Comparison of TI Voice-Band CODECs for Telephony Applications

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ABSTRACT

This application report describes the different types of voice-band CODECs for telephony applications such as client modem analog interface circuits, central office line card CODEC/filter combos, and voice-band audio processors. A summary of the characteristics of each is included. This report focuses on the recommended client modem analog interface circuits (AICs) fabricated by Texas Instruments and their specific features and applications. It also compares the features and uses of voice-band audio processors with analog interface circuits.

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1 Introduction

This application report summarizes the voice-band CODECs available from TI™ for use in telephony applications. The types of voice-band CODECs include:

- Analog interface circuits (AICs), also called client modem CODECs
- Voice-band audio processors (VBAP™)
- Central office CODECs, also called PCM CODEC/filter combos, or line card CODECs

Table 1 lists the features of the various types of voice-band CODECs:

Table 1. Types of Voice-Band CODECs With Features

VOICE-BAND CODECs			
	ANALOG INTERFACE CIRCUIT (AIC)	**VOICE-BAND AUDIO PROCESSOR (VBAP)**	**PCM CODEC/FILTER COMBO**
Primary market	Modems	Battery operated or hand held equipment	Central office line card, wired telephony
Distinguishing features	Highly programmable, high performance	Microphone interface, low power consumption	CODEC with an integrated voice-band filter (CCITT/Bellcore compliant)
Power dissipation	<120 mW per channel (typ)	40 mW (typ, at 5 V) 20 mW (typ, at 3.3 V) operating	<90 mW (typ), operating
Power supply requirements	Single rail	Single rail	Dual-rail power supplies usually required (±5 V)

2 Voice-Band CODECs

Voice-band CODECs can be found in either central office (CO) applications, client modem applications, or in personal communications systems, as described above. TI manufactures products for each of these applications. See Figure 1 for the possible locations of each type of CODEC .

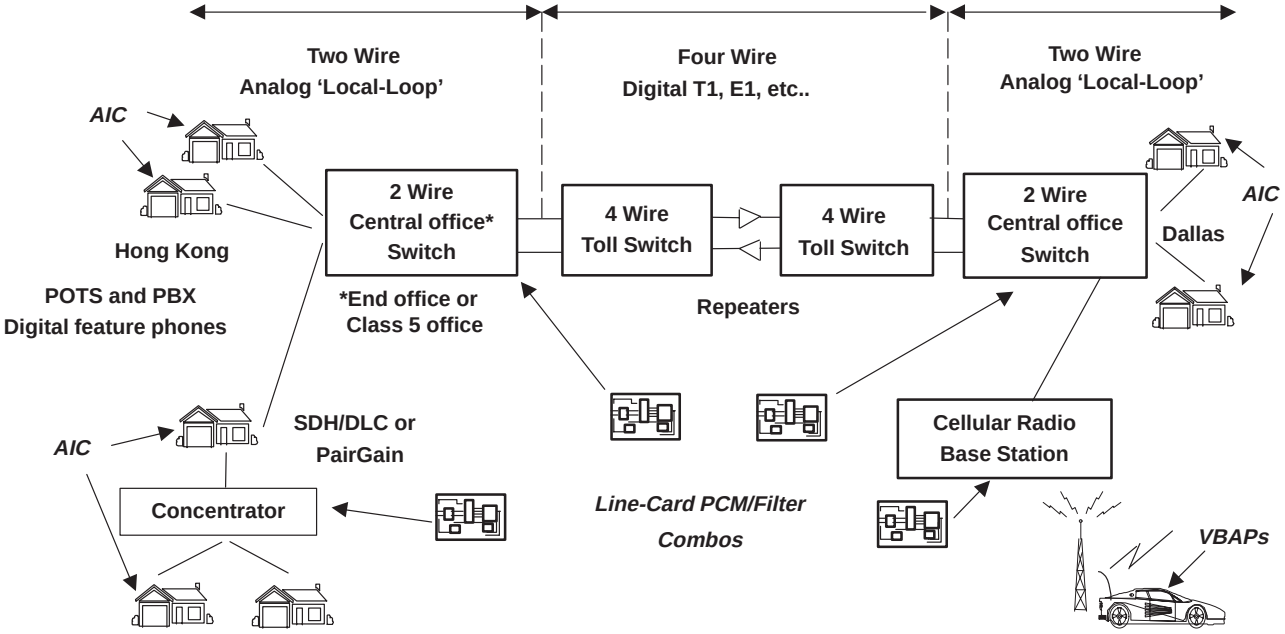

Figure 1. Voice-Band CODEC Applications

2.1 Client Modem CODECs (AICs)

Client modem CODECs, also called analog interface circuits or AICs, are a complete data acquisition system on a chip. The term *analog interface circuit* or AIC is used by Texas Instruments to describe the circuitry used to interface analog signals to a digital processor. AICs contain:

- Signal conditioning and filtering on both the analog input and output
- An A/D converter
- Digital processing interface to transmit or receive the digital data to/from an external host processor
- D/A converter

In addition, AICs can contain any of the following:

- Hybrid amplifiers (600-Ω drivers)
- Speaker drivers
- Programmable gain amplifiers
- Microphone bias circuitry

- Audio mixing capabilities
- Voice and data channels
- Flash write enable circuitry for writing flash memory devices
- Power monitoring and power-on reset circuitry
- Analog and/or digital loopback circuitry
- Master/slave circuitry

Figure 2 shows a block diagram and external interfaces of an AIC with many features, the TLC320AD535. This AIC has data and voice channel CODECs, speaker drivers, microphone bias circuitry, hybrid amplifiers, and flash memory write enable circuitry. In addition, each channel can be independently powered down.

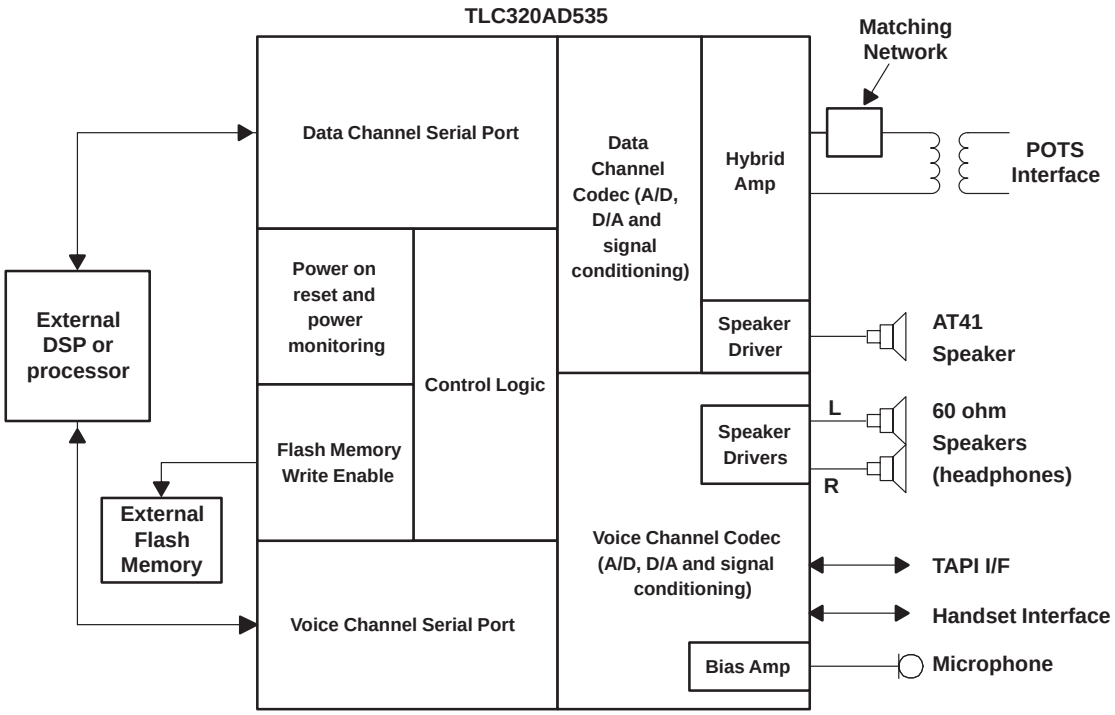

Figure 2. TLC320AD535 Block Diagram

2.1.1 Programmable Features of AICs

AICs have a small register set that is used to program the desired configuration of the device. The AIC's configuration is programmed via the same serial port which transmits and receives the digitized data to/from the interconnected processor. The types of features that may be controlled via programming include:

- Generating a software reset
- Enabling/disabling power down mode
- Enabling/disabling digital and/or analog loopback

- Selecting the input to the monitor amplifier
- Selecting the gain for the monitor amplifier, analog input, analog output, speaker driver
- Selecting the normal or auxiliary analog input to the A/D converter
- Enabling/disabling phone mode
- Selecting the number of slave devices available
- Enabling/disabling the external sample clock
- Selecting the sample frequency
- Enabling/disabling the delayed frame sync for slave devices and its characteristics

2.1.2 Features of the Recommended TI AICs

Table 2 lists the recommended client modem AIC's manufactured by TI, along with their features. Please note that older AICs are still available, but the devices recommended below have more features and better cost for the performance.

Table 2. AIC Features for Client Modem Applications (Recommended Devices)

RECOMMENDED TI AICs: FEATURES					
FEATURE	**TLC320AD535**	**TLC320AD545**	**TLV320AD543**	**TLC320AD56**	**TLC320AD50 TLC320AD52**
Number of channels	2, one voice and one data	1	1	1	1
Programmable gain amplifiers	Yes, both channels	Yes	Yes	No	Yes
Microphone bias	Yes	No	No	No	No
Number of speaker drivers	3	1	1	No	No
Types of speaker drivers	8 Ω AT41, Two 60 Ω drivers for headphones	8 Ω AT41	8 Ω AT41	No	No
Master/slave functionality	No	No	No	No	3 slaves (AD50) 1 slave (AD52)
600 Ω driver	Yes	Yes	Yes	No	Yes
Flash write enable circuit	Yes	Yes	Yes	No	No
Analog and digital loopback capability	Yes	Yes	Yes	Digital only	Yes
H/W and S/W power-down modes	S/W only	S/W only	S/W only	Yes	Yes

All of the recommended TI AICs contain sigma-delta technology converters. The sigma-delta converters have higher dynamic range and excellent signal to noise characteristics as compared to traditional converters. This is due to oversampling and the noise shaping characteristics of the modulator. Sigma-delta converters are useful for high-resolution conversion of low-frequency signals, along with low-distortion conversion of signals in the audio frequency range.

2.1.3 Technical Specs of the Recommended TI AICs

Table 3 lists the technical specifications of the recommended AICs. Note the high resolution and excellent signal-to-noise specifications.

Table 3. AIC Technical Specifications (Recommended Devices)

RECOMMENDED TI (AICS): SPECS					
TECHNICAL SPECIFICATIONS	**TLC320AD535**	**TLC320AD545**	**TLV320AD543**	**TLC320AD56**	**TLC320AD50 TLC320AD52**
Power supply requirements	5 V or 3.3 V (±10%) or both	5 V or 3.3 V (±10%) or both	3 V (±10%)	5 V (±5%) or 5 V analog and 3 V (±10%) digital	5 V (10%, –5%) or 5 V analog and 3 V (±10%) digital
Sample frequency (max)	11.025 kHz	11.025 kHz	11.025 kHz	22.05 kHz	22.05 kHz
Resolution (bits)	16	16	16	16	16
Bandwidth	4.96	4.96	4.96	8.82	9.92
Power Dissipation (typ, mW)	240	120	90	100	120
DAC SNR† (dB, typ), VI=0dB	76	77	77	85	89
DAC THD+N† (dB, typ)	74 V_I = –3 dB	78 V_I = –3 dB	78 V_I = –3 dB	84 V_I = 0 dB	79 V_I = 3 dB
ADC SNR† (dB, typ) VI=–1 dB	80	81	78	86	89
ADC THD+N† (dB, typ), VI=–3 dB	77	76	76	78	82
Dynamic range (dB, typ)	80	80	79	85	88
Converter technology	Sigma delta	Sigma delta	Sigma delta	Sigma delta	Sigma delta

† The test condition is a 1020-Hz input signal with an 8-kHz conversion rate.

2.1.4 Recommended TI AIC and Modem Algorithms

The AIC is a client-side device specifically targeted for modem applications. Table 4 lists the various modem algorithms along with the suggested TI AIC. Note that the combination of AIC performance, DSP algorithm robustness, and operational *line* conditions is what make a modem design successful. All of these should be considered when choosing the AIC.

The item of interest when evaluating an AIC with a modem algorithm is the signal-to-noise ratio (SNR) specification of the AIC.

Table 4. Modem Algorithm and Recommended AIC

MODEM ALGORITHM	RECOMMENDED AIC (Client Modem CODEC)	SAMPLE RATES (k Samples/Sec)	TYPICAL SNR REQUIREMENTS
V.90	TLC320AD535, TLC320AD545, TLC320AD50, TLC320AD52	9.6	>80 dB
V.34	TLC320AD535, TLC320AD545, TLV320AD543, TLC320AD56, TLC320AD52, TLC320AD50	8.4, 11.2, 12.8	>70 dB
V.32bis	TLC320AC01†, TLC320AC02†	7.2, 9.6	>55 dB
V.22bis	TLC320AC01†, TLC320AC02†	8, 9.6	>35 dB

† The TLC320AC01 and AC02 are older devices.

2.1.5 Applications for AICs

The AIC can be used in a variety of applications (besides modems) such as:

- Teller machines

- Security systems
- Gaming
- Point-of-sale terminals
- Metering
- Feature phones, TV phones, voice over IP applications

2.2 Central Office CODECs (PCM CODEC/Filter Combos)

In central office applications, the voice-band CODEC is found on a line card. Every subscriber telephone line has an associated line card at the central office or concentrator.

The central office CODECs are referred to as *combos* or *line-card CODECs*. They combine a pulse-coded modulation (PCM) CODEC with a voice-band filter, and they provide all the functions necessary to interface a 2-wire analog telephone circuit with a time-division multiplexed (TDM) system.

The CODEC compands (compresses/expands) the digitized data using one of two types of logarithmic functions, A-law or μ-law. North American and Japanese systems use the μ-law companding algorithm, while European networks use the A-law companding algorithm.

See Figure 3 for a block diagram of a central office line card.

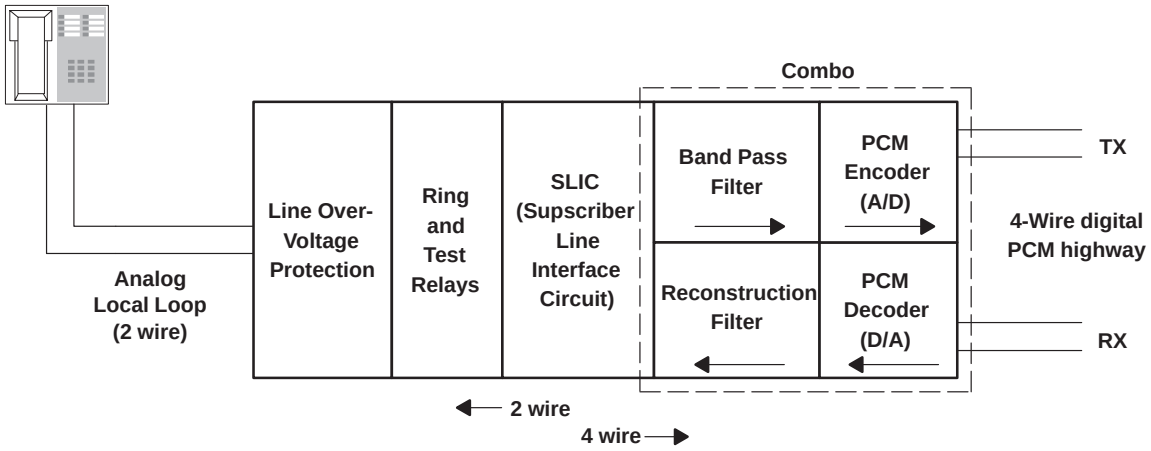

Figure 3. Line Card Block Diagram

2.2.1 Recommended TI Central Office CODECs

Table 5 contains the suggested central office CODECs manufactured by TI, along with their features.

Table 5. Voice Band CODECs for Central Office/Line Card Applications

DEVICE PART NUMBER	DESCRIPTION	TIMING	CLOCK FREQUENCY	COMPANDING ALGORITHM	FEATURES
TCM29C13A, TCM29C13	PCM CODEC/filter combo	Intel	1.536, 1.544, 2.048 MHz	μ-law and A-law	The A version has reduced noise.
TCM29C14A, TCM29C14	PCM CODEC/filter combo	Intel	1.536, 1.544, 2.048 MHz	μ-law and A-law	The A version has reduced noise.
TCM29C16A, TCM29C16	PCM CODEC/filter combo	Intel	2.048 MHz	μ-law	The A version has reduced noise.
TCM29C17A, TCM29C17	PCM CODEC/filter combo	Intel	2.048 MHz	A-law	The A version has reduced noise.
TCM37C14A	PCM CODEC/filter combo	Intel	1.536, 1.544, 2.048 MHz	μ-law and A-law	Reduced noise, programmable gain
TCM37C15A	PCM CODEC/filter combo	Intel	2.048 MHz	A-law	Reduced noise, programmable gain
TCM38C17	Quad channel PCM CODEC/filter combo	Intel	2.048 MHz	μ-law and A-law	Single 5-V supply, four channels
TP3054A, TP3054B, TP13054B	PCM CODEC/filter combo	National	1.536, 1.544, 2.048 MHz	μ-law	Single-ended output, B version has reduced noise, TP1xx are industrial temperature
TP3056B	PCM CODEC/filter combo	National	2.048 MHz	μ-law and A-law	Single-ended output
TP3057A, TP3057B, TP13057B	PCM CODEC/filter combo	National	1.536, 1.544, 2.048 MHz	A-law	Single-ended output, B version has reduced noise, TP1xx are industrial temperature
TP3064A, TP3064B, TP13064B	PCM CODEC/filter combo	National	1.536, 1.544, 2.048 MHz	μ-law	Differential output, B version has reduced Noise, TP1xx are industrial temperature
TP3067A, TP3067B, TP13067B	PCM CODEC/filter combo	National	1.536, 1.544, 2.048 MHz	A-law	Differential output, B version has reduced noise, TP1xx are industrial temperature
TCM29C18, TCM129C18	PCM CODEC/filter combo	Intel	2.048 MHz	μ-law	DSP interface to TMS320 DSPs
TCM29C19, TCM129C19	PCM CODEC/filter combo	Intel	1.536 MHz	μ-law	DSP interface to TMS320 DSPs
TCM29C23, TCM129C23	PCM CODEC/filter combo	Intel	Up to 4 MHz	μ-law and A-law	DSP interface to TMS320 DSPs

Timing is the distinguishing factor between the TP30xx and TCMxxCxx devices. One uses National timing, and the other uses Intel timing, named for their respective companies. The modes and the frame syncs of the Intel and National timing devices differ. Refer to the device data sheets for the particular device's frame sync specifications, or refer to application report SLWA006, *PCM CODEC/Filter Combo Family Device Design-in and Applications Data.*

2.3 Voice-Band Audio Processors (VBAPs)

Voice-band audio processors perform the transmit encoding (A/D conversion) and receive decoding (D/A conversion) along with signal filtering for voice-band communications systems. VBAPs are single-chip, single-rail audio pulse coded modulation (PCM) CODECs that provide all the filtering and frame sync timing necessary for a standard voice channel. VBAPS are usually a client-side device. The term VBAP is a trademark of Texas Instruments.

2.3.1 VBAP Applications

The primary application for VBAPs is in battery-powered, digital cellular telephones, but VBAPs can be used in any application requiring an interface between voice and a digital system. One of the features of VBAPs in general is their low power consumption (typically less than 50 mW when active and as little as 1.4 μW when powered down).

Some of the other types of applications for VBAPs include:

- Hands-free cellular kits
- Wireless local loop
- Speaker phones
- Digital telephone answering devices (DTAD)
- Voice modems
- Digital intercoms
- Digital public exchanges (PBXs)
- Voice interfaces to computers
- Voice activated security systems
- Multimedia applications for personal computers
- Two-way voice pagers
- Digital still camera

Figure 4 shows a general diagram of how the VBAP fits into the voice system. The main feature of a VBAP is the direct interface to both a piezo speaker and an electret microphone.

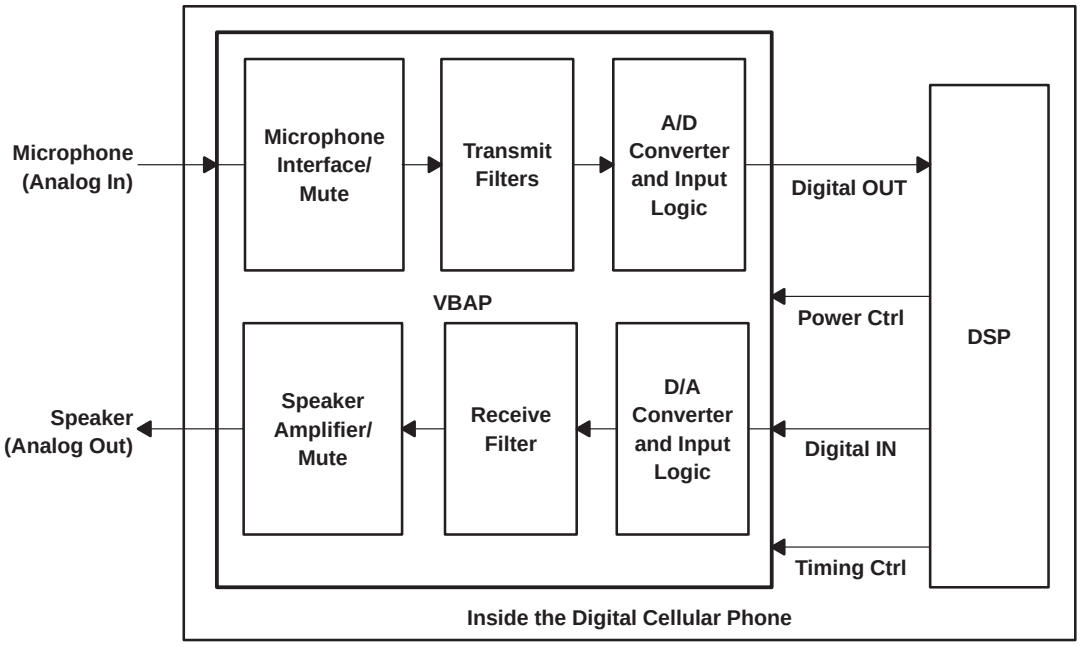

Figure 4. Voice-Band Audio Processor Application

2.3.2 Features of Recommended TI VBAPs

Table 6 contains a list of VBAPs and their features manufactured by TI. Note the low active power consumption of these devices, which makes them ideal for battery powered, wireless applications.

Table 6. Voice Band Audio Processors (VBAPs)

DEVICE PART NUMBER	POWER SUPPLY	POWER CONSUMPTION (Active/Pwr Down)	RESOLUTION (Bits)	MASTER CLOCK FREQUENCY	SAMPLE RATE (Max)	PASSBAND
TLV320AC36 (μ-law) TLV320AC37 (A-law)	3 V (±10%)	20 mW/2 mW (typ)	Companded: 8 Linear: 13	2.048 MHz	16 kHz	To 7.2 kHz
TLV320AC40 (μ-law) TLV320AC41 (A-law)	3 V (±10%)	20 mW/2 mW (typ)	Companded: 8 Linear: 13	1.152 MHz	16 kHz	To 7.2 kHz
TLV320AC56 (μ-law) TLV320AC57 (A-law)	3 V (±10%)	20 mW/ 2mW (typ)	Companded: 8 Linear: 13	2.048 MHz	16 kHz	To 7.2 kHz
TCM320AC36 (μ-law) TCM320AC37 (A-law)	5 V	40 mW/3 mW (typ)	Companded: 8 Linear: 13	2.048 MHz	16 kHz	To 7.2 kHz
TWL1101 (μ-law)	3 V	33 mW/90 μW (max)	Companded: 8 Linear: 13	2.048 MHz	8 kHz	To 3.5 kHz
TWL1103 (μ-law and A-law)	3 V (±10%)	19 mW/27 μW (max at 2.7 V)	Companded: 8 Linear: 15	2.048 MHz	8 kHz	To 3.5 kHz

The TWL1101 and TWL1103 VBAPs use sigma-delta technology in the converters. The remaining devices use switched-capacitor technology. The TWL family of devices has both a data interface (PCM interface) and a control interface (I^2C interface).

The above VBAPs (excluding the AC40 and AC41) operate from a standard 2.048-MHz master clock to meet the requirements for U.S. Analog, U.S. Digital, CT2, DECT, GSM, and *PCS Standards for Hand-Held Battery-Powered Telephones*. The TLV320AC40 and AC41 operate from a standard 1.152-MHz master clock to meet the requirements for *DECT Standards for Hand-Held Battery-Powered Telephones.*

2.3.3 Programmable Features of VBAPs

The TLVxxx and TCMxxx VBAP devices have only one feature that is programmable, the volume control. This feature is only available when the device is operating in linear mode.

The TWL family of devices has a small register set, accessed via the I^2C bus interface. The following programmable features can be controlled via the I^2C interface on the TWL family:

- Transmit amplifier gain
- Receive amplifier gain
- Sidetone gain
- Volume control
- Earphone control (selection/mute)
- PLL powered up/down (TWL1101)
- Microphone selection/bias

- TX channel high pass and slope filters (enabled/disabled)
- RX channel high-pass filter (enabled/disabled)
- μ-law/linear mode selection
- PCM loopback
- DTMF control (TWL1103)
- Pulse density modulated buzzer control (TWL1103)

3 VBAPs vs AICs

VBAPs and AICs are similar in that they are manufactured for voice band applications, are single-chip data conversion systems, and are found in client-side applications. Table 7 compares VBAPs and AICs.

Because of their feature-rich nature, the AICs consume more power. The VBAPs are designed for low-power and/or battery-fed applications that need to meet cellular telephone specifications.

The AICs are designed for applications which need better resolution and superior signal-to-noise specifications. These applications are typically modem applications.

Table 7. Comparison of AICs vs VBAPs

CHARACTERISTIC	AIC	VBAP
Power consumption?	Medium	Low
Operate from a single power supply?	Some	Yes
Operate below 3 V?	No	Yes
Designed to meet cellular phone specifications? (CT2, DECT, GSM, etc.)	No	Yes
Contain sigma delta converters?	Yes	Some devices (TWL family)
Microphone interface?	Some devices	Yes
Multi-channel?	Some devices	No
Pin selectable linear and companding modes?	No (linear only)	Yes
High resolution?	Yes (14 or 16 bits)	Yes (13–15 bits in linear mode)
Master/slave functionality?	Some devices	No
Multiple standby power down modes?	No	Yes
Programmability?	Yes	TWL family – yes TCM and TLV families –- limited

4 Summary

Voice-band codecs can be categorized as audio interface circuits, line card codecs, or voice-band audio processors. Each has been designed with a specific product area in mind. When choosing a voice-band codec, the designer should investigate the feature set and technical specifications to determine the best device for the application.

5 References

1. *PCM Codec/Filter Combo Family Device Design-In and Application Data Design Considerations* (SLWA006)
2. *Designing with the Voice-band Audio Processor* (SLWA001)
3. *TWL1101 Voice-Band Audio Processor data sheet* (SLWS074)
4. *TWL1103 Voice-Band Audio Processor data sheet* (SLVS259)
5. *TLC320AD535C/I Data Manual* (SLAS202)
6. *TLC320AD50C/I, TLC320AD52C Data Manual* (SLAS131)
7. *TLC320AD56C Data Manual* (SLAS101)
8. *TLV320AD543 Data Manual* (SLAS214)
9. *TLC320AD545C/I Data Manual* (SLAS206A)
10. *TLV320AC36, TLV320AC37 3-V Voice-Band Audio Processors* data sheet (SLWS006)
11. *TLV320AC40, TLV320AC41 3-V Voice-Band Audio Processors* data sheet (SLWS045)
12. *TLV320AC56, TLV320AC57 3-V Voice-Band Audio Processors* data sheet (SLWS044)
13. *TCM320AC36, TCM320AC37 Voice-Band Audio Processors* data sheet (SLWS003)

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