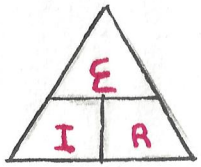
Ohm's Law



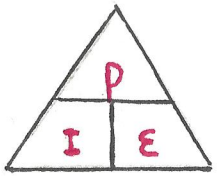
$\mathcal{E} = I \times R$

$I = \frac{\mathcal{E}}{R}$

$R = \frac{\mathcal{E}}{I}$

ex. 12v & 30A

$\frac{12v}{30A} \rightarrow$ .4 Ω



$P = I \times \mathcal{E}$

$I = \frac{P}{\mathcal{E}}$

$\mathcal{E} = \frac{P}{I}$

ex. .5A & 15v

.5A × 15v → 7.5w

* Knowing <u>any 2</u> quantities allows you to solve for the missing values.

Schematic Symbols

Resistors

- Fixed
- variable
- photo
- tapped
- thermistor

Capacitors

- Fixed
- non polarized
- electrolytic
- variable

Inductors

- air core
- iron core
- adjustable
- ferrite bead
- tapped

Switches

- SPST
- SPDT
- Normally open
- Normally closed

Transformers

- air core
- iron core
- adjustable

Diodes

- Led
- Diode
- Zener
- variable
- thyristor (SCR)
- triac
- bridge rectifier

Transistors

- PNP
- NPN

*Never Points Near

Misc.

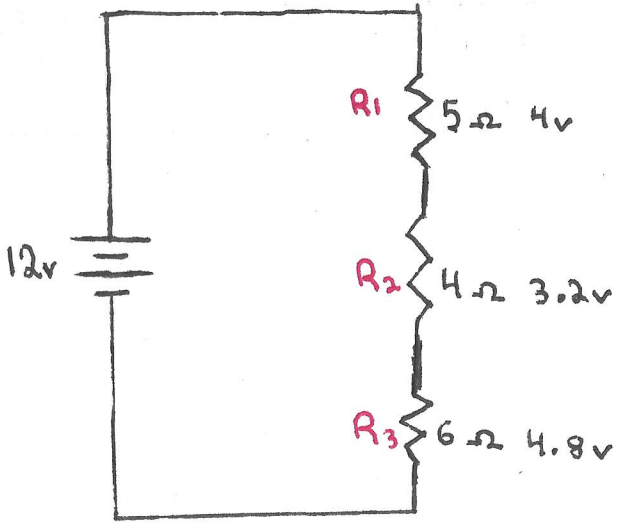
- antenna
- fuse or
- quartz crystal
- incandescent
- AC plug

Grounds

- Chassis
- Earth

Kirchoff's Law

* Current is constant in a series loop.



$\mathcal{E}_T = 12v$
$I_T = .8A$
$R_T = 15\Omega$
$P_T = 9.6w$

$\mathcal{E}_{R_1} = 4v$
$\mathcal{E}_{R_2} = 3.2v$
$\mathcal{E}_{R_3} = 4.8v$

$R \times I_T = \mathcal{E}_R$

$P_{R_1} = 3.2w$
$P_{R_2} = 2.56w$
$P_{R_3} = 3.84w$

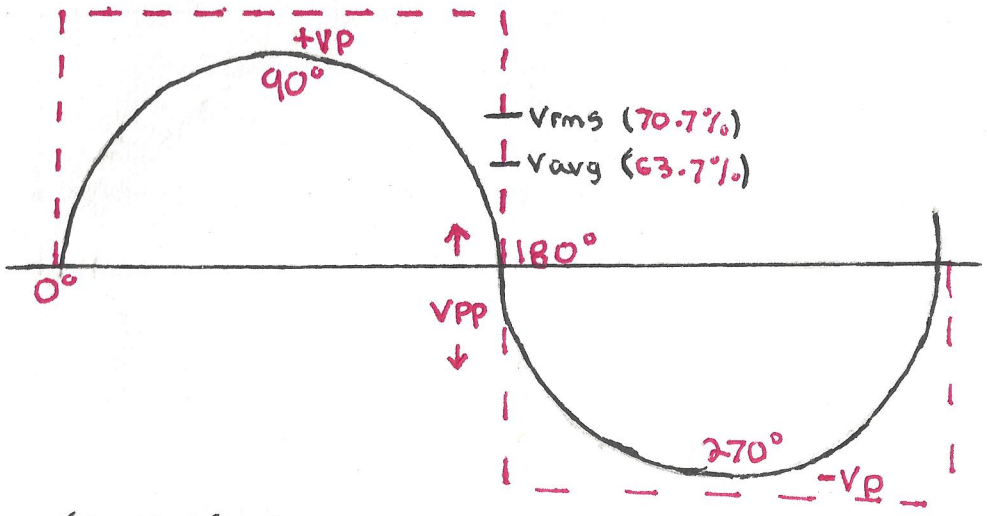
$P = I \times \mathcal{E}$

$I_{R_1} = .8A$
$I_{R_2} = .8A$
$I_{R_3} = .8A$

$I_T = \mathcal{E}_T \div R_T$

* The sum of all voltage drop across a series circuit add up to the applied voltage.

AC Voltages



$F = \frac{1}{time}$ $T = \frac{1}{frequency}$

Vint = Sin(location) × Vp
ex. Sin(90)·10 = 90
Sin(22)·10 = 3.74

Conversions

1. Vrms = (Vp)(.707)
2. Vpp = (Vp)(2)
3. VA = (Vp)(.637)
4. Vp = (Vrms)(1.414)
5. Vp = (Vpp)(.5)
6. Vp = (VA)(1.57)

1. V effective = V peak × .707
2. V peak to peak = V peak × 2
3. V average = V peak × .637
4. V peak = V effective × 1.414
5. V peak = V peak to peak × .5
6. V peak = V average × 1.57

Inductors

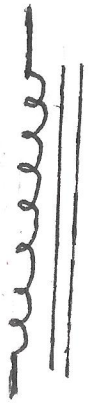
* prevents sudden changes in current.
  - Blocks high frequencies
  - Delays current flow

* measured in Henries (L)

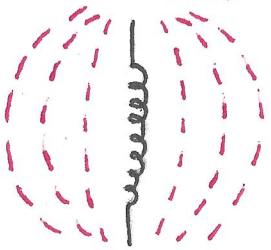
* Inductance is effected by...
  1. Number of turns
  11. Size of coils
  111. Distance between coils
  IV. Core material
  V. Thickness of wire

Air Core

Iron Core



* When current is no longer applied, the magnetic field collapses, producing a counter-electromotive force.



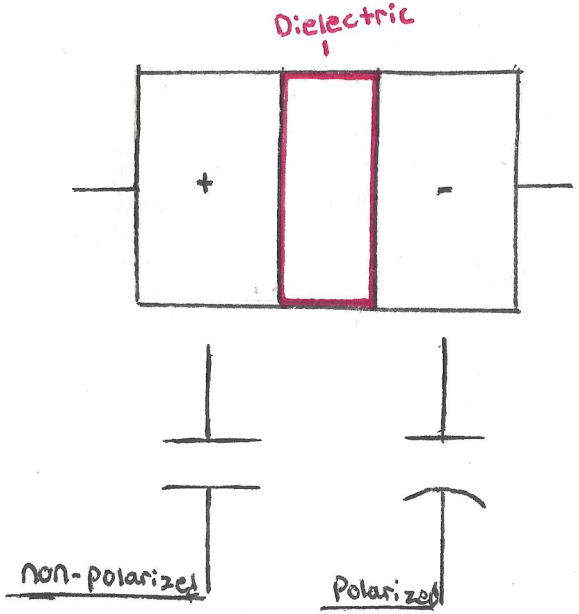
*magnetic field

Capacitors

* Capacitors **Store** a charge
  - Blocks **low frequencies**

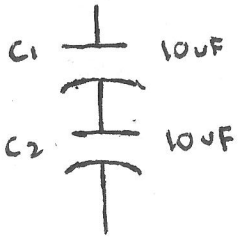
* Consists of 2 plates and a core
  - Core is called the dielectric
  - Cores can consist of...
    1. Air
    2. Mylar
    3. Paper
    4. Ceramic
    5. mica
    6. electrolytic oils

* Capacitance (F) is effected by...
  1. Plate **area**
  2. Plate **spacing**
  3. **Dielectric** material



Series Capacitors

Reciprocal Formula

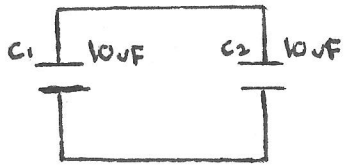


- $C = \frac{A}{D}$

- $\frac{1}{\frac{1}{C1}+\frac{1}{C2}} = \frac{1}{\frac{1}{10}+\frac{1}{10}} =$ **5uF**

Parallel Capacitors

Add values



- $C_T = C_1 + C_2$

- 10uF + 10uF = **20uF**

Transistors

* Transistors are used for...
  1. Amplification
     - uses a second power supply to amplify a signal
  2. Converting
     - changes highs and lows
       ex. binary
  3. Switching/tuning

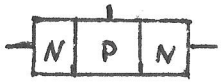
* Transistors consist of...
  1. Base
  2. Collector
  3. Emitter

* Gain = $\frac{\text{Output}}{\text{input}}$

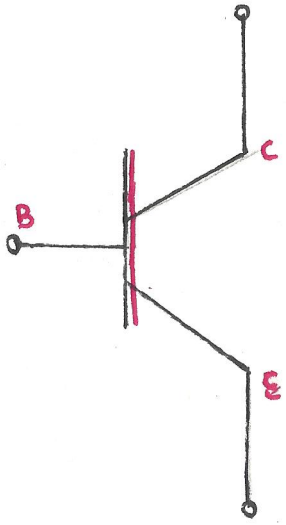
ex. input current: 160 uA

output current: 36 mA

Gain = 225 mA

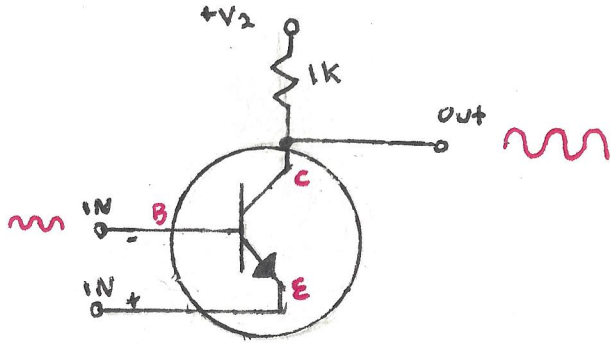


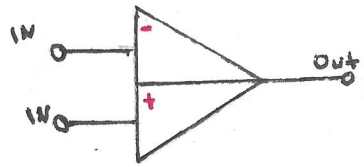
"Never Points Near"

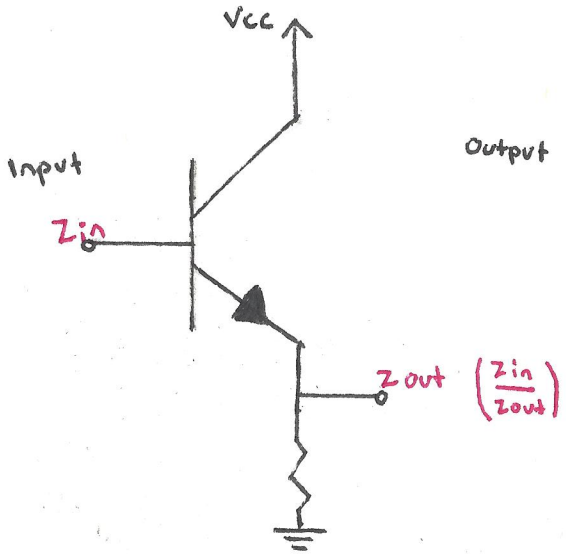


Transistor Op-Amp Circuit

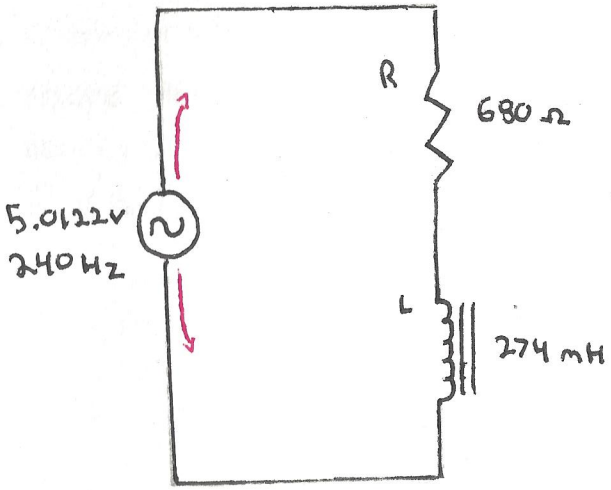
- Operational Amplifier
- Input : $P_{DC} = V_{DC} \times I_{DC}$
- Output: $P_{AC} = \frac{V_{AC}^2}{R}$
- Efficiency: $\eta = \frac{P_{AC}}{P_{DC}}$







Circuit Calculations



$X_L = 413\ \Omega$
$Z = 795.59\ \Omega$
$I_R = 6.29\ mA$
$I_L = 6.29\ mA$
$I_T = 6.29\ mA$
$\theta^\circ = 31.27^\circ$
$V_R = 4.27v$
$V_L = 2.59v$
$P_T = 26.85\ mW$
$P_A = 31.52\ mW$

$X_L = 2\pi FL$
$X_L = 2(3.14)(240)(274)$
$X_L = \boxed{413\ \Omega}$

(impedance)
$Z = R^2 + X_L^2$
$Z = (680)^2 + (413)^2$
$Z = \boxed{795.59\ \Omega}$

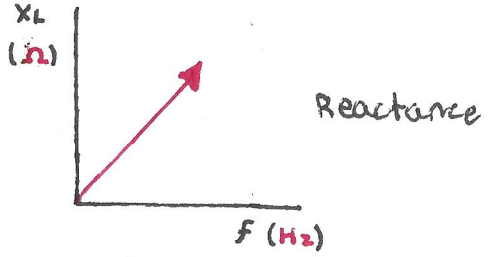
SOH CAH TOA
$\theta^\circ = \frac{X}{R} = \frac{opp}{adj}$
$413 / 680$
$\theta^\circ = 31.27^\circ$

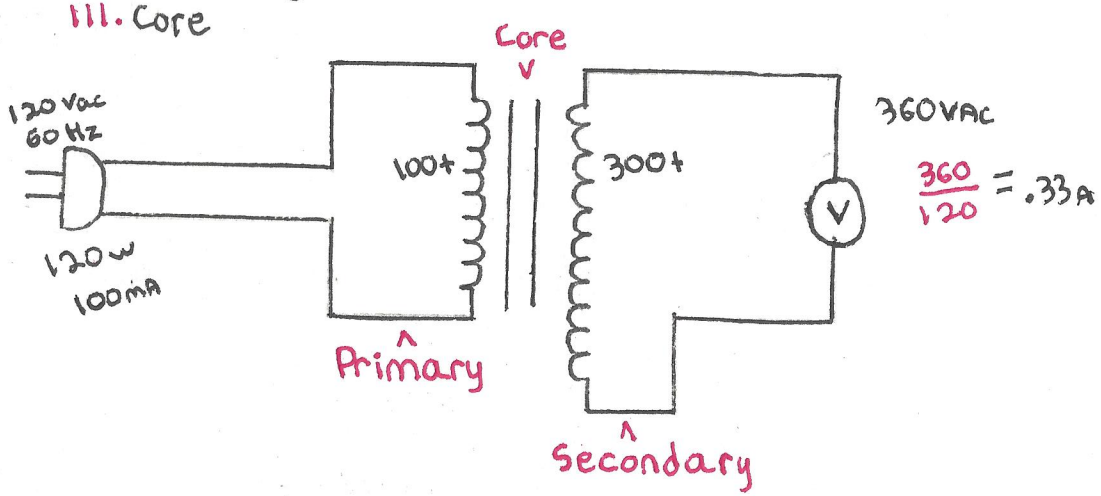
$P_T = I_T \times E_R$
$P_T = 6.29 \times 4.27$
$P_T = \boxed{26.85\ mW}$
$P_A = I_T \times E_T$
$P_A = 6.29 \times 5.0122$
$P_A = \boxed{31.52\ mW}$

Transformers

- Transformers step up and down voltage.
- measured in reactance (X_L).
- more turns will increase voltage, but decrease current.
  - double voltage = half current.
- A transformer consists of...
  1. Primary Coil
  2. Secondary Coil
  3. Core

$$X_L = 2\pi f L$$



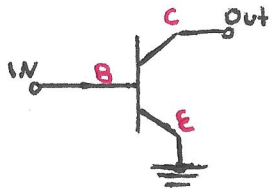


$\frac{360}{120} = .33A$

NPN Amplifier Bias

1. Common Emitter

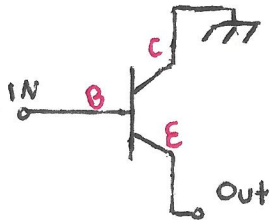
Voltage gain



II. Common Collector

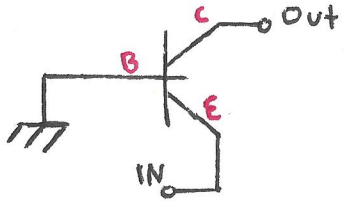
Current gain

"Emitter Follower"



III. Common Base

uncommon configuration



Amplifier Classes

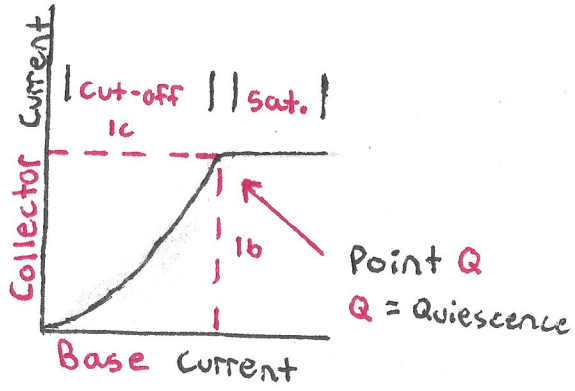
- 3 classes of amplifiers

Class A
Always on
Least efficient
Highest Clarity

Class B
Half on Half off
Average efficiency
Average clarity

Class C
on when needed
most efficient
Least clarity

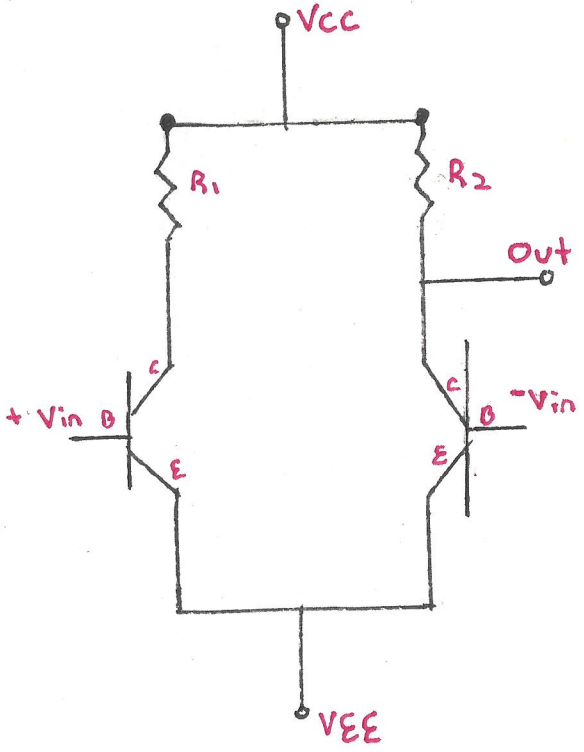
- Amplifier factors
  1. Gain
  2. Input/output resistence
  3. Frequency response (20Hz - 20kHz)



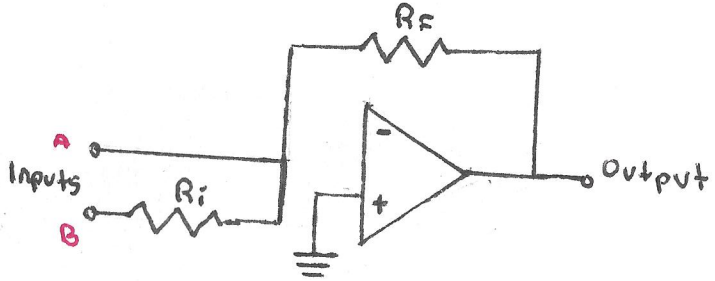
Difference Amplifier

- Amplifies difference between 2 input voltages.
  - Supresses any voltage common.
- 2 inputs : 1 output.
- Difference gain = $\frac{\text{output}}{\text{input}} = \frac{(\text{diff. of } V_{out})}{(\text{diff. of } V_B)}$

  ex. $\frac{(5v - 3v)}{(V_B(5) - V_B(3))}$ or $\frac{(5v-3v)}{(\text{Diff.}(V_{in}))}$
- If input A = input B ∴ Output = Input.
- Common mode gain = $\frac{\text{Change in } V_{out}}{\text{Change in } V_{in}}$



Op-Amp Adder



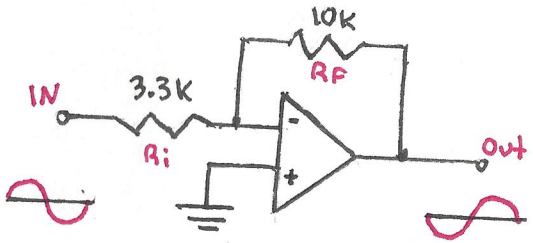
Gain : $K = -\left(\frac{R_F}{R_i}\right)$

Output : $Out = (k)(B + A)$

- negative / inverter gain
- equal inputs = double output
- equal voltage w/ opposite polarity ∴ output = 0

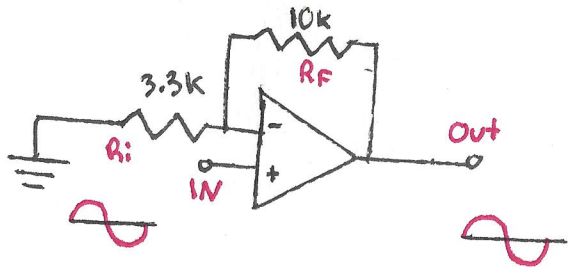
  ex. 5v & -5v = 0v out

Non-Inverting Op-Amp



Inverting Op-Amp

$$A = -\frac{R_F}{R_i} = -3$$



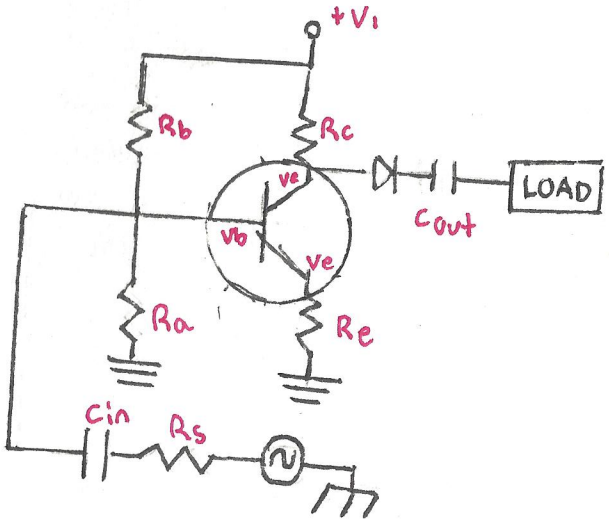
Non-Inverting Op-Amp

$$A = \left(\left(\frac{R_F}{R_i}\right) + 1\right) = 4$$

- Voltage applied to the (-) is inverted.
- Voltage applied to the (+) is not inverted.

Voltage Divider Bias Amp.

- Common Emitter (most common)

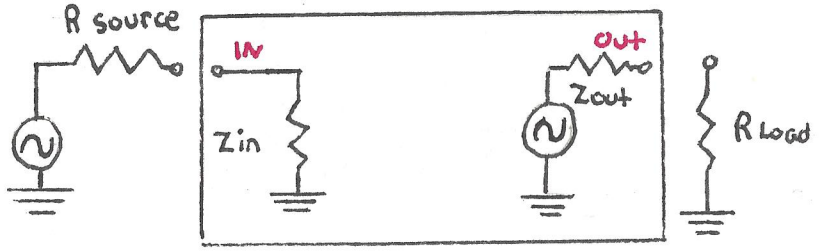


- Cout: keeps DC from load
- Rc: load resistor
- Rb: bias base current
- Ra: bias base current
- Re: emitter resistance
- β: Gain (100)
- * All fixed values.
- * Bypass caps increase gain.

- Voltage divider: $Vb = \frac{(Rb+Ra)\cdot Vc}{}$
- Ve = Vb - voltage across Vb & Ve
  or Ve = Vb - saturation
- $A = \frac{\text{collector Resistance}}{\text{Emitter Resistance}}$ (Theoretical Gain)

Input - Output Impedance

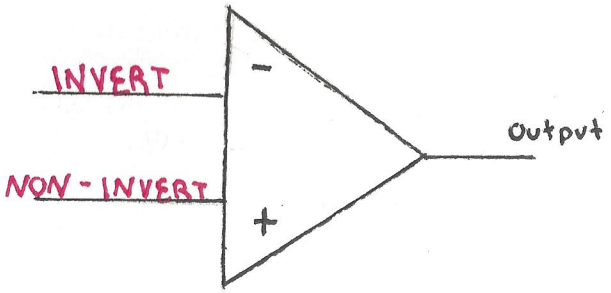
- The lower Zin, the less input appears at the input terminals.
- The lower Zin, the more current can flow from the signal generator.
  - voltage is lost.

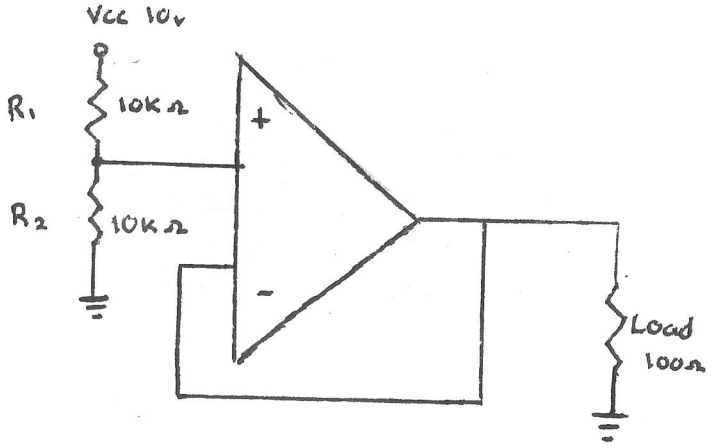


Source ^ Amp ^ Load ^

- Zout is measured from output to ground.
  - output impedance = collector load resistance
  - Zout = Rc
- Input impedance should be as <u>high</u> as possible as to minimize input signal loss.
  - Zin as ↑ HIGH ↑ as possible.
  - Zout as ↓ LOW ↓ as possible.

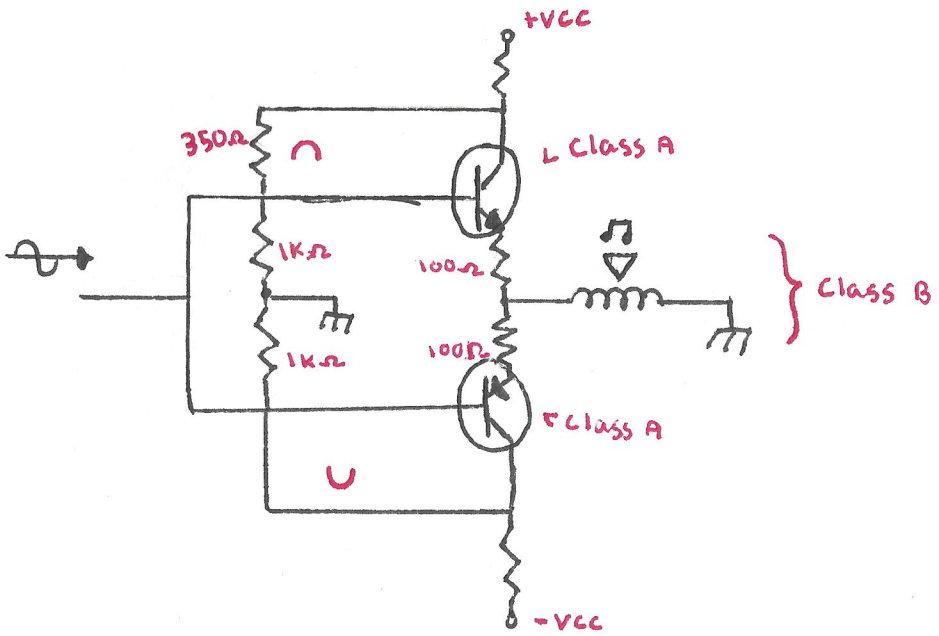
Follower Op-Amp





- If voltage is connected to the (-) input
  - Rf (feedback resist) is 0.
- Output = (+) Input
  - Follower op-amp
- Used in...
  - buffers
  - logic circuits
  - isolation amp.

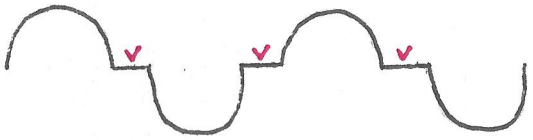
PNP & NPN (Class B)



- NPN amplifies top half of wave.
  - all positives
- PNP amplifies bottom half of wave.
  - all negatives
- Consists of two alternating Class A.

Distortion

I.

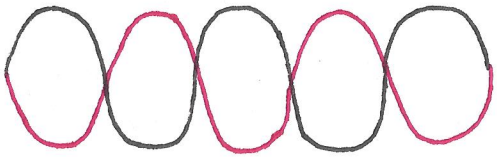


- Switching Distortion
  - (+) and (-) pause briefly.

II.

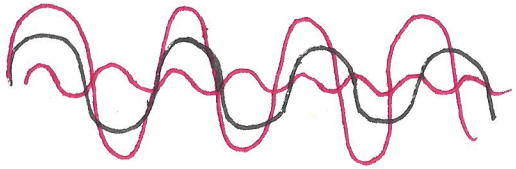
- Clipping
  - Results from overdriven amps.

III.



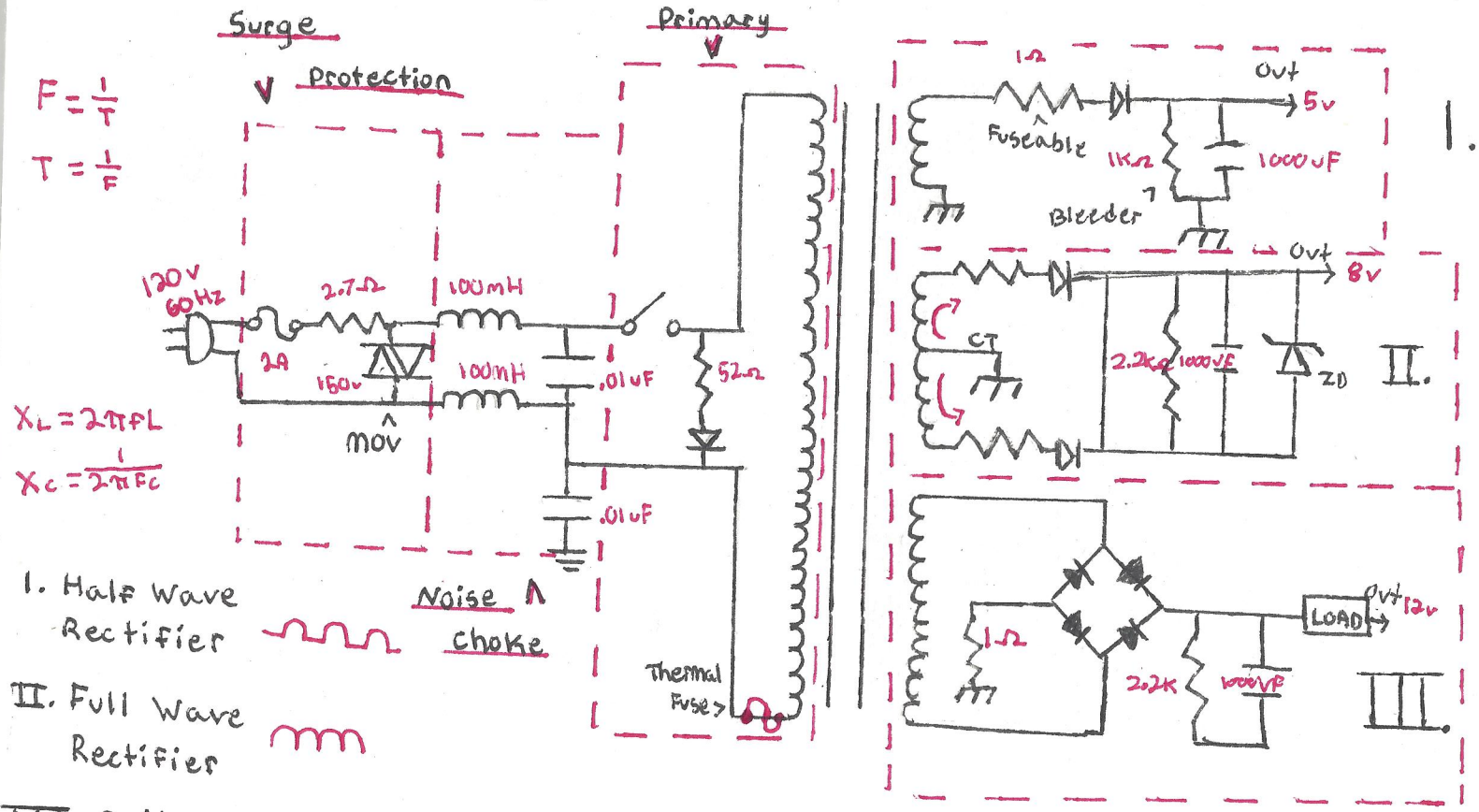
- Phase Distortion
  - 180° out of phase
  - inaudible

IV.



- Total Harmonic Distortion (THD)
  - Too many signals to amplify
  - ex. Orchestra

Regulated Power Supply



$X_L = 2\pi FL$

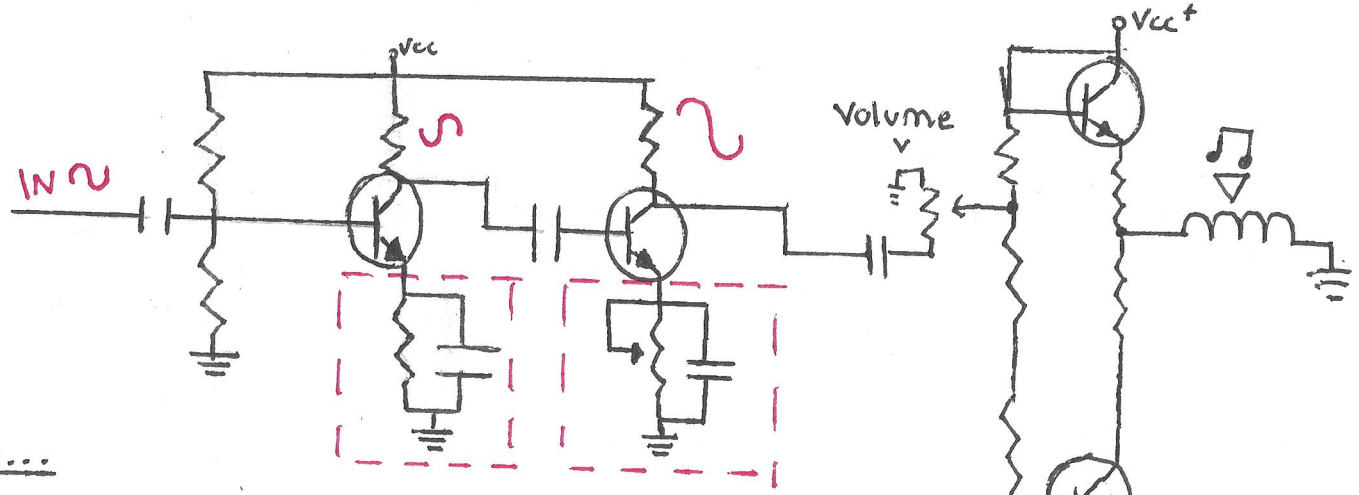
$X_C = \frac{1}{2\pi FC}$

I. Half Wave Rectifier

II. Full Wave Rectifier

III. Bridge Rectifier

Trouble - Shooting



Step...

I. Visually inspect components

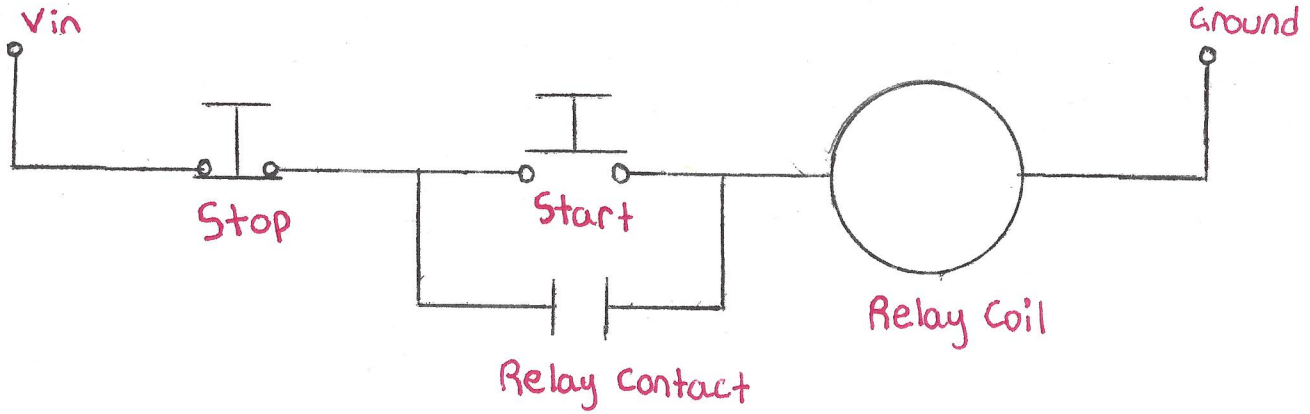
II. Check for heat

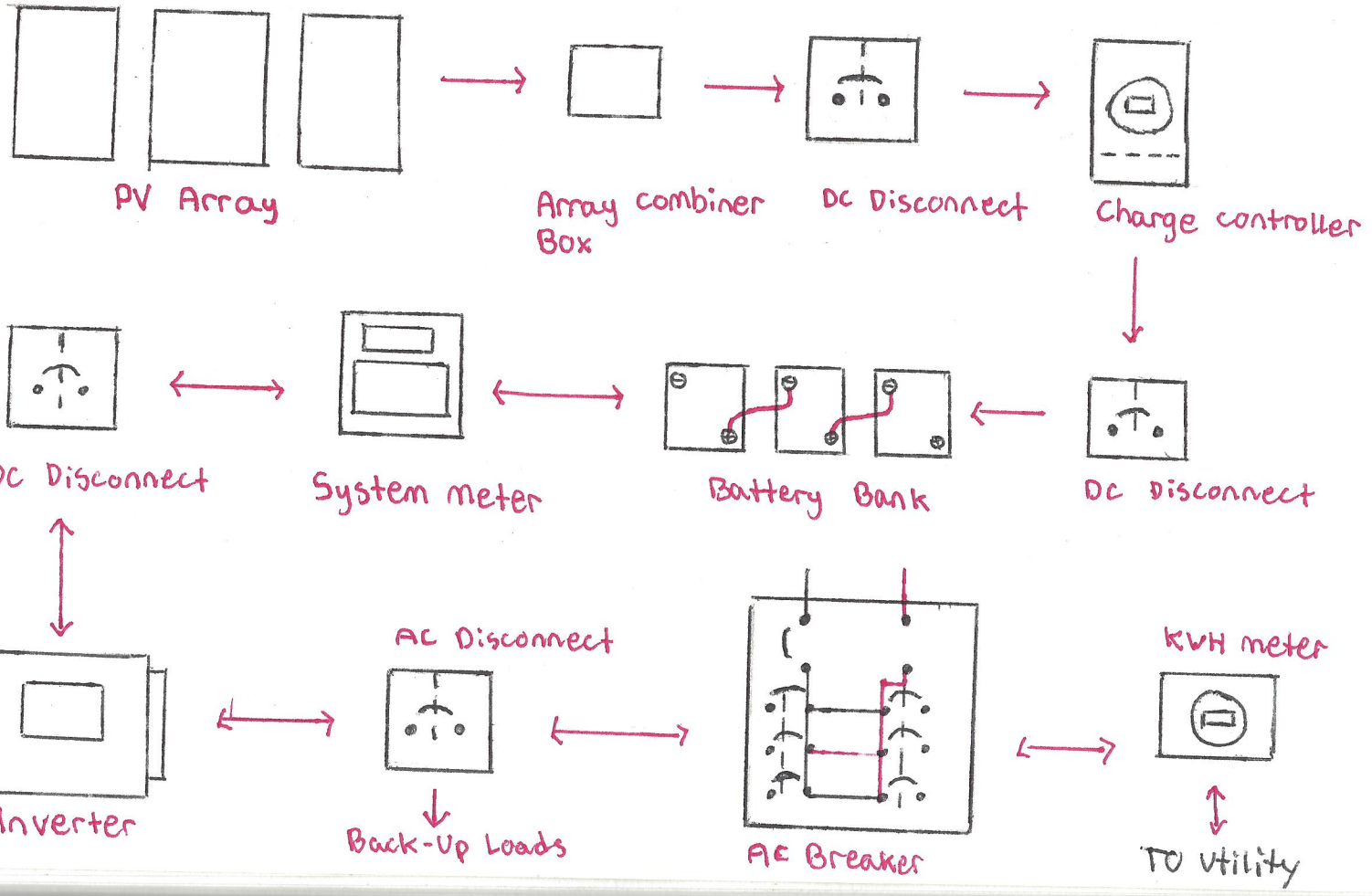
III. Test DC

IV. Test AC

- De-emphasis circuit.
  - prevents thermal runaway.
- Potentiometer for tone control.

Seal-In Circuit



- Start/Stop circuit
- Pressing the start button energizes the relay coil, closing the relay contact and maintaining current flow to the coil.
- Frequently used in...
  - Emergency Stops
  - Pump Systems
  - Industrial Motor Control

Grid Tied (with Backup)