Few electronic components, power supply and soldering

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Outline

- Passive components: Resistors, Capacitors, Inductors
- Active components: Transistors, Operational amplifiers
- Power supplies
- Few things to note about soldering
The Resistor

- resists the flow of charge through itself, hence allowing us to control the current
- SI unit - ohm (Ω)
- can be made of various kinds of material, but whatever the choice it must conduct some electricity otherwise it wouldn't be of any use
- Fixed value and variable type
- Resistor terms and abbreviations
### Fixed value resistors
- construction of a carbon film resistor
  - a thin film of carbon is deposited onto a small ceramic rod.
  - resistive coating is spiraled away in an automatic machine until the resistance between the two ends of the rod is as close as possible to the correct value.
  - cheap and easily available, with values within ±10% or ±5% of their marked, or 'nominal' value
- Metal film and metal oxide resistors
  - are made in a similar way
  - can be made more accurately to within ±2% or ±1% of their nominal value.
  - There are some differences in performance between these resistor types
- Wirewound
  - winding thin wire onto a ceramic rod.
  - They can be made extremely accurately for use in multimeters, oscilloscopes and other measuring equipment.
  - can pass large currents without overheating and are used in power supplies and other high current circuits

### Variable value
- a resistor whose value can be adjusted by turning a shaft or sliding a control.
- also called **potentiometers** or **rheostats**
- allow the resistance of the device to be altered by hand.
- Some examples include:
  - A rheostat: a variable resistor with two terminals, one fixed and one sliding. It is used with high currents.
  - a potentiometer: a common type of variable resistor. One common use is as volume controls on audio amplifiers and other forms of amplifiers
# The Resistor

## Color Coding for Resistors

<table>
<thead>
<tr>
<th>Color</th>
<th>Significant Digits (1 and 2)</th>
<th>Multiplier (3)</th>
<th>Tolerance (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Brown</td>
<td>1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Red</td>
<td>2</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Orange</td>
<td>3</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>Yellow</td>
<td>4</td>
<td>10,000</td>
<td></td>
</tr>
<tr>
<td>Green</td>
<td>5</td>
<td>100,000</td>
<td></td>
</tr>
<tr>
<td>Blue</td>
<td>6</td>
<td>1,000,000</td>
<td></td>
</tr>
<tr>
<td>Violet</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grey</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gold</td>
<td></td>
<td>0.1</td>
<td>5%</td>
</tr>
<tr>
<td>Silver</td>
<td></td>
<td>0.01</td>
<td>10%</td>
</tr>
<tr>
<td>(None)</td>
<td></td>
<td>0.01</td>
<td>20%</td>
</tr>
</tbody>
</table>

![Resistor Color Code Diagram](image)
Calculations

- **Ohm’s law**
  \[ V = IR \]
  An ideal resistor obeys the law across all frequencies and amplitudes of voltage or current.

- **Power dissipation**
  The power dissipated by a resistor is the voltage across the resistor multiplied by the current through the resistor:
  \[ P = IV \]
  The total amount of heat energy released is the integral of the power over time:
  \[ W = \int_{t_1}^{t_2} v(t)i(t) \, dt \]
  If the average power dissipated exceeds the power rating of the resistor, the resistor will depart from its nominal resistance, and will then be destroyed by overheating.
**The Resistor**

**Series and parallel circuits**

- **Parallel**

  \[
  \frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}
  \]

- **Series**

  \[R_{\text{eq}} = R_1 + R_2 + \cdots + R_n\]
The ideal resistor

- The resistance remains constant regardless of the applied voltage or current through the device or the rate of change of the current.

Non-ideal characteristics

- A resistor has a maximum working voltage and current above which the resistance may change (drastically, in some cases) or the resistor may be physically damaged (overheat or burn up, for instance).

- A maximum power is determined by the physical size.

- Common power ratings for carbon composition and metal-film resistors- 1/8 W, 1/4 W, 1/2 W.

- Metal-film and carbon film resistors are more stable than carbon resistors against temperature changes and age.

- Real resistors also introduce some inductance and a small amount of capacitance, which change the dynamic behavior of the resistor from the ideal.
Non-ideal characteristics

- Non-ideal characteristics include temperature dependence

- All resistors will have some degree of voltage dependence
  - Normally, voltage dependence has a negligible effect, but in applications with high voltages, or those with low distortions and wide dynamic ranges, it can be significant

- All resistors must have thermal noise, which is equal to:
  \[ V = (4kTBR)^{1/2} \]
  - \( V \) = the rms noise voltage
  - \( k \) = Boltzmann's constant
  - \( T \) = temperature (Kelvin)
  - \( B \) = noise bandwidth
  - \( R \) = resistance

- Noise sources are usually referred to as
  - contact noise
  - shot noise
Non-ideal characteristics

- Contact noise
  - dependent on both current and the resistor's shape and size.
  - $1/f$ frequency characteristic.
  - the result of dynamic variations in conductivity, due to imperfect contact between two (or more) materials.
  - Contact noise can be significant in metal oxide, and some metal film resistors as See the section Shot noise for an explanation of that type of resistor noise.

- Shot noise
  - dependent upon current, so the more average DC current through a resistor, the more noise you get.
  - the DC current must keep to a minimum
  - For higher DC currents best practice is to use a wirewound or metal film in these applications.
**RESISTOR TERMS AND ABBREVIATIONS**

- **Resistor Tolerance**
  - expressed as the deviation from nominal value in percent and is measured at 25°C only with no appreciable load applied

- **Temperature Coefficient of Resistance (TCR)**
  - expressed as the change in resistance in ppm (0.0001%) with each degree of change in temperature Celsius (Co)

- **Frequency Response**
  - the change in resistance with changes in frequency
  - more difficult to measure.

- **Noise**
  - are measured with very specialized equipment, very difficult to measure.
  - best approach is to use resistor types with low or no noise in applications that are sensitive to noise

- **Voltage Coefficient**
  - the change in resistance with applied voltage
  - is associated with Carbon Composition Resistors and Carbon Film Resistors.
Thermocouple Effect
- due to the Thermal emf generated by the change in the temperature at the junction of two dissimilar metals.
- due to the materials used in the leads or in the case of Wirewound Resistors the resistive element
- can be minimized by keeping both leads at the same temperature.

Stability
- the change in resistance with time at a specific load, humidity level, stress, and ambient temperature.
- The wider the temperature changes and the more rapid these changes in are, the greater the change in resistance.
- If severe, can literally destroy the resistor.

Reliability
- the degree of probability that a resistor will perform its desired function.
- two ways of defining Reliability.
  - Mean Time Between Failures (MTBF)
  - Failure Rate per 1,000 hours of operation.
RESISTOR TERMS AND ABBREVIATIONS

- **Temperature Rating**
  - the maximum allowable temperature that the resistor may be used.
  - a resistor may be rated at full load up to +85°C derated to no load at +145°C.

- **Power Rating**
  - based on physical size, allowable change in resistance over life, thermal conductivity of materials, insulating and resistive materials, ambient operating conditions.
  - all resistors are not rated alike.

- It is important that all of the above characteristics be considered when selecting a particular style and tolerance for each application.
Resistors and capacitors

- Frequency dependent resistors
- an electrical device that can store energy in the electric field between a pair of closely-spaced conductors (called 'plates')

- capacitance \( C \) is a measure of the amount of charge \( Q \) stored on each plate for a given potential difference or voltage \( V \) which appears between the plates:

\[
C = \frac{Q}{V}
\]

- Can't dissipate power

- Used
  - in electrical circuits as energy-storage devices
  - to differentiate between high-frequency and low-frequency signals
- electric charge accumulates on the plates
- an **electric field** is created in the region between the plates
- electric field creates a potential difference \( V = E \cdot d \)

\[
C \approx \frac{\varepsilon A}{d}; \quad A \gg d^2
\]

The electrons within dielectric molecules are influenced by the electric field, causing the molecules to rotate slightly from their equilibrium positions.

Energy stored:

\[
E_{\text{stored}} = \frac{1}{2} CV^2 = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} VQ
\]
How capacitor works? Charging and Discharging

- the size of a capacitor affects its charging/discharging.
- **Charging** :- When a voltage is applied across the plates of a capacitor (through a resistor, to stop very large currents inherent to low-resistance systems), an equal charge builds up on each plate.
- **Discharging** :-If voltage is removed, the plates are now connected together through a resistance, a current will flow between them, equalizing the charge on the plates.
- current will fall off as the charge difference driving it falls.
The unit is the farad (F).

Generally, capacitors have values of around one millionth of a farad (µF).

<table>
<thead>
<tr>
<th>preferred</th>
<th>in pF</th>
<th>in nF</th>
<th>in µF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1pF</td>
<td>1</td>
<td>0.001</td>
<td>0.000,001</td>
</tr>
<tr>
<td>10pF</td>
<td>10</td>
<td>0.01</td>
<td>0.000,01</td>
</tr>
<tr>
<td>100pF</td>
<td>100</td>
<td>0.1</td>
<td>0.000,1</td>
</tr>
<tr>
<td>1nF</td>
<td>1000</td>
<td>1</td>
<td>0.001</td>
</tr>
<tr>
<td>10nF</td>
<td>10,000</td>
<td>10</td>
<td>0.01</td>
</tr>
<tr>
<td>100nF</td>
<td>100,000</td>
<td>100</td>
<td>0.1</td>
</tr>
<tr>
<td>1µF</td>
<td>1,000,000</td>
<td>1000</td>
<td>1</td>
</tr>
</tbody>
</table>

Generally, capacitors have a 20% tolerance (although more precise capacitors do exist if needed).
Types of Capacitors

- **Electrolytic (1μF-10mF, for low-frequency circuits, polar, leaking, temperature sensitive, should be used with ceramic capacitors in parallel)**

  - Tantalum (1μF-500μF, low-leakage electrolytic)

- **Polyester (Mylar) (1nF-10μF, general purpose, temperature sensitive)**

- **Ceramic (10pF-0.1μF, high-frequency filtering, temperature sensitive)**

- **Polystyrene, polypropylene (10pF-10μF, high quality)**
Non-ideal properties of practical capacitors

- **Voltage**
  - Only take a certain voltage across the plates before the dielectric breaks down, and current flows through the capacitor.
  - The common voltage limits for capacitors are:
    - 10V, 16V, 25V, 35V, 63V, 100V, 200V, 450V

- **Temperature**
  - Some capacitors contain liquid than must not be allowed to boil or freeze.
  - The common top temperature ranges for capacitors are:
    - 85°C, 105°C

- **Q factor, dissipation and tan-delta (loss angle)**
  - "Q" (quality) factor (and the inverse, dissipation factor, $D$ or tan-delta), relates capacitance at a certain frequency to the combined losses due to dielectric leakage and series internal resistance dissipation factor (dielectric loss).
  - The lower the 'Q', the lousier the capacitor.
  - High Q capacitors tend to exhibit low DC leakage currents.
  - Tan-delta is the tangent of the phase angle between voltage and current in the capacitor.
Non-ideal properties of practical capacitors

- **Equivalent series resistance (ESR)**
  - an effective [resistance](#) that used to describe the resistive parts of the impedance of certain electronic components
  - A low ESR capacitor typically has an ESR of 0.01 Ω

- **Equivalent series inductance (ESL)**
  - mainly caused by the leads used to connect the plates to the outside world and the series interconnects used to join sets of plates together internally
  - For any real-world capacitor, there is a frequency above DC at which it ceases to behave as a pure capacitance. the (first) resonant frequency
  - Large capacitors tend to have much higher ESL than small ones

- **Maximum voltage and current**
  - Important properties of capacitors - the maximum working voltage (potential, measured in volts) and the amount of energy lost in the dielectric
  - For high-power or high-speed capacitors, the maximum ripple current, peak current, fault current, and percent voltage reversal

- **Temperature dependence**
  - major non-ideality is temperature coefficient (change in capacitance with temperature)
  - usually quoted in parts per million (ppm) per degree Celsius
Non-ideal properties of practical capacitors

- **Aging**
  - After long storage, the electrolyte and dielectric layer within electrolytic capacitors may deteriorate;

- **Dielectric absorption (soakage)**
  - *dielectric absorption or soakage* unwanted charge storage
    - In the construction of long-time-constant integrators, it is important that the capacitor will not retain a residual charge when shorted
    - effectively creates a memory effect in the capacitor
    - This is a non-linear phenomenon
    - important when building very low distortion filters
    - for safety, high voltage capacitors are stored with their terminals short circuited

- **Non-linearity**
  - Capacitors may also change capacitance with applied voltage.
  - prevalent in high 'k' ceramic and some high voltage capacitors.
  - can be source of non-linearity when building low distortion filters

- **Leakage**
  - Capacitors also have some level of parasitic resistance across the terminals which is called 'leakage'.
  - limits how long capacitors can store
Capacitors and inductors

- AC circuits have continuously changing values of voltage and current
- Inductors and capacitors continuously oppose these changes
- Opposition to current is called reactance
- Measured in ohms

\[ X_L = 2\pi fL \]
\[ X_C = \frac{1}{2\pi fC} \]
A simple inductor made from a coil of conductor with the magnetic field associated with the current \( I \)

- a passive element that stores energy in the form of a magnetic field, or B-field.
- made by winding wire or other conductive material into a coil
- When a current passes through the coil, a magnetic field is set up
- are made from copper wire but not always
- The nature of the material enclosed by the inductor (i.e. inside the coil) affect the behavior of the inductor
- The permeability, \( \mu \), of this material governs how strong the magnetic field will be for a given current
- Common core materials are air, iron or ferrite
- Iron and ferrite types-more efficient because
  - of the two, ferrite is more efficient because stray electricity cannot flow through it so easily
  - it has a high resistance
  - Ferrite is more expensive but operates at much higher frequencies than iron cores
Inductor Equations

An inductor stores magnetic flux proportional to the current through it:

\[ L = \frac{\Phi}{i} \]

The inductance \( L \) (units of Henries) is set by the construction of the inductor:

\[ L = \frac{\mu_0 \mu_r N^2 A}{l} \]

\( \mu_0 \) = permeability of free space = \( 4\pi \times 10^{-7} \) H/m
\( \mu_r \) = relative permeability of core material
\( N \) = number of turns
\( A \) = area of cross-section of the coil in square m
\( l \) = length of coil in metres (m)
Important Qualities of Inductors

- Current carrying capacity is determined by wire thickness and resistivity.
- The inductance of the coil: the response of the inductor to a changing current.

\[ L = \frac{\mu_0 \mu_r N^2 A}{l} \]

- The inductance is determined by several factors:
  - Coil shape: short and squat is best.
  - Core material.
  - The number of turns in the coil.
    - must be in the same direction, or they will cancel out, and you will have a resistor.
Important Qualities of Inductors

**Series Inductances**

\[ L_{\text{total}} = L_1 + L_2 + \ldots + L_n \]

**Parallel Inductances**

\[ L_{\text{total}} = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \ldots + \frac{1}{L_n}} \]
Inductor Behavior

- Voltage across inductor is proportional to
  - the rate of change of current through it:

- Inductors act to resist changes in current
- Inductor voltage can change quickly
- Inductors store energy

- Quality factor: Q

  - Q (quality factor) - ratio of its ability to store energy to the sum total of all energy losses within the component.
    \[ Q = \frac{X}{R} \]

where

- \( Q \) = quality factor (no units)
- \( R \) = total resistance associated with energy losses (in ohms)
- \( X \) = reactance (in ohms). (\( XL = 2\pi fL \) for inductors)
Every practical component has some resistance, some capacitance and inductance.
an "electronically-controlled resistor"
Two of the pins act like a normal resistor (more or less).
The other "control" pin controls the resistance "seen" between the other 2 pins.

Popular uses –
- building a signal amplifier
- it can also be used as a switch

Current and voltage used to control the resistance between the two terminals
- In the BJT, the current flowing into the base controls the resistance between the E & C
- In an FET (unipolar), the voltage at the gate controls the resistance between S & D

BJT and the FET
- BJT's are much faster and high current devices, while
- FETs are small-sized low-power devices..
Bipolar Junction Transistor

- Current through the collector and emitter terminals is controlled by the current entering the base

- Construction
  - Base (lightly doped region) - sandwiched between the emitter and collector
  - The collector handles large quantities of current, high doping
  - The emitter: Less doping concentration, large area to provide more current than the collector
  - Two types: NPN and PNP
Bipolar Junction Transistor

Common base circuit

Common emitter circuit
Field Effect Transistor

Field Effect Transistor (FET) is a Unipolar device
Conduction is controlled by the electric field.

**Principle of FET Operation**

- Conducting semiconductor channel between two ohmic contacts - source and drain
- The gate terminal controls the channel current
- The gate structure acts as two terminal device
  - MOS-structure (MOSFET)
  - p-n junction (JFET)
  - Schottky barrier (MESFET)
  - Heterojunction (HFET)
- The gate is very high-impedence terminal

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Field Effect Transistor: JFET

one type of semiconductor material is located inside a bulk material of the other kind i.e. p inside n, or n inside p

Characteristic curves for a typical N-channel JFET
Field Effect Transistor: MOSFET

Electric field from gate pushes away p-type ‘holes’ and attracts/allows electrons from n-type into channel.

![Diagram of MOSFET with labels for metal contacts, insulating layer, source, gate, drain, and channel. A graph showing drain current vs. drain voltage with different voltage levels indicated.]
## Comparision between BJT and FET

<table>
<thead>
<tr>
<th></th>
<th>BJT</th>
<th>FET</th>
</tr>
</thead>
<tbody>
<tr>
<td>a current controlled current device</td>
<td>a voltage controlled current device</td>
<td></td>
</tr>
<tr>
<td>works as a current controlled amplifier</td>
<td>works as a voltage controlled amplifier</td>
<td></td>
</tr>
<tr>
<td>Types (npn and pnp)</td>
<td>Types (n-channel &amp; p-channel)</td>
<td></td>
</tr>
<tr>
<td>electrons and holes both forms the BJT current</td>
<td>either electrons or holes forms FET current</td>
<td></td>
</tr>
<tr>
<td>Does not have a high input impedance</td>
<td>FET has a high input impedance</td>
<td></td>
</tr>
<tr>
<td>Highly sensitive to input signal</td>
<td>Low sensitive to input signal</td>
<td></td>
</tr>
<tr>
<td>More sensitive to temperature variations</td>
<td>Less sensitive to temperature variations</td>
<td></td>
</tr>
<tr>
<td>Not small in size as compared to FET</td>
<td>Smaller in size, hence useful for making IC hips</td>
<td></td>
</tr>
</tbody>
</table>
Operational amplifier

- A combination of transistors, resistors, and (sometimes) capacitors that Amplifies the difference between two input voltages and produces a single output

  - Original application — analog computers
  - Original construction — discrete components
    - Vacuum tubes
    - Transistors
    - Now — an integrated circuit
  - Applications now — extremely broad

- Called operational amplifier due to the use of this amplifier to perform specific electronic circuit functions or operations, such as summation, integration, differentiation, etc.
Operational amplifier
Operational amplifier

- **Op-Amp Parameters**
  - $A_{od} =$ differential or open-loop gain
  - **Output:**
    - 180° out of phase with $v_1$ (inverting)
    - In phase with $v_2$ (non-inverting)
  - Op-amp responds only to differences between $v_2$ and $v_1$
    - Common-mode signal when $v_2 = v_1 \neq 0$
    - Characteristic called “common-mode rejection”

Max output voltage cannot be greater than $|V_{cc}|$, usually less by 1 to 2 V.

Diagram showing voltage $v_0$ vs. $v_{2} - v_{1}$ with saturation and output voltage at $+V_{cc}$ and $-V_{cc}$.
## Operational amplifier

### Real vs Ideal Op-amp

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Ideal Op Amp</th>
<th>Real OpAmp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differential voltage gain A</td>
<td>Infinite</td>
<td>$10^5-10^9$</td>
</tr>
<tr>
<td>Commam mode voltage gain</td>
<td>$10^{-5}$</td>
<td>$10^5-10^9$</td>
</tr>
<tr>
<td>Gain bandwidth product</td>
<td>infinite</td>
<td>1-20 MHz</td>
</tr>
<tr>
<td>Input resistance R</td>
<td>Infinite</td>
<td>$10^6$ ohm (bipolar)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$10^9-10^{12}$ ohm (FET)</td>
</tr>
<tr>
<td>Output resistance</td>
<td>0</td>
<td>100-100 ohm</td>
</tr>
</tbody>
</table>
Inverting Amplifier

\[
\frac{V_{\text{out}}}{V_{\text{in}}} = -\frac{R_F}{R}
\]
Operational amplifier

Non-Inverting Amplifier

\[
\frac{V_{out}}{V_{in}} = 1 + \frac{R_F}{R}
\]
Operational amplifier

Summing Circuits

- Used to add analog signals
- Voltage averaging function into summing function

Calculate closed loop gain for each input

\[ A_{CL1} = \frac{-R_f}{R_1} \quad A_{CL2} = \frac{-R_f}{R_2} \quad A_{CL3} = \frac{-R_f}{R_3} \]

\[ V_o = V_{in} \cdot A_{CLn} \quad V_o = -V_1 \cdot \frac{R_f}{R_1} - V_2 \cdot \frac{R_f}{R_2} - V_3 \cdot \frac{R_f}{R_3} \]

If all resistors are equal in value:

\[ V_o = -(V_1 + V_2 + V_3) \]
Operational amplifier

Difference Circuit

- Used to subtract analog signals
- Output signal is proportional to difference between two inputs

\[
V_{out} = \frac{V_2 (R_3 + R_1)R_4}{(R_4 + R_2)R_1} - \frac{V_1 R_3}{R_1}
\]

If all resistors are equal: 

\[
V_{out} = V_2 - V_1
\]
Integrating Circuit

Operational amplifier

- Replace feedback resistor of inverting op-amp with capacitor
- A constant input signal generates a certain rate of change in output voltage
- Smoothes signals over time

\[
\frac{dv_{\text{out}}}{dt} = - \frac{V_{\text{in}}}{RC}
\]

or

\[
V_{\text{out}} = \int_{0}^{t} \frac{V_{\text{in}}}{RC} \, dt + c
\]

Where,

\[c = \text{Output voltage at start time (t=0)}\]
Differentiating Circuit

- Input resistor of inverting op-amp is replaced with a capacitor
- Signal processing method which accentuates noise over time
- Output signal is scaled derivative of input signal

\[ V_{out} = -RC \frac{dv_{in}}{dt} \]
At $V_{ac} > V_{dc}$,

- Current will pass through the diode.
- Capacitor will be charged up by the applied voltage from the transformer.

At $V_{ac} > V_{dc}$,

- the diode will refuse to conduct.
- none of the charge in the capacitor will be removed again via the diode.
- it will be available to the output load and the capacitor can supply current to the amplifiers, etc,
- in practice, always be a modest voltage drop across the diode when it conducts, so $V_{dc}$ will never be as large as the peak positive value of $V_{ac}$. 
Basics of Power Supplies

A regulated power supply provides electrical energy which is precisely controlled.

Two types

- **Constant-Voltage**, A Constant-Voltage (CV) supply provides a DC voltage that can be set to any desired value over a specified range. An ideal constant-voltage supply has a zero output impedance, as illustrated in Figure a.

- **Constant-Current**, a constant-current (CC) supply gives a regulated current independent of the voltage over the load (up to the maximum allowable voltage), as shown in Figure b.

Figure: Output characteristic of a constant-voltage (a) and constant-current (b) supply.

A more versatile power supply—the *Constant-Voltage/Constant-Current* supply which can be used to provide either a constant voltage or a constant current.
constant-voltage/ constant-current supply

- **CV mode**
  - Assume that one connects a resistive load to the power supply. The supply has been set at a voltage $V=V_s$ and current $I=I_s$.
  - Current through the resistor is then given by Ohm's law: $I=V/R$.
  - As long as the current is below the maximum value $I_s$, the voltage over the resistor will be constant and equal to $V_s$.

- **CC mode**
  - If one decreases the resistance such that the current exceeds the maximum allowable value $I_s$, the current will be limited to $I_s$ and the power supply operates in the.
  - The resistance $R_c=V_s/I_s$ is called the critical resistance and determines whether one operates in the CV ($R_L>R_c$) or CC ($R_L<R_c$) mode.
Preparing the soldering iron

- **Place the soldering iron in its stand and plug in.**
  - The iron will take a few minutes to reach its operating temperature of about 400°C.
- **Dampen the sponge in the stand.**
  - The best way to do this is to lift it out the stand and hold it under a cold tap for a moment,
  - then squeeze to remove excess water.
  - It should be damp, not dripping wet.
- **Wait a few minutes for the soldering iron to warm up.**
  - You can check if it is ready by trying to melt a little solder on the tip.
- **Wipe the tip of the iron on the damp sponge.**
  - This will clean the tip.
- **Melt a little solder on the tip of the iron.**
  - This is called 'tinning' and it will help the heat to flow from the iron's tip to the joint. It only needs to be done when you plug in the iron, and occasionally while soldering if you need to wipe the tip clean on the sponge.

You are now ready to start soldering!

**PRACTICE MAKES PERFECT !!!**
What is solder?
- an alloy (mixture) of tin and lead,
- typically Sn 60%-Pb 40%
- Melting temperature -about 200°C.

What is flux?
- tiny cores in solder, like the wires inside a mains flex
- corrosive, like an acid
- cleans the metal surfaces as the solder melts
- Without flux most joints would fail because metals quickly oxidize and the solder itself will not flow properly onto a dirty, oxidised, metal surface
- The best size of solder for electronic circuit boards is 22swg (swg = standard wire gauge).

<table>
<thead>
<tr>
<th>COMPOSITION</th>
<th>MELTING RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIN %</td>
<td>LEAD %</td>
</tr>
<tr>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>30</td>
<td>70</td>
</tr>
<tr>
<td>40</td>
<td>60</td>
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<td>50</td>
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<td>60</td>
<td>40</td>
</tr>
<tr>
<td>63</td>
<td>37</td>
</tr>
<tr>
<td>62</td>
<td>36</td>
</tr>
</tbody>
</table>
| 45 | 53 | - | 2 | 170-215  
Grade Sn Pb 53 Zn |
| 40 | 58 | - | 2 | 175-220  
Grade Sn Pb 58 Zn |
Making soldered joints

- Hold the soldering iron like a pen, near the base of the handle.

  Touch the soldering iron onto the joint to be made.

- Feed a little solder onto the joint.
  - It should flow smoothly onto the lead and track to form a volcano shape.
  - Make sure you apply the solder to the joint, not the iron.

- Remove the solder, then the iron, while keeping the joint still.
- Allow the joint a few seconds to cool before you move the circuit board.
- Inspect the joint closely.
Using a heat sink
• Some components, such as transistors, can be damaged by heat
• When soldering, a crocodile clip can be used as a heat sink

• A dry joint is a poorly soldered one.
• A good joint is smooth and shiny.
• If the joint has moved during soldering it will be dull and crinkly.
• If you have taken too long it will have solder spikes.
<table>
<thead>
<tr>
<th>Components</th>
<th>Pictures</th>
<th>Soldering advice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>![Resistors Image]</td>
<td>No special precautions are required. Connect either way round.</td>
</tr>
<tr>
<td>Diodes</td>
<td>![Diodes Diagram]</td>
<td>Diodes must be connected the correct way round: a = anode, k = cathode. Use a heat sink with germanium diodes.</td>
</tr>
<tr>
<td>IC holders (DIL sockets)</td>
<td>![IC Holders Image]</td>
<td>Ensure the notch is at the correct end. Do not insert the IC at this stage to prevent it being damaged by heat.</td>
</tr>
<tr>
<td>Presets (small variable resistors)</td>
<td>![Presets Image]</td>
<td>No special precautions are required. On stripboard take care to ensure you insert them the correct way round.</td>
</tr>
<tr>
<td>Capacitors, non-polarised (less than 1μF)</td>
<td>![Capacitors Image]</td>
<td>No special precautions are required. Connect either way round. Take care to identify their value.</td>
</tr>
<tr>
<td>Capacitors, electrolytic (1μF and greater)</td>
<td>![Capacitors Image]</td>
<td>Electrolytic capacitors must be connected the correct way round, they are marked with + or - near one lead.</td>
</tr>
</tbody>
</table>
Desoldering

1. With a desoldering pump (solder sucker)
   - Set the pump by pushing the spring-loaded plunger down until it locks.
   - Apply both the pump nozzle and the tip of your soldering iron to the joint.
   - Wait a second or two for the solder to melt.
   - Then press the button on the pump to release the plunger and suck the molten solder into the tool.
   - Repeat if necessary to remove as much solder as possible.
   - The pump will need emptying occasionally by unscrewing the nozzle.

2. With solder remover wick (copper braid)
   - Apply both the end of the wick and the tip of your soldering iron to the joint.
   - As the solder melts most of it will flow onto the wick, away from the joint.
   - Remove the wick first, then the soldering iron.
   - Cut off and discard the end of the wick coated with solder.
   - After removing most of the solder from the joint(s) you may be able to remove the wire or component lead straight away (allow a few seconds for it to cool).
   - If the joint will not come apart easily apply your soldering iron to melt the remaining traces of solder at the same time as pulling the joint apart, taking care to avoid burning yourself.
Safety Precautions

Never touch the element or tip of the soldering iron.
- They are very hot (about 400°C) and will give you a nasty burn.

Take great care to avoid touching the mains flex with the tip of the iron.
- The iron should have a heatproof flex for extra protection. Ordinary plastic flex melts immediately if touched by a hot iron and there is a risk of burns and electric shock.

Always return the soldering iron to its stand when not in use
- Never put it down on your workbench, even for a moment!

Allow joints a minute or so to cool down before you touch them.

Work in a well-ventilated area.
- The smoke formed as you melt solder is mostly from the flux and quite irritating.
- Avoid breathing it by keeping your head to the side of, not above, your work.

Wash your hands after using solder.
- Solder contains lead.

Treatment for minor burns
- Most burns from soldering are likely to be minor and treatment is simple:
  - Immediately cool the affected area under gently running cold water.
  - Keep the burn in the cold water for at least 5 minutes (15 minutes is recommended).
  - If ice is readily available this can be helpful too, but do not delay the initial cooling with cold water.

Do not apply any creams or ointments.
- The burn will heal better without them. A dry dressing, such as a clean handkerchief, may be applied if you wish to protect the area from dirt.

Seek medical attention if the burn covers an area bigger than your hand.
Thanks for your attention and patience