redpitaya

DC CIRCUIT ANALYSIS:
(only applies to linear circuits)

- Ohm's Law: $V = IR$
- Power: $P = IV = I^2R = \frac{V^2}{R}$
- Kirchhoff's Laws: KVL (Voltage law): $\sum V_n = 0$, KCL (Current Law): $\sum I_i = 0$
- Superposition: Total current/voltage is the sum of currents/voltages from each source
  - V_{Total}=$V_1 + V_2 + V_3$ ...
  - I_{Total}=$I_1 + I_2 + I_3$ ...
- Max Power Transfer: Maximum power transfer when R_{LOAD}=R_{SOURCE}
- Thevenin's Theorem: Any linear circuit with two terminals can be replaced by a single voltage source and a series resistor
- Norton's Theorem: Any linear circuit with two terminals can be replaced by a single current source and a parallel resistor
- Norton/Thevenin equivalences
  - $V_{TH} = I_N R_N$
  - $I_N = V_{TH}/R_{TH}$
  - $R_{TH=}R_N$
- Mesh Analysis (for each loop n): $\sum V_n = 0$
- Nodal Analysis (at each node i): $\sum I_i = 0$

AC CIRCUIT ANALYSIS:

- Active Power: $P = |V||I|\cos(\theta)$
- Complex Power: $S = P + jQ$
- Phasor: $X = |X|e^{j\theta} = |X|(cos\theta + jsin\theta)$
- Series RLC:
  - $Z = \sqrt{R^2 + (x_L - x_c)^2}$
  - $f_R = \frac{1}{2\Pi\sqrt{LC}}$
- Parallel RLC:
  - $Y = \sqrt{G^2 + (B_L - B_C)^2}$
  - $f_R = \frac{1}{2\Pi\sqrt{LC}}$

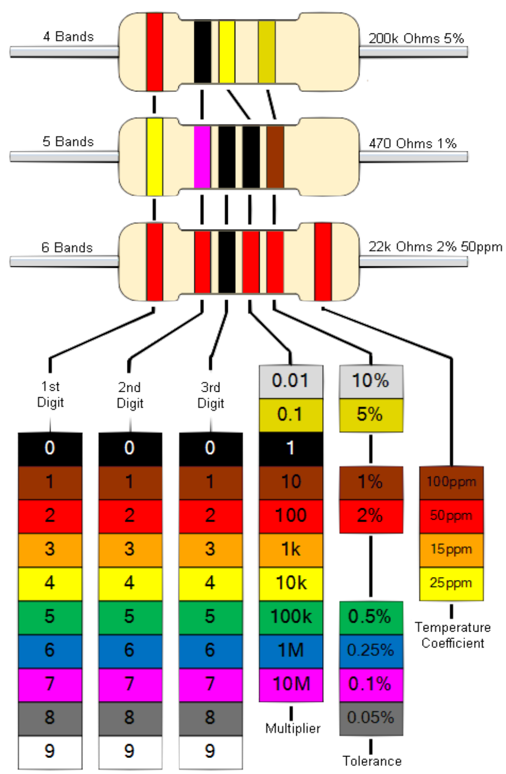
CAPACITORS:

- Capacitive Reactance: $X_C = \frac{1}{2\Pi fC}$
- Energy in a Capacitor: $E = \frac{1}{2}CV^2$
- Capacitance: $C = \varepsilon\frac{A}{d}$
- Capacitors in Series: $\frac{1}{C}$=$\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$
- Capacitors in Parallel: $C = C_1 + C_2 + C_3$

INDUCTORS:

- Inductive Reactance: $X_L = 2\Pi fL$
- Energy in an Inductor: $E = \frac{1}{2}LI^2$
- Inductance: $L = \frac{N^2\mu A}{l}$
- Inductors in Series: $L_{total} = L_1 + L_2 + L_3$
- Inductors in Parallel: $\frac{1}{L_{total}} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}$

RESISTORS COLOR CODE



DIODES

Types of Diodes:

- **Rectifier Diode:** Used for power rectification
- **Zener Diode:** Operates in the breakdown region for voltage regulation
- **Schottky Diode:** Has a low forward voltage drop and a fast switching action
- **LED:** Light emitting diode
- **Photodiode:** Converts light into current
- **Varactor Diode:** Voltage dependent capacitor
- **Tunnel Diode:** Negative differential resistance, low capacitance

Forward Bias Diode equations:

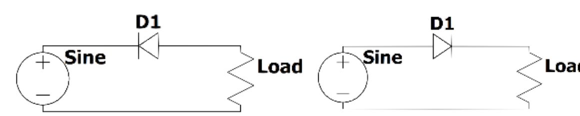
- $I(v) = I_S[\exp\left(\frac{v}{\eta V_T}\right) - 1]; v > Vz$
- $I(v) \approx I_S \exp\left(\frac{v}{\eta V_T}\right)$

Reverse Bias Diode equations:

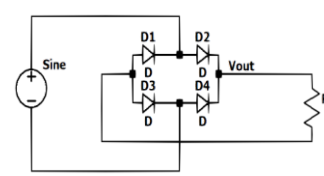
- $I \approx -I_S\left[\exp\left(\frac{v}{\eta V_T}\right) - 1\right]$
- $I(v) \approx I_S; V_Z$<v<0

Rectifier Circuits:

- **Half-Wave Rectifier:** Only one half (positive(right) or negative(left)) of the AC signal is allowed to pass through.



- **Full-Wave Rectifier:** Both positive and negative halves of the AC signal are allowed to pass through, but are flipped to produce the same polarity output.



TRANSISTORS

Types of Transistors:

- BJT (Bipolar Junction Transistor): Includes NPN and PNP types. Used for switching, amplification and regulation.
- FET (Field Effect Transistor): Includes JFET and MOSFET (n-channel and p-channel). They have high input impedance. Typically used for switching, power electronics, analog circuits, voltage regulators, ...

BJT(NPN):

Linear: $V_{BE} > 0, V_{BC} < 0$; $I_C = \beta I_B$

Saturation: $V_{BE} > 0, V_{BC} > 0$; $I_C \approx I_{CMAX}$

Cutoff: $V_{BE} < 0, V_{BC} < 0$; $Ic \approx 0$

JFET:

Linear: $V_{GS} < V_P, V_{DS} < V_{GS} - V_P$

$$I_{DS} = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

Saturation: $V_{GS} < V_P, V_{DS} \geq V_{GS} - V_P$

$$I_{DS} = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 \rightarrow V_P\text{=Pinch-off Voltage}$$

MOSFET(N-channel):

Linear: $V_{GS} > V_T, V_{DS} \leq V_{GS} - V_T$

$$I_{DS} = \mu_n C_{ox}\frac{W}{L}\left[(V_{GS} - V_T)V_{DS} - \frac{V_{DS}^2}{2}\right](1 + \lambda V_{DS})$$

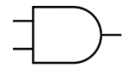
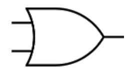
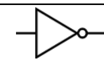
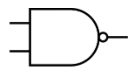
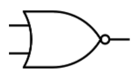
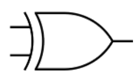
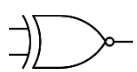
Saturation: $V_{GS} > V_T, V_{DS} > V_{GS} - V_T$

$$I_{DS} = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS} - V_T)^2(1 + \lambda V_{DS})$$

DECIBELS

- Power Gain: $\boldsymbol{Gp(dB) = 10log(\frac{Pout}{Pin})}$
- Voltage Gain: $\boldsymbol{Gv(dB) = 20log(\frac{Vout}{Vin})}$

DIGITAL LOGIC GATES

Function	Symbol	Exp	Truth Table		
			Input		Output
			B	A	Y
AND		A*B	0	0	0
			0	1	0
			1	0	0
			1	1	1
OR		A+B	0	0	0
			0	1	1
			1	0	1
			1	1	1
Inverter		!A		0	1
				1	0
NAND		!(A*B)	0	0	1
			0	1	1
			1	0	1
			1	1	0
NOR		!(A+B)	0	0	1
			0	1	0
			1	0	0
			1	1	0
XOR		A^B	0	0	0
			0	1	1
			1	0	1
			1	1	0
XNOR		!(A^B)	0	0	1
			0	1	0
			1	0	0
			1	1	1

SIGNAL ANALYSIS

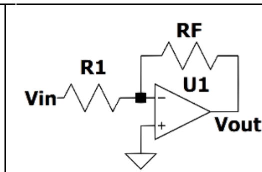
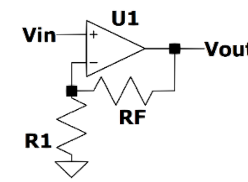
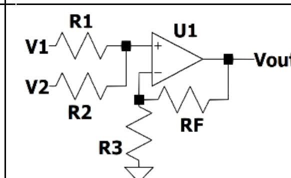
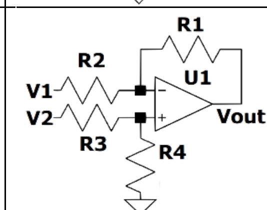
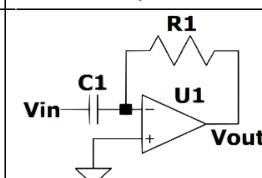
- Fourier Transform: $\boldsymbol{F(\omega) = \int_{-\infty}^{\infty} e^{-i\omega t} f(t)\, dt}$
- Fourier Series: $X_k = \frac{1}{T}\int_{\tau}^{T+\tau} x(t)\, e^{-ik\omega_0 t} dt$
- Laplace Transform $\boldsymbol{F(s) = \int_0^{\infty} f(t) e^{-st}\, dt}$
- Power Spectral Density: $S(\omega) = \lim_{\tau\to\infty}(\frac{|X(\omega)|^2}{\tau})$

Nyquist-Shannon Sampling Theorem:

- Nyquist Rate: fs ≥ 2B, where fs is the sampling frequency and B is the bandwidth of a continuous-time signal.

OPERATIONAL AMPLIFIERS

- Infinite input impedance, zero output impedance, infinite gain.
- No current flows into the input terminals.
- The difference between the voltages at the input terminals is zero (when in negative feedback).

Inverting Amplifier $Vout = -\left(\frac{RF}{Rin}\right)Vin$	
Non-Inverting Amplifier $Vout = (1 + \frac{Rf}{Rin})Vin$	
Summing Amplifier $Vout = -\frac{RF}{Rin}\ (V1 + V2)$	
Difference Amplifier $Vout = (\frac{RF}{Rin})(V2 - V1)$	
Differentiator $Vout = -RC(\frac{dVin}{dt})$	
Integrator $Vout = \left(\frac{1}{RC}\right)\int Vin\, dt$