Radios

A radio is a device that uses all of the ideas we've been talking about all semester long . . .

Electric fields;
Magnetic fields;
AC Circuits;
Inductors, capacitors and resistors in an AC setting;
Speakers;
Transistors and diodes;
Transformers;
Clever electronics;

In other words, this is going to be a cumulative review extravaganza . . . Woohoo!

Radio sending circuit

A simplified **radio sending unit** circuit is shown below.

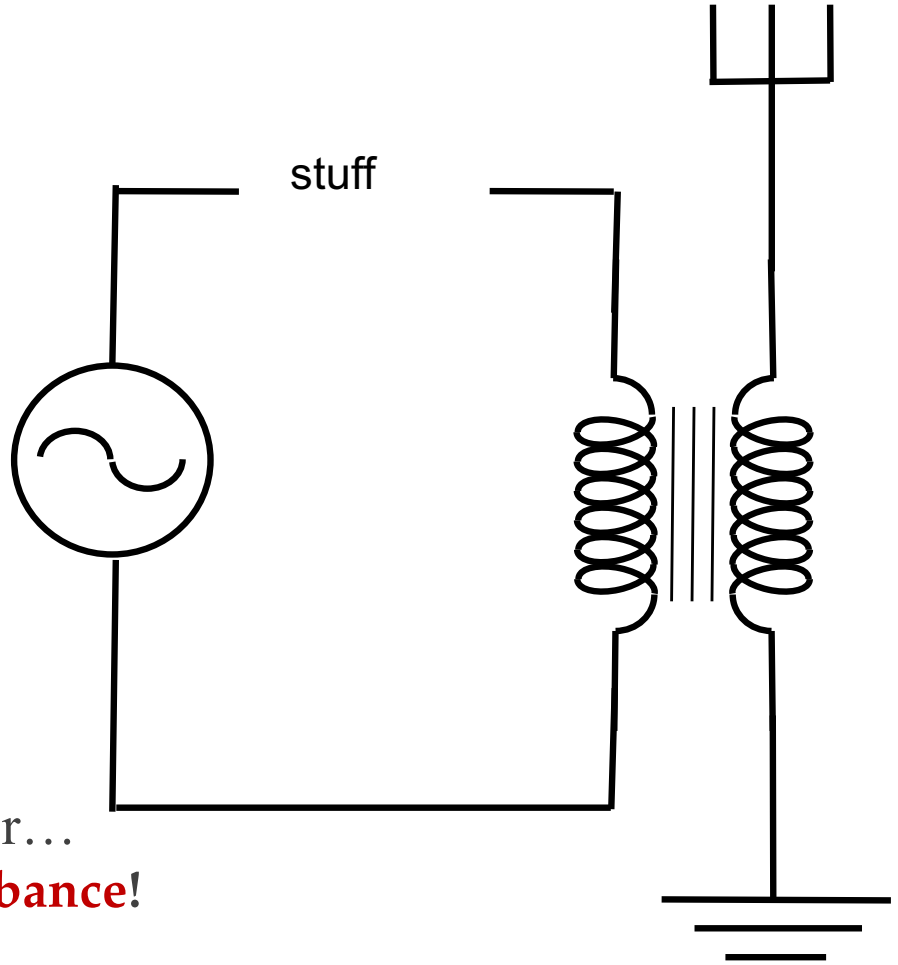
How does it work?

Charge flows up/down the antenna at high frequency due to the AC signal. This produces, around the antenna:

A rapidly varying **electric field** whose direction and magnitude change constantly, and

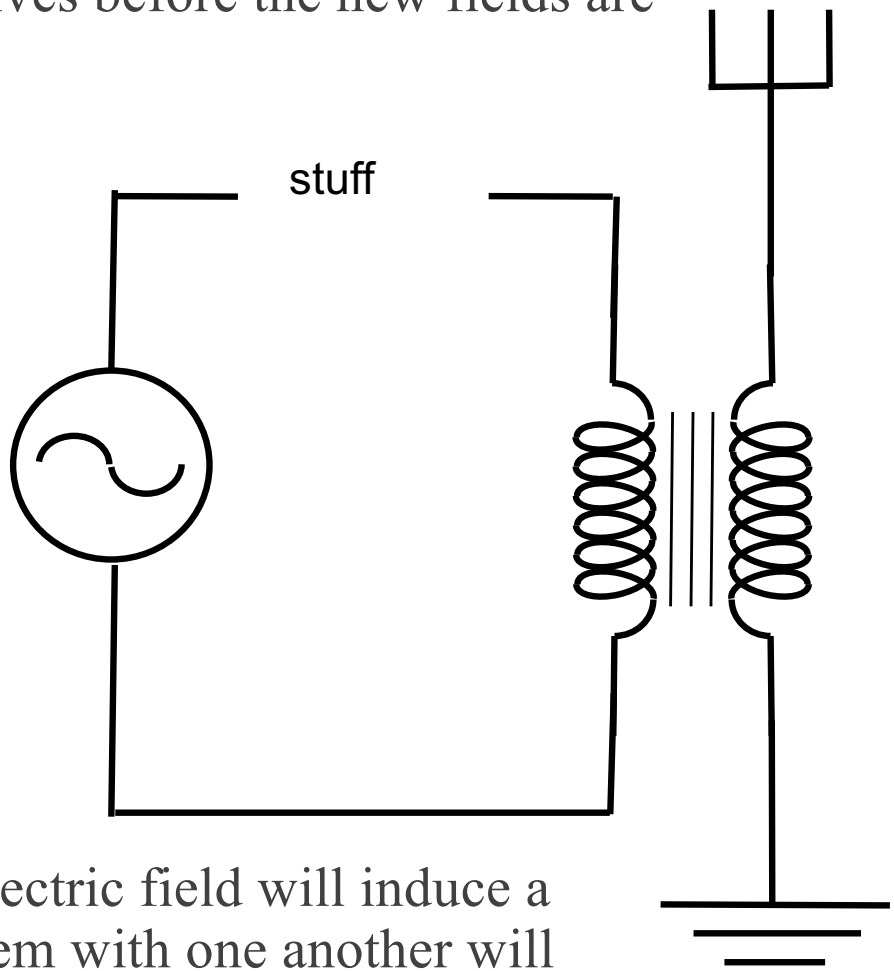
A rapidly varying **magnetic field** whose direction and magnitude change constantly.

These two fields are perpendicular to each other and in sync with each other… producing an **electromagnetic disturbance!**



If the generator's AC is below 500,000 hz, there will be enough time for the fields to collapse back down on themselves before the new fields are set up in the region around the antenna.

But if the AC is above 500,000 Hz, the fields won't have enough time to collapse and instead will "flip off" the antenna due to "electrical pressure.



If this happens, the disturbances will leave the antenna as an electromagnetic waves moving at $3x10^8$ m/s, or the speed of light.

As an interesting side note, at that speed the changing magnetic field will induce an electric field, and the changing electric field will induce a magnetic field, and the two moving in tandem with one another will more or less feed one another. It only works at that speed, the "speed of light," but that is how electromagnetic waves can move through empty space without a medium. They are their own medium.

EM waves

- Radio waves are at the lower end of the frequency spectrum for EM waves (visible light is much higher frequency)

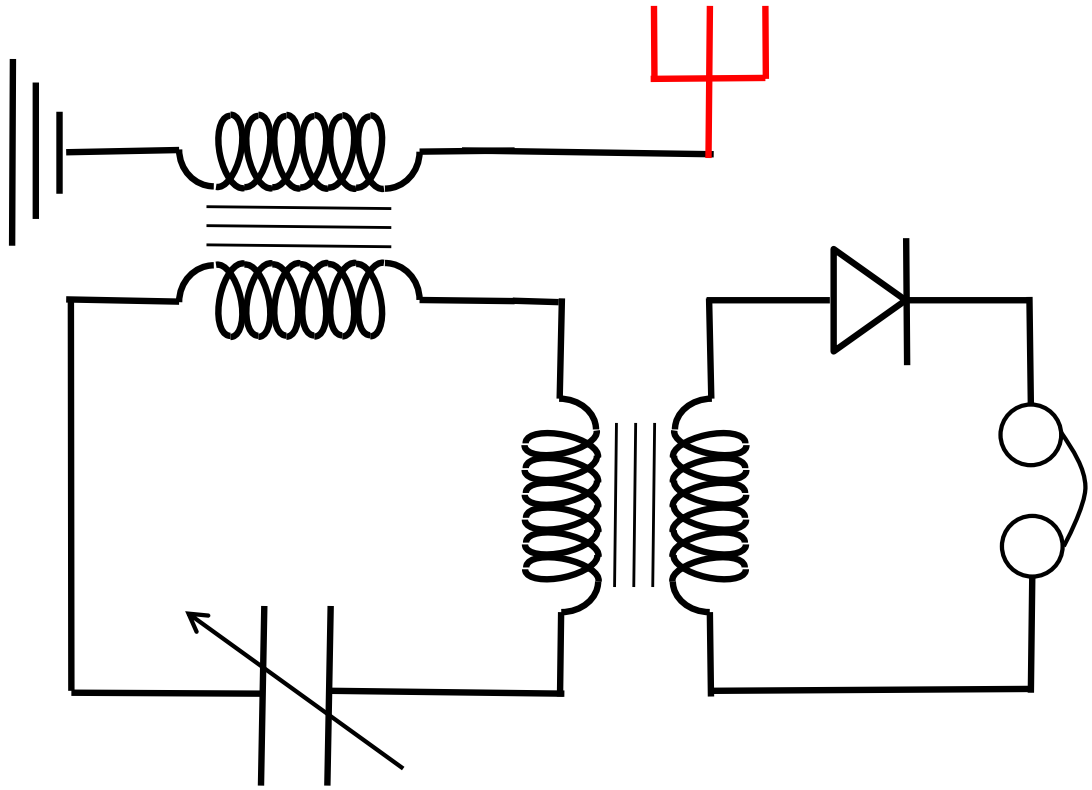
  -- Radio waves range from about 0.5×10^6 Hz to 1.7×10^6 Hz

- Each radio station has an assigned frequency for its signal -- when you tune to the Dodger game on AM570, that number is telling you the frequency!
  - The actual frequency is in kHz, so AM570 = 570×10^3 Hz = 570,000 Hz
  - When I was a kid, KFWB Channel 98 was a rock and roll station (it's a news station now) -- the units on the radio dial were 10 kHz, so KFWB was (and is) 980,000 Hz

Radio receiving circuit

- A **radio receiving circuit** is shown here.

❑ The electromagnetic wave impinges on the antenna and motivates its charge carriers to move in exactly the same way the charge carriers on the sending antenna moved while generating the wave in the first place.



❑ Problem is, every station in the area has its signal impinging on the antenna.

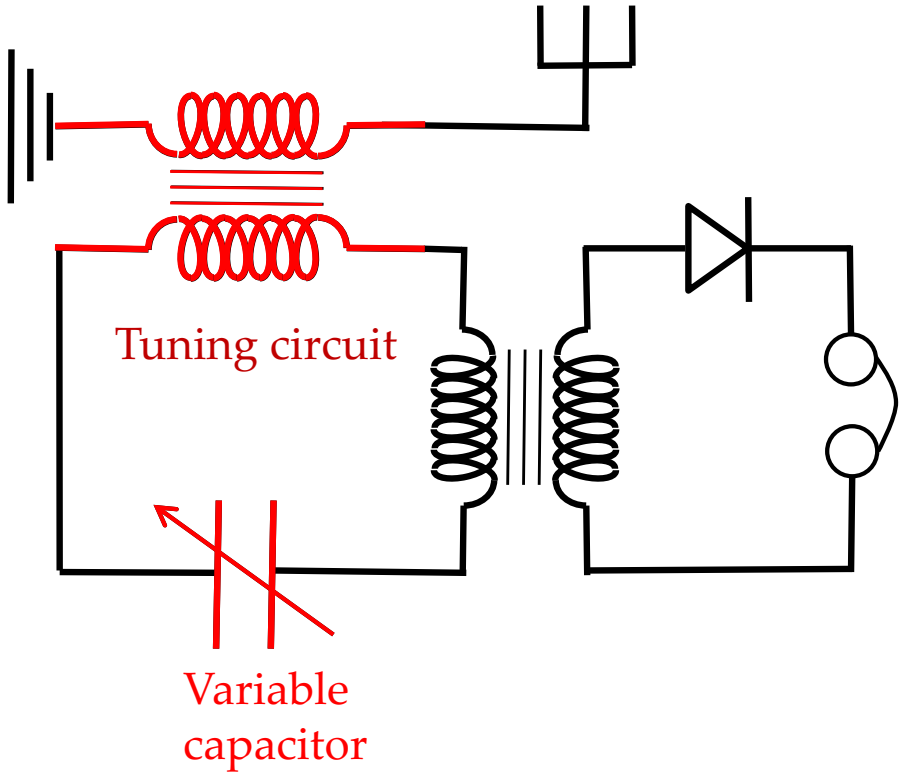
❑ What clever thing might we do to home in on the one frequency we want to listen to? Enter the **tuning circuit.**

Radio receiver and tuning circuit

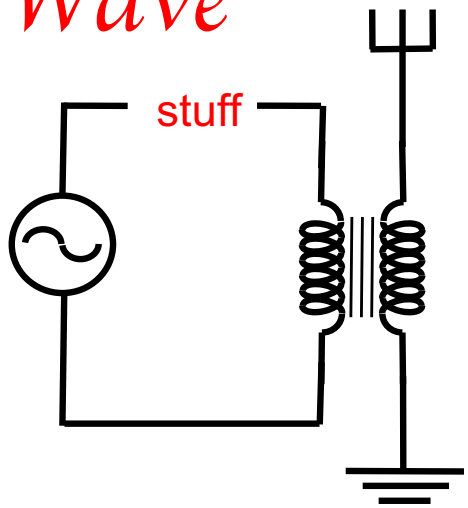
- A transformer transfers all the signals impinging on the antenna to the tuning circuit.
- The tuning circuit, being an RLC circuit, has a resonant frequency of

$$\nu = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$$

- Using the variable capacitor, we can tune the natural frequency of the circuit to the frequency of the station we want. That signal will amplify and the others will dampen out and go away.



Putting Information on the Wave



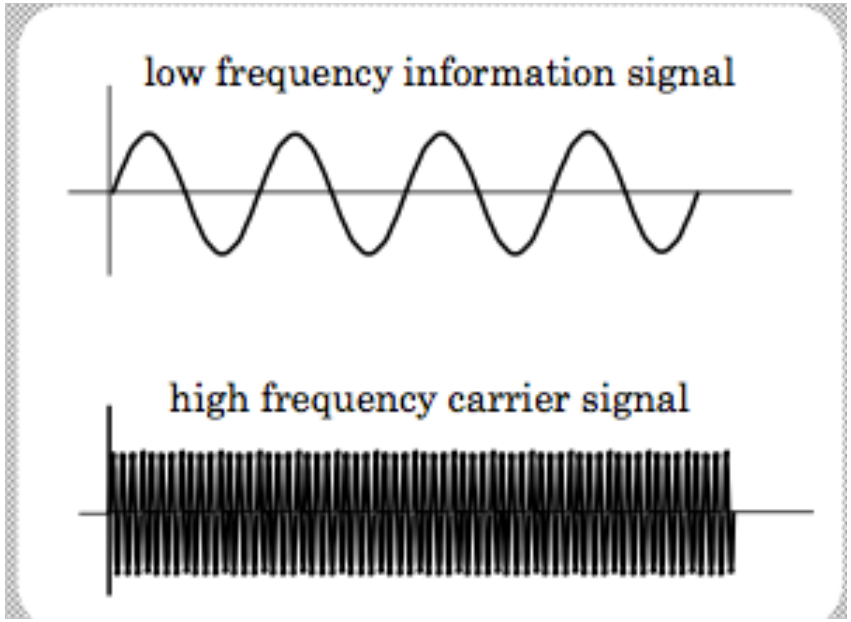
1.) So what is actually transferred to the speaker circuit?

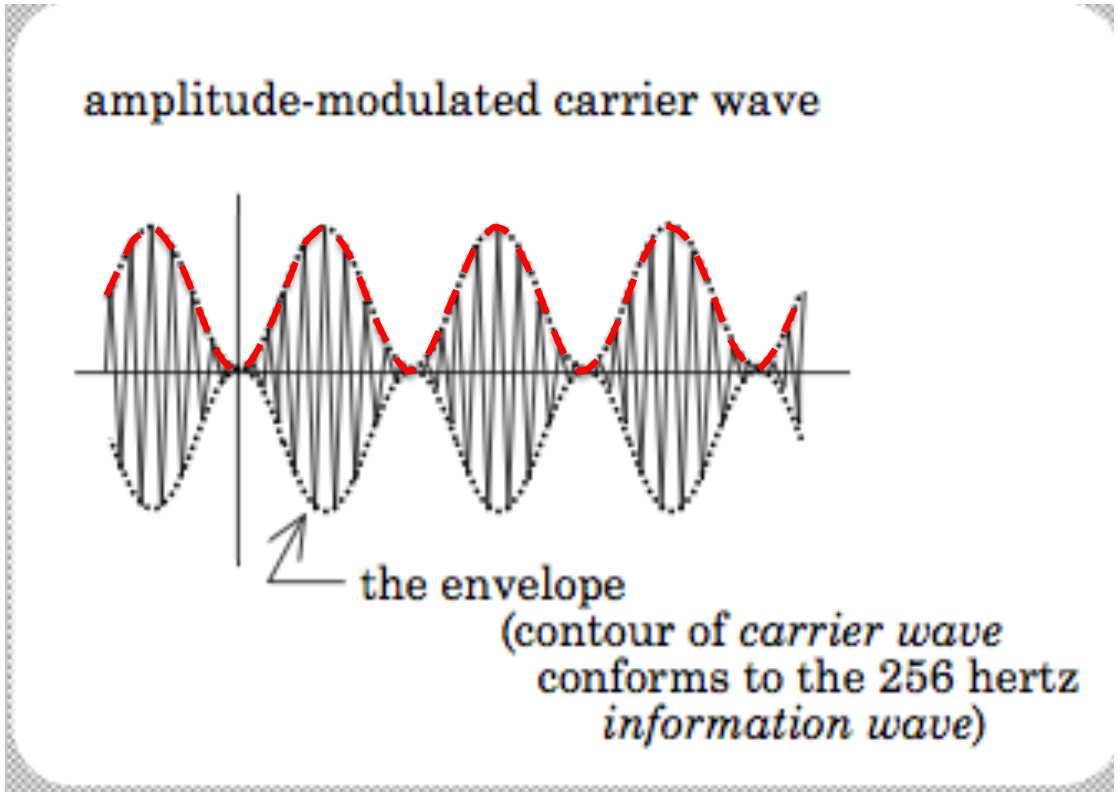
2.) How do we get information onto a single frequency radio station signal?

3.) That's where "the stuff" alluded to in the sending circuit comes in.

4.) It takes the high frequency "carrier wave" and puts the "information wave" onto it.

5.) How so? It modulates the amplitude of the carrier wave so that it looks like the information wave.



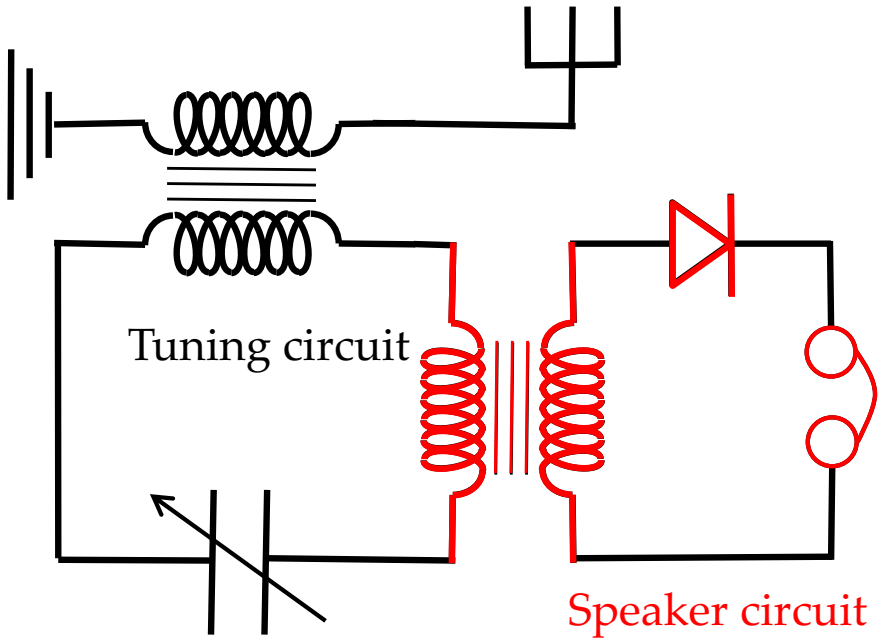


Amplitude modulation as the mode of information transfer is why these radios are called "AM" radios.

Modulating the frequency is the key to "FM" radios.

Speaker circuit

The speaker, which is located in what is called "the Speaker Circuit," is as we described a few weeks ago: a coil and fixed magnet at the base of the cone, which oscillates to match the induced AC current in the coil.

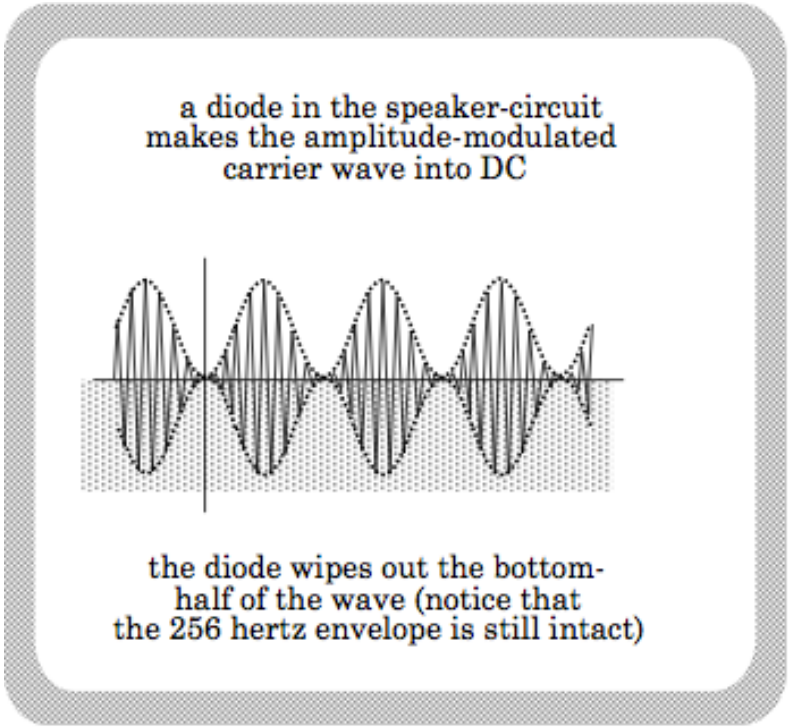


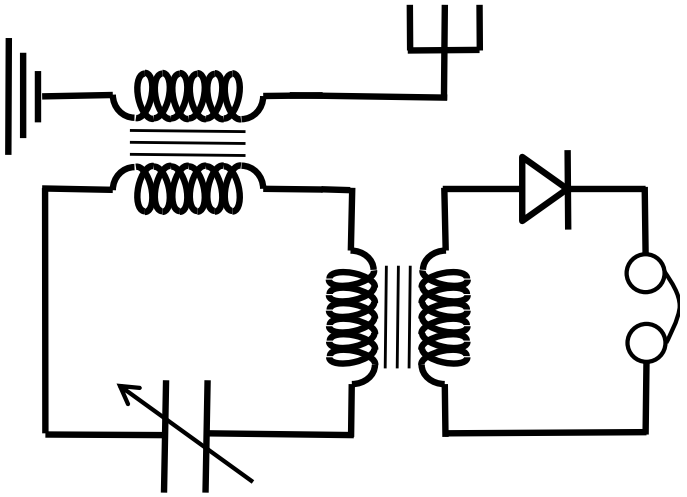
The signal in the Tuner Circuit is transferred to the Speaker Circuit via another transformer.

If we put radio frequency 1,000,000 Hz AC through a speaker coil, the speaker will just sit there (too inert to move). So how does this help us?

Speaker as Decoder

If we used a diode to make the AC in the Speaker Circuit into DC . . .



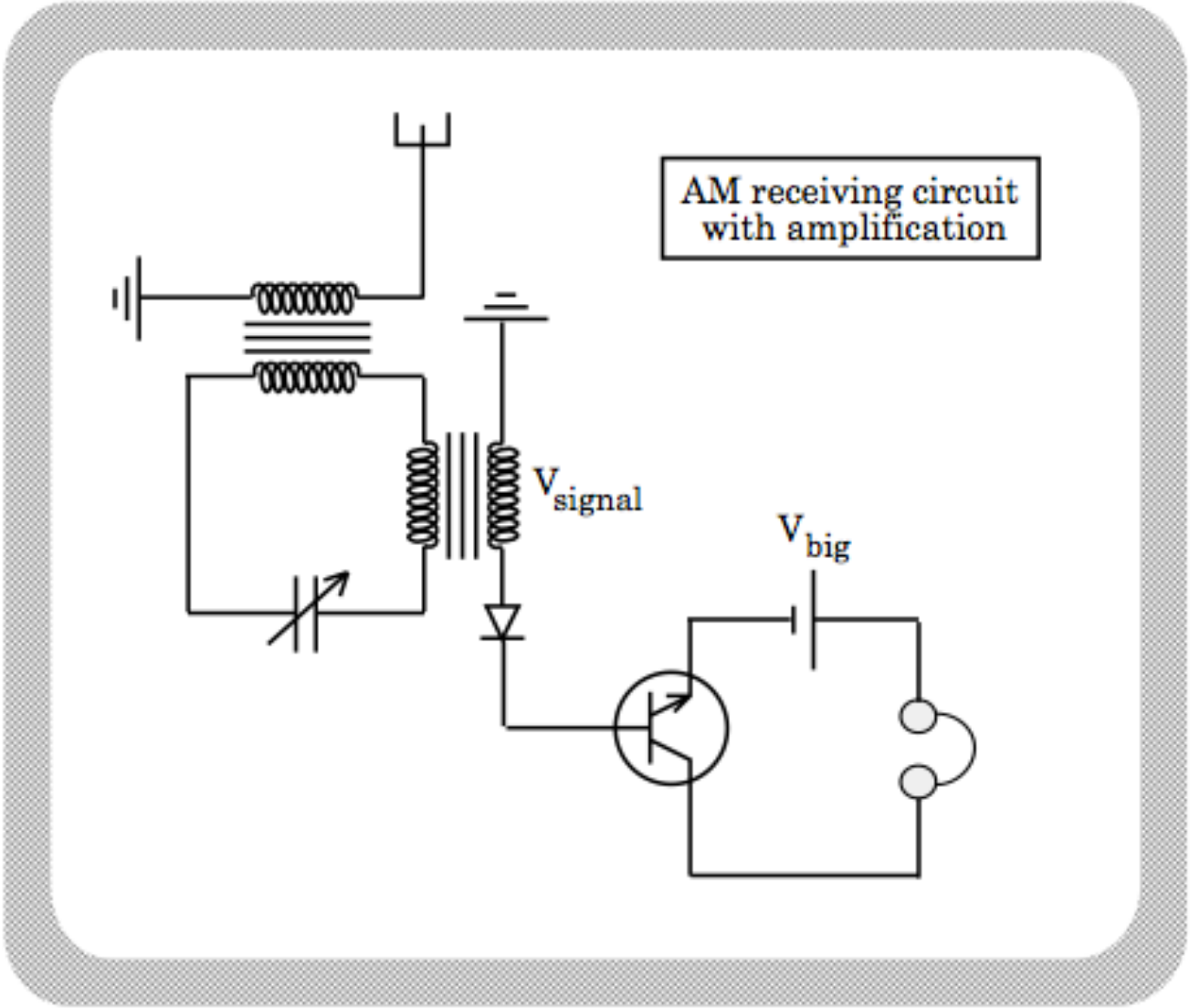


. . . the general trend of current will motivate the speaker to flex in and out with the average of the signal, which is to say that the speaker cone's motion will be governed by the envelope of the amplitude modulated wave, where the envelope is the same as the information wave.

Amplification

But what if we want amplification?

To amplify the signal, all we need is a transistor as shown in the sketch.



Frequency modulation (FM)

And for the amusement of it, though we're not going to look at its circuitry, FM radio put information on their waves as follows: