Crystal Radio Engineering
Driving Speakers

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Introduction

One of the high achievements in crystal radios is being able to drive a speaker and being able to hear the signal across the room. The sound will not be loud but will be definitely audible and even understandable if the room is otherwise quiet. The author has done this and it is a nice feeling of accomplishment. Driving a speaker is only possible if everything in the radio has been done in the best way and the antenna and particularly the ground system is decent. The radio station being received generally needs to be within 20 km and be operating at 50 kW. This will result in a whopping 10 to 100 microwatt audio signal to the speaker! Believe it or not, you can hear that in a quiet room. If you can get as much as a milliwatt to the speaker then everyone can definitely hear it.

Speakers

A speaker is typically constructed of a stiff suspended cone with a coil that is positioned inside a very powerful permanent magnet. Electrical current in the coil makes a magnetic field that reacts with the permanent field thus moving the cone in response. This process converts electrical energy to acoustical energy.

Speakers are typically rated in dBa acoustical output at a distance of one meter for one watt of applied electrical power. Typical speakers range from around 80 (inefficient) to over 90 (efficient) dBa at 1 meter for one watt. The electrical efficiency of a speaker has little if anything to do with its sound quality or price.

A common speaker impedance is 8 ohms but other impedances exist between 2 and 16 ohms. The impedance of a speaker is not the DC resistance (ideally that would be zero) of its voice coil but is a complex relation involving the coupling of the speaker cone to the surrounding air. A back emf is generated by the moving coil and that forms an impedance that varies across the audio spectrum. The published impedance of a speaker is typically measured at a frequency of 1,000 Hz although other frequencies may be referenced if the speaker is intended for use at the very high or very low end of the audio spectrum.

A speaker has too low an impedance to directly connect to the detector of a crystal radio. A transformer must be used. The type of transformer you need is not easily found. You generally want a transformer that has is designed for a primary impedance of at least 5,000 but preferably 20,000 ohms or more. The specified secondary impedance should be reasonably close to that of the speaker you will be using. Miniature transformers are typically very inefficient and have a loss in the 3 to 6 dB range. Large transformers typically have a loss of 1 dB or less – that is what you want.

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An "ideal" transformer would match about 20,000 to 50,000 ohms on the primary to 8 ohms on the secondary and would probably weigh a half pound or more (large size translates to low loss). However, the author has never found such a commercial transformer and plans someday to wind such a transformer. It is possible to find transformers to match 50,000 ohms to 1,000 ohms and other transformers to match 1,000 ohms to 8 ohms. This combination will work – not ideal – but much better than nothing.

There is no rule that says you have to use the exact impedance each winding is designed for. You can generally go up or down a factor of two or more with little ill effect. If your impedance is lower than the winding is specified for then high frequency response will not be as good and losses will likely be higher. If your impedance is higher than the winding is specified for then low frequency response will not be as good and losses will likely be higher. Keep in mind that a few dB of extra loss will not stop your radio from working unless your signals are so weak that this extra loss makes them inaudible. What you want to do is to make the radio work however and then you can think about optimizations afterwards.

A typical speaker mounted in the proper enclosure will produce a sound level in the 85dBa for one watt of power at a distance of one meter. That is very loud. Humans can hear a much lower sound level. It would only take about 10 mW for this same speaker to produce the volume of normal speaking level. A power of only 100 uW would be definitely audible in a quiet room. Thus, if the signal strength of a station we want to pick up is in the 1 mW range then driving a speaker is practical. The following table shows some typical examples.

Power to Speaker	**dBa @ 1 meter**	**Example volume level**
1 Watt	85 dBa	Loud
100 mW	75 dBa	"Normal" volume on radio or TV
10 mW	65 dBa	Typical conversation
1 mW	55 dBa	Quiet conversation
100 uW	45dBa	Whisper
10 uW	35 dBa	Typical background noise level in a home

Table 1: Sound levels

Although there may be exceptions, miniature (less than 4 inches across) speakers typically are very inefficient. You will probably find that the best speakers for crystal radio purposes are in the 4 to 8 inches across range. Larger speakers may work well too. It is important that the speaker be mounted in an enclosure designed to maximize the volume. Some designs that emphasize high fidelity are inefficient – which is not a consideration in the high fidelity business.

Do not waste time attempting to make a speaker work until you have very good volume in headphones. That is a clue that speaker operation can work.