load and others assuming a **matching load**[4]—a load equal to the output impedance. For this reason, it is best to measure the actual output of any source.

1.6 Capacitors

Capacitors have two terminal and are composed of two conductive surfaces separated by some distance. One surface has charge q and the other $-q$. A capacitor stores energy in an *electric field* between the surfaces.

Let a capacitor with voltage v across it and charge q be characterized by the parameter **capacitance** C, where the constitutive equation is

$$q = Cv.$$

The capacitance has derived SI unit **farad (F)**, where $\mathrm{F} = \mathrm{A} \cdot \mathrm{s}/\mathrm{V}$. A farad is actually quite a lot of capacitance. Most capacitors have capacitances best represented in μF, nF, and pF.

The time-derivative of this equation yields the v-i relationship (what we call the "elemental equation") for capacitors. capacitor elemental equation A time-derivative! This is new. Resistors have only algebraic i-v relationships, so circuits with only sources and resistors can be described by *algebraic* relationships. The dynamics of circuits with capacitors are described with *differential equations*.

(a) bipolar capacitor. (b) polarized capacitor

Figure 1.9. capacitor circuit diagram symbols.

Capacitors allow us to build many new types of circuits: filtering, energy storage, resonant, blocking (blocks dc-component), and bypassing (draws ac-component to ground).

Capacitors come in a number of varieties, with those with the largest capacity (and least expensive) being **electrolytic** and most common being **ceramic**. There are two functional varieties of capacitors: **bipolar** and **polarized**, with circuit diagram symbols shown in figure 1.9. Polarized capacitors can have voltage drop across in only one direction, from **anode** (+) to **cathode** (−)—otherwise they are damaged or may **explode**. Electrolytic capacitors are polarized and ceramic capacitors are bipolar.

4. A matching load can be shown to have maximum power transfer.

So what if you need a high-capacitance bipolar capacitor? Here's a trick: place identical high-capacity polarized capacitors **cathode-to-cathode**. What results is effectively a bipolar capacitor with capacitance *half* that of one of the polarized capacitors.

1.7 Inductors

A **pure inductor** is defined as an element in which **flux linkage** λ—the time integral of the voltage—across the inductor is a monotonic function $\mathcal{F}$ of the current i; i.e. the pure constitutive equation is

$$\lambda = \mathcal{F}(i).$$

An **ideal inductor** is such that this monotonic function is linear, with slope called the **inductance** L; i.e. the ideal constitutive equation is

$$\lambda = Li$$

The units of inductance are the SI derived unit **henry (H)**. Most inductors have inductance best represented in mH or μH.

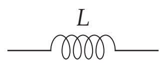

Figure 1.10. Inductor circuit diagram symbol.

The elemental equation for an inductor is found by taking the time-derivative of the constitutive equation. inductor elemental equation

Inductors store energy in a *magnetic field*. It is important to notice how inductors are, in a sense, the *opposite* of capacitors. A capacitor's current is proportional to the time rate of change of its voltage. An inductor's voltage is proportional to the time rate of change of its current.

Inductors are usually made of wire coiled into a number of turns. The geometry of the coil determines its inductance L.

Often, a **core** material—such as iron and ferrite—is included by wrapping the wire around the core. This increases the inductance L.

Inductors are used extensively in radio-frequency (rf) circuits, with which we won't discuss in this text. However, they play important roles in ac-dc conversion, filtering, and transformers—all of which we will consider extensively.

The circuit diagram for an inductor is shown in figure 1.10.