DSP/BIOS Audio Interface Driver

Architecture/Design Document

Revision History

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0.2	Imtiaz SMA	October 23 2008	Fixed the review comments given for the document.
0.3	Imtiaz SMA	September 8 2008	Updated the IOCTLs for the audio driver.
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1 System Context

The Audio interface driver architecture presented in this document is situated in the context of DSP BIOS 6.x based drivers. But the design is relevant to other architectures also as the audio interface driver is essentially independent of the hardware.

Note: The usage of structure names and field names used throughout this design document is only for indicative purpose. These names shall not necessarily be matched with the names used in source code.

1.1 Terms and Abbreviations

Term	Description
API	Application Programmer's Interface
CSL	TI Chip Support Library – primitive h/w abstraction
IP	Intellectual Property
ISR	Interrupt Service Routine
OS	Operating System
Audio driver	Audio interface driver
Audio device driver	Driver for audio devices like McASP or McBSP etc
Audio codec driver	Driver for audio codec devices like TLV320AIC31 etc

1.2 Disclaimer

This is a design document for the Audio interface driver for the DSP/BIOS operating system. Although the current design document explain the Audio interface driver in the context of the BIOS 6.x driver implementation, the driver design still holds good for the BIOS 5.x driver implementation as the BIOS 5.x driver is a direct port of BIOS 6.x driver. The BIOS 5.x drivers conform to the IOM driver model whereas the BIOS 6.x drivers confirm to the IDriver model. The subsequent section explains how this document can be used to understand and modify the IOM drivers found in this product. Please note that all the flowcharts, structures and functions described here in this document are equally applicable to the Audio interface driver 5.x.

1.3 IOM driver Vs IDriver

The following are the main difference between the BIOS 5.x and BIOS 6.x driver. Please refer to the reference documents for more details in the IOM driver model.

1. All the references to the stream module should be treated as references to a module that provides data streaming. In BIOS 5.x the equivalent modules are SIO and GIO.

2. This document refers to the IDriver model supported by the BIOS 6.x.All the references to the IDriver should be assumed to be equivalent to the IOM driver model.

3. The BIOS 6.x driver uses a module specifications file (*.xdc) for the declaration of the enumerations, structures and various constants required by the driver. The equivalent of this xdc file is the header file XXX.h and the XXXLocal.h.

   Note: The XXXLocal.h file contains all the declaration specified in the "internal" section of the corresponding xdc file.

4. In BIOS 6.x creation of static driver instances follow a different flow and cause functions in module script files to run during build time. In BIOS 5.x creation of driver (for both static and dynamic instances) result in the execution of the mdBindDev function at runtime. Therefore any references to module script files (*.xs files) can be ignored for IOM drivers.

5. The XXX_Module_startup function referenced in this document can be ignored for IOM drivers.

6. IOM drivers have an XXX_init function which needs to be called by the application once per driver. This XXX_init function initializes the driver data structures. This application needs to call this function in the application initialization functions which are usually supplied in the tci file.

7. The functionality and behavior of the functions is the same for both driver models. The mapping of IDriver functions to IOM driver functions are as follows:

IDriver	IOM driver
XXX_Instance_init	mdBindDev
XXX_Instance_finalize	mdUnbindDev
XXX_open	mdCreateChan
XXX_close	mdDeleteChan
XXX_control	mdControlChan
XXX_submit	mdSubmitChan

8. All the references to module wide config parameters in the IDriver model map to macro definitions and preprocessor directives (#define and #ifdef etc) for the IOM drivers. e.g.

   a. XXX_edmaEnable in IDriver maps to –D XXX_EDMA_ENABLE for IOM driver.

   b. XXX_FIFO_SIZE in IDriver maps to #define FIFO_SIZE in IOM driver header file

9. In BIOS 6.x a cfg file is used for configuring the BIOS and driver options whereas in the BIOS 5.x the "tcf" and "tci" files are used for configuring the options.

10. In BIOS 5.x driver support for multiple devices is implemented as follows. A chip specific compiler define is required by the driver source files (-DCHIP_COMAPL137). Based on the include a chip specific header file (e.g soc_OMAPL137) which contains chip specific defines is used by the driver. In order to support a new chip, a new soc_XXX header file is required and driver sources files need to be changed in places where the chip specific define is used.

1.4 Related Documents

1.	TBD	DSP/BIOS Driver Developer's Guide
2.	SPRUFM1	Mcasp user guide (draft)

1.5 Hardware

The audio interface driver is essentially independent of the underlying hardware. But the configurations required by the driver are configured during the compile time depending on the platform.xs file.

1.6 Software

The Audio interface driver discussed here is intended to run in DSP/BIOS™ V6.10 on the C674x DSP.

1.7 Design Philosophy

This device driver is written in conformance to the DSP/BIOS IDriver model and handles the configuration of the Aic31 ADC and DAC sections independently.

A codec performs conversion of audio streams from digital to analog formats and vice versa. It involves configuring the DAC and ADC sections of the codec. An application might be using multiple instances of AIC31 codecs in a single audio configuration. In such a case the application needs to configure each audio codec independently.

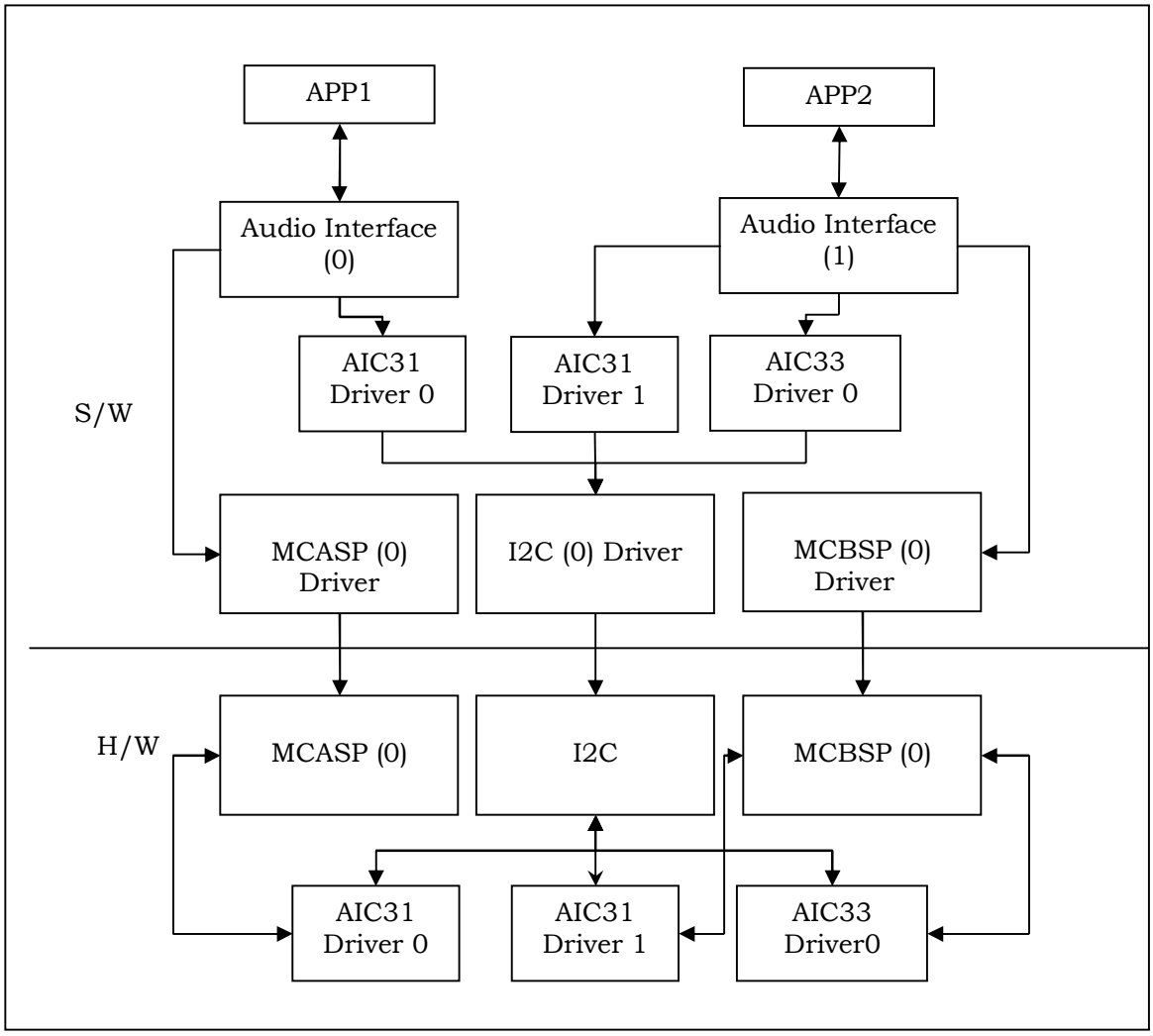
The design of the DSP BIOS based AIC31 IDriver intends to make the configuration of all AIC31 codecs simple. Using an Aic31 IDriver interface makes it possible to configure multiple codecs by specifying their control bus and their address on the bus. The Aic31 driver provides the flexibility to configure the required configuration for all the instances during the build time(it is also possible to do so dynamically). It also allows the application to manage multiple instance of the codec with a single interface

1.8 Design Description

This section describes the need for a separate audio interface driver over the audio device driver and audio codec drivers.

In a given hardware platform there are many different types of audio data transport devices (McASP,McBSP etc) are present. Also, there might be multiple instances of each of these devices available. Each of these devices in turn will be interfacing with multiple codecs available on board. Also the codecs can be controlled using different control buses like I2c or Spi etc.). The diagram below shows an imaginary scenario.

The hardware consists of one Mcasp and one McBSP instance. There are two instances of AIC31 codecs and one AIC33 codec on board. All the codecs are configured using the I2c instance 0. The Mcasp instance 0 interfaces with the AIC31 instance 0 and the McBSP instance 0 interfaces with the AIC31 codec instance 1 and the AIC33 codec instance 0.



This kind of complex audio configuration requires the sample applications to configure each of the audio device and audio codec individually. In case of multiple audio codecs to be handled, it is required to do bookkeeping of all the codecs to be configured and the channel handles returned by them.

In such complex scenarios the audio interface driver provides the application developers to configure the entire audio configuration through a single interface .it maintains all the internal bookkeeping required and thereby providing the application developer with a simplified interface.

Figure 1 Sample Hardware configuration

The design of audio interface driver is intended to provide the necessary abstraction to the application in interacting with the various audio configurations so that the application can be ported from one platform to another easily with minimum changes. It is also intended that the audio interface driver will also facilitate in easy addition of new audio configurations like addition of new codecs etc, new audio devices etc with minimum code changes.

1.8.1 Operating Environment and dependencies

Details about the tools and DSP/BIOS versions that the driver is compatible with, can be found in the system Release Notes.

1.8.2 System Architechture

The block diagram below shows the overall system architecture.

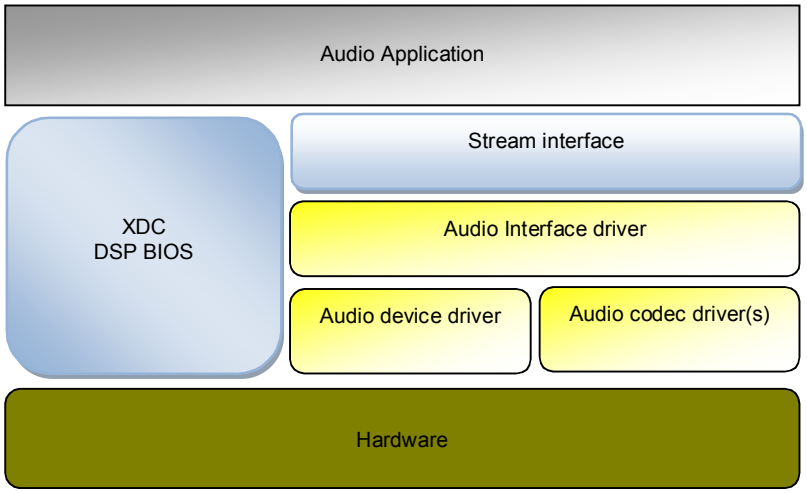


Figure 2 System Architecture

The Audio interface driver is a complete IDriver comaptible driver.it lies below the stream layer, which is an class driver layer provided by DSP BIOS™ (please note that the stream layer is designed to be OS independent with appropriate abstractions).Depending on the audio configurations it is interfacing with the audio interface driver will interface with an audio device driver (like Mcasp driver or Mcbsp driver) and also with the required number of codec drivers.

The Application can use the stream APIs to interface with the audio interface driver.The driver inturn will interface with the underlying drivers.

Figure 2 shows the overall device driver architecture. For more information about the IDriver model, see the DSP/BIOS™ documentation. The rest of the document elaborates on the architecture of the Device driver by TI.

1.8.3 Design Goals

The following are the key device driver design goals being factored by proposed audio interface driver:

1. Simple unified interface for the application to access the various audio configurations through a set of well defined APIs.
2. Easy addition of new audio devices and audio codecs with minimum changes in the application.
3. Easy porting of applications using the audio interface drivers across various platforms.
4. Audio interface driver should be platform independent.

Note:

1. The audio interface driver will have a maximum of 1 audio device in a given instance.
2. The audio interface driver will not perform any IO transfers with the audio codec other than configuring the codec and controlling the codec.(no data transfers).
3. The audio interface driver will not perform any module startup checks for the underlying audio device drivers and audio codec drivers.

1.9 Component Interfaces

In the following subsections, the interfaces implemented by each of the sub-component are specified. The audio interface driver module is an object of IDriver class one may need to refer the IDriver documentation to access the audio interface driver in raw mode or could refer the stream APIs to access the driver through stream abstraction. The structures and config params used would be documented in CDOC format as part of this driver development.

1.9.1 IDriver Interface

This audio interface driver is intended to be an XDC module and this module would inherit the IDriver interfaces. Thus the audio interface driver module becomes an object of IDriver class. Please note that the terms “Module” and “Driver or IDriver” would be used in this document interchangeably.

As per xdc specification, an module should feature a xdc file, xs file and source file as a minimum.

Audio module specifications file (Audio.xdc)

The XDC file defines the following in its public section: the data structures, enums, constants, IOCTLS, error codes and module wide config variables that shall be exposed for the user.

These definitions would include

ENUMS: Operation modes, device types etc.

STRUCTURES: channel configuration structures etc.

CONSTANTS: error ids and ioctls and various other constants.

Also this files specifies the list of configurable items which could be configured/specified by the application during instantiation (instance parameters)

In its private section it would contain the data structures, enums, constants and module wide config variables which are internal to the driver. The Instance objects (the driver object) and channel objects which contain all the info related to that particular IO channel. This information might be irrelevant to the User. The instance object is the container for all driver variables, channel objects etc. In essence, it contains the present state of the instance being used by the application

The XDC framework translates this into the driver header file (Audio.h) and this header file shall be included by the applications, for referring to any of the driver data structures/components. Hence, XDC file contains everything that should be exposed to the application and also accessed by the driver.

Please note that by nature of the specification of the xdc file, all the variables (independent or part of structure) need to be initialized in xdc file itself.

Audio module script file (Audio.xs)

The script file is the place where static instantiations and references to module usage are handled. This script file is invoked when the application compiles and refers to the Audio module/driver. The Audio.xs file contains two parts

1. Handling the module use references

   When the module use is called in the application cfg for the audio module, the module use function in the Audio.xs file is used to initialize the details of number of instances supported for this particular CPU.This gives the flexibility to design, to handle multiple SOC with single c-code base (as long as the hardware is similar).

2. Handling static instantiation of the Audio instance

   When the Audio instance is instantiated statically in the application cfg file, (please note that dynamic instantiation is also possible from C file) the instance static init function is called. If a particular instance is configured with set of instance parameters (from CFG file) they are used here to configure the instance state. The instance state is populated based on the instance number, like the default state of the driver, channel objects etc.

The Audio IDriver module implements the following interfaces

Function Name	Description
Audio_Instance_init	Function to create a new instance of the audio interface dynamically
Audio_open	Function to open a channel for data communication
Audio_submit	Function to transfer/receive data using a previously opened channel

Audio_control	Function to pass control commands to the audio device and codecs
Audio_close	Function to close a previously opened channel
Audio_Instance_finalize	Function to delete the audio interface driver instance.

1.10 Design Philosophy

This device driver is written in conformance to the DSP/BIOS IDriver model and handles communication to and from an Audio configuration (Audio device plus the codecs it is interfacing with).

1.10.1 The Module and Instance Concept

The IDriver model, conforming to the XDC framework, provides the concept of the *module and instance* for the realization of the device and its communication path as a part of the driver implementation.

The module word usage (Audio module) refers to the driver as one entity. Any detail, configuration parameter or setting which shall apply across the driver shall and thus shall configure the module behavior, shall be a module variable. However, there can also be module wide constants. For example, whether the function parameters need to be checked can be enabled or not can be selected by setting module wide variable “paramCheckEnable” and can be set by the application.

This instance word usage (Audio instance 1) refers to every instantiation of module due to a static or dynamic create call. Each instance shall represent an instance of device directly by holding info like the TX/RX channel handles, device configuration settings, hardware configuration etc. This is represented by the Instance_State in the Audio module configuration file.Hence every module shall only support the as many number of instantiations as the number of Audio devices hardware instances on the SOC.

2 AUDIO Driver Software Architecture

This section details the data structures used in the Audio IDriver module and the interface it presents to the Stream layer. A diagrammatic representation of the IDriver module functions is presented and then the usage scenario is discussed in some more details.

Following this, we’ll discuss the dynamic view of the driver where the driver operational scenarios are presented.

2.1 Static View

2.1.1 Functional Decomposition

The driver is designed keeping a device, also called instance, and channel concept in mind.

This driver uses an internal data structure, called channel, to maintain its state during execution. This channel is created whenever the application calls a Stream create call to the Audio IDriver module. The channel object is held inside the Instance State of the module. (This instance state is translated to the Audio_Object structure by the XDC frame work). The data structures used to maintain the state are explained in greater detail in the following *Data Structures* sub-section.

2.1.2 Data Structures

The IDriver employs the Instance State (Audio_Object) and Channel Object structures to maintain state of the instance and channel respectively.

In addition, the driver has two other structures defined – the device params and channel params. The device params structure is used to pass on data to initialize the driver during module start up or initialization. The channel params structure is used to specify required characteristics while creating a channel. For current implementation channel parameters only contain the channel parameters required by the individual audio device driver and the audio codec drivers.

The following sections provide major data structures maintained by IDriver module and the instance.

2.1.2.1 The Instance State (Audio_Object)

The instance state comprises of all data structures and variables that logically represent the actual instance. It preserves the input and output channels for transmit and receive, parameters for the instance etc.

Element Type	Element Name	Description
UInt8	instNum	Instance number of the audio interface driver
Audio_DriverState	devState	Status of the audio interface driver instance (created/deleted)
Audio_DeviceType	adDevType	Audio device type
String	adDevName	Audio device driver name in driver table
UInt8	acNumCodecs	Number of codecs in this instance
Channel_Object	ChanObj[NUM_CHANS]	TX and RX channel objects

2.1.2.2 The Channel Object

The interaction between the application and the device is through the instance object and the channel object. While the instance object represents the actual hardware instance, the channel object represents the logical connection of the application with the driver (and hence the device) for that particular IO direction. It is the channel which represents the characteristic/types of connection the application establishes with the driver/device and hence determines the data transfer capabilities the user gets to do to/from the device. For example, the channel could be input/output channel. This capability provided to the user/application, per channel, is determined by the capabilities of the underlying device. Per instance we have two channels, each for transmit and receive.

Element Type	Element Name	Description
Audio_DriverState	chanState	Channel status variable(opened /closed)
Ptr	aiAudioChanHandle	Channel handle for the audio device channel
UInt32	aiAudioCodecHandle [numCodecInstances]	Array holding the channel handles of all the audio codec driver channels
DriverTypes.DoneFxn	cbFxn	Callback function specified by the stream
UArg	cbArg	Argument to the call back function
Audio_ChannelConfig	aiChannelConfig	Structure holding the channel parameters

2.1.3 Channel Parameters(Audio_ChannelConfig)

This configuration structure is used to specify the audio interface driver channel initialization parameters. The audio interface driver can be opened in two modes (RX and TX). Hence there will be one channel parameters structures one for each channel (i.e. two channel parameter structures for each instance of audio interface).

The structure internally contains the channel parameters required by the audio device and the audio codecs. This structure needs to be supplied by the user during the opening of the audio interface channel or else the default values will be taken by the driver.

Element Type	Element Name	Description
Ptr	chanParam	Pointer to audio device channel configuration parameters
ICodec.ChannelConfig	acChannelConfig	Audio codec channel configuration data structures for all codecs

Table 1 Audio_Channelconfig

2.1.4 Audio_IoctlParam

The audio interface driver interfaces to multiple drivers. Hence an application will need to supply additional information (like the device to which the command is to be passed, the extra information required by the command etc) when using a control command on any device. This structure is used by the application to specify the additional information that will be required during an IOCTL command to the device. This data structure will carry the IOCTL command argument and the information about which device this command is addressed to etc.

Element Type	Element Name	Description
Audio_ModuleSel	aiModule	Device to pass the command to (Audio device / audio codec)
Uint32	codecId	Instance number of the codec(if aiModule is audio codec)
Ptr	ioctlArg	Pointer to command specific data

Table 2 Audio_IoctlParam

2.2 Audio Interface driver data types

This section describes the data types used by the audio interface driver.

2.2.1 Audio_DeviceType

The “Audio_DeviceType” specifies the type of audio device supported by the audio interface driver framework. This is used by the driver to identify the type of audio device it has to communicate with.

Enumeration Class	Enum	Description
Audio_DeviceType	Audio_DeviceType_McASP	Audio Device type is McASP.
	Audio_DeviceType_McBSP	Audio Device type is McBSP.
	Audio_DeviceType_VOICE_CODEC	Audio Device type is voice codec
	Audio_DeviceType_UNKNOWN	Audio Device type is unknown

Table 3 Audio_DeviceType

2.2.2 Audio_IoMode

The “Audio_IoMode” enumerated data type specifies the operational mode of the channel i.e. either transmission mode or reception mode.

Enumeration Class	Enum	Description
PSP_audiolfloMode	Audio_IoMode_RX	Audio Interface channel mode is RX
	Audio_IoMode_TX	Audio Interface channel mode is TX

Table 4 Audio_IoMode

2.2.3 Audio_ModuleSel

The “Audio_ModuleSel” enumerated data type specifies the device type i.e. it is an audio device or an audio codec. This is used in IOCTL function to find to which device the IOCTL is to be sent to (i.e. to the audio device or to the audio codecs).

Enumeration Class	Enum	Description
Audio_ModuleSel	Audio_ModuleSel_AUDIO_DEVICE	Audio Interface module is Audio Device
	Audio_ModuleSel_AUDIO_CODEC	Audio Interface module is Audio Codec

Table 5 Audio_ModuleSel

2.3 Dynamic View

2.3.1 Input / Output using Audio driver

In Audio driver, the application can perform IO operation using Stream_read/write() calls (corresponding IDriver function is Audio_Submit()). The handle to the channel, buffer for data transfer, size of data transfer and timeout for transfer should be provided.

The Audio module receives this information via Audio_submit. Here some sanity checks on the driver shall be done like valid buffer pointers, etc and then the io request is then routed to the underlying audio device driver which in turn will perform the hardware operations.

2.3.2 Functional Decomposition

The Audio interface driver, seen in the RTSC framework, has two methods of instantiation, or instance creation – Static and Dynamic. By static instantiation we mean, the invocation of the create call for the module in the configuration file of the application. This is called so because, the creation of the instance is at build time of the application. By dynamic instantiation we mean, the invocation of the create call for the module during runtime of the application.

The two types of instantiation of the module are handled in different ways in the module. The static instantiation of the module is handled in the module script file, and the dynamic instantiation is handled in the C file.

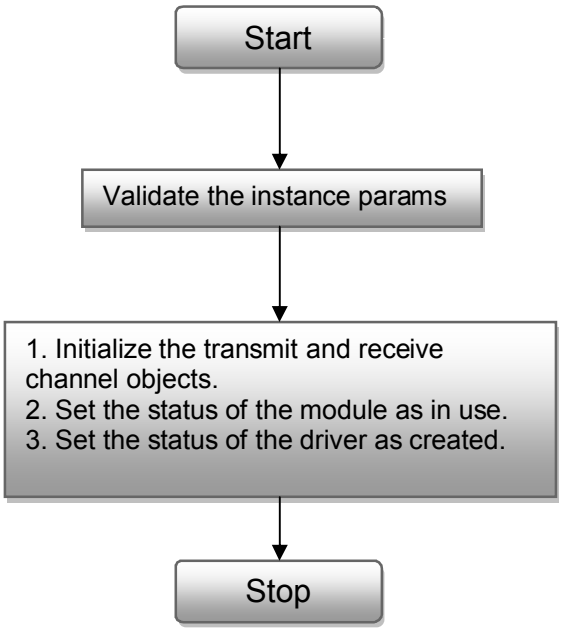
This design concept explained in the sections to follow.

2.3.2.1 instance$static$init of XS file

This function is called during the creation of a context statically. The user specified parameters will be updated to the audio interface driver data strutures.

Note: The instance params provided by the applications (from the CFG file) would override the default value of those parameters from XDC file.

Figure 3 instance$static$init() flow diagram



2.3.2.2 Audio_Instance_init()

The instance init function is called when the module is dynamically instantiated. This is the only context available for initialization per instance, when doing dynamic (application C file during run time) instantiation. Hence, this function should be including all the initialization done in the instance static init in the module script file and the module startup function. The return, value of this function represents the extent to which the instance (and hence its resources) were initialized. For example, we could use return value of 0 for complete (successful) initialization done, return value of 1 for failure at the stage of a resource allocation and so on. This return value is preserved by the RTSC/BIOS framework and passed to the Instance_finalize function, which does a clean up of the driver during instance removal accordingly.

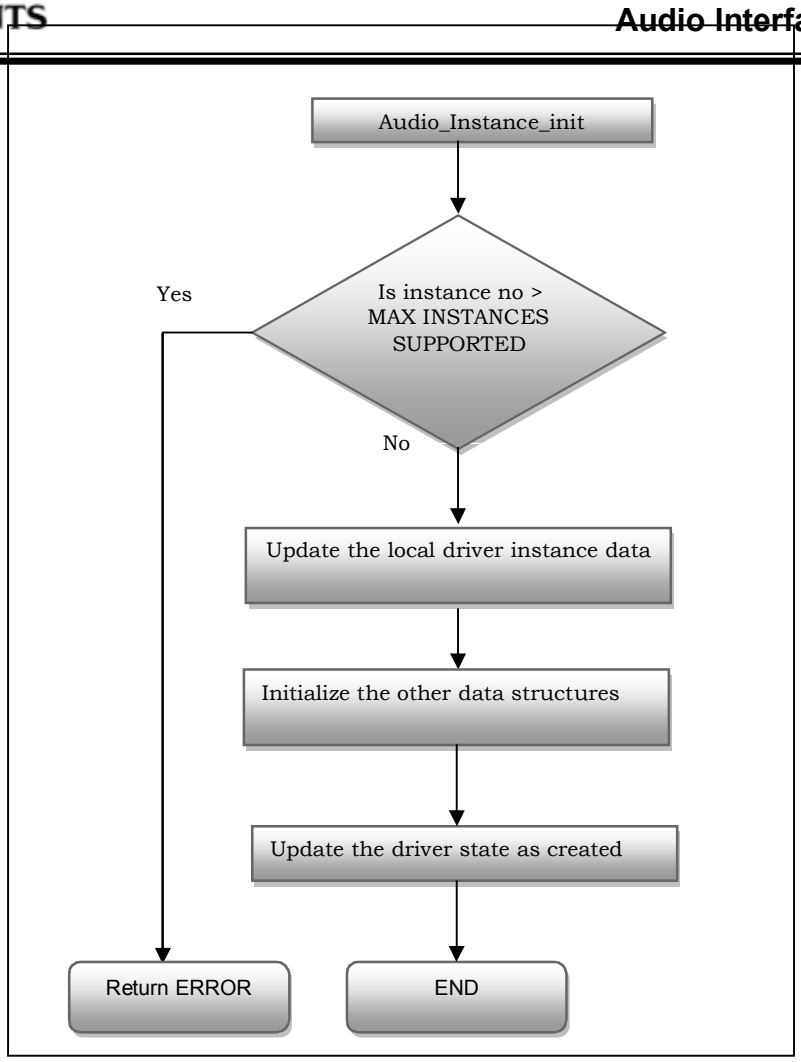


Figure 4 Audio_Instance_Init() flow diagram

2.3.2.3 *Audio_Instance_finalize()*

The instance finalize function does a final clean up before the driver could be relinquished of any use. Here, all the resources which were allocated during instance initialization shall be unallocated. After this the instance no more is valid and needs to be reinitialized. Please note that the input parameter for this function is the initialization status returned from the instance) init function. This helps in de-allocation of resources only that were actually allocated during instance_init.

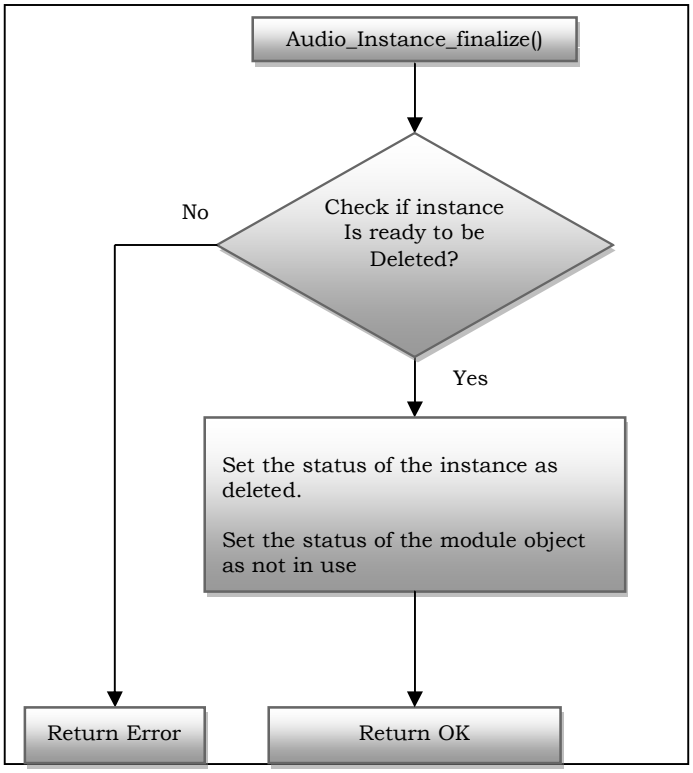


Figure 5 Audio_Instance_initialize control Flow

2.3.2.4 *Audio_open()*

The Audio_open function opens a channel which can be used for transmitting or receiving the data. The channel can be opened only in the TX mode or RX mode but not both.

This function is called in response to the “stream_create” function called by the Application. The IDriver translates the stream call to this function.

The open function call tries to open a data transaction channel in the requested mode i.e. (either TX or RX).if it is successful in creating a channel, this API returns a channel handle. This channel Handle is to be used by the channel for all further communications by the channel (e.g. IO request submission, IOCTL submission etc).

Internally the Function performs the following things. It validates the data provided by the application. Once the data is validated the audio driver then loops through all the audio codecs requested to be opened by the application. It uses the name of the audio codec driver to match the driver from the driver table and get the driver handle. If a matching driver is found the audio interface then uses the handle to open the audio codec channel with the data provided by the application in the “chanParams”. if a matching driver is not found or the opening of the channel fails then the audio driver returns an Error code to the stream.

Once all the required codecs are opened successfully then the audio driver then tries to match the audio device name in the driver table. On successful match it uses the driver handle to open the channel to the audio device.

Once the audio device is successfully opened then the audio driver updates the status of the current channel to opened and then returns the handle to the audio channel to the stream which will be used by the application in further communications with the channel.

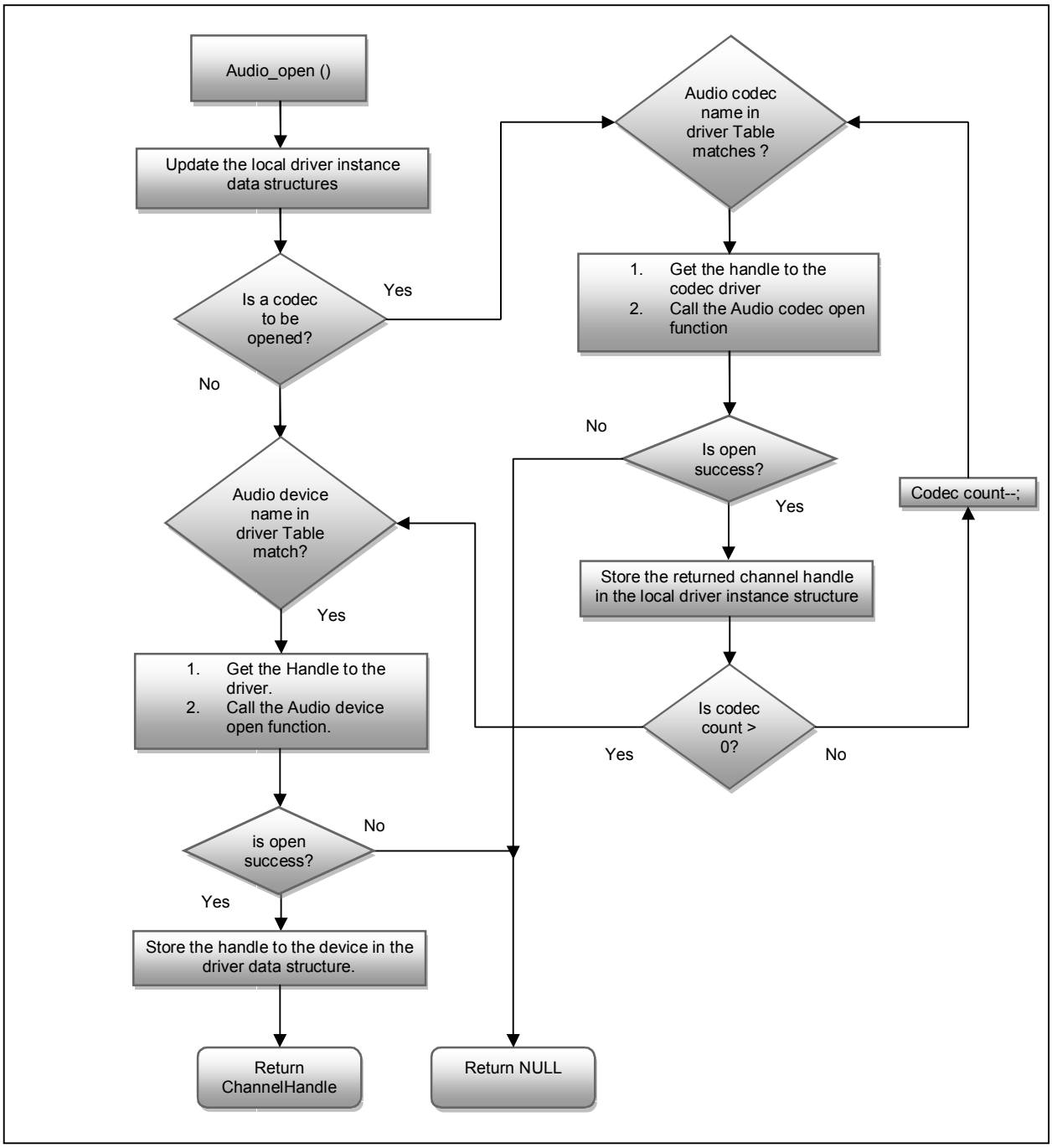


Figure 6 Audio_open () control flow

2.3.2.5 *Audio_close()*

The application uses a logical channel for transacting with the driver. The application has to open the channel for transaction before using it. Once the application has completed all the transactions and does not want to use the channel for any more transactions, it can close the channel. The application needs to call the function “Stream_delete” so that the channel can be deleted.

Once the channel is closed, it is no longer available for the transactions. If required the channel can be opened by using the “Audio_open” function.

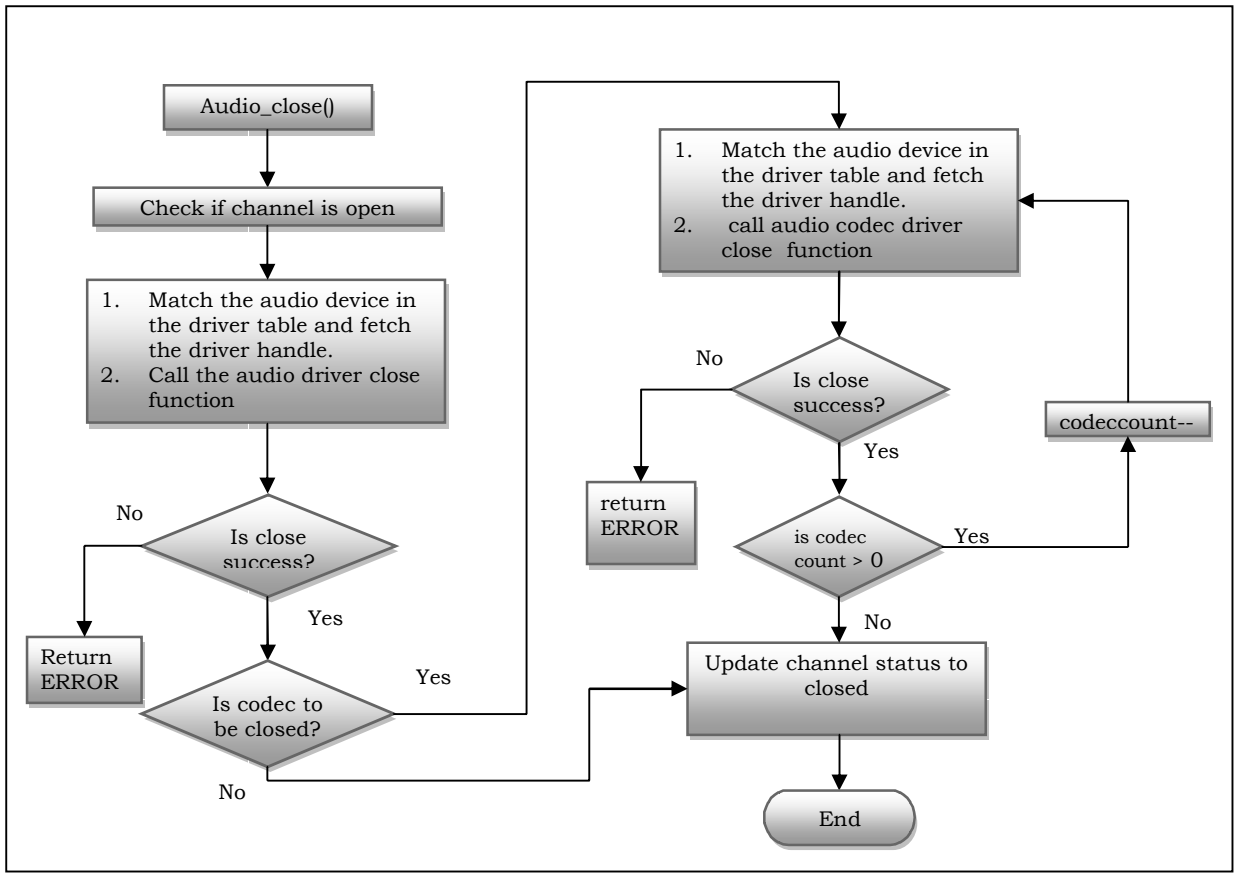


Figure 7 Audio_close() flow diagram

2.3.2.6 Audio_control()

The Audio_control function provides an interface for the application to pass control commands to the audio device and the audio codecs.

In the audio interface driver, the driver is controlling multiple devices like the audio device (McASP or McBSP) and various number of codecs. The application may be trying to pass the control command to any one of these devices. Hence the control command requires a special structure to be passed along with the command, which will allow the driver to identify the device to which the control command has to be routed.

The “stream_control” function called by the application translates to the “Audio_control” function in the IDriver. When a control command is received by the audio interface, it interprets the “Audio_IoctlParam” structure to find the device type to which the command is addressed.

If the device to be controlled is Audio device then the audio driver matches the driver name in the driver table and then retrieves the handle to the driver. Then using the handle, the control function of the audio device driver is called.

If the device to be controlled is an audio codec then the audio driver matches the driver name in the driver table. If the match is not found then an error is raised. If a match is found then the audio driver retrieves the handle to the driver and uses this handle to call the control function of the appropriate audio codec driver.

Note: It should be observed that the user’s IOCTL request completes in the context of calling thread i.e., application thread of control.

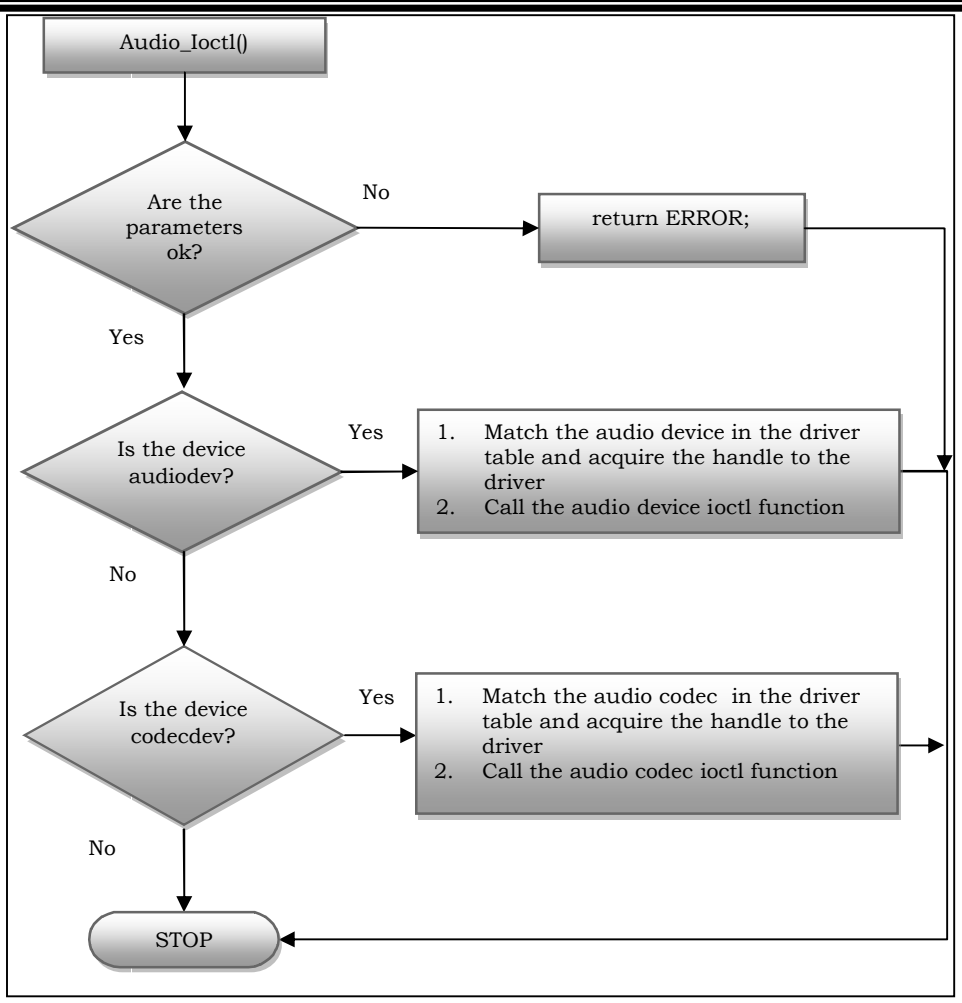


Figure 8 Audio_control () control Flow

2.3.2.7 Audio_submit()

The application invokes the Audio_submit () to submit a data receive or transmit request to the audio device. Since the audio codec drivers does not support any data transfer request from the user, all the io transfer request commands will be routed to the audio device only.

Although the audio interface driver by inheritance of the IDriver module should be an asynchronous driver, the audio driver's mode of working (sync/async) is directly dependent on the underlying drivers it interfaces with. Hence if the underlying audio device driver is working in synchronous mode, then the audio driver will also be in synchronous mode and vice versa.

Note: please note that the audio driver never routes any IO requests to the audio codecs as the audio codec drivers do not handle any data transfer requests from the application.

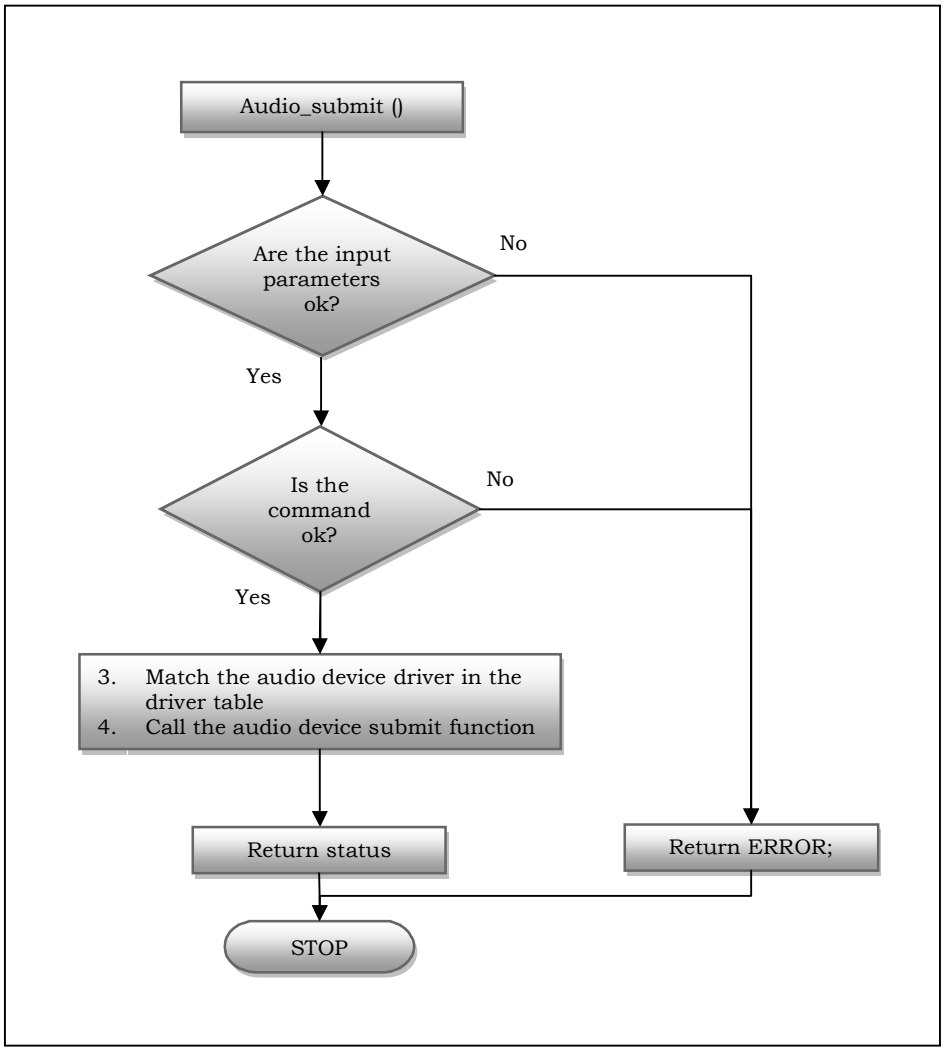


Figure 9 Audio_submit control flow

3 IOCTL commands

The application can perform the IOCTLs on any of the devices interfaced by the audio interface driver. Please refer to the individual driver guide for the IOCTLS supported by them. Please refer to the Audio_control () section to send a control command to an underlying device.

S.No	IOCTL Command	Description
1	Audio_IOCTL_SAMPLE_RATE	IOCTL to configure the sample rate for the audio configuration (both the audio device and the codec).