Dual mode Bluetooth Controller via PCM-CODEC Interface for Audio Application

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Abstract: *Bluetooth may be a inaccessible development standard utilized for exchanging data between settled and flexible contraptions over brief divisions utilizing UHF radio waves with within the mechanical, coherent and restorative radio bunches, from 2.402GHz to 2.480 GHz. PCM codec is an A/D interface for speech signals. The Bluetooth center framework underpins co- ordinate transport of application information that's isochronous and of a consistent rate (either bit-rate or frame-rate for pre-framed information) employing a SCO or ESCO consistent joins. These coherent joins save physical channel transfer speed and give a consistent rate transport bolted to the piconet clock. The codec interface block is used to interface an external PCM (8KHz voice data) or a stereo codec with the baseband controller for direct transfer of voice data on isochronous links to external CODEC. Bluetooth baseband supports two CODEC interface protocols 1) for audio links it is the PCM interface and 2) for mono/stereo music data from audio codec it uses IIS interface. This enables the source of isochronous data to be directly interfaced to the baseband controller, if it is not required to be processed by firmware. It also provides the host access path where source of isochronous data will be any application running on host and data is written and read directly into baseband SCO/ESCO FIFOs from firmware. In this paper PCM is verified in Cadence tool and simulated images are shown.*

Keywords— Pulse Code Modulation (PCM), Bluetooth Classic (BC), Bluetooth Low Energy (BLE), Synchronous Connection Oriented Link (SCO), Enhanced Synchronous Connection Oriented Link (ESCO).

I. INTRODUCTION

Bluetooth has undergone several revisions. Versions are specified below.

Bluetooth Classic (revisions 1.0–3.0): Range, data speed, and power consumption are all factors that help differentiate between the various versions. The modulation plot and information packet utilized choose some factors. When the primary Bluetooth version was discharged, it cleared the way for today's remote earphones, speakers, and amusement controllers. However, Bluetooth 1.0 was much slower back then than it is now. The information rates were restricted to 1 Mbps, and the extend was as it were 10 meters. Gaussian Frequency Shift Keying was the modulation scheme used in the first iteration of Bluetooth (GFSK). The tweaked carrier in GFSK switches between 0s and 1s. GFSK had two schemes 8DPSK and p/4-DQPSK. These schemes had data rates of 2 Mbps and 3 Mbps respectively. When 802.11 was introduced with 24Mbps speed for the transfer of data, Bluetooth 3.0 boosted data speeds even further. Short-range wireless systems will now provide a secure, high-speed link, paving the way for significant advancements in wireless technology. However, early models of Bluetooth had a major drawback that prevented widespread IoT integration, power consumption. Tiny devices will continue to suffer from poor battery life due to energy consumption [5].

Bluetooth Low Energy (BLE): One more version of Bluetooth i.e. version 4.0 was introduced. This is commonly called as Bluetooth Low Energy, as it was mainly intended for wireless communication between small devices (BLE)[3]. Using GFSK, BLE gives speed of 1Mbps, due to the requirement of low power consumption. While BLE's maximum data throughput of 1Mbps is insufficient for products such as wireless headphones that need a constant flow of data without any interruption. Many battery-operated IoT applications with round coin sized cells (e.g., beacons) are now possible thanks to Bluetooth Low Energy's emphasis on lowering energy demands. Bluetooth 5, which is the latest trend, is an advancement over previous Bluetooth versions [6]. It's only designed for low-power applications, but it outperforms BLE in terms of speed and range. Bluetooth 5 consists four data rates to handle various communication ranges: 2Mbps, 1Mbps, 500kbps, and 125kbps. Speed of 125kbps was used as it was the best speed due to the analogy in communication i.e. increasing the range decreases the speed automatically. Like in Tiny sensors there is no need of sending much data, due to which reducing the speed helps the tiny MEMS devices(sensors) to send data up to 240 meters. The ability to transmit data at 2Mbps, on the other hand, is designed for applications with shorter range and high data transfer speed(rate). Bluetooth 5's data speed versatility allows low-powered devices to transmit much more advanced data to the end user.

II. DUAL MODE BLUETOOTH

Bluetooth 5 gives potential devices with more power and control. Dual-Mode Bluetooth 5 reflects a step forward by combining Bluetooth Classic and BLE in a single IP [2]. An example a Dual-Mode Bluetooth application is the modern smart mobile. Bluetooth Classic gets the foremost consideration on smartphone, because it permits network with remote earphones, headphones and speakers [1] where persistent usage causes battery to lose its energy as fast as possible. Bluetooth feature enables not to use the wired devices for data communication and it also enables the communication between smartphone and multiple gadgets at a time which is less data intensive like wellness trackers showing heart rate, temperature etc. Dual-mode Bluetooth or Bluetooth 5 is an innovation in IoT applications using music gushing, voice acknowledgment and other IoT applications [2]. Existing arrangements within the showcase are either under- powered or need back for basic Bluetooth capacities, driving originators to compromise on their plans. The Dual-mode Bluetooth 5 not as it were highlights long-range dual-mode and BLE work bolster, but moreover incorporates low power, high-performance processor with class-leading security and peripherals needed for lots application related to IOT. Bluetooth Vitality, or BLE, is the foremost later version of Bluetooth innovation, more seasoned adaptations of Bluetooth, known as Bluetooth Classic, are still commonly utilized nowadays for applications that require a consistent stream of information at a tall throughput [3]. Illustrations incorporate remote speakers and earphone, which require a unfaltering stream of high-quality information at tall speeds to guarantee ideal sound quality. BLE, on the other hand, is implied for applications that as it were ought to send little bits of data in brief bursts, in arrange to constrain the sum of control utilized – thus the utilize of the words, "low energy." Illustrations of BLE applications incorporate moo fueled sensors that work on a coin cell battery and does not transmit much more than little sums of straightforward information [6]. Not all applications would advantage from having both Bluetooth Classic and Bluetooth Moo Vitality. Be that as it may, in the event that item requires extra adaptability and the reasons are legitimized, introducing both Bluetooth Classic and BLE is continuously an option.

III. PULSE CODE MODULATION

Pulse-code Modulation (PCM) may be a strategy utilized to carefully speak to examined analog signals [4]. All computers and its devices with computerized sound uses this technique as standard. The PCM handle is commonly executed on a single circuit called an analog-to-digital converter (ADC) which produces discrete representation of the input which is then encoded as advanced information. A few PCM streams may too be multiplexed into a bigger total information stream, for the most part for transmission of different streams over a single physical interface. One procedure is called time-division multiplexing (TDM) and is broadly utilized, outstandingly within the advanced open phone framework.

IV. PCM CODEC

A Codec could be a gadget or computer program which encodes or interprets a advanced information stream or signal. In electronic communications, an endec may be a gadget which acts as both an encoder and a decoder on a flag or information stream, and subsequently may be a sort of Codec.A coder or encoder encodes an input data for transmission, in terms of frames, and the decoder work inverts the encoding. Codec have applications in videoconferencing, spilling media, and video altering applications. A sound Codec changes over analog sound signals into computerized signals for transmission or encodes them for capacity. A Codec may moreover compress the information to diminish transmission capacity or capacity space. The PCM Codec is an A/D interface used for speech signals with some encoders, decoders and channels. This device is a low power consuming device with lots of different choices for code conversion. The device operates in 8-bit form which is (A-law or µlaw) with companding nature or 15 bit form which is very direct selected by I2C interface.

V. CODE CONVERTERS

PCM is most efficient method in quantizing the analog input data where the waveform produced after the digitization shows the different levels of waveform which is encoded in binary. Due to quantization error some levels are not properly levelled, but the encoding method is chosen such a way that error is minimized as much as possible. So, representation of 8 kHz data requires minimum of 13 bits. But for distant transmission this representation is not so efficient, so companding technique is used in most systems. companding is a technique where the input data is initially compressed and then it is transmitted through a channel of fixed bandwidth. This technique is commonly used in the field where bandwidth is limited, like in telephonic speech representation from 13 to 8 bits to satisfy bandwidth requirements. After Companding, i.e., output from Companding gives 8-bit data. To encode this there are two prominent methods according European standard are A- law and µ-law Both the laws are logarithmic quantization techniques which are having less SNR. Each 8-bit logarithmic code consist of sign bit (1 bit), chord bit (3 bits) and step bits (4 bits).

A. A-law

A-law is a standard in Europe which is used in telephonic quantization encoding. In Europe the standard chosen value for the parameter A is 87.7.Definition of A-law is given in Fig 1 where x is the input which needs to compressed/companded.

$$F(x) = \begin{cases} \dfrac{A*|x|}{1+\ln(A)} & 0 \le |x| < \dfrac{1}{A} \\[2ex] \dfrac{\operatorname{sgn}(x)*(1+\ln(A|x|))}{1+\ln(A)} & \dfrac{1}{A} \le |x| \le 1 \end{cases}$$

Fig. 1. Definition[2] of A law

B. µ-law

Countries like USA and Japan follow one more companding technique i.e., µ-law. Both countries have made a standard such that the input 13 bits is directly companded and the value of m is 255(only in USA and Japan).

$$F(x) = \frac{\operatorname{sgn}(x) * \ln(1+\mu|x|)}{\ln(1+\mu)} \quad 0 \le |x| \le 1$$

Fig. 2. µ-law Definition[2]

Both laws quite similar but there are some differences which are listed below:

a) µ-law encoders ordinarily work on straight 13-bit size information, But A-law operates on 12 bits

b) The sign bit is turned around

c) The reversal design is used in 8-bit code which are connected.

Table III represents a µ-law where the input data is encoded. S=1, when input test is positive and S=0, when input test is negative. Table I outlines an A-law where the input data is encoded. S=0, when input test is positive and S=1, when input test is negative.

TABLE I

A-LAW ENCODING

Linear Input Data	A-Law Encoded Output
0000000ABCDX	S000ABCD
0000001ABCDX	S001ABCD
000001ABCDXX	S010ABCD
00001ABCDXXX	S011ABCD
0001ABCDXXXX	S100ABCD
001ABCDXXXXX	S101ABCD
01ABCDXXXXXX	S110ABCD
1ABCDXXXXXXX	S111ABCD

After the input information is encoded through the rationale characterized within the table, a reversal design is used on code of 8 bit to extend thickness of moves on the transmission line, an advantage to hardware execution. Then reversal design is connected by performing the XOR'ing of the code (8 bit) and 0x55.

TABLE II

A-LAW DECODING

A-Law Encoded Input	Linear Output Data
S000ABCD	0000000ABCD1
S001ABCD	0000001ABCD1
S010ABCD	000001ABCD10
S011ABCD	00001ABCD100
S100ABCD	0001ABCD1000
S101ABCD	001ABCD10000
S110ABCD	01ABCD100000
S111ABCD	1ABCD1000000

TABLE III

MU-LAW ENCODING

Linear Input Data	Mu-Law Encoded Output
00000001ABCDX	S000ABCD
0000001ABCDXX	S001ABCD
000001ABCDXXX	S010ABCD
00001ABCDXXXX	S011ABCD
0001ABCDXXXXX	S100ABCD
001ABCDXXXXXX	S101ABCD
01ABCDXXXXXXX	S110ABCD
1ABCDXXXXXXXX	S111ABCD

After the input information is encoded through the rationale characterized within the table, a reversal design is used on code of 8 bit to extend thickness of moves on the transmission line, an advantage to hardware execution. Then reversal design is connected by performing the XOR'ing of the code (8 bit) and 0xFF. Table IV outlines the µ-law translating table, applied after turning around the reversal design. The least critical bits disposed of within the encoding handle are approximated by the middle esteem of the interim.

TABLE IV

MU-LAW DECODING

Mu-Law Encoded Input	Linear Output Data
S000ABCD	00000001ABCD1
S001ABCD	0000001ABCD10
S010ABCD	000001ABCD100
S011ABCD	00001ABCD1000
S100ABCD	0001ABCD10000
S101ABCD	001ABCD100000
S110ABCD	01ABCD1000000
S111ABCD	1ABCD10000000

VI. RESULTS

In Figure 3, the data transmission and reception from external world is observed. Figure 4 and Figure 5 shows the BT1,BT2 FIFO in which the data is being stored ,which has been received from external interface signals. In Figure 6, data from Rx BT2 FIFO is further observed in Codec Top signal, PCM signals are enabled which intern encodes the input data during transmission and decodes during reception depending on the type of code conversion chosen. Then a serialized output is observed in Figure 7 at the output.

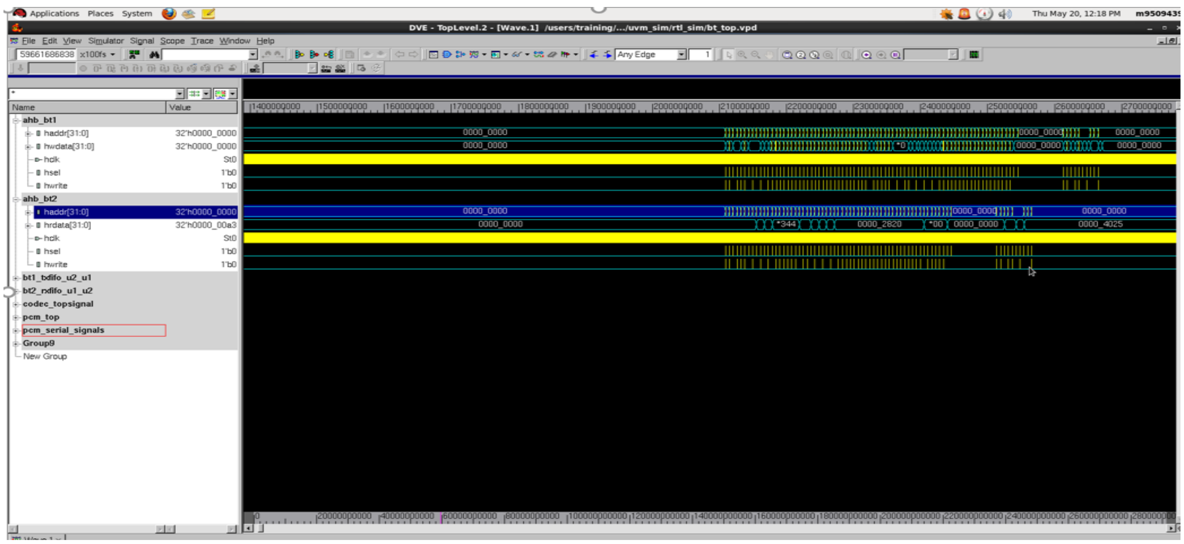

Fig. 3. Transmission and Reception Via External Interface

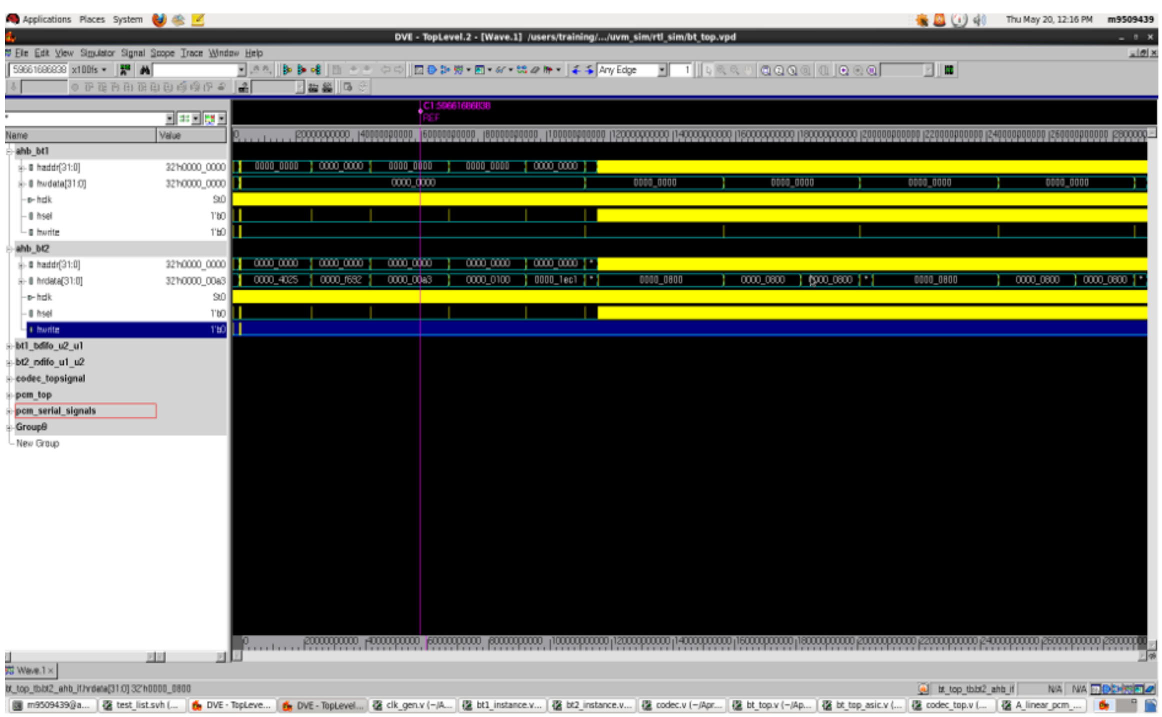

Fig. 4. BT 1 FIFO signals

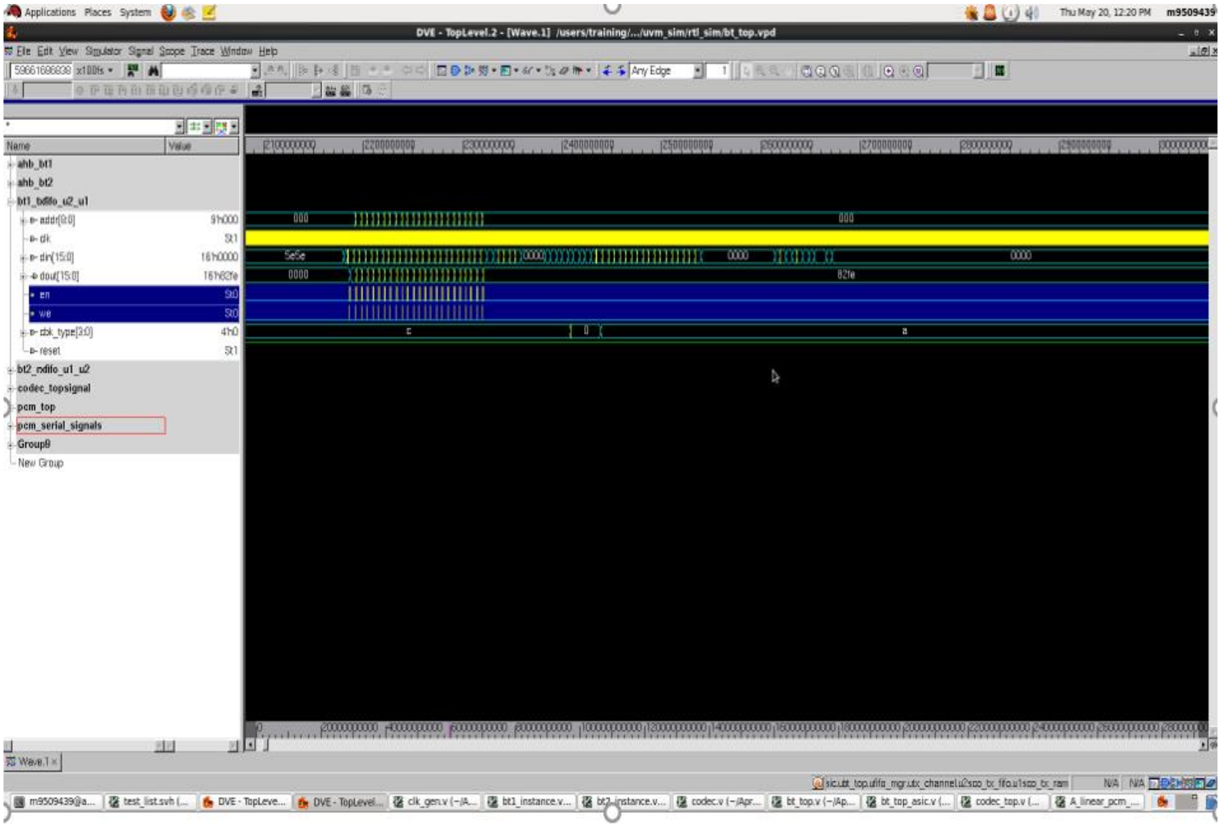

Fig. 5. BT 2 FIFO signals

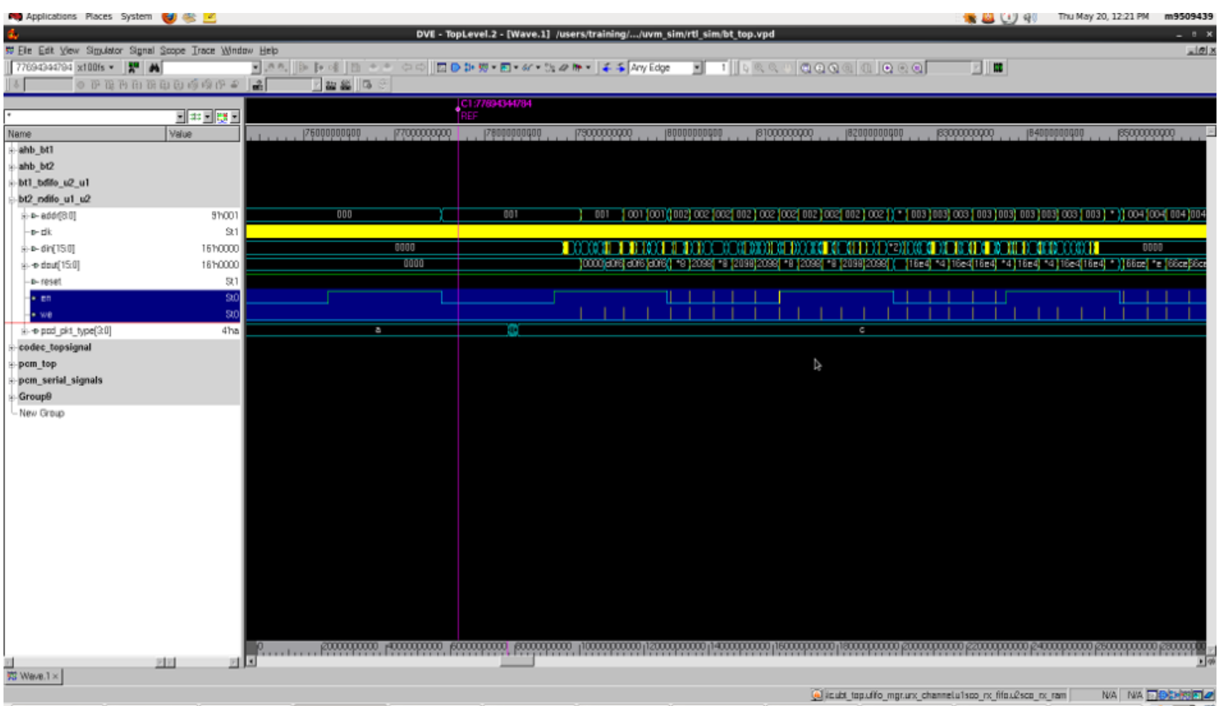

Fig. 6. PCM-CODEC signals

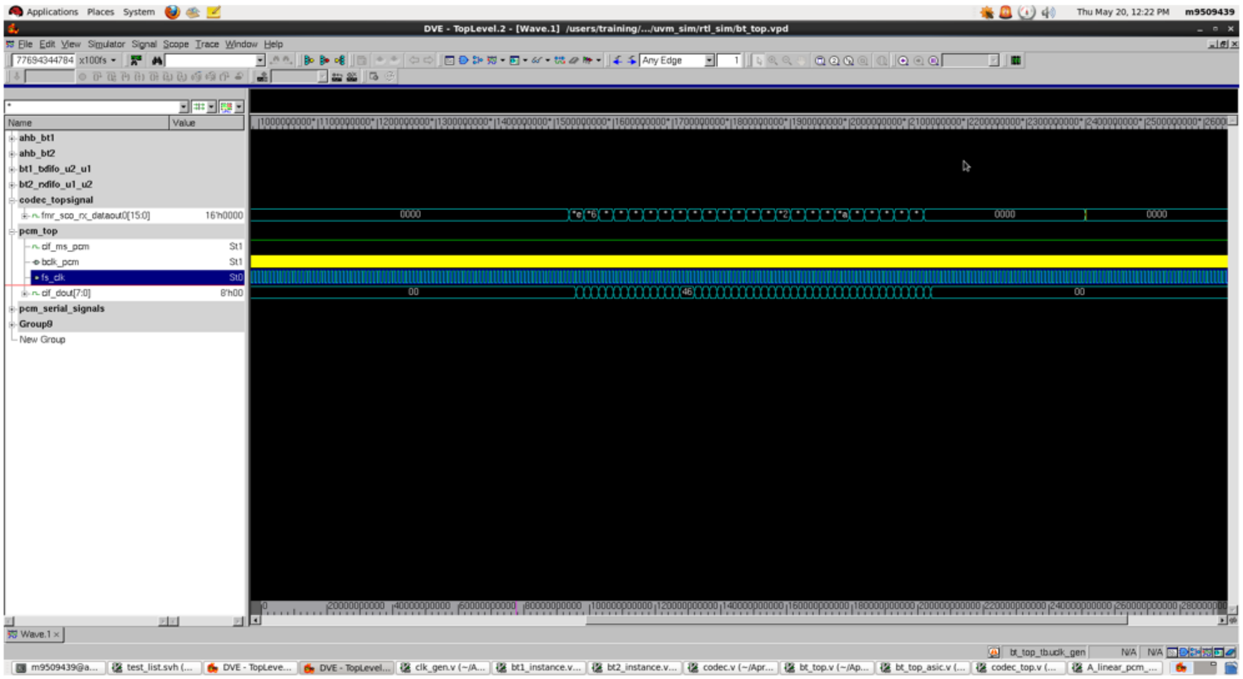

Fig. 7. Serial Output

VII. CONCLUSION

The Bluetooth technology gives a brief understanding regarding the wireless communication technology, among many interfaces in the Bluetooth its observed that PCM interface is the basic known interface for transmitting and receiving audio data. PCM interface is used for audio format data. In this project the input data is of 8Khz frequency. The PCM Codec interface allows the data to be sampled, encrypted and compressed without compromising in quality of the original data. PCM has an advantage of not losing any data packets while transmitting or receiving and it also removes noise in the input data which makes it a better interface in the Bluetooth architecture along with other interfaces.

REFERENCES:

[1] T. M. Pavithran and R. Bhakthavatchalu, ”UVM based testbench archi- tecture for logic sub-system verification,” 2017 International Conference on Technological Advancements in Power and Energy (TAP Energy), Kollam, 2017, pp. 1-5, doi: 10.1109/TAPENERGY.2017.8397323.

[2] M. A. Rahman, N. Kamal, M. Bin Ibne Reaz and F. H. Hashim, ”Dual-mode receiver architecture for Bluetooth and IEEE 802.11b stan- dards,” 2015 International Conference on Computer, Communications, and Control Technology (I4CT), Kuching, 2015, pp. 117-121, doi: 10.1109/I4CT.2015.7219549.

[3] A. Pipino, A. Liscidini, K. Wan and A. Baschirotto, ”Bluetooth low energy receiver system design,” 2015 IEEE International Symposium on Circuits and Systems (ISCAS), Lisbon, 2015, pp. 465-468, doi: 10.1109/ISCAS.2015.7168671.

[4] Gwo-Yang Wu, Liang-Bi Chen, Yuan-Long Jeang and Gwo-Jia Jong, ”An optimal PCM codec soft IP generator and its application,” 2002 IEEE International Conference on Field-

Programmable Technology, 2002. (FPT). Proceedings., Hong Kong, China, 2002, pp. 315-317, doi: 10.1109/FPT.2002.1188700.

[5] Journal of the Korean Physical Society, Vol. 42, No. 2, February 2003, pp. 200-205. Sunhee Kim and Seungjun Lee" CAD and VLSI Lab.,Department of Information Electronics Engineering, Ewha Womans University, Seoul 120-750.

[6] P. Wiecha, M. Cieplucha, P. Kloczko and W. A. Pleskacz, "Architecture and design of a Bluetooth Low Energy Controller," 2016 MIXDES - 23rd International Conference Mixed Design of Integrated Circuits and Systems,Lodz,2016,pp.164-167,doi: 10.1109/MIXDES.2016.7529724.