Wireless Module Expert

# GSM Module
# Audio Design Guide

**GSM/GPRS Series**

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# About the document

## History

| Revision | Date | Author | Description |
|---|---|---|---|
| 1.0 | 2009-11-02 | Tracy Zhang | Initial version |
| 1.1 | 2009-11-20 | Tracy Zhang | 1. Added some acronym.<br>2. Added a Audio Power Amplitude manufacturer.<br>3. Added a solution to TDD noise.<br>4. Modified cover. |
| 1.2 | 2010-11-20 | Roy Chen | 1. Added a diagram of audio channel |
| 3.0 | 2013-05-24 | Jerry You | 1. Added reference design of audio circuit (M1x, M95, M80).<br>2. Added AT command AT+QAPS. |

# Contents

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# 1 Introduction

## 1.1. Summary

This document provides reference and suggestion on audio circuit design and audio parameter selection for Quectel M1x, M95 and M80 modules.

## 1.2. Safety Information

The following safety precautions must be observed during all phases of the operation, such as usage, service or repair of any cellular terminal or mobile incorporating module. Manufacturers of the cellular terminal should send the following safety information to users and operating personnel and to incorporate these guidelines into all manuals supplied with the product. If not so, Quectel does not take on any liability for customer failure to comply with these precautions.

Full attention must be given to driving at all times in order to reduce the risk of an accident. Using a mobie while driving (even with a handsfree kit) cause distraction and can lead to an accident. You must comply with laws and regulations restricting the use of wireless devices while driving.

Switch off the cellular terminal or mobile before boarding an aircraft. Make sure it switched off. The operation of wireless appliances in an aircraft is forbidden to prevent interference with communication systems. Consult the airline staff about the use of wireless devices on boarding the aircraft, if your device offers a Fight Mode which must be enabled prior to boarding an aircraft.

Switch off your wireless device when in hospitals or clinics or other health care facilities. These requests are desinged to prevent possible interference with sentitive medical equipment.


GSM cellular terminals or mobiles operate over radio frequency signal and cellular network and cannot be guaranteed to connect in all conditions, for example no mobile fee or an invalid SIM card. While you are in this condition and need emergent help, please remember using emergency call. In order to make or receive call, the cellular terminal or mobile must be switched on and in a service area with adequate cellular signal strength.

Your cellular terminal or mobile contains a transmitter and receiver. When it is ON , it receives and transmits radio frequency energy. RF interference can occur if it is used close to TV set, radio, computer or other electric equipment.

In locations with potencially explosive atmospheres, obey all posted signs to turn off wireless devices such as your phone or other cellular terminals. Areas with potencially exposive atmospheres including fuelling areas, below decks on boats, fuel or chemical transfer or storage facilities, areas where the air contains chemicals or particles such as grain, dust or metal powders.

# 2 Audio Circuit Design

M1x and M95 have two hardware audio channels except M80. Three audio channels are defined in software. AT+QAUDCH is used to read and set the software audio channel. This chapter provides audio interface circuit and some solutions to resolve TDD noise and ECHO issues.

**Table 1: Audio Hardware Configuration**

| Module | (AIN1/AOUT1) | | (AIN2/AOUT2) | | AOUT3 |
|---|---|---|---|---|---|
| | MIC | SPK | MIC | SPK | SPK |
| M1x | Differential & Internal Bias | Differential | Differential & Internal Bias | Signal-end | / |
| M95 | Differential & Internal Bias | Differential | Differential & Internal Bias | Differential | / |
| M80 | Differential & Internal Bias | Differential | Differential & Internal Bias | Signal-end | Differential |

**Notes**

1. M95 module has built-in class AB amplifier and also supports voice and ringtone at channel AOUT2.
2. M80 module supports voice and ringtone at channel AOUT2. AOUT1 and AOUT3 can also output ringtone but via AT+QRCH=1(only used at M80).
3. M80 module has built-in class AB amplifier at channel AOUT3, and the maximum power is 800mW.

## 2.1. Audio Circuit Reference

### 2.1.1. M1x

#### 2.1.1.1. Microphone Reference Circuit

M1x module provides electrets-microphone bias voltage for AIN1 and AIN2. Microphone reference circuit is shown as below:

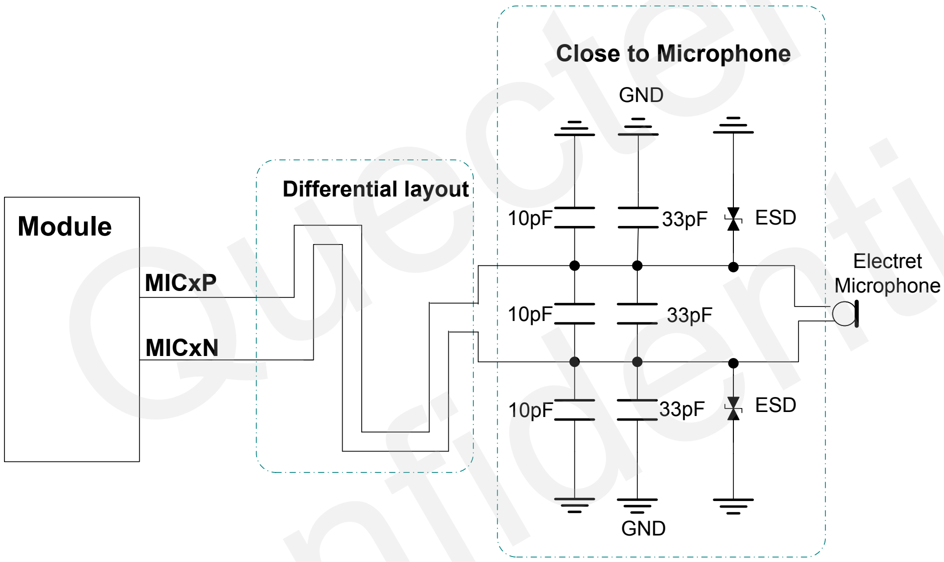


**Figure 1：Microphone Reference Circuit for AIN1&AIN2**

**Notes**

1. To avoid TDD noise issue during voice, capacitors is recommended to add close to microphone and SPK.
2. TVS components are used to protect microphone and receiver from ESD damage. It has to close to audio device and audio interface.

#### 2.1.1.2. Receiver Reference Circuit

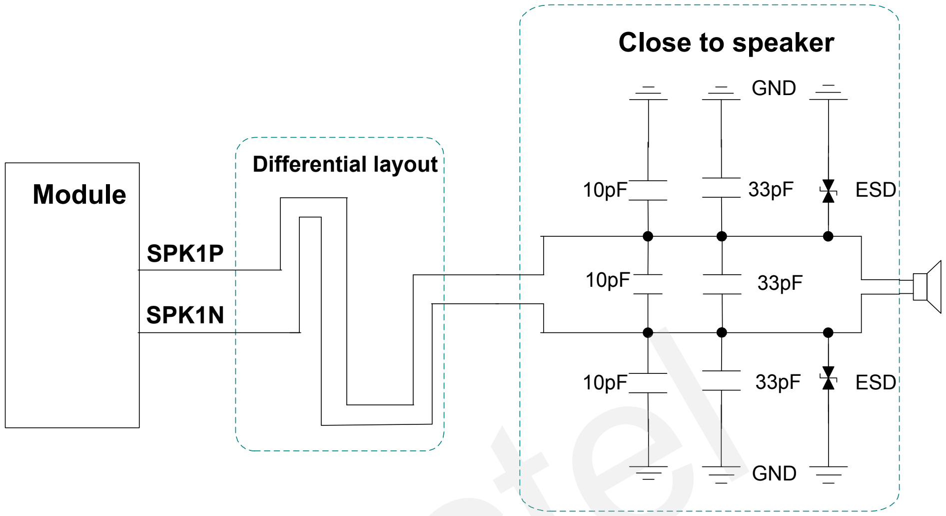


Figure 2: Receiver Reference Circuit for AOUT1

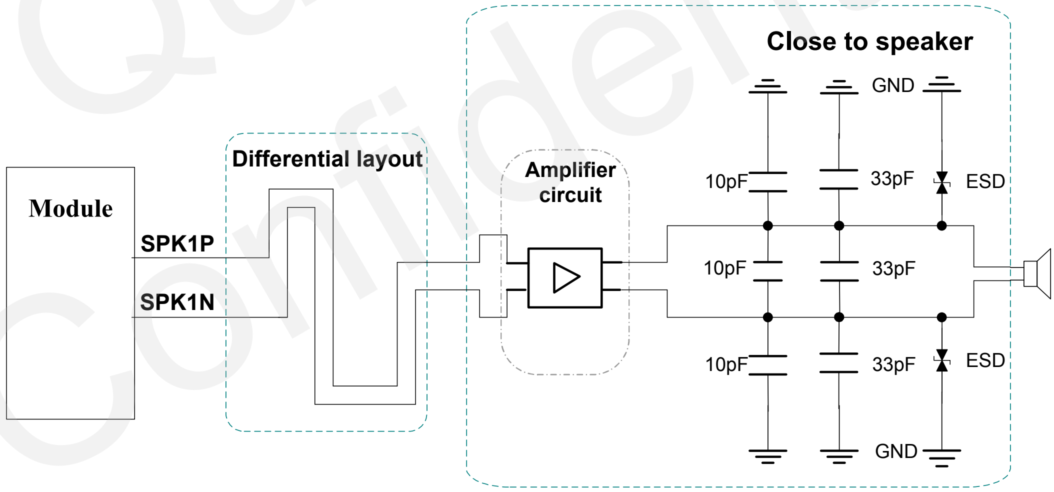


Figure 3: Receiver Reference Circuit with Audio Power Amplifier for AOUT1

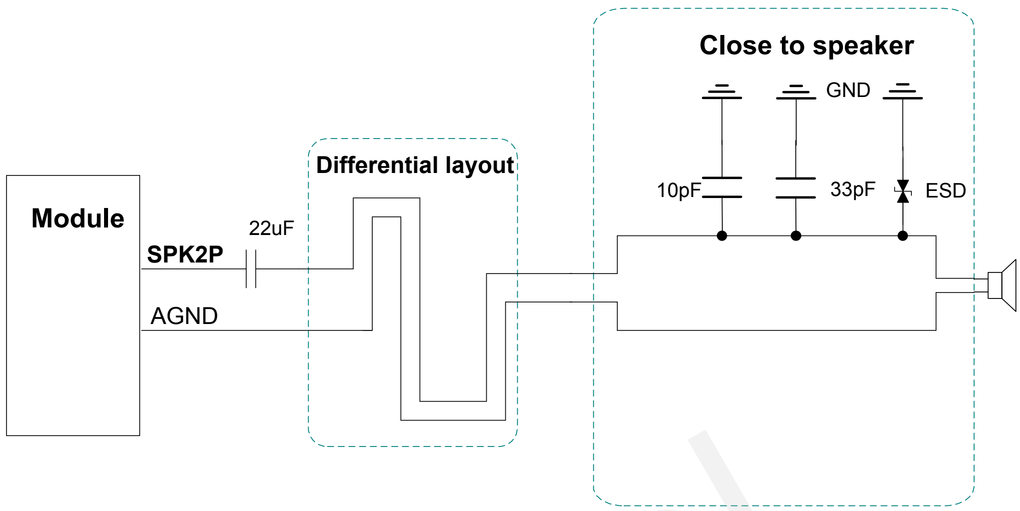


Figure 4: SPK Reference Circuit for AOUT2

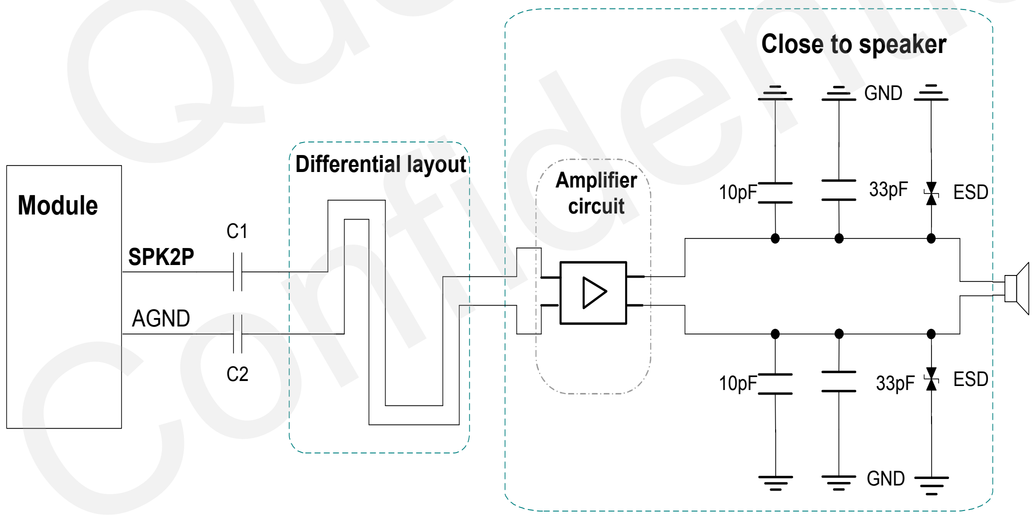


Figure 5: Receiver Reference Circuit with Audio Power Amplifier for AOUT2

**Note**

For the value of C1 and C2, please refer to input impedance of audio power amplifier.

#### 2.1.1.3. Headset Reference Circuit

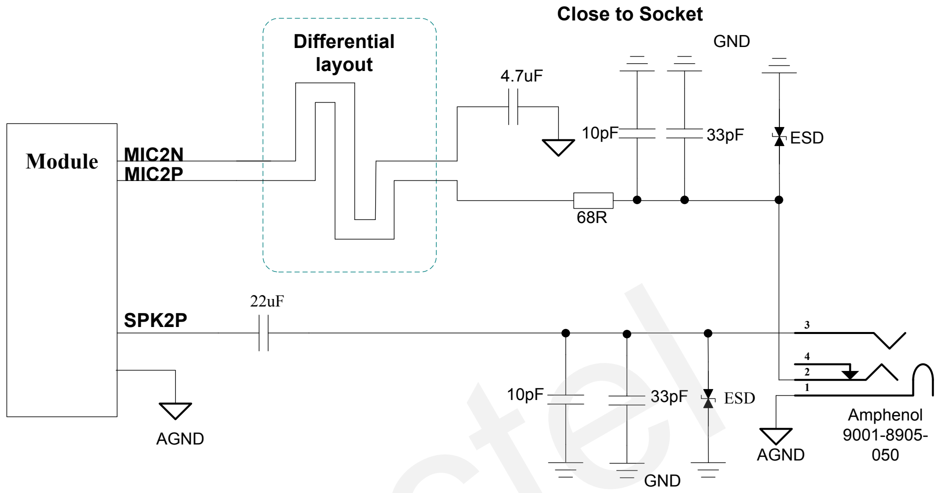


Figure 6：Headset Reference Circuit

### 2.1.2. M95

### 2.1.3. Microphone Reference Circuit

M95 module provides electrets-microphone bias voltage for AIN1 and AIN2. Reference circuit for microphone is shown as bellow:

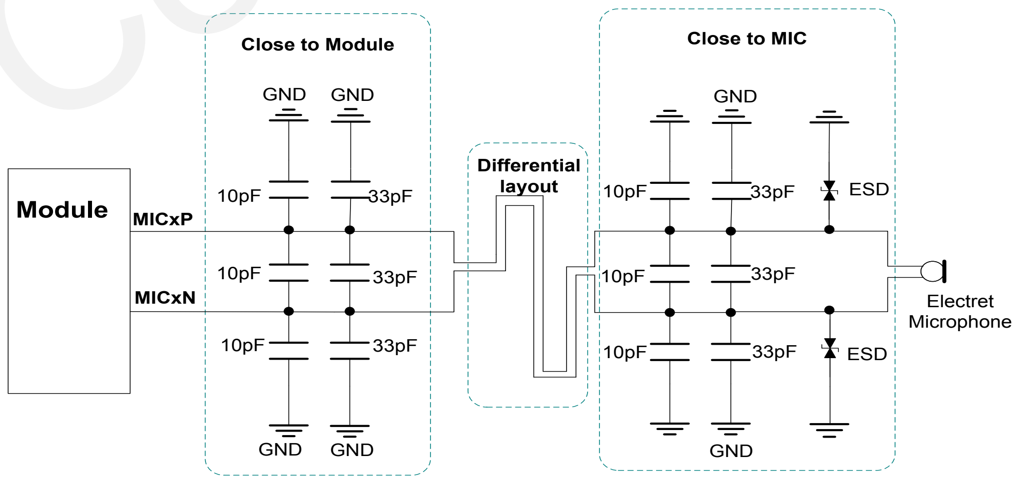


Figure 7：Microphone Reference Circuit for AIN1&AIN2

#### 2.1.3.1. Receiver Reference circuit

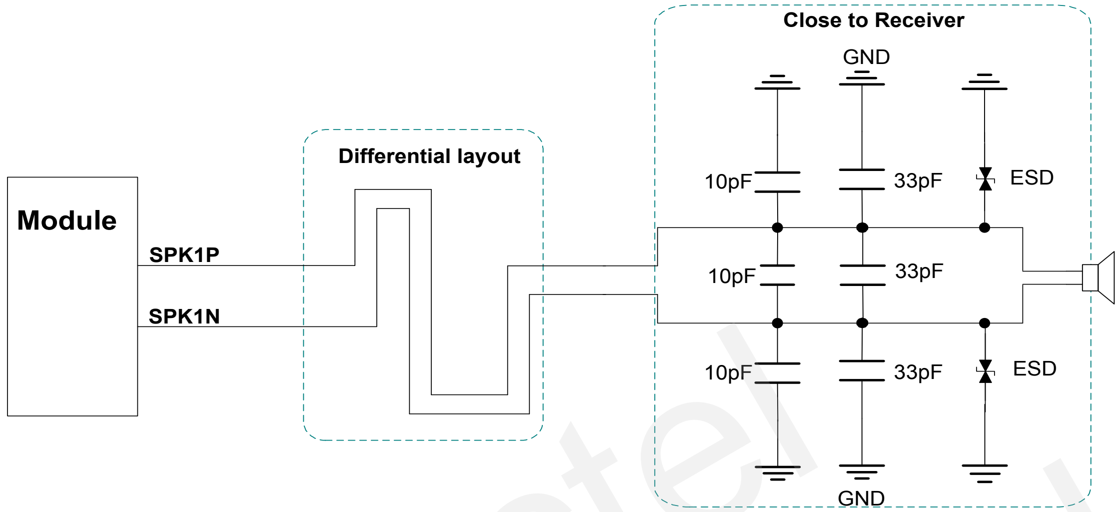


Figure 8：Receiver Reference Circuit for AOUT1

#### 2.1.3.2. Headset Reference Circuit

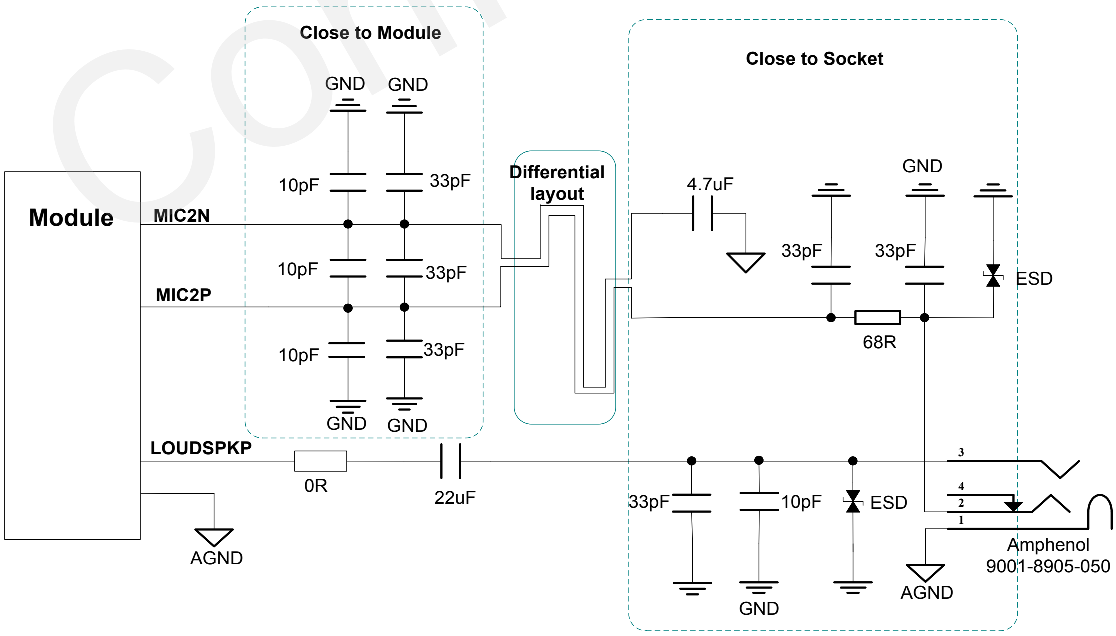


Figure 9：Headset Reference Circuit

### 2.1.3.3. SPK Reference Circuit

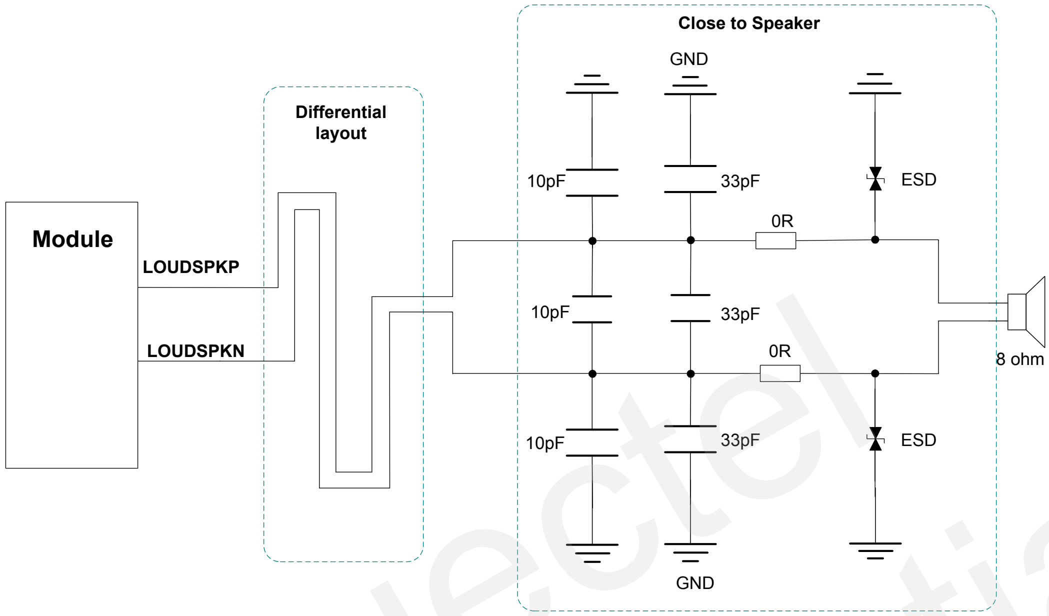


Figure 10：SPK Reference Circuit

### 2.1.4. M80

#### 2.1.4.1. Microphone Reference Circuit

M80 provides electrets-microphone bias voltage for AIN1 and AIN2. Reference circuit for microphone is illustrated as following figure.

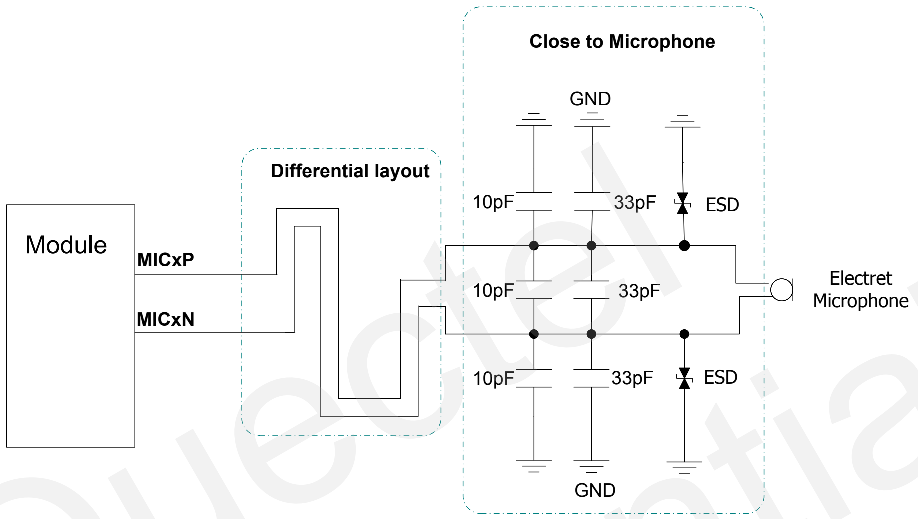


**Figure 11：Microphone Reference Circuit for AIN1&AIN2**

#### 2.1.4.2. Receiver Reference Circuit

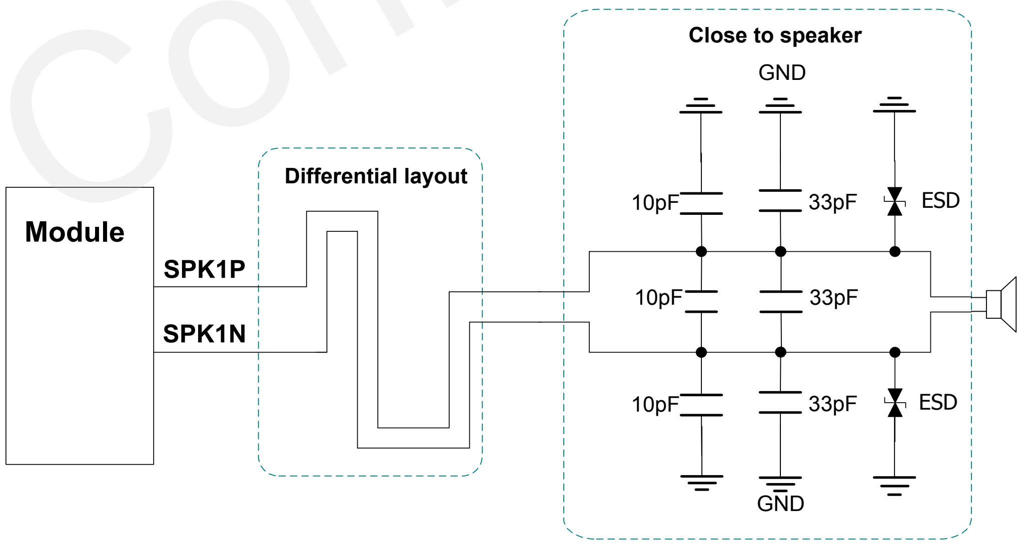


**Figure 12：Receiver Reference Circuit for AOUT1**

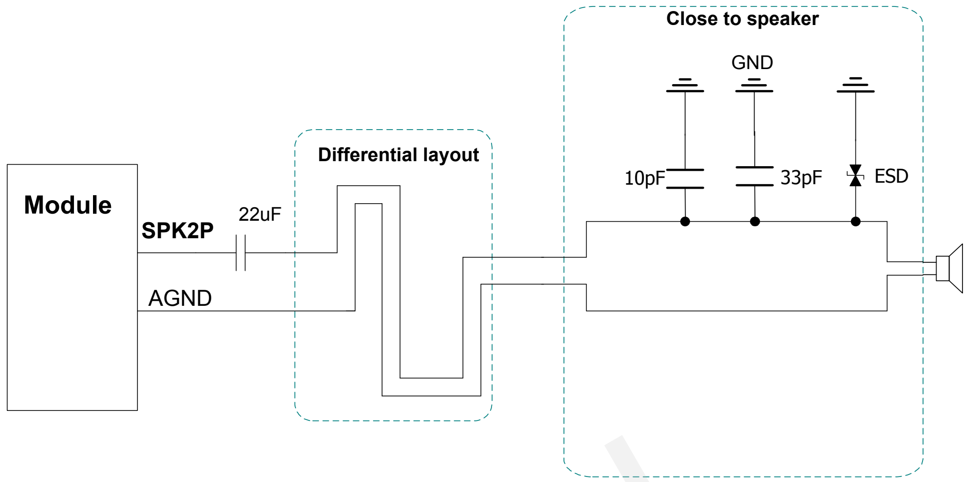


**Figure 13：SPK Reference Circuit for AOUT2**

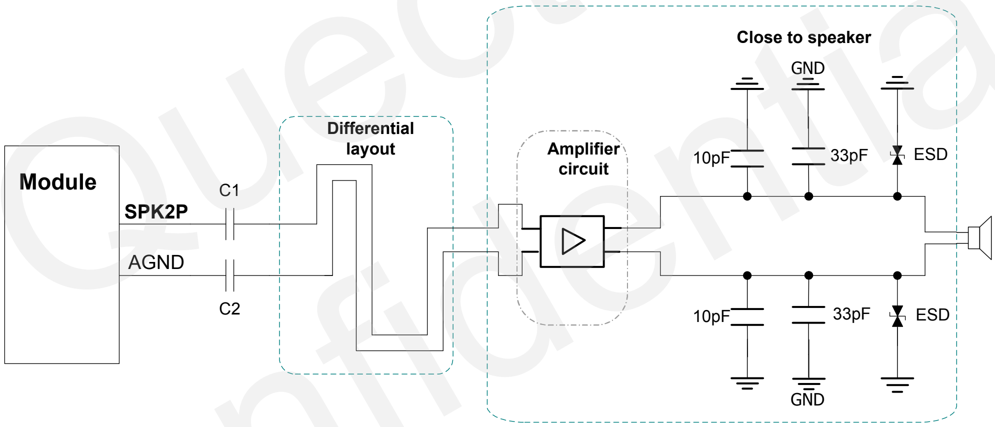


**Figure 14：SPK Reference Circuit with audio power amplifier for AOUT2**

**Note**

TPA6205A1 from TEXAS INSTRUMENTS is recommended, which is a audio power amplifier device and can driver a 8Ω speaker impedance.

#### 2.1.4.3. Headset Reference Circuit

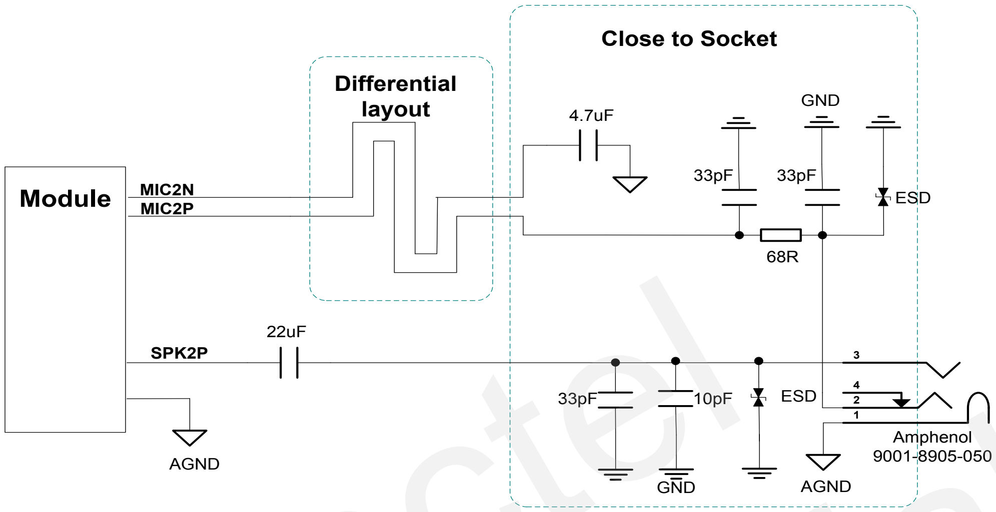


**Figure 15：Headset Reference Circuit**

#### 2.1.4.4. SPK Reference Circuit

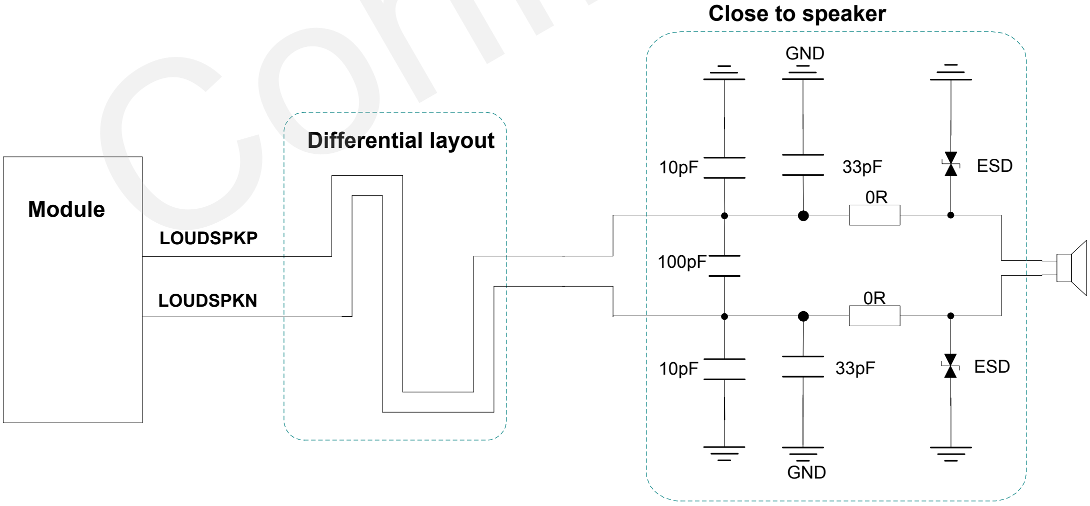


**Figure 16：SPK Reference Circuit**

Notes

1. Capacitors have to place close to audio component or audio interface and layout must be short.
2. Antenna interface must be stay away from audio components and layout of audio circuit. Layout of power supply must be stay away from audio and cannot be parallel.
3. Differential audios have to meet the rule of layout.

## 2.2. Ringtone

M1x does not support ringtone via channel AOUT1, but support to output ringtone via channel AOUT2.

M95 outputs ringtone via channel AOUT2 by default.

M80 outputs ringtone via channel AOUT2 by default; channel AOUT1 can output ringtone via AT+QAUDCH=0 and AT+QRCH=1. Please refer to AT command description for detailed information about AT+QRCH.

| AT+QRCH | |
|---|---|
| Test Command<br>**AT+QRCH=?** | Response<br>**+QRCH: (0,1)**<br><br>**OK** |
| Read Command<br>**AT+QRCH?** | Response<br>**+QRCH: <n>**<br><br>**OK** |
| Write Command<br>**AT+QRCH=<n>** | Response<br>**OK**<br><br>If error is related to ME functionality:<br>**+CME ERROR: <err>** |
| Reference | |

### Parameter

| | | |
|---|---|---|
| **<n>** | 0 | Default output channel is AOUT2. (M80's default audio channel is AOUT2/AOUT3. |
| | 1 | Output ringtone at any audio channel which is decided by AT+QAUDCH. (e.g. if |

AT+QAUDCH=0, ringtone will output via AOUT1)

## 2.3. Hands-free Application at Channel AIN1/AOUT1

Channel AIN1/AOUT1 could be used as hands-free function, because input audio signal is differential circuit and it is a good way to suppress common-mode noise.

SPK circuit is recommended as following:

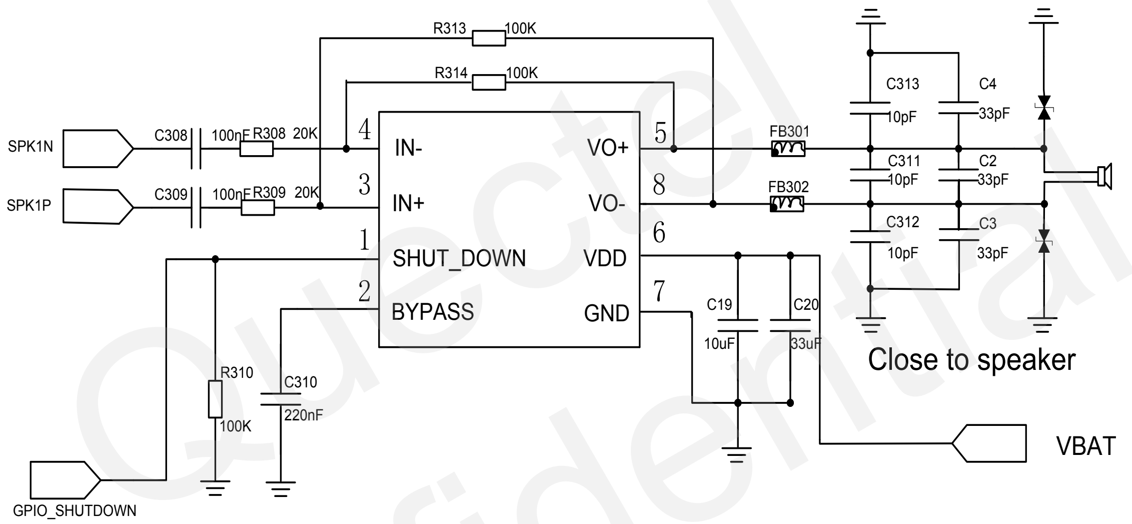


**Figure 17：Hands-free Reference Circuit at Channel AIN1/AOUT1**

**Note**

GPIO_SHUTDOWN is controlled by I/O of external chip.

## 2.4. Suggestion for Audio Layout

Power supply ripple, unbalanced ground and RF burst radiation have negative effect to audio layout. Layout of MIC1P/MIC1N, SPK1P/SPK1N must meet the rule of differential signal. Moreover, these two pairs of signals should be separated from each other by flooding ground to avoid echo issue from SPK signal to MIC signal. Figure 18 shows an example.

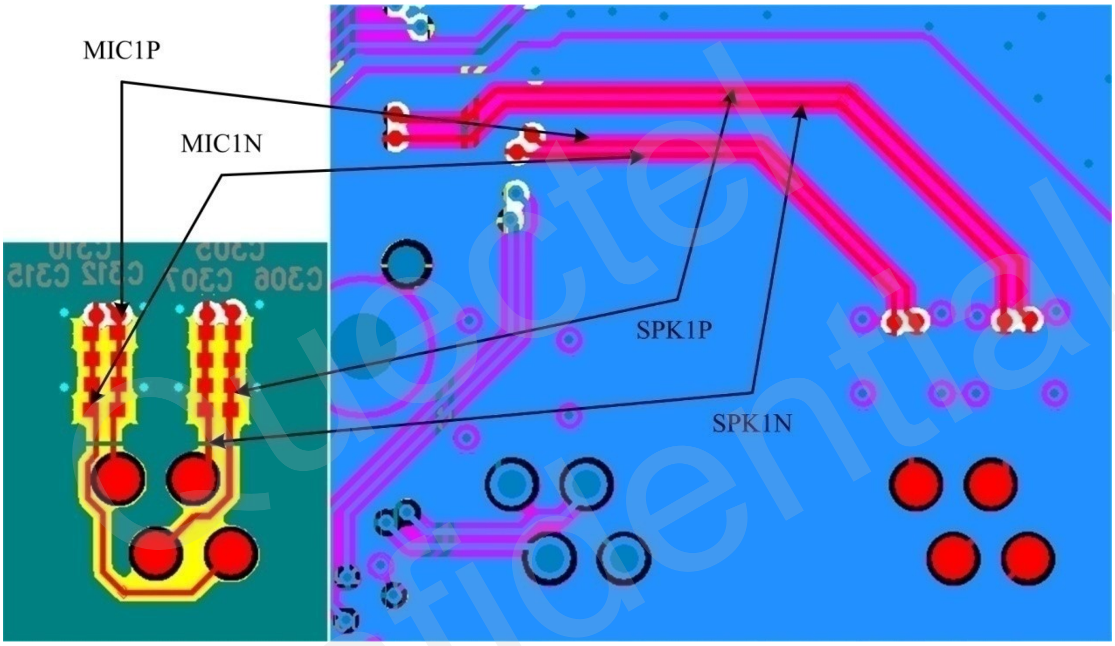


**Figure 18：Layout of Audio**

## 2.5. TDD Noise Solution

It is important to avoid or reduce TDD noise in audio circuit design and layout. This chapter provides some solution to resolve it.

1. It is strongly recommended to add an electrets-microphone within two capacitors (10pF and 33pF) in handset and hands-free application. These two capacitors could largely suppress coupling TDD noise from RF interference.

2. Capacitors have to place close to audio component or audio interface, layout must be short.

3. Flood ground area should be as large as possible to reduce the ground impedance and improve ground integrality.

4. Reduce power voltage ripple, especially the power supply in audio circuits. A wide layout is used from power source (like adapter interface, battery connector, or LDO output pin) to audio power supply. Good antenna matching is also important to reduce power ripple.

5. The filtering capacitors and ESD protection devices should be connected to main digital ground, and other audio components should use AGND from the module interface. Please be noted that the AGND pin should not be connected with main digital ground at PCB, or else, it could lead to TDD noise.

6. Antenna must be stay away from audio components and layout of audio circuit. Keep the distance at least 5cm from antenna to microphone.

7. Layout of power supply must be stay away from audio and cannot be parallel.

## 2.6. Suggestion for Mechanical Design

It is important to consider how to suppress echo in the equipment with hands-free function or in an application which microphone and speaker are very close to each other.

The mechanical structure design has significant impact on echo issue. If it is not properly designed, the echo suppressing arithmetic in software could not make up echo issue caused by bad mechanical structure, and even force to redesign.

Echo issue could be generated by several paths as shown in Figure 19.

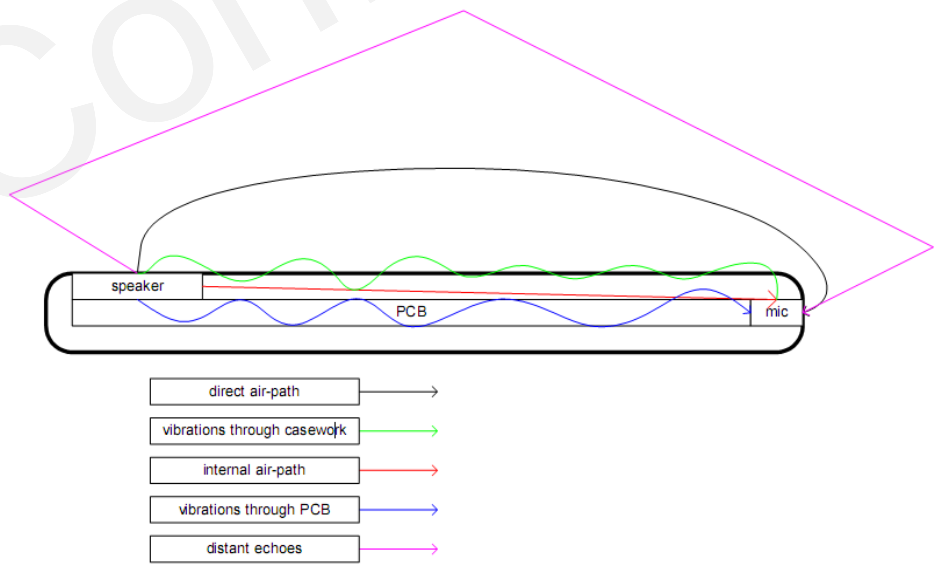


**Figure 19：Five Echo Paths**

In these five paths, internal air-path and direct air-path are the first influential factors. Other three factors (vibrations through casework, vibrations through PCB, distant echoes) are secondary.

How to deal with echo issue from internal air-path:
Separating microphone from internal space of chassis by foam or rubber ring can effectively suppress the inner echo interference. Figure 20 shows recommended design for microphone socket.

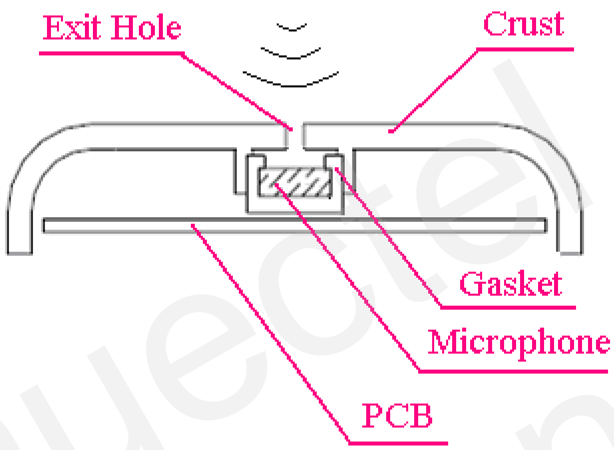


**Figure 20：Microphone Socket Design**



**Note**

The best installation way of microphone socket is to encase microphone by silicone cover except for front cavity, and design a cylindrical hole whose center is the exit hole inside the chassis, make the microphone with silicone cover just fit the cylindrical hole, so as to only let voice enter into microphone from the exit hole, and not from leak of chassis interior. Certain air space room should be reserved in the front cavity of microphone as it is necessary for good microphone performance.

Figure 21 shows recommended design for speaker socket.

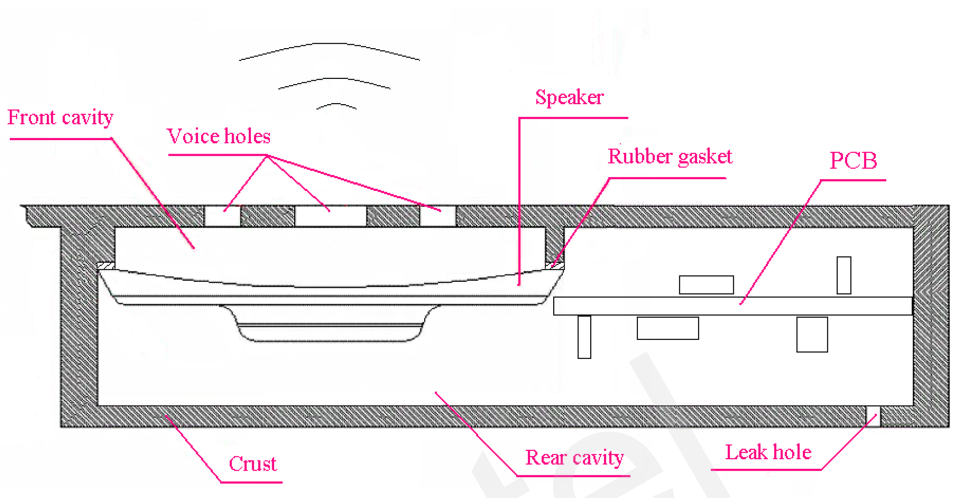


**Figure 21：Speaker socket design**

A good way to suppress the internal echo path is to seal the rear cavity of receiver, which is usually expensive. The rear cavity of receiver and speaker is important for good voice quality. A sealed rear cavity with sufficient space could produce a good voice output. An 8Ω speaker is often big and difficult to give an independently sealed rear cavity for it. However, sealing microphone socket in chassis is always useful. Furthermore, the whole chassis must be sealed as far as possible. If there is any unavoidable leak hole, keep it far away from microphone. If the leak hole is close to microphone, the voice coming from the hole could be picked up by MIC, and then leads to echo at the far end. If the leak hole is close to speaker, the output voice quality could be aggravated at certain extent.

## 2.7. Component of SPK

A SPK and receiver with higher sensitivity, flatter frequency response, less THD and impedance of 32Ω(receiver), 16Ω(receiver) or 8Ω(speaker) is recommended. These technical data are often shown in data sheet of SPK and receiver. For SPK, its frequency response and THD performance can be tested by speaker test system. SPK frequency and THD response are shown in Figure 22 and Figure 23.

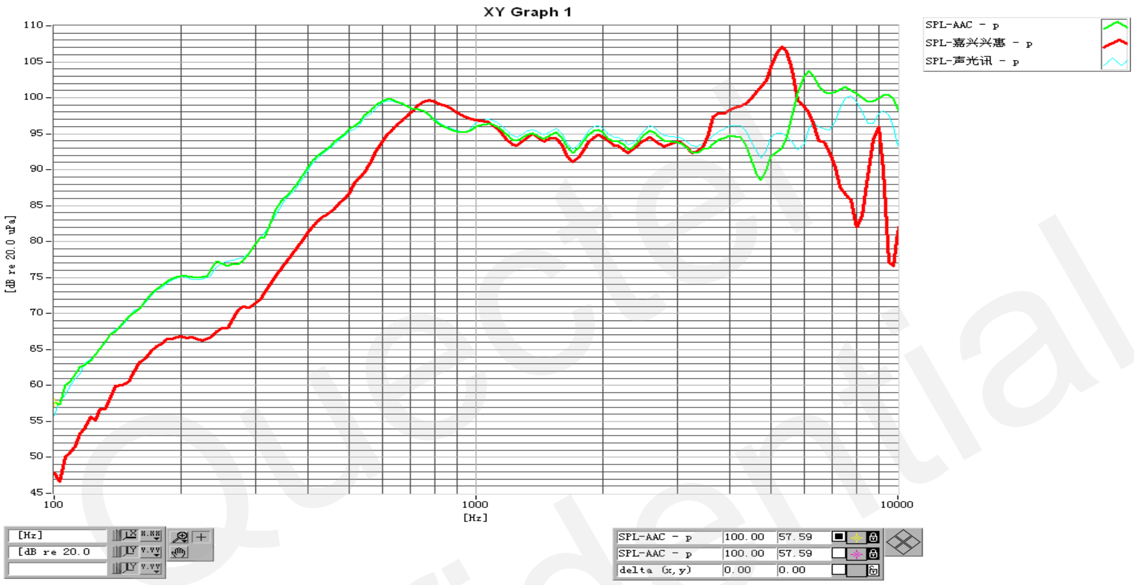


**Figure 22：SPK Frequency Response**

**Note**

Horizontal axis is frequency, longitudinal axis is loudness and unit is dB.

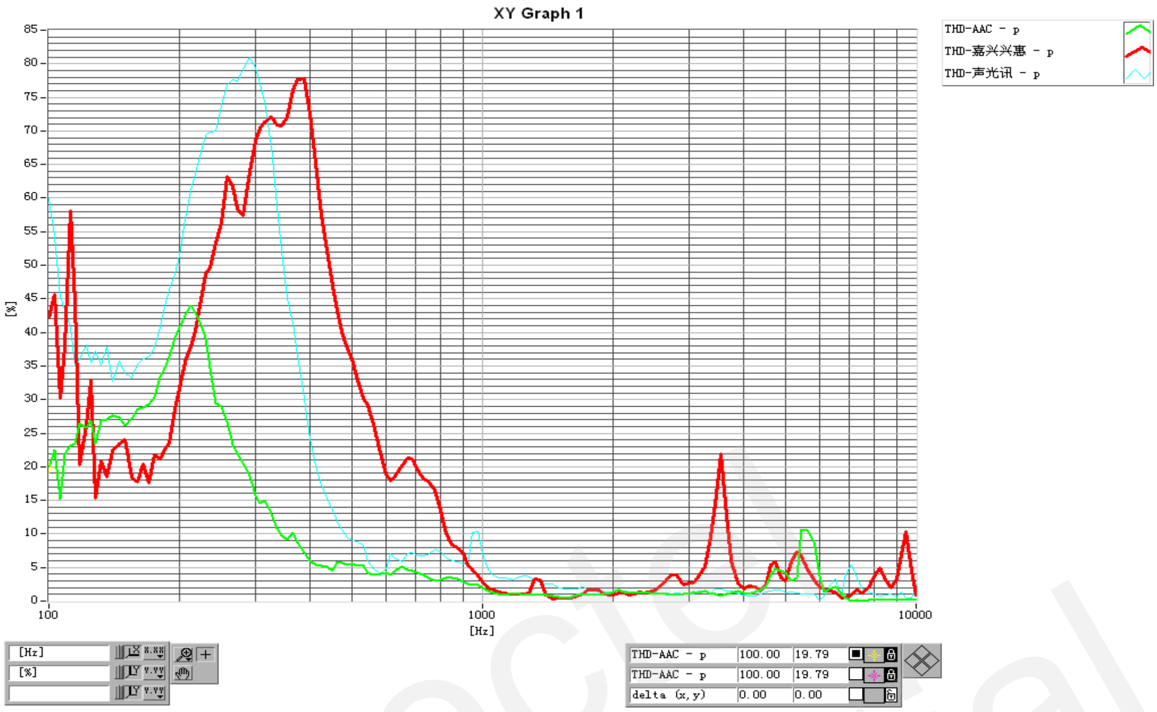


**Figure 23：SPK THD**

**Note**

1. Horizontal axis is frequency, longitudinal axis is distortion and unit is %
2. Figure 23, the three colors represent three venders' products. After comprehensive comparison, the green one performs the best, and the blue one is second, and the red one is the worst.

## 2.8. Component of Microphone

It is recommended to use an electret microphone with a sensitivity of -42±3dB/Pa @ 2V（not less than -44±3dB）and impedance of 2.2kΩ . If RF TDD noise is detected at the MIC, please contact MIC vendor for product with better RF suppression capability. Furthermore, the microphone channel circuit can be optimized to decrease TDD issue at MIC side.

# 3 Description and Suggestion

M1x, M95 has two audio channels in hardware, named AIN1/AOUT1 and AIN2/AOUT2. Three channels are defined in software, named channel 0, channel 1 and channel 2. Software channel 0 is applied in hardware channel AIN1/AOUT1, software channel 1 and channel 2 are applied as hardware channel AIN2/AOUT2. Headset application is used at software channel 1. Software channel 2 is designed for hands-free application of hardware channel AIN2/AOUT2.

M80 has three audio channels in hardware, named AIN1/AOUT1, AIN2/AOUT2 and AOUT3. Channel AOUT3 is used as output of hands-free application. Software channel 0 is applied as hardware channel AIN1/AOUT1. Software channel 1 is applied as hardware channel AIN1/AOUT1.

## 3.1. AT Command

Audio parameters will be introduced as following chapter and audio parameters can be set via AT command.

### 3.1.1. AT+QAUDCH

AT+QAUDCH is used to read and set audio software channel. How to read and set audio software channel via AT+QAUDCH is shown as following:

| AT+QAUDCH | |
|---|---|
| Test Command<br>**AT+QAUDCH=?** | Response<br>**+QAUDCH:** (list of supported <**n**>s)<br><br>**OK** |
| Read Command<br>**AT+QAUDCH?** | Response<br>**+QAUDCH: <n>**<br><br>**OK** |
| Write Command<br>**AT+QAUDCH=[<n>]** | Response<br>**OK**<br>If error is related to ME functionality:<br>**+CME ERROR: <err>** |

| | |
|---|---|
| Reference | |

**Parameter**

| | | |
|---|---|---|
| **<n>** | 0 | Normal audio channel (default) |
| | 1 | Headset audio channel |
| | 2 | Loudspeaker audio channel |

### 3.1.2. How to Modify Volume

#### 3.1.2.1. AT+QMIC

AT+QMIC is used to modify the analog gain of microphone. It can increase or reduce the gain of microphone.

| **AT+QMIC a** | |
|---|---|
| Test Command<br>**AT+QMIC=?** | Response<br>**+QMIC:** (list of supported <**channel**>s）, (list of supported <**gain-level**>s)<br><br>**OK** |
| Read Command<br>**AT+QMIC?** | Response<br>**+QMIC: <gainlevel(Normal_Mic)>,<gainlevel(Headset_Mic)>,<gainlevel(Loudspeaker_Mic)>**<br><br>**OK** |
| Write Command<br>**AT+QMIC=<channel>,<gain-level>** | Response<br>**OK**<br>If error is related to ME functionality:<br>**+CME ERROR: <err>** |
| Reference | |

**Parameter**

| | | |
|---|---|---|
| **<channel>** | 0 | Normal microphone |
| | 1 | Headset microphone |
| | 2 | Loudspeaker microphone |

| | |
|---|---|
| **<gain-level>** | Range is 0 - 15 |

#### 3.1.2.2. AT+CLVL

AT+CLVL is used to modify the analog gain of receiver. It can increase or reduce loudness of downlink speech.

| AT+CLVL | |
|---|---|
| Test Command<br>**AT+CLVL=?** | Response<br>**+CLVL:** (list of supported **<level>**s)<br><br>**OK** |
| Read Command<br>**AT+CLVL?** | Response<br>**+CLVL: <level>**<br><br>**OK** |
| Write Command<br>**AT+CLVL=<level>** | Response<br>**OK**<br>If error is related to ME functionality:<br>**+CME ERROR: <err>** |
| Reference<br>GSM 07.07 | |

**Parameter**

| | |
|---|---|
| **<level>** | Integer type value (0-100) with manufacturer specific range (Smallest value represents the lowest sound level) |

**Note**

If the gain-level is too high, receiving distortion would happen.

### 3.1.2.3. AT+QSIDET

AT+QSIDET is used to adjust the side tone gain.

| AT+QSIDET | |
|---|---|
| Test Command<br>**AT+QSIDET=?** | Response<br>**+QSIDET:** (list of supported <**gainlevel**>s)<br><br>**OK** |
| Read Command<br>**AT+QSIDET?** | Response<br>**+QSIDET(NORMAL_AUDIO): <gainlevel>**<br><br>**OK**<br>**+QSIDET(HEADSET_AUDIO): <gainlevel>**<br><br>**OK** |
| Write Command<br>**AT+QSIDET=<gainlevel>** | Response<br>**OK**<br>If error is related to ME functionality:<br>**+CME ERROR: <err>** |
| Reference<br>GSM 07.07 | |

**Parameters:**

| | |
|---|---|
| <**gainlevel**> | Gain level of side tone.<br>Value range: 0~255<br>Disable: 0 |

**Note**

Side tone is disabled and cannot be adjusted in hands-free application.

### 3.1.3. Echo Algorithm

AT+QAPS is used to modify echo algorithm parameters of all three software audio channels.

| AT+QAPS | |
|---|---|
| Set Command<br>**AT+QAPS=<mode>,<type>,<channel>,<setting>** | Response<br>**+QAPS: <op>,<para1>[,<para2>[,<para3>]][,<setting>]**<br><br>**OK** |
| Set Command<br>**AT+QAPS=<op>,<para1>[,<para2>[,<para3>]][,<setting>]** | Response<br>If <op> is read,<br>**+QAPS:<result list>**<br><br>**OK**<br><br>If <op> is write,<br>**OK**<br>If format is error, response<br>**+CME ERROR: <err>** |

**Parameters:**

| | |
|---|---|
| **<op>** | Operation<br>0 Get old value<br>1 Set new value |
| **<para1>** | Type of parameters<br>0 Input FIR Coeffs<br>1 Output FIR Coeffs<br>2 FIR output Index<br>3 Speech Common Para<br>4 Speech Mode Para |
| **<para2>** | Group/mode of parameters<br>When para1=0/1/4, para2 is a must.<br>Ranges from 0~2, corresponding to the audio mode.<br>0 Normal mode<br>1 Headset mode<br>2 Loudspeaker mode<br>See detailed information in notes below. |
| **<para3>** | Batch number of parameters. |

| | |
|---|---|
| | When para1=0/1, para3 is a must and 10 elements consist one batch. |
| **<setting>** | List of integers, with dot (".") separated. |

**Note**

<setting>
Par0：（AEC）Acoustic echo control NLP control word
Par1：（AEC）AEC control word
Par2：（AEC）Echo suppressor control word
Par3：NDC
Par4：NDC
Par5：NDC
Par6：NDC
Par7：DGA Digital gain control word
Par8：NDC
Par8：NDC
Par9：NDC
Par10：NDC
Par11：NDC
Par12：AES Aggressive echo suppression
Par13：DMNR
Par14：DMNR
Par15：N/A

**For example:**

**Read:**
**AT+QAPS=0,4,0** // Read audio parameters of normal audio mode (software channel 0).
**+QAPS: 4,0,"96.253.16388.31.57351.31.400.0.80.4325.99.0.20488.0.0.8192"**

**OK**

**AT+QAPS=0,4,1** // Read audio parameters of headset audio mode (software channel 1).
**+QAPS: 4,1,"96.253.10756.31.57351.31.400.0.80.4325.99.0.16392.0.0.0"**

**OK**

**AT+QAPS=0,4,2** // Read audio parameters of loudspeaker audio mode (software channel 2).
**+QAPS: 4,2,"254.224.3208.31.57351.24607.400.132.80.4325.99.0.16392.0.0.0"**

**OK**

**Write and Save:**
//Write and save audio parameters of normal audio mode (software channel 0).

```
AT+QAPS=1,4,0, "96.253.16388.31.57351.31.400.0.80.4325.99.0.20488.0.0.8192"
OK
//Write and save audio parameters of loudspeaker audio mode (software channel 2).
AT+QAPS=1,4,2, "254.224.3208.31.57351.24607.400.132.80.4325.99.0.16392.0.0.0"
OK
```

**Note**

Quectel module has configured default parameters in software. For some special applications, such as AIN1/AOUT1 being applied in hands-free, or echo issue caused by bad circuits or mechanical structure. Some of parameters can be modified to fix echo issue. Advices of audio parameters in different application are provided in the next section.

#### 3.1.3.1. Description of Par0, Par2 and Par12

- Par0-（AEC） NLP control word
  Value range: 0~256
  Disable: 0
  The large value has a positive effect on ECHO issue.
- Par2-（AEC）Echo suppressor control word
  Value range: 32512~0
  Disable: 32512
  The smaller value has a positive effect on ECHO issue.
- Par12- AES Aggressive echo suppression
  Value range: 32513~0
  Disable: 32513
  The smaller value has a positive effect on ECHO issue.

**Note**

Par0, Par2, Par12 have the most significant effect on ECHO issue.

#### 3.1.3.2. Recommended Application Field

There are some recommended parameters when module works in voice or DTMF application, shown as below:

Voice

```
AT+QAPS=1,4,0,"96.253.10756.31.57351.31.400.0.80.4325.99.0.20488.0.0.8192"
AT+QAPS=1,4,0,"128.253.10756.31.57351.31.400.0.80.4325.99.0.16392.0.0.8192"
AT+QAPS=1,4,0,"192.253.10756.31.57351.31.400.0.80.4325.99.0.16392.0.0.8192"
AT+QAPS=1,4,0,"192.253.10756.31.57351.31.400.0.80.4325.99.0.8223.0.0.8192"
AT+QAPS=1,4,0,"192.253.5256.31.57351.31.400.0.80.4325.99.0.8223.0.0.8192"
AT+QAPS=1,4,0,"192.253.2218.31.57351.31.400.0.80.4325.99.0.8223.0.0.8192"
AT+QAPS=1,4,0,"248.253.2218.31.57351.31.400.0.80.4325.99.0.8223.0.0.8192"
```

DTMF

```
AT+QAPS=1,4,2,"128.224.2218.31.57351.24607.400.132.80.4325.99.0.8223.0.0.0"
AT+QAPS=1,4,2,"192.224.750.31.57351.24607.400.132.80.4325.99.0.2079.0.0.0"
AT+QAPS=1,4,2,"224.224.511.31.57351.24607.400.132.80.4325.99.0.513.0.0.0"
```

```
AT+QAPS=1,4,2,"128.253.2218.31.57351.24607.400.132.80.4325.99.0.8223.0.0.0"
AT+QAPS=1,4,2,"192.253.750.31.57351.24607.400.132.80.4325.99.0.2079.0.0.0"
AT+QAPS=1,4,2,"224.253.511.31.57351.24607.400.132.80.4325.99.0.513.0.0.0"
```

# 4 Appendix A

Table 2: Reference Document

| NO. | Name | Remark |
|---|---|---|
| [1] | M1x_AT_Commands_Manual | AT Commands Manual |
| [2] | Mxx_Hardware_Design | Hardware Design |

Table 3: Description of ECHO and TDD noise

| Noun | Explanation |
|---|---|
| ECHO | Talking quality can be obviously affected when echo problem is present. Description of ECHO issue: The far end could hear its own voice from the module side (the near end) in talking. ECHO issue can be caused by the near end of some reasons, such as receiving circuit coupling to the microphone circuit, unsealed mechanical structure, high SPK loud voice, or high sensitivity microphone. ECHO issue has a negative effect on talking. |
| TDD noise | TDD noise could be present at the far end of the near end while talking. RF power aptitude generates a burst keeping 576us in every 4.615ms. It could be coupling to audio circuit. The envelope curve of the RF burst could be present due to filtering effect and make a noise in the audio circuit path as a constant pulse at 217Hz and its harmonic frequencies. Another of the reason is from the power supply. The burst consumption of current can cause obvious ripple at the supply voltage at 217Hz. If the ripple at the supply voltage conducts to audio circuit through power supply or ground, TDD noise could be present at the far end or the near end. |