Fundamental Electrical Concepts

Charge, Current, Voltage,

Power and Energy

Chapter 2, sec. 2.2 & 2.3

Electric Charge (Q)

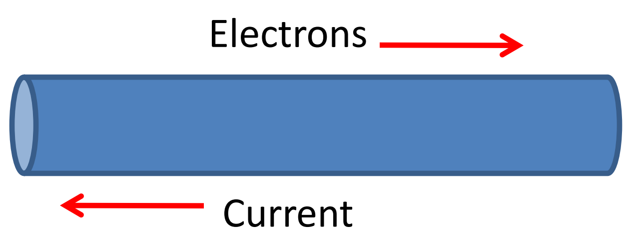
- Characteristic of subatomic particles that determines their electromagnetic interactions

- An electron has a $-1.602 \cdot 10^{-19}$ Coulomb charge

- The rate of flow of charged particles is called current

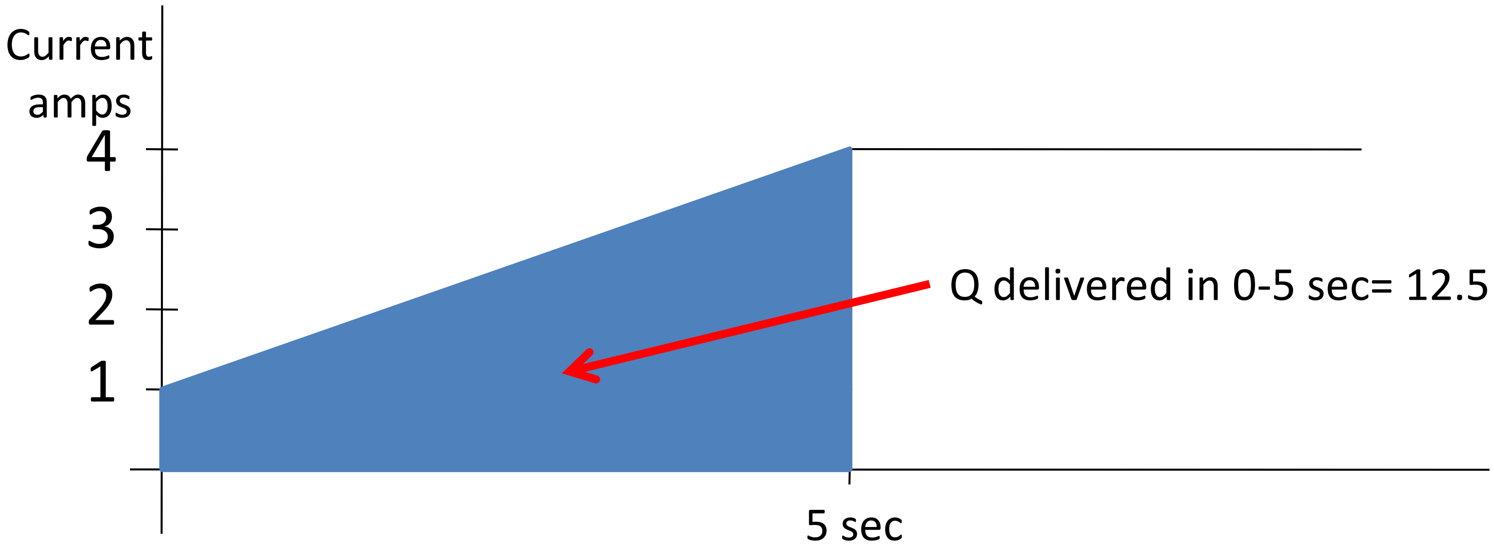
Current (I)

- Current = (Number of electrons that pass in one second) · (charge/electron)
  - -1 ampere = ($6.242 \cdot 10^{18}$ e/sec) ·($-1.602\ 10^{-19}$Coulomb/e)
  - Notice that an ampere = Coulomb/second
- The negative sign indicates that the current inside is actually flowing in the opposite direction of the electron flow



Current

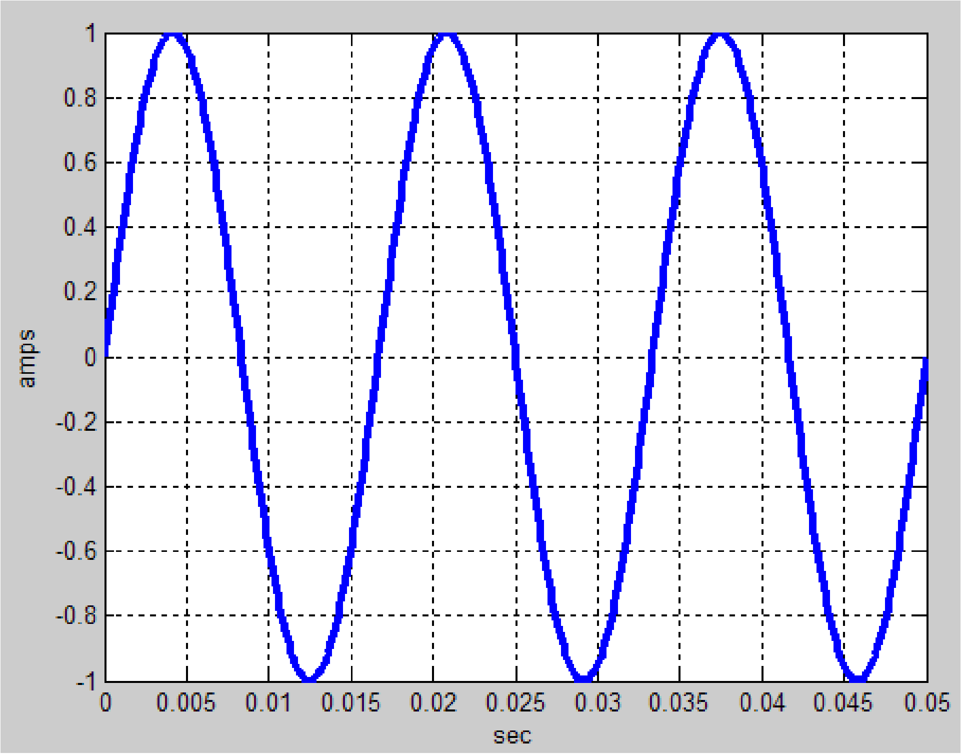
- i = dq/dt – the derivitive or slope of the charge when plotted against time in seconds
- Q = ∫ i · dt – the integral or area under the current when plotted against time in seconds



AC and DC Current

- DC Current has a constant value

- AC Current has a value that changes sinusoidally



- Notice that AC current changes in value and direction

- No net charge is transferred

Why Does Current Flow?

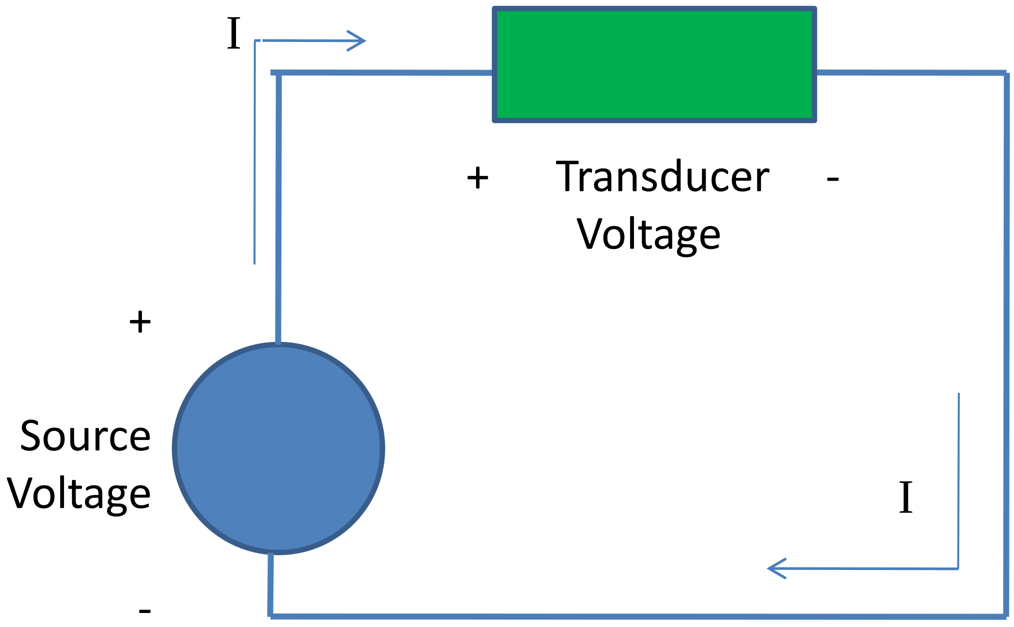
- A voltage source provides the energy (or work) required to produce a current
  - Volts = joules/Coulomb = dW/dQ
- A source takes charged particles (usually electrons) and raises their potential so they flow out of one terminal into and through a transducer (light bulb or motor) on their way back to the source's other terminal

Voltage

- Voltage is a measure of the potential energy that causes a current to flow through a transducer in a circuit
- Voltage is always measured as a difference with respect to an arbitrary common point called ground
- Voltage is also known as electromotive force or EMF outside engineering

A Circuit

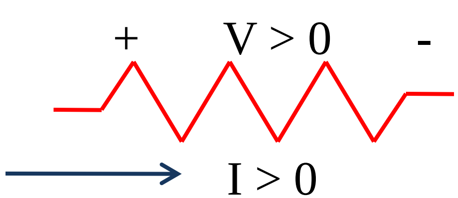
- Current flows from the higher voltage terminal of the source into the higher voltage terminal of the transducer before returning to the source



➢The source expends energy & the transducer converts it into something useful

Passive Devices

- A passive transducer device functions only when energized by a source in a circuit
  - Passive devices can be modeled by a resistance
- Passive devices always draw current so that the highest voltage is present on the terminal where the current enters the passive device



- **Notice that the voltage is measured across the device**
- **Current is measured through the device**

Active Devices

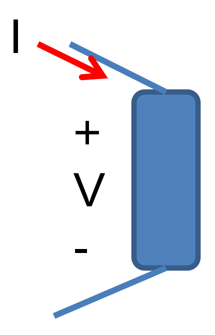
- Sources expend energy and are considered active devices
- Their current normally flows out of their highest voltage terminal
- Sometimes, when there are multiple sources in a circuit, one overpowers another, forcing the other to behave in a passive manner

Power

- The rate at which energy is transferred from an active source or used by a passive device
- P in watts = dW/dt = joules/second
- P= V·I = dW/dQ · dQ/dt = volts · amps = watts
- W = ∫ P · dt – so the energy (work in joules) is equal to the area under the power in watts plotted against time in seconds

Conservation of Power

- Power is conserved in a circuit - $\sum P = 0$
- We associate a positive number for power as power absorbed or used by a passive device
- A negative power is associated with an active device delivering power

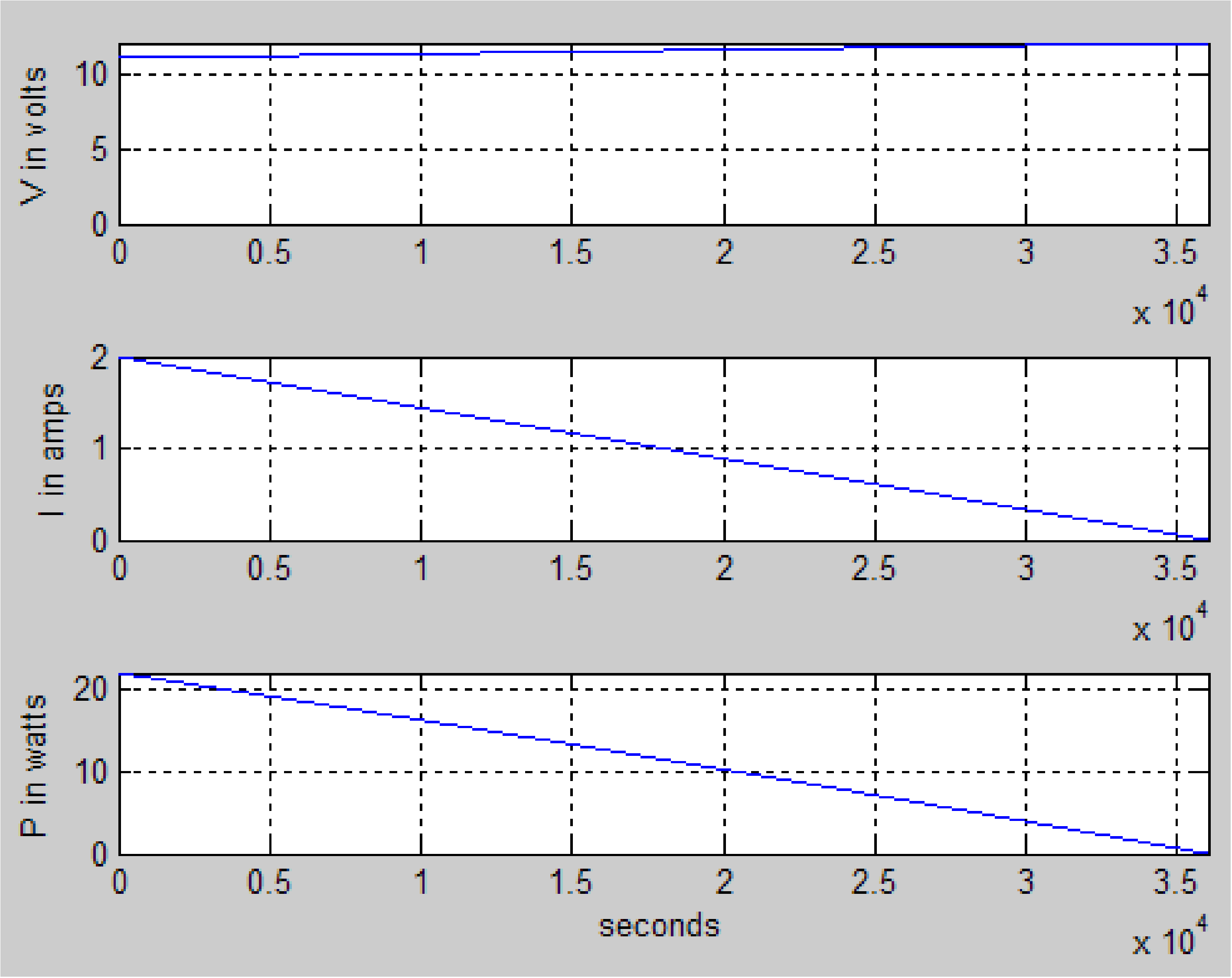


If I=1 amp V=5 volts Then passive P=+5 watts (absorbed)	If I= -1 amp V=5 volts Then active P= -5 watts (delivered)	If I= -1 amp V= -5 volts Then passive P=+5 watts (absorbed)

Example

- A battery is 11 volts and as it is charged, it increases to 12 volts, by a current that starts at 2 amps and slowly drops to 0 amps in 10 hours (36000 seconds)
- The power is found by multiplying the current and voltage together at each instant in time
- In this case, the battery (a source) is acting like a passive device (absorbing energy)

Voltage, Current & Power



Energy

- The energy is the area under the power curve
  - ➢ Area of triangle = .5 · base · height
  - ➢ W=area= .5 · 36000 sec. · 22 watts = 396000 J.
  - ➢ W=area= .5 · 10 hr. · .022 Kw. = 110 Kw.·hr
- So 1 Kw.·hr = 3600 J.
- Since 1 Kw.·hr costs about $0.10, the battery costs $11.00 to charge

Homework Application

- Calculate the cost per mile of a plug-in electric vehicle with the following parameters
  - A 120 volt source is used for 6 hours at a current of 20 amps at a cost of $0.10/KWhr each night to charge the battery pack in the vehicle
  - The car will operate for 50 miles on a charge
- Determine the cost per mile for a gas-powered vehicle getting 25 mpg using $3.75 per gal. gas
- How much would you save in fuel cost per year if you averaged 40 plug-in miles per day