ENG1009 Electronics Formula sheet

Current

Current $I = \frac{Q}{t}$

Kirchhoff's First Law $\sum_{i=1}^{n} I_i = 0$

Electric Fields

Energy of a Charge in an Electric Field $E = Vq$

Electric Field Strength $E = \frac{V}{d}$

Force on a charge in a field $F = qE$

Resistance

Current and Voltage through a Resistor $V = IR$

Power dissipated through a Resistor $P = IV, \quad P = I^2R, \quad P = \frac{V^2}{R}$

Resistors in Series $R_T = R_1 + R_2 + \cdots + R_n$

Resistors in Parallel $R_T = \left(R_1^{-1} + R_2^{-1} + \cdots + R_n^{-1}\right)^{-1}$

Impedance

Complex Form $Z = R + jX$

Absolute Value $|Z| = \sqrt{R^2 + X^2}$

Net Reactance $X = X_L - X_C$

Current and Voltage given Impedance $V = IZ$

Admittance $Y = Z^{-1}$

Capacitance

Capacitor Defining Equation $I = C \times \frac{dV}{dt}$

Capacitance of a Parallel Plate Capacitor $C = \frac{\varepsilon_0 \varepsilon_r A}{d}$

Charge stored $Q = CV$

Energy Stored $E = \frac{1}{2}CV^2$

Capacitors in Series $C_T = (C_1^{-1} + C_2^{-1} + \cdots + C_n^{-1})^{-1}$

Capacitors in Parallel $C_T = C_1 + C_2 + \cdots + C_n$

RC cutoff frequency $f_c = \frac{1}{2\pi RC}$

RC filter quality $Q = \frac{1}{\omega RC}$

Capacitor Charging quantity X $X_t = X_0 \times \left(1 - e^{-\frac{t}{RC}}\right)$

Capacitor Discharging quantity X $X_t = X_0 \times e^{-\frac{t}{RC}}$

Capacitor Reactance

$X = \frac{1}{2\pi fC}$

RC phase difference $\Delta\theta = \tan^{-1}\left(\frac{1}{\omega RC}\right)$

Inductance

Inductor Defining Equation $V = L\frac{dI}{dt}$

Inductance of a coil $L = \frac{\mu N^2 A}{l}$

Inductor Reactance $X_L = 2\pi fL$

Inductors in Parallel $L_{total} = \left(L_1^{-1} + L_2^{-1} + \cdots + L_n^{-1}\right)^{-1}$

Inductors in Series $L_{\text{total}} = L_1 + L_2 + \cdots + L_n$

RL cutoff frequency $f_c = \frac{R}{2\pi L}$

RL filter quality $Q = \frac{\omega L}{R}$

Transformers

Induced E.M.F $V = -N\frac{\Delta\Phi}{\Delta t}$

Power and current $\frac{V_{\text{secondary}}}{V_{\text{primary}}} = \frac{I_{\text{primary}}}{I_{\text{secondary}}} = \text{Power}$

Turn Ratio $n = \frac{N_{\text{primary}}}{N_{\text{secondary}}} = \frac{V_{\text{primary}}}{V_{\text{secondary}}}$

Inductive Reactance $X_L = 2\pi f \frac{\mu N^2 A}{l}$

Mutual Inductance $L_M = k\sqrt{L_1 L_2}$

Reflected Resistance $R_{\text{pri}} = \frac{R_L}{n^2}$

Efficiency $\eta = \left(\frac{P_{\text{out}}}{P_{\text{in}}}\right) 100\%$

Typical Permeability values:
(In terms of μ_r)
Vacuum: 1
Air: 1.0000004
Aluminium: 1.00004
Cobalt: 250
Nickel: 600
Ferrite: 1,400-15,000
Iron: 5,000
Mumetal: 100,000

RLC circuits

Impedance $|Z_T| = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$

Q-Factor $Q = \frac{E_{\text{Stored}}}{E_{\text{Lost per cycle}}}$

Series **Circuit Q-Factr** $Q = \frac{R}{X_L}$

Resonant Frequency $f_r = \frac{1}{2\pi\sqrt{LC}}$

Q-Factor for a parallel circuit $Q = R \times \sqrt{\frac{C}{L}}$

Average DC Output Voltage of Full-Wave Rectifier:

$$V_{\text{avg}} = \frac{2V_{\text{peak}}}{\pi} \Rightarrow V_{\text{peak}} = \frac{\pi V_{\text{avg}}}{2}$$

Energy

Power $P = \frac{E}{t}$

Work Done $W = F \times d$

The power dissipated by the Zener is the product of its voltage and current:

$$P_Z = V_Z \times I_Z.$$

Periodic Functions and Waves

Angular Frequency $\omega = 2\pi f$

RMS of a sinusoidal wave $RMS = \frac{\text{Peak Amplitude}}{\sqrt{2}}$

RMS of any wave $RMS = \sqrt{\frac{1}{T}\int_{T_1}^{T_2} [f(t)]^2 \, dt}$

General Wave-Function Equation $v(t) = A\cos(\omega t + \theta)$

Average Wave Power $P_{average} = \frac{\int_0^T p(t)dx}{T}$

BJT equations:

Base Current (for saturation):

$$I_B = \frac{I_C}{\beta_{\text{forced}}}$$

Base Resistor	$R_2 = \frac{V_{in} - V_{BE}}{I_B}$
Load Resistor	$R_1 = \frac{V_{\text{drop across } R_1}}{I_C}$

the formula for a Zener's series resistor electrosch

$$R = \frac{V_{\text{supply}} - V_Z}{I_Z}$$

Properties of an Ideal Op-Amp

An ideal operational amplifier is a theoretical device with extremely favorable characteristics for circuit analysis. Key properties include:

- Infinite Open-Loop Gain: The differential voltage amplification is unboundedly high (A → ∞) people.engr.tamu.edu . Even a micro-volt difference between the inputs drives the output to saturation.
- Infinite Input Impedance: It draws no input current (i.e. input currents = 0) people.engr.tamu.edu . This means connecting a load to the op-amp's inputs does not alter the source signals.
- Zero Output Impedance: It can source or sink any amount of current without internal voltage drop people.engr.tamu.edu . The op-amp behaves like an ideal voltage source at its output.
- Infinite Bandwidth: All frequencies are amplified equally; there is no cutoff frequency (the gain-bandwidth product is infinite) people.engr.tamu.edu .
- Infinite Slew Rate: The output can change instantaneously with no delay (no slew-induced distortion) physics-ref.blogspot.com .

Cheatsheet By Jake Stockley

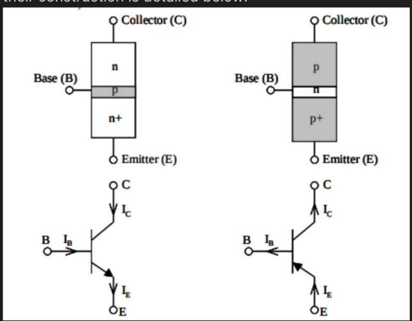
Zener diode — the quick but thorough overview

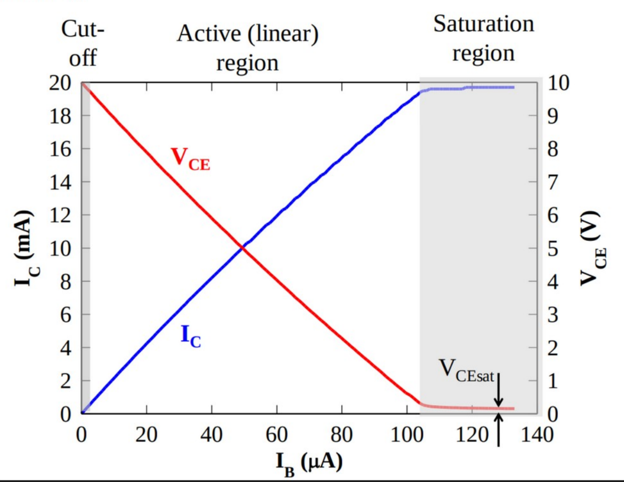
Aspect	Key points
What it is	A Zener diode is a highly-doped silicon PN-junction diode designed to operate in reverse breakdown at a precisely controlled voltage called the Zener (or breakdown) voltage V_Z.
How it works	- In *forward bias* it behaves like any diode (≈0.7 V drop for silicon). - In reverse bias, once the applied voltage reaches V_Z (e.g., 3 V, 5.1 V, 12 V …) the junction enters breakdown and conducts heavily, but the voltage across it remains almost constant at V_Z. - Two microscopic mechanisms create this breakdown: • Zener effect (quantum tunnelling) dominant for $V_Z \lesssim 5\mathrm{V}$. • Avalanche effect (carrier impact ionisation) dominant above ≈5 V.
I-V characteristic	Reverse region shows a sharp "knee" at V_Z, followed by an almost vertical, slightly sloping line (finite dynamic resistance).
Why it matters	Because V_Z is stable over a wide current range (typically 1 mA – 50 mA), a Zener diode is an inexpensive voltage reference / regulator. By feeding it through a resistor from a higher supply, it "clamps" the node to V_Z.
Basic design formula	For a supply V_S, desired Zener current I_Z and load current I_L: $R = \frac{V_S - V_Z}{I_Z + I_L}$. The resistor limits current to keep the Zener within its power rating $P_{\max} = V_Z I_Z$.
Common uses	• Reference for comparators, ADCs, op-amp circuits. • Simple shunt regulators for low-power rails. • Surge suppression / transient clamps (TVS diodes are rugged Zeners).
Practical notes	• Zener voltage has a tolerance (e.g., ±5 %). • Temperature coefficient: low-voltage Zeners have negative temp-co; high-voltage ones have positive; ≈5.6 V parts are near-zero. • Always use a series resistor or current-limited source; otherwise the diode will overheat.

The Bipolar Junction Transistor is a three-Terminal Component that is either:

- A NPN transistor
- A PNP transistor

They are both made with different arrangements of p-type and n-type Semiconductors, and their construction is detailed below:





This graph shows how the Current and Voltage across the Transistor varies given the Base-Current. You can think of it like how increasing the Base-Current is like decreasing the "Resistance" of a component, decreasing the Voltage around it while increasing the Circuit's Current.

For the regions:

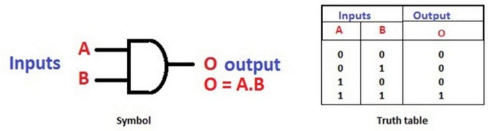
- The Cut-off region is for switching OFF
- The Active region ifs for "Amplifying" the Base-Current, dependent on the equation:

$$I_c = \beta I_b$$

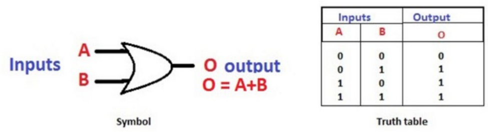
The formula for Amplification is:

$$A_v = \frac{-R_c}{r_d}$$

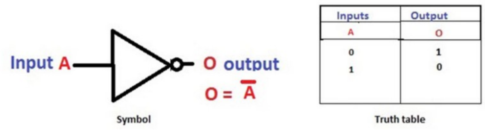
Where:
A_v is the Amplification gain
R_c is the Resistance of the collecting Resistor
r_d is the Resistance of the Bipolar Junction Transistor



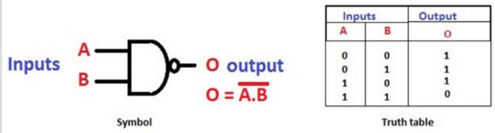
AND Gate and its Truth Table

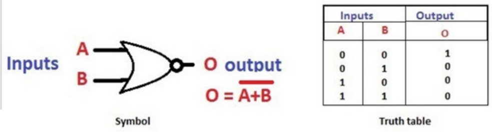


OR Gate and its Truth Table

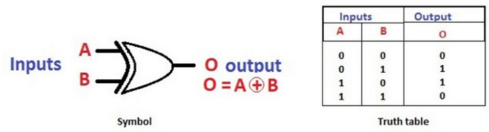


NOT Gate and Its Truth Table

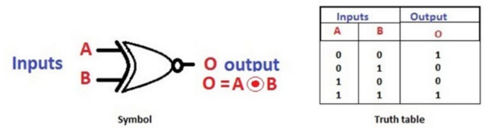




NOR Gate and Its Truth Table

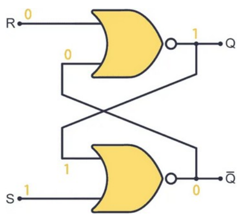


EX-OR gate and Its Truth Table



EX-NOR Gate and Its Truth Table

SR-LATCH



JK-FLIP FLOP