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 sound ports
- Differential or Singled Ended Output
- High 63.5 dBA SNR
- Low THD:
  - 1% THD at 116 dB SPL
  - AOP at 131 dB SPL (Standard Mode)
  - AOP at 134 dB SPL (High-AOP Mode)
- 115 µA supply current
- 3.50 x 2.65 mm^2 footprint
- -40 to 85 °C operating temperature

2. Applications

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

3. Description

The SKR0400 is a directional MEMS microphone with a dipole pickup pattern for superior acoustic signal isolation. The microphone maintains this polar pattern across the audible frequency range. Diffuse noise is attenuated by 4.8 dB across the audible range while direct sound is rejected with >20 dB attenuation at the null.

Packaged in a subminiature 9.3 mm^2 footprint, the SKR0400 can be used in the most sized-constrained applications. The SKR0400 features 63.5 dBA SNR and does not reach 1% THD until 116 dB SPL, despite its small size. This large dynamic range ensures high-quality voice pick-up in both near-field and far-field applications. The SKR0400 dramatically improves both noise and directional performance over conventional omnidirectional microphone arrays.

When integrating the SKR0400 into a product, the device can be implemented to produce a cardioid polar pattern rather than a dipole. Pairing multiple SKR0400 microphones enables the designer to implement traditional DSP and machine learning-based algorithms not possible with omnidirectional arrays. These algorithms maximize the performance of the end-product with enhanced beamforming and spatial understanding of the sound field. Additionally, SKR0400 microphones bring true stereo capture to small form factor consumer devices when configured in a Blumlein pair.

4. Functional Block Diagram

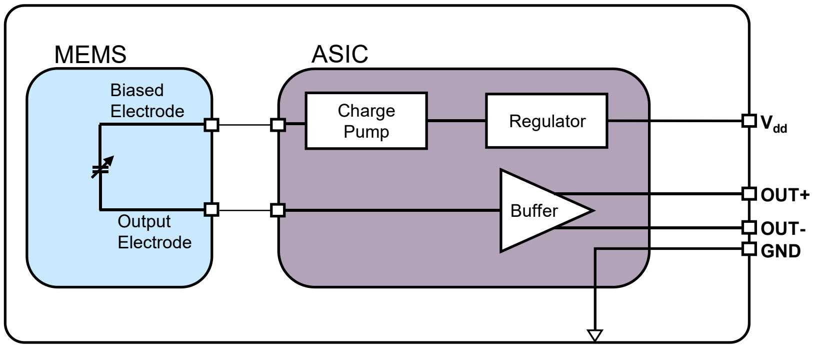

Figure 4.1: Functional block diagram

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6. Typical Application Circuit

The SKR0400 has two operating modes: standard mode and high-AOP mode. To configure the microphone in standard mode, set V_{dd} between 1.6 V and 2.0 V. To configure the microphone in high-AOP mode, set V_{dd} between 2.2 V and 3.6V. The microphone cannot be operated with V_{dd} between 2.0 V and 2.2 V.

A 0.1 µF capacitor should be placed between V_{dd} and GND as close to the microphone as possible to reduce supply noise. A capacitor C_{out} should be used to block the microphone output DC from the application processing input. This capacitor a creates high-pass filter according to $C_{out} = 1/\pi f_c R_{AP}$ (e.g. 80 nF), where f_c (e.g. 20 Hz) is the desired cutoff frequency and R_{AP} (e.g. 100 kOhm) is the application processor resistance.

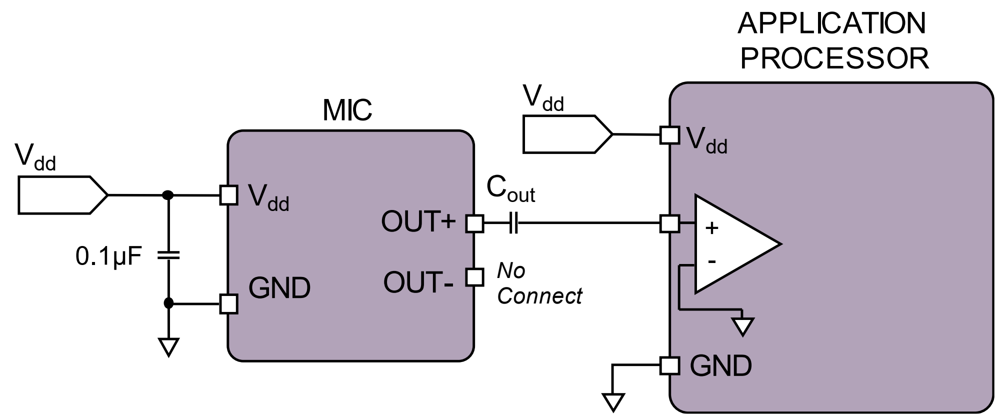


Figure 6.1: Typical single-ended application circuit

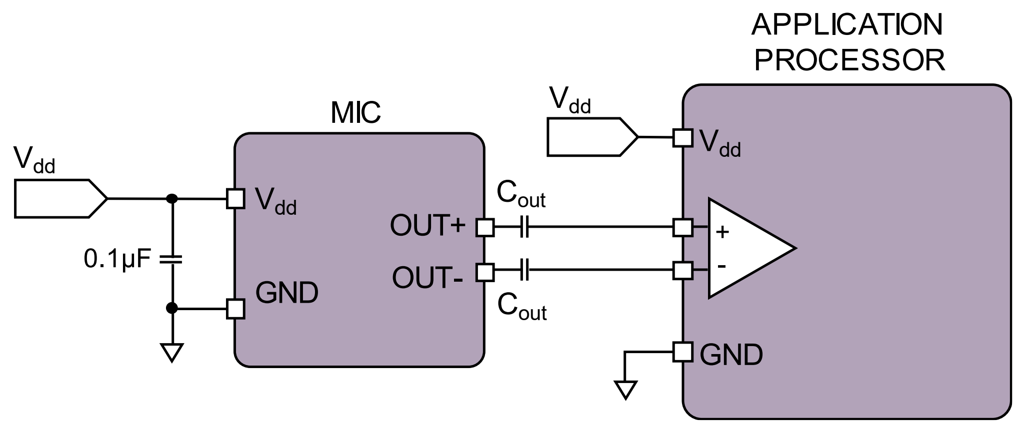


Figure 6.2: Typical differential application circuit

7. Specifications

7.1 Acoustic and Electrical Specifications

Test conditions throughout full datasheet unless otherwise indicated: 25 ºC, 55 ± 20% R.H., V_{dd} = 1.8 V, differential, 3 m away, 10 mm acoustic path length[1], no load, bottom (PCB) port facing toward loudspeaker. 0º is defined as the port hole on the PCB.

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Pickup Pattern				Dipole (figure-8)		
Polarity		Increasing sound pressure at top (lid) port		Increasing output voltage		
		Increasing sound pressure at bottom (PCB) port		Decreasing output voltage		
Average Directivity Index[2]		Integrated from 20 Hz to 20 kHz		4.8		dB
Null Angle				90, 270		º
Supply Voltage	V_{dd}	Standard Mode	1.6	1.8	2.0	V
		High-AOP Mode	2.2	2.8	3.6	
Supply Current	I_{dd}	V_{dd} = 1.8 V		115		µA
		V_{dd} = 2.8 V		160		
Sensitivity	S	94 dB SPL, 1 kHz, Single-Ended	-36	-35	-34	dBV/Pa
		94 dB SPL, 1 kHz, Differential	-30	-29	-28	
Noise Floor		Single-Ended		-92.5		dBV(A)
		Differential		-86.5		
Signal to Noise Ratio[3]	SNR	20 Hz to 20 kHz, 94 dB SPL, Single-Ended		64		dB(A)
		20 Hz to 20 kHz, 94 dB SPL, Differential		63.5		
Total Harmonic Distortion[4]	THD	94dB SPL, 1kHz		<0.1		%
		1% THD, 1 kHz		116		dB SPL
Acoustic Overload Point	AOP	10% THD, 1 kHz, Standard Mode		131		
		10% THD, 1 kHz, High-AOP Mode		134		
Resonant Frequency	Fres			4.3		kHz
Phase Response		75 Hz		-7		º
		1 kHz		-38		
		3 kHz		-109		
Group Delay		250 Hz		91		µs
		600 Hz		95		
		1 kHz		98		
		4 kHz		82		
Power Supply Rejection Ratio	PSRR	200 mVpp sine wave on Vdd at 1 kHz, Single-Ended		64		dB
		200 mVpp sine wave on Vdd at 1 kHz, Differential		58		
Power Supply Rejection	PSR+N	200mVpp 7/8 duty cycle rectangular waveform @ 217 Hz on V_{dd}, A-weighted, BW = 20 kHz, Single-Ended		-84		dBV(A)
		200mVpp 7/8 duty cycle rectangular waveform @ 217 Hz on V_{dd}, A-weighted, BW = 20 kHz, Differential		-84		
DC Voltage Output		V_{dd} = 1.8 V		0.836		V
		V_{dd} = 2.8 V		1.336		
DC Offset		OUT+ to OUT-			±10	mV
Output Impedance	Z_{out}				100	Ω
Startup Time		Sensitivity within 1 dB of final value, outputs AC coupled		15		ms

[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 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 SKR0400 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. For more information, refer to the app note: AN-110: Attributes of Soundskrit Directional Microphones.

Directivity Index and Average Directivity Index Calculation

The directivity index measures the ratio of the microphone output for a sound positioned directly in front of the microphone (θ = 0º) 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.

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

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. For more information, refer to the app note: AN-110: Attributes of Soundskrit Directional Microphones.

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. For more information, refer to the app note: AN-110: Attributes of Soundskrit Directional Microphones.

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

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 equalization and THD calculation, refer to the app note: AN-110: Attributes of Soundskrit Directional Microphones.

7.3 Absolute Maximum Ratings

Meeting or exceeding the conditions listed as Absolute Maximum Ratings could permanently damage the devices. Operating the devices at these ratings could impact device reliability.

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

7.4 Performance Curves

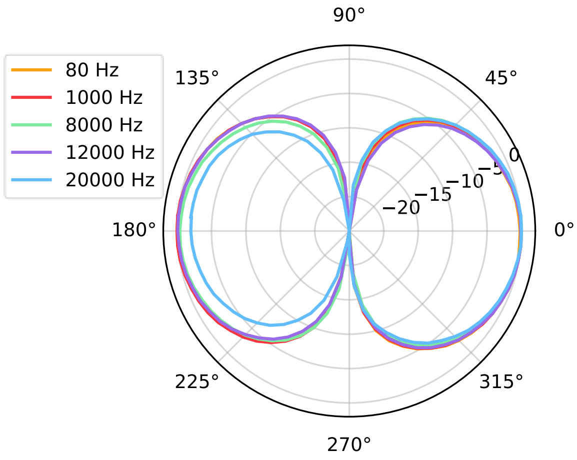


Figure 7.1: Pickup pattern vs. frequency

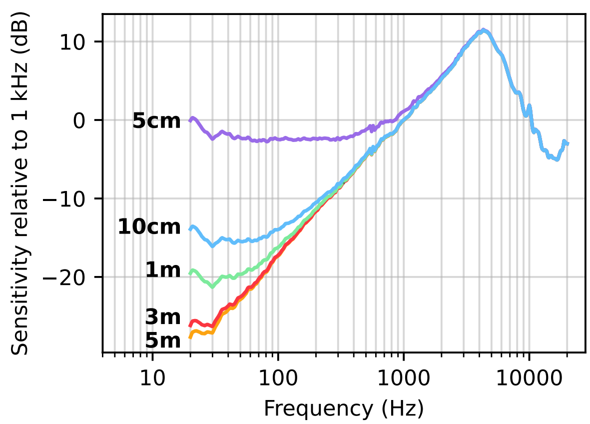


Figure 7.2: Typical magnitude response[5]

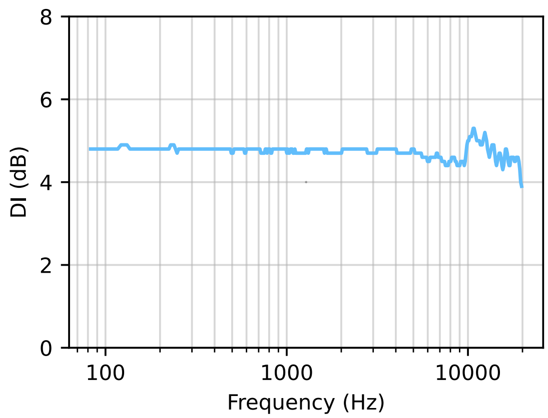


Figure 7.3: Directionality index vs frequency

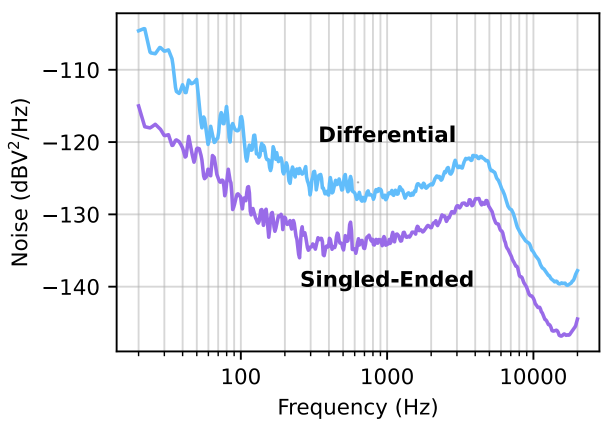


Figure 7.4: Typical noise floor

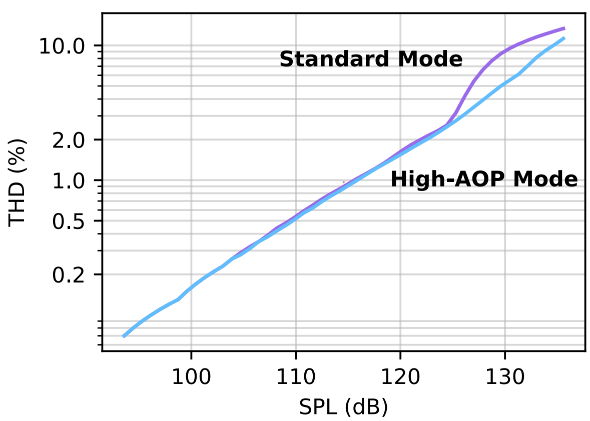


Figure 7.5: Typical THD (1 kHz) vs SPL

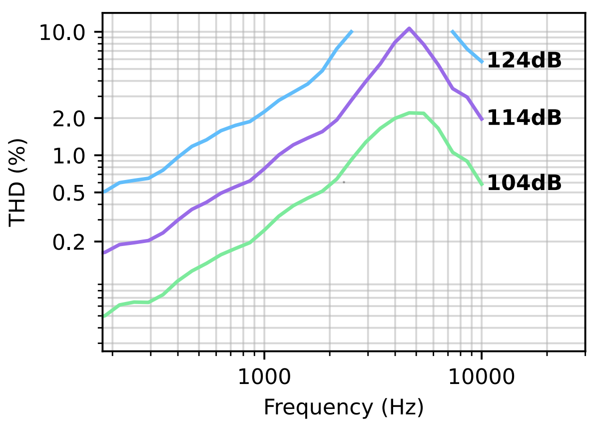


Figure 7.6: THD vs frequency

[5] The increased bass response at close distances is known as the 'Proximity Effect.' See AN-100 for details.

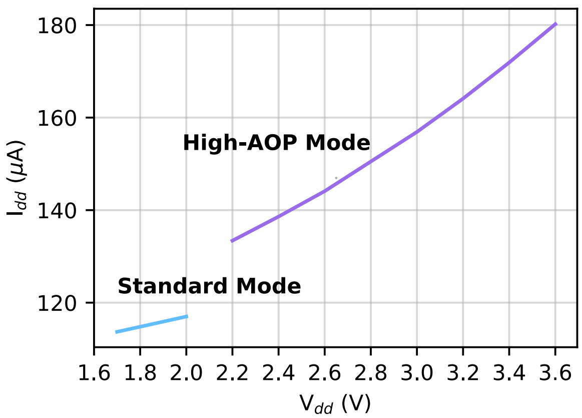


Figure 7.7: Input voltage vs supply current

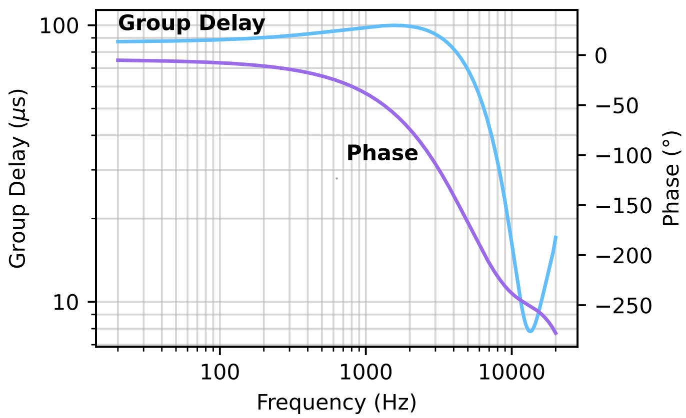


Figure 7.8: Typical phase and group delay

8. Mechanical, Packaging, and Manufacturing Information

8.1 Mechanical Drawing and Pinout

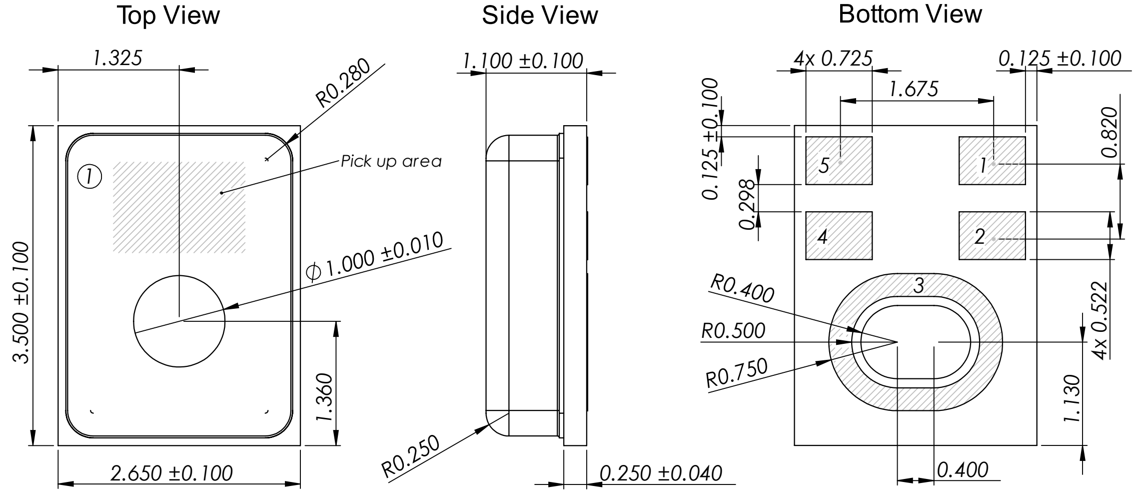


Figure 8.1: Mechanical drawings (mm)

Table 8.1: Mechanical specifications

Item	Dimensions (mm)
Length	3.500 ± 0.100
Width	2.650 ± 0.100
Height	1.100 ± 0.100
Top Acoustic Port	1.000 ± 0.010
Bottom Acoustic Port	1.200 x 0.800 ± 0.050
PCB Thickness	0.250 ± 0.040

Table 8.2: Pinout

Pin #	Pin Name	Description
1	OUT+	Non-Inverted Output Signal
2	OUT-	Inverted Output Signal
3, 4	GND	Ground
5	V_{dd}	Power Supply

Additional Notes:

- Do not put a vacuum over the port hole.
- The pick-up area begins 0.25 mm from any edge or the port hole.
- Use reflow profile standard J-STD-020D.

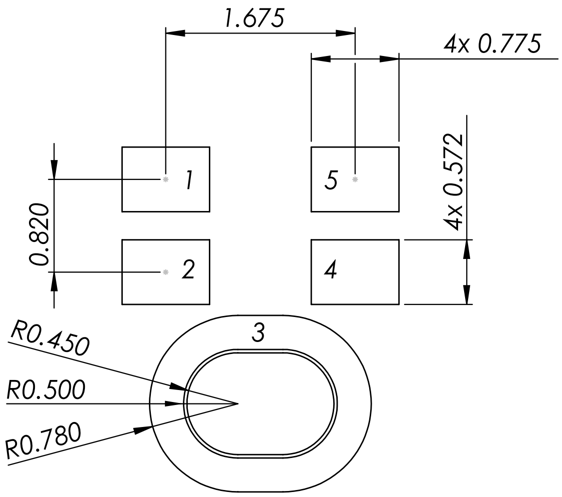


Figure 8.2 Example land pattern (mm)

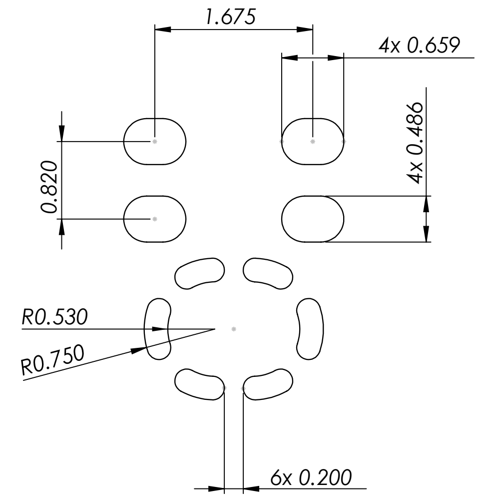


Figure 8.3 Example solder stencil pattern (mm)

8.2 Recommended Reflow Profile

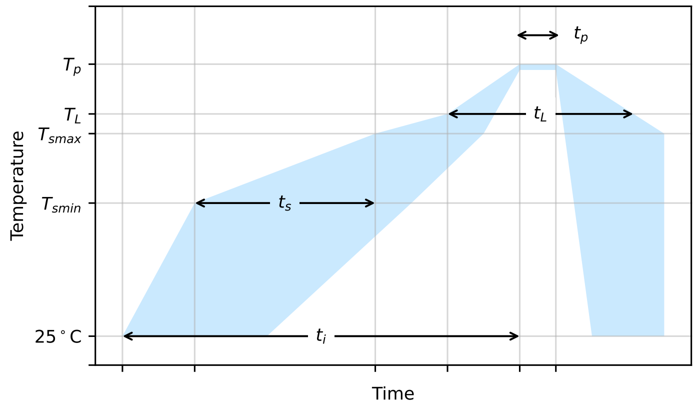


Figure 8.4: Reflow profile

Table 8.3: Reflow profile

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

9. Packaging and Ordering Information

9.1 Tape and Reel Packaging

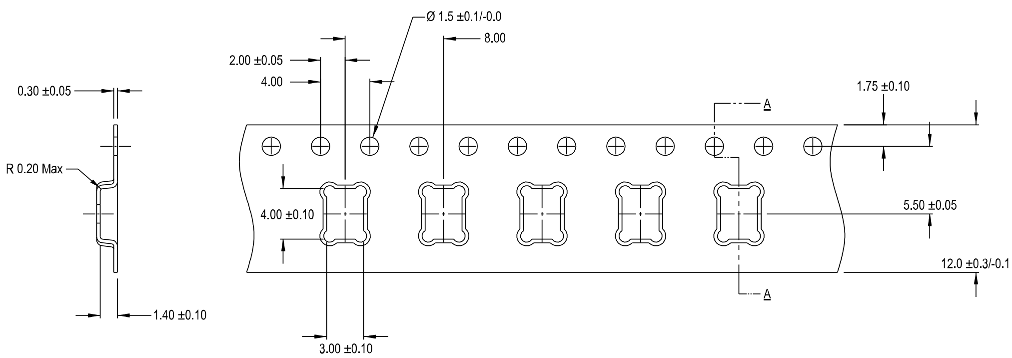


Figure 9.1 Reel dimensions (mm)

Table 9.1: Ordering Information

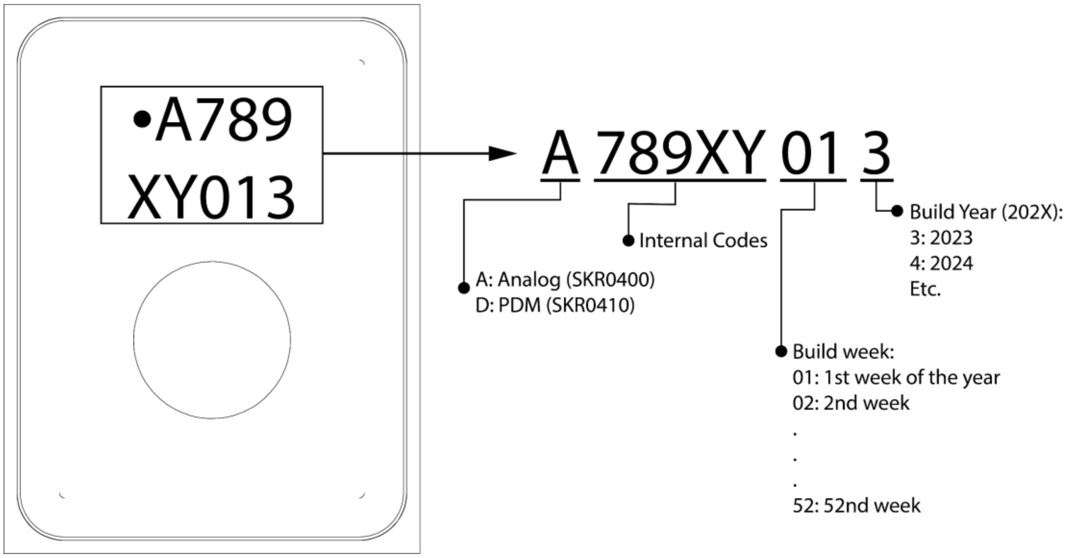
Model Number	Reel Diameter	Quantity per Reel
SKR0400-7	7"	1400
SKR0400-13	13"	4600

Table 9.2: 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}

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

9.2 Product Marking



9.3 Protective Tape

The microphone is packaged with a layer of Kapton tape covering the top hole as pictured in Figure 9.2. To remove, use wide tweezers to catch the edge of the tape from the top side as shown in Figure 9.3. After mounting the microphone on a PCB, the tape can be removed using one pair of tweezers as shown in method one. If the microphone is not mounted, use another pair of wide tweezers to hold the part down as shown in method two.

Figure 9.2: MEMS with Kapton tape

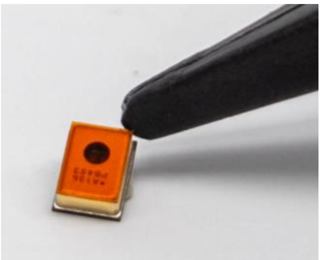


Figure 9.3: Method one

Figure 9.4: Method two

10. 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	JS002-2018
ESD-HBM	3 discharges of ±2 kV with direct contact to I/O pins	JS001-2017
ESD-LID/GND	3 discharges of ±8 kV with direct contact to lid while unit is under bias	IEC-61000-4-2
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
Latch up	Trigger current from ±200mA	JESD 78F
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
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

11. Device and Documentation Support

11.1 Application Notes

AN-100: Comparing Soundskrit Directional Microphones to Omnidirectional Microphones

AN-110: Attributes of Soundskrit Directional Microphones

AN-130: Designing Linear Arrays with Directional Microphones

11.2 Additional Support

For additional design and applications support, please reach out to applications@soundskrit.ca.

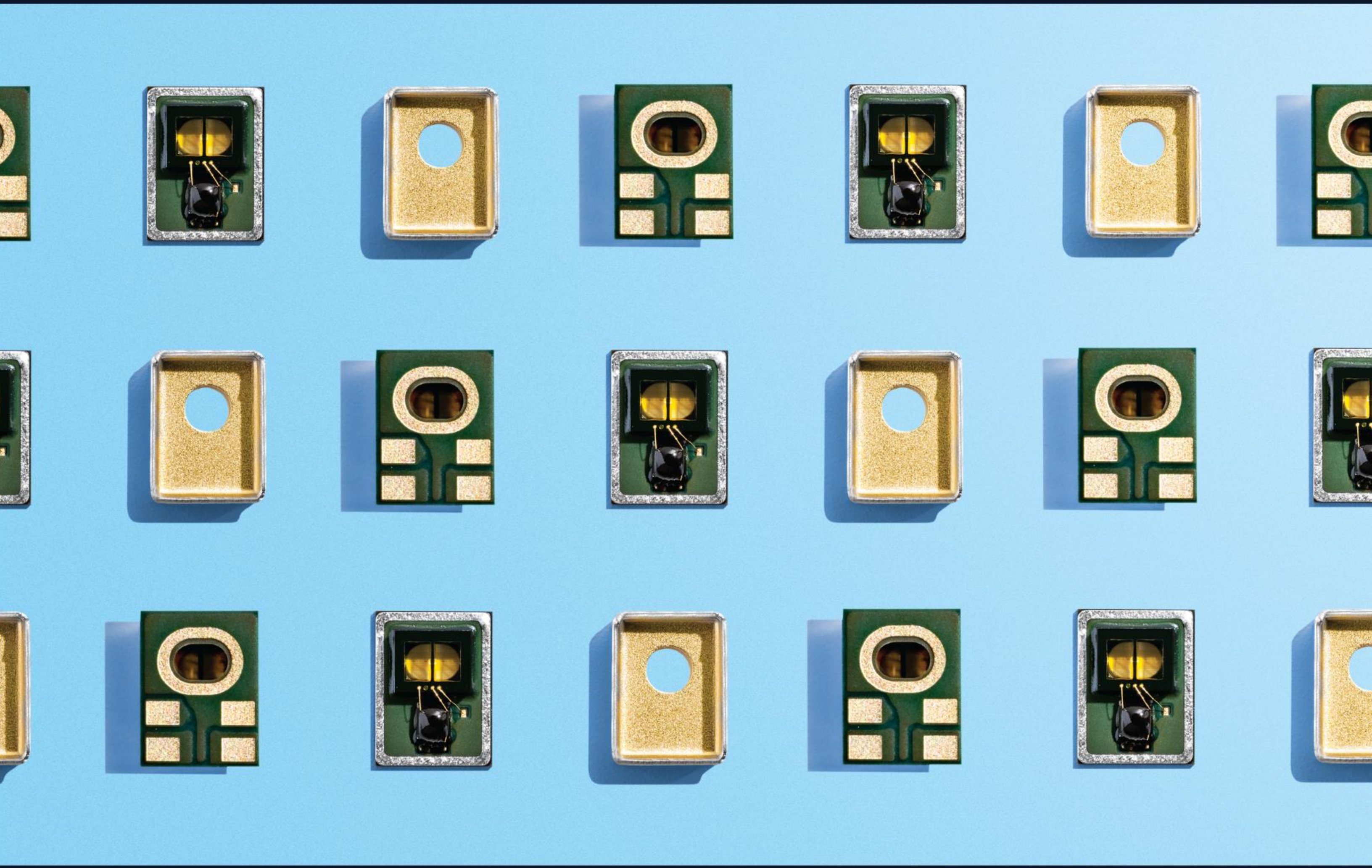
Soundskrit offers a suite of software algorithms to take full advantage of the utility our microphones provide. With a range from lightweight linear DSP tools to multichannel, machine learning based processing, we have a solution to meet any performance requirements. For more information, contact us or head to soundskrit.ca/software

12. Revision History

Revision Label	Revision Date	Sections Revised
-	January 2023	Official release
A	April 2023	Application circuit and recommendations
B	December 2023	Added product marking and handling instructions

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.



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