Practical Tricks with Transformers

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Practical Tricks with Transformers

- Quick review of inductance and magnetics
- Switching inductive loads
- How many voltages can we get out of a $10 Home Depot transformer
- Current transformers

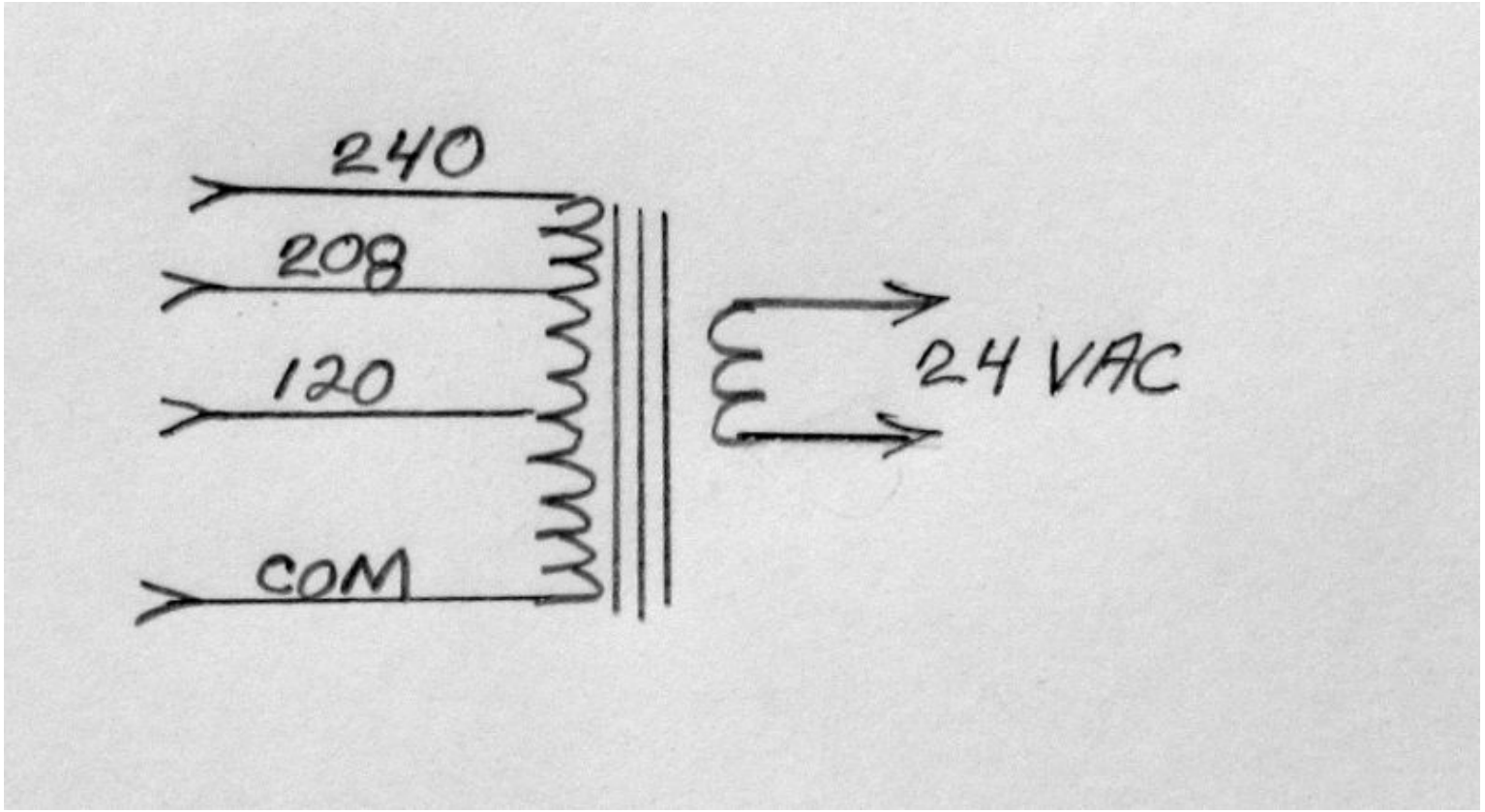
Our Example Transformer

- We will use a Packard PF42440 120/208/240 to 24 volt transformer available at Home Depot on line for $10 as an example.
- We will show how to get 32 different voltages from 12 to 264 volts from the transformer for a variety of applications.

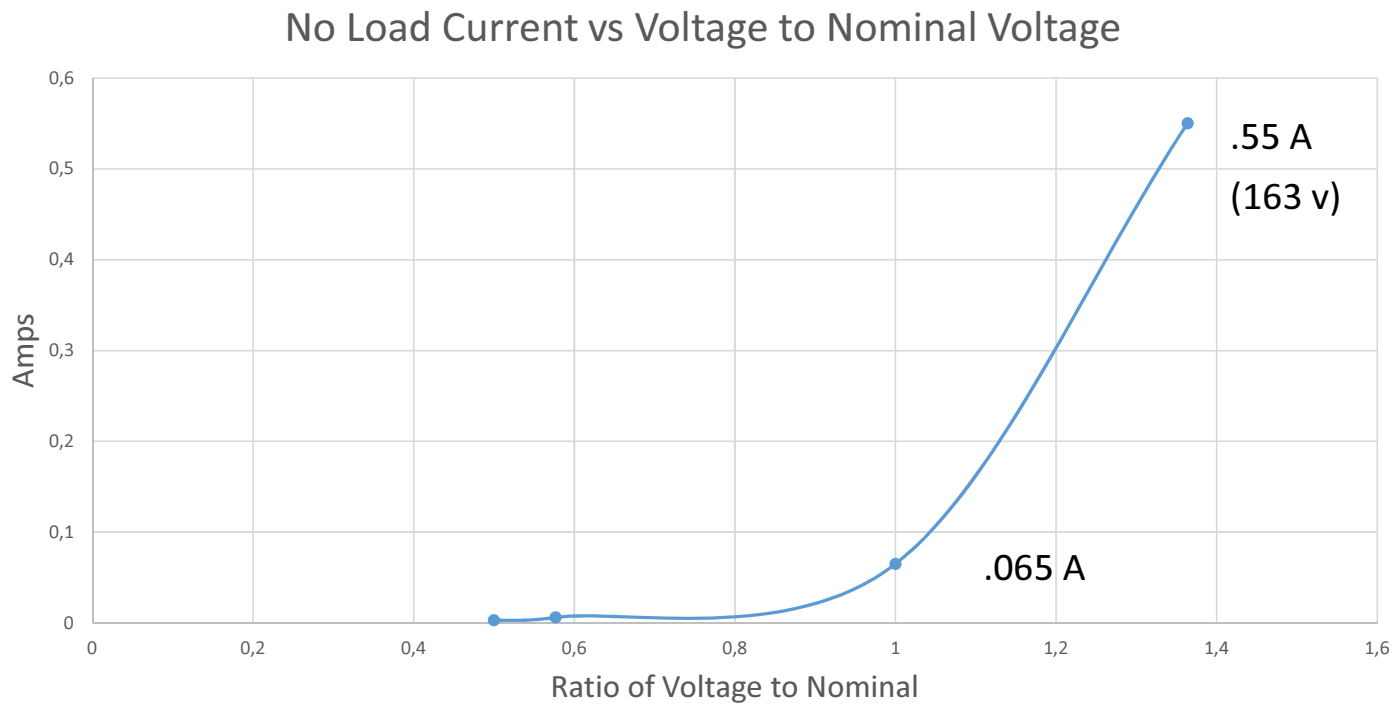
No Load Characteristics

- If we look at a transformer with an open secondary it will look like an inductor.
- Reactance will equal X= 2*Pi*Frequency*L
- Current will equal I=Volts/X

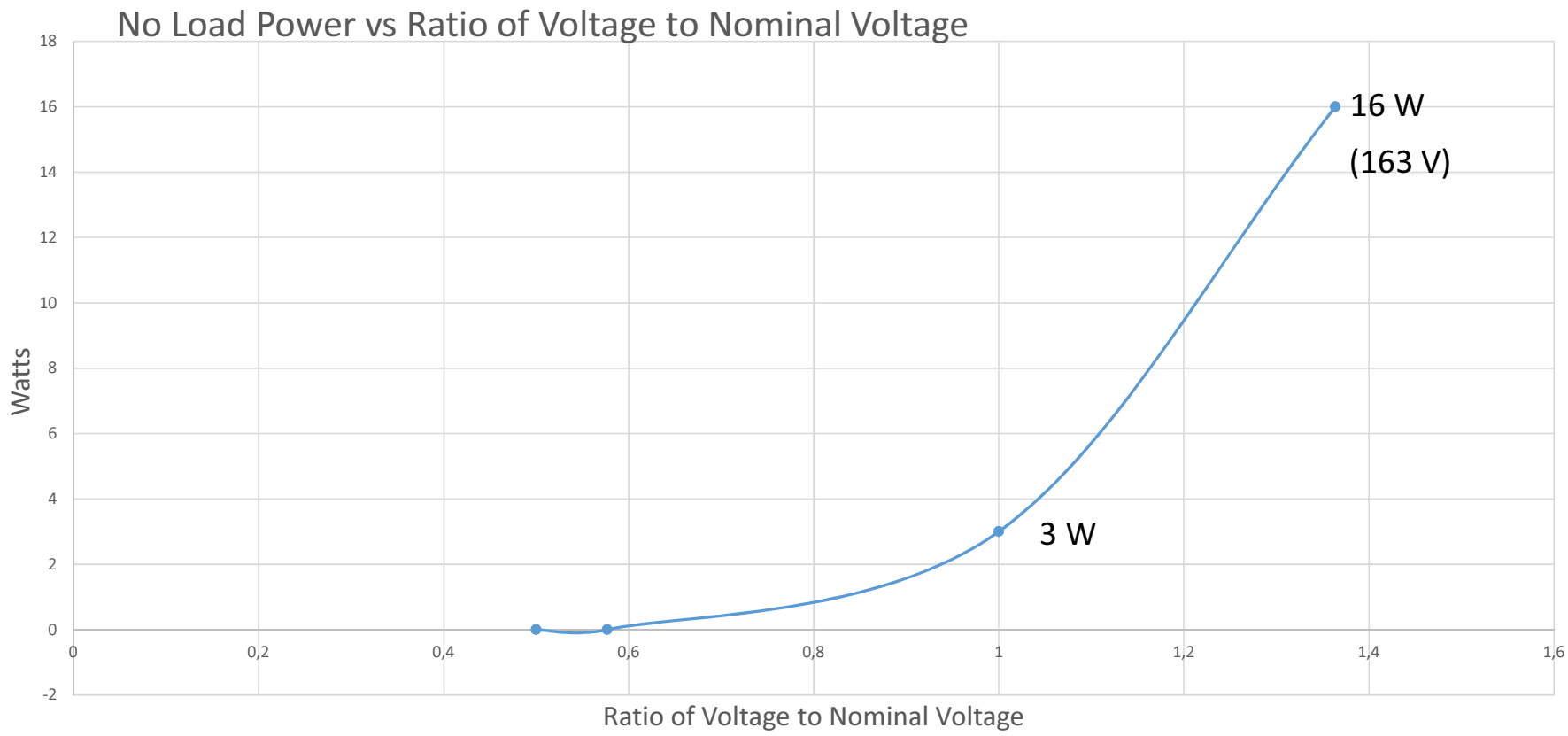
The Home Depot Transformer Connections



No Load Current vs Voltage



No Load Power vs Voltage

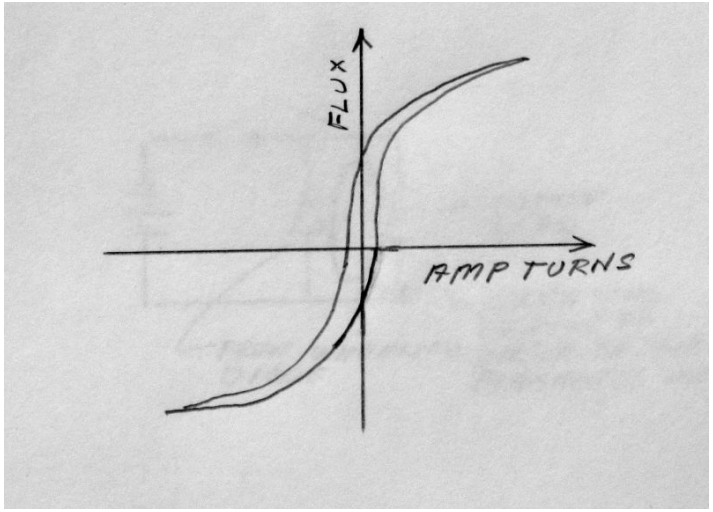


Practical Take Away

- I have an old radio rated for 110 VAC.
- My line voltage runs between 122 and 129 volts
- What can I expect from the transformer and life of the tubes?
- Would it pay to somehow reduce the voltage?

Why the Nonlinear Current and Power Curves?

- A typical curve of the magnetizing force vs magnetic flux for steel is nonlinear.



- Magnetic Circuit
  - Amps*turns = Voltage
  - Flux = Current
  - Reluctance = Resistance
  - Permeance = Conductance

Electric Circuit

More on Magnetics

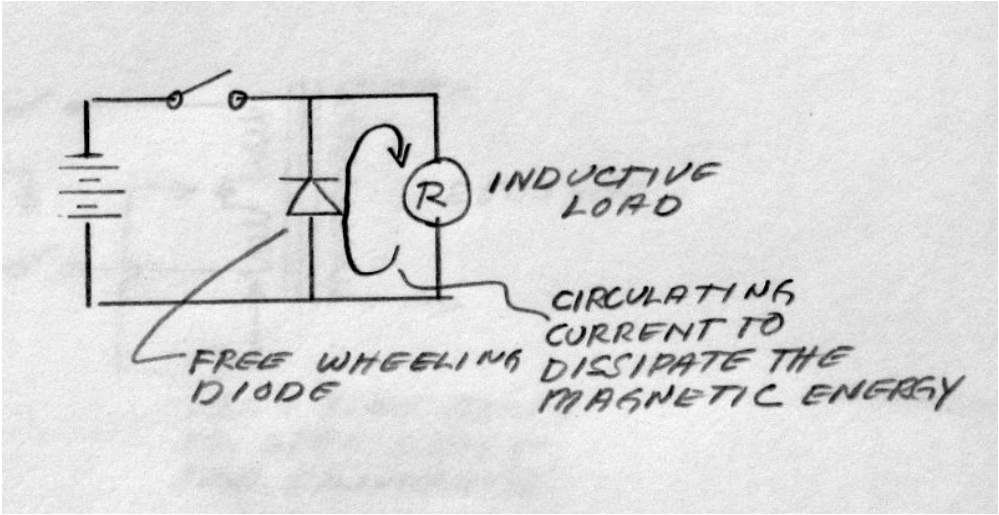
- There is always a little residue magnetism left in the steel
  - This is the area in the center of the loop
  - This energy is lost each electrical cycle
  - Called hysteresis
- A voltage will be induced in a conductor to resist a change in flux
  - Example of the magnet in the tube
  - Called Eddy currents
  - The core is made up of laminated steel that has a blue insulating oxide finish
  - The laminations break most of the current paths with changing flux
- Enough energy must be stored in the magnetic field to replace the power put in the first part of the AC cycle
  - Remember no power is lost in a perfect inductor. Power is stored and returned during the cycle
  - If the frequency is doubled, only half the steel is needed

Magnetic Energy

- Magnetic flux is a form of energy
- In soft steel the flux can only exist with current (Except for a little hysteresis)
  - When an inductor is switched on, there is no field present and can draw very high currents to establish the field
  - The current called inrush can blow fuses
- When an inductor is switched off the field collapses
- The voltage in the each turn is proportional to the rate the flux changes therefore generating very high voltages to keep the current flowing till the energy is dissipated
  - Example with a coil and 4 NE2 neon bulbs (70 volts per bulb when firing)
  - What is the voltage on the 240 secondary?

Safely Switching Inductive Loads

- Free wheeling diode



- Resistors, capacitors and surge protectors can also be used

Putting it All Together

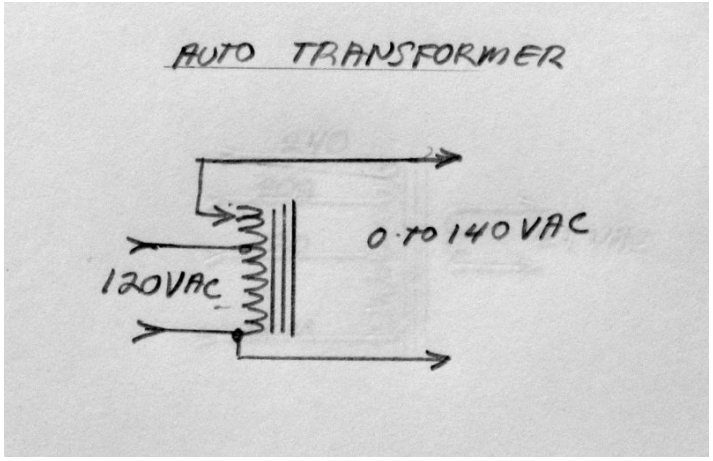
- A voltage is generated in an inductor to match the applied voltage
  - The volts per turn is the same for any coil
- The voltage is the sum of the volts on each coil and the changing flux
- Flux is generated by the current through the inductor
- Enough current will be drawn to meet the flux requirements in the first statement
  - This known as the magnetizing current
- The maximum voltage on a transformer is a function of:
  - The amount of steel
  - The number of turns
  - Limited by the steel saturating

A Practical Moment

- Ignoring loses, the higher the frequency the less steel and copper is required
  - Less steel requires shorter coils
  - Less stored energy
  - Inductive reactance = 2*Pi*Frequency*L
- Aircraft uses 400 Hz AC. Weight =60/400 or .15 the weight of a 60Hz system
- A switching power supply running at 60KHz would be .001 the weight of a 60Hz system
  - Example 1 KW, 12 volt, 83 amp power supply

The Autotransformer

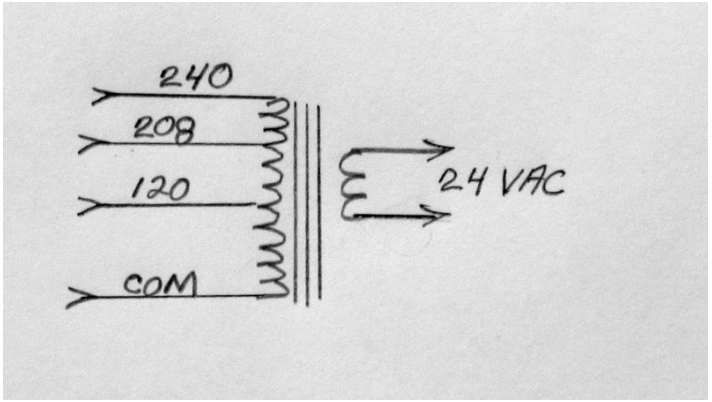
- The primary winding acts is also the secondary



- A variac is a an adjustable autotransformer
- The same can be done with fixed transformers

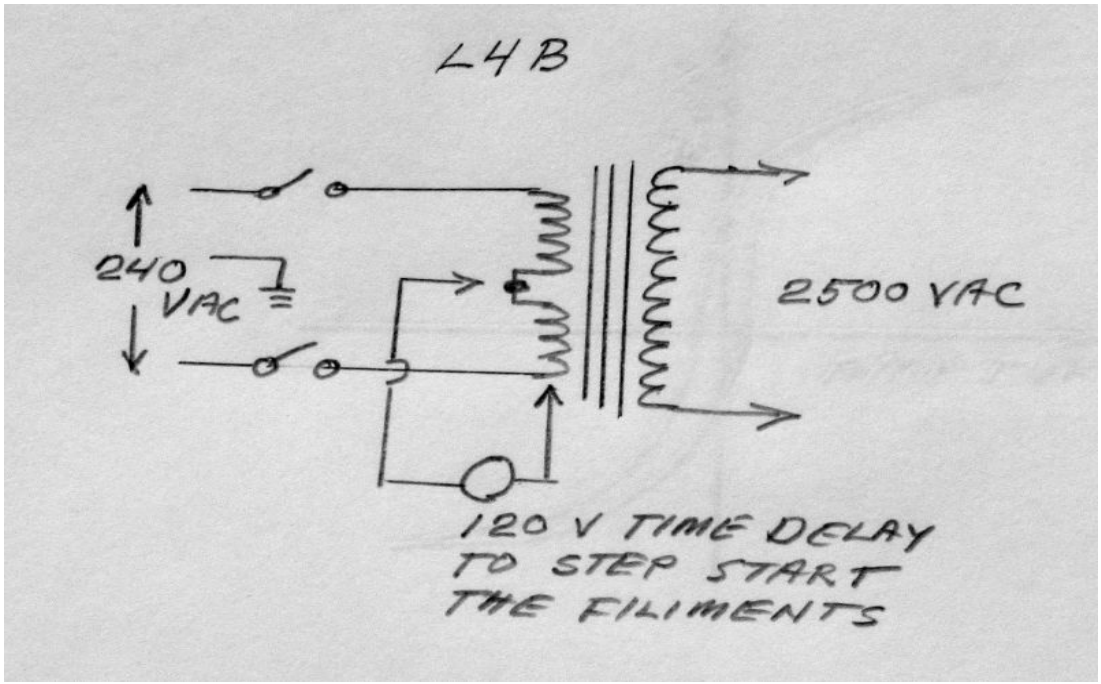
The Home Depot transformer

- With 120 volts applied to the primary you will have 208 and 240 volts on the other 2 taps
  - The leads MUST be insulated
- With 240 connected to the primary you will have 120 and 208 volts available



A Practical Moment

- I have a 240 volt feed to the L4B amplifier and needed 120 volts for a step start timer
- Solution:

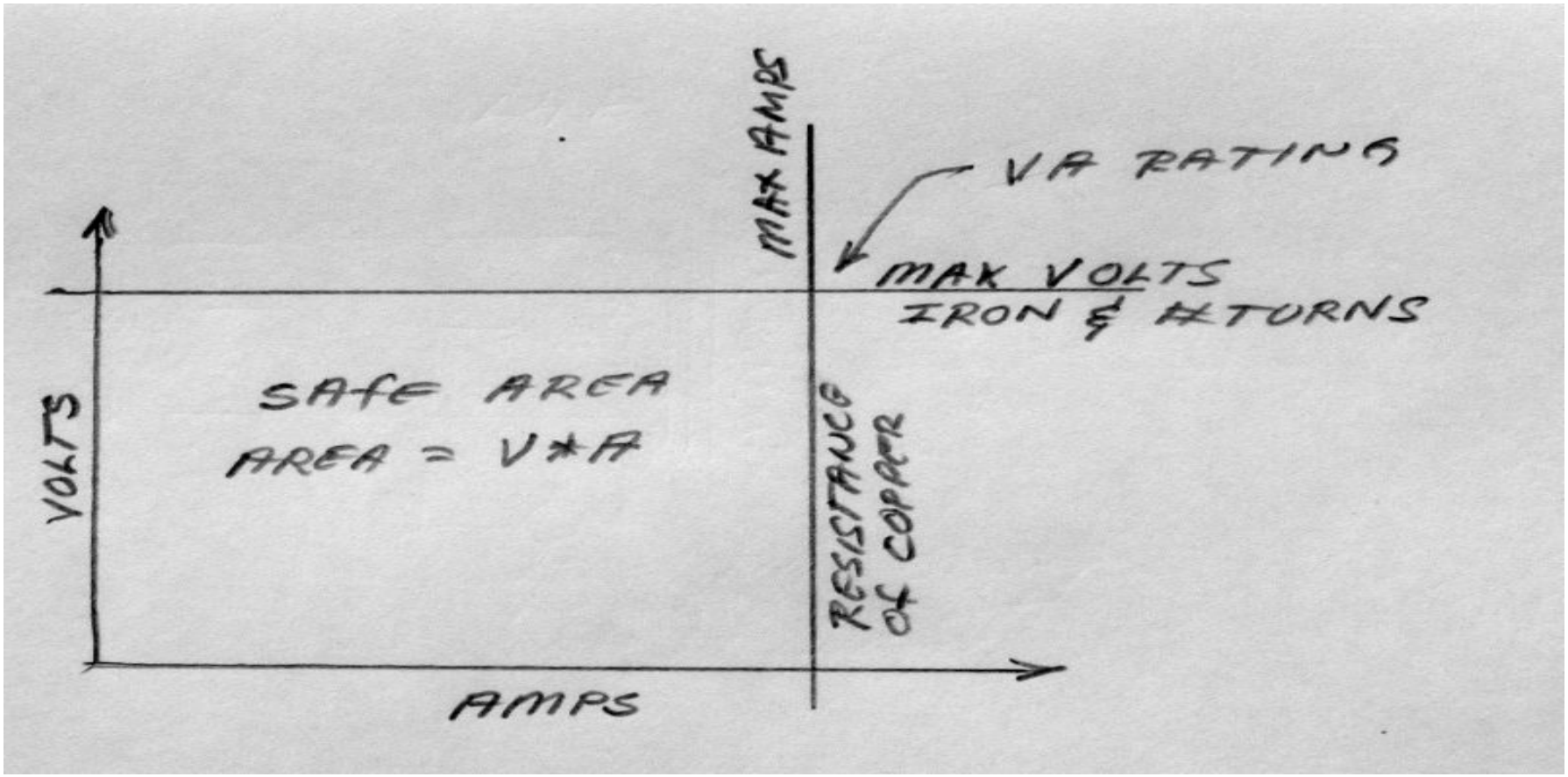


- I'll use the Home Depot transformer the same way to power the main 120 volt power relay in the new amplifier

Maximum Power and Current

- The transformer is rated for 40VA
  - VA is volts times current
  - VA is an optimistic estimate of power due to power factor
- Maximum current on a winding
  - Maximum current on the 24 volt winding is 40/24 = 1.66A
  - Max on the 120 volt winding is 40/120 = .33 A
  - Max on the 208 volt winding is 40/208 = .19 A
  - Max on the 240 volt winding is 40/240 =1.66 A

Safe Limits for a Transformer



Voltage Possibilities

- 120 volts to the 120 tap
  - 24 V on the secondary
  - Plus the 208 and 240 volts on the primary
- 120 volts to the 208 tap
  - 13.8 V (120/208*24)
  - Plus 69 and 138 volts on the primary
- 120 volts to the 240 tap
  - 12 V
  - Plus 60 and 104 volts on the primary

A Practical Moment

- I needed 24 VDC. I had a 48 Volt non regulated supply with a 120/240 volt input
- Solution: run the power supply on the 240 volt setting with 120 volts
  - The power supply is on all the time for control of an antenna
  - The supply is loaded only occasionally

- Benefits with 120 volts to the 240 setting:

120 volt connection	240 volt connection
.25 amps	.11 amps
13 watts	4 watts
60 VDC	30VDC

- Saving 9 watts or about $1 per month with continuous duty

Buck /Boost Configurations

- Each coil turn generates a voltage that can be added or subtracted to any other voltage on the transformer
  - This true for any combination of transformers. They do not have to have the same core or phase.
- 120 VAC to the 120 tap and 24 volts on the secondary there are 9 combinations!
  - 120 +/- 24volts= 96 or 144 VAC
  - 208 +/- 24 volts=184 or 232VAC
  - 240 +/-24 volts= 216 or 264 VAC
- 120 VAC to the 208 tap and 13.8 volts on the secondary:
  - 120+/-13.8, 69+/-13.8, 138+/-13.8
- 120 VAC to the 240 tap and 12 volts on the secondary:
  - 120+/-12, 60+/-12, 104+/-12

More!!!

- Connect the 120 volts to the 120 volt tap
- 208-120 gives 88 volts
  - In addition 88+/-24
- 240-208 gives 32 volts
  - In addition 32+/-24

Industrial Control Transformers

- Typically the primary is 240/480 volts
  - Dual windings that can be put in series or parallel
- Typically the secondary is 120/240 volts
  - Dual windings
- Lots of possibilities!
- Great 1:1 isolation transformers

Identifying Unknown Transformers

- Measure the winding resistances
  - The highest resistance is typically the highest voltage
  - It is generally safe to apply 120V to the highest voltages.
    - Most transformers are designed for 120, 240, or 480 volts
  - If in doubt:
    - Use a second transformer and apply 12 or 24 VAC
    - Use a 40 wat bulb is series with the power cord
- Weigh the transformer to estimate the power
  - A rule of thumb is each pound is good for 20 VA
  - A rule of the finger is if you can keep your finger on it for 15 seconds it is probably OK at about 140F
    - Use caution if there is a chance of a short to the core!

Testing Our Transformer

- Resistances
  - Red to green = 1.2 ohms (24 volts)
  - White to black = 19.9 ohms (120 volts)
  - White to red =52 ohms (208 volts)
  - White to orange = 64.5 ohms (240 volts)
- Weight
  - Weight =1.6 pounds
  - 1.6 X 20 watts per pound = 32 watts (rated 40watts)

A Practical Moment

- I needed to measure current going into my new amplifier. A current shunt on the DC side gave too low of a voltage to go into the Arduino micro computer.
  - 0 to .060 volts from the shunt
- Solution: removed the secondary winding of a old transformer and replace it with a 1 turn secondary.
  - 120 volts on the primary produced .24 volts on the secondary
  - Turns on the primary equals 120/.24 or 500 turns
- Current Through the 1 turn makes flux that creates a voltage on the old primary winding
- 15 amps AC yielded 20 volts on the old primary.
  - Voltage drop on the single turn is 20/500 or .04 volts
  - The 20 volts is rectified and filtered to monitor the drain current of the amplifier and fed into the processor

Current Transformers

- Measuring large amounts of power having a voltage drop is typically unacceptable
  - This drop is due to the inductance of the single turn winding
- Current transformers are normally run with the secondary shorted
  - By shorting the secondary the flux of the primary is cancelled by the secondary

Clip on Amp Meters

- A common form of a current transformer with a single turn primary
  - If you need more sensitivity add more turns
  - 10 turns gives a multiplier of 10
  - There are no fractional turns!
- Only one lead goes through the meter
  - If both leads go through the meter the flux is cancelled if there is no leakage.
  - If there is leakage you will read the difference ie a GFI detector

A Practical Moment

- Looking for radiation on a feed line or RFI getting into extraneous equipment?
- Make up a current transformer out of a clip on choke
  - A bunch of turns on a clip on choke is the secondary
  - A diode and capacitor is the RF detector
  - Most any meter will read the current
- Move it up and down the line to read if and where common mode currents exist

A Practical Moment

- A choke type balun is form of a current transformer
- If net current (equal but opposite) is zero the is no flux created and therefore no reactance.
- If the currents are not equal it acts like a transformer adding voltage to low lead and subtracting voltage from the other
- To check what the balun is doing it can be disabled by a single shorted turn of wire. That will cancel any flux due to the unbalance currents

Questions ?

- More than you ever wanted to know about transformers!
- Discussion