Bluetooth (Audio) Guide[1]

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Guide has been tested on

BeagleY-AI (target):	**Debian 12.x**
PC OS (host):	**Debian 12.x**

This document guides the user through the Bluetooth pairing process, and briefly outlines integration of an Bluetooth audio device into C code. This guide serves as a consolidation of several resources which are spread across online forums, especially with respect to the opaque error messages that appear during the process. These steps (particularly Section 2) may be applicable to non-audio use cases, but this has not been tested.

Table of Contents

1. Introduction....1
2. Connect Bluetooth Device....2
  2.1 Instructions....2
  2.2 Troubleshooting....3
3. Utilize Bluetooth Audio in C Program....5
  3.1 Prerequisites....5
  3.2 Instructions....5
  3.3 Troubleshooting....6

Formatting

1. Commands for the host Linux's console are show as:
   `(host)$ echo "Hello PC world!"`
2. Commands for the target (BeagleY-AI) Linux's console are shown as:
   `(byai)$ echo "Hello embedded world!"`
3. Almost all commands are case sensitive.

1. Introduction

From the BeagleY-AI documentation (p. 59), the target's wireless networking module is based on the Texas Instruments CC3301. This integrated circuit only supports the Bluetooth Low Energy (BLE) technology; Bluetooth Classic is not supported. Our project will be transmitting data to audio devices, such as earbuds and speakers, where (to our knowledge) BLE is not yet widely

[1] Formatting based on guides provided by Dr. Brian.

supported. As a result, use of a Bluetooth USB Adapter such as the ASUS USB-BT500 was required. Depending on the Bluetooth technologies supported on the intended device, this additional hardware may not be necessary, though the subsequent steps provided below may not be entirely transferrable.

2. Connect Bluetooth Device

2.1 Instructions[2,3]

1. Install the required library (dependencies will also be installed):
   ```
   (byai)$ sudo apt install blueman
   ```
2. If a USB adapter is required, plug it in to the target via USB. No driver installation was required for the ASUS adapter specified above.
3. The MAC address of the Bluetooth device may be required to connect to the target. To determine this address, connect the device to your smartphone (on Android 13: Settings > Connected devices > (gear next to device) > Device's Bluetooth address (at the bottom of the page)).
   The MAC address is a set of six paired hexadecimal values (bytes) in the form `FF:FF:FF:FF:FF:FF`. For the purposes of this guide, the MAC address will be `25:8F:9D:00:45:96`. Note that the Bluetooth tools used are case-sensitive, so the alphabetical hexadecimal characters (e.g. `A`, `B`, …) need to be capitalized.
4. Start the command-line tool to connect your USB device:
   ```
   (byai)$ bluetoothctl
   ```
   Your command line will change from `(byai)$` to `[bluetooth]#`.
5. Ensure your Bluetooth device is on and in discovery mode.
6. Start up the scan:
   ```
   [bluetooth]# agent on
   [bluetooth]# default-agent
   [bluetooth]# scan on
   ```
   From here, many messages will be printed as device availability changes or Bluetooth messages are sent; these messages make it difficult to track command outputs. To resolve this, one can turn off the scan, see which devices are available, and restart the scan if the intended device has not yet been found:
   ```
   [bluetooth]# scan off
   [bluetooth]# devices
   [bluetooth]# scan on
   ```

[2] carmelito, "Bluetooth Maze - Connecting the Beaglebone Wireless to a Bluetooth Speaker", Element14: https://community.element14.com/challenges-projects/design-challenges/bluetoothunleashed/b/blog/posts/bluetooth-maze---connecting-the-beaglebone-wireless-to-a-bluetooth-speaker

[3] Jason Kridner, "Setup a Bluetooth speaker on BeagleBone Blue", GitHub: https://gist.github.com/jadonk/d05d96243bc26b3c08a5293d29f78839

Continue this process as needed until the intended Bluetooth device appears, as below:

```
[bluetooth]# devices
...other devices...
Device 25:8F:9D:00:45:96 X2
...other devices...
```

The name of the hardware device (an Ortizan X2 speaker, in this case) may appear; if no name is available, the MAC address will be displayed again, with dashes instead of colons (e.g. `25-8F-9D-00-45-96`). (See step 3 to determine MAC address.)

7. Connect the Bluetooth device with your target (tab completion is available):

```
[bluetooth]# trust 25:8F:9D:00:45:96
[bluetooth]# pair 25:8F:9D:00:45:96
[bluetooth]# connect 25:8F:9D:00:45:96
```

The final command should provide an output similar to the following:

```
Attempting to connect to 25:8F:9D:00:45:96
[CHG] Device 25:8F:9D:00:45:96 Connected: yes
[NEW] Endpoint /org/bluez/hci0/dev_25_8F_9D_00_45_96/sep1
[NEW] Endpoint /org/bluez/hci0/dev_25_8F_9D_00_45_96/sep2
[NEW] Transport /org/bluez/hci0/dev_25_8F_9D_00_45_96/sep1/fd3
Connection successful
[CHG] Transport /org/bluez/hci0/dev_25_8F_9D_00_45_96/sep1/fd3 State: active
[CHG] Transport /org/bluez/hci0/dev_25_8F_9D_00_45_96/sep1/fd3 Volume: 0x0068 (104)
[CHG] Device 25:8F:9D:00:45:96 ServicesResolved: yes
```

The two devices are now paired; some feedback should also be offered by the Bluetooth device to indicate success (e.g. a chime is played, a message is spoken, an LED changes colour, etc).

Pairing may connect the devices for a few seconds before they disconnect; this should be resolved once the `connect` command is run. See troubleshooting below if the issue persists.

8. Exit the Bluetooth command-line tool by running `[bluetooth]# exit`.
9. If an audio device was connected, executing the following command will play a .wav file:

```
(byai)$ aplay /usr/share/sounds/alsa/Front_Center.wav
```

2.2 Troubleshooting

i. `[bluetooth]# scan on` returns `No default controller available`: if a USB adapter is being used, ensure it is plugged in by running `(byai)$ lsusb`. Sample output (adapter highlighted):

```
Bus 002 Device 002: ID 0451:8140 Texas Instruments, Inc. TUSB8041 4-Port Hub
Bus 002 Device 001: ID 1d6b:0003 Linux Foundation 3.0 root hub
Bus 001 Device 003: ID 0b05:190e ASUSTek Computer, Inc. ASUS USB-BT500
Bus 001 Device 002: ID 0451:8142 Texas Instruments, Inc. TUSB8041 4-Port Hub
Bus 001 Device 001: ID 1d6b:0002 Linux Foundation 2.0 root hub
```

If the issue persists, shut down the target (`(byai)$ sudo poweroff -f`), and experiment with inserting the adapter before powering on the target, or plugging in the adapter after the target has powered on.

ii. `[bluetooth]# scan on` returns `Failed to start discovery: org.bluez.Error.InProgress`: a Bluetooth scan is already in progress. It can be disabled with `[bluetooth]# scan off`, at which point the scan can be turned on again.[4]

iii. `[bluetooth]# scan on` returns `Failed to start discovery: org.bluez.Error.NotReady`: ensure the Bluetooth service is running by executing `(byai)$ systemctl status bluetooth`. If it is, check if it is blocked by running `(byai)$ rfkill list`. The service can be unlocked by running `(byai)$ rfkill unblock all`.[5]

iv. When trying to connect or pair your device, if you get an error message which mentions trust, try running `[bluetooth]# trust 25:8F:9D:00:45:96` again.

v. `[bluetooth]# connect 25:8F:9D:00:45:96` returns `Failed to connect: org.bluez.Error.Failed br-connection-profile-unavailable`: ensure `pulseaudio-module-bluetooth` is installed (see Section 3), and try again after rebooting the target/Bluetooth device.[6] Also check that the Bluetooth device is not already connected to something else.

vi. In general, Bluetooth pairing of an unknown device does not seem very reliable. If you encounter issues such as `org.bluez.Error.Failed br-connection-page-timeout`[7] or `Failed to connect: org.bluez.Error.Failed br-connection-unknown` when trying to connect, or the device disconnects a few seconds after running `[bluetooth]# connect`, experiment with restarting the target, restarting the Bluetooth device, restarting the Bluetooth daemon via `(byai)$ systemctl restart bluetooth`,[8] or re-pairing the Bluetooth device (i.e. running `[bluetooth]# remove 25:8F:9D:00:45:96`, then restarting from step 6 in Instructions). There are less obstacles and errors once a device has been successfully paired.

vii. Running `[bluetooth]# help` provides additional commands which may be helpful in connecting a Bluetooth device. Additional resources are available on the Arch Linux Wiki: https://wiki.archlinux.org/title/Bluetooth.

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[4] Jim Henderson, "Failed to start bluetooth discovery", openSUSE Forums: https://forums.opensuse.org/t/failed-to-start-bluetooth-discovery/168133/4 (*Additional solutions available.)*

[5] "bluetooth.service running, but bluetoothctl says "org.bluez.Error.NotReady"", Unix & Linux Stack Exchange: https://unix.stackexchange.com/q/508221 (*Additional solutions available.)*

[6] "[SOLVED] Bluetooth connect failed: br-connection-profile-unavailable", Arch Linux Forums: https://bbs.archlinux.org/viewtopic.php?id=270465 *(Additional solutions available.)*

[7] "[SOLVED] Bluetooth "br-connection-page-timeout", Linux Mint Forum: https://forums.linuxmint.com/viewtopic.php?t=397429

[8] Fabian Röling, "PulseAudio fails to set card profile to 'a2dp_sink'. How can I see the logs and figure out whats wrong?", Ask Ubuntu: https://askubuntu.com/questions/765233/pulseaudio-fails-to-set-card-profile-to-a2dp-sink-how-can-i-see-the-logs-and/773391#comment2251777_966153

3. Utilize Bluetooth Audio in C Program

3.1 Prerequisites

This guide portion assumes that the user has installed the sound libraries included in Dr. Brian's Zen Hat Audio Guide (Steps 1, 3 and 5). Check the course website for an updated version if the link does not work.

3.2 Instructions[9]

1. Install the required library and dependencies (will be installed automatically):
   `(byai)$ sudo apt install pulseaudio-module-bluetooth`
2. Execute the following command to give the new library root access:
   `(byai)$ sudo gpasswd -a root pulse-access`
3. **Reboot the target:**
   `(byai)$ sudo reboot -f`
4. The following commands must be run whenever the target is booted:
   a. `sudo LANG=C pulseaudio -vvvv --log-time=1 -D --system --disallow-exit --disable-shm`
   b. `sudo pactl load-module module-bluetooth-policy`
   c. `sudo pactl load-module module-bluetooth-discover`
   d. `echo connect 25:8F:9D:00:45:96 | bluetoothctl`
   e. `pactl set-default-sink bluez_sink.25_8F_9D_00_45_96.a2dp_sink`

   Note that the third command takes a few seconds to execute, and the final command uses underscores instead of colons for the MAC address. A sample output for these commands is as follows:
   a.
   ```
   (   0.000|   0.000) W: [pulseaudio] main.c: Running in system mode, but --disallow-module-loading not set.
   (   0.000|   0.000) N: [pulseaudio] main.c: Running in system mode, forcibly disabling exit idle time.
   (   0.068|   0.068) I: [pulseaudio] main.c: Daemon startup successful.
   ```
   b. `10`
   c. `11`
   d.
   ```
   [bluetooth]# connect 25:8F:9D:00:45:96
   Attempting to connect to 25:8F:9D:00:45:96
   ```
   e. (no output)

   These can be combined into a bash script which runs on startup (perhaps accepting a MAC address as an argument?). A sleep command such as `sleep 5` can be added to the script after command (d) to allow time for the Bluetooth pairing process.
5. At this point, the sample project wave_player provided by Dr. Brian will play audio. Note that in the audioMixer_template project (provided for Assignment 3, "BeatBox"), the `selem_name` variable in the `audioMixer_setVolume` function will need to be changed to

[9] Jason Kridner, "Setup a Bluetooth speaker on BeagleBone Blue", GitHub: https://gist.github.com/jadonk/d05d96243bc26b3c08a5293d29f78839

"Master". The value of this variable can be determined by running `(byai)$ alsamixer` and reading the name at the bottom (below the volume bar). Once again, check the course website if the provided links do not work.

3.3 Troubleshooting

i. If the first command above returns with **`Daemon startup failed.`** instead of `Daemon startup successful.`, the command may have been executed already. If not, try restarting the target and running the commands/script again.

ii. `pactl set-default-sink ...` command fails with `Failure: No such entity`:

1. Check that the Bluetooth device is not already connected to something else.
2. If using a script, ensure there is a sufficient wait between commands (d) and (e).
3. Execute `(byai)$ pactl list sinks` to see the sinks (audio outputs) available to the PulseAudio library. Each entry will look like this:

```
Sink #5
        State: IDLE
        Name: bluez_sink.25_8F_9D_00_45_96.a2dp_sink
        Description: X2
        ...
```

a. There is no sink listed with the MAC address of the Bluetooth device: ensure `(byai)$ sudo gpasswd -a root pulse-access` has been executed. Experiment with turning the Bluetooth device on and off, restarting the target (and re-rerunning the commands), and re-connecting the Bluetooth device.

b. The state of the sink is listed as `SUSPENDED`: this may occur if the audio device is idle (i.e. has not been playing audio) for an extended period. This can be resolved by modifying the PulseAudio configuration.[10] First, open `/etc/pulse/default.pa`:

```
(byai)$ nano /etc/pulse/default.pa
```

Next, comment (add a `#` in front of) the following line (line ~111):

```
load-module module-suspend-on-idle
```

Then, kill the service (it will restart automatically after being killed):

```
(byai)$ killall pulseaudio
```

Additional restarts of the target may be required. Note that changing this setting seems to increase the power consumption of the Bluetooth device (i.e. the battery does not last as long).

c. The sink suffix of the Bluetooth device is a different profile, such as `handsfree_head_unit`: not using the A2DP profile may also cause sub-par audio quality, or mono (one-channel) playback when stereo audio (with a left and right channel) is available (e.g. from an MP3 file).

[10] Sam Brightman, "pulseaudio sink always suspended", Unix & Linux Stack Exchange: https://unix.stackexchange.com/a/171925

- Once again, experiment with re-connecting the Bluetooth device, and restarting the target/Bluetooth device.

The following two options have not been tested:

- A script is also available to change to the A2DP profile.[11]
- Finally, the issue may be caused by the profile of the card associated with the device. One can edit the Bluetooth audio configuration to resolve this:[12]

  ```
  (byai)$ sudo nano /etc/bluetooth/audio.conf
  ```

  Add the following to the file and save it. Create the file if it does not exist.

  ```
  [General]
  Enable=Source,Sink,Media,Socket
  ```

  Then, restart Bluetooth:

  ```
  (byai)$ systemctl restart bluetooth
  ```

  After connecting the device again via `bluetoothctl` (see Section 2), retrieve the index of the card (shown as `Card #<index>`):

  ```
  (byai)$ pactl list cards short
  ```

  And set its profile:

  ```
  (byai)$ pacmd set-card-profile <index> a2dp_sink
  ```

iii. `snd_mixer_selem_get_playback_volume_range: Assertion `elem' failed.` when the `setVolume` function is called in the application: ensure the `selem_name` variable has been updated to `"Master"` following the installation of PulseAudio, and that the start-up commands provided in step 4 of Section 3.2 have been executed.

iv. Running audio programs as superuser (e.g. `(byai)$ sudo ./waveplayer`) does not produce audio: the root does not have access to PulseAudio by default. First, compare the outputs of `(byai)$ alsamixer` and `(byai)$ sudo alsamixer` (check the "Card" and "Chip" listed in the top left). If the two commands have different values, run the following commands, then restart the target:[13]

```
(byai)$ sudo adduser pulse bluetooth
(byai)$ sudo adduser pulse audio
(byai)$ sudo adduser root bluetooth
(byai)$ sudo systemctl --global disable pulseaudio.service pulseaudio.socket
(byai)$ sudo nano /etc/pulse/client.conf
```

(change `autospawn = yes` to `autospawn = no`)

```
(byai)$ sudo adduser <username> pulse-access
```

(i.e. `Brian`)

The two `alsamixer` commands above should now have the same output. Beware that there are user security concerns when modifying the library permissions in this way.

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[11] Emil Gelev, "Change Bluetooth Headphones default audio mode (A2DP Sink vs HSP/HFP)", Ask Ubuntu: https://askubuntu.com/a/1188159

[12] Jimubao, "PulseAudio fails to set card profile to 'a2dp_sink'. How can I see the logs and figure out whats wrong?", Ask Ubuntu: https://askubuntu.com/a/966153 *(Additional solutions available.)*

[13] "Running PulseAudio as System-Wide Daemon", freedesktop.org: https://www.freedesktop.org/wiki/Software/PulseAudio/Documentation/User/SystemWide/