Developing *Bluetooth*® Audio Devices

Topics

- *Bluetooth* Technology Intro
- *Bluetooth* Audio Profiles
- *Bluetooth* Audio Codecs
- Application Connectivity
- NFC Pairing
- Licensing
- iOS Device Considerations
- Android Device Considerations
- Developing a Bluetooth Audio Device with Bluegiga WT32i Bluetooth Audio Module
- More Information
- Questions and Answers

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Bluetooth Technology Intro

- *Bluetooth*® technology is the global wireless standard enabling:
  - Convenient, secure connectivity technology for range of devices
- Created by Ericsson in 1994 and originally meant as a wireless alternative to RS-232 data cables to exchange data over short distances using radio transmissions.
- Bluetooth operates in the unlicensed industrial, scientific and medical (ISM) band at 2.4 to 2.485 GHz, using a spread spectrum, frequency hopping, full-duplex signal at a nominal rate of 1600 hops/sec.
- The 2.4 GHz ISM band is available and unlicensed in most countries

Bluetooth Technology Intro

- Three main versions exists today:
  - *Bluetooth* BR/EDR (*Bluetooth* classic)
    - This is *Bluetooth* as we mostly know it today
  - *Bluetooth* low energy (*Bluetooth* Smart / Bluetooth 4.0)
    - Ultra low power version of *Bluetooth* meant for low power sensors and accessories
    - Not suitable for audio today
  - *Bluetooth* High Speed Technology
    - Bluetooth meant for high speed data transmission
    - Not very well adopted
- Applications covered by *Bluetooth*
  - Cable replacement
  - Headset and hands-free kits
  - Stereo audio devices
  - Keyboards and mice
  - Health, medical and sports sensors

Bluetooth Technology Intro

- **Features of *Bluetooth* technology**
  - Frequency 2.4GHz
  - Typically 10-100 meters range
  - Very interference tolerant because of adaptive frequency hopping (AFH) capability
  - Reliable
  - Secure – support authentication, authorization and encryption
  - Low power
  - Interoperable

- **Very well adopted**
  - Windows
  - Linux
  - Apple iOS and OSX
  - Android

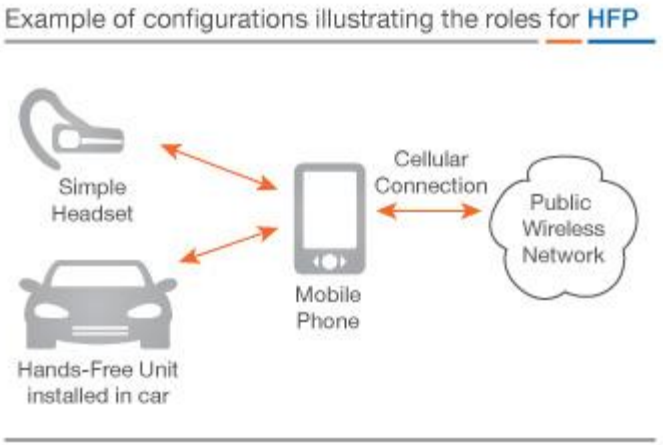
- Standard maintained and developed by Bluetooth SIG

Bluetooth Technology Intro

- ***Bluetooth* for Audio Applications**
  - Most adopted standard for wireless audio transmission
    - AirPlay for example only works with Apple devices
  - Supports voice (8 and 16kHz)
  - High quality stereo audio (up to 48kHz)
  - Multiple profiles exist for audio transmission
  - Application connectivity
  - Low power
  - Relatively low cost

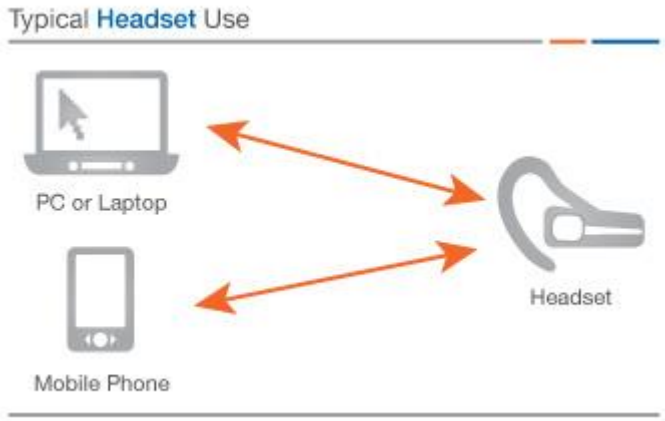
Bluetooth Audio Profiles

- **Hands-Free Profile (HFP)**
- Enables voice transmission from for example a mobile phone to a wireless headset
- Audio transmitted over a synchronous SCO channel and a separate data channel used for controlling the audio stream (AT commands)
- **Features**
  - Mono audio
  - Sampling rates from 8 to 16kHz
  - Typical audio delay 20-30ms
  - Uses CVSD (8kHz) and alternative mSBC (16 kHz) (in HFP v.1.6) audio codecs
  - AT commands can be used for example to control the mobile phone and accept/reject calls dial numbers etc.
- Specification



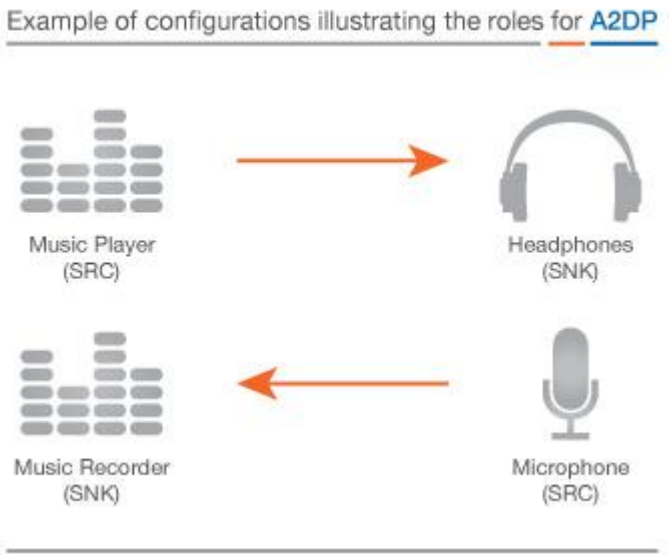
Bluetooth Audio Profiles

- **Headset Profile (HSP)**
- Enables voice transmission from for example a mobile phone to a wireless headset
- Audio transmitted over a synchronous SCO channel
- Mostly made obsolete by HFP profile, but still supported by some legacy devices
- **Features**
  - Mono audio
  - 8kHz sampling rate
  - Typical audio delay 20-30ms
  - Uses CVSD (8kHz) audio codec
- Specification



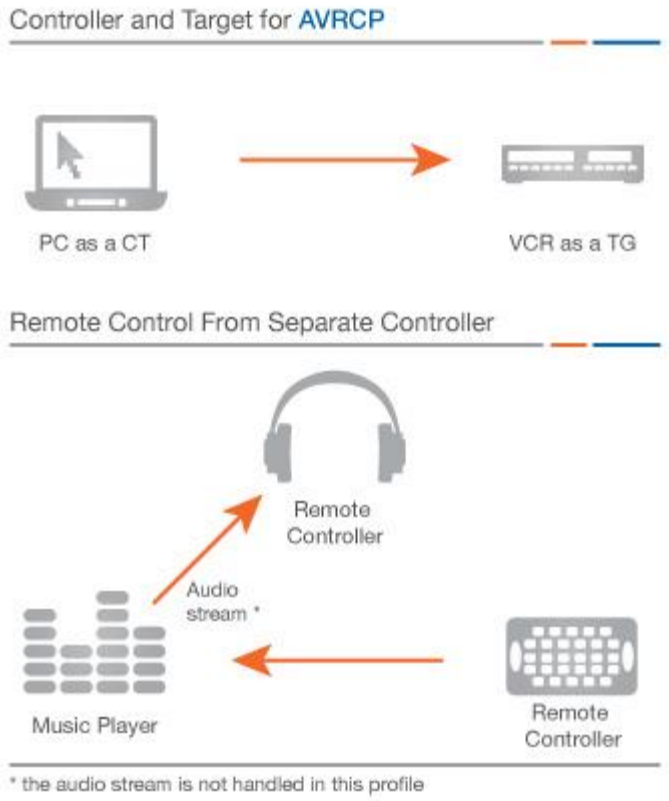
Bluetooth Audio Profiles

- **Advanced Audio Distribution Profile (A2DP)**
- Enables stereo audio streaming for the music player (source) to headphones or speakers (sink)
- Audio transmitted over ACL data channel and a separate control channel used for controlling the stream
- **Features**
  - Mono or stereo audio
  - Sampling rates from 16 to 48kHz
  - Bit rates from 127kbps to 345kbps
  - Typical audio delay 100-200ms
  - Uses SBC audio compression algorithm
  - Alternative optional audio codecs can be used and most common are
    - aptX
    - Advanced Audio Coding (AAC)
- Specification



Bluetooth Audio Profiles

- **A/V Remote Control Profile (AVRCP)**
- Enables the audio sink to control the audio sources music player and streaming status
- Uses a data channel to transmit the control information between the audio controller and the target
- AVRCP v.1.5 enables also advanced features like media browsing, audio player and playlist management
- **Features**
  - Enables audio stream status control (Play, Pause, Stop)
  - Enables transmission of track, title and other media information
  - Indications of streaming status and track changes
  - Content browsing (Albums, Artists, songs etc.)
  - Content searching
  - Audio player management
  - Playlist management (add/remove songs, now playing)
- Specification

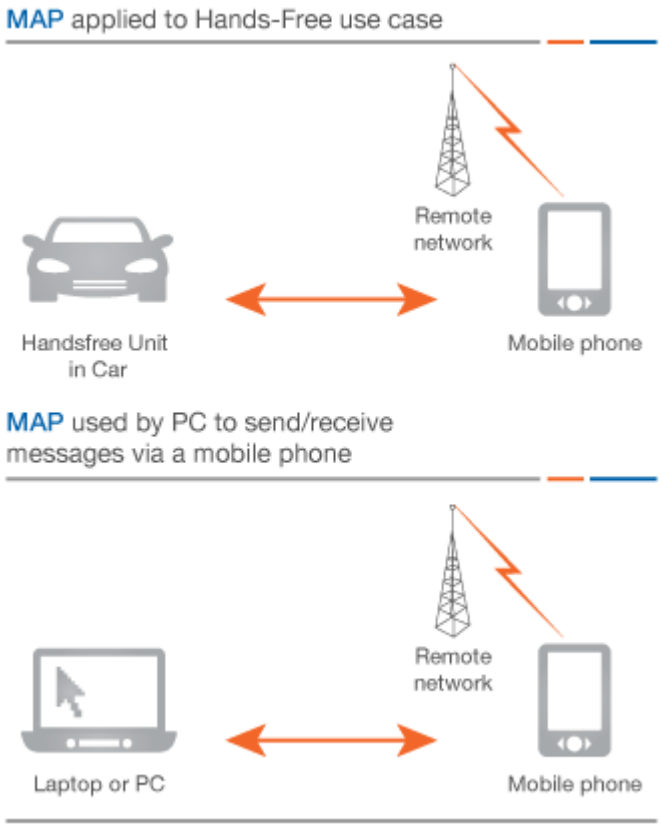


Bluetooth Audio Profiles

- **Phone Book Access Profile (PBAP)**
- The PBAP profile enables the exchange of phone book objects between for example a smart phone and a car kit
- Uses a data channel to transmit vCARDs over a Bluetooth connection
- **Features**
  - Download phone book items
  - Access call history
  - Access subscriber number information
- Specification

Bluetooth Audio Profiles

- **Message Access Profile (MAP)**
- The MAP profile enables the exchange of messages between for example a smart phone and a car kit
- Uses a data channel to transmit SMS and email notifications and messages over *Bluetooth*
- **Features**
  - New SMS and email notifications
  - Browsing message folders
  - Downloading messages
  - Uploading messages
- Specification



Bluetooth Audio Codecs

- **SBC**
  - Low complexity Sub-band Coding
  - Provides reasonably good audio quality at medium bit rates while keeping low computational complexity
  - Only Mandatory codec that must be supported for A2DP

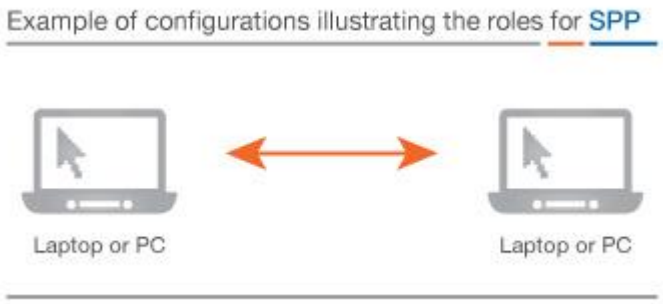
- **mSBC**
  - a 16 kHz monaural configuration of the SBC codec
  - Used by Hands-Free Profile v.1.6
  - Also often called Wide Band Speech(WBS)
  - Developed to support mobile networks with HD voice

- **aptX®**
  - A higher quality alternative to SBC codec used in A2DP
  - Adopted to many Android platforms like Samsung Galaxy S-series and also Apple OSX devices
  - Device list

- **Advanced Audio Coding (AAC)**
  - A higher quality alternative to SBC codec used in A2DP
  - Adopted by Apple to iOS devices

Application Connectivity

- ***Bluetooth* also allows wireless data transmission between devices**
  - Enables for example enhanced features for audio devices
  - Audio accessories can for example be controller from a smart phone application
    - Firmware updates
    - Changing settings
    - etc.



- **Serial Port Profile**
  - SPP defines how to set up virtual serial ports and connect two *Bluetooth* enabled devices for transparent data transmission
  - Supported by Android, Windows and Linux devices
  - Data rates typically 0 – 500 kbps

- **Apple iAP Profile**
  - Apple's alternative to SPP profile
  - Enables data transmission between iOS devices and accessories
  - Has advanced features like automatic application download and launch
  - Available only to MFI (Made for iPhone) licensees

NFC Pairing

- **Near Field Communication (NFC)**
  - **NFC** is a set of standards for smart phones and other devices to establish radio communication with each other in close proximity - usually within one or two inches
  - NFC has built-in support to initiate a *Bluetooth* paring procedure and connection establishment

- **How to do NFC pairing?**
  - Simplest way is to program a low cost NFC tag (f.ex. sticker) with the unique information of the *Bluetooth* device:
    - MAC address
    - Supported services (f.ex. A2DP, HFP etc.)
  - Sticker can be easily placed into the product into an easily accessible location
  - Touch the tag with NFC enabled smart phone and the pairing and connection sequence will be started
  - Program the tags on the production line with the Bluetooth devices unique MAC address

- **Supported platforms**
  - NFC enabled Android and Windows phones
  - NFC not supported by Apple iOS devices

Licensing

- **MFI – Made for iPhone**
  - You need to be part of Apple MFI program to access the iAP technology
  - Sign up at: https://developer.apple.com/programs/mfi/
  - End product needs to be tested and approved by Apple

MFi Program

- **aptX Audio Encoder/Decoder**
  - $6000 technology trasfer fee (TTF) to CSR
  - End product needs to be qualified by CSR
  - License fee @ 1 – 10k units: ~$1

- **AAC Audio Decoder**
  - AAC needs a separate license: http://www.vialicensing.com/licensing/aac-fees.aspx
  - $15000 one-time fee
  - License fee for first 1 to 500k units: $0.98

VIA LICENSING®

iOS Device Considerations

- **Supported *Bluetooth* Profiles**
  - HFP v.1.6
  - A2DP
  - AVRCP v.1.4
  - PBAP
  - MAP (SMS notifications only)
  - iAP
  - Link
- **Supported Audio Codecs**
  - SBC
  - AAC (iOS6 and newer)
  - mSBC
- **Application Connectivity**
  - No support for SPP – iAP supported instead
  - You do not need to be part of MFI in order to develop *Bluetooth* Apps for iOS
  - Device must be reviewed and approved by Apple
- **A2DP and iAP in same device**
  - If the device implements both A2DP and iAP Apple mandates that AAC is used

Android Device Considerations

- **Supported *Bluetooth* Profiles (Android 4.4)**
  - HFP v.1.6
  - HSP v.1.2
  - A2DP
  - AVRCP v.1.3
  - PBAP
  - MAP (SMS notifications only)
  - SPP
- **Supported Audio Codecs**
  - SBC
  - aptX (Not by all devices)
  - mSBC
- **Application Connectivity**
  - SPP supported
  - No licensing unlike with Apple, but the platform is open
- **Android market is fairly fragmented**
  - Devices on the market have 2.x, 3.x and 4.x, so profile and feature support will vary

Developing a *Bluetooth* Audio Device

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Developing a *Bluetooth* Audio Device

- In this section we describe the some design considerations and tips that need to be taking into account when designing Bluetooth Audio devices
  - **1st:** Short introduction of WT32i *Bluetooth* Audio Module
  - **2nd:** Short introduction of iWRAP6 *Bluetooth* Software
  - **3rd**: RF & Hardware Design Tips
  - **4th**: Software Design and Development

WT32i Key Features

- ***Bluetooth* 3.0 compliant**
- **Excellent Radio Performance**
  - Transmit power: +6.5 dBm
  - Receiver sensitivity: 90 dBm
  - Link budget: 96.5 dB
  - Chip antenna or U.FL connector
- **Audio Features**
  - Integrated DSP
  - 16-bit stereo codec
  - 44.1kHz ADC, 48kHz DAC
  - Analog, I2S, PCM, SPDIF, and microphone interfaces
- **Integrated Battery Charger**
  - Tri-state charger
  - Support Li-Ion and Li-Poly up to 4.2V
  - Configurable charging current
- **Operating Voltage**: 1.8V to 3.6V
- **Temperature Range**: -40C to +85C
- ***Bluetooth*, CE, FCC, IC, Korea and Japan Qualified**

WT32i Specifications

- **Host Interfaces**
  - UART with hardware flow control
  - Up to 921kbps
- **USB**
  - Charging support
- **I2C**
  - Software I2C support
  - Can for example connect to Apple authenticaton chip or external audio codec
- **GPIO**
  - 10 software configurable GPIO pins
- **ADC**
  - 2 x 10-bit ADC
- **Led Driver**
  - Indicates battery charger status
- **Firmware Programming Interface**

WT32i Specifications

- **Differential Analog Audio Interfaces**
  - Built-in 16-bit stereo codec
  - 95 dB SNR
  - Dual ADC upto 44.1 kHz
  - Dual DAC up to 48kHz
  - Microphone input with internal bias
- **Digital Audio Interfaces**
  - I2S
  - SPDIF
- **Integrated DSP**
  - Audio encoding
  - Audio deconding
  - CVC audio enhancement
    - Noise supression
    - Packet loss concelment
    - Echo cancellation

WT32i Current Consumption

WT32i current consumption @ 3.3V

- **TX Peak**
  75 mA
- **Idle Mode (No connections)**
  2.1 to 2.3 mA
- **Connected, not streaming**
  2.5 to 5 mA
- **A2DP Streaming**
  ~28 mA
- **Deep Sleep:**
  80 uA

Range

DKWT32i range against iPhone4 and Samsung S4 phones were tested with the setup shown in Figure 1 by placing the phone 1.5 meter above ground.

Figure 6: DKWT32i vs iPhone

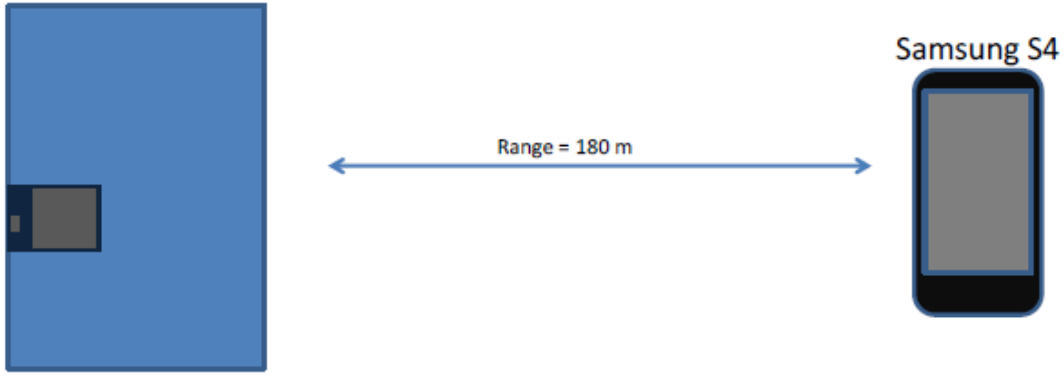
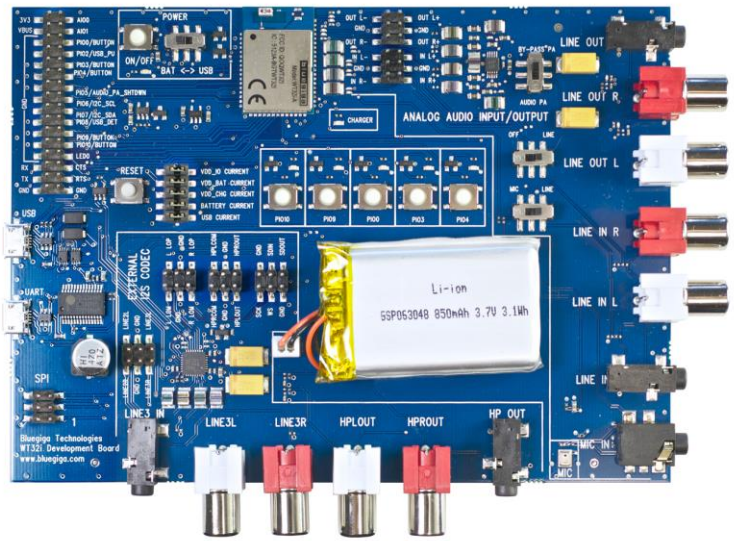


Figure 7: DKWT32i vs Samsung S4

Development Tools



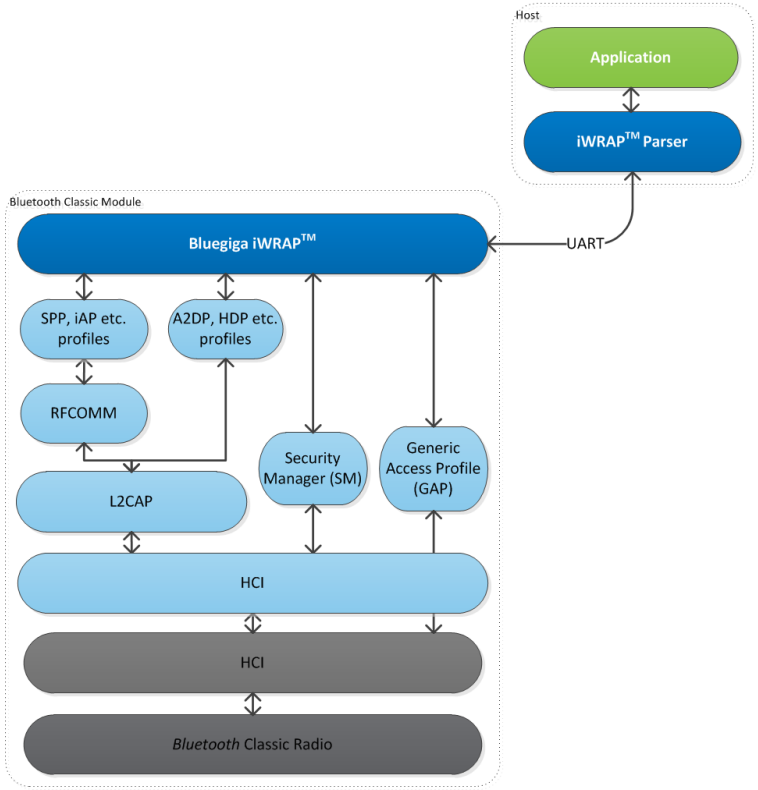
- **WT32i Development Kit**
  - WT32i-A Bluetooth Module
  - 850mAh Li-Ion battery
  - 3.5mm and RCA audio input and output jacks for stereo and mono audio
  - Built-in SMD microphone
  - External I2S audio codec and Headphone Amplifier
  - USB and UART-to-USB interfaces
  - 5 buttons and leds
  - Programming interface
  - Current measurement point
  - I/O headers
  - I2C extension connector

  + Firmware programming tools
  + USB cable

- **iWRAP6 *Bluetooth* Software**
  - iWRAP™ API documentation
  - A2DP, AVRCP, HFP, PBAP etc. profile application notes
  - iAP example application for iOS

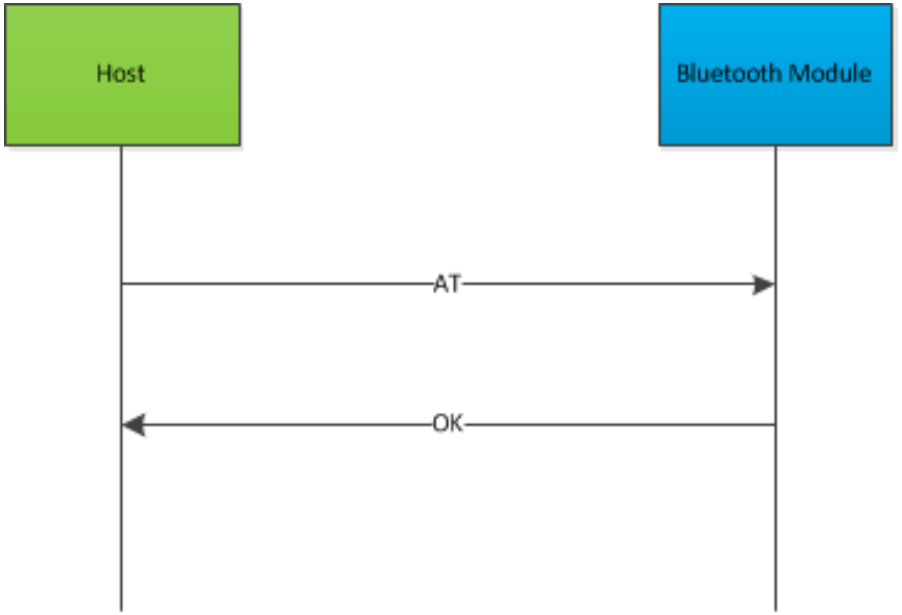
iWRAP™ *Bluetooth* Software

- ***Bluetooth 3.0* compliant**
  - Up to 6 simultanous connections
  - 500+ kbps througput over SPP
- **Inplements 13 *Bluetooth* profiles**
  - **Audio**: A2DP, AVRCP v.1.5, HFP v1.6, HSP, PBAP and MAP
  - **Data**: SPP, OBEX and HID
- **Apple iAP1 and iAP2 Profiles**
  - Provides application connectivity to Apple iOS devices
- **iWRAP API for external host processors**
  - ASCII ”AT-like” commands over UART
- **aptX, AAC, SBC and mSBC Audio Codecs**
  - Wide Band Speech
  - aptX support for Android and OSX
  - AAC support for iOS devices
- **Field Upgradable**
  - DFU over UART support



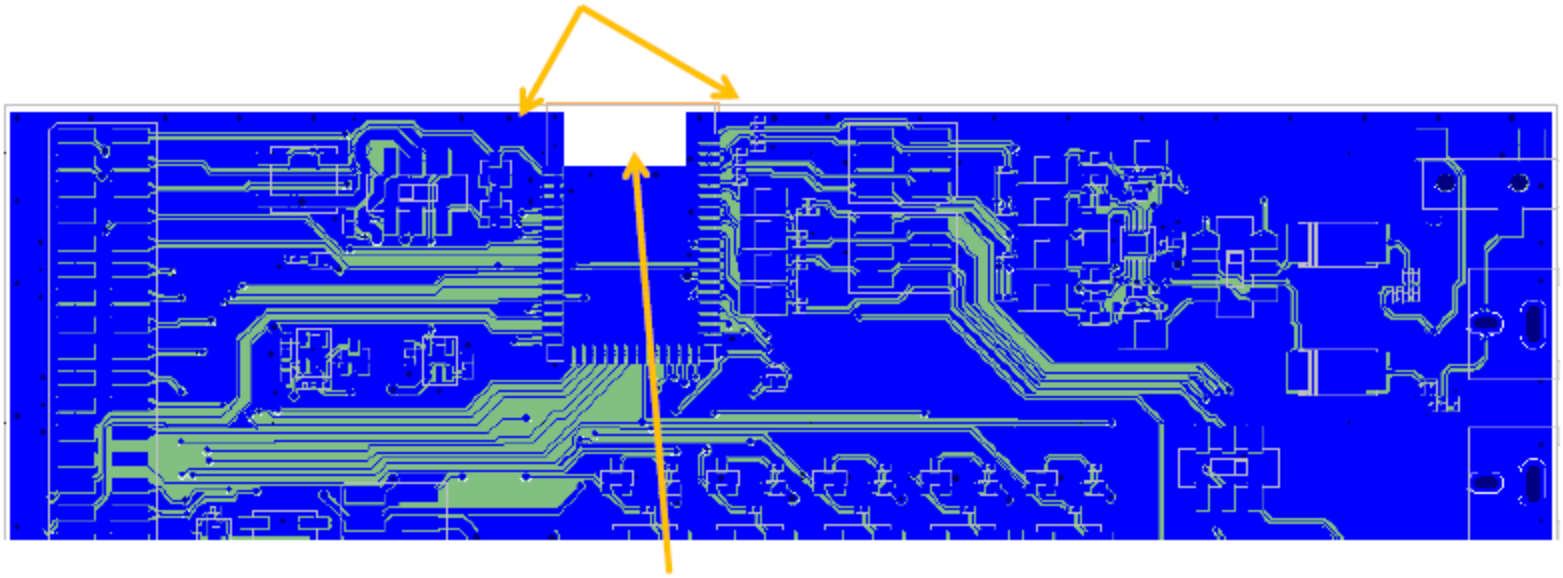
iWRAP™ Software

- **iWRAP™ protocol** : A simple ASCII based (AT like) command, response and event protocol between the host and the stack
  - Used when a separate host (MCU) is used to control WT32i over UART



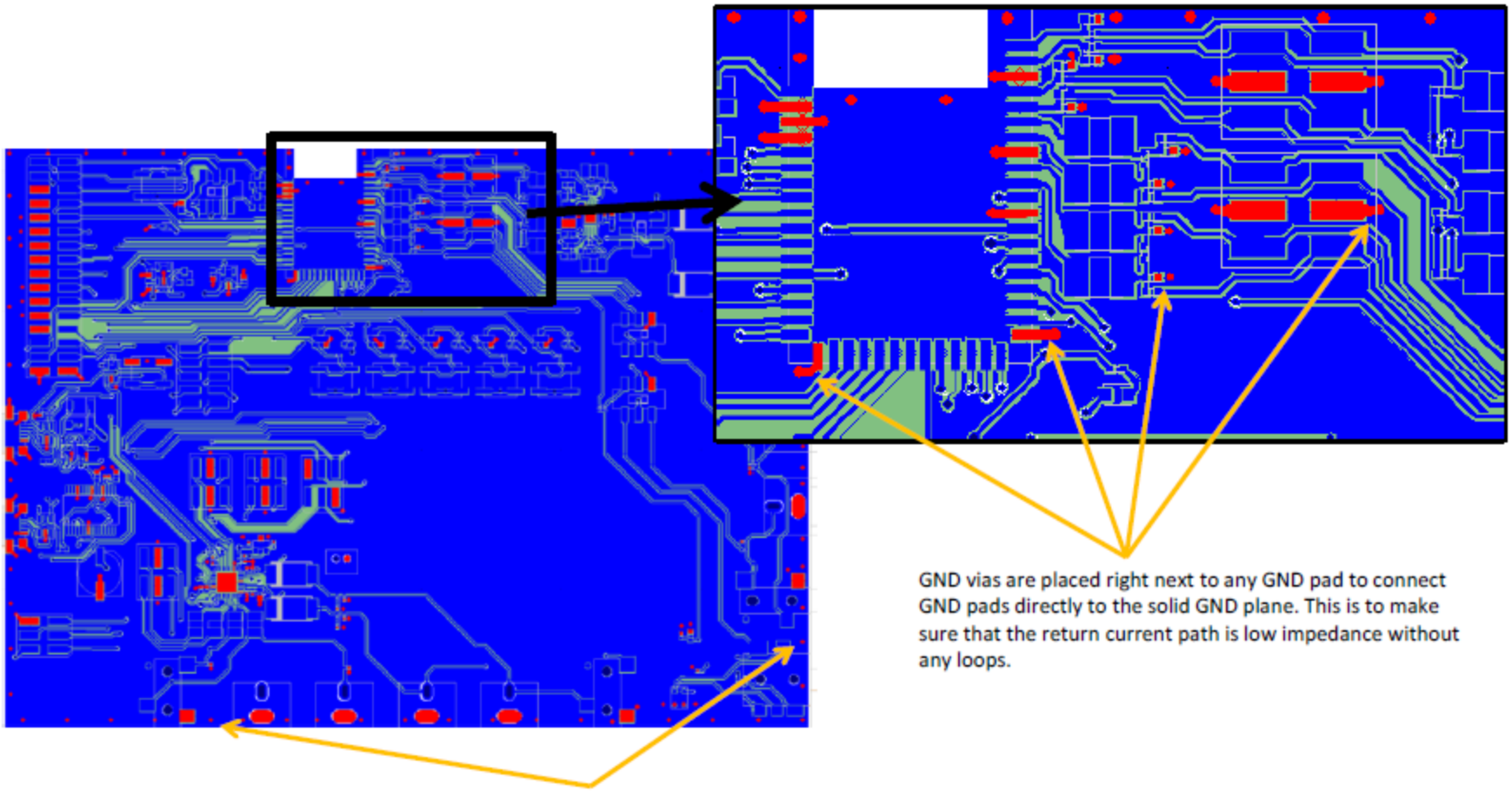
RF Design with WT32i

GND plane is required on both sides of the Antenna. The antenna uses the GND plane as a part of radiator and the lack of GND plane will signifficantly reduce the performance.

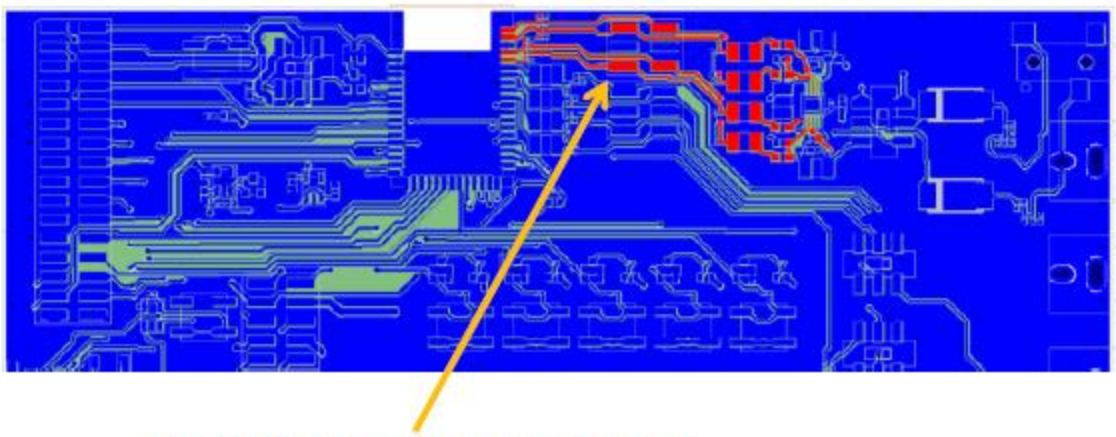


Metal clearance area under the antenna.
Antenna placed at the edge of the PCB.

Hardware Design with WT32i



Hardware Design with WT32i



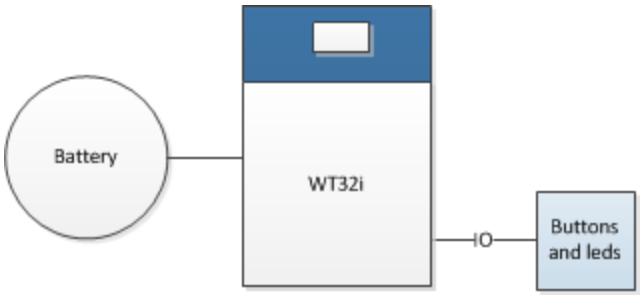
Differential audio signals are traced parallel to make sure they have perfect common mode rejection . All the audio traces are routed on a solid GND plane.

Single ended design can also be made, but it's much more sensitive to noise and interference

4 layer PCB recommended if single ended design is made

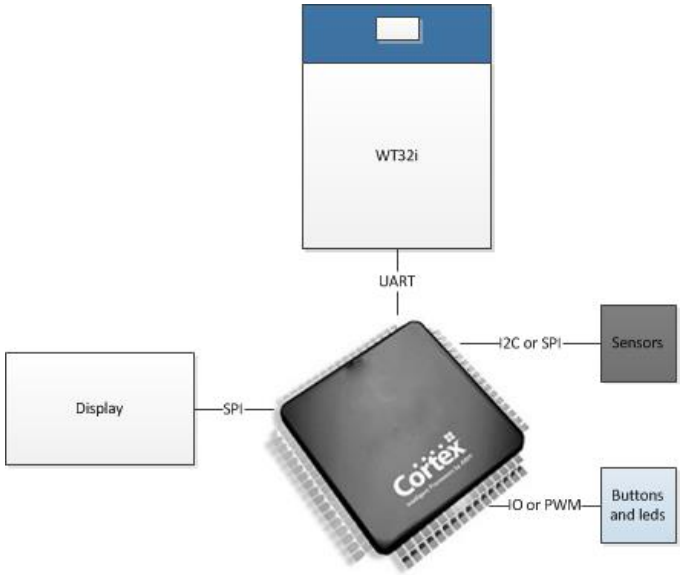
Use Cases

- **Standalone architecture**: No separate host processor
  - Simple devices can be made without a host controller
  - iWRAP can be preconfigured to accept pairings, connections and reconnect automatically
  - Simple button presses and led indications can also be preconfigured



Use Cases

- **Hosted architecture**: A separate MCU is used
  - Allows more complex devices to be made f.ex. multiple connections, PBAP and MAP usage and application connectivity
  - WT32i connected to the MCU via UART
  - iWRAP's ASCII protocol used to communicate with the WT32i over UART



AT command can be used to check the communication with iWRAP over UART works. OK response inducates the communication is OK.

```
AT

OK
```

To discover other *Bluetooth* device you can issue "**INQUIRY**" command to iWRAP as a parameter you give the inquiry time in units of 1.28 seconds. iWRAP will perform the inquiry and output the list of discovered devices.

```
INQUIRY 1

INQUIRY_PARTIAL 00:14:a4:8b:76:9e 72010c
INQUIRY 1
INQUIRY 00:14:a4:8b:76:9e 72010c
```

In order to initiate pairing process form iWRAP can issue “**PAIR**” command from iWRAP and you need to give the MAC address of the remote device as a parameter.

```
PAIR 54:72:4f:90:a9:f8

PAIR 54:72:4f:90:a9:f8 OK
```

In order to initiate a connection process to another device you need to issue a “**CALL**” command from iWRAP. As connection parameters you need to give the MAC address the L2CAP psm or RFCOMM channel and the profile to connect to.

```
CALL 54:72:4f:90:a9:f8 19 A2DP

CALL 0
CONNECT 0 A2DP 19
CONNECT 1 A2DP 19
A2DP STREAMING START 0
```

In order to enable/disable Bluetooth profiles the SET PROFILE command is used.
Whenever the profile configuraton is changed a resre tis needed to update the service database.

```
SET PROFILE HFP Hands-Free
SET PROFILE HSP ON
SET PROFILE A2DP SINK
SET PROFILE AVRCP CONTROLLER
SET PROFILE SPP Bluetooth Serial Port
SET PROFILE PBAP ON
```

To enable/disable the audio codecs and configure them the SET CONTROL CODEC command needs to be used. The last parameter indicates priority and smaller number indicates higher priority.

```
SET CONTROL CODEC AAC JOINT_STEREO 44100 0
SET CONTROL CODEC APT-X JOINT_STEREO 44100 1
SET CONTROL CODEC SBC JOINT_STEREO 44100 2
```

Software Design & Development

Most common settings, that need to be configured for a Bluetooth audio device

SET BT NAME DKWT32i	Local device's name
SET BT CLASS 240428	Class-of-Device (device type) setting
SET BT AUTH * 0000	PIN code for legacy Bluetooth pairing
SET BT LAP 9e8b33	Inquiry access code
SET BT PAGEMODE 4 2000 1	Visibility and connectability configuration
SET BT POWER 6 6 6	Default, maximum and inquiry TX power settings
SET BT ROLE 0 f 2580	*Bluetooth* role settings
SET BT SNIFF 0 20 1 8	Sniff power saving mode settings
SET BT SSP 3 0	*Bluetooth* Secure Simple Pairing configuration
SET CONTROL AUDIO INTERNAL INTERNAL EVENT AA9	Audio interface routing and stream indication IO
SET CONTROL BAUD 115200,8n1	Local UART settings
SET CONTROL CODEC SBC JOINT_STEREO 44100 1	A2DP codec settings for SBC codec
SET CONTROL GAIN 8 8	ADC and DAC gain settings
SET CONTROL MICBIAS 8 2	Microphone bias and voltage settings
SET CONTROL PREAMP 1 1	Audio pre-amplifier settings
SET CONTROL VREGEN 2 02	Internal regulator configuration Enables ON/OFF button on DKWT32i

Advanced configuration options

SET BT SCO	This command sets the SCO parameters used for (regular) CVSD and MSBC connections.
SET CONTROL BATTERY	Enables low battery warnings and automatic shutdown
SET CONTROL EXTCODEC	Enables external I2S audio codec configuration over I2C
SET CONTROL VOLSCALE	HFP volume scale control
SET CONTROL BIND	Binds iWRAP commands to IO pins

Using profiles like HFP, AVRCP, PBAP and MAP

LIST

LIST 3
LIST 0 CONNECTED A2DP 672 0 0 522 0 0 54:72:4f:90:a9:f8 19 OUTGOING ACTIVE MASTER ENCRYPTED 0
LIST 1 CONNECTED A2DP 672 0 0 522 0 0 54:72:4f:90:a9:f8 19 OUTGOING ACTIVE MASTER ENCRYPTED 0
LIST 2 CONNECTED AVRCP 672 0 0 517 0 0 54:72:4f:90:a9:f8 17 INCOMING ACTIVE MASTER ENCRYPTED 0

SET 2 SELECT

AV PLAY
A2DP STREAMING START 0

AV PAUSE
A2DP STREAMING STOP 0

More Information

- WT32i documentation, manuals, applicattion notes and firmware:
  - iWRAP User Guide
  - HFP and HSP Application Note
  - A2DP and AVRCP Application Note
  - PBAP and MAP Application Note
  - iAP Application Note available separate for MFI licensees
  - All documents

- Bluegiga
  - www.bluegiga.com
  - www.bluegiga.com/support

- *Bluetooth* SIG
  - www.bluetooth.org
  - www.bluetooth.com

More Information

- iOS Development
  - iOS Dev Center
- Android Development
  - Android Developers
- aptX Technology
  - Link
- AAC technology
  - Link

Thank You