1. Characteristics

- Directional from 20 Hz to 20 kHz
- Smallest total solution size
- Dual sound ports
- Differential or singled ended output
- 67.5 dBA SNR
- 1% THD at 108 dB SPL
- AOP at 128 dB SPL
- 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 SKR0600 is a directional MEMS microphone with 67.5 dB SNR which enables integration in small formfactor devices and a configurable polar pattern.

The high SNR of the SKR0600 allows greater integration flexibility while maintaining high performance. The port spacing, tube length, and port size can be reduced to package the SKR0600 into portable, space constrained devices, bringing the benefits of directional microphones to product categories such as TWS, hearing aids, and mobile.

The flexibility offered by the SKR0600 also extends to the directional characteristics. The transducer of the SKR0600 was designed to reduce the impact on performance of acoustic meshes. With this, the microphone can be adjusted to exhibit a hypercardioid or cardioid polar pattern with an SNR of 65.0 dB by adding the appropriate acoustic mesh.

The SKR0600 is the most flexible microphone offering available from Soundskrit. The SKR0600 is suited for applications where the smallest size, highest performance, or maximum directionality is desired. These directional microphones ensure high quality audio with low background noise is possible in all consumer electronics of any form factor.

4. Functional Block Diagram

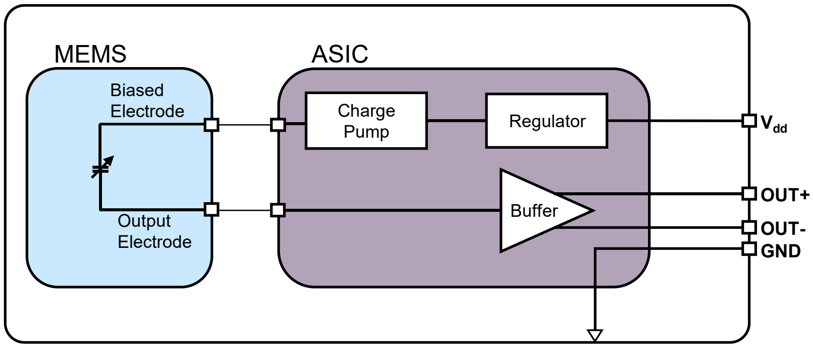


Figure 4.1: Functional block diagram

5. Table of Contents

6. Typical Application Circuit

The SKR0600 can be operated normally with V_{dd} from 1.6 – 2.0 V and 2.2 – 3.6 V. V_{dd} should not be set from 2.0 V – 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's DC output 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.

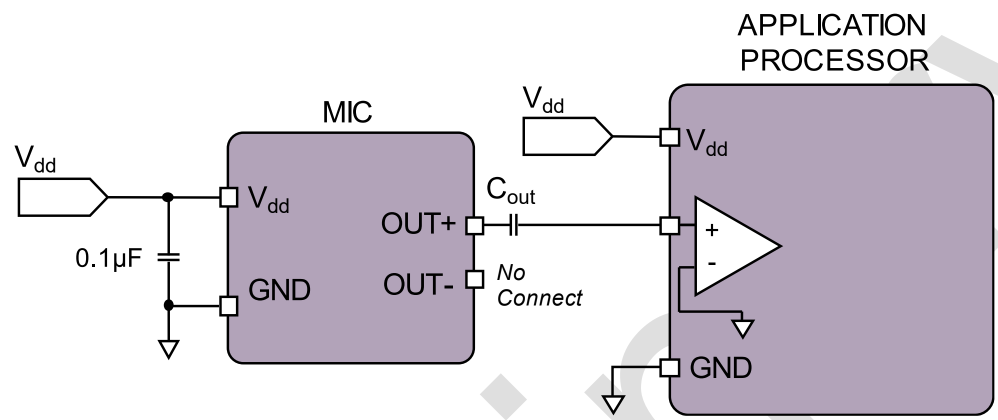


Figure 6.1: Typical single-ended application circuit

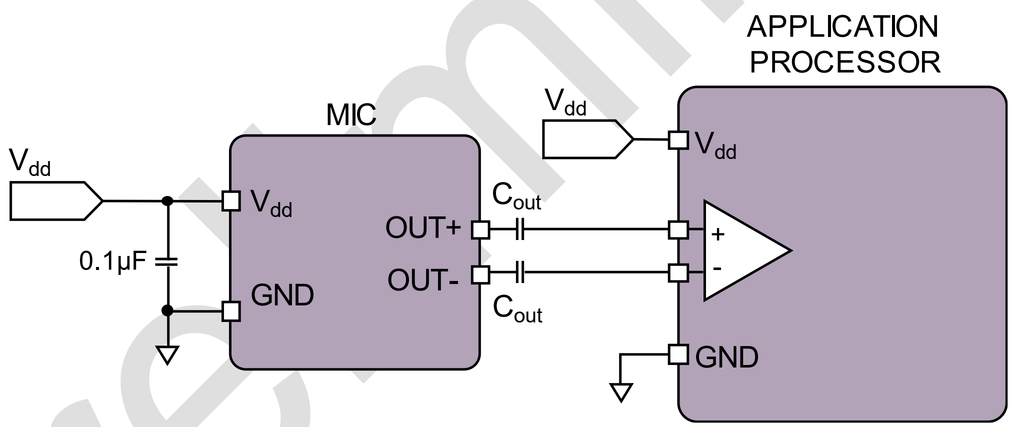


Figure 6.2: Typical differential application circuit

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 port		Increasing output voltage		
		Increasing sound pressure at bottom 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}		1.7	1.8	2.0	V
			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	-32	-31	-30	dBV/Pa
		94 dB SPL, 1 kHz, Differential	-26	-25	-24	
Noise Floor		Single-Ended		-91		dBV(A)
		Differential		-85		
Signal to Noise Ratio[3]	SNR	20 Hz to 20 kHz, 94 dB SPL, Single-Ended		67.5		dB(A)
		20 Hz to 20 kHz, 94 dB SPL, Differential		67.0		
Total Harmonic Distortion[4]	THD	94dB SPL, 1kHz		<0.1		%
		1% THD, 1 kHz		108		dB SPL
Acoustic Overload Point	AOP	10% THD, 1 kHz		128		
Resonant Frequency	Fres			3.3		kHz
Phase Response		75 Hz		0		º
		1 kHz		-19		
		3 kHz		-96		
Group Delay		250 Hz		68		µs
		600 Hz		55		
		1 kHz		54		
		4 kHz		96		
Power Supply Rejection Ratio	PSRR	200 mV_{pp} sine wave on V_{dd} at 1 kHz, Single-Ended		67		dB
		200 mV_{pp} sine wave on V_{dd} at 1 kHz, Differential		62		
Power Supply Rejection	PSR+N	200 mV_{pp} 7/8 duty cycle rectangular waveform @ 217 Hz on V_{dd}, A-weighted, BW = 22.4kHz, Single-Ended		-85		dBV(A)
		200 mV_{pp} 7/8 duty cycle rectangular waveform @ 217 Hz on V_{dd}, A-weighted, BW = 22.4kHz, 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 SKR0600 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 (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 microphones with cardioid polar patterns which reduce noise from the rear rather than the sides, the **unidirectional index** (UI) is used. UI measures the ratio of the microphone output for a sound positioned in front of the microphone versus sound with the same amount of total acoustic power coming from the back of the microphone. Both omnidirectional microphones and dipole microphones have a UI of 0 dB.

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.

7.3 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

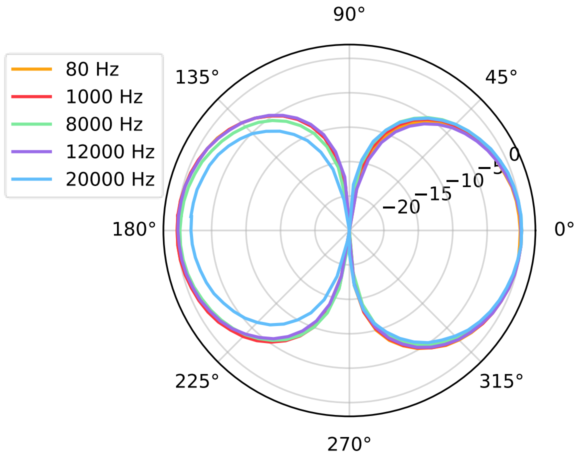


Figure 7.1: Pickup pattern vs. frequency

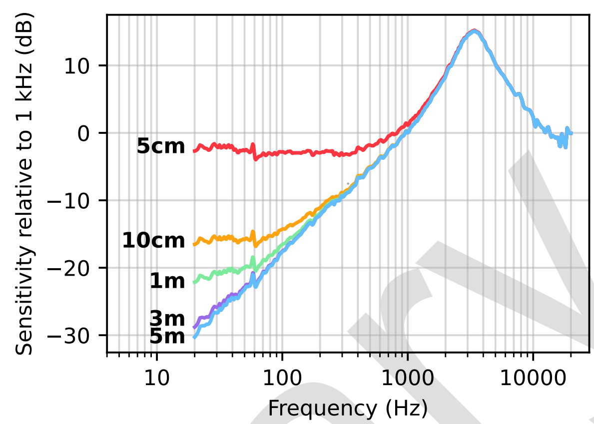


Figure 7.2: Typical magnitude response[5]

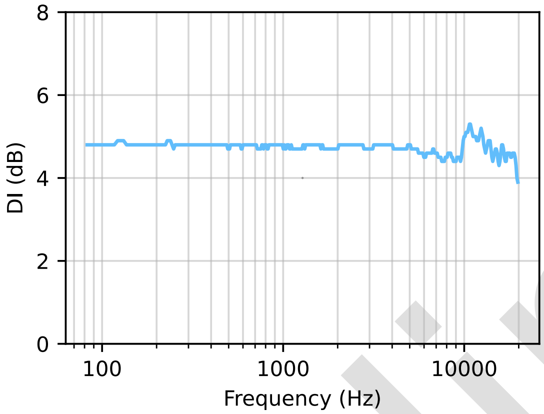


Figure 7.3: Directionality index vs frequency

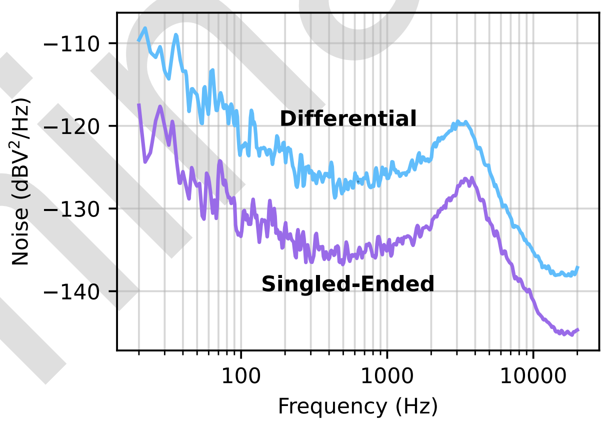


Figure 7.4: Typical noise floor

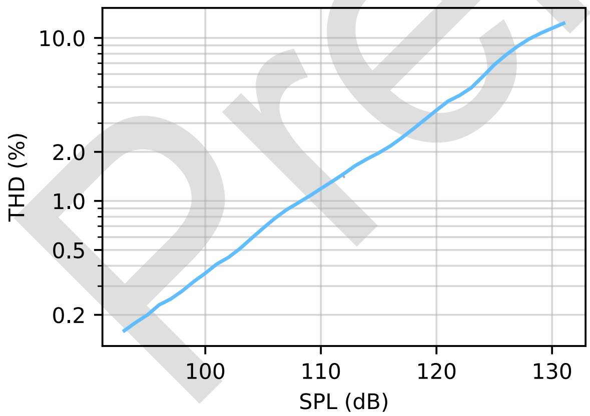


Figure 7.5: Typical THD (1 kHz) vs SPL

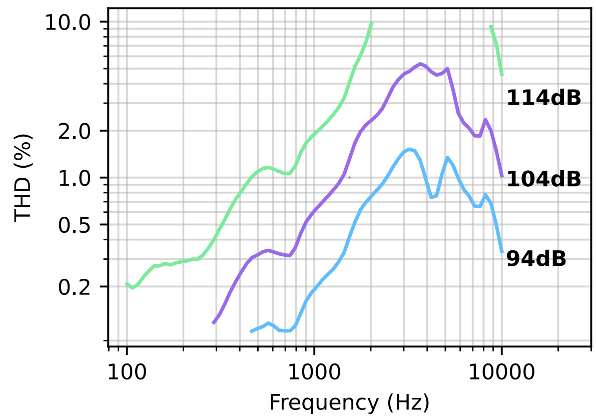


Figure 7.6: THD vs frequency

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

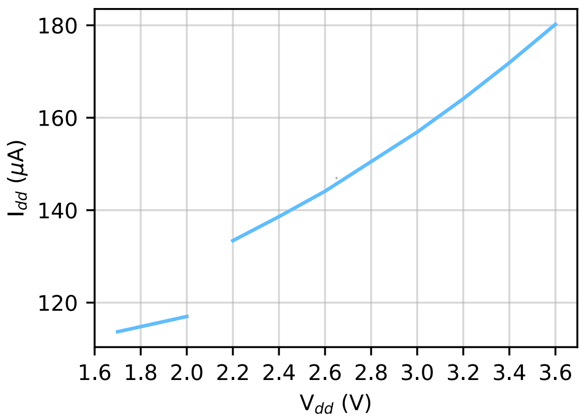


Figure 7.7: Input voltage vs supply current

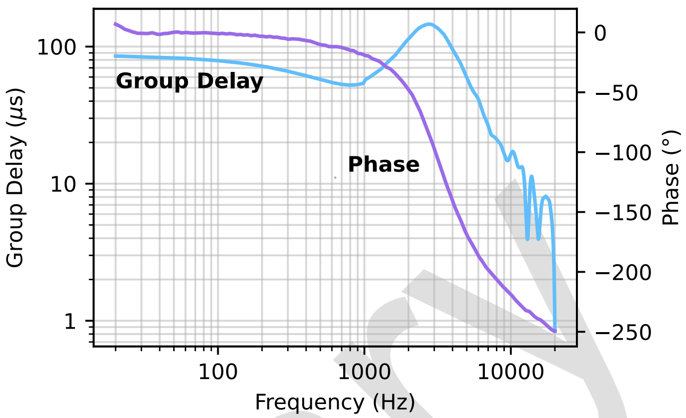


Figure 7.8: Typical phase and group delay

8. Mechanical, Packaging, and Manufacturing Information

8.1 Mechanical Dimensions

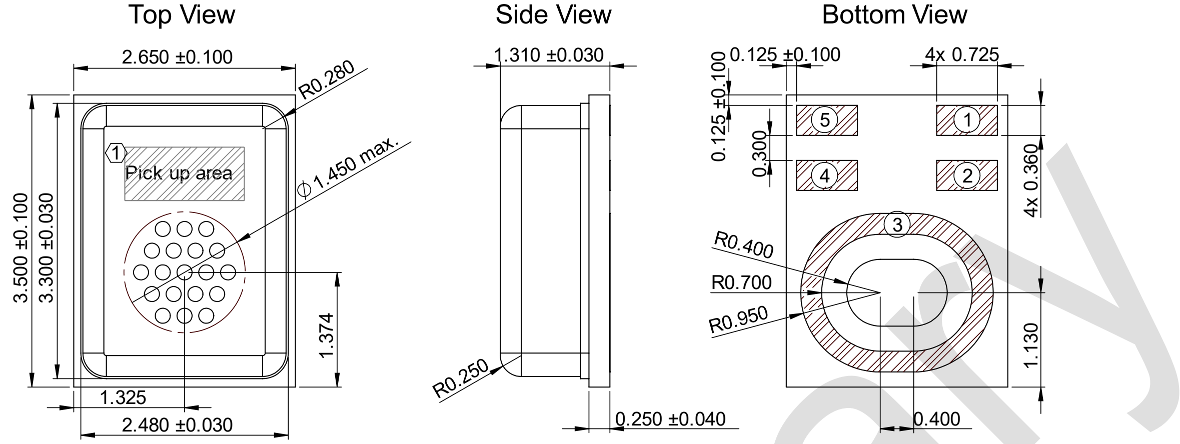


Figure 8.1: Mechanical drawings (mm)

Table 8.1: Mechanical specifications

Item	Dimensions (mm)
Length	3.500 ± 0.100
Width	2.650 ± 0.100
Height	1.310 ± 0.030
Lid Port Array OD	1.450 max
Bottom Acoustic Port	1.200 x 0.800 ± 0.050
PCB Thickness	0.250 ± 0.030

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 Note:

- The pick-up area begins 0.25 mm from any edge or the port hole.

8.2 Land Pattern and Solder Stencil

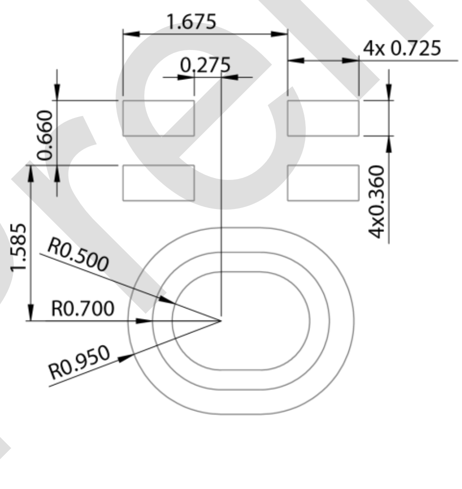


Figure 8.2 Example land pattern (mm)

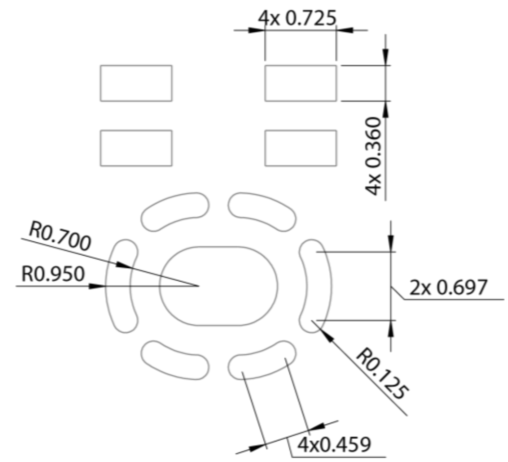


Figure 8.3 Example solder stencil pattern (mm)

8.3 CAD Models

The CAD model for this microphone is available here: SKR0600 STEP File

A KiCAD compatible layout and footprint is available here: KiCAD Layout

8.4 Packaging and Ordering Information

Soundskrit follows JEDEC moisture classification standards.

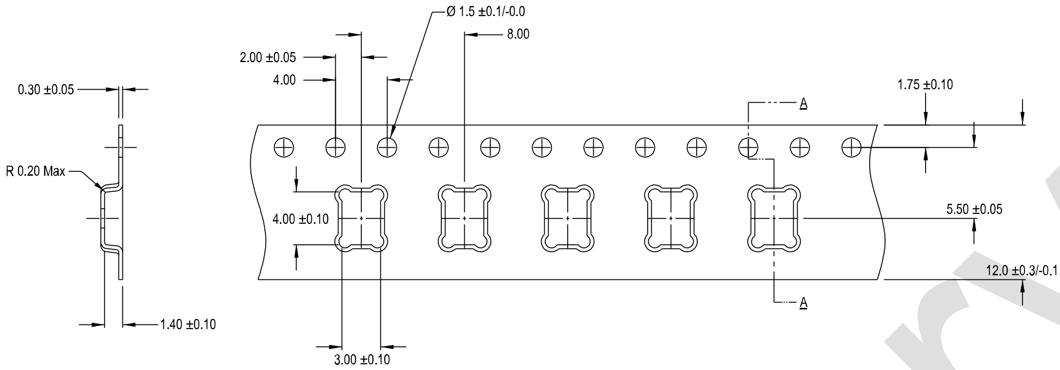


Figure 8.4 Reel dimensions (mm)

Table 8.3: Ordering Information

Model Number	Reel Diameter	Quantity per Reel
SKR0600-7	7”	1500
SKR0600-13	13”	5000

Table 8.4: 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 Protective Tape and Reflow Profile

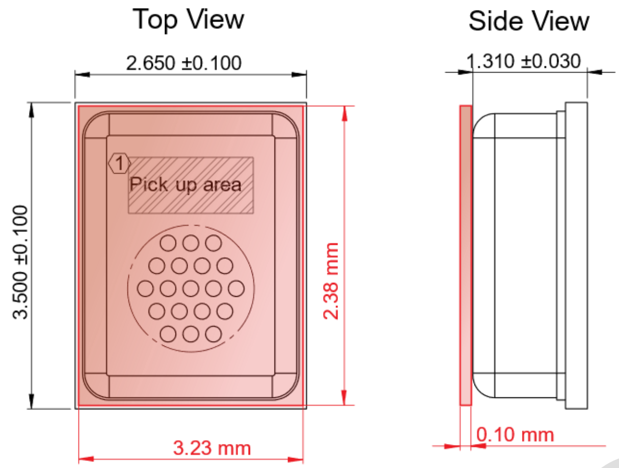
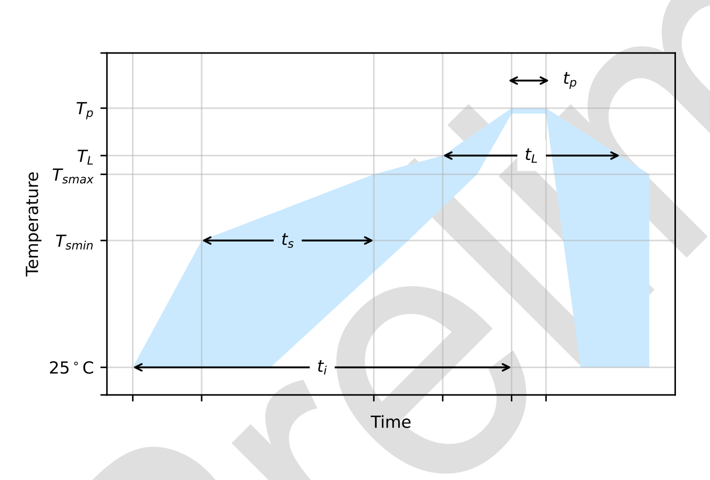


Figure 8.5: Mechanical drawing with protective tape

The microphone is packaged with a layer of reflow compatible Kapton tape covering the top port as pictured in Figure 8.5. This tape is to protect the microphone during assembly. Do not remove the Kapton tape prior to soldering the microphone or nearby components. To remove, use wide tweezers to catch the edge of the tape from the top side.

Below is the recommended reflow profile for soldering the microphone.



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

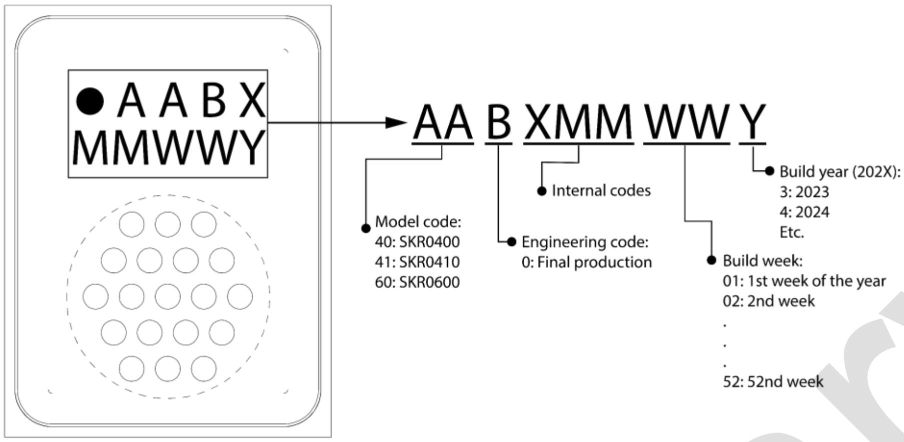
Figure 8.6: Reflow profile

Additional notes:

- Use reflow profile standard J-STD-020D
- The SKR600 is classified as MSL 3
- Do not remove the Kapton tape prior to reflow

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

8.6 Product Marking

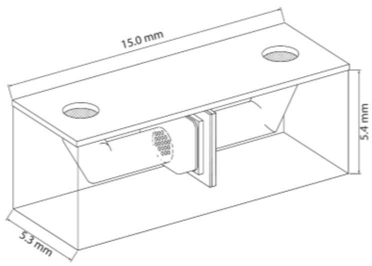


Engineering samples of the microphone were available using other marking schemes. If the microphone marking does not match the above or does not have the honeycomb array port opening see the prior revision of this datasheet here: SKR0600 Preliminary Datasheet Rev -

9. Acoustic Design Recommendations

Below are several configuration options that show how key parameters, such as acoustic channel length, acoustic path length, and acoustic mesh resistance, can be adjusted to modify the polar pattern and solution size when using the SKR0600. For more detail on integrating the SKR0600 into a product, please reach out to contactus@soundskrit.ca.

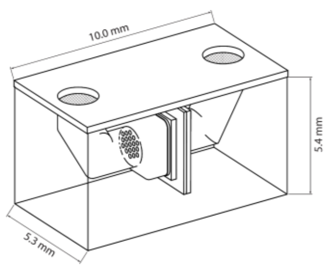
High-performance Dipole 'V' Configuration



Design Parameters	
Channel Length	15.8mm
Path Length	12mm
Front Mesh	0
Rear Mesh	0

Performance Characteristics	
SNR	67.5 dB
DI	4.8 dB
UI	0 dB

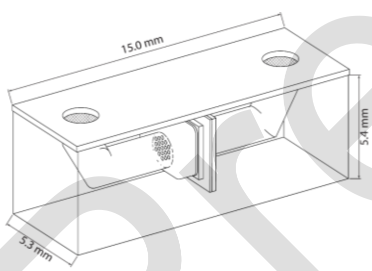
Compact Dipole 'V' Configuration



Design Parameters	
Channel Length	13mm
Path Length	8mm
Front Mesh	0
Rear Mesh	0

Performance Characteristics	
SNR	65 dB
DI	4.8 dB
UI	0 dB

High-performance Hypercardioid 'V' Configuration



Design Parameters	
Channel Length	15.8mm
Path Length	12mm
Front Mesh	0
Rear Mesh	360 Rayl

Performance Characteristics	
SNR	66 dB
DI	4.94 dB
UI	6.03

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-210: Designing Linear Arrays with Directional Microphones

11.2 Additional Support

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

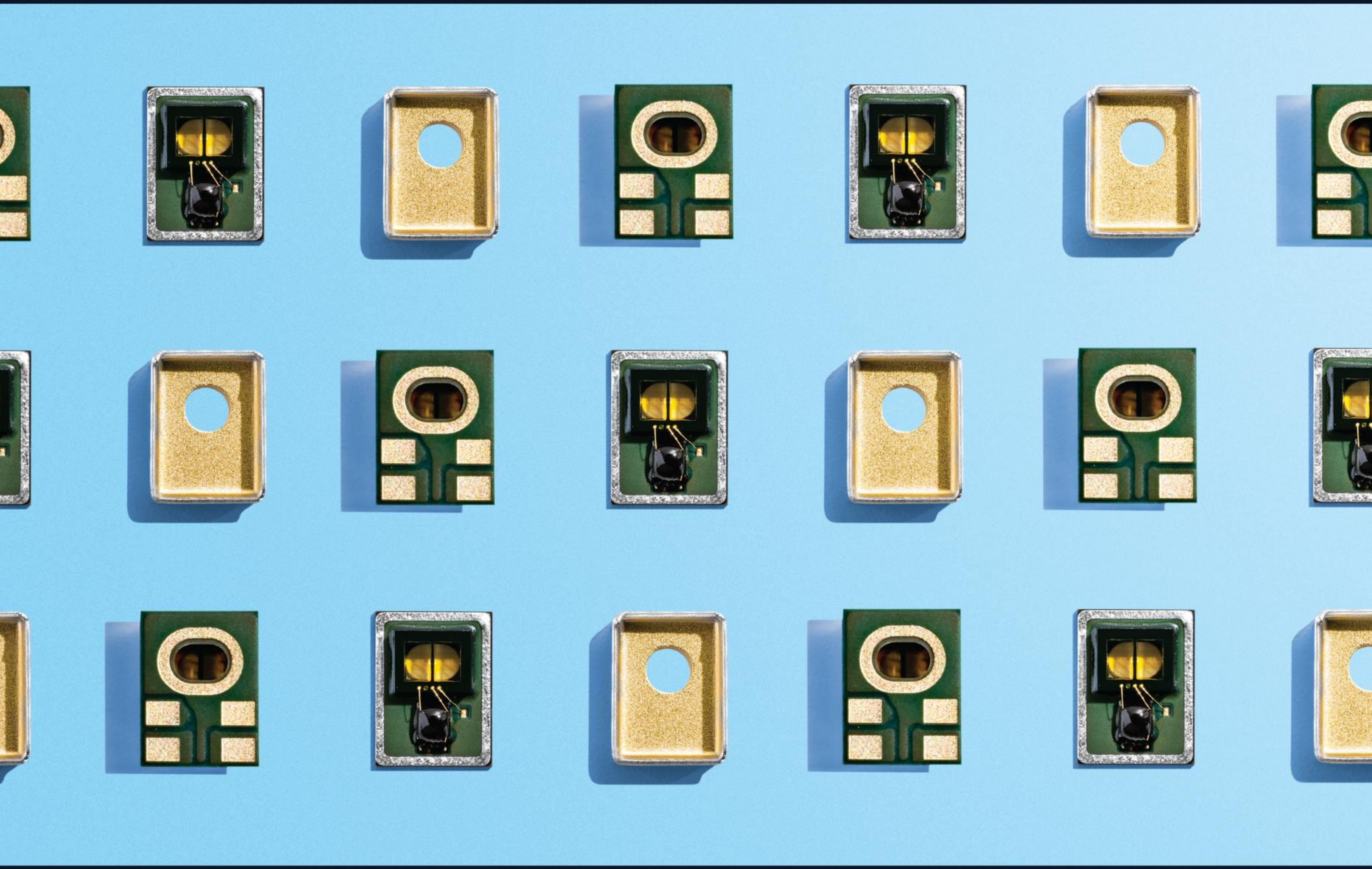
Soundskrit offers a suite of software algorithms to take full advantage of the utility our microphones provide. With a range from lightweight linear DSP tools to multichannel, machine learning based processing, we have a solution to meet any performance requirements. For more information, contact us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

12. Revision History

Revision Label	Revision Date	Sections Revised
-	August 2023	Preliminary release
A	February 2024	Updated mechanical packaging, added reference design information

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.



soundskrit

Hear the impossible.