Application Report
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Voice Over Remote Control

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ABSTRACT

This application report describes the voice over RF protocol used for Texas Instruments *Bluetooth*® low energy (BLE) and RF4CE remote control solutions.

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1 Introduction

Sending voice data over a low-power wireless protocol enables multiple use cases, such as, voice recognition or baby monitoring. This application report presents the fundamental concepts of the voice implementation used in Texas Instruments BLE and RF4CE remote control solutions.

1.1 Main Features

- 16 kHz sampling rate, 16 bits resolution
- 4:1 compression perform on-chip
- Required throughput -- 64 kbps
- RF4CE application throughput up to 90 kbps
- BLE application throughput is higher than RF4CE and dependent on the system

1.1.1 Abbreviations and Acronyms

Table 1. Abbreviations and Acronyms

BLE	Bluetooth Low Energy
FA	Frequency Agility
I2C	Inter-IC
I2S	Inter-IC Sound
IC	Integrated Circuit
IMA-ADPCM	Interactive Multimedia Association-Adaptive Differential Pulse Code Modulation
kbps	Kilo bits per second
LL	Link Layer
MAC	Medium Access Control
NWK	Network Layer
PDM	Pulse Density Modulation
RC	Remote Control
RF	Radio Frequency
RF4CE	Radio Frequency for Consumer Electronics
SPI	Serial Peripheral Interface

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1.2 Solutions

1.2.1 Block Diagram

There are multiple devices available from Texas Instruments and Figure 1 through Figure 3 show the components used in the various voice enabled Remote Controllers.

In case of the CC25xx generation, an external codec is connected to an analog microphone. It is configured via inter-integrated circuit (I2C) and audio is retrieved via inter-IC sound (I2S). The master clock is provided by CC25xx, which also acts as an I2S slave. The I2S slave is implemented using the serial peripheral interface (SPI) module in slave operation, with a word clock connected to the chip select pin.

In the CC26xx devices, no external codec is required as the bit stream from a digital microphone can be read directly by the device, and the PDM stream can be processed in software.

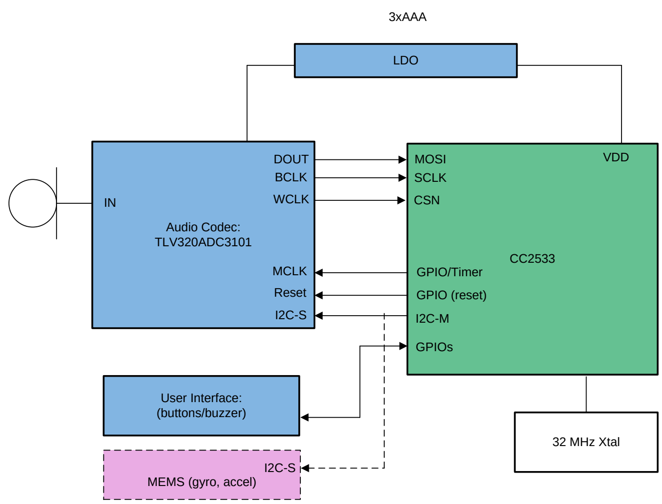

Figure 1. CC2533

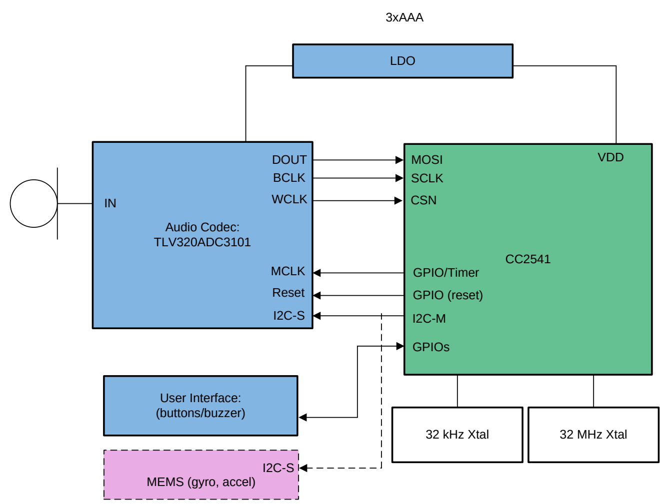

Figure 2. CC2541

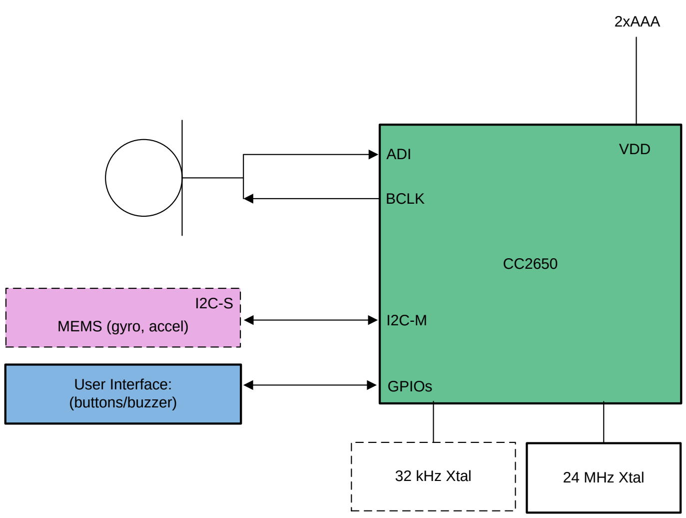

Figure 3. CC2650

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1.2.2 Audio Flow Diagram

Figure 4 and Figure 5 show various audio flows from the microphone via RF to speaker.

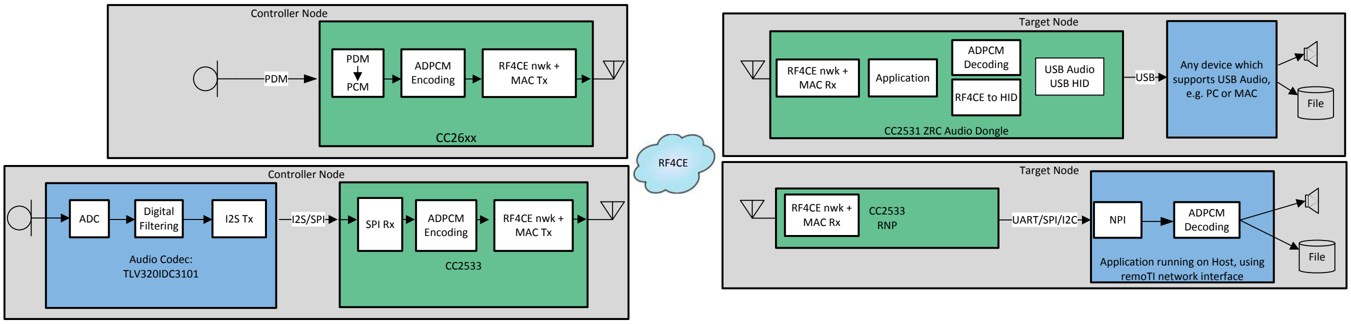

Figure 4. RF4CE

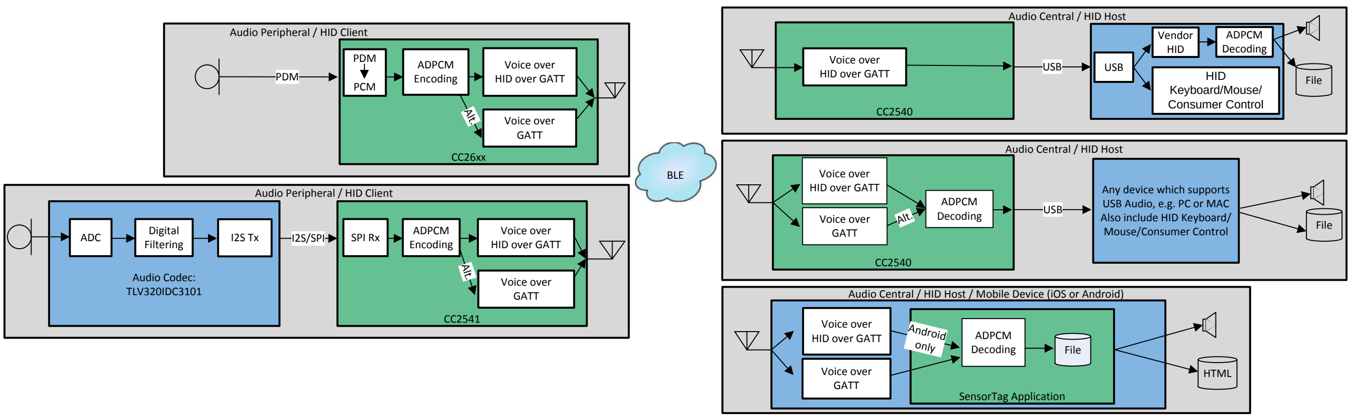

Figure 5. BLE

1.2.3 Audio Protocol

In order to transmit audio data over BLE or RF4CE, it is necessary to have a protocol in place. A protocol defines rules on how to interpret data. To save power, do not transmit audio continuously. As such, an audio stream has a finite beginning and end. In addition to indicating the audio data, the beginning of transmission can be identified as well as the end. This has the added benefit of allowing the recipient to prepare for an audio stream.

1.2.3.1 RF4CE

To improve rate, re-transmission on different channels can be removed, which is necessary to re-acquire channels in case they are changed mid-stream. Locking the RF channel removes this need.

For RF4CE, there is a very easy way to transmit your own vendor specific data, which is simply called vendor specific data transmission. Since there is no official protocol to transmit audio data, vendor specific data is used. Texas Instruments already defines several vendor specific data protocols, such as an Over-the-Air-Download protocol and a latency test protocol.

Table 2. Start Frame

Number of Bytes	1	1	1	1	1
Field	Protocol ID	CMD ID	Sample Frequency	Sample Width	Mode
	0x50	0x00	8: 8kHz 16: 16kHz	8, 12 or 16 bits	0: RAW 1: IMA-ADPCM

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Table 3. IMA-ADPCM Data Frame

Number of Bytes	1	1		1	1	1	var
Field	**Protocol ID**	**Seq No**	**ID**	Header 1	Header 2	Header 3	Audio Samples
	0x50	[7:3]	[2:0]				
		0-31	0x01				

Table 4. Stop Frame

Number of Bytes	1	1
Field	**Prot/ocol ID**	**CMD ID**
	0x50	0x02

Table 5. Raw PCM Data Frame

Number of Bytes	1	1	1	var
Field	**Protocol ID**	**CMD ID**	**Seq No**	**Audio Samples**
	0x50	0x03	0-255	16 bits LSB PCM

1.2.3.2 BLE

There is no standard way of transmitting audio via BLE. It is, however, quite simple to wrap the audio data into a vendor defined profile service. One such option is vendor defined characteristics where audio is transmitted over GATT. Another option is to wrap the audio data into vendor-specific HID profile service. The latter is preferred by those who are familiar with writing vendor specific HID report handlers. The performance is equal between the two options. The first byte in each of the following tables, Protocol ID, is only valid for RF4CE.

Table 6. Start Frame

Number of Bytes	1
Field	CMD ID
	0x04

Table 7. BLE ADPCM Data Frame Part #1/5 Frame

Number of Bytes	1		1	1	1	16
Field	**Seq No**	**ID**	Header 1	Header 2	Header 3	Audio Samples
	[7:3]	[2:0]				
	0-31	0x01				

Table 8. BLE ADPCM Data Frame Part #2/5 Frame

Number of Bytes	20
Field	Audio Sample

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Table 9. BLE ADPCM Data Frame Part #3/5 Frame

Number of Bytes	20
Field	Audio Sample

Table 10. BLE ADPCM Data Frame Part #4/5 Frame

Number of Bytes	20
Field	Audio Sample

Table 11. BLE ADPCM Data Frame Part #5/5 Frame

Number of Bytes	20
Field	Audio Sample

Table 12. Stop Frame

Number of Bytes	1
Field	**CMD ID**
	0x00

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1.2.4 Sequence Diagram

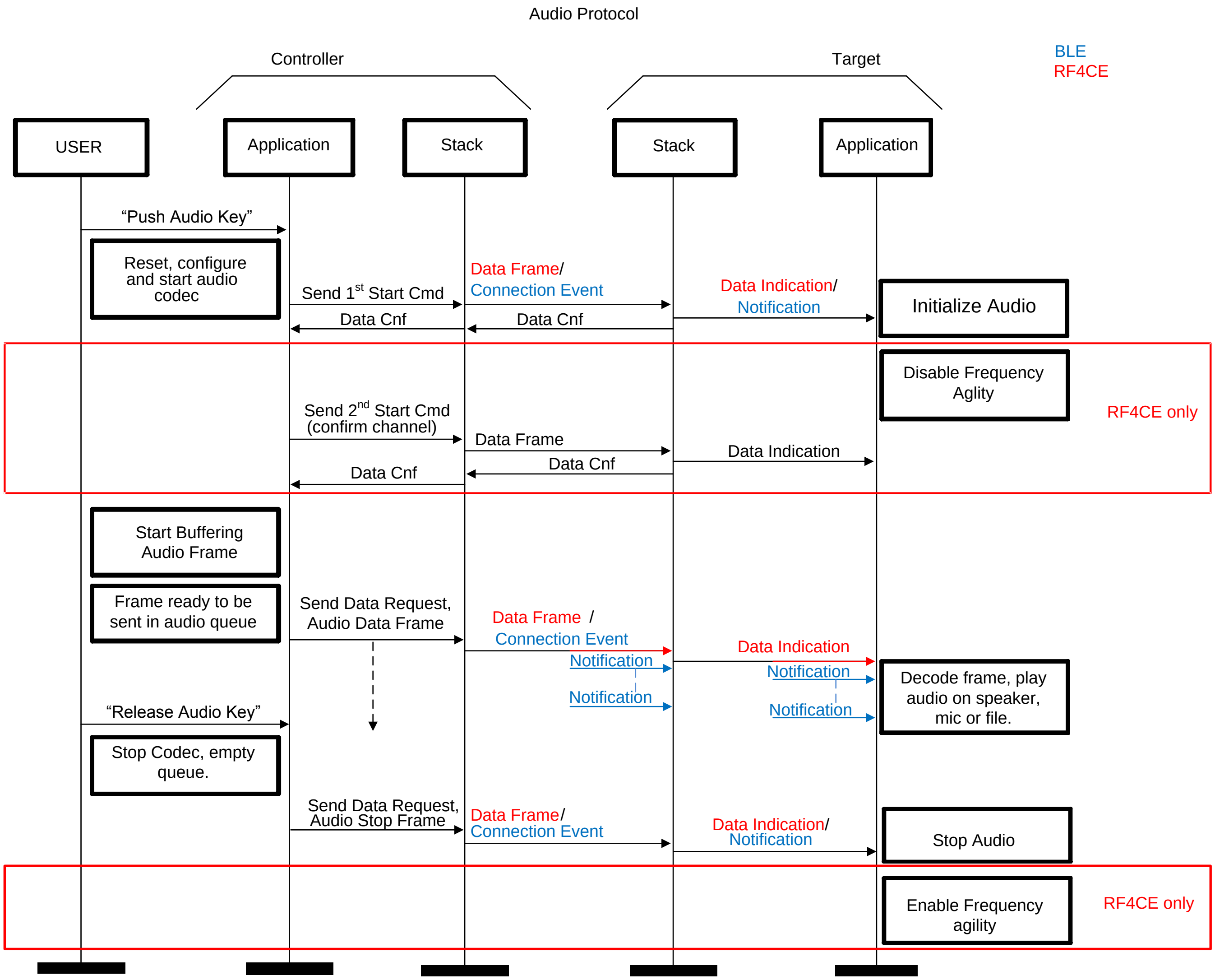

Figure 6. Sequence Diagram

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