# ECE313 Music & Engineering Microphones, Speakers and Electricity

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# Overview

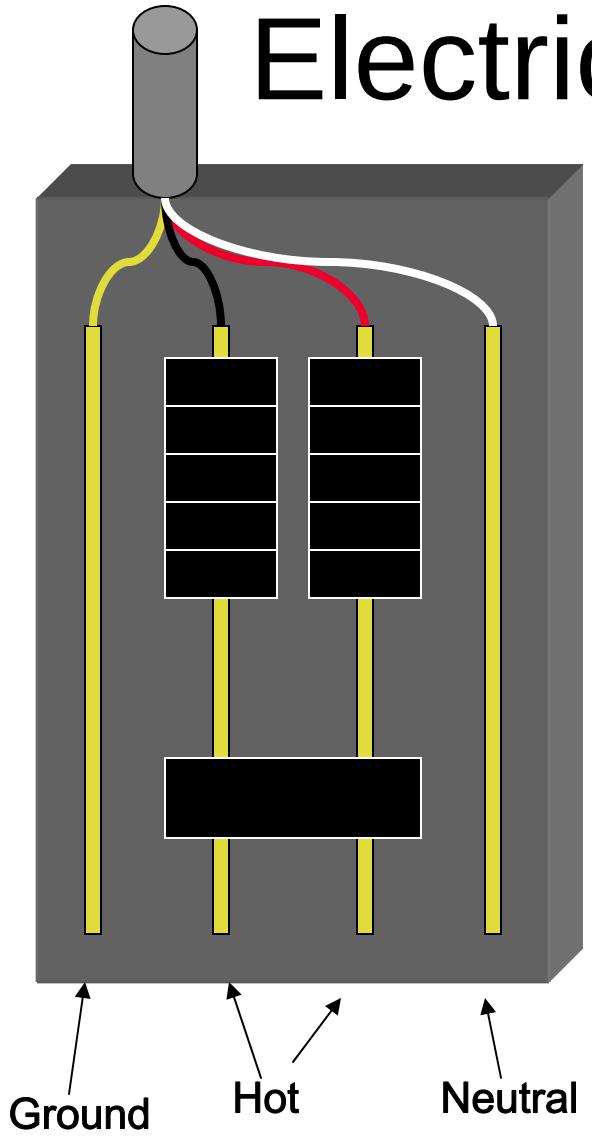
- A/C Electrical Basics
- Microphones
  - Dynamic
  - Condenser
  - Ribbon
- Speakers
  - Voice Coil
  - Electro-Static
- Other stuff
  - The Theremin - the first electronic instrument
  - Power!
  - Ground Loops
  - Active and Passive filters (the tone stack)

# Alternating Current Basics

# WARNING!

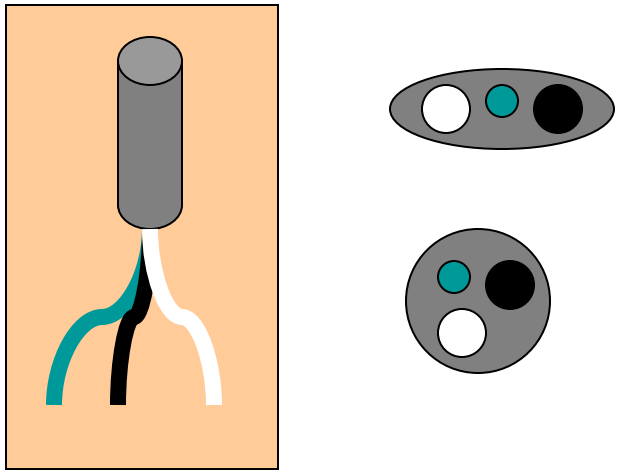
- Electricity can kill you
  - There is a reason the Electric Chair was chosen as a method of execution
  - It only takes a couple of milliamps across the heart to cause the muscles to react
- The information provided her is for educational purposes only.

# Electrical Distribution

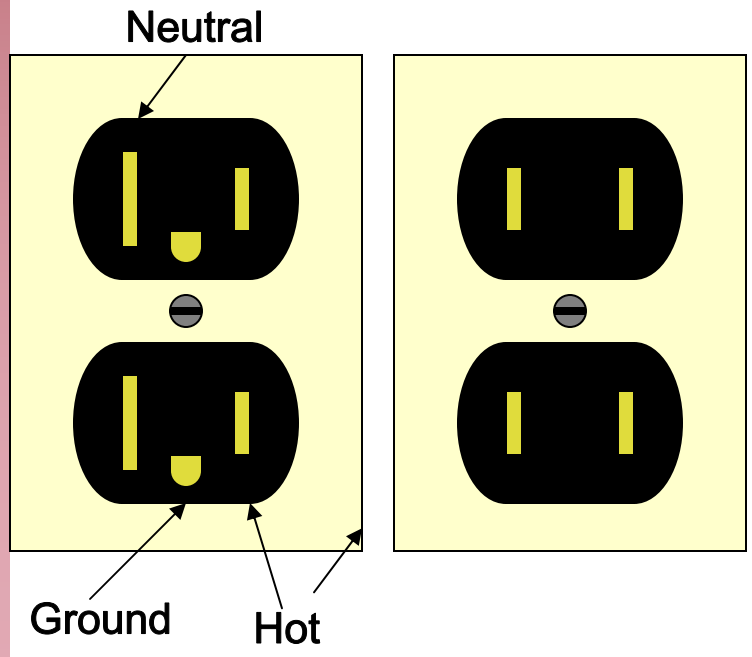



- Most houses are fed with nominally 110 VAC @ 60 Hz
  - Actual voltage depends on system and network load
  - This is typically called Single Phase,
    - although there are really two phases
    - Each is 180 degrees from the other
- There are four conductors in the panel
  - The two “hot” conductors run through the center of the panel.
    - Loads are tied to the hot bars through circuit breakers (that overload and break the circuit if too much current is drawn)
    - The loads should be evenly balanced between the two phases so minimal current flows in the neutral wire to the pole.
    - Some loads require 220 volts. These require a breaker that connects to both phases.
  - There is a neutral conductor that is tied to ground on the distribution pole outside of the house – this should carry minimal current
  - The ground conductor should be tied to a water pipe inside the house and should never conduct current.

# Outlets





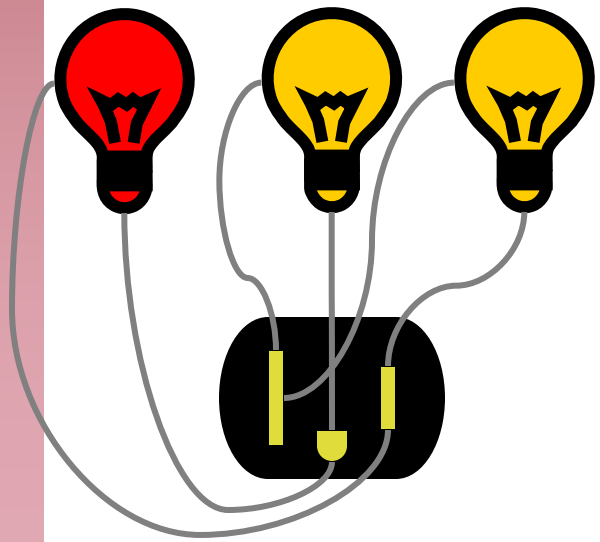



- From the Breaker box, power runs to outlets
  - There are two common types of wire for outlet level distribution
    - Armored cable – (often called BX) has a hard outer shell that protects it from many forms of physical damage
    - Romex – Is the three conductors incased in a single sheaf of vinyl
  - A typical run of electrical wire has three colored conductors
    - Black = hot, which is at 110VAC relative to ground
    - White = neutral the return leg of the circuit
    - Green = Safety Ground. Chasses should be tied to this and it should not conduct current.
- Outlets have evolved through the years to the current 3 prong standard (shown at left).
  - On older outlets, the ground connect was made through the screw, and not an explicit part of the plug
  - Polarized plugs made neutral separate from hot

# Why do we care?

- Safety!
  - Modern amplifiers usually connect the chassis ground to earth ground, but was not always the case.
    - Often, the chassis was supposed to be set at ground potential through “the death cap”
    - On many older amplifiers, with out a polarized plug, the “anti-hum” switch often switched the connections between hot and neutral
      - This could allow the chassis to float at 110VAC relative to ground.
      - This would be especially dangerous if the PA was grounded correctly.
- Noise
  - Ground Loops

# Testing Outlets



- You can get a very simple outlet tester at the hardware store for about $5.
- Before plugging an amplifier into strange power, you should check all of the outlets with one of these.
- Newer testers also have a button to test ground-fault circuits.
  - A ground fault circuit interrupt (GFCI) detects when the current flowing in the hot and neutral legs are imbalanced
  - An imbalance indicates that significant current is running to ground.
  - GFCI outlets are required in bathrooms, kitchens and outdoor outlets.

# Ground Loops

- When ground is connected in more than one place, the loop acts like an antenna (or a guitar pickup)
- To avoid Ground Loops, use a star topology
  - For unbalanced cables, lift the signal ground at one end to prevent ground loops
- Use filters if necessary to reduce
  - Radio Frequency Interference
  - Electro-Magnetic Interference
- There are three types of shield cable (listed in increasing order of effectiveness)
  - Braided
  - Stranded
  - Foil

# Wire Size

- Wire is measured in terms of the American Wire Gage (AWG)
  - Numbers range from 0000,000,00,0,1,2,…40 and higher
  - Higher numbers indicate thinner diameters
  - The resistance is a function of the diameter
- House wiring is typically
  - 14 gage for a 15 amp circuit
  - 12 gage for a 20 amp circuit
- Circular Mils are really square mils!

| Gage | Diameter (mils) | Circular Mils (Area) | Ohms per 1000 ft at 25 C |
|---|---|---|---|
| 1 | 289.3 | 83,690 | 0.1264 |
| 2 | 257.6 | 66,370 | 0.1593 |
| 10 | 101.9 | 10,380 | 1.018 |
| 12 | 80.81 | 6530 | 1.619 |
| 14 | 64.08 | 4107 | 2.575 |
| 20 | 31.96 | 1022 | 10.35 |
| 22 | 25.35 | 642.4 | 16.46 |
| 24 | 20.10 | 404.0 | 26.17 |
| 40 | 3.145 | 9.88 | 1069 |

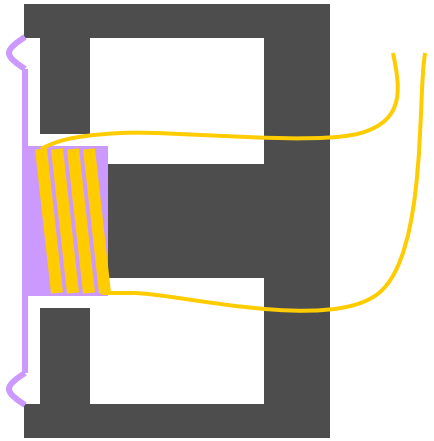
# Microphones

- A Microphone is a transducer
  - It converts acoustic energy into electrical energy
- The quality of the given recording depends on
  - The externals – placement in the environment relative to the sound source
  - The internals – quality of the microphone, the pattern, etc
- Two major prevalent types of microphones.
  - Dynamic
  - Condenser

# Microphones

# Moving Coil Dynamic Microphone

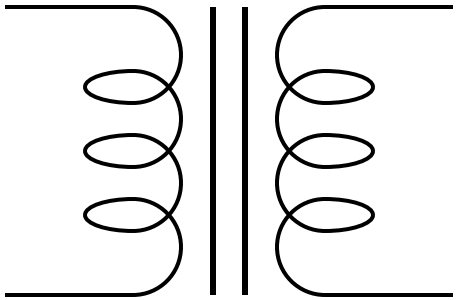
- Operates by electromagnetic induction
  - When conductive metal cuts the flux of a magnetic field, a current is induced.
- Parts
  - Mylar diaphragm (roughly 0.35 mils think). - reacts to the acoustic energy
  - Voice Coil – connected to the diaphragm so it moves when the diaphragm moves
  - Magnetic field – the armature that the voice coil moves in. A permanent magnet creates the lines of flux that the voice coil moves in.
- Operation
  - Acoustic sound waves strike the diaphragm
  - Diaphragm moves in response to pressure changes, this moves the voice coil
  - Voice coil cuts the flux lines of the magnet
  - Electrical signal is induced in the wires

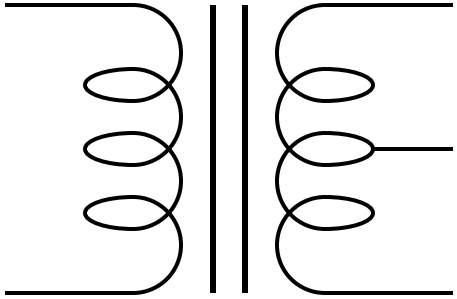


# Ribbon Microphone

- A Ribbon Microphone is another type of dynamic microphone
- The Ribbon is a very thin (~2 micro meters) aluminum ribbon that is placed in a strong magnetic field.
- The Ribbon receives acoustic energy and moves in vibration.
- A voltage is induced on the ribbon.
- Because the of the short length of the ribbon, the impedance is very low.
  - A transformer is needed to convert the low impedance ribbon up to the 150 – 600 ohm range typical for dynamic microphones
- Ribbons are somewhat fragile as a strong sound could tear the ribbon

# Aside: Transformers

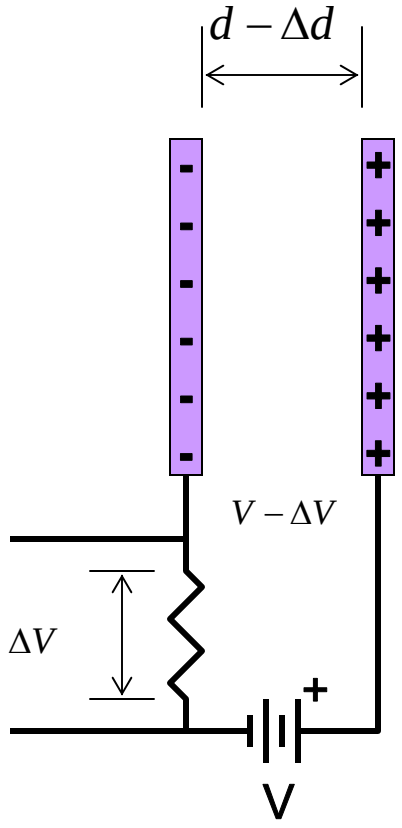




- Transformers are often used in audio to couple AC signals while blocking DC signals.
- Transformers are a set of coils wrapped around a common ferro-magnetic core.
  - Current flowing through winding one induces a current in the other winding.
- Transformers are usually specified by the number of turns (N) in the secondary side relative to the primary side.
  - The AC voltage is transformed a $V_{out}=V_{in}*N$
  - The AC current is transformed as $I_{out}=I_{in}*N$
  - Using Ohms law, we find that $Z_{out}=Z_{in}*N^2$
- Transformers may also have a center tap.
  - If this is used as a ground reference, the two outer legs provide out of phase signals

# Condenser Microphone

- The condenser is another name for which passive electrical component
- Parts
  - The head of the microphone contains two plates, one fixed and one movable.
  - These two plates are the parallel plates of a capacitor.



# Condenser Microphone

- The Charge on a capacitor is the product of the voltage applied and the capacitance of the device.
- The capacitance of a parallel plate capacitor is the product of the permittivity of the material and the Area of the plates divided by distance between the plates
- As one plate is moved by sound waves, the distance between the two plates changes
- This changes the capacitance of the element and creates the voltage.

$$Q = CV$$

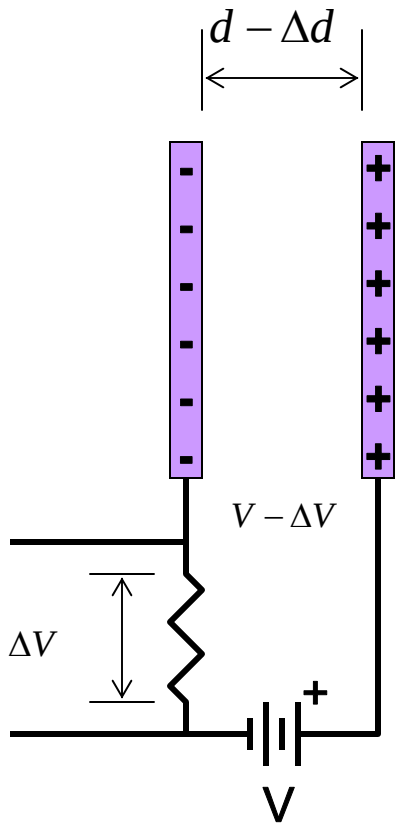
$$C = \frac{\varepsilon A}{d}$$

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

$$\Delta V = \frac{Q \cdot \Delta d}{\varepsilon A}$$

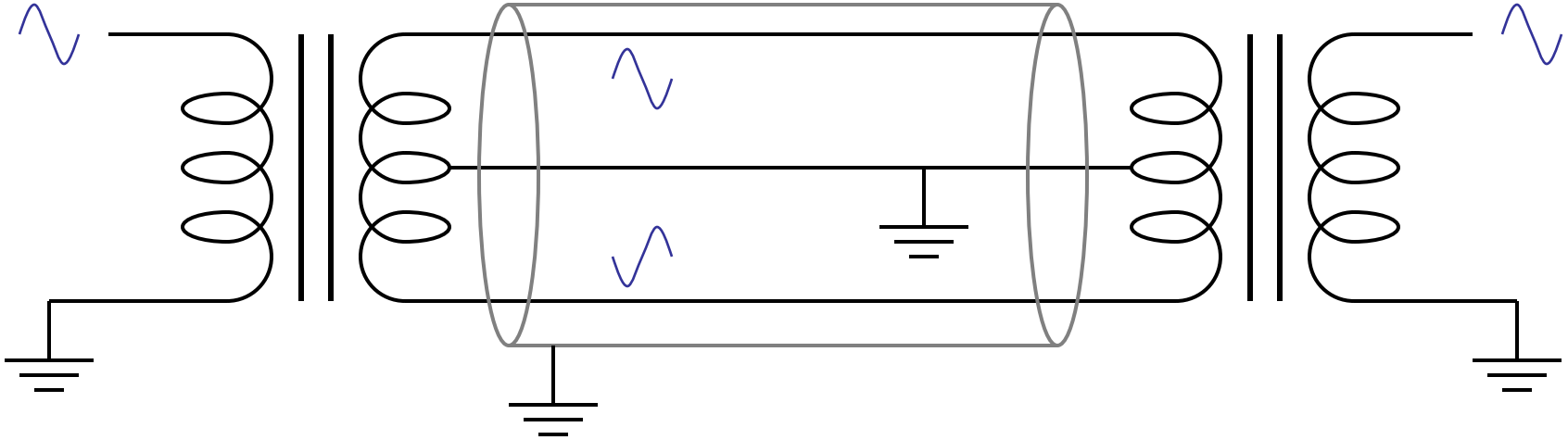
# Condenser Microphone Voltage

- In order for the Condenser microphone to function it needs a source of charge.
  - The charge is created by applying a batter to the two plates.
  - The charge will flow onto the plates until an equilibrium is achieved
  - The charge is considered constant.
  - The output voltage is created by the change in capacitance
- The resistance inside in the microphone must be large such that the time constant is larger than audio frequencies (this allows the charge to be considered constant)
- The signal induced is very small and the impedance of the microphone is very large
  - An pre-amplifier is required and must be built into the base of the microphone to minimize noise




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

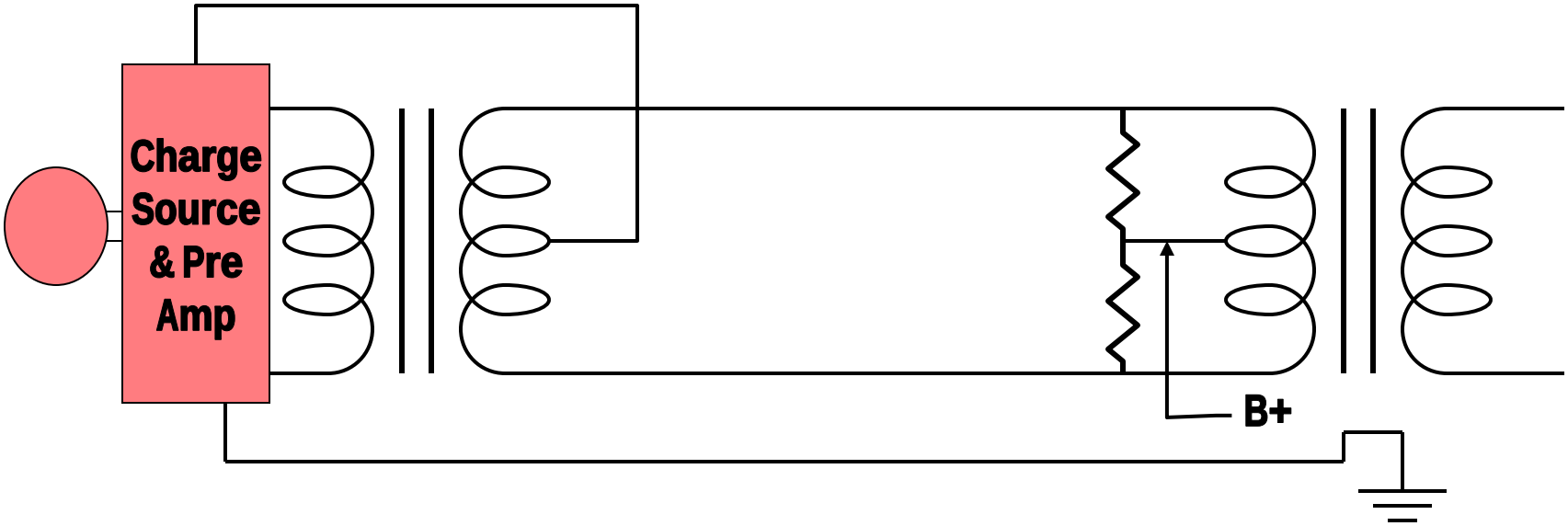
# Aside: Balanced Lines



- One popular technique for minimizing noise interference is to use balanced cables.
- Instead of just a signal and ground conductor, balanced lines typically use 3 or 4 conductors
  - Signal
  - Inverted Signal
  - Signal Ground
  - Shield Ground
- There are a few common connectors
  - Tip, Ring, Shield ¼” jacks
  - XLR

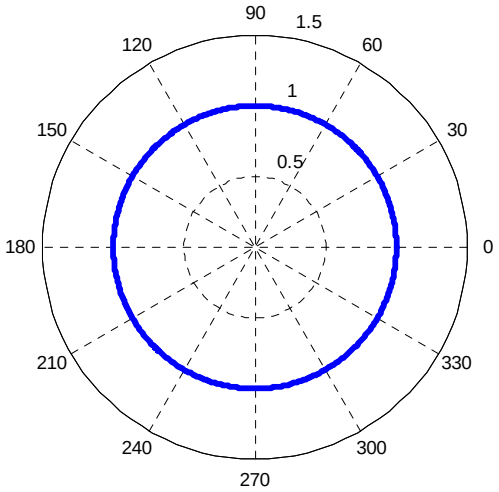
# Phantom Power

- All condensers need a source of power
  - To provide charge for the plate
  - To power in the internal pre-amplifier
- A common technique for supplying power to a condenser is to use “phantom power”
  - The puts a DC voltage on both of the signal lines of a balanced cable
  - The microphone extracts this voltage and uses it to power the charge source and the pre amp.



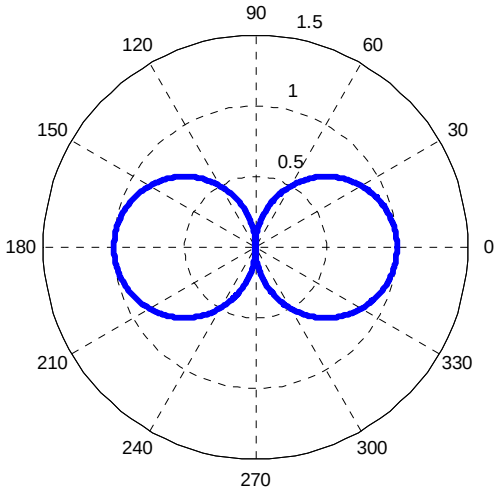
# Directivity

Omni



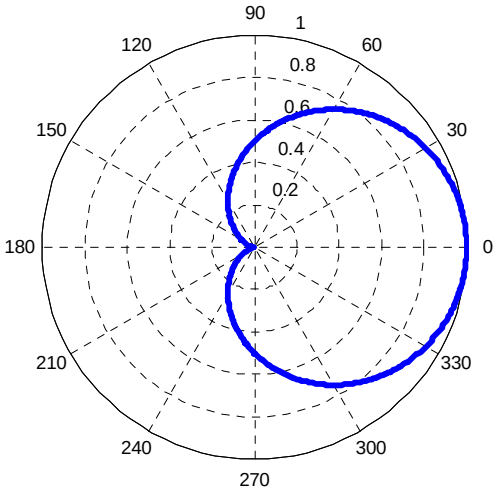

$\rho=1$

Figure 8




$\rho=|\cos(\theta)|$

Cardioid




$\rho=.5+.5*\cos(\theta)$

- Microphones usually some combination of the above three basic patterns
  - Omni – receives signals from all directions equally
  - Bi-Directional (figure 8) – received from two directions well, but less from other directions
  - Cardioid – A mixture of Omni and figure 8.
- Can Mix further to get other patterns
  - Hyper Cardioid
  - Super Cardiod

# Specifications

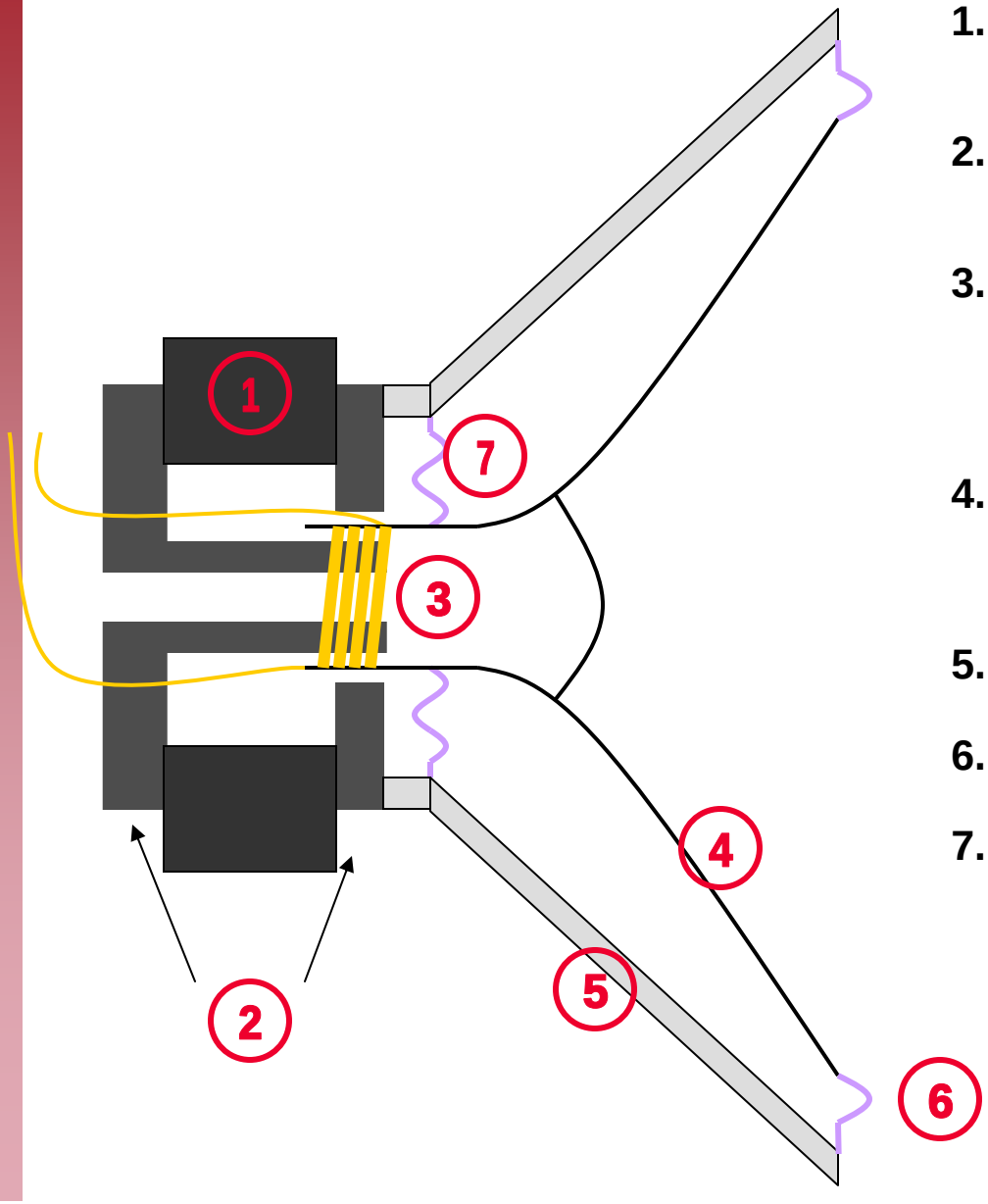
- Frequency Response
  - Microphones may be designed to be as flat as possible, or may include a characteristic response in parts of the spectrum
  - The frequency response will depend on the angle of the sound source relative to the front of the microphone element.
  - Directional microphones often suffer from a Proximity effect – there is an increased bass response when used close to the sound source
- Transient Response – how quickly does the microphone react to a transient sound (impulse)
  - Dynamic microphones are generally the slowest – the most mass to move
  - Ribbon microphones are much quicker
  - Condensers are probably the most accurate
- Sensitivity – What is the voltage output given a known input in Sound Pressure Levels (SPLs)

# Impedance

- Microphones all have different output impedances based on physical parameters
- 2 broad categories
  - Low Impedance = 50, or 150-250 ohm
  - High Impedance = 20k – 50k ohm
- High impedance microphones were preferred with vacuum tubes because of the high input impedance of tubes
- Cables
  - High impedance microphone lines are more susceptible to electrostatic noise.
    - A shield cable is required
    - This shield cable acts a capacitive load
  - Very low impedance (50 ohm) microphones can be run with twisted pair cable
  - Low impendence microphones (150 – 250 ohm) are usually run with balanced cables (typically through XLR connectors)

# Speakers

# Woofer

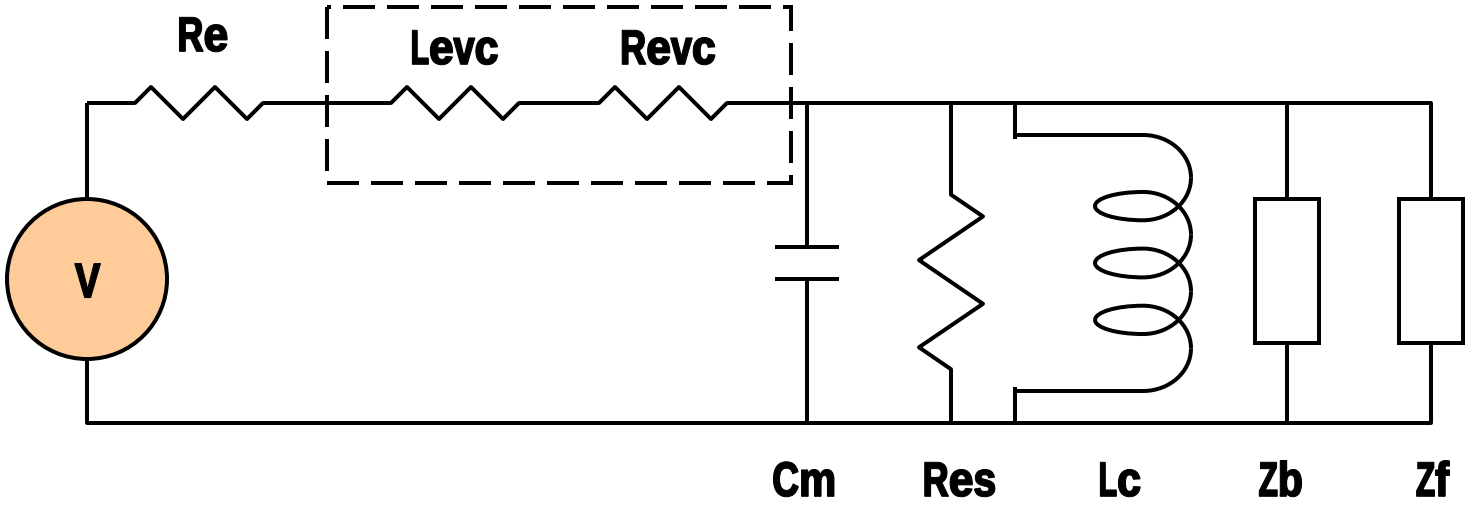



1. **Magnet** – creates the magnetic force used to move the speakers
2. **Front Plate & Pole Piece** – directs the lines of magnetic flux to focus on the speaker
3. **Voice Coil** – input signal is connected to the voice coil to move the speaker in response to an electrical signal
4. **Cone** – Connected to the voice coil, this moves the air in response to the electrical signal
5. **Frame** – The structure that supports the speaker
6. **Surround –** Holds the outer edge of the speaker
7. **Spider –** Supports the inner edge of the speaker and provides the main restoring force

# Systems

- Motor System
  - Magnet, Pole Piece, Front gap/plate & Voice coil
  - Acts like a motor to move the speakers in response to an electrical signal
  - For it to work properly, the flux through the coil must be uniform
    - Overhung geometries – coil is much larger than the gap
    - Underhung geometries – gap magnet is much larger than the coil width.
- Diaphragm
  - Cone & Dust Cap
  - Ideally Approximates a piston pushing air
  - Limits
    - Lower Frequency – limited by the resonant frequency of the speaker (below which it takes more energy to operate at)
    - High Frequency – limited by air resistance
      - Smaller cones are used for higher frequencies
- Suspension
  - Spider & Surround
  - Provides restoring, holds the speaker cone

# Electrical Model




- Re – DC resistance of the voice coil
- Revc – real part of voice coil inductance
- Levc – imaginary part of voice coil inductance
- Cm – driver mass
- Lc – driver compliance
- Res – driver suspension losses
- Zb – rear radiation of the driver
- Zf – front radiation of the driver

# References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- http://www.woofertester.com/