1. Characteristics

- Directional from 20 Hz to 20 kHz

  Dipole polar pattern

  4.8 dB diffuse noise rejection

  >20 dB noise rejection at the null

  Dual acoustic ports

- PDM output

- 67.5 dBA SNR

- 1% THD at 109 dB SPL 1 kHz

- AOP at 134 dB SPL

- 730 µA supply current at 2.4 MHz

- 3.50 x 2.65mm^2 footprint

- -40 to 85 °C operating temperature

2. Applications

- Webcams
- AR and VR Devices
- Headsets
- Conferencing Devices
- Laptops and Tablets
- OTC Hearing Aids
- Smart Speakers
- Wearables
- Automotive

3. Description

The SKR0610 is a directional PDM MEMS microphone with a dipole pickup pattern for superior signal isolation. The microphone maintains this polar pattern across the audible frequency range and features an exceptionally high 67.5 dBA SNR. The high SNR makes the SKR0610 ideal for products that require professional-grade audio quality or extended listening ranges.

Packaged in a subminiature 9.3 mm^2 footprint, the SKR0610 can be used in the most size-constrained applications. The SKR0610 features 67.5 dBA SNR and does not reach 1% THD until 109 dB SPL. This large dynamic range ensures high-quality voice pick-up in both near-field and far-field applications. The SKR0610 dramatically improves both noise and directional performance over conventional omnidirectional microphone arrays.

The SKR0610 is the most flexible directional microphone offering, suited for applications where the smallest size, highest performance, or maximum directionality is desired. The transducer of the SKR0600 can easily be converted to exhibit a hypercardioid or supercardioid polar pattern with the simple application of an acoustic mesh. When combined with an omnidirectional microphone, the SKR0610 can be leveraged to create ultra-high SNR beamformers. These directional microphones ensure that high-quality audio with low background noise can be obtained in products of any form factor.
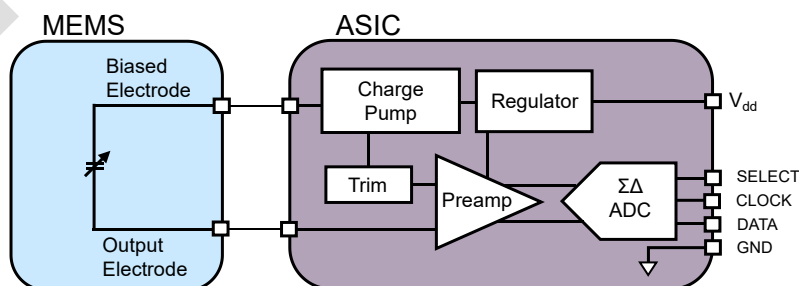
4. Functional Block Diagram

Figure 4.1: Functional block diagram

5. Table of Contents

www.soundskrit.ca   Copyright © 2023 Soundskrit Inc

6. Typical Application Circuit

The SKR0610 can be used alone, as shown in the single microphone application circuit or paired with another PDM microphone, dipole or omnidirectional, as shown in the stereo application circuit.

The recommended operating conditions are CLK = 3.072 MHz and V_{dd} = 1.8 V. Using CLK <3.072 MHz will increase high-frequency noise and decrease SNR due to insufficient oversampling of the PDM signal. CLK >3.072 MHz will increase the current consumption without any improvement in SNR, AOP, or any other specification. Using V_{dd} >1.8 V will increase current consumption without any improvement in SNR, AOP, or any other specification for the SKR0610, and for many omnidirectional microphones will significantly increase low-frequency noise and decrease SNR.

The PDM interface (PDM to PCM converter) of the application processor should have a resolution ≥24 bit to achieve maximum SNR. A 16-bit resolution can also be used but will add high-frequency noise on the SKR0610. If the SKR0610 is paired with an omnidirectional microphone, the omnidirectional microphone should have a sensitivity ≥-26 dB to avoid increasing overall high-frequency noise.

A 0.1 µF capacitor should be placed between V_{dd} and GND as close to the microphone as possible to reduce supply noise. According to the PCB trace impedance, damping resistors R_{term} of 33 Ω to 100 Ω may be placed near the microphone DATA pin and near the application processor's CLOCK to reduce overshoots and ringing.
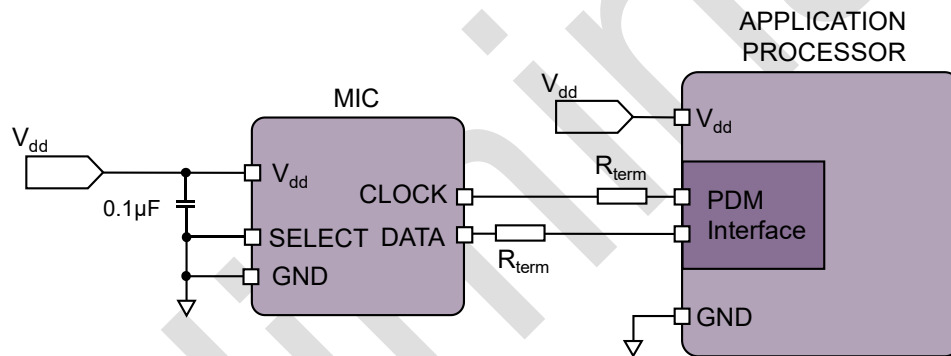

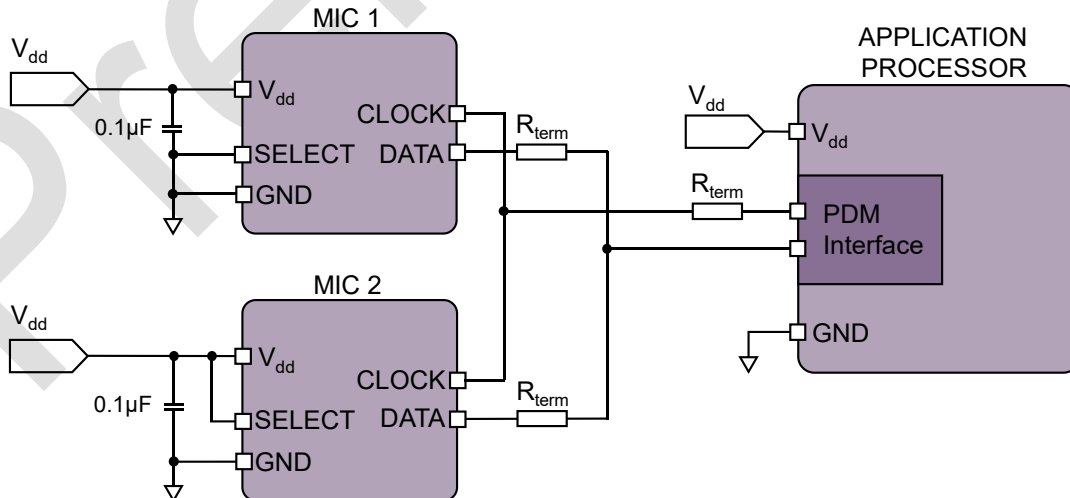*Figure 6.1: Typical single microphone application circuit*

Figure 6.2: Typical stereo application circuit

7. Specifications

Unless otherwise specified, all measurements are taken with these test conditions: 25 ºC, 55 ± 20% R.H., V_{dd} = 1.8 V, f_{clock} = 3.072 MHz, T_{edge}<3 ns, SELECT grounded, 3 m away, 10 mm acoustic path length[1], no load, PCB port facing toward the loudspeaker (0º rotation).

7.1 Acoustic and Electrical Specifications

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Pickup Pattern				Dipole (figure-8)		
Polarity		Increasing sound pressure at lid port		Increasing density of 1's		
		Increasing sound pressure at PCB port		Decreasing density of 1's		
Average Directivity Index[2]		Integrated from 20 Hz to 20 kHz		4.8		dB
Null Angle				90, 270		º
Supply Voltage	V_{dd}		1.6	1.8	3.6	V
Supply Current	I_{dd}	f_{clock} = 3.072 MHz		780		µA
		f_{clock} = 2.400 MHz		730		
		f_{clock} = 1.536 MHz		675		
		f_{clock} = 0.768 MHz		290		
	$I_{standby}$	f_{clock} < 0.100 MHz		5		
Sensitivity	S	f_{clock} ≥ 1.536 MHz, 94 dB SPL, 1 kHz	-31	-30	-29	dBFS
		f_{clock} = 0.768 MHz, 94 dB SPL, 1 kHz	-15	-14	-13	
Noise Floor		f_{clock} = 3.072 MHz		-89.0		dBFS(A)
		f_{clock} = 2.400 MHz		-89.0		
		f_{clock} = 1.536 MHz		-86.5		
		f_{clock} = 0.768 MHz, 20 Hz to 8 kHz		-73.5		
Signal to Noise Ratio[3]	SNR	f_{clock} = 3.072 MHz, 94 dB SPL		67.5		dB(A)
		f_{clock} = 2.400 MHz, 94 dB SPL		67.0		
		f_{clock} = 1.536 MHz, 94 dB SPL		62.0		
		f_{clock} = 0.768 MHz, 20 Hz to 8 kHz, 94 dB SPL		67.0		
Total Harmonic Distortion[4]	THD	1% THD, 1 kHz		109		dB SPL
Acoustic Overload Point	AOP	10% THD, 1 kHz		134		
Resonant Frequency	F_{res}			3.6		kHz
Phase Response		75 Hz		-11		º
		1 kHz		-35		
		3 kHz		-89		
Group Delay		250 Hz		79		µs
		600 Hz		72		
		1 kHz		68		
		4 kHz		92		
Power Supply Rejection Ratio	PSRR	200 mV$_{pp}$ sine wave on V_{dd} at 1 kHz		75		dB(V/FS)
Power Supply Rejection	PSR+N	200 mV$_{pp}$ 7/8 duty cycle rectangular waveform @ 217 Hz, A-weighted, BW = 22.4 kHz		-89		dBFS(A)
Output Load Capacitance	C_{load}	On DATA pin		200		pF
Clock Duty Cycle		f_{clock} < 2.7 MHz	45		55	%
		f_{clock} ≥ 2.7 MHz	48	50	52	
Clock Frequency	f_{clock}	Standard Mode	0.768		3.072	MHz
		Standby Mode	0.010		0.250	
		Clock Off Mode			0.001	
Logic Input/Output Low	V_{IL} / V_{OL}		-0.3		0.35V_{dd}	V
Logic Input/Output High	V_{IH} / V_{OH}		0.65V_{dd}		0.3+V_{dd}	V
Delay Time for Valid Data	t_{DV}	Delay time from CLOCK edge (0.5V_{DD}) to DATA valid (<0.3V_{DD} or >0.7V_{DD})	30		180	ns
Delay Time for High Z	t_{HZ}	Delay time for CLOCK edge (0.5V_{DD}) to DATA high impedance state	1		14	ns
Startup Time		Sensitivity within 1 dB of final value, outputs AC coupled		60		ms

Table 7.1: Acoustic and electrical specifications

---

[1] The acoustic path length is the minimum distance a soundwave must travel between the ports of the microphone. See Acoustic Path Length Definition for details.

[2] The directivity index is a measure of directionality based on the ratio of direct sound to diffuse sound captured. See Directivity Index Calculation for details.

[3] A directional microphone has a non-flat frequency response, as such the SNR must be calculated for the entire frequency range. See SNR Calculation for details.

[4] To calculate the THD of a microphone with a non-flat frequency response, the frequency response must first be equalized. See THD Calculation for details.

7.2 Absolute Maximum Ratings

Stresses at or above the Absolute Maximum Ratings could permanently damage the devices.

Parameter	Absolute Maximum Rating	Unit
V_{dd} to GND	5.0	V
Input Current	±5	mA
Storage Temperature	-40 to 100	°C
Operating Temperature	-40 to 85	°C

Table 7.2: Absolute maximum ratings

7.3 Timing Diagram
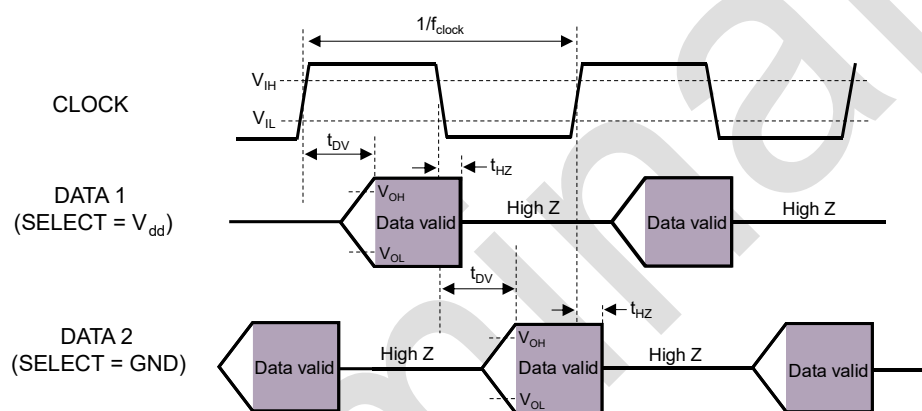
Figure 7.1: Timing diagram for output logic for select pin options

Microphone	Select	Asserts DATA on	Latch DATA on
Mic (High)	V_{dd}	CLOCK rising edge	CLOCK falling edge
Mic (Low)	Grounded	CLOCK falling edge	CLOCK rising edge

Table 7.3: Microphone select input

7.4 Specification Calculation Details

Acoustic Path Length Definition

The acoustic path length is the minimum distance a sound wave must travel around the microphone package between the two ports. The microphone is designed to perform best with path lengths found in end-products, which are typically 10 mm or greater. All specifications are measured with a standard 10 mm path length, the minimum recommended path length when integrating the device.

Directivity Index and Average Directivity Index Calculation

The **directivity index** (DI) measures the ratio of the microphone output for a sound positioned directly in front of the microphone ($\theta = 0^\circ$) versus sound with the same amount of total acoustic power coming from all directions equally. The directivity index at each frequency is calculated with the equation below.

$$DI = 10 log_{10}\left(4 \frac{amplitude(\theta = 0)^2 \left[\frac{V^2}{Pa^2}\right]}{\int_0^{2\pi} amplitude(\theta)^2 \left[\frac{V^2}{Pa^2}\right] |sin\,\theta| d\theta}\right)$$

Equation 7.1: Directivity Index

The average directivity index is calculated by logarithmically weighting the directionality index at each frequency and then taking the average of these weighted values from 20 Hz to 20 kHz.

SNR Calculation

The SNR of a directional microphone with a non-flat frequency response must be calculated differently than the typical method used for omnidirectional microphones that have a flat frequency response. Instead of only using the 1 kHz sensitivity, the electrical noise of the microphone at each frequency (units of V^2/Hz) must be divided by the corresponding sensitivity squared at each frequency (units of V^2/Pa^2) to obtain the input referred acoustic noise at each frequency (units of Pa^2/Hz). Then, the acoustic noise is A-weighted by multiplying it by the A-weighting factor (A_w) and this A-weighted acoustic noise is integrated over the full audio bandwidth and converted to an equivalent sound pressure level (dBA SPL) by dividing by the reference pressure (P_{ref}=20 µPa). Finally, the SNR is calculated by subtracting the integrated input referred noise from 94 dB SPL. The equation for the calculation is shown below.

$$SNR = 94 - 20 log_{10}\left(\frac{1}{P_{ref}^2 [Pa^2]} \int_{20Hz}^{20kHz} \frac{noise\left[\frac{V^2}{Hz}\right]}{sensitivity\left[\frac{V^2}{Pa^2}\right]} A_w df\,[Hz]\right)$$

Equation 7.2: Full-spectrum SNR calculation

THD Calculation

THD is calculated by playing an acoustic sine wave at a specific sound pressure level and frequency and dividing the sum of the powers of the harmonic components of the captured signal by the power of the fundamental frequency. To calculate the THD of a microphone with a non-flat frequency response, the response must first be equalized to equally weigh the fundamental frequency and its respective harmonics.

For more information on these calculations, refer to the app note: AN-110: Attributes of Soundskrit Directional Microphones.
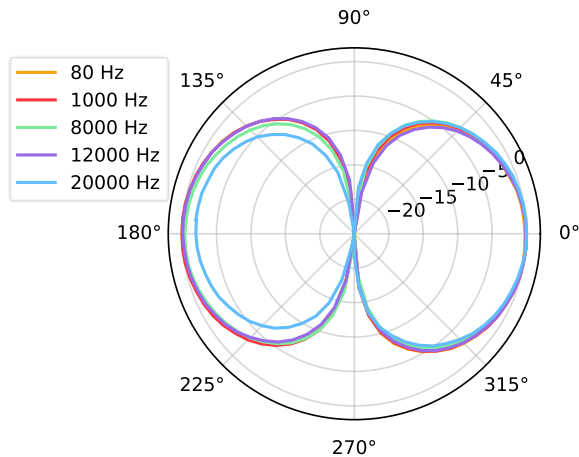
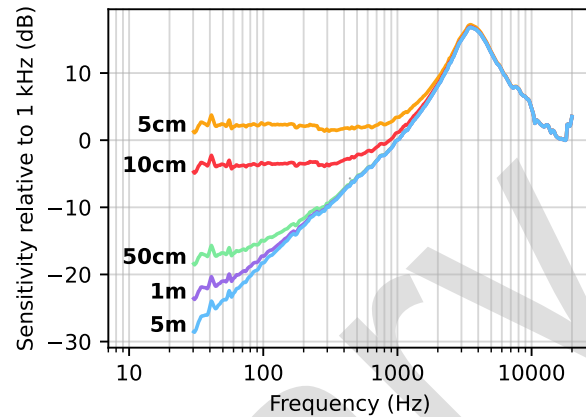## 7.5 Performance Curves

Figure 7.2: Pickup pattern vs. frequency
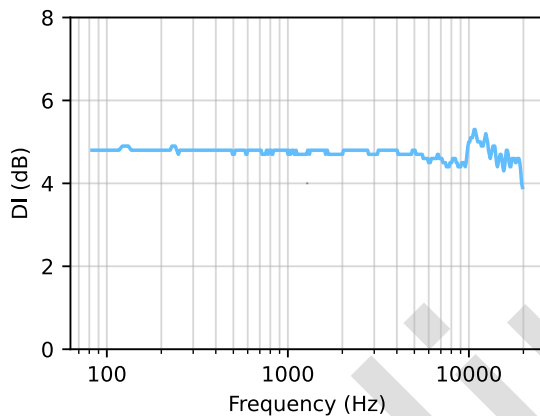

Figure 7.3: Magnitude response[5]

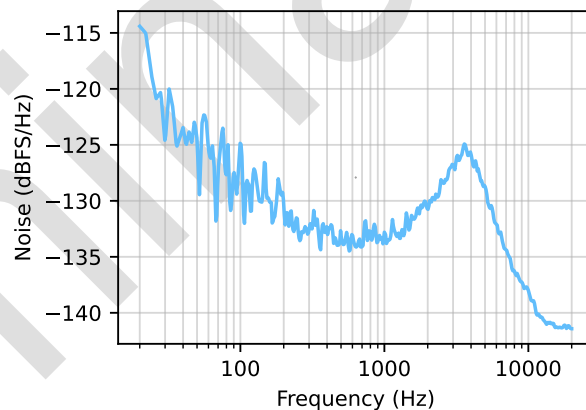*Figure 7.4: Directionality index vs frequency*
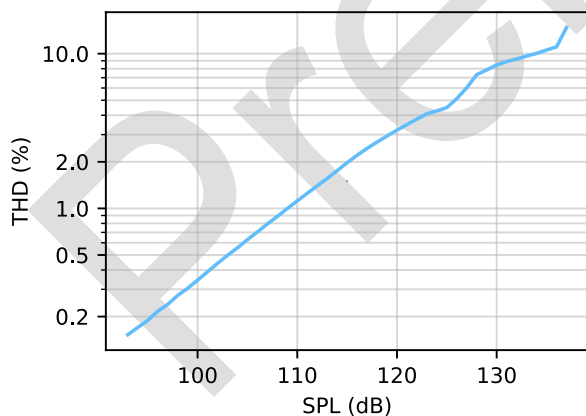

Figure 7.5: Noise floor

Figure 7.6: THD (1 kHz) vs SPL
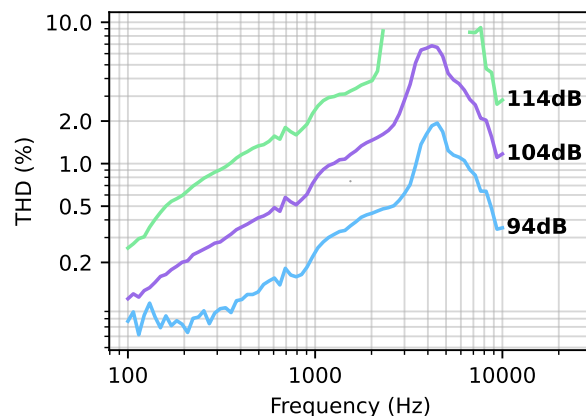

Figure 7.7: THD vs frequency

---

[5] The increased bass response at close distances is known as the 'Proximity Effect.' See AN-110 for details.

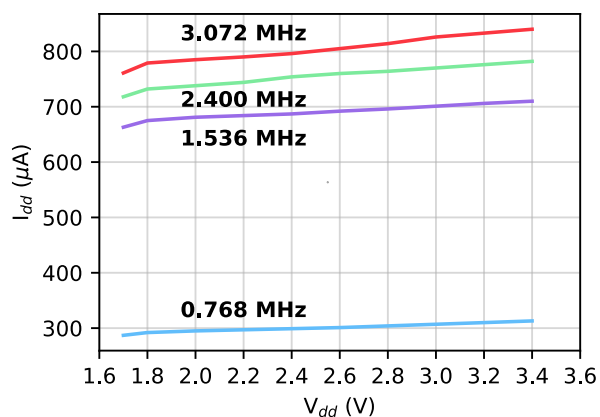www.soundskrit.ca Copyright © 2023 Soundskrit Inc

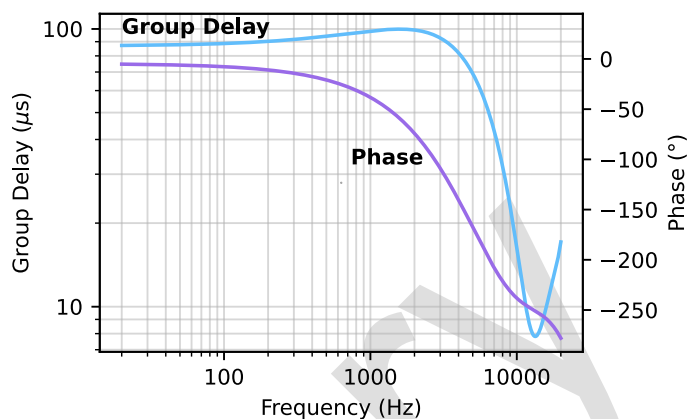Figure 7.8: Supply current vs input voltage

Figure 7.9: Phase and group delay

8. Mechanical, Packaging, and Manufacturing Information
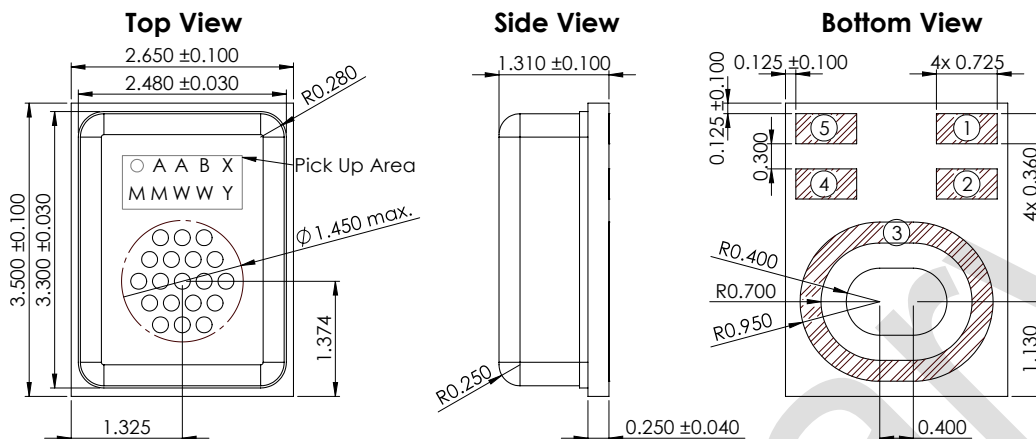
8.1 Mechanical Dimensions and Product Marking

Figure 8.1: Mechanical drawings (mm) and product marking

Table 8.1: Mechanical specifications

Item	Dimensions (mm)
Length	3.500 ± 0.100
Width	2.650 ± 0.100
Height	1.310 ± 0.100
Lid Port Array OD	1.450 max
Bottom Acoustic Port	1.200 x 0.800 ± 0.050

Table 8.2: Pinout

Pin #	Pin Name	Description
1	DATA	PDM Output Signal
2	SELECT	LR Select Input
3	GND	Ground
4	CLOCK	Clock
5	VDD	Power Supply

Table 8.3: Product marking

Marking	Description
AA	Model Code: SKR0AA0
B	0: Final Production
XMM	Internal Codes
WW	Week WW of the year
Y	Year 202Y

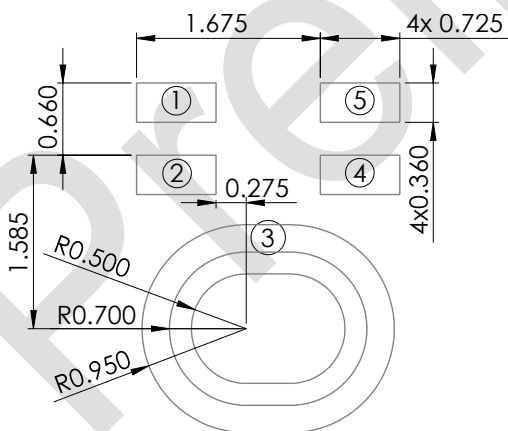## 8.2 Land Pattern and Solder Stencil
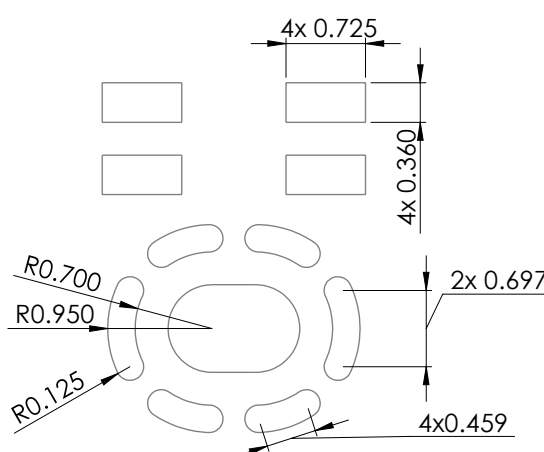

Figure 8.2 Example land pattern (mm)

Figure 8.3 Example solder stencil pattern (mm)

8.3 CAD Models

The CAD model and KiCAD layout and footprint are available here: STEP File and KiCAD.

8.4 Packaging and Ordering Information
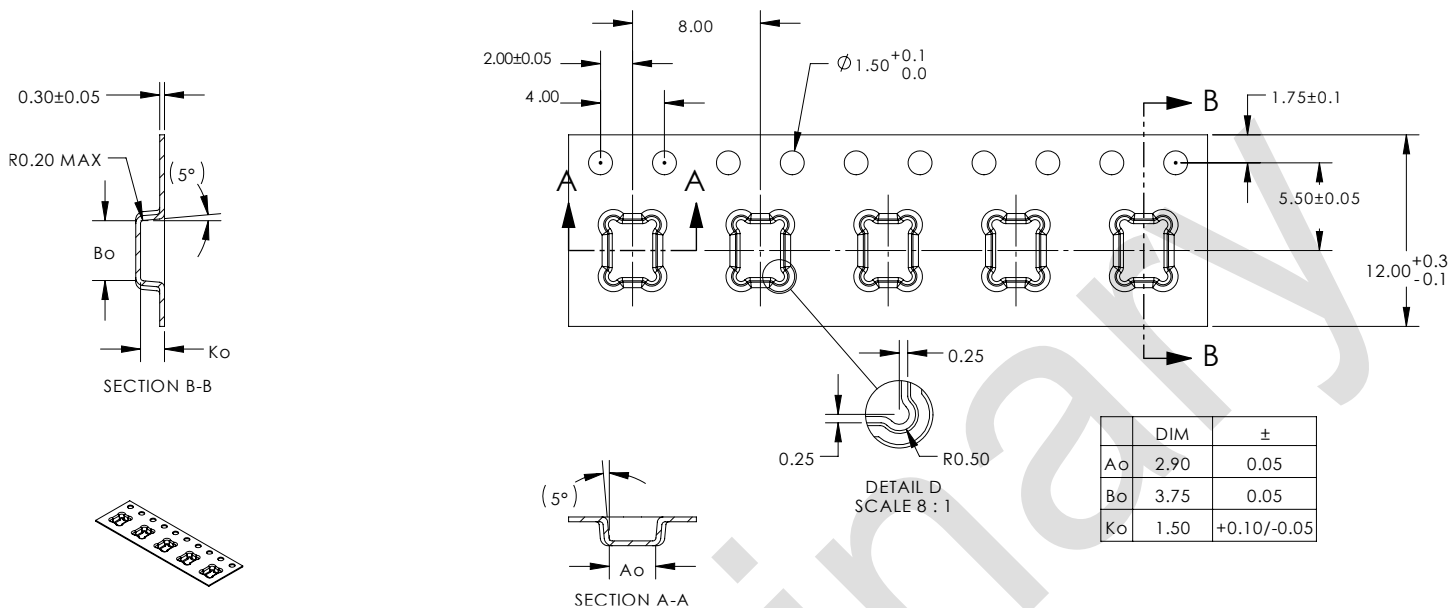
Figure 8.3 Reel dimensions (mm)

DIM	±
Ao	2.90	0.05
Bo	3.75	0.05
Ko	1.50	+0.10/-0.05

Table 8.4: Ordering Information

Model Number	Reel Diameter	Quantity per Reel
SKR0610-7	7"	1300
SKR0610-13	13"	5000

Table 8.5: Packaging Information

Component	Surface Resistance (Ω)
Reel	10^5 to 10^{12}
Carrier Tape	10^5 to 10^{11}
Cover Tape	10^5 to 10^{12}

8.5 Reflow Profile and Handling Instructions

Figure 8.5 shows the recommended reflow profile for soldering the microphone. The reflow profile is based on the standard J-STD-020D. The microphone has a moisture sensitivity level (MSL) of Class 1.
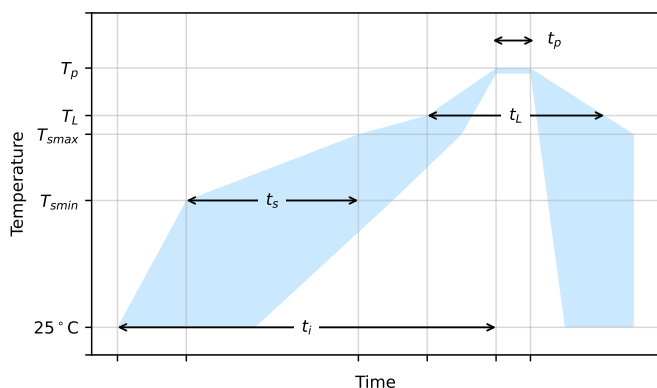
Profile Feature	Symbol	Pb-Free Assembly
Temperature Min	T_{smin}	140 °C
Temperature Max	T_{smax}	200 °C
Time from T_{smin} to T_{smax}	t_s	70 seconds
Ramp-up rate from T_L to T_p		3 °C/second max
Liquidous temperature	T_L	217 °C
Time maintained above T_L	t_L	150 seconds
Peak package body temperature	T_p	260 °C
Time within 5 °C of T_p	t_p	30 seconds[6]
Ramp-down rate from T_p to T_L		2 °C/second max
Maximum time 25 °C to peak temperature	t_i	8 minutes

Figure 8.5: Reflow profile

The microphone is packaged with a layer of reflow-compatible Kapton tape covering the lid port. This tape protects the microphone during reflow and assembly and should only be removed at the latest stage possible in the assembly process. Do not remove the Kapton tape prior to soldering the microphone or nearby components. To remove the Kapton tape, use tweezers to catch the edge of the tape and peel the tape off.
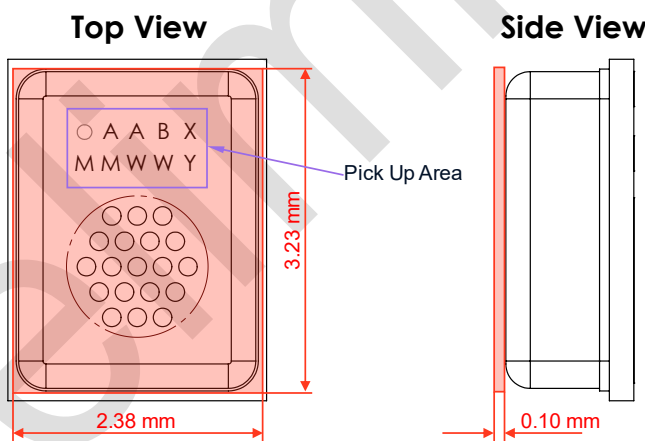

Figure 8.6: Mechanical drawing with protective tape

The MEMS microphones should be handled using industry standard pick and place equipment or appropriate manual handling procedures. To minimize device damage, please carefully follow the guidelines below:

- Use the pick-up area shown in Figure 8.6.
- Do not apply a vacuum or high pressure over the top or bottom acoustic port hole.
- Do not apply air blow and ultrasonic cleaning procedures over the acoustic port hole.
- Do not board wash or clean after the reflow process.
- Do not expose the acoustic port hole to harsh chemicals.
- Do not directly expose the acoustic port hole to solder fumes or vapor phase soldering.
- Do not apply a vacuum when packing parts in sealed bags at a suction flow rate faster than 0.85 CFM.

[6] Tolerance for peak profile temperature (T_P) is defined as a supplier minimum and a user maximum.

9. Reliability Specifications

The microphone sensitivity must deviate by no more than 1 dB from the initial value after 3 reflow cycles for the reflow test and no more than 3 dB for the other tests.

Test	Test Condition	Standard
ESD-CDM	3 discharges of ±500 V with direct contact to I/O pins	JEDEC-JS002
ESD-HBM	3 discharges of ±2 kV with direct contact to I/O pins	JEDEC-JS001
ESD-LID/GND	3 discharges of ±8 kV with direct contact to lid while unit is under bias	IEC-61000-4-2
Free Fall	Microphone put in a 150g block, drop from 1.5m onto concrete floor, 4 drops for each surface and corner, total 40 drops	IEC 60068-2-32
High Temperature Bias	+125 °C for 1,000 hours under bias	JESD22 A-108F
High Temperature Storage	+125 °C for 1,000 hours	JESD22 A-103E
Low Temperature Bias	-40 °C for 1,000 hours under bias	JESD22 A-108F
Low Temperature Storage	-40 °C for 1,000 hours	JESD22-A119A
Mechanical Shock	5 shocks of 10,000 g / 0.1 msec in each direction of ±x, ±y, ±z, 30 shocks in total	IEC 60068-2-27
Reflow	3 reflow cycles with +260 °C peak temperature	IPC-JEDEC J-STD-020E
Temperature Humidity Bias	+85 °C/85% R.H. for 1,000 hours under bias	JESD22-A101D
Thermal Shock	100 cycles, air-to-air, -40 °C to +125 °C, 15 minutes soak	JESD22.A104E
Tumble	Microphone put in a 150g block, drop from 1m onto steel base, rotation speed 10-11 times/min, 300 drops	IEC 60068-2-32
Vibration	4 cycles of 4 minutes each in each x, y, z axis from 20 Hz to 2000 Hz with peak acceleration of 20 G	MIL-STD-883E-2007-2-A

Table 9.1: Reliability specifications

10. Device and Documentation Support

Supporting application notes can be found on our application notes page.

11. Revision History

Revision Label	Revision Date	Sections Revised
-	July 2024	Preliminary release
A	August 2024	Updated performance specifications and curves. Update mechanical and packaging images.
B	November 2024	Updated notes on typical application circuit

Soundskrit developed the first high-performance directional MEMS microphone on the market, leveraging years of research in bio-inspired MEMS based on how spiders and other insects in nature hear. In combination with Soundskrit's in-house audio processing algorithms, directional microphones can be used to capture and isolate any sound in an environment with a fraction of the size, power, and computation of traditional omnidirectional-based microphone arrays.

Soundskrit was founded in 2019 and is headquartered in Montreal, Quebec with an R&D facility in Ann Arbor, Michigan.