**Units**

The basic electrical units are coulombs for charge, volts for voltage, amperes for current and ohms for resistance and impedance.

**Voltage**

The potential difference *V* between two points is the work per unit charge required to move the charge between the two points

**Current**

Electric current *i*(*t*) through a surface is defined as the rate of charge transport through a surface

which is a function of time since denotes instantaneous charge. A constant current is written as .

**Power**

The power dissipated in a circuit element:

*v*

*i*

*v*

*i*

Negative Power: Source of Power

Positive Power: Sink of Power

Power Dissipated in a resistor:

**Ohm’s Law**

*v*

*i*

*R*

*v*

*i*

*R*

**Resistor Combinations**

Resistors in Series (share the same current):

Resistors in Parallel (share the same voltage):

Two Resistors in Parallel:

**Kirchhoff’s Voltage Law:**

**Kirchhoff’s Current Law:**

**Superposition Theorem**

The total response of a linear network is the sum of the responses to each independent source acting alone. Replace voltage sources with short circuits, replace current sources with open circuits.

**Source Transformations:**

*VS*

*a*

*b*

*RS*

=

*RS*

*a*

*b*

*a*

*b*

*RS*

=

*RS*

*a*

*b*

**Source Equivalents:** For an arbitrary circuit

Sources and Resistors

*b*

*a*

The Thevenin Equivalent Circuit is:

*VTH*

*VTH* = *VOC*

*ISC*

*a*

*b*

*RTH*

The Norton Equivalent Circuit is:

*IN*

*VOC*

*IN* = *ISC*

*a*

*b*

*RN*

A load resistor connected between terminals *a-b*, for maximum power transfer .

**Node Voltage Analysis:** Apply KCL at each node.

**Mesh Current Analysis:** Apply KVL around each loop.

**Maximum Power Transfer Theorem**

Maximum power transfer to the load occurs when .

Maximum Power:

Efficiency:

*VTh*

*RTh*

*RL*

Thevenin Equivalent Circuit

**Capacitors and Inductors:**

|  |  |
| --- | --- |
| *C*  *iC* (*t*)  *vC* (*t*) | *L*  *iL* (*t*)  *vL* (*t*) |
|  |  |
|  |  |
|  |  |
| Cannot change instantaneously | Cannot change instantaneously |
| DC Steady State: Open Circuit | DC Steady State: Short Circuit |
| Capacitors in Parallel: | Inductors in Parallel: |
| Capacitors in Series: | Inductors in Series: |

**RC and RL Transient Circuits:**

*C*

*R*

*V*

*i*(*t*)

*vR*(*t*)

*vC*(*t*)

*t =* 0

For :

*R*

*V*

*t =* 0

*i*(*t*)

*vR*(*t*)

*vL*(*t*)

*L*

For :

where and denote initial conditions and the parameters and are termed the respective time constants.

General solution of RC and RL circuits.

where is the time when the switch is operated.

|  |  |
| --- | --- |
| **RLC Transient Circuits** | |
| Series RLC Circuit |  |
| Parallel RLC Circuit |  |
| Resonant Frequency |  |
| Overdamped |  |
| Critically Damped |  |
| Underdamped |  |

**AC Circuits:**

For a sinusoidal voltage or current of frequency (Hz) and period (seconds), , where the angular frequency in radians/s. The general equation for a sinusoid voltage or current is:

The RMS value of a sinusoid is

Phasor Transforms of Sinusoids

For a circuit element, the impedance is defined as the ratio of phasor voltage to phasor current.

For a resistor,

For a capacitor,

For and inductor,

where is the capacitive reactance and is the inductive reactance.

**AC Machines:**

The synchronous speed for ac motors is given by

, where

the line voltage frequency (Hz)

the number of poles

The slip for an induction motor is

, where

the rotational speed (rpm)

**NEC Safety Factor:**

**Number Systems and Codes**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Binary  Base 2 | Decimal  Base-10 | Hexa-decimal  Base 16 | Octal  Base 8 | BCD  Code | Gray  Code |
| 0000 | 0 | 0 | 0 | 0 | 0000 |
| 0001 | 1 | 1 | 1 | 1 | 0001 |
| 0010 | 2 | 2 | 2 | 2 | 0011 |
| 0011 | 3 | 3 | 3 | 3 | 0010 |
| 0100 | 4 | 4 | 4 | 4 | 0110 |
| 0101 | 5 | 5 | 5 | 5 | 0111 |
| 0110 | 6 | 6 | 6 | 6 | 0101 |
| 0111 | 7 | 7 | 7 | 7 | 0100 |
| 1000 | 8 | 8 | 10 | 8 | 1100 |
| 1001 | 9 | 9 | 11 | 9 | 1101 |
| 1010 | 10 | A | 12 | -- | 1111 |
| 1011 | 11 | B | 13 | -- | 1110 |
| 1100 | 12 | C | 14 | -- | 1010 |
| 1101 | 13 | D | 15 | -- | 1011 |
| 1110 | 14 | E | 16 | -- | 1001 |
| 1111 | 15 | F | 17 | -- | 1000 |

**Logic Gates:** The three basic logic operations are the “AND (•),” “OR (+).” and “Exclusive-OR ” functions.

|  |  |  |  |
| --- | --- | --- | --- |
| Function  Inputs | AND  A  B  C | OR  A  B  C | XOR  A  B  C |
|  |  |  |  |
| 0 0 | 0 | 0 | 0 |
| 0 1 | 0 | 1 | 1 |
| 1 0 | 0 | 1 | 1 |
| 1 1 | 1 | 1 | 0 |

As commonly used, *A* AND *B* is often written *AB* or *A*•*B*.

The NOT operator inverts the sense of a binary value

(0→1, 1→0)

|  |  |  |
| --- | --- | --- |
| NOT  A  C | Input | Output |
|  |  |
| 0 | 1 |
| 1 | 0 |

**De Morgan’s Theorems:**

First Theorem:

Second Theorem:

These theorems define the NAND gate and the NOR gate.

NAND Gates:

NAND

A

B

C

NAND

A

B

C

NAND Gates:

NOR

A

B

C

NOR

A

B

C

**Op Amps:**

*v*1

*v*2

*v*0

Ideal Op-Amp: where is large and is small. For linear Op-Amp Circuits, the input currents are zero and .

*R*1

*va*

*vb*

*R*2

*vo*

If , Non-Inverting Amplifier:

If , Inverting Amplifier: .

*R*1

*va*

*vb*

*RF*

*vo*

*R*2

Summing Amplifier:

*R*1

*va*

*vb*

*R2*

*vo*

*R*1

*R*2

Difference Amplifier:

**AC Power**

The complex power (volt-amperes) is defined by

where is the complex conjugate of the phasor current. The real power , (watts) is defined by

where is the angle measured from to . The power factor is . If leads , the power factor is leading. If lags , the power factor is lagging.

The reactive power , (vars) is

**Power Triangle:**

VA

W

VARS

**Balanced Three-Phase Systems**

The Line-to-Line voltage is related to the Line-to-Neutral voltage by the following:

For a Balanced Three-Phase Load, the magnitude of the phase currents are

where is the total load in volt-amps, and the neutral current is

**Maximum Power Transfer:**

In an AC circuit, maximum power transfer to the load impedance , occurs when the load impedance equals the complex conjugate of the Thevenin Equivalent Impedance.

For Maximum Power Transfer: .

**Frequency Dependent Circuits:**

Gain:

**Resonance:**

The resonant frequency for parallel and series RLC circuits is

Series RLC Circuit:

*C*

*R*

*L*

Impedance:

Impedance at resonant Frequency:

Quality Factor:

Bandwidth:

Parallel RLC Circuit:

*C*

*R*

*L*

Admittance:

Impedance at resonant Frequency:

Quality Factor:

Bandwidth:

**Ideal Transformer:**

*N*1 : *N*2

*VP*

*VS*

*IP*

*IS*

*ZS*

*ZP*

Turns Ratio:

The impedance seen at the input is