signals

examples of signals

length of column of mercury in a thermometer
angles of hands on a clock
or needle of automobile speedometer
intensity and frequency of sound when a tool removes metal from stock turning in a lathe
electrical signals: voltage ~ power collected by antenna, current ~ light intensity, etc
digital signals: ADC + microprocessor convert electrical signal to message in some protocol

and *unwanted* signals (== *noise*)

light leaks thru a crack in your camera’s body
people talk at the table next to yours
strong radio station near weak one you want
observation-to-observation variation
measurand fluctuates (slouch or stand straight)
instrument fluctuates (meter stick trembles)
fundamental natural sources of fluctuation:
thermal motion (“Johnson” or “Nyquist” noise)
interval-to-interval statistical count variations (shot noise)
“chaos”, “uncertainty principle”, etc (1/f noise)

transduction

transduction (between modalities)

conversion of an environmental parameter into a signal is what we call *sensing*

temperature → length of mercury column

force → resistance of (stretched) length of wire

conversion of a signal into an environmental change is what we call *actuation*

finger pushes → lever moves → toilet flushes

signal → power amplifier → current through a resistor → heating of the environment

signal → power amplifier → robot arm motor → motion

the signal is almost always electrical ...

... in modern times; it wasn’t always so!

electrical signals

before ~1960s almost all signals were effectively length measurements:

temperature → length of column of mercury

voltage → position of meter needle along arc

and occasionally some digital counting

e.g., geiger tube + electrical or electronic counter

by the 1980s almost all signals were electrical quantities represented digitally:

voltage ← light frequency (color) on sensor

current ← light intensity (power) on sensor

parameters: resistance = voltage / current

review of elementary electricity & electronics

basic electrical concepts

charge: number of electrons, protons, etc
(each carrying a fundamental unit of charge)
current: charge per unit time flowing through an imagined surface that cuts a wire,
or flowing into or out of a device terminal
voltage: potential energy per unit charge,
“pressure” in response to which current flows
general rule of transport:
measure of x {energy} per unit y {charge}
measure of y {charge} per unit time
rate {power} = (x/y) {voltage} * (y/t) {current}

basic electrical devices

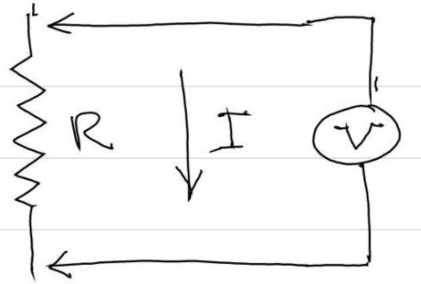
resistor R (or, generally, *impedance*): current I that flows *thru it* ~ voltage V applied *across it*
capacitor C: time derivative of voltage applied *across it* ~ current that flows *into* or *out of it*
inductor L: time integral of voltage applied *across it* ~ current that flows *through it*

$I = \{V/R,\ C\ dV/dt,\ \int V\ dt/L\}$

$V = \{R\ I,\ \int I\ dt/C,\ L\ dI/dt\}$ ← *most usual form*

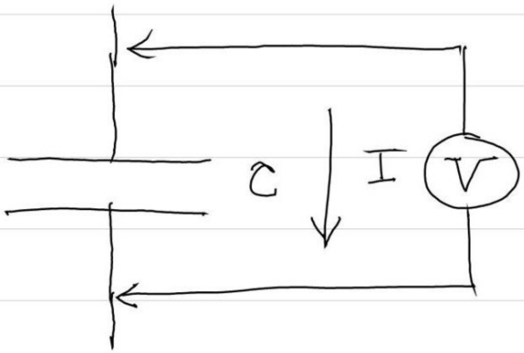
$= \{R\ dQ/dt,\ Q/C,\ L\ d^2Q/dt^2\}$

$Q = \{\int V dt/R,\ CV,\ \int\int V\ dt\ dt'/L\}$



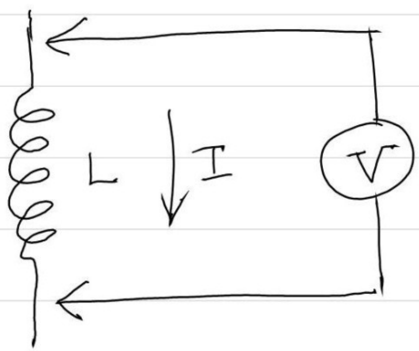
$$I = \frac{V}{R}$$ force a voltage, measure the current

$$V = IR$$ force a current, measure the voltage



$$I = C\frac{dV}{dt}$$ force a (changing) voltage, measure the current

$$V = \frac{1}{C}\underbrace{\int I\,dt}_{Q \text{ charge}}$$ force a current, measure the voltage (as its integral)



$$I = \frac{1}{L}\int V\,dt$$ force a voltage, measure the current (as its integral)

$$V = L\frac{dI}{dt}$$ force a (changing) current, measure the voltage

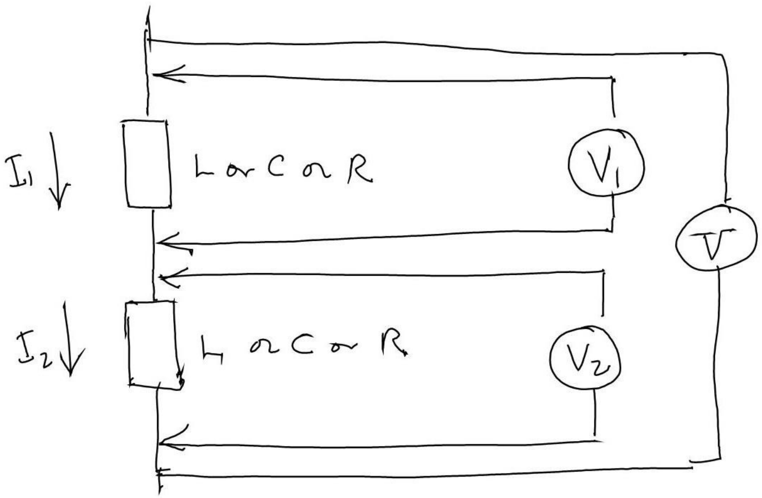
electrical & electronic sensors

basic electrical sensors

many are sources of voltage, current, or charge
CCD pixel voltage ~ integrated light intensity
Ionscan signal current ~ explosive vapor concentration
Geiger tube charge pulse ~ incident ionizing radiation particle energy
many others are “parametric”
strain gauge resistance ~ stretching of wire
humidity sensor capacitance ~ relative humidity
proximity sensor inductance ~ nearby metal

Electrical Components in Circuits

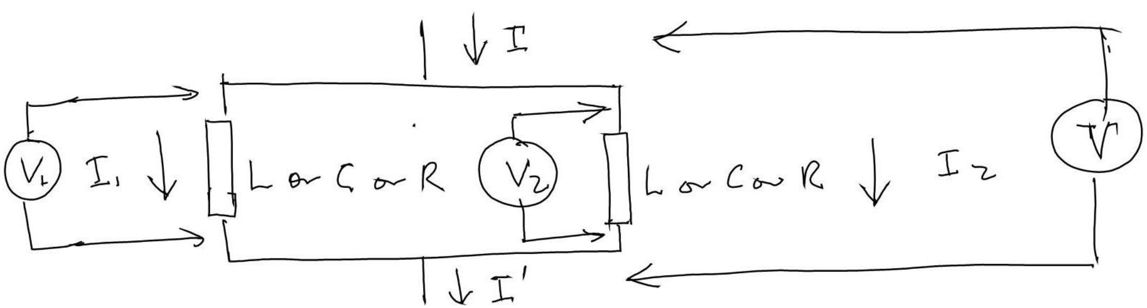
Series:



$$I = I_1 = I_2$$

$$V = V_1 + V_2$$

Parallel:

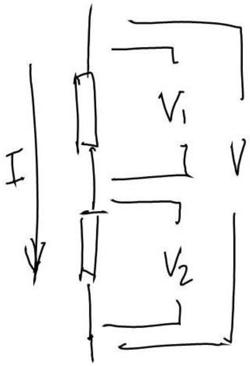


$$I' = I = I_1 + I_2$$

$$V = V_1 = V_2$$

that in series resistances, inductances, and reciprocal capacitances add, whereas in parallel reciprocal resistances, reciprocal inductances, and capacitances add (with the proviso, for inductors, that they are really independent, i.e., they do not share each others magnetic fields)

{Resistors, Inductors, Capacitors} in Series & Parallel

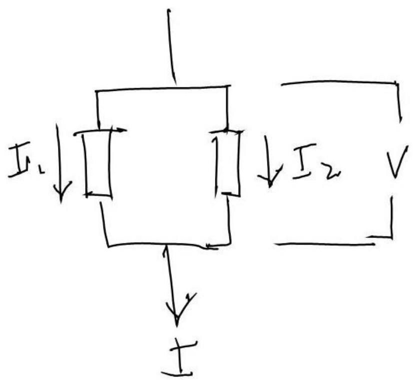


$$V_1 = \left\{ I R_1,\ \dot{I} L_1,\ \int I\,dt\ \frac{1}{C_1} \right\}$$

$$V_2 = \left\{ I R_2,\ \dot{I} L_2,\ \int I\,dt\ \frac{1}{C_2} \right\}$$

$$V = \left\{ I R,\ \dot{I} L,\ \int I\,dt\ \frac{1}{C} \right\}$$

So $R = R_1 + R_2$, $L = L_1 + L_2$, $\frac{1}{C} = \frac{1}{C1} + \frac{1}{C2}$



$$I_1 = \left\{ \frac{V}{R_1},\ \frac{1}{\cdot}\frac{V}{L_1},\ \frac{1}{\int dt}\ C_1 V \right\}$$

$$I_2 = \left\{ \frac{V}{R_2},\ \frac{1}{\cdot}\frac{V}{L_2},\ \frac{1}{\int dt}\ C_2 V \right\}$$

$$I = \left\{ \frac{V}{R},\ \frac{1}{\cdot}\frac{V}{L},\ \frac{1}{\int dt}\ C V \right\}$$

So $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$, $\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2}$, $C = C_1 + C_2$

We will see later, when we discuss AC signals and their decomposition into Fourier frequency components, that “dot” or “d/dt” is usefully written
$j2\pi f$
and
“integral dt”
is usefully written
$1/\ j2\pi f$

basic principle is often concealed!

- Simultaneous detection of explosives and narcotic traces
- 10,4" colour touch screen display.
- Extended internal memory for storing measurement data. Results are exportable via USB link.
- An advanced sampling wand eliminates the need for the operator to handle sample swab after every sample.
- A new, regenerative Air Purification System reduces maintenance and cost of ownership.

Download Ionscan 500DT leaflet
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The IONSCAN® Model 500DT has been carefully designed to rapidly and simultaneously detect and identify trace amounts of drugs or explosives.

SPECIFICATIONS

Technology	Dual Ion Mobility Spectrometry (DIMS)
Drug detection	Cocaine, Heroin, PCP, THC, Methamphetamine, LSD, Marijuana and others Detected to sub-nanogram levels.
Explosives detection	RDX, PETN, TNT, Semtex, Nitrates, NG, HMX and others.