Microphone Power Gating

INTRODUCTION

Many mobile consumer products require very low power audio capture solutions for scenarios such as voice control.

Traditionally, all on-board microphones have been supplied power from a single source in such a way that all of the microphones are powered on or powered off together. In some use cases, the additional power consumption of powering unused microphones results in an unacceptable degradation in battery life. This application note describes a number of options and trade-offs for controlling power consumption in a multimic application. The act of controlling power consumption levels is referred to as “power gating” throughout the rest of this document.

EXAMPLE USE CASE

The example in the diagram below shows the placement of four microphones in a mobile phone.

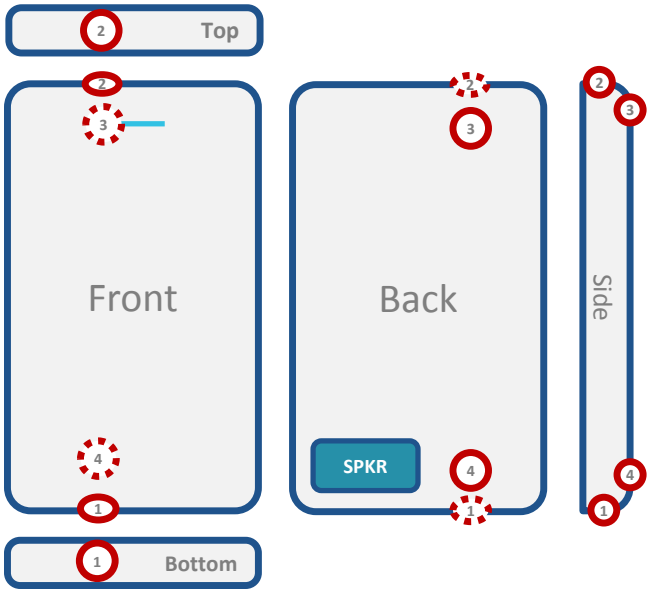

Figure 1 Example Microphone Placement in a Mobile Phone

In different use cases, different combinations of these microphones will be used. The table below gives an example of which microphones might be used by the Cirrus SoundClear™ suite of audio processing algorithms.

FEATURE	USE CASE	MIC 1	MIC 2	MIC 3	MIC4
SoundClear Control	Voice Control		✓		
SoundClear Voice	Video Call	✓	✓		
	Voice Call	✓	✓		✓
SoundClear Record	Video Capture	✓	✓	✓	✓

Figure 2 Example Microphone Requirements for Different Use Cases

In order to extend battery life, power consumption should be optimised across all use cases and one aspect of doing that is to ensure that only the required microphones are consuming power in each use case. Applications with multiple microphones and multiple use cases using different microphone combinations, require flexible microphone power gating solutions in order to achieve good battery life.

POWER SUPPLY CONTROL

One way to selectively turn groups of microphones on or off is to switch their supply on or off. Microphone supplies are typically provided from a low noise MICBIAS output from the CODEC. Some Cirrus CODECs have multiple MICBIAS outputs that can be enabled and disabled independently. Groups of microphones can be connected to these such that each group will only be enabled when its respective MICBIAS supply is enabled. The diagram below shows a power gating solution for two groups of microphones.

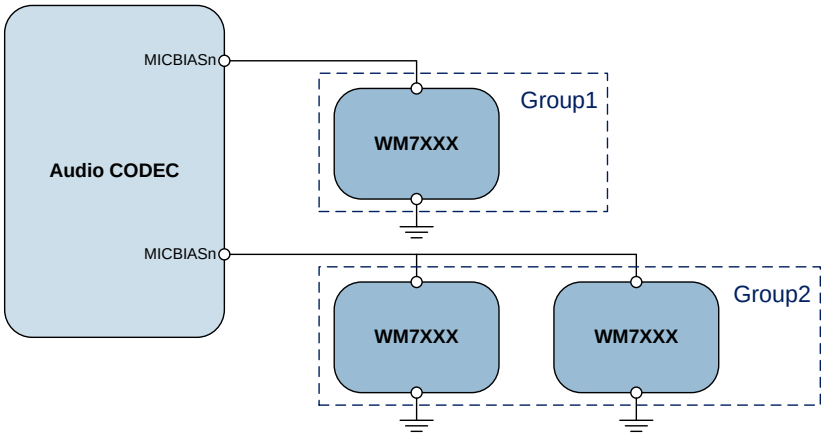

Figure 3 Power Gating using Independently Enabled MICBIAS Outputs

In some cases the desired number of microphone groups may exceed the number of MICBIAS outputs. External switches can be used in these cases to provide additional power supply control. Suitable FETs should be selected to provide a high enough 'off' resistance and low enough 'on' resistance at the gate voltages available.

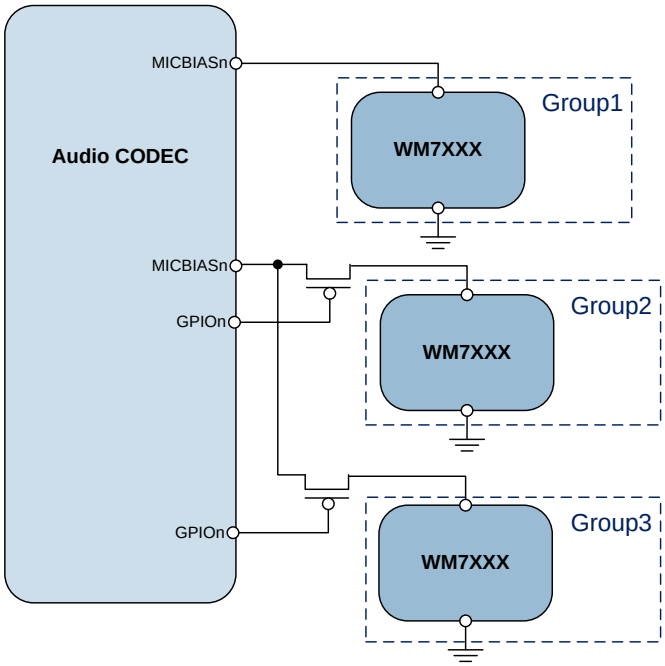

Figure 4 Power Gating using Discrete PMOS Devices

Some Cirrus CODECs also include a general purpose switch that can be used in place of an external switch. An example of this is shown below.

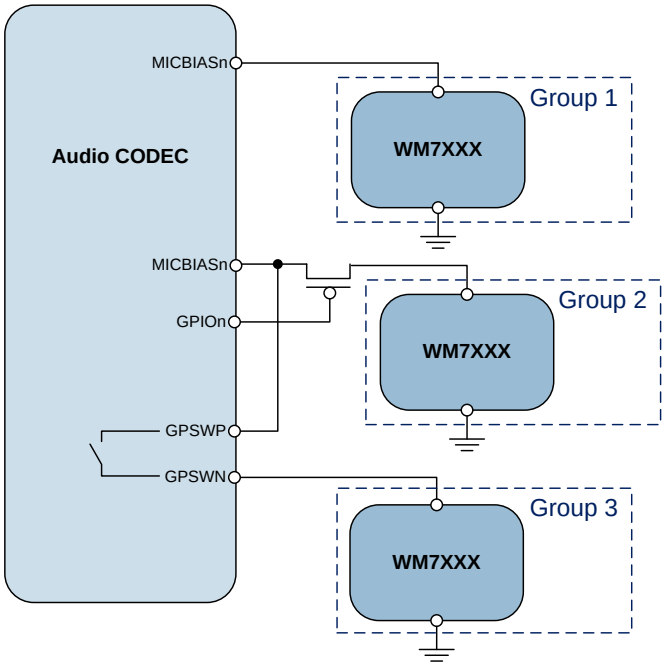

Figure 5 Power Gating using the General Purpose Switch

DESIGN CONSIDERATIONS

- The maximum output current from each MICBIAS is limited. The maximum number and type of microphones that can be supported by each MICBIAS output is restricted by this current limit.
- In some Cirrus CODECs the MICBIAS generators are supplied by an internal charge-pump and LDO. The maximum output current from the Charge Pump and LDO is limited, and will also determine the maximum number and type of microphones that can be supported.
- The maximum output current from each MICBIAS may depend on whether the respective output is in regulating mode or bypass mode. The maximum combined current from all MICBIAS outputs may also depend on the configuration of the Charge Pump and LDO that supplies them. The level of immunity to power supply ripple in each of these circuits may also vary according to the operating mode.
- MICVDD can be used as a microphone supply, however, on some Cirrus CODECs, MICVDD is required to be high in order to use any of the analogue inputs or MICBIAS outputs. As a consequence, external clock control switches must be used if it is a requirement to power down microphones supplied by MICVDD whilst any of the analogue inputs or MICBIAS outputs are in use.
- The power-up/power-down time for power supply controlled microphones will be limited by the charge/discharge time of the MICBIAS and microphone decoupling capacitors.
- When using switches or FETs for additional supply gating:
    - The ‘on’ and ‘off’ state resistance needs to be considered to ensure the desired functionality is achieved.
    - The voltage drop across the switch (or FET) will increase as the current drawn increases. If suitable switches or FETs are chosen, the voltage drop will be small, but the droop or ripple this will cause at the microphone supply pins should still be taken into consideration.
    - External switches and FETs will require GPIOs pins to control them.
    - The supply domain voltage of the GPIO pins used to drive any external FET gates will determine the achievable on/off resistance of an external FET.

CLOCK CONTROL

Digital microphones can operate in pairs where the clock input signal (DMICCLK) is shared, and each microphone outputs pulse density modulated data onto a time-domain multiplexed bus (DMICDAT).

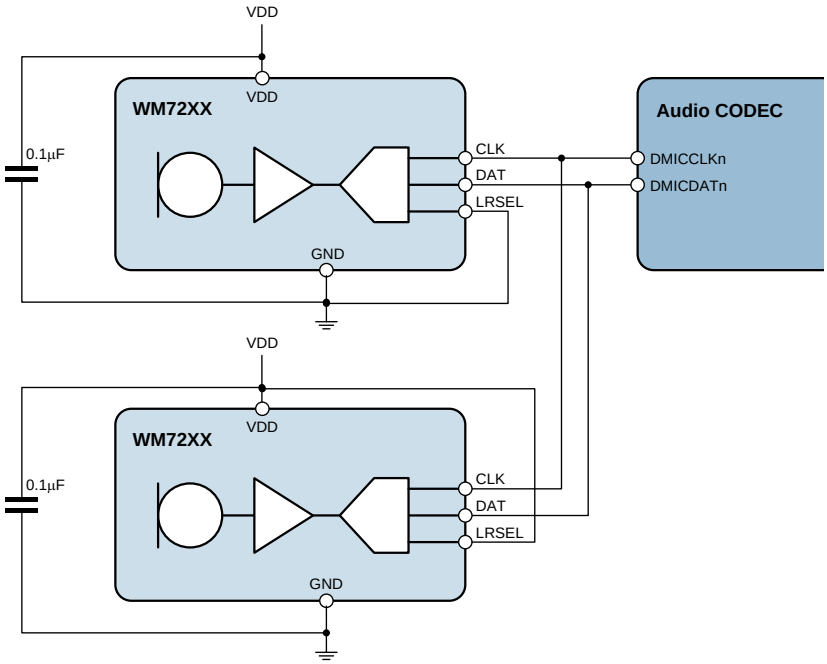

Figure 6 Example Digital Microphone Schematic

Cirrus digital microphones can be effectively power gated by selectively enabling or disabling their input clocks. When the microphone has power, but no clock, it enters a low power sleep mode. During this mode the current consumption is very low; typically <10µA.

The diagram below shows a simplified digital microphone circuit, highlighting each digital microphone pair as a group that can be independently power gated simply by enabling or disabling their shared input clock.

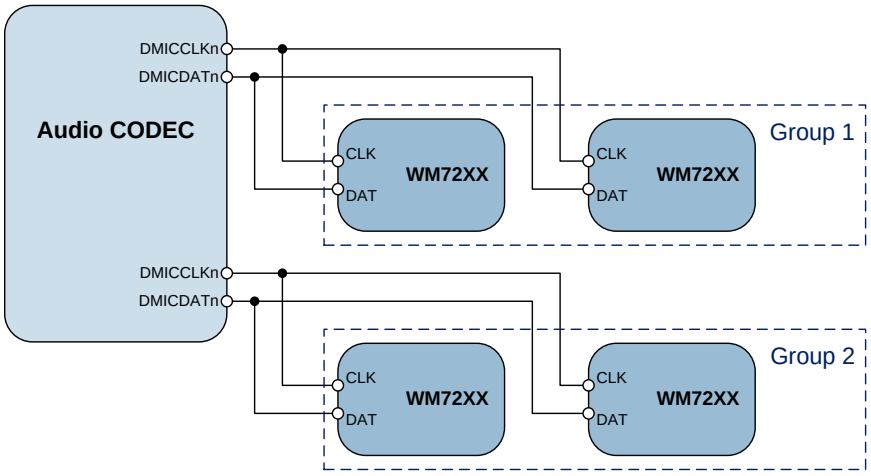

Figure 7 Clock Gating Using a Standard Digital Microphone Circuit

DESIGN CONSIDERATIONS

- Typically digital microphones will be connected to CODEC DMIC interfaces in pairs, sharing the same input clock line. This means that power gating by controlling the clock alone will not allow one of those microphones to be 'on' whilst the other is 'off'.
- Connecting only one digital microphone to each CODEC DMIC interface will allow independent clock gating of single microphones, however, it will limit the total number of digital microphones that can be supported by the CODEC. In some cases this will not be enough to support all the required microphones in the application.
- Digital MEMS microphones in their normal operating mode typically dissipate more power than an equivalent analogue MEMS microphones, however, the overall system power consumption is typically less because of the power consumption savings in the CODEC.
- Operating two digital microphones on separate interfaces is less power efficient than a stereo connection to a single interface due to the power consumption overheads associated with enabling each DMIC interface on the CODEC.
- Additional clock control using external switching of the clock signals to different microphones is possible if carefully designed, but it is not recommended.

COMBINED SUPPLY AND CLOCK CONTROL

Individual Cirrus digital microphones in an array can be independently enabled without sacrificing CODEC digital microphone inputs or using external components if a combination of power supply control and clock control is used.

An example circuit diagram is shown below:

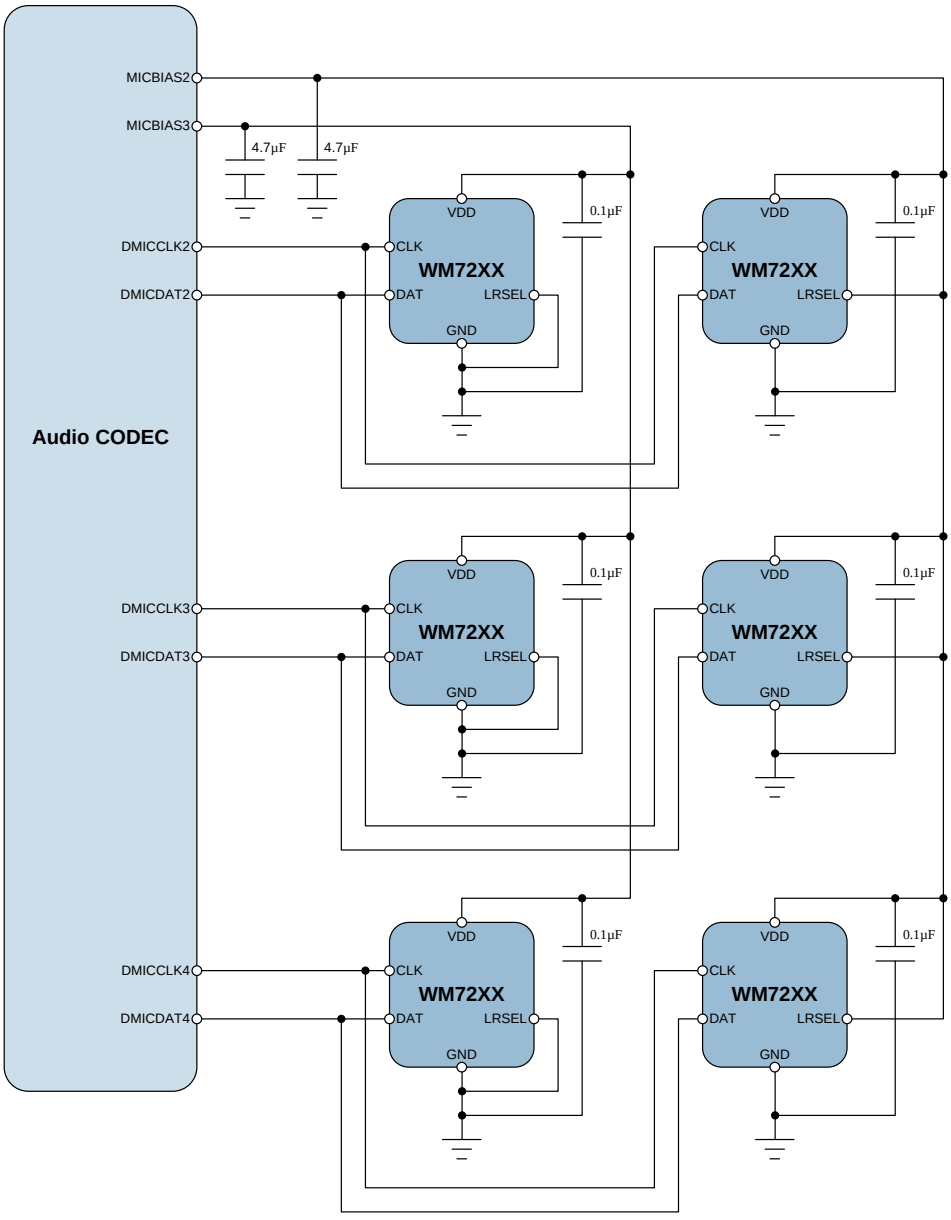

Figure 8 Digital Microphone Array with Combined Supply and Clock Gating

In this circuit, each digital microphone pair is power gated by enabling or disabling the respective DMIC interface on the CODEC. Within every DMIC pair, each microphone is supplied from a different MICBIAS supply and can therefore be power gated independently from the other. By giving each microphone a unique clock source and power source combination, it is possible to independently enable any one microphone by enabling its supply and clock. Any Cirrus digital microphone being supplied power, but no clock, will be in a very low power sleep mode. A Cirrus digital microphone being supplied clock, but no power, will be off.

Cirrus digital microphone clock inputs are specifically designed so that they will not impact the clock signal integrity even when the microphone supply voltage is low or floating; allowing a microphone that is powered up to receive a valid clock even when sharing a clock input with a microphone that is

powered down. Equally, Cirrus digital microphone data outputs are designed to be high impedance when powered down or in 'sleep' mode; allowing a microphone that is powered up to output data normally even when sharing a data output line with a microphone that is powered down or in 'sleep' mode.

DESIGN CONSIDERATIONS

- When power gating microphones using this method, it is possible to enable any one microphone whilst the remaining microphones are either 'off' or in 'sleep' mode. However, when enabling more than one microphone, some combinations will result in more microphones being enabled than may be required. For example, when enabling the microphones on DMICCLK2/MICBIAS2 and DMICCLK3/MICBIAS3, then the microphones on DMICCLK2/MICBIAS3 and DMICCLK3/MICBIAS2 will also be enabled. Use cases should be considered when deciding which microphones should be placed in which physical locations in the application such that power-critical use cases do not cause more microphones to be enabled than are required.
- Greater flexibility of what microphone combinations can be enabled or disabled independently can be achieved by using more than two MICBIAS outputs or including external circuitry for additional power gating options.
- There are power consumption overheads associated with enabling a MICBIAS output or a DMIC interface on the CODEC. The overhead associated with enabling a DMIC interface is typically greater than that associated with enabling a MICBIAS output. This means that enabling two microphones on the same MICBIAS output but different DMIC interfaces will typically consume more power than enabling two microphones on the same DMIC interface but with different MICBIAS supplies.
- Clocking a digital microphone that is in a power down state (supply is low) consumes some current to drive the load capacitance, typically <100uA per microphone.

CONCLUSION

Mobile consumer products supporting multiple microphone connections can often benefit from one or more power gating techniques to reduce power consumption. Power supply control and clock control can be used to provide the flexibility to independently enable individual microphones. Power supply and clock control can be combined in systems using Cirrus digital MEMS microphones and audio hub CODECs to deliver a flexible power gating solution that allows any one microphone in an array of microphones to be enabled independently of the others without requiring any additional external components.

Contacting Cirrus Logic Support

For all product questions and inquiries, contact a Cirrus Logic Sales Representative.
To find one nearest you, go to www.cirrus.com.