processor receives a packet of information from the transmission channel or storage medium and constructs an Rx Frame command packet to send to the Q4413. The Rx Frame command provides a frame of compressed speech data from the processor to the Q4413 for decoding. The Rx Frame command is issued every 20 ms within a 19 ms window before the Rx Frame Tick. The Rx Frame command packet contains the data rate for the frame as well as the valid data bits needed to reconstruct the speech signal. The Decoder reconstructs the speech from the received packet and provides the reconstructed PCM speech samples to the RXD output. The processing delay between the arrival of the Rx Frame command packet and transmission of the first PCM sample to the codec is approximately 3 ms.

The Q4413 contains a feature that allows selected data frames to be "Blanked" or "Erased" to reduce the effects of system noise and transmission errors. The

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result of system noise and transmission errors are pops and clicks heard at the Decoder end. The "Blank" feature is used by the Encoder to eliminate the pops and clicks when a known disruption in the system occurs. Such disruptions could include configuration changes or transmission of a frame of control information instead of compressed speech data. The "Blank" indication is provided in the Tx Frame command and sent to the Decoder in an Rx Frame command. The "Erase" feature eliminates the pops and clicks caused by transmission errors over the transmission medium. This feature is used by the processor on the Decoder side when a packet of information is received from the transmission channel with bit errors. One bit error could have a major effect (or minor effect depending on which bits are in error) on the decoded speech quality. Therefore, when a packet is received with errors, it is best to use the "Erase" feature. The "Erase" indication is sent by the processor to the Decoder in the Rx Frame command. Both the "Blank" and "Erase" features command the Decoder to estimate what the reconstructed frame of speech data should be without having actual compressed speech data.

FIXED RATE MODE

In Fixed Rate Mode, the same data rate is used for compressing and decompressing each frame. This is accomplished by setting the maximum and minimum data rate limits in the Tx Frame command to be equal. Valid fixed rates are 6200 and 13300 bps. The Decoder operates the same way as described above in the *Speech Encoding and Decoding* section.

VARIABLE RATE MODE

Variable Rate Mode dynamically varies the data rate of each frame based on the speech signal energy. Variable Rate Mode selects from data rates of 1000, 6200, and 13300 bps.

Variable Rate Mode determines the data rate for each frame based on the energy of the speech. If the signal energy is high, the maximum (or full) rate will be used. If the signal energy is at a medium level, the intermediate (or half) rate will be used. If the signal energy is low, the 1000 bps data rate will be used. (Full Rate is defined as 13300 bps. Half Rate is defined as 6200 bps.)

The Tx Frame command provides the maximum and minimum data rate parameters. The maximum data rate can be set to either Full or Half Rate, and the minimum data rate can be set to either 1000 bps or Half Rate. The Tx Frame response packet contains the data rate that the Encoder selects for each frame and the compressed speech data.

The Q4413 Encoder also contains a unique feature for tracking the background noise level to optimize the voice quality and compression rate when in Variable Rate Mode. The background noise estimate gradually adjusts the adaptive rate thresholds to float above the level of the background noise. A Reinitialize Background Noise Estimate command may be issued at any time to immediately set the compression rate thresholds. The processor typically issues the Reinitialize Background Noise Estimate command when the Q4413 are initialized or at the initial onset of valid PCM data to the Q4413.

The Decoder operates the same way as described in the *Speech Encoding and Decoding* section.

RATE REDUCTION MODE

Rate Reduction Mode lowers the average data rate below that of Variable Rate Mode while maintaining high speech quality. QUALCOMM's rate reduction algorithm, SmartRate™, is the key to this intelligent coding technique. The Rate Reduction command is used to enable this mode.

There are five different rate reduction levels which allow the user to influence the average data rate by controlling the percentage of frames that will be encoded at a reduced rate. Level 0 represents normal variable rate operation in which the rate decision is based solely on input speech signal energy. In levels 1, 2, and 3, a certain percentage of frames which would normally be encoded at Full Rate (13300 bps) are encoded at Half Rate (6200 bps) or Quarter Rate (2700 bps). In level 4, all of the normally Full Rate packets are encoded at Half Rate. This is equivalent to operating the Q4413 in Variable Rate Mode with 6200 bps chosen as the maximum rate. For more

information on the rate reduction levels refer to the *Rate Reduction Command* in the *Q4413 Variable Rate Vocoder/Echo Canceller Commands* section.

The SmartRate rate reduction algorithm is used in levels 1,2, and 3 to decide which frames can be encoded at a reduced rate. SmartRate is the second stage of the PureVoice rate determination algorithm. Refer to Figure 4 for an illustration of the two stages of the PureVoice rate determination algorithm.

The first stage monitors speech signal energy and determines whether a frame contains active speech rather than background noise or pauses. The second stage works to further classify the active speech. SmartRate analyzes various characteristics of the input speech in order to determine whether the speech is voiced or unvoiced, stationary or transitional. Once this classification is made, the algorithm can choose the optimal encoding rate for the current frame.

Voiced speech is the vowel sounds in words, and is characterized by periodic frequency resonations. Unvoiced speech is comprised mainly of consonants and is random in frequency content. The advantage of being able to distinguish between voiced and unvoiced speech is that unvoiced speech can be encoded at a reduced rate without degrading voice quality. Unvoiced speech can represent 30% of active speech, and therefore when it is encoded at Half or Quarter Rate rather than Full Rate the result will be a significant reduction of the average transmission rate of the compressed speech.

Stationary speech is the continuation of a sound which has already begun. Transitional speech is a frame in which the speaker is changing from one distinct sound to another. The ability to properly distinguish stationary from transitional speech is important to the rate reduction algorithm. Transitional speech must be encoded at Full Rate to smoothly represent the change from one sound to another while stationary speech can be encoded at a lower data rate with no perceptible degradation in voice quality.

The rate decision example, also shown in Figure 2, is the first stage of the PureVoice rate determination algorithm. When the Rate Reduction Mode is enabled, the encoding rate is not solely determined by input speech energy. SmartRate calculates various statistics of the input speech to determine the optimal encoding rate for the current frame. In certain cases, the frame can be encoded at a lower data rate without affecting voice quality. Figure 4 illustrates the two stages of the PureVoice rate determination algorithm.

AVERAGE RATE LIMIT

The Average Rate Limit command is used when the desired maximum average encoded data rate must be limited between Half Rate and Full Rate for active speech. Variable Rate Mode must be selected for the Average Rate Limit command to operate properly. This command will force some frames that would normally be encoded at Full Rate to be encoded at Half Rate instead. For example, an Average Rate Limit selection of 7/8 will cause 75% of the Full Rate frames to be encoded at Full Rate and 25% of the Full Rate frames to be encoded at Half Rate. The resulting maximum average is 11638 bps. See Figure 5 for an example.

This feature affects only the Encoder side of the Q4413. The processor handles the compressed data from the Tx Frame and Rx Frame commands exactly as described in the *Speech Encoding and Decoding* section.

Figure 4. Two Stages in the Rate Determination Algorithm

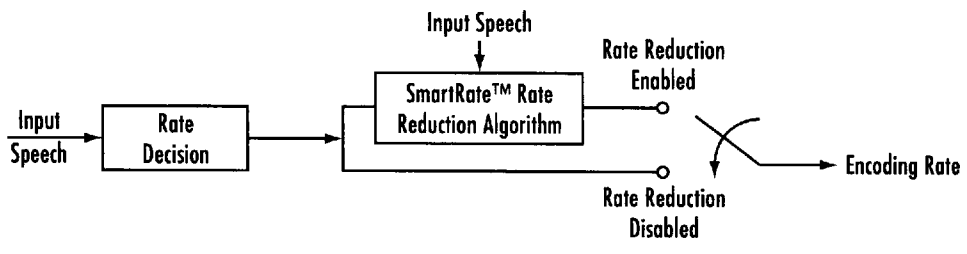

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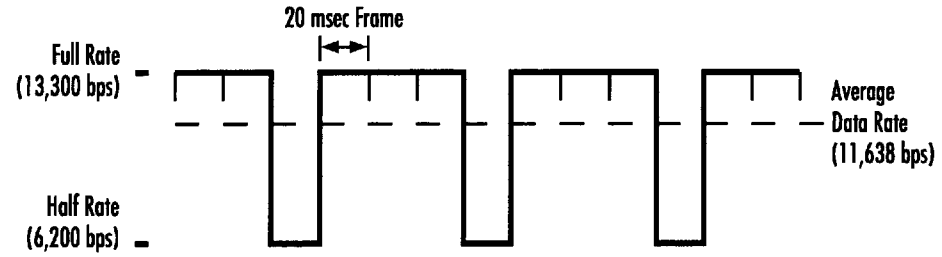
Figure 5. Average Rate Limit Operation During Speech



VOX MODE

VOX Mode is used to eliminate potential echo during hands-free telephone operation (i.e. speakerphone applications). This mode can be used in conjunction with Fixed, Variable, Reduced Rate or Average Rate Limit Modes described above. In VOX Mode, the Q4413 operates in one of three states: Idle, Tx and Rx. The Idle state allows transmission in both directions, whereas the Tx and Rx states allow half-duplex operation only. The VOX Mode will remain in the Idle state until the Decoder signal energy and background noise energy differ by a programmable amount. Once the VOX leaves the Idle state, the active states (Tx or Rx) are entered by comparing the Encoder's signal and background noise energy to the Decoder's signal and background noise energy. The Decoder typically has priority over the Encoder. Therefore, if both users are speaking at the same time, the user at the far end will have priority.

The VOX Mode command enables and establishes the parameters for VOX Mode operation. There are five programmable parameters that enable the processor to tailor the VOX Mode operation to the specific requirements of the system. These parameters include:

- Energy Decay Factor: Selects the sensitivity for the near-end speech input so that it will not be cut off during pauses.
- Background Noise Decay Factor: Selects the rate at which the background noise estimates are allowed to increase.
- Decoder Background Noise Floor: Sets the lower limit of the Decoder background noise threshold. This is required because VOX Mode will not operate efficiently if the background noise is too low.
- Decoder VOX Threshold: Sets the receive signal (from the far end) energy threshold. VOX is not required if the receive energy from the far-end is less than 6 dB above the Decoder's background noise.
- Encoder Weighting Factor: Sets a weighting factor, which scales the Encoder's speech energy before the Encoder/Decoder energy comparison is made to determine which side will have priority.

For more information, refer to the *VOX Command* in the *Q4413 Variable Rate Vocoder/Echo Canceller Commands* section.

SLEEP MODE

The Q4413 Variable Rate Vocoder/Echo Canceller has two different Sleep Modes which conserve power when the device is not in operation. The Q4413 will enter its standard Sleep Mode whenever it is idle (i.e. any encoding or decoding is complete). It will wake up every 125 µs when the PCM sample strobes are active. In this mode, the power dissipation is 36 mW. The Sleep Mode command puts the Q4413 into a deep sleep. All internal clocking is disabled, and the power dissipation is only 0.25 mW. A hardware reset must be issued in order to reinitialize the Q4413 from deep sleep. Also, the initialization sequence must be repeated in order to reconfigure the Q4413 for desired operation.

SAMPLE SLIPPING

Sample Slipping is a mechanism that adjusts the Tx Offset and Rx Offset relative to the VRS without having to reinitialize the Q4413. This mode is available to compensate for differences between the PCM and the transmission channel timing.

Automatic sample slipping can be enabled or disabled within the Configuration command. In order to use automatic sample slipping, the system must produce a hardware or software VRS signal every 20 ms. Automatic sample slipping will not work properly if the VRS is only issued once. When automatic sample slipping is enabled, the Q4413 will count PCM samples. There should be 160 samples between the VRS pulses. If there is a timing mismatch, the Q4413 will repeat or discard samples to correct it.

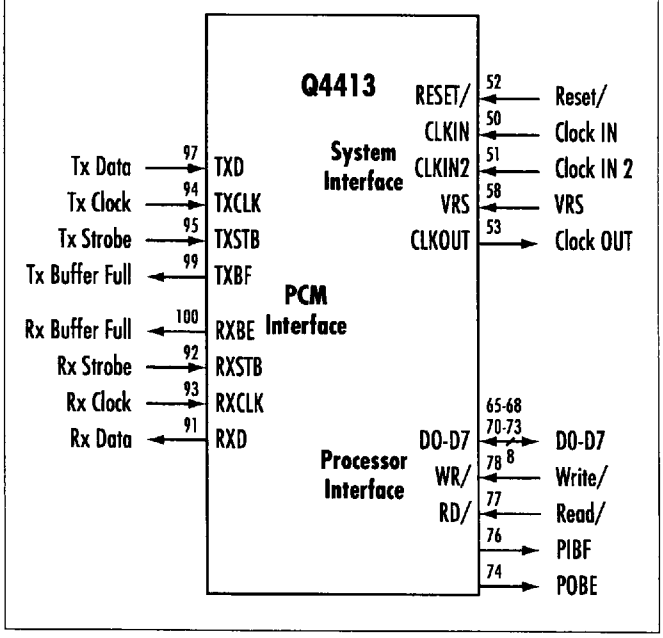
If the user has a way of monitoring the 20 ms timing external to the Q4413, sample slipping can be performed manually by using the Sample Slipping command. There are four different options within the Sample Slipping command. Tx + 1 and Tx -1 adjust the Tx Offset either backward or forward relative to the VRS. When the value of the Tx Offset is increased by one, a sample from the PCM input is deleted, and the internal Q4413 Encoder timing is shifted back one sample. When the value of Tx Offset is decreased by one, a sample from the PCM input is repeated, and the internal Q4413 Encoder timing is shifted forward one sample. Similarly, Rx + 1 and Rx - 1 adjust the Rx Offset either backward or forward by one PCM sample period relative to the VRS. When the value of Rx Offset is increased by one, a PCM output sample is repeated and the internal Q4413 Decoder timing is shifted forward one sample. When the value of Rx Offset is decreased by one, a PCM output sample is deleted, and the internal Q4413 Decoder timing is shifted back one sample.

The timing of the Tx Frame and Rx Frame commands must be adjusted to follow the changes in the Tx and Rx Offsets caused by sample slipping. The window in which the *Tx Frame* and *Rx Frame* commands can occur will move forward or backward in time depending on which sample slipping option was chosen by the user.

OPERATIONAL INTERFACES

The Q4413 Variable Rate Vocoder/Echo Canceller operational interfaces are comprised of the system interface, PCM interface, and processor interface. Figure 6 shows the Q4413's interfaces. The system interface provides connections for the general purpose signals used by the Q4413. The PCM interface provides all connections necessary for interfacing to a standard μ-law, A-law or linear codec. The processor interface provides all connections for interfacing to a standard 8-bit microprocessor data bus. The operation and use of each of these interfaces are discussed in detail below.

Figure 6. Q4413 Variable Rate Vocoder/Echo Canceller Interface



SYSTEM INTERFACE

The system interface contains the RESET/, CLKIN, CLKIN2, VRS, and CLKOUT signals. The following is a description of each of these signals.

RESET/

The RESET/ signal is an active "Low" input that resets the entire Q4413 Variable Rate Vocoder/Echo Canceller. A "High"-to-"Low" transition causes the Q4413 to enter the reset state and remain in this condition until the signal returns "High" again. The RESET/ signal must remain active for at least twelve input clock periods (133 ns). All output signals are tri-stated during reset, and all internal timers and registers are cleared. After the reset condition is removed, the Q4413 will initialize the internal PureVoice algorithm and wait for the Configuration and Initialize commands. There must be at least 1 ms

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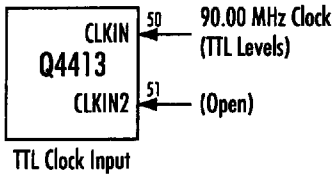
between the end of the reset condition and the beginning of the first command that is sent to the Q4413.

CLKIN AND CLKIN2

The CLKIN and CLKIN2 inputs are used for the external 90 MHz clock. A TTL level clock signal must be connected to CLKIN. CLKIN2 should be left open. Figure 11 shows a typical clock input configuration using a TTL logic level clock input.

Figure 7. Clock Input Configuration



VRS

The VRS is used to set the 20 ms frame timing for the Encoder and Decoder. This signal is used by the Q4413 to synchronize the transmission and reception of coded speech data to and from the processor. The Encoder Frame Timing and Decoder Frame Timing are independent from each other but both are derived from the VRS via the Tx Offset and Rx Offset parameters in the Initialize command. This input can be a single active "High" pulse occurring one time after the Initialize command has been issued or a continuous stream of pulses spaced 20 ms apart. The pulse must be "High" for at least 2 µs, but no more than 250 µs. The VRS signal must be asserted each time that the Q4413 has been reset or has been reconfigured by the Initialize command. The VRS function can also be performed by issuing the Software VRS command after the Initialize command has been issued.

CLKOUT

The CLKOUT signal is a buffered version of the CLKIN signal divided by two (i.e. 45 MHz). This output can be used to clock other devices in the system.

PCM INTERFACE

Figure 6 shows the Q4413 interface to a PCM codec via the serial PCM interface. The input samples from the codec to the PCM interface control the timing of the Q4413. A frame is encoded every 160 PCM input samples or 20 ms. The TXD and RXD signals are the data lines in and out of the Q4413. The TXSTB and RXSTB signals are used to gate the data in and out of the Q4413. The TXCLK and RXCLK signals are used to clock the data in and out of the Q4413. The TXBF and RXBE are optional signals for transferring data to and from the Q4413 without a PCM codec device.

TXD AND RXD

TXD and RXD are the serial data input and serial data output signals. The Q4413 Variable Rate/Echo Canceller sends and receives serial PCM data to and from the PCM codec. Using the Configuration command, the user can configure the Q4413 to accept the PCM data either LSB or MSB first.

TXCLK AND RXCLK

The rising edge of the TXCLK input is used to clock each of the TXD serial data bits from the PCM codec into the Q4413. This clocking operation is enabled by the TXSTB input. Likewise, the rising edge of the RXCLK input is used to clock each of the RXD serial data bits out of the Q4413. This clocking operation is enabled by the RXSTB input. In applications where the input and output timing are synchronous, the TXCLK and RXCLK signals can be connected, and the TXSTB and RXSTB signals can be connected. The frequency of the TXCLK and RXCLK can be from 64 kHz to 16 MHz as long as the 8 kHz sample rate is maintained. For µ-law and A-law codecs, there will be 8 data bits transferred into or out of the codec every 125 µs. For a linear codec, there will be 16 data bits transferred. Figure 8 shows the PCM timing for the case when a µ-law or an A-law codec is used and the MSB first option is chosen in the Configuration command.

TXSTB AND RXSTB

The TXSTB and RXSTB inputs are used to enable the clocking of PCM samples into or out of the Q4413 respectively. These active "Low" inputs must be supplied at an 8 kHz (125 µs) rate. The TXSTB and

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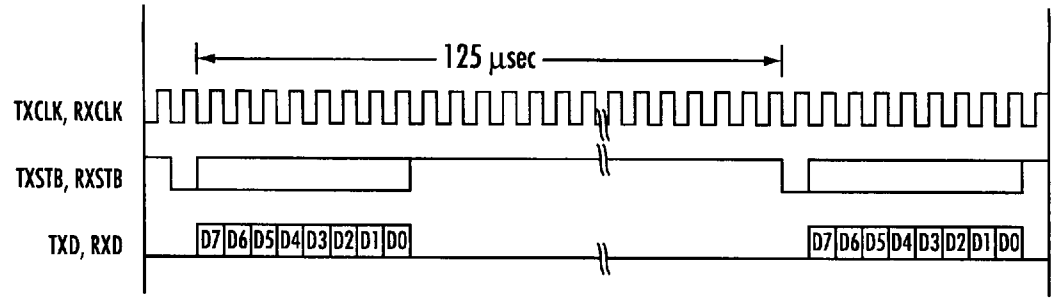
Figure 8. Tx and Rx PCM Timing



RXSTB inputs can pulse "Low" for one bit period or remain "Low" for the entire data transfer. For more information, refer to *PCM Tx Timing* and *PCM Rx Timing* under the *Timing Characteristics* section.

TXBF AND RXBE

The optional TXBF and RXBE output signals are used when transferring PCM data to and from the Q4413 Variable Rate Vocoder/Echo Canceller without a PCM codec. The TXBF output indicates whether or not the Q4413's PCM input buffer is full. Data input to the PCM input buffer when it is full will be lost. The RXBE output indicates whether or not the Q4413's PCM output buffer is empty. There are several applications where these signals can be used. One such application might be in a system where digitized PCM speech samples are stored in memory and a processor is used to transfer the samples to the Q4413's PCM interface. These two handshake signals may be monitored by the processor to speed up the data transfer and minimize external circuitry. The strobes and clocks are still required by the Q4413 for proper data transfer but can be generated by the processor.

PROCESSOR INTERFACE

The Q4413 Variable Rate Vocoder/Echo Canceller communicates with the processor via the 8-bit parallel processor interface shown in Figure 3. All communication to and from the Q4413 must be initiated by the processor, since the Q4413 acts as a slave to the processor. Consequently, the packets sent by the processor to the Q4413 are called command packets. Packets sent by the Q4413 to the processor are called response packets. This section also contains a description of the frame timing, the data transfer between the Q4413 and the processor, the Tx and Rx frame data bit definition, and the read and write protocol.

RD/ AND WR/

The Read and Write inputs are active "Low" signals driven by the processor. When the RD/ signal goes "Low", the Q4413 will place one byte (8 bits) of the response register contents on the processor data bus. The rising edge of the WR/ signal is used to latch data from the processor into the Q4413.

D0 TO D7

The processor data bus is an 8-bit wide parallel bi-directional bus. Command and response information is transferred between the Q4413 and processor using this bus.

FRAME TIMING

Transmission and reception of packets of compressed speech to and from the processor occur independently. The Tx Offset and Rx Offset parameters are used by the Q4413 to configure its internal timing with the timing of the Tx Frame and Rx Frame commands from the processor. Upon reset of the Q4413, the processor provides the Tx Offset and Rx Offset parameters (in units of PCM samples) from the VRS via the Initialize command as shown in Figure 9.

There are typically only two commands transferred between the processor and the Q4413 during each 20 ms frame. Due to double buffering of the Tx and Rx Frame data, the processor may send the Rx Frame data via the Rx Frame command to the Q4413 any time

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Figure 9. Frame Timing and Encoding Delay

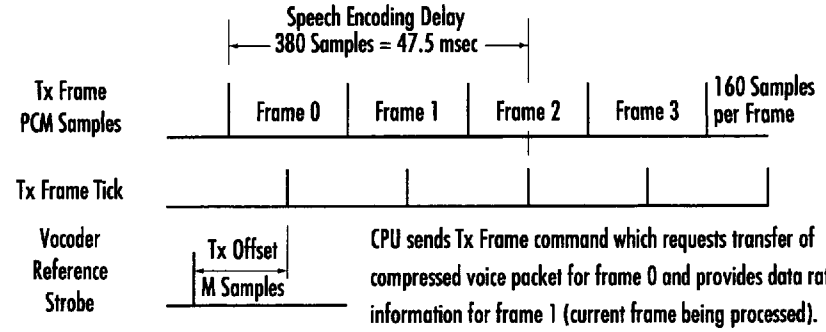
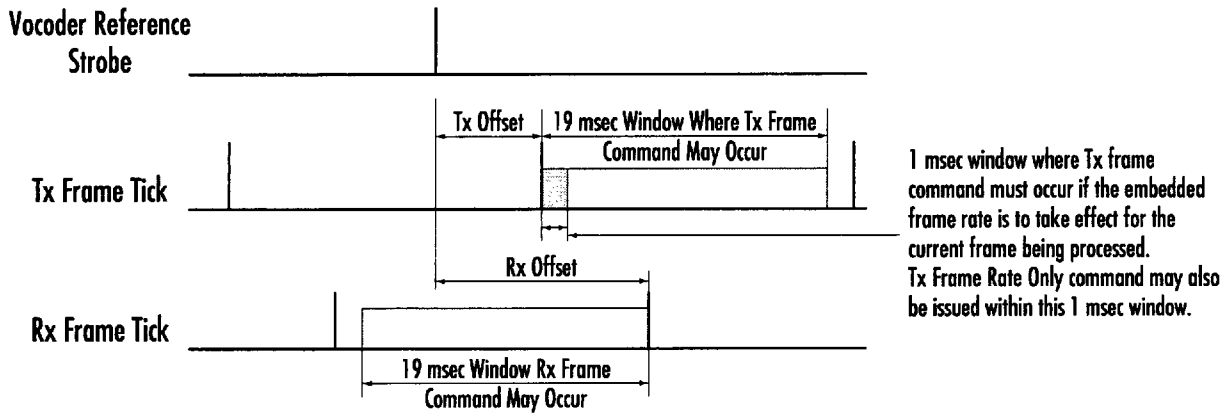


Figure 10. Tx and Rx Frame Timing



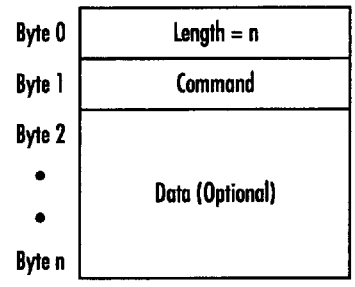
within a 19 ms window before the Rx Frame Tick. Similarly, the processor may obtain Tx Frame data via the Tx Frame command from the Q4413 any time within a 19 ms window after the Tx Frame Tick as shown in Figure 10.

The Tx Frame command also contains the data rate parameters for the next frame. If the data rate must change for the current frame being processed, then the Tx Frame command must be issued within the first 1 ms after the Tx Frame Tick. If the 1 ms window is missed, then the new data rate limits will not take effect until the next frame. If the data rate for the current frame must change and the Tx Frame command cannot be issued within the 1 ms window, then the Tx Frame Rate Only command may be issued. This command is simple to issue within the 1 ms window since data is not transferred and the additional processing during this period is minimal.

Q4413 VARIABLE RATE VOCODER/ECHO CANCELLER AND PROCESSOR DATA TRANSFER

Data transfer between the Q4413 Variable Rate Vocoder/Echo Canceller and the processor is always initiated by sending a command packet from the processor to the Q4413. Some commands will require the processor to read a response packet from the Q4413 after a command packet has been sent. The command packet always consists of a length byte, followed by a command byte and the associated data bytes (if any). Figure 11 shows the format of the command packet.

Figure 11. Command Packet Format



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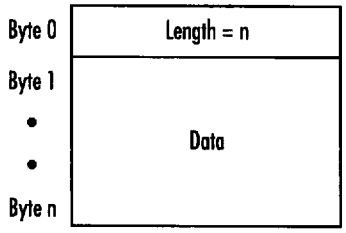
There are only three commands which require a response packet from the Q4413. These are the Tx Frame, Diagnostic Test, and Test Result commands. The response packet contains only the length byte and the data bytes associated with the command that was sent. Figure 12 shows the format of the response packet.

Figure 12. Response Packet Format



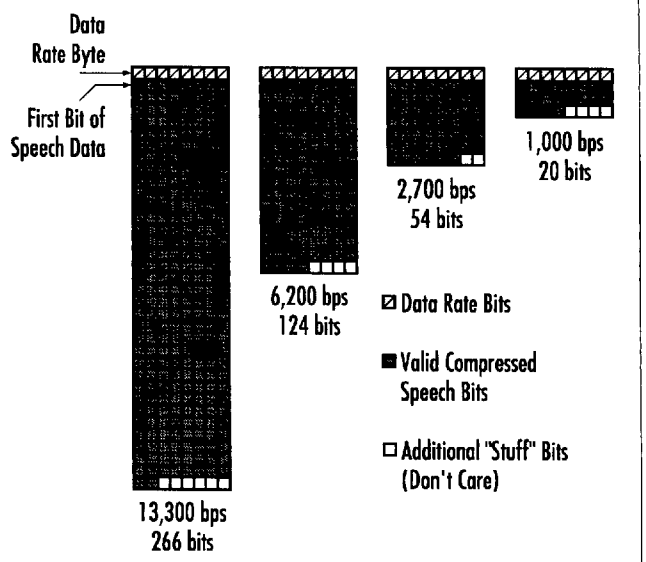
The processor initiates communication by writing the length byte of a command packet to the Q4413. The user must monitor the Parallel Input Buffer Full (PIBF) pin (pin 76) in order to determine when the next data byte of the command packet can be written. PIBF will go "High" sometime after the rising edge of the WR/ input indicating that data has been latched into the parallel input register. After the Q4413 reads the data from this register, PIBF will go "Low" again indicating that the next data byte can be written. The Q4413 needs up to 20 µs to respond to the length byte and get ready to receive the rest of the command packet. After PIBF goes "Low" in response to the length byte, the delay between the rising edge of WR/ and the falling edge of PIBF will be reduced to a maximum of only 0.5 µs.

After the remaining bytes of the command packet have been written, the Q4413 needs up to 10 µs to process this data and compose a response packet if the command requires one. Subsequent data bytes will be available within 0.5 µs of the RD/ input going "Low". The Parallel Output Buffer Empty (POBE) pin (pin 74) will go "High" sometime after the rising edge of the RD/ input indicating that data has been driven onto the microprocessor bus. After the Q4413 writes the next data byte to the parallel output register, POBE will go "Low" again indicating that the next data byte of the response can be read. It is not a requirement to monitor the POBE pin because the user can simply wait 10 µs after the last write cycle, and then start reading the response packet at a rate of 0.5 µs per byte or slower.

TX AND RX FRAME DATA BIT DEFINITION

Packets of compressed speech data are transferred between the processor and Q4413 by the Tx Frame and Rx Frame commands. The number of valid compressed data bits varies based on the data rate. The first byte contains the encoded data rate information. The remaining bytes contain a varying number of valid data bits based on the selected encoded data rate. Figure 13 illustrate the Tx and Rx Frame data bit map that the processor follows to extract useful data for transmitting or storing.

Figure 13. Q4413 Tx and Rx Frame Data Bit Definition

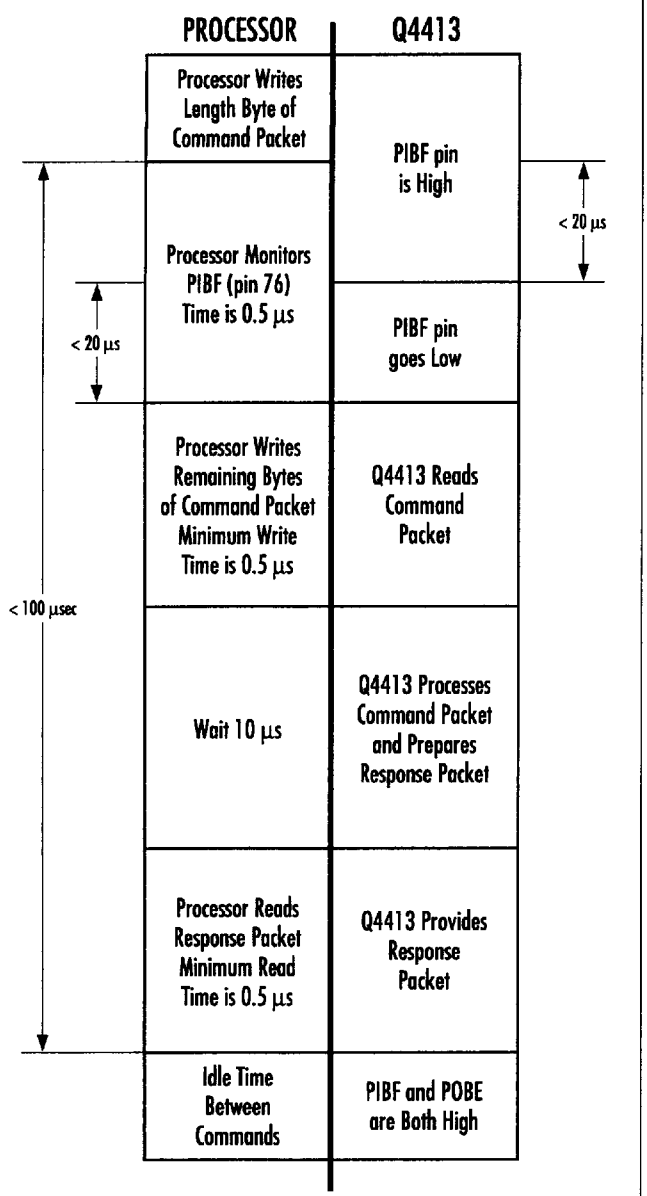


READ AND WRITE PROTOCOL

The data transfer protocol between the Q4413 and the processor is governed by the timing requirements stated in this section. Figure 14 shows a pictorial representation of the Read and Write timing requirements.

After the processor initiates a data transfer by writing the length byte of a command packet to the Q4413, the Q4413 requires up to 20 µs before the PIBF pin goes "Low" indicating that the Q4413 is ready to accept the next data byte from the processor. The time

Figure 14. Packet Transfer Latency



interval between PIBF going "Low" and the execution of a processor write must not exceed 20 µs. Once the PIBF pin goes "Low" the processor may consecutively write the remaining bytes in the command packet with a maximum write rate of up to 0.5 µs per byte. A typical transfer rate is 3.0 µs.

There are different requirements for transferring a response packet from the Q4413 to the processor. After the last data byte of the command packet has been written to the Q4413, the processor must wait 10 µs. This is the maximum time it will take for the Q4413 to be ready with the response packet. The processor may then consecutively read all of the remaining bytes in the response packet with a maximum read rate of 0.5 µs per byte. The entire operation from writing the command packet to reading the response packet (if there is one) MUST NOT exceed 100 µs.

After the initialization sequence is completed, the Tx Frame and Rx Frame commands are used to transfer compressed data packets into and out of the Q4413 for speech encoding and decoding. The write and read timing is illustrated in Figure 15 and Table 1.

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Figure 15. Packet Transfer Timing Diagram

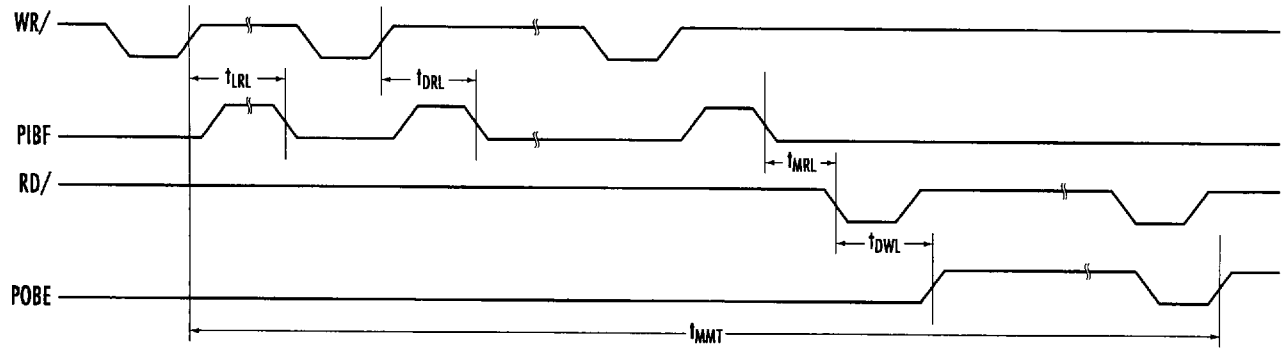

Table 1. Packet Transfer Timing Parameters

PARAMETER	SYMBOL	MIN	MAX	UNITS
Length Byte Response Latency	t_{LRL}	–	20	µs
Data Read Latency	t_{DRL}	–	0.5	µs
Message Response Latency	t_{MRL}	–	15	µs
Data Write Latency	t_{DWL}	–	0.5	µs
Microprocessor Message Transaction Time	t_{MMT}	–	100	µs

Note: The parameters t_{MRL} and t_{DWL} are only relevant to commands which require a response from the vocoder.

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Q4413 VARIABLE RATE VOCODER/ECHO CANCELLER COMMANDS

Control of the Q4413 and data transfer to and from the processor is accomplished with a predefined command set and response set. Table 2 provides a summary list of the Q4413 commands and Table 3 provides a summary of responses from the Q4413. Data items that are required for each command are described within the angle brackets. Tables 4 through 26 describe the individual commands and responses.

Table 2. Q4413 Variable Rate Vocoder/Echo Canceller Commands

Command	# of Data Bytes	Command Name and Data Required
00	0	Software Reset
01	0	Software VRS
02	0	Sleep Mode
0B	1	Loop Back <Type (Audio or Packet)>
0E	1	Diagnostic Test <Type of Test>
0F	0	Test Result
20	1	Configuration <Feature Configuration>
21	2	Initialize <Tx Offset, Rx Offset>
22	1	Tx Frame <Frame Rate for Next Tx Frame>
23	??	Rx Frame <Frame Rate, Frame Data>
24	1	Tx Frame Rate Only <Frame Rate for Next Frame>
25	0	Reinitialize Background Noise Estimate
26	11	Voice Operated Switch <VOX Parameters>
27	2	Output Volume Control <Output Volume Multiplier>
28	8	Tone Generation <Tone Parameters>
29	1	Muting Control <Type (Input or Output)>
2A	1	Sample Slipping <Type>
2B	2	Average Rate Limit <Rate Limit Flag, Rate Limit Factor>
2C	15	Programmable Filter <Type Filter Coefficients>
2F	2	Input Volume Control <Input Volume Multiplier>
30	0	Echo Canceller Reset
32	1	Rate Reduction <Reduced Rate Level>
33	1	Codec Volume Control <3-bit Volume Control>

Table 3. Q4413 Variable Rate Vocoder/Echo Canceller Responses

Command Echo	# of Data Bytes	Response Name and Description
0E	10	Diagnostic Test <Firmware Version #, Time, Date>
0F	1	Test Result <Diagnostic Test Result>
22	??	Tx Frame <Frame Rate, Tx Frame Data, Optional Tone Detection Result>

Note: ?? refers to the variability of a number. The number of data bytes present in the Rx Frame Command and the Tx Frame Response depend on the data rate chosen to encode that specific 20 ms frame. See Figure 13 for the number of data bytes associated with each data rate.

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SOFTWARE RESET COMMAND

Command — 00 (hex)

Function — Commands the Q4413 to perform a software reset.

Number of Data Bytes — Command Packet = 2
No Response Packet

Description

This command can be used in place of a hardware reset. The user must wait 1 ms after issuing this command before issuing the Initialization or Configuration command. Table 4 shows the Software Reset command structure.

Table 4. Software Reset Command Structure

Byte #	Value								Description
0	0	0	0	0	0	0	0	1	1 Byte to Follow (01 Hex)
1	0	0	0	0	0	0	0	0	Software Reset Command

SOFTWARE VRS COMMAND

Command — 01 (hex)

Function — Generates the Vocoder Reference Strobe (VRS) internally.

Number of Data Bytes — Command Packet = 0
No Response Packet

Description

This command may be used instead of the hardware VRS input. It may be issued one time after the Initialize command has been issued to establish the Tx Frame and Rx Frame timing or it can be issued every 20 ms. Table 5 shows the Software VRS command structure.

Table 5. Software VRS Command Structure

Byte #	Value								Description
0	0	0	0	0	0	0	0	1	1 Byte to Follow (01 Hex)
1	0	0	0	0	0	0	0	1	Software VRS Command

SLEEP MODE COMMAND

Command 02 (hex)

Function Commands the Q4413 to enter Sleep Mode.

Number of Data Bytes Command Packet = 0
No Response Packet

Description

This command orders the Q4413 to enter deep Sleep Mode, and then wait for a hardware reset. After the reset occurs, the initialization sequence must be repeated in order to reconfigure the Q4413 for desired operation. Deep Sleep Mode may be entered to conserve power when there is no requirement for speech compression. The power dissipation is only .25 mW in this mode. Table 6 shows the Sleep Mode command structure.

Table 6. Sleep Mode Command Structure

Byte #	Value								Description
0	0	0	0	0	0	0	0	1	1 Byte to Follow (01 Hex)
1	0	0	0	0	0	0	1	0	Sleep Mode Command

LOOP BACK COMMAND

Command 0B (hex)

Function Enables and disables both audio and packet loop back.

Number of Data Bytes Command Packet = 1
No Response Packet

Description

If audio loop back is chosen, the Q4413 will loop back the PCM samples from the Encoder's input to the Decoder's output. If packet loop back is chosen, the Q4413 will loop back the Rx packets as Tx packets to the processor. Table 7 shows the Loop Back command structure.

Table 7. Loop Back Command Structure

Byte #	Value								Description
0	0	0	0	0	0	0	1	0	2 Bytes to Follow (02 Hex)
1	0	0	0	0	1	0	1	1	Loop Back Command
2	0	0	0	0	0	0	R1	R0	R1 = Packet Loop Back R0 = Audio Loop Back (1 = Enable 0 = Disable)

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DIAGNOSTIC TEST COMMAND

Command — 0E (hex)

Function — Performs Q4413 self diagnostics.

Number of Data Bytes — Command Packet = 1
Response Packet = 10

Description

This command performs an ALU Test and a RAM Test on the Q4413. Each test is selectable by setting the associated bit in the data word to a "1" as shown in Tables 8a and 8b.

The response packet from the Q4413 includes the firmware version number and time. (Note: This response does not contain the diagnostic test results. The diagnostic test results will come from the Test Result command.) Tables 8a and 8b show the Diagnostic Test command and response structures.

Table 8a. Diagnostic Test Command Structure

Byte #	Value								Description
0	0	0	0	0	0	0	1	0	2 Bytes to Follow (02 Hex)
1	0	0	0	0	1	1	1	0	Diagnostic Test Command
2	0	0	0	0	0	M1	M2	0	Type of Tests. M1 = ALU, M2 = RAM

Table 8b. Diagnostic Test Response Structure

Byte #	Value								Description
0	0	0	0	0	1	0	1	0	10 Bytes to Follow (0A Hex)
1	X	X	X	X	X	X	X	X	Firmware Version (Major Rev #)
2	X	X	X	X	X	X	X	X	Firmware Version (Minor Rev #)
3 to 5	X	X	X	X	X	X	X	X	Time Minutes After 00:00 Jan. 6, 1980
6	0	0	0	0	0	0	1	0	Device Type (02 = Q4413 Vocoder/ Echo Canceller)
7 to 0A	0	0	0	0	0	0	0	0	Reserved Bytes (All 4 Bytes = 00 Hex)

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TEST RESULT COMMAND

Command — 0F (hex)

Function — Transfers diagnostic test results from the Q4413 to the processor.

Number of Data Bytes — Command Packet = 0
Response Packet = 1

Description

This command sends the diagnostic test result to the processor. The test result byte provided in the response packet contains 2 bits indicating the results of the two tests (RAM, and ALU). Each bit is set to "1" if the test passed and "0" if the test failed. Tables 9a and 9b show the Test Result command and response structures.

Table 9a. Test Result Command Structure

Byte #	Value								Description
0	0	0	0	0	0	0	0	1	1 Byte to Follow (01 Hex)
1	0	0	0	0	1	1	1	1	Test Result Command

Table 9b. Test Result Response Structure

Byte #	Value								Description
0	0	0	0	0	0	0	0	1	1 Byte to Follow (01 Hex)
1	0	0	0	0	0	M1	M2	1	Test Result: M1 = ALU, M2 = RAM, (1 = Passed)

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CONFIGURATION COMMAND

Command — 20 (hex)

Function — This command is issued during the initialization process to configure the Q4413.

Number of Data Bytes — Command = 1
No Response Packet

Description

The Configuration command enables and disables five different features of the Q4413. When tone muting is enabled, DTMF tones are replaced with background noise when detected. FAX tones will never be muted. Disabling the decoder postfilter will improve voice quality when in a tandem vocoding situation (i.e. two separate vocoders are communicating in a full-duplex application). If the tone detector is enabled, the Q4413 appends two tone detection result bytes to the Tx packet. Enabling automatic sample slipping forces the Q4413 to match 160 PCM samples to every 20 ms frame. The Q4413 will count PCM samples between the VRS pulses. If a mismatch occurs, PCM samples will be either discarded or repeated to maintain synchronization. The Configuration command also allows the user to choose the type of codec that will be used (μ-law, A-law or linear), and the bit order of the PCM samples leaving the Q4413. Table 10a shows the Configuration command structure, and Table 10b shows the parameters used in this command. If the Configuration command is not issued, the defaults listed in Table 10b will take effect.

Table 10a. Configuration Command Structure

Byte #	Value								Description
0	0	0	0	0	0	0	1	0	2 Bytes to Follow (02 Hex)
1	0	0	1	0	0	0	0	0	Configuration Command
2	M	P	D	E	S	B	C	C	Configuration Parameters

Table 10b. Configuration Parameters

Parameter	Value	Description	Default
Tone Muting (M)	0	Disable Tone Muting	Disabled
	1	Enable Tone Muting	
Postfilter (P)	0	Disable Postfilter	Enabled
	1	Enable Postfilter	
Tone Detector (D)	0	Disable Tone Detector	Enabled
	1	Enable Tone Detector	
Echo Canceller (E)	0	Disable Echo Canceller	Enabled
	1	Enable Echo Canceller	
Sample Slipping (S)	0	Disable Automatic Sample Slipping	Enabled
	1	Enable Automatic Sample Slipping	
Bit Order (B)	0	LSB First	MSB First
	1	MSB First	
Codec Type (CC)	00	μ-law	μ-law
	01	A-law	
	10	13-bit Linear	

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INITIALIZE COMMAND

Command	21 (hex)
Function	Sets the Tx Offset and Rx Offset and instructs the Q4413 to look for the VRS signal.
Number of Data Bytes	Command Packet = 2 No Response Packet

Description

This command sets the Q4413 Tx Offset and Rx Offset (frame timing). The two data bytes specify the relative timing of the Tx Frame Tick and the Rx Frame Tick to the VRS. This command resets the memory inside the Q4413. Therefore, this command should not be used a second time without ensuring that the Q4413 on the other end (if the application has one) is at the same reset state as well. Table 11a shows the Initialize command structure, and Table 11b shows the Tx/Rx Offset parameters.

Table 11a. Initialize Command Structure

Byte #	Value								Description
0	0	0	0	0	0	0	1	1	3 Bytes to Follow (03 Hex)
1	0	0	1	0	0	0	0	1	Initialize Command
2	X	X	X	X	X	X	X	X	Tx Offset (0 to A0 (160 Samples))
3	X	X	X	X	X	X	X	X	Rx Offset (0 to 0A (160 Samples))

Table 11b. Tx/Rx Offset Parameters

Parameter	Description
Tx Offset	Sets the time from VRS to the Tx Frame Tick. This value represents the number of PCM samples (125 μs per sample) from VRS to the Tx Frame Tick.
Rx Offset	Sets the time from VRS to the Rx Frame Tick. This value represents the number of PCM samples (125 μs per sample) from VRS to the Rx Frame Tick.

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TX FRAME COMMAND

Command	22 (hex)
Function	Transfers one packet of compressed speech data from the Q4413 to the processor.
Number of Data Bytes	Command Packet = 1 Response Packet = ??

Description

This command orders the Q4413 to transfer a packet of compressed speech data to the processor. The response packet from the Q4413 contains the compressed speech data for the current frame, a byte containing the specific data rate for the frame, and the appended data flag with the optional tone detection result. Tables 12a and 12b show the Tx Frame command and response packet structures. Table 12c shows the DTMF tone detection byte, and Table 12d shows the FAX/Data tone detection byte.

The highest and lowest allowable data rates for the next frame to be processed are also embedded in the Tx Frame command. It is with these data rate parameters that the Fixed Rate or Variable Rate Mode is selected. If one of the fixed data rates is desired, the highest data rate and lowest data rate bytes will contain the same selection. (Valid fixed rate selections are 6200 and 13300 bps and "Blanked.") The "Blanked" selection will cause a Tx Frame response packet to be transferred with no valid data. This is typically used when a system control packet must be transmitted over the channel in place of a compressed speech data packet. (Note: The receive side must send the Q4413 a "Blanked" selection, versus an "Erasure", upon receiving a system control update.)

The Variable Rate Mode is enabled by selecting the lowest desired data rate and the highest desired data rate. Valid data rate selections for the lower data rate are 1000 and 6200 bps. Valid data rate selections for the highest data rate are 6200 and 13300 bps.

This command may be issued any time within a 19 ms window after the Tx Frame Tick. The data rates in this command affect the next 20 ms frame. If new data rates need to be applied to the current frame in process, this command must be issued within a 1 ms window after the Tx Frame Tick. This is described in the *Operational Interfaces* section.

Table 12a. Tx Frame Command Structure

Byte #	Value								Description
0	0	0	0	0	0	0	1	0	2 Bytes to Follow (02 Hex)
1	0	0	1	0	0	0	1	0	Tx Frame Command
2	N	N	N	N	M	M	M	M	N = Highest Data Rate, M = Lowest Data Rate

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Table 12b. Tx Frame Response Structure

Byte #	Value								Description
0	X	X	X	X	X	X	X	X	?? Bytes to Follow
1	0	0	0	T	F	F	F	F	T = Tone Detection Flag, F = Data Rate
2 to ??	X	X	X	X	X	X	X	X	X = Tx Frame Data
?? +1	X	X	X	X	X	X	X	X	DTMF Tone Detection Byte
?? +2	X	X	X	X	X	X	X	X	FAX/Data Tone Detection Byte

Note: The tone detection flag will be "0" when tone detection is disabled and no result bytes are appended. It will be "1" when tone detection is enabled and 2 tone detection result bytes are appended.

Data Rate Definition:	Value	Description	Response Data Required
	00 (Hex)	"Blanked"	None
	01 (Hex)	1000 bps	3 Bytes
	02 (Hex)	2700 bps	7 Bytes
	03 (Hex)	6200 bps	16 Bytes
	04 (Hex)	13300 bps	34 Bytes

Packets at 2700 bps are only generated in Rate Reduction Mode.

Note: The 1000 bps, 2700 bps, 6200 bps and 13300 bps packets are 20 bits, 54 bits, 124 bits and 266 bits in length respectively. The remaining bits of the last byte of each packet are padded with zeros.

Table 12c. DTMF Tone Detection Byte

Bit #	Tone Frequency
7	1633 Hz
6	1477 Hz
5	1336 Hz
4	1209 Hz
3	941 Hz
2	852 Hz
1	770 Hz
0	697 Hz

Note: If bit value = "0" tone is not present.
If bit value = "1" tone is present.

Table 12d. FAX/Data Tone Detection Byte

Bit #	Tone Frequency
7:2	Reserved
1	2100 Hz
0	1100 Hz

Note: If bit value = "0" tone is not present.
If bit value = "1" tone is present.

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RX FRAME COMMAND

Command — 23 (hex)

Function — Transfers one packet of compressed speech data from the processor to the Q4413.

Number of Data Bytes — Command Packet = ??
No Response Packet

Description

This command orders the Q4413 to receive a compressed packet of speech data from the processor. The data rate for the packet is also included in this command. An "Erasure" may be used by the processor when transmission errors are detected. The processor must detect that errors are present within a packet and then issue an "Erasure" to mask the error. The Q4413 estimates what the reconstructed speech will be when an "Erasure" or a "Blanked" selection occur. The "Blanked" selection is discussed in the *Tx Frame Command* section. Tables 13 shows the Rx Frame command structure. This command may be issued any time within a 19 ms window before the Rx Frame tick.

Table 13. Rx Frame Command Structure

Byte #	Value								Description
0	X	X	X	X	X	X	X	X	?? Bytes to Follow
1	0	0	1	0	0	0	1	1	Rx Frame Command
2	0	0	0	0	F	F	F	F	F = Data Rate
3 to ??	X	X	X	X	X	X	X	X	X = Rx Frame Data

Data Rate Definition:	Value	Description	Response Data Required
	00 (Hex)	"Blanked"	None
	01 (Hex)	1000 bps	3 Bytes
	02 (Hex)	2700 bps	7 Bytes
	03 (Hex)	6200 bps	16 Bytes
	04 (Hex)	13300 bps	34 Bytes
	0E (Hex)	"Erasure"	None

Packets at 2700 bps are only generated in Rate Reduction Mode.

Note: The 1000 bps, 2700 bps, 6200 bps and 13300 bps packets are 20 bits, 54 bits, 124 bits and 266 bits in length respectively. The remaining bits of the last byte of each packet are padded with zeros.

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TX FRAME RATE ONLY COMMAND

Command	24 (hex)
Function	Uses the specified range of data rates for the current frame being processed.
Number of Data Bytes	Command Packet = 1 No Response Packet

Description

This command changes the data rate parameters of the Encoder without transferring data. This command is used when the data rate for the current frame must change and a Tx Frame command cannot be issued within the required 1 ms window after the Tx Frame Tick. The Tx Frame Rate Only command must be issued within the 1 ms window after the Tx Frame Tick in order for the new data rate ranges to take affect on the current frame. Table 14 shows the Tx Frame Rate Only command structure.

Table 14. Tx Frame Rate Only Command Structure

Byte #	Value								Description
0	0	0	0	0	0	0	1	0	2 Bytes to Follow (02 Hex)
1	0	0	1	0	0	1	0	0	Tx Frame Rate Only Command
2	N	N	N	N	M	M	M	M	N = Highest Data Rate M = Lowest Data Rate

Data Rate Definition:	Value	Description	Response Data Required
	00 (Hex)	"Blanked"	None
	01 (Hex)	1000 bps	3 Bytes
	02 (Hex)	2700 bps	7 Bytes
	03 (Hex)	6200 bps	16 Bytes
	04 (Hex)	13300 bps	34 Bytes

Packets at 2700 bps are only generated in Rate Reduction Mode.

Note: The 1000 bps, 2700 bps, 6200 bps and 13300 bps packets are 20 bits, 54 bits, 124 bits and 266 bits in length respectively. The remaining bits of the last byte of each packet are padded with zeros.

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REINITIALIZE BACKGROUND NOISE ESTIMATE COMMAND

Command — 25 (hex)

Function — Reinitializes the Q4413 background noise estimate.

Number of Data Bytes — Command Packet = 0
No Response Packet

Description

This command reinitializes the background noise estimate to optimize the data rate thresholds in the Encoder when Variable Rate Mode is enabled. This command is typically issued at the onset of valid PCM input data to the Q4413. This feature is described in the *Speech Encoding and Decoding* section. Table 15 shows the Background Noise Estimate command and structure.

Table 15. Reinitialize Background Noise Estimate Command Structure

Byte #	Value								Description
0	0	0	0	0	0	0	0	1	1 Byte to Follow (01 Hex)
1	0	0	1	0	0	1	0	1	Reinitialize Bkgd Noise Est Command

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VOX COMMAND

Command — 26 (hex)

Function — Enables or disables the VOX function.

Number of Data Bytes — Command Packet = 11
No Response Packet

Description

This command enables or disables the VOX function and configures the VOX parameters. The VOX function is enabled when hands-free telephone operation is required. The VOX feature is described in the *Operational Modes* section. Table 16a shows the VOX command structure and Table 16b shows the VOX parameters.

Table 16a. VOX Command Structure

Byte #	Value								Description
0	0	0	0	0	1	1	0	0	12 Bytes to Follow (0C Hex)
1	0	0	1	0	0	1	1	0	VOX Command
2	0	0	0	0	0	0	0	X	X = VOX Enable or Disable 1 = Enable, 0 = Disable
3	X	X	X	X	X	X	X	X	Energy Decay Factor MS Byte
4	X	X	X	X	X	X	X	X	Energy Decay Factor LS Byte
5	X	X	X	X	X	X	X	X	Background Noise Decay Factor MS Byte
6	X	X	X	X	X	X	X	X	Background Noise Decay Factor LS Byte
7	X	X	X	X	X	X	X	X	Decoder Background Noise MS Byte
8	X	X	X	X	X	X	X	X	Decoder Background Noise LS Byte
9	X	X	X	X	X	X	X	X	Decoder VOX Threshold MS Byte
A	X	X	X	X	X	X	X	X	Decoder VOX Threshold LS Byte
B	X	X	X	X	X	X	X	X	Encoder Weighting Factor MS Byte
C	X	X	X	X	X	X	X	X	Encoder Weighting Factor LS byte

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Table 16b. VOX Parameters

Parameter	Description
Enable/Disable	0 = Disable 1 = Enable
Energy Decay Factor <MS Byte, LS Byte>	Reasonable values are between 0.5 and 1.0. Typical value is 0.875. This value must be multiplied by 2^{14} to get the correct parameter for the VOX command. (2^{14} x 0.875 = 14336 => 3800 hex). The Energy Decay factor is used to keep the VOX Mode from disabling the near-end speaker during pauses between words and syllables. This parameter allows the user to select the speech energy decay time.
Background Noise Decay Factor <MS Byte,LS Byte>	Reasonable values are between 1.0 and 1.2. Typical value is 1.01. This value must be multiplied by 2^{14} to get the correct parameter for the VOX command. (2^{14} x 1.01 = 16548 => 40A4 hex). This parameter determines how fast the background noise estimate is allowed to increase.
Decoder Background Noise Floor<MS Byte, LS Byte>	Typical value is 40. This value must be multiplied by 4 to get the correct parameter for the VOX command. (4 x 40 = 160 => 00A0 hex). This parameter limits how low the Decoder background noise is allowed to drop. VOX Mode does not work efficiently if the Decoder background noise goes below a certain level.
Decoder VOX Threshold <MS Byte, LS Byte>	Typical value is 6dB. This value must be multiplied by 2^{8} to get the correct parameter for the VOX command. (2^{8} x 4.0 = 1024 => 0400 hex). If the far-end speaker energy is less than 6 dB above the Decoder's background noise, then there is no need for echo suppression, and the VOX Mode stays in the idle state.
Encoder Weighting Factor <MS Byte, LS Byte>	Typical value is 0. This value must be multiplied by 2^{8} to get the correct parameter for the VOX command. (2^{8} x 0 = 0 => 0000 hex). The Encoder's energy is weighted by this parameter to allow switching to be varied on the relative loudness of the two speakers. For typical conversations, it has been found that good performance is obtained by settling this parameter to zero so that the far-end speaker has complete priority. Settling this parameter to a fractional amount will allow the near-end speaker to interrupt the far-end speaker by speaking loudly. It is not recommended to set this parameter to values above one because parts of speech may be cut out due to noise in the environment.

OUTPUT VOLUME CONTROL COMMAND

Command — 27 (hex)

Function — This command sets the output volume.

Number of Data Bytes — Command Packet = 2
No Response Packet

Description

This command controls the Q4413 output volume. The volume control multiplier is in the linear domain. It consists of a 16-bit word with eight fractional bits (i.e., 0100 represents unity gain; 0200 is two times; and 0080 is ½). Table 17 shows the Output Volume Control command structure.

Table 17. Output Volume Control Command Structure

Byte #	Value								Description
0	0	0	0	0	0	0	1	1	3 Bytes to Follow (03 Hex)
1	0	0	1	0	0	1	1	1	Output Volume Control Command
2	X	X	X	X	X	X	X	X	Output Volume Multiplier MS Byte
3	X	X	X	X	X	X	X	X	Output Volume Multiplier LS Byte

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TONE GENERATION COMMAND

Command — 28 (hex)

Function — This command performs tone generation.

Number of Data Bytes — Command Packet = 8
No Response Packet

Description

This command enables or disables and configures the Tone Generation feature of the Q4413. Single tones or DTMF tones may be generated by providing the frequency, volume, and duration parameters. A single tone is generated when the same value is used for the first tone and the second tone. Do not enter a zero for the value of the second tone. The Q4413 continues operating during tone generation; thus, received packets must continue to be passed to the Q4413 even though tone generation overrides voice output. The Q4413 must receive the Initialize command before tone generation can occur. Sending the Tone Generation command a second time with new frequencies while tones are being generated will cause all parameters to be overwritten and an instantaneous change in output frequency will occur. However, sending the command again with the same frequencies will not cause any change in phase of the output tones. This allows the duration to be extended by sending multiple commands. Table 18a shows the Tone Generation command structure and Table 18b shows the Tone Generation parameters.

Table 18a. Tone Generation Command Structure

Byte #	Value								Description
0	0	0	0	0	1	0	0	1	9 Bytes to Follow (09 Hex)
1	0	0	1	0	1	0	0	0	Tone Generation Command
2	X	X	X	X	X	X	X	X	F1 Tone MS Byte
3	X	X	X	X	X	X	X	X	F1 Tone LS Byte
4	X	X	X	X	X	X	X	X	F2 Tone MS Byte
5	X	X	X	X	X	X	X	X	F2 Tone LS Byte
6	X	X	X	X	X	X	X	X	Volume Tone MS Byte
7	X	X	X	X	X	X	X	X	Volume Tone LS Byte
8	X	X	X	X	X	X	X	X	Duration MS Byte
9	X	X	X	X	X	X	X	X	Duration LS Byte

Table 18b. Tone Generation Parameters

Parameter	Description
First Tone (F1)	<MS Byte, LS Byte> Expressed as 32768 x cos (πF1/4000)
Second Tone (F2)	<MS Byte, LS Byte> Expressed as 32768 x cos (πF2/4000)
Volume	<MS Byte, LS Byte> 7FFF is Full Scale of a μ-law Codec
Duration	<MS Byte, LS Byte> Duration of the tones in 5 ms increments is expressed as a negative number. For example, 20 ms is expressed as FFFC hex.

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MUTING CONTROL COMMAND

Command — 29 (hex)

Function — Enables or disables Input or Output Muting.

Number of Data Bytes — Command Packet = 1
No Response Packet

Description

This command enables or disables the Muting feature of the Q4413. Input Muting causes "comfort noise" Tx packets to be encoded at 1000 bps. Output Muting causes PCM samples to be replaced with "comfort noise" at the estimated background noise level. Output Muting does not affect DTMF output. Table 19 shows the Muting Control command structure.

Table 19. Muting Control Command Structure

Byte #	Value								Description
0	0	0	0	0	0	0	1	1	3 Bytes to Follow (03 Hex)
1	0	0	1	0	1	0	0	1	Muting Control Command
2	0	0	0	0	0	0	R1	R0	R1 = Input Muting R0 = Output Muting (1 = Enabled, 0= Disabled)

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SAMPLE SLIPPING COMMAND

Command	2A (hex)
Function	Directs the Q4413 to perform Sample Slipping on a one time basis.
Number of Data Bytes	Command Packet = 1 No Response Packet

Description

Sample Slipping adjusts the vocoder's frame timing to compensate for differences between the VRS timing and the PCM sample timing. Ideally, 160 PCM samples should occur during each 20 ms frame.

There are four different options within the Sample Slipping command. Tx + 1 and Tx – 1 adjust the Tx Offset either backward or forward relative to the VRS. When the value of the Tx Offset is increased by one, a sample from the PCM input is deleted, and the internal Q4413 Encoder timing is shifted back one sample. When the value of Tx Offset is decreased by one, a sample from the PCM input is repeated, and the internal Q4413 Encoder timing is shifted forward one sample. Similarly, Rx + 1 and Rx – 1 adjust the Rx Offset either backward or forward by one PCM sample period relative to the VRS. When the value of Rx Offset is increased by one, a PCM output sample is repeated and the internal Q4413 Decoder timing is shifted forward one sample. When the value of Rx Offset is decreased by one, a PCM output sample is deleted, and the internal Q4413 Decoder timing is shifted back one sample. Table 20a shows the Sample Slipping command structure, and Table 20b shows the Sample Slipping types.

Table 20a. Sample Slipping Command Structure

Byte #	Value								Description
0	0	0	0	0	0	0	1	0	2 Bytes to Follow (02 Hex)
1	0	0	1	0	1	0	1	0	Sample Slipping Command
2	0	0	0	0	0	0	X	X	Sample Slipping Type (See Table 19b. for value to enter here.)

Table 20b. Sample Slipping Types

Type (hex)	Description
00	Tx + 1 (Throw away an input sample.)
01	Tx - 1 (Repeat an input sample.)
10	Rx +1 (Repeat an output sample.)
11	Rx - 1 (Throw away an output sample.)

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AVERAGE RATE LIMIT COMMAND

Command — 2B (hex)

Function — Limits the average data rate of the Q4413.

Number of Data Bytes — Command Packet = 2
No Response Packet

Description

This command limits the maximum average data rate of the Q4413 Encoder. The Average Rate Limit is selectable between Half and Full Rates (6200 bps and 13300 bps). The Average Rate is programmed by selecting a rate factor value along with Variable Rate Mode. For example, if "S" = 1 and variable rate is selected, the average rate of ¾ is equal to 9975 bps. If "S" = ½ (by setting bit 1 of the Rate Flag to "0" and the Rate Factor to "2"), the maximum Average Rate is ⅔ or 8867 bps. Table 21a shows the Average Rate Limit command structure and Table 21b shows the Average Rate Limit parameters.

Table 21a. Average Rate Limit Command Structure

Byte #	Value								Description
0	0	0	0	0	0	0	1	1	3 Bytes to Follow (03 Hex)
1	0	0	1	0	1	0	1	1	Average Rate Limit Command
2	0	0	0	0	0	0	R1	R0	Rate Limit Flag (See Table 20b.)
3	X	X	X	X	X	X	X	X	Rate Limit Factor (See Table 20b.)

Table 21b. Average Rate Limit Parameters

Parameter	Description
Rate Limit Flag	Bit R0 1 = Enable Average Rate Limit 0 = Disable Average Rate Limit Bit R1 1 = "S" = Rate Limit Factor 0 = "S" = 1/Rate Limit Factor
Rate Limit Factor	An 8-bit Unsigned Integer The maximum average rate of the Q4413 is equal to (2S + 1)/(2(S + 1)).

PROGRAMMABLE FILTER COMMAND

Command — 2C (hex)

Function — This command enables/disables the input or output filters, and loads new filter coefficients for the input and output filters of the Q4413.

Number of Data Bytes — Command Packet = 15
No Response Packet

Description

The PCM samples are optionally filtered by a programmable filter. The 14 data bytes (7 coefficients) are the coefficients for a 14-tap, symmetric (i.e. a0 = a13, a1 = a12, ...), linear phase FIR filter. The filter is disabled by setting coefficient a6 (the last two data bytes) to "0". The coefficients are expressed as: (Value x 16384). The transfer function is:

$$H(z) = \sum_{i=0}^{6} a_i \left[z^{-1} + z^{-(13-i)}\right]$$

This command allows the user to fine tune the frequency response of the Q4413 to achieve the best possible voice quality for a specific application. Table 22 shows the Programmable Filter command structure.

Table 22. Programmable Filter Command Structure

Byte #	Value								Description
0	0	0	0	1	0	0	0	0	16 Bytes to Follow (10 Hex)
1	0	0	1	0	1	1	0	0	Programmable Filter Command
2	0	0	0	0	0	0	0	X	X = Filter Type (0 = Input Filter, 1 = Output Filter)
3 to 10	X	X	X	X	X	X	X	X	Filter Coefficients (Value x 16384)

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INPUT VOLUME CONTROL COMMAND

Command — 2F (hex)

Function — This command sets the input volume.

Number of Data Bytes — Command Packet = 2
No Response Packet

Description

This command changes the PCM sample input gain to the Q4413. The volume control multiplier is in the linear domain. It consists of a 16-bit word with eight fractional bits (i.e. 0100 represents unity gain; 0200 is two times; and 0080 is ½). Table 23 shows the Input Volume Control command structure.

Table 23. Input Volume Control Command Structure

Byte #	Value								Description
0	0	0	0	0	0	0	1	1	3 Bytes to Follow (03 Hex)
1	0	0	1	0	1	1	1	1	Input Volume Control Command
2	X	X	X	X	X	X	X	X	Input Volume Multiplier MS Byte
3	X	X	X	X	X	X	X	X	Input Volume Multiplier LS Byte

ECHO CANCELLER RESET COMMAND

Command — 30 (hex)

Function — Commands the Q4413 to reset and restart the echo canceller.

Number of Data Bytes — Command Packet = 0
No Response Packet

Description

This command resets the Q4413's internal echo canceller. Table 24 shows the Echo Canceller Reset command structure.

Table 24. Echo Canceller Reset Command Structure

Byte #	Value								Description
0	0	0	0	0	0	0	0	1	1 Byte to Follow (01 Hex)
1	0	0	1	1	0	0	0	0	Echo Canceller Reset Command

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RATE REDUCTION COMMAND

Command	32 (hex)
Function	This command puts the Q4413 into Rate Reduction Mode.
Number of Data Bytes	Command = 1 No Response Packet

Description

Rate Reduction Mode lowers the average data rate below that of normal variable rate operation while maintaining high speech quality. The Rate Reduction command enables this mode, and allows the user to select one of the rate reduction levels. There are five different rate reduction levels which influence the average data rate by controlling the percentage of frames that will be encoded at a reduced rate. Table 24b shows the reduced rate levels. Level 0 is equivalent to Normal Variable Rate Mode with 13300 bps chosen as the highest data rate, and 1000 bps chosen as the lowest data rate. In levels 1, 2, and 3, a certain percentage of frames which would normally be encoded at Full Rate (13300 bps) are encoded at Half Rate (6200 bps) or Quarter Rate (2700 bps). In level 4, all of the normally Full Rate packets are encoded at Half Rate. Level 4 is equivalent to operating the Q4413 in Variable Rate Mode with 6200 bps chosen as the maximum rate. Table 25a shows the Rate Reduction command structure, and Table 25b gives the definition of each rate reduction level.

Table 25a. Rate Reduction Command Structure

Byte #	Value								Description
0	0	0	0	0	0	0	1	0	2 Bytes to Follow (02 Hex)
1	0	0	1	1	0	0	1	0	Rate Reduction Command
2	0	0	0	0	0	X	X	X	XXX = Rate Reduction Level

Table 25b. Rate Reduction Levels

Reduced Rate Level	Binary Value (XXX in Byte2)	Percent of Normally Full Rate Packets to be Full Rate	Percent of Normally Full Rate Packets to be ½ Rate	Percent of Normally Full Rate Packets to be ¼ Rate
0	000	100%		
1	001	70%	30%	
2	010	70%		30%
3	011	40%	30%	30%
4	100		100%	

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CODEC VOLUME CONTROL COMMAND

Command — 33 (hex)

Function — This command provides volume control capability to an external linear codec.

Number of Data Bytes — Command = 1
No Response Packet

Description

This command is only valid when the linear codec option has been selected using the Configuration command. The Q4413 has been designed to work with the Texas Instruments TCM320AC3/4X Voice-Band Audio Processors. The TI codecs support a 13-bit linear codec interface and have a 3-bit Volume Control command. The 3 bits of volume control are appended to the LSB of the 13-bit serial output of the Q4413. Table 26 shows the Codec Volume Control command structure.

Table 26. Codec Volume Control Command Structure

Byte #	Value								Description
0	0	0	0	0	0	0	1	0	2 Bytes to Follow (02 Hex)
1	0	0	1	1	0	0	1	1	Codec Volume Control Command
2	0	0	0	0	0	X	X	X	X = Volume Control Bits (000 = Maximum Volume, 111 = Minimum Volume)

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TECHNICAL SPECIFICATIONS

PIN DESCRIPTIONS (PQFP PACKAGE)

Following are the functions and operations of the input and output pins of the Q4413 in the PQFP package. Figure 16 shows the location of the pins; Table 27 describes the function of each pin.

Figure 16. Q4413 Variable RateVocoder/Echo Canceller Pinout

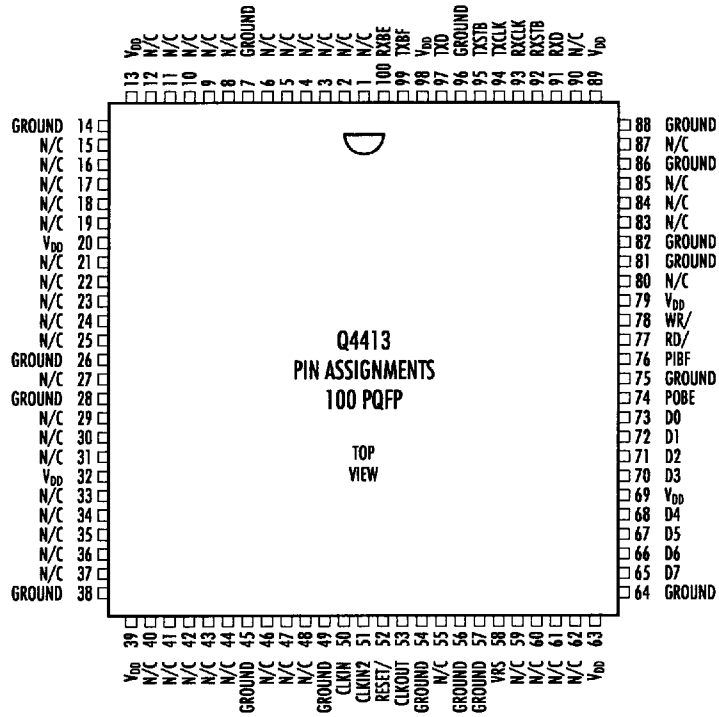

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Table 27. Q4413 Variable Rate Vocoder/Echo Canceller Pin Functions (PQFP Package)

Name	Pins	Type	Function
CLKIN	50	Input	Clock Input for TTL Clock
CLKIN2	51	Input	Leave open for TTL Clock
RESET/	52	Input	Q4413 Reset (Active Low)
CLKOUT	53	Output	Q4413 Clock Output (45 MHz)
VRS	58	Input	Vocoder Reference Strobe
D7 - D0	65, 66, 67, 68, 70, 71, 72, 73	Input/Output	CPU Data Bus Interface. Pin 65 is the MSB.
POBE	74	Output	Parallel Output Buffer Empty
PIBF	76	Output	Parallel Input Buffer Full
RD/	77	Input	Output Data Strobe
WR/	78	Input	Input Data Strobe
RXD	91	Output	PCM Data Output
RXSTB	92	Input	PCM Output Load (8 kHz)
RXCLK	93	Input	PCM Output Clock
TXCLK	94	Input	PCM Input Clock
TXSTB	95	Input	PCM Input Load (8 kHz)
TXD	97	Input	PCM Data Input
TXBF	99	Output	PCM Input Buffer Full
RXBE	100	Output	PCM Output Buffer Empty
VDD	13, 20, 32, 39, 63, 69, 79, 89, 98	Power	+5 Volt Power
VSS	7, 14, 26, 28, 38, 45, 49, 54, 56, 57, 64, 75, 81,82, 86, 88, 96	Ground	Digital Ground
N/C	1-6, 8-12, 15-19, 21-25, 27, 29-31, 33-37, 40-44, 46-48, 55, 59-62, 80, 83-85, 87, 90	Unused	Make no connection to these pins.

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ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Table 28 provides the absolute maximum ratings for the Q4413. Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Table 28. Absolute Maximum Ratings

PARAMETER	SYMBOL	MIN	MAX	UNITS
Storage Temperature	T_S	- 65	+ 150	°C
Operating Temperature	T_A	- 40	+ 85	°C
Junction Temperature	T_J	–	+ 125	°C
Voltage on Any Input Pin	–	- 0.5	+ 5.75	V

DC ELECTRICAL CHARACTERISTICS

Table 29 shows the DC electrical characteristics for the Q4413.

Table 29. DC Electrical Performance Characteristics

PARAMETER	SYMBOL	MIN	MAX	UNITS	NOTES
Supply Voltage	V_{DD}	4.75	5.25	V	–
High-level Input Voltage (Non-clock Inputs)	V_{IH}	$0.7 \times V_{DD}$	–	V	–
Low-level Input Voltage (Non-clock Inputs)	V_{IL}	–	$0.3 \times V_{DD}$	V	–
Clock High-level Input Voltage (TTL Input)	V_{IH}	2.0	–	V	–
Clock Low-level Input Voltage (TTL Input)	V_{IL}	–	0.8	V	–
Input Clock Frequency	C_X	–	90	MHz	–
Input Current	I_{IL}	- 5	–	µA	–
	I_{IH}	–	5	µA	–
High-level Output Voltage	V_{OH}	V_{DD} - 0.7	–	V	I_{OH} = - 2.0 mA
	V_{OH}	V_{DD} - 0.2	–	V	I_{OH} = - 50 µA
Low-level Output Voltage	V_{OL}	–	0.4	V	I_{OL} = 2.0 mA
	V_{OL}	–	0.2	V	I_{OL} = 50 µA
Output Tri-state Current	I_{OZL}	- 10	–	µA	–
	I_{OZH}	–	+10	µA	–
Input Capacitance	C_I	–	10	pF	–
Power Dissipation (Active Mode)	P_D	–	300	mW	V_{DD} = 5.0 V, C_X = 90 MHz
Power Dissipation (Standard Sleep Mode)	P_D	–	36	mW	V_{DD} = 5.0 V, C_X = 90 MHz
Power Dissipation (Deep Sleep Mode)	P_D	–	0.25	mW	V_{DD} = 5.0 V, C_X = 90 MHz

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TIMING CHARACTERISTICS

Figures 17-24 and Tables 30-37 provide the timing specifications for the Q4413. These specifications are valid only for the following conditions:

T_A = – 40 °C to + 85 °C

V_{DD} = 5 V ± 5%, V_{SS} = 0 V

Capacitance Load on Outputs (C_L) = 50 pF

Figure 17. Q4413 Variable Rate Vocoder/Echo Canceller Clock Timing Diagram

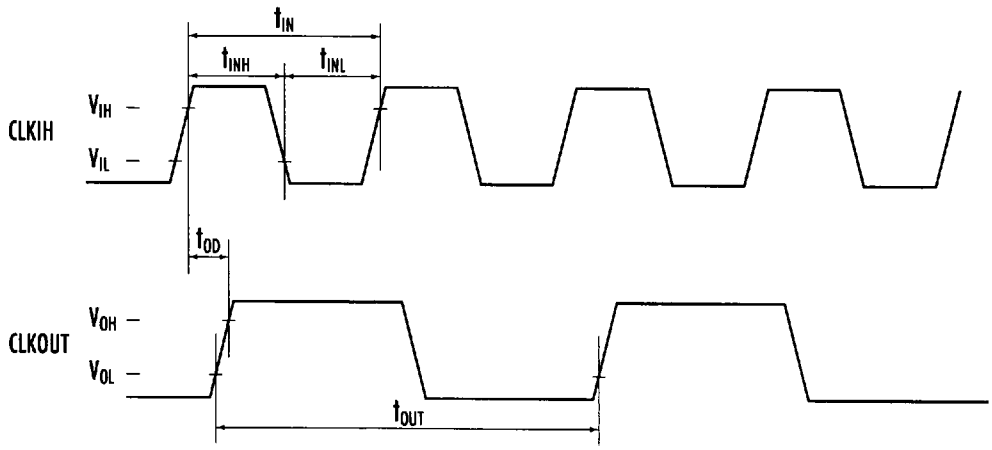

Table 30. Q4413 Variable Rate Vocoder/Echo Canceller Clock Timing Parameters

PARAMETER	SYMBOL	MIN	MAX	UNITS
CLKIN Period (High to High)	t_{IN}	11	–	ns
CLKIN Low Time (Low to High)	t_{INL}	4	–	ns
CLKIN High Time (High to Low)	t_{INH}	4	–	ns
CLKOUT Delay (High to High)	t_{OD}	–	12	ns
CLKOUT Period (Low to Low)	t_{OUT}	2T*	–	ns

*T = t_{IN}

Figure 18. Reset Timing Diagram

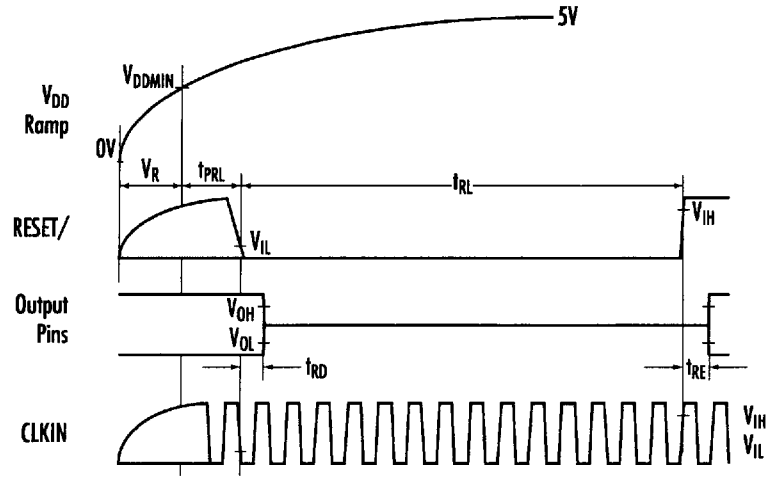

Table 31. Reset Timing Parameters

PARAMETER	SYMBOL	MIN	MAX	UNITS
Power On to RESET Low	t_{PRL}	20	–	ms
Reset Pulse (Low to High)	t_{RL}	12T*	–	ns
V_{DD} Ramp	V_R	–	10	ms
RESET Disable Time (Low to Tri-state)	t_{RD}	–	100	ns
RESET Enable Time (High to Valid)	t_{RE}	–	100	ns

*T = t_{IN}

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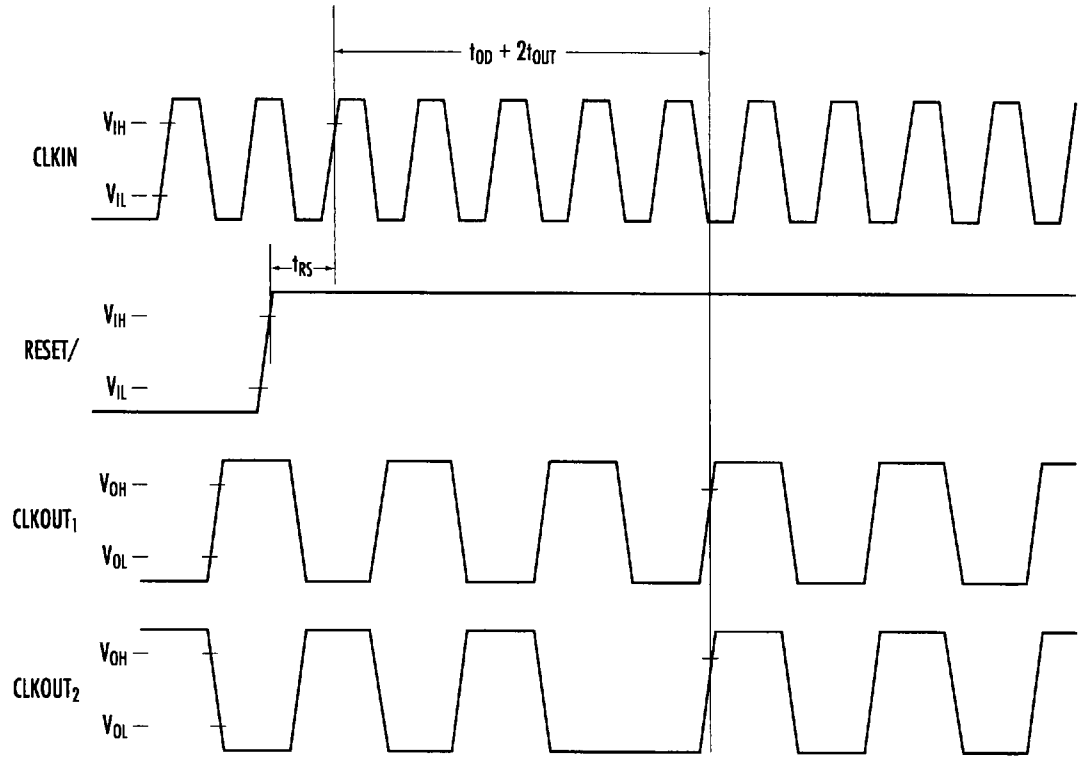
Figure 19. Reset Synchronization Timing Diagram



Note: CLKOUT$_1$ and CLKOUT$_2$ are two possible CLKOUT states before RESET/. CLKOUT is free-running.

Table 32. Reset Synchronization Timing Parameters

PARAMETER	SYMBOL	MIN	MAX	UNITS
Reset Setup (High to High)	t_{RS}	2	T/2 -5*	ns

*T = t_{IN}

Figure 20. Vocoder Reference Strobe Timing Diagram

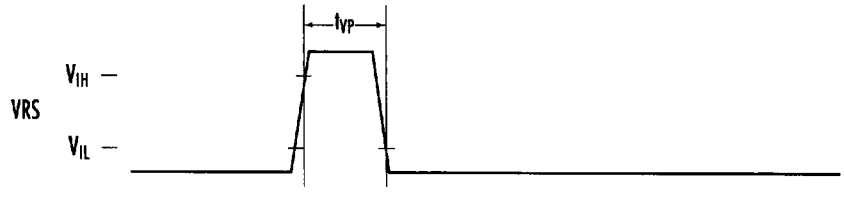


Table 33. Vocoder Reference Strobe Timing Parameters

PARAMETER	SYMBOL	MIN	MAX	UNITS
Pulse Period (Low to High)	t_{VP}	2T*	–	ns

*T = t_{IN}

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Figure 21. Write Timing Diagram

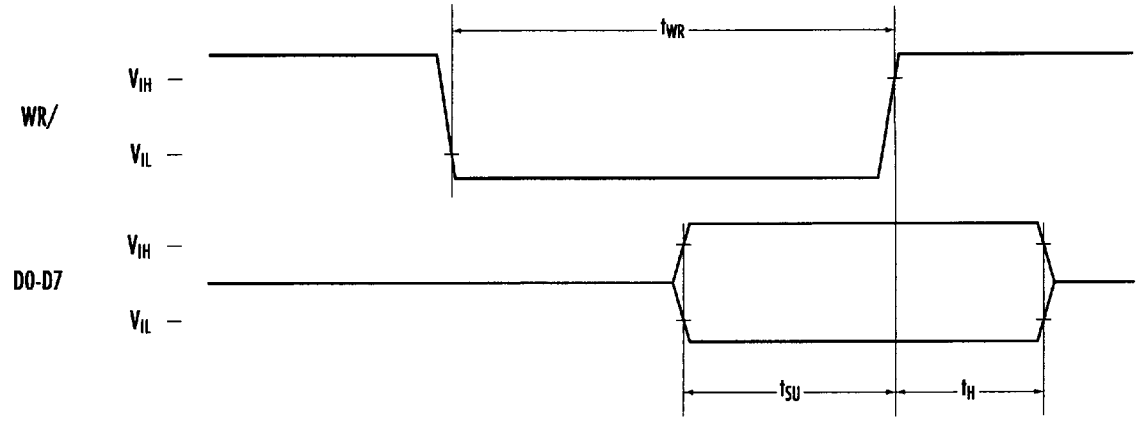

Table 34. Write Timing Parameters

PARAMETER	SYMBOL	MIN	MAX	UNITS
WR/ Pulse Width (Low to High)	t_{WR}	T*	–	ns
D0-D7 Setup Time (Valid to High)	t_{SU}	8	–	ns
D0-D7 Hold Time (High to Valid)	t_H	0	–	ns

*T = t_{IN}

Figure 22. Read Timing Diagram

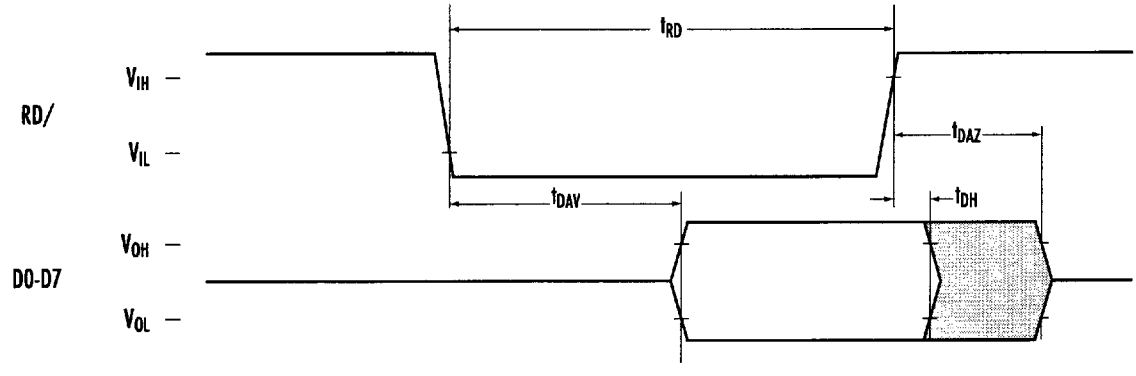

Table 35. Read Timing Parameters

PARAMETER	SYMBOL	MIN	MAX	UNITS
RD/ Pulse Width (Low to High)	t_{RD}	T*	–	ns
RD/ Low to D0 to D7 Valid	t_{DAV}	–	28	ns
RD/ High to D0 to D7 Tri-state	t_{DAZ}	–	20	ns
Data Hold After RD/ Rising	t_{DH}	6	–	ns

*T = t_{IN}

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Figure 23. PCM Tx Timing Diagram

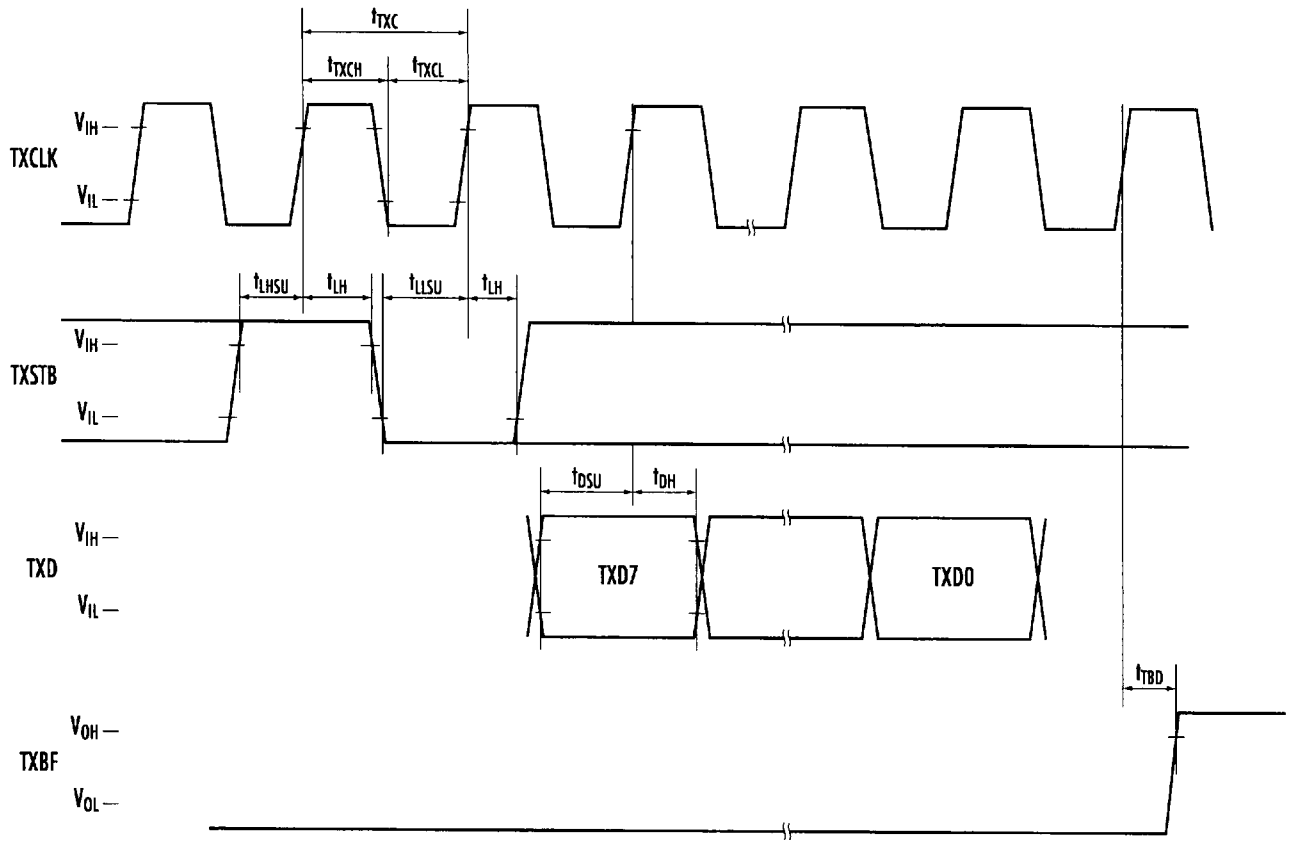

Table 36. PCM Tx Timing Parameters

PARAMETER	SYMBOL	MIN	MAX	UNITS
TXCLK Period (High to High)	t_{TXC}	40	–	ns
TXCLK Low Time (Low to High)	t_{TXCL}	18	–	ns
TXCLK High Time (High to Low)	t_{TXCH}	18	–	ns
TXSTB High Setup (High to High)	t_{LHSU}	8	–	ns
TXSTB Low Setup (Low to High)	t_{LLSU}	8	–	ns
TXSTB Hold (High to Invalid)	t_{LH}	0	–	ns
TXD Setup (Valid to High)	t_{DSU}	7	–	ns
TXD Hold (High to Invalid)	t_{DH}	0	–	ns
TXBF Delay (High to Invalid)	t_{TBD}	–	35	ns

Note: Linear codecs will have 16 Tx data bits instead of 8. The timing parameters will remain the same.

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Figure 24. PCM Rx Timing Diagram

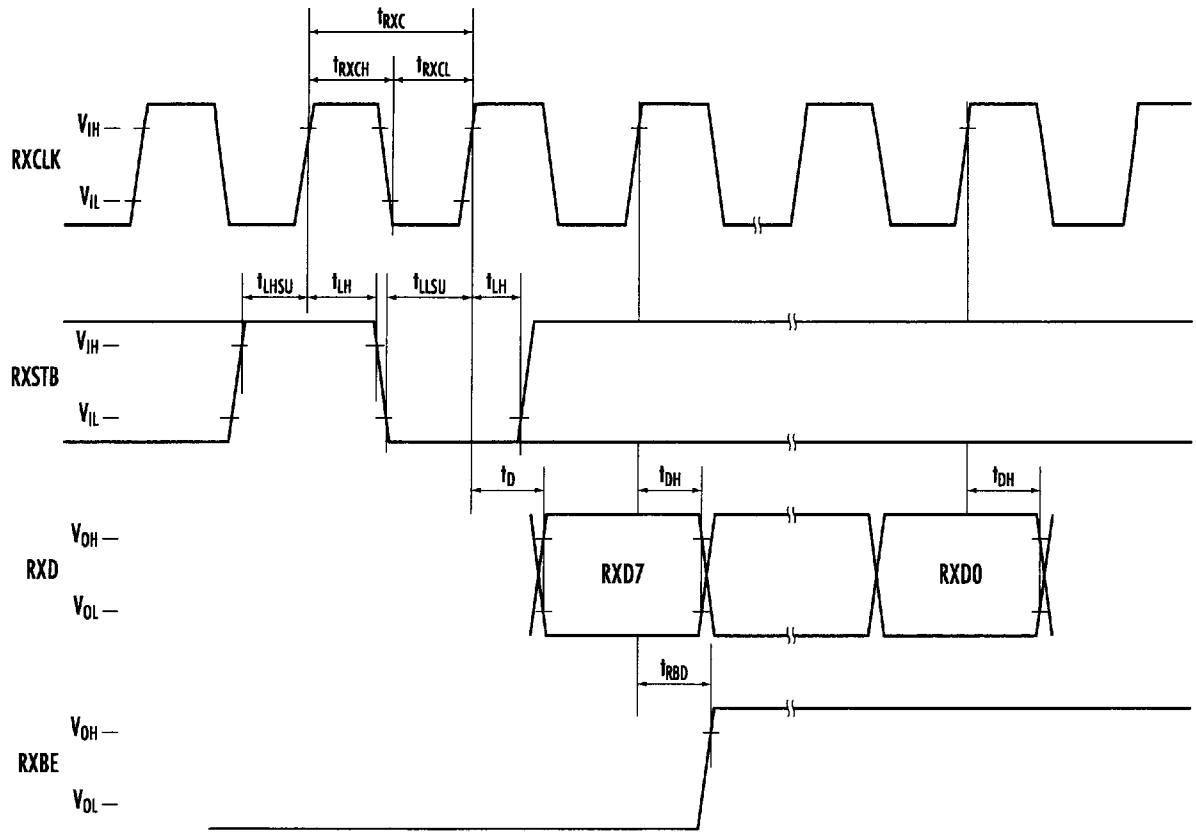

Table 37. PCM Rx Timing Parameters

PARAMETER	SYMBOL	MIN	MAX	UNITS
RXCLK Period (High to High)	t_{RXC}	40	–	ns
RXCLK Low Time (Low to High)	t_{RXCL}	18	–	ns
RXCLK High Time (High to Low)	t_{RXCH}	18	–	ns
RXSTB High Setup (High to High)	t_{LHSU}	8	–	ns
RXSTB Low Setup (Low to High)	t_{LLSU}	8	–	ns
RXSTB Hold (High to Invalid)	t_{LH}	0	–	ns
RXD Delay (High to Valid)	t_D	–	35	ns
RXD Hold (High to Invalid)	t_{DH}	5	–	ns
RXBE Delay (High to High)	t_{RBD}	–	35	ns

Note: Linear codecs will have 16 Rx data bits instead of 8. The timing parameters will remain the same.

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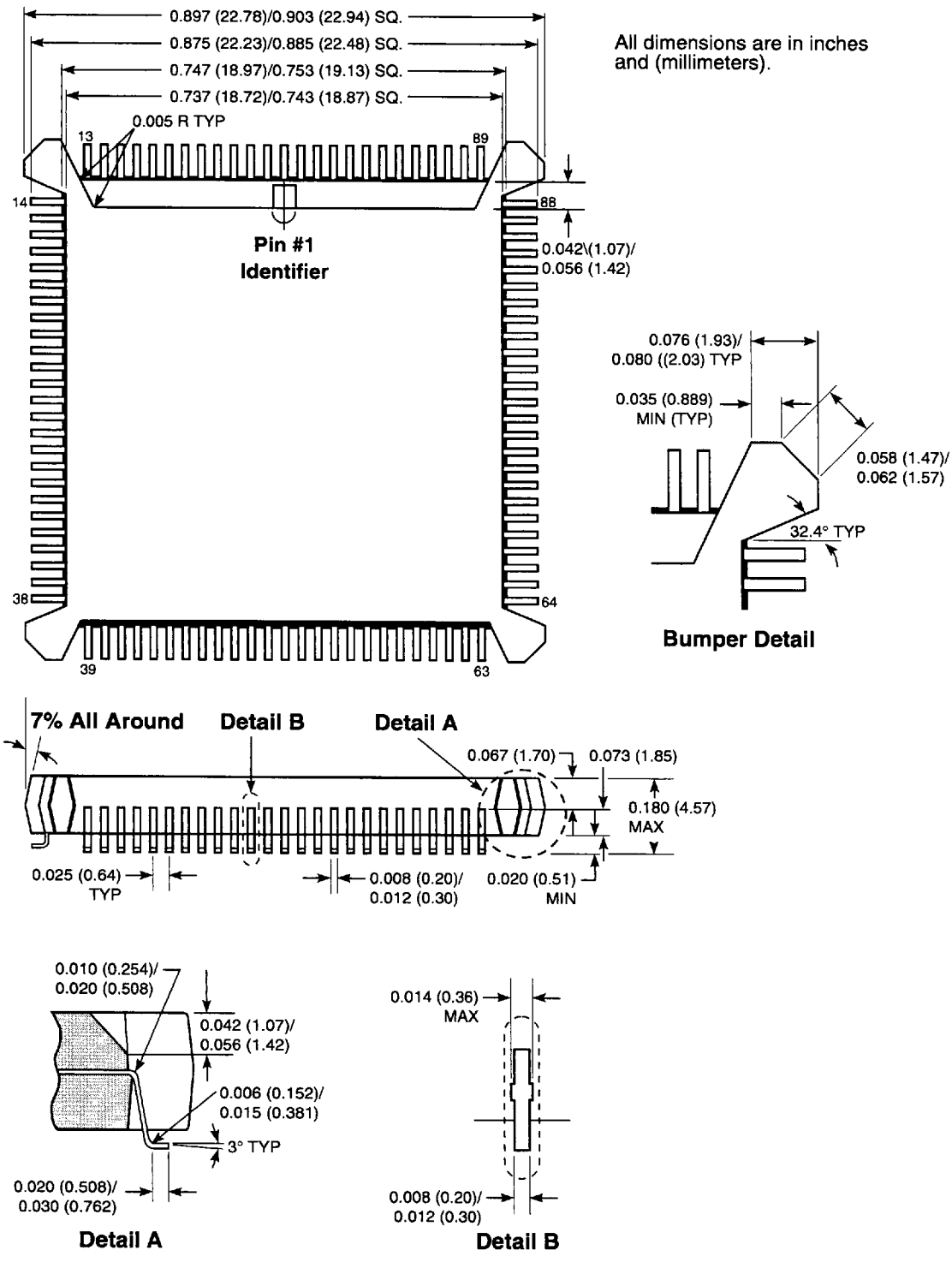
Q4413 VARIABLE RATE VOCODER/ECHO CANCELLER PACKAGING

The Q4413 is packaged in a 100-pin plastic quad flat pack (PQFP). Figure 29 shows the package outline and dimensions. A recommended socket for the PQFP package is: 3M P/N 2-0100-07243-000-018-007.

Figure 25. Q4413 Variable Rate Vocoder/Echo Canceller 100-pin PQFP Packaging



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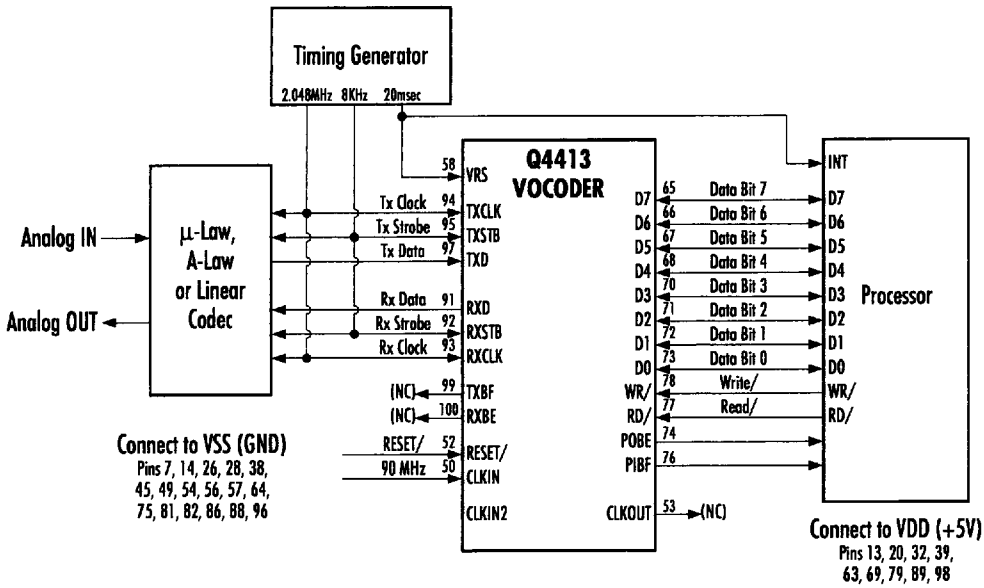
APPLICATIONS INFORMATION

Figure 26 illustrates how the Q4413 Vocoder can be used in a voice compression system.

Figure 26. Typical Q4413 Variable Rate Vocoder/Echo Canceller Configuration Example



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