

how does an electret microphone work

An **electret microphone** is a type of **condenser (capacitor) microphone** that has a *permanently charged material* inside — which lets it work without needing an external high-voltage power supply.

Here's the idea step-by-step.



## 1. The basic principle: sound → electrical signal

An electret mic converts **sound waves** into electricity using **capacitance changes**.

Inside the microphone are two main parts:

- a **thin movable diaphragm**
- a **fixed back plate**

Together, they form a tiny capacitor.

When sound waves hit the diaphragm:

- air pressure makes it vibrate
- the distance between diaphragm and back plate changes
- the capacitor's electrical properties change

This variation creates an electrical signal that matches the sound.

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## ⚡ 2. What makes it an *electret* microphone?

In a normal condenser microphone, the capacitor plates must be charged using an external voltage (like phantom power).

An electret microphone instead uses an **electret material**.

An **electret** is:

- a dielectric material

- that holds a **permanent electric charge**
- similar to how a magnet permanently holds a magnetic field

Because the charge is already built in:

- ✓ no external polarization voltage is needed
- ✓ the microphone can be very small and cheap

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### 3. Why it still needs power

Even though the electret provides the charge, the microphone usually still needs **low-voltage power** (typically 1.5–5 V).

That power runs a tiny internal amplifier:

👉 usually a **JFET transistor**

Why this is needed:

- the capacitor signal has **very high impedance**
- cables and circuits cannot handle it directly
- the JFET converts it into a usable low-impedance output

So power is for amplification — **not** for creating the charge.

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### 4. Internal structure (simplified)

Code



```
Sound waves
  ↓
[ Diaphragm ] ← moves
  ||
[ Electret layer ]
  ||
[ Back plate ]
  ↓
Capacitance change
  ↓
JFET buffer amplifier
  ↓
Audio signal output
```













## ✓ 5. Why electret microphones are everywhere

They are used in:

- smartphones
- laptops
- headsets
- hearing aids
- lavalier microphones
- webcams

because they are:

- tiny
  - inexpensive
  - sensitive
  - low power
- 

## Quick analogy

Think of it like:

- **sound pushes a charged membrane**
  - movement changes an electric field
  - electronics translate that movement into voltage
- 

If you want, I can also explain:

- the difference between **electret vs dynamic microphones**
- how MEMS microphones evolved from electrets
- or show the exact circuit used with Arduino/Raspberry Pi.



can you explain physical details and metric for small electret microphone

Sure — let's go deeper into the **physical construction, dimensions, and typical electrical/mechanical metrics** of a *small electret microphone capsule* (the kind used in phones, headsets, Arduino projects, etc.).

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## 1. Physical construction (real internal layers)

A small electret microphone capsule is basically a **precision electro-mechanical system** packed into a metal can.

### Main internal parts

From front → back:

Code



```
Sound hole
  ↓
Metal case (ground)
  ↓
Flexible diaphragm (metalized polymer)
  ↓ ← air gap (~10–30 μm)
Electret layer (charged dielectric)
  ↓
Backplate (metal electrode)
  ↓
JFET preamplifier chip
  ↓
Output pin + ground case
```

## ✚ Diaphragm

- Material: **Mylar (PET)** or similar polymer
- Coating: ultra-thin metal layer (gold/aluminum)
- Thickness:  
**2–6 μm**
- Diameter:  
**4–10 mm** (depending on capsule size)

The diaphragm must be:

- extremely light
- mechanically elastic
- electrically conductive

## ⚡ Electret layer

This is the key component.

Typical materials:

- PTFE (Teflon)
- fluoropolymer films

Properties:

- permanently trapped electric charge

- surface charge density  $\approx$

**0.5–2 mC/m<sup>2</sup>**

Charge lifetime:

✓ often **20–50 years**

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### **Air gap (critical dimension)**

Distance between diaphragm and backplate:

👉 **10–30 micrometers**

This tiny spacing determines:

- sensitivity
- noise
- frequency response

Too large → low sensitivity

Too small → diaphragm sticks

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## **2. Typical capsule sizes**

Common commercial electret microphone diameters:

| Type     | Diameter | Height   |
|----------|----------|----------|
| Mini     | 4 mm     | 1.5–2 mm |
| Standard | 6 mm     | 2.2–3 mm |
| Large    | 9–10 mm  | 4–6 mm   |

Example:

- Very common capsule: **6 × 2.7 mm**

Weight:

**≈ 0.1–0.3 g**

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## **3. Electrical characteristics (typical)**

## Internal capacitance

The diaphragm + backplate form a capacitor:

$$C = 10\text{--}50 \text{ pF}$$

Very small — which is why amplification is required immediately.

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## Bias / supply voltage

Needed for internal JFET:

- **1.5 – 10 V**
- typical: **2 V**

Current consumption:

- **0.2 – 0.8 mA**
- 

## Output impedance

After JFET buffer:

- **1–3 kΩ**

Without the JFET:

👉 hundreds of megaohms.

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## 4. Acoustic performance metrics

### Sensitivity

Measured at **1 kHz, 94 dB SPL**

Typical:

$$-44 \text{ dBV/Pa}$$

(range –35 to –50 dBV/Pa)

Meaning:

94 dB sound pressure produces about:

$\approx 6\text{--}10\text{ mV RMS}$

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## Frequency response

Typical small capsule:

- **20 Hz – 16 kHz**
- speech-optimized versions:  
**100 Hz – 10 kHz**

High-frequency limit mainly depends on diaphragm mass.

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## Signal-to-noise ratio (SNR)

Usually:

- **55–70 dB**

Equivalent noise level:

- **24–35 dBA**
- 

## Maximum sound pressure level

Before distortion:

- **110–130 dB SPL**
- 

## 5. Mechanical physics (why it works well)

The diaphragm behaves like a **tensioned circular membrane**.

Key physical relationships:

### Resonant frequency

Approximately:

$$f_0 \propto \sqrt{\frac{T}{\rho}}$$

where:

- $T$  = diaphragm tension
- $\rho$  = surface mass density

Designers tune tension so resonance lies **above speech range**.

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## Capacitance variation

Sound causes displacement:

$$C = \frac{\epsilon A}{d}$$

Small motion (~nanometers!) changes distance  $d$ , producing measurable voltage variation.

Typical diaphragm motion:

- **10–100 nm** for normal speech.

That's smaller than bacteria.

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## 6. Why the metal case matters

The outer can is not just protection:

- ✓ electromagnetic shielding
- ✓ acoustic cavity tuning
- ✓ ground reference
- ✓ mechanical stiffness

The front hole size controls high-frequency response.

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## 7. Real example specification (6 mm capsule)

| Parameter   | Value  |
|-------------|--------|
| Diameter    | 6 mm   |
| Height      | 2.7 mm |
| Capacitance | 20 pF  |

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| Parameter   | Value      |
|-------------|------------|
| Supply      | 2 V        |
| Current     | 0.5 mA     |
| Sensitivity | -44 dBV/Pa |
| SNR         | 60 dB      |
| Max SPL     | 120 dB     |

If you want next, I can show you **the full small-signal equivalent circuit** (with equations) or explain **how manufacturers tune frequency response mechanically** — which is surprisingly clever engineering.



show the full small-signal equivalent circuit

Good — now we move to the **engineering model** used when designing real microphone preamps.

The **small-signal equivalent circuit** of an electret microphone combines:

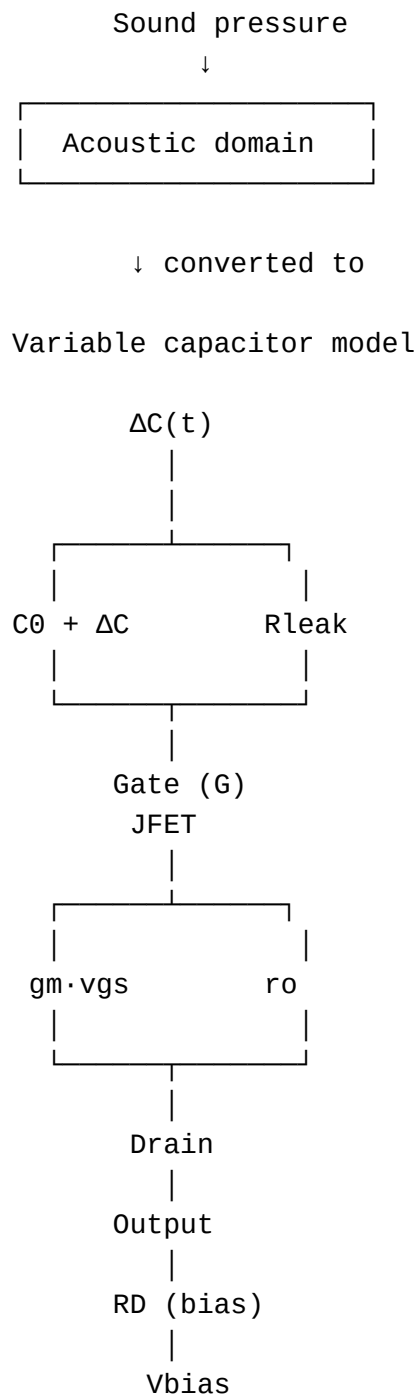
1. **variable capacitor transducer**
2. **built-in JFET impedance converter**
3. **bias network**

## Small-Signal Equivalent Circuit of an Electret Microphone

Below is the practical electrical model used in circuit analysis.

 Code





Let's break this carefully.

## 1 Capacitor Transducer Model

The microphone capsule behaves as a **charged capacitor**.

### Static capacitance

$$C_0 \approx 10\text{--}50\text{ pF}$$

Sound causes displacement:

$$C(t) = C_0 + \Delta C(t)$$

Because charge already exists (electret),

$$Q = \text{constant}$$

so voltage varies:

$$V = \frac{Q}{C}$$

Small change gives:

$$v_{sig} \approx -\frac{Q}{C_0^2} \Delta C$$

✓ Mechanical motion → voltage signal.

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## Leakage resistance

Real capsules include:

$$R_{leak} = 1\text{--}10\text{ G}\Omega$$

representing:

- dielectric leakage
- humidity paths

This sets **very low-frequency rolloff**.

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## 2 Why a JFET is Required

The raw capsule impedance:

$$Z_C = \frac{1}{\omega C}$$

Example at 1 kHz:

$$C = 20\text{ pF}$$

$$Z_C \approx 8\text{ M}\Omega$$

Impossible to drive cables directly.

So manufacturers place a **JFET source follower** inside.

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### 3 JFET Small-Signal Model

Inside nearly every electret mic:

👉 **common-drain (source follower)**

#### Equivalent model

Parameters:

- transconductance:

$$g_m \approx 0.3\text{--}1\text{ mS}$$

- output resistance:

$$r_o \approx 20\text{--}100\text{ k}\Omega$$

Small-signal drain current:

$$i_d = g_m v_{gs}$$

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### 4 External Bias Resistor

Typical real connection:

Code

```
Vbias (2-5V)
  |
  RB
  |----- audio output
  |
Electret Mic
  |
  GND
```

Where:

$$R_B = 2.2\text{ k}\Omega \text{ to } 10\text{ k}\Omega$$

This resistor:

- ✓ powers JFET
- ✓ converts current variations → voltage signal

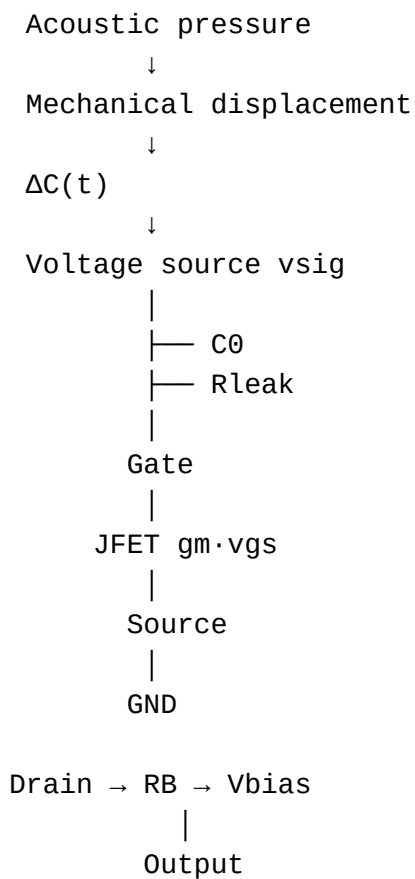
Output voltage:

$$v_o = -i_d R_B$$

## 5 Complete Linear Small-Signal Model

Putting everything together:

</> Code



## 6 Frequency Response Mechanisms

Three dominant poles appear:

### (A) Low-frequency cutoff

From leakage:

$$f_L = \frac{1}{2\pi R_{leak} C_0}$$

Typically:

- 5–50 Hz
- 

## (B) Output high-pass (coupling capacitor)

If output capacitor exists:

$$f = \frac{1}{2\pi R_{load} C_{out}}$$

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## (C) High-frequency rolloff

Caused by:

- diaphragm mass
- acoustic damping
- FET capacitances

Usually:

**10–20 kHz**

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## Key Insight (Important)

An electret microphone is electrically equivalent to:

✓ a **charge-biased variable capacitor voltage source**

followed by

✓ a **JFET source follower buffer**

So internally it behaves almost like:

**a tiny built-in preamplified condenser microphone**

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## 8 Typical Small-Signal Numbers

| Parameter           | Typical        |
|---------------------|----------------|
| Capsule capacitance | 20 pF          |
| Gate impedance      | >1 G $\Omega$  |
| gm                  | 0.5 mS         |
| Output impedance    | 1–3 k $\Omega$ |
| Output signal       | 5–20 mV RMS    |
| Bias voltage        | 2 V            |

If you want, next I can show something very useful:

- ✓ **SPICE equivalent model**
- ✓ **noise model (why electrets hiss)**
- ✓ **derivation from acoustic pressure → volts**
- ✓ **why MEMS microphones replaced electrets in phones**

Just tell me which direction you want.

