Introduction to Linear and Switched Mode Power Supplies

By

WA8KKN

Power Supplies -- Linear and Switched Mode Power Supplies

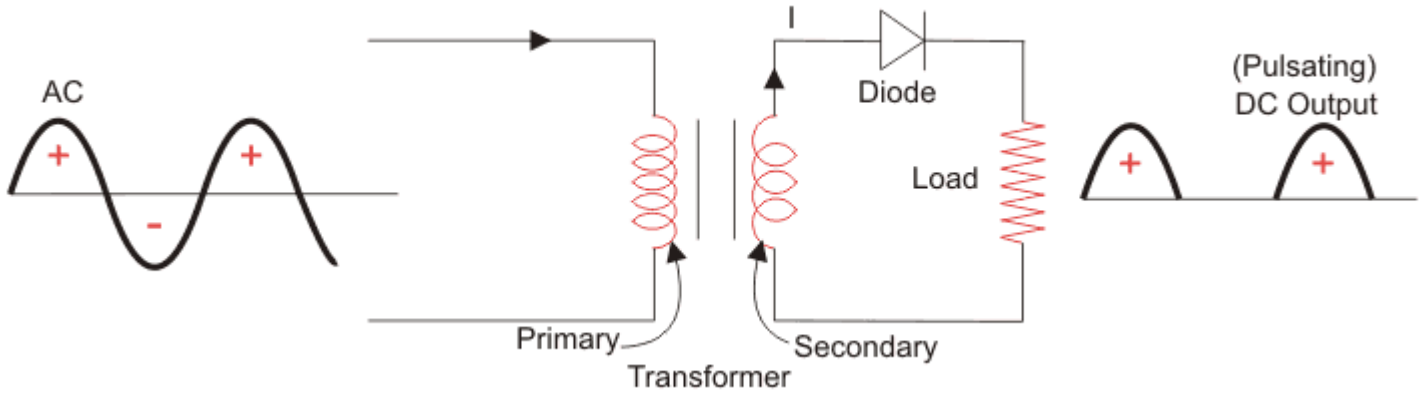
- Purpose of this talk
- Overview Basic AC to DC power supplies
- Comparison between A Linear DC Power Supply and a Switch Mode Power Supply (SMPS)
- Linear Power Supply
- Switch Mode Power Supply (SMPS)
- Questions & Answers

Purpose of this talk

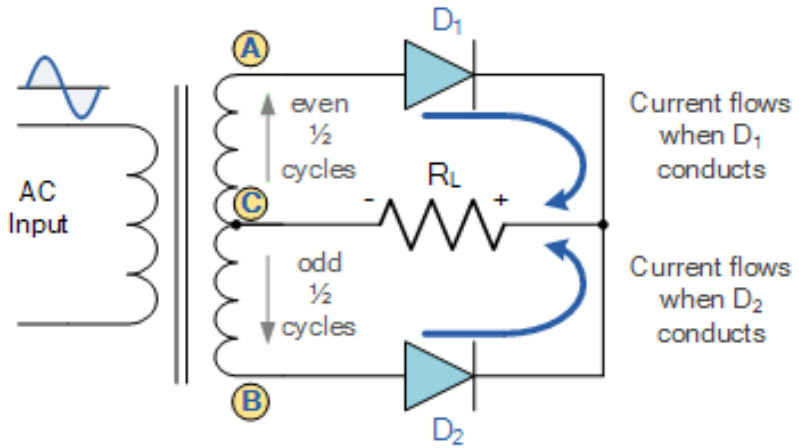
- Introduction to Linear and Switched Mode Power Supplies For The Ham
- Block diagrams of various power supplies
- Prerequisites
  - Ohms Law (I = E/R)
  - Power = (I x E, I^2 x R, or E^2/R)
- Where to go for more information
  - Search Engines (Google, DuckDuckGo, etc…)
  - Repeater Builders Web Site
  - Manufacturer's site
- BTW: The power supply is the most overlooked component in a system

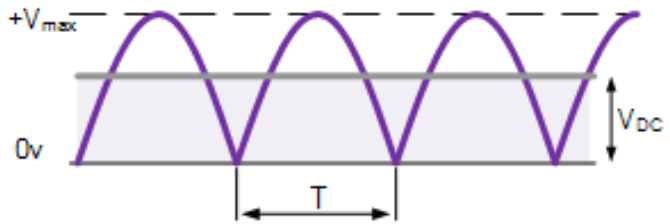
An Overview of Power Supply Basics

Half Wave Rectifier Circuit



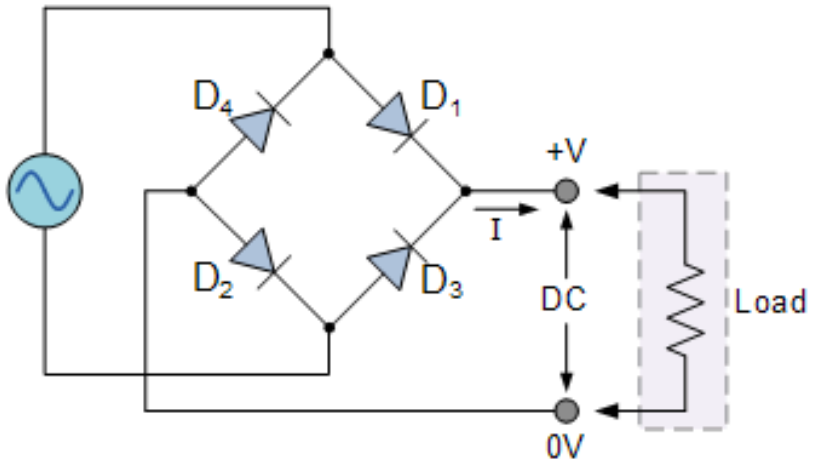
Full Wave Rectifier Circuit



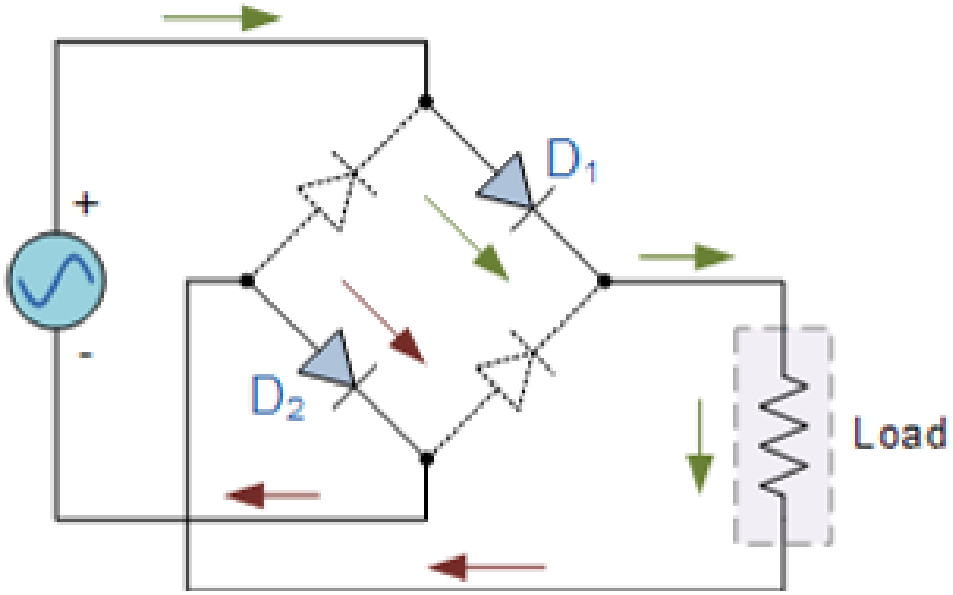


Resultant Output Waveform

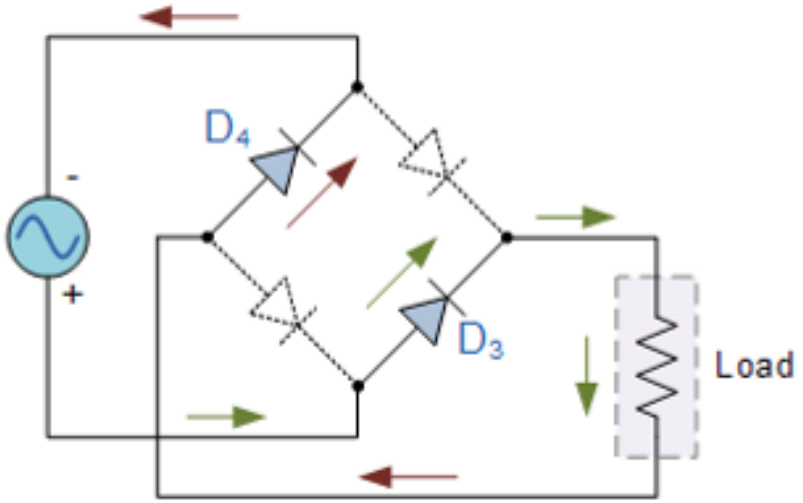
The Diode Bridge Rectifier

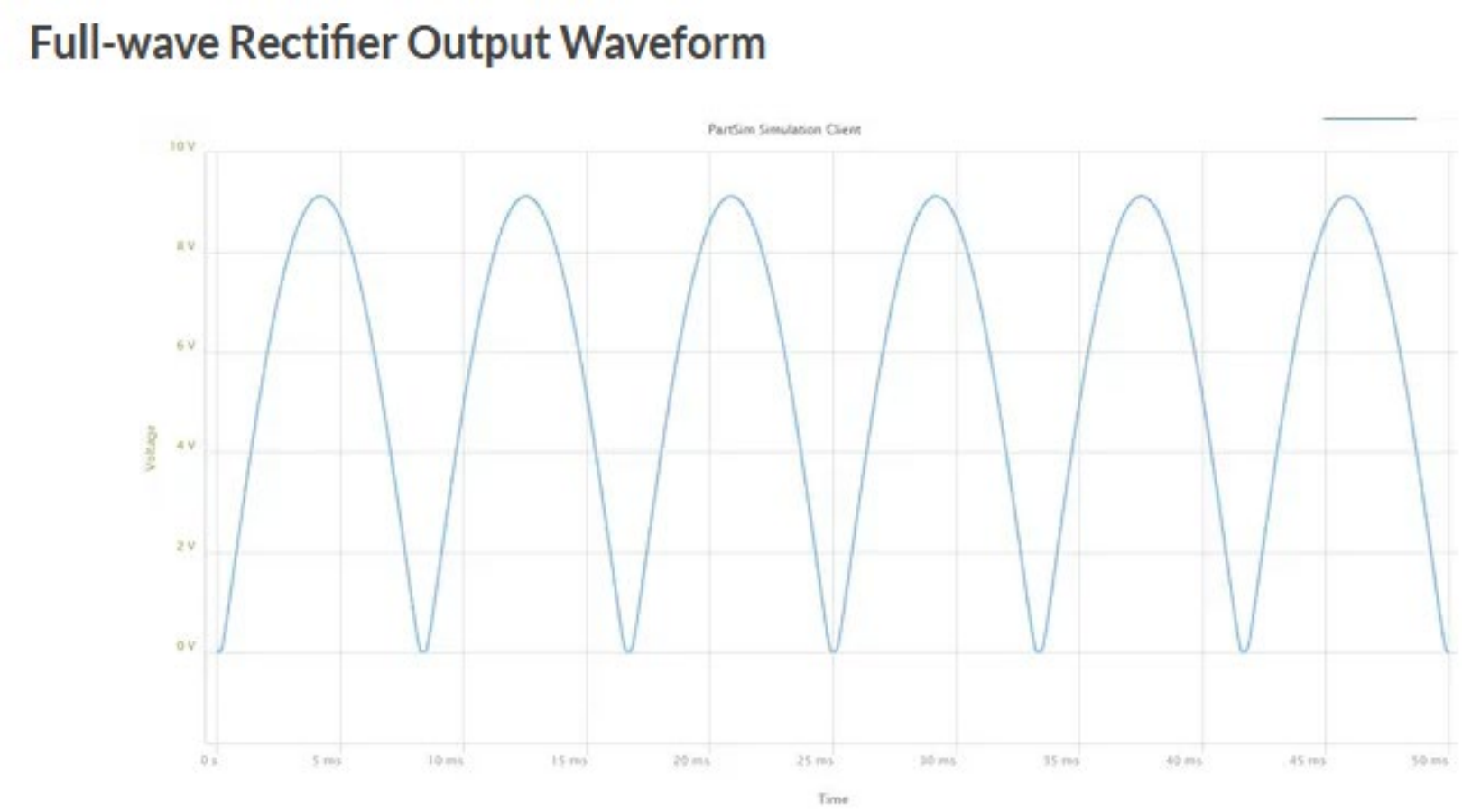


The Positive Half-cycle

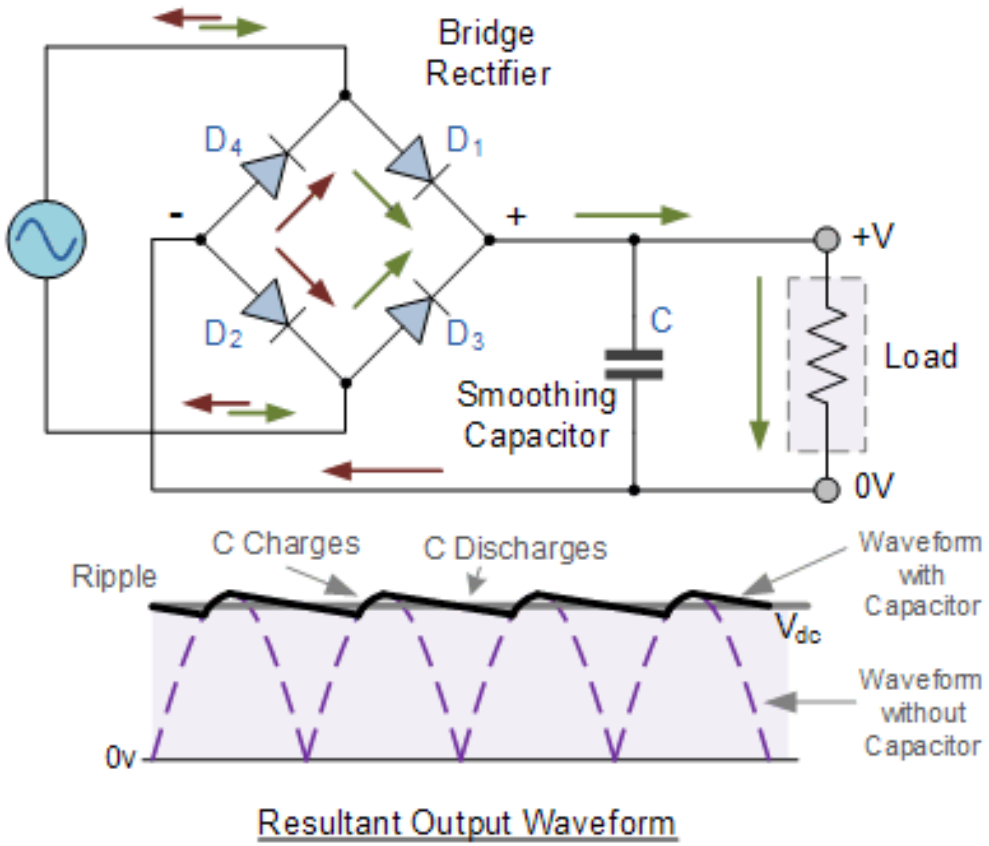


The Negative Half-cycle



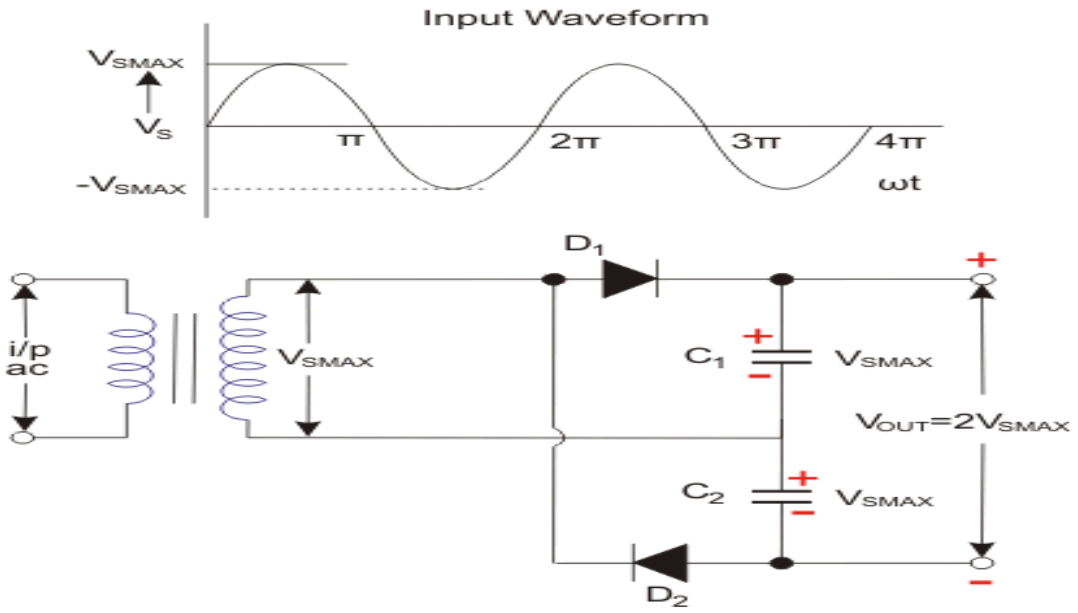

Full-wave Rectifier Output Waveform
PartSim Simulation Client
10 V
8 V
6 V
4 V
2 V
0 V
Voltage
0 s
5 ms
10 ms
15 ms
20 ms
25 ms
30 ms
35 ms
40 ms
45 ms
50 ms
Time

Full Wave Rectifier with Smoothing Capacitor



Resultant Output Waveform

Power Supplies -- Linear and Switched Mode Power Supplies



In this doubler, right through the positive cycle of input AC voltage, the first diode (D_1) is in the conducting state.

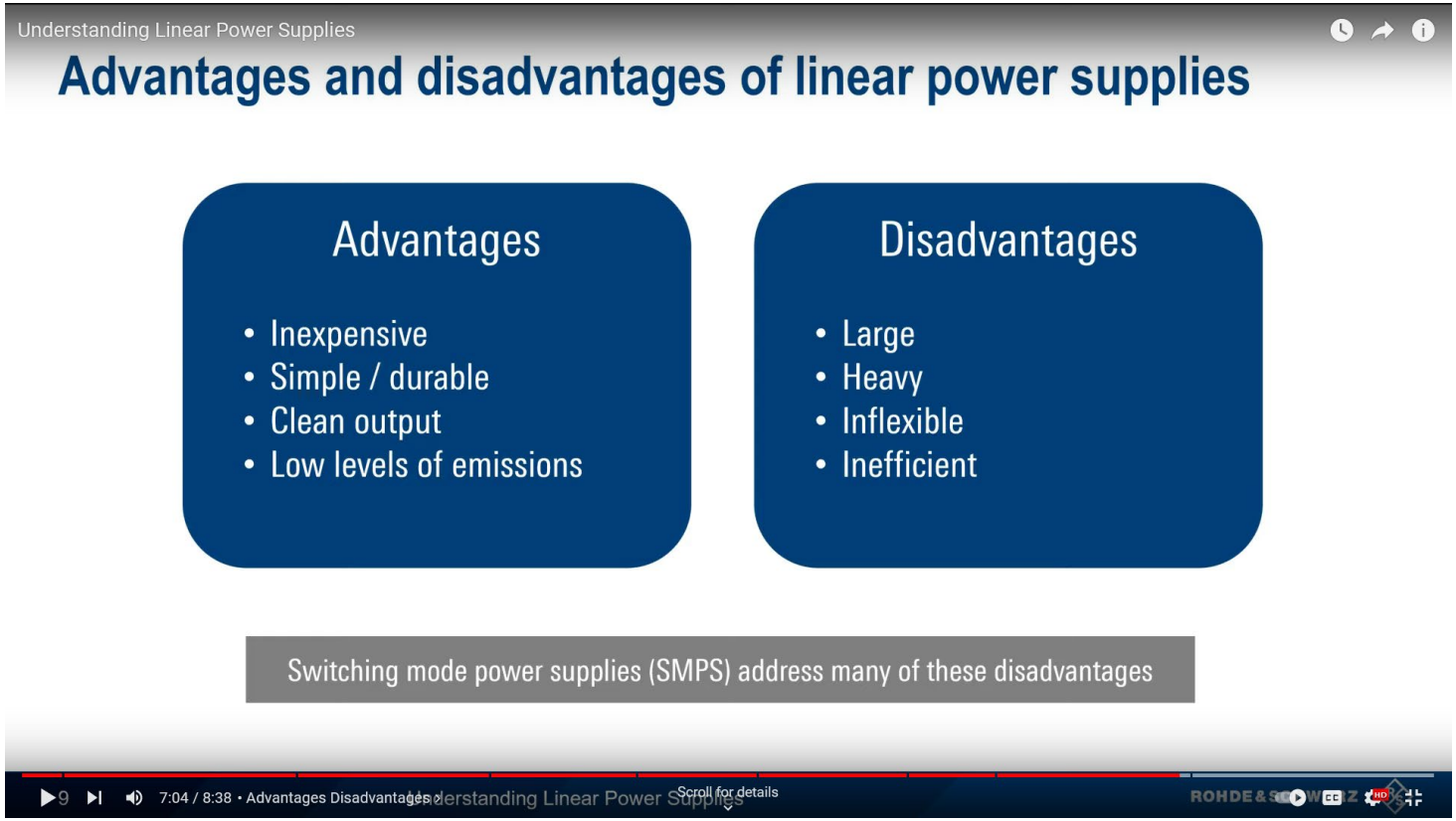
That is a forward biased state, and it will charge the connected capacitor (C_1) equal to the peak value of AC secondary voltage of transformer (V_{SMAX}).

At this time, D_2 will be in reverse biased condition or non-conducting state. Throughout the negative cycle of input AC voltage, the second diode (D_2) will be in forwarding biased state, and the second capacitor (C_2) gets charged.

In the no-load condition, the entire voltages of two capacitors $V_{C1} + V_{C2} = 2V_{SMAX}$ are delivered as the output voltage.

When a load is connected across the output terminals, the output voltage (V_{out}) may be less than $2V_{S\,MAX}$.

Comparison between A Linear DC Power Supply And a Switch Mode Power Supply (SMPS)



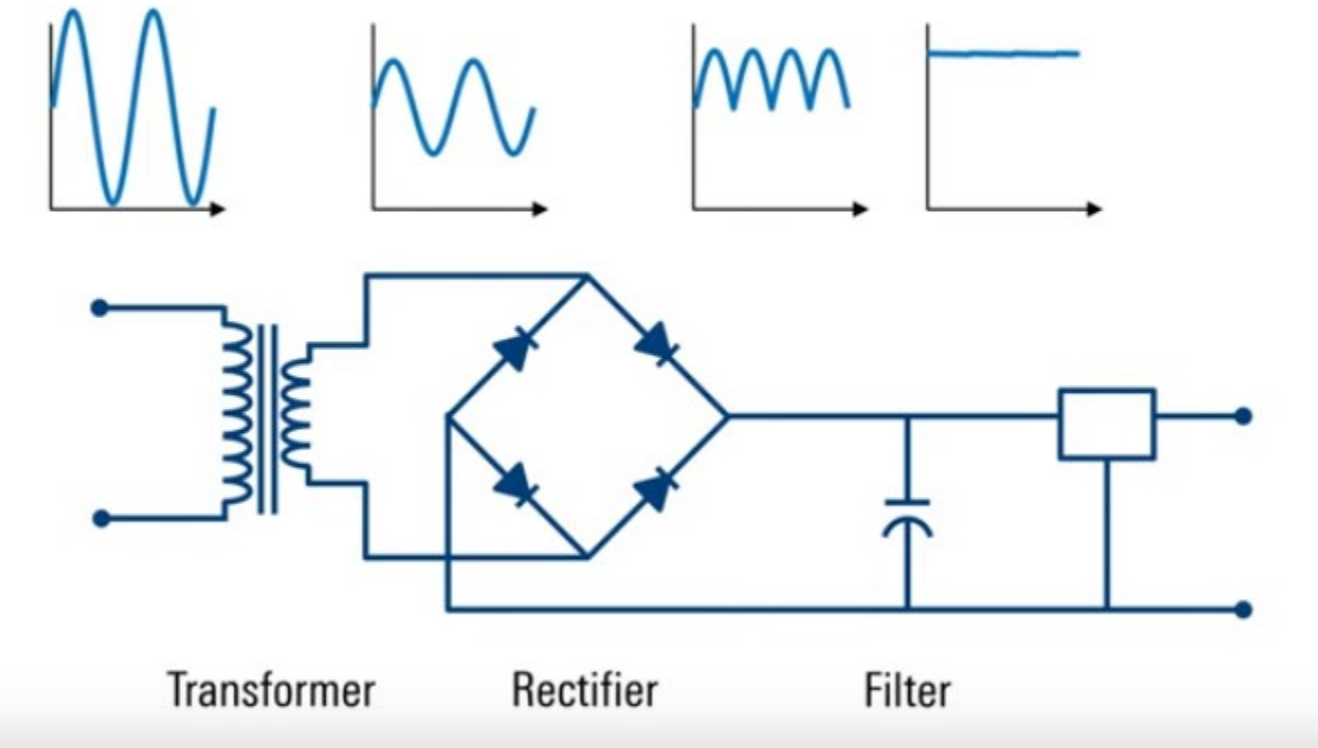
Linear Power Supplies are usually RFI free.

Linear Power Supply and. Switching Power Supply Basic Overview

Feature	Switch Mode Power Supply (SMPS)	Linear Power Supply
Operating Principle	Power transistor switches rapidly between on and off states, converting input DC voltage to high-frequency AC, then to the desired output voltage	Transforms input AC voltage to a lower level, rectifies it to DC, and regulates voltage in a linear mode by heat dissipation
Efficiency	High (about 80% or higher) due to switching states	Lower (about 60%), as it continuously dissipates power as heat
Size and Weight	Smaller and lighter	Larger and heavier due to heat sinks
Heat Generation	Generates less heat due to higher efficiency	More heat due to lower efficiency requires heat sinks to dissipate this energy
Complexity and Cost	More complex in design, with higher initial costs offset by efficiency and component size	Simpler and potentially more cost-effective in design and manufacturing
Output Noise and Ripple	More electrical noise and ripple, requiring additional filtering for sensitive electronics	Produces cleaner output with less noise and ripple, preferred in sensitive audio and analog applications
Applications	Preferred for applications requiring high efficiency, compact size, and a wide input voltage range	Favored in applications requiring minimal noise and less sensitivity to size and efficiency

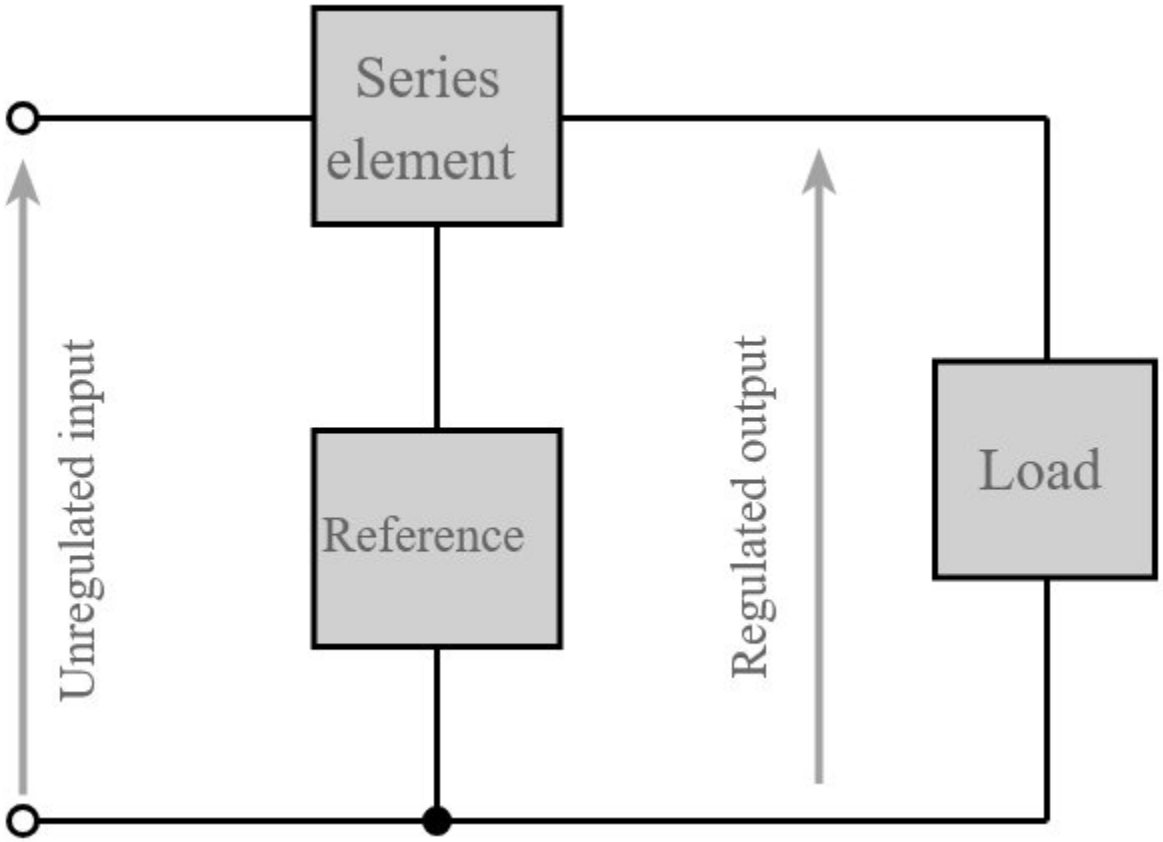
Linear Power Supplies

Typical AC to DC Analog Linear Power Supply



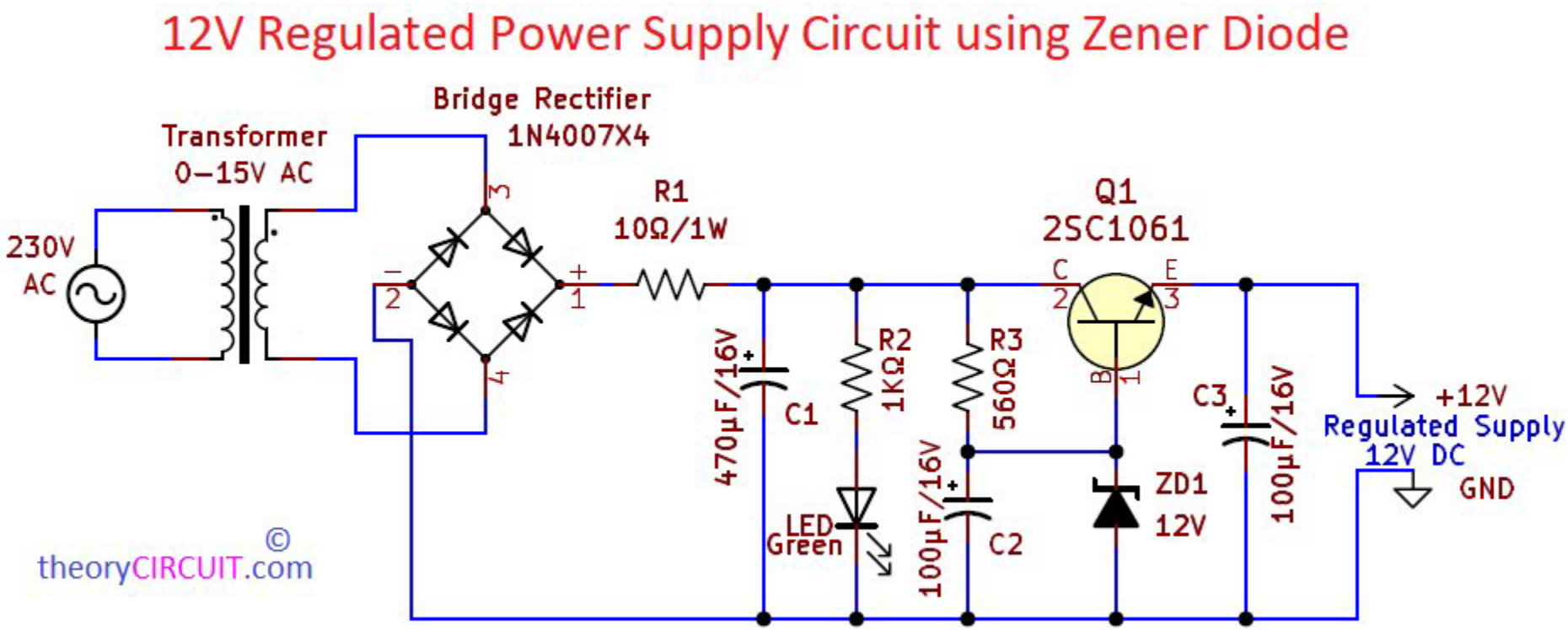
https://www.youtube.com/watch?v=Wlh20roJiZU

Power Supplies -- Linear and Switched Mode Power Supplies



“This is simplistic block diagram of a linear power supply.”

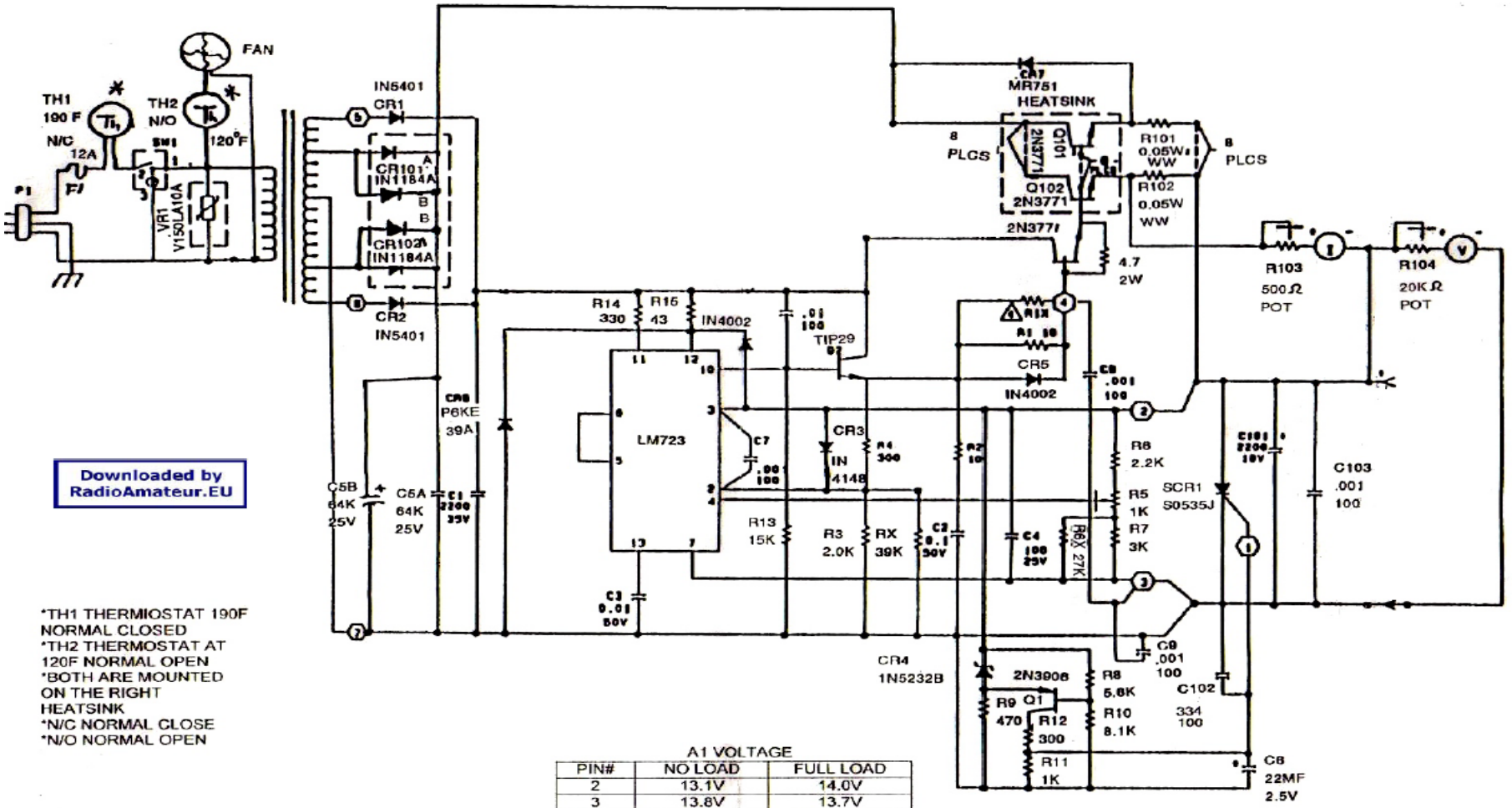
The series element acts as a variable resistor while keeping the voltage across the load constant. The series element generates a lot of heat.


12V Regulated Power Supply Circuit using Zener Diode
Bridge Rectifier
1N4007X4
Transformer
0–15V AC
230V
AC
R1
10Ω/1W
Q1
2SC1061
C
E
B
2
3
1
R2
1KΩ
R3
560Ω
470µF/16V
C1
LED
Green
100µF/16V
C2
ZD1
12V
C3
100µF/16V
+12V
Regulated Supply
12V DC
GND
©
theoryCIRCUIT.com

Linear Power Supply (Astron RS-35M)

Linear Power Supply (Astron)

Power Supplies -- Linear and Switched Mode Power Supplies



*TH1 THERMIOSTAT 190F
NORMAL CLOSED
*TH2 THERMOSTAT AT
120F NORMAL OPEN
*BOTH ARE MOUNTED
ON THE RIGHT
HEATSINK
*N/C NORMAL CLOSE
*N/O NORMAL OPEN

A1 VOLTAGE

PIN#	NO LOAD	FULL LOAD
2	13.1V	14.0V
3	13.8V	13.7V
4	7.2V	7.2V
5	7.2V	7.2V
6	7.2V	7.2V
7	0.0V	0.0V
10	14.8	16.5
11	29.0V	25.0V
12	29.0V	25.0V
13	16.1V	17.8V

UNLESS OTHERWISE NOTED
1. ALL RESISTORS 5%, 0.5W, C.F. IN OHMS
2. ALL CAPASITORS IN MICROFARADS.
3. ○ PRINTED CIRCUIT BOARD
4. △ TO BE SELECTED IN TEST.

ASTRON CORPORATION IRVINE, CALIFORNIA

DATE: 6-23-97

RS-70A & RS-70M

Crowbar

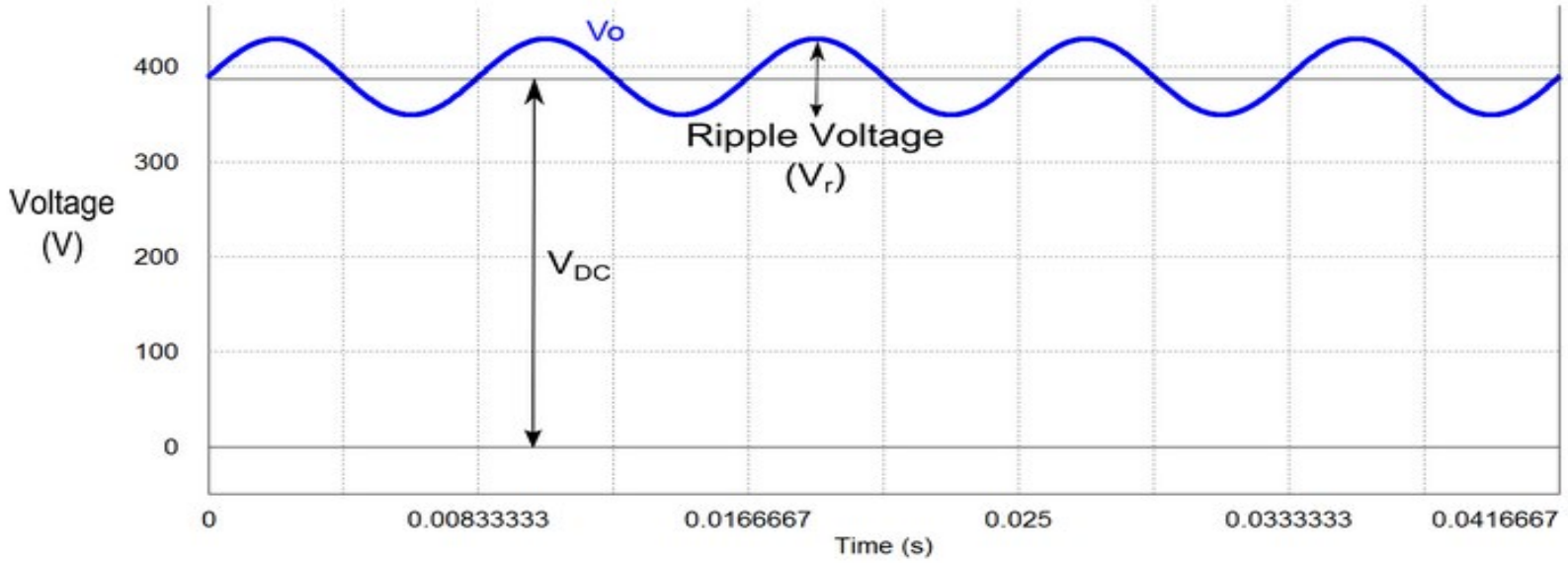
This device Is Used in the Astron Linear Supply

(See previous page)

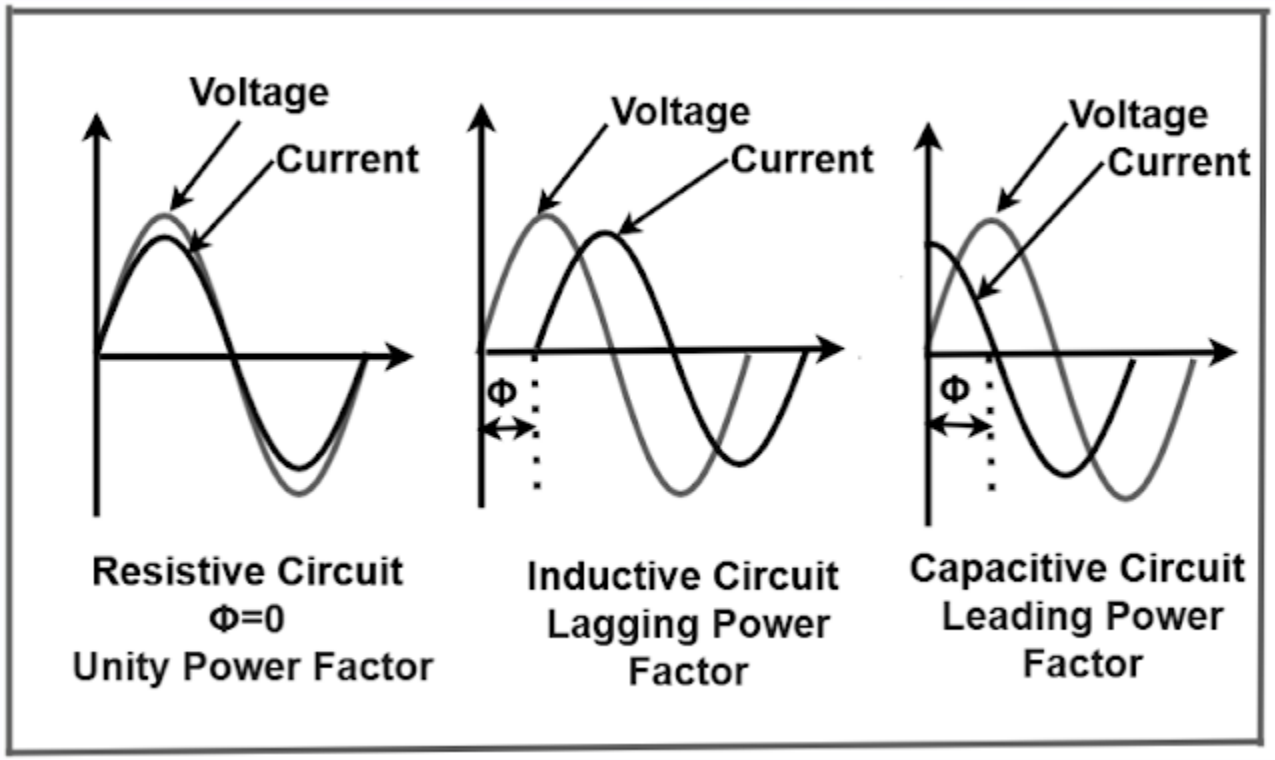
Typical AC Ripple of A Linear Power Supply

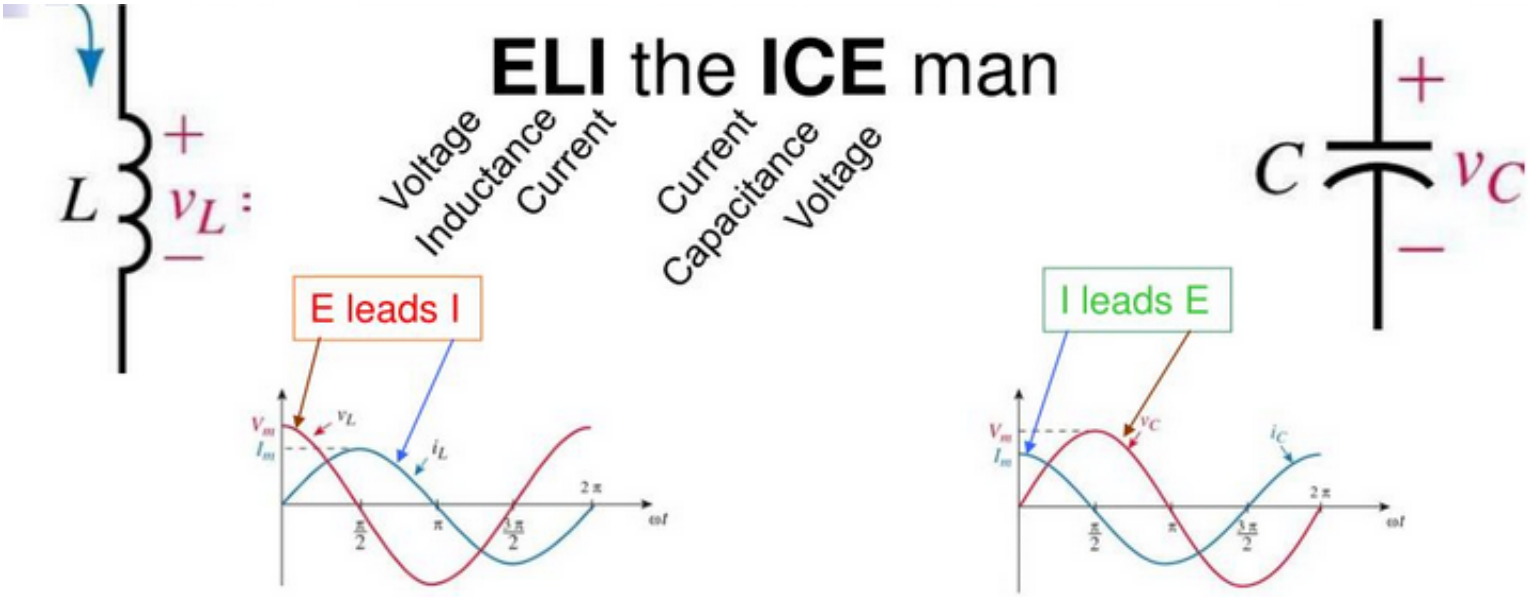
What is AC Ripple?

AC ripple refers to the unwanted fluctuations in the direct current (DC) output of a power supply that arise from the alternating current (AC) input. These fluctuations occur due to incomplete suppression of the AC waveform during the rectification process. Ripple manifests as periodic variations superimposed on the DC voltage, which can lead to instability in electronic circuits.



AC Input Sinusoidal Components of a Linear Supply





When voltage is applied to an inductor, it resists the change of current. The current builds up more slowly, lagging in time and phase.

Since the voltage on a capacitor is directly proportional to the charge on it, the current must lead the voltage in time and phase to conduct charge to the capacitor plate and raise the voltage

Switched Mode Power Supplies

Benefits of a Switching Power Supply

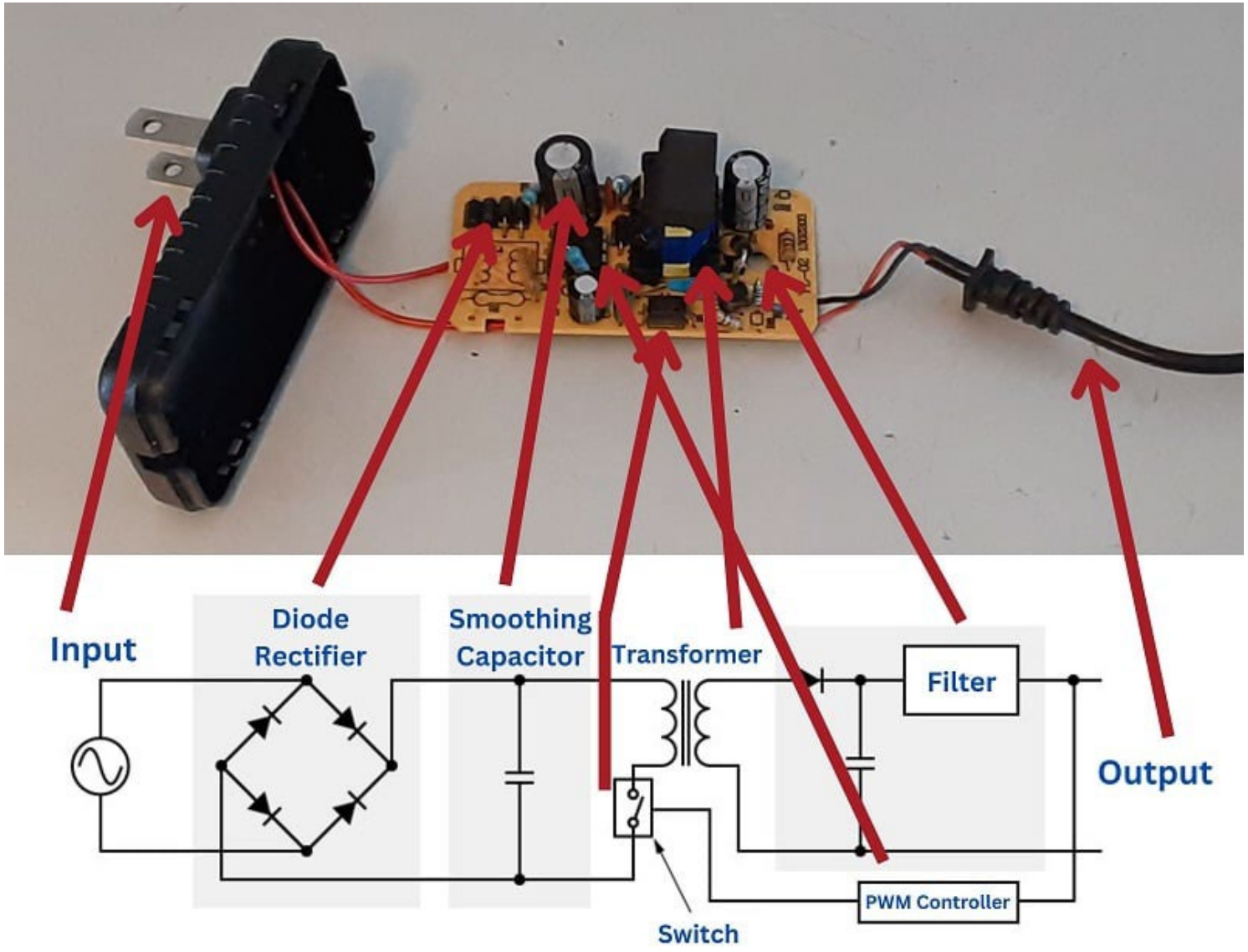
- Transformers are smaller due to operating at a high frequency 30 KHz or greater
- Smaller Capacitors due to smaller Higher Frequency RC time constants
- Internal circuitry wire sizes are smaller due to Higher Voltages lower current

NON benefits of a Switching Power Supply

- Higher “Noise” on the DC output (AC Ripple & Switching Noise)
- Poor Transient Response filtering
- RF Noise generated throughout the 1 MHZ to 450 MHz spectrum

Power Supplies -- Linear and Switched Mode Power Supplies

Stages in a Switched Mode Power Supply



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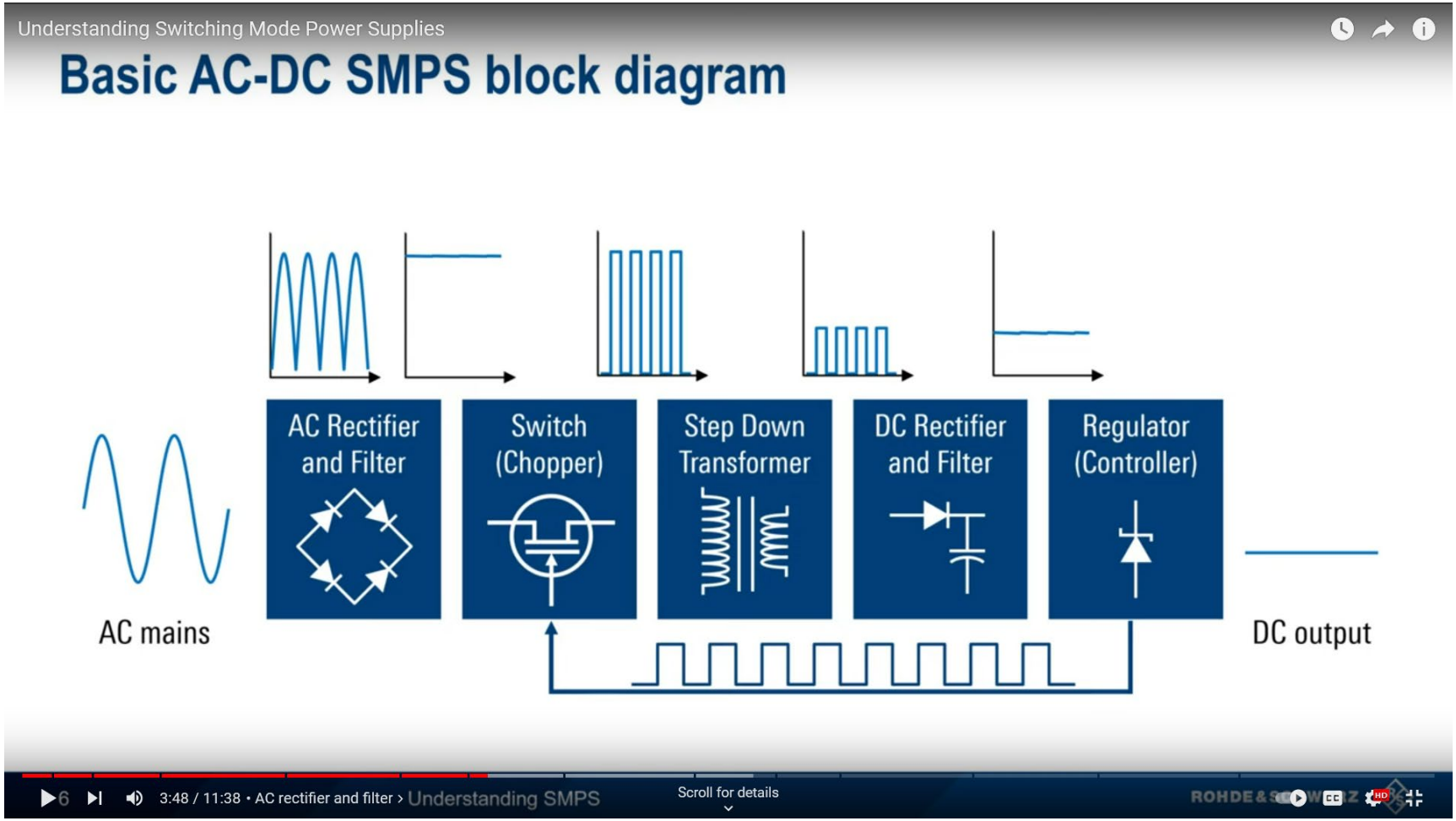
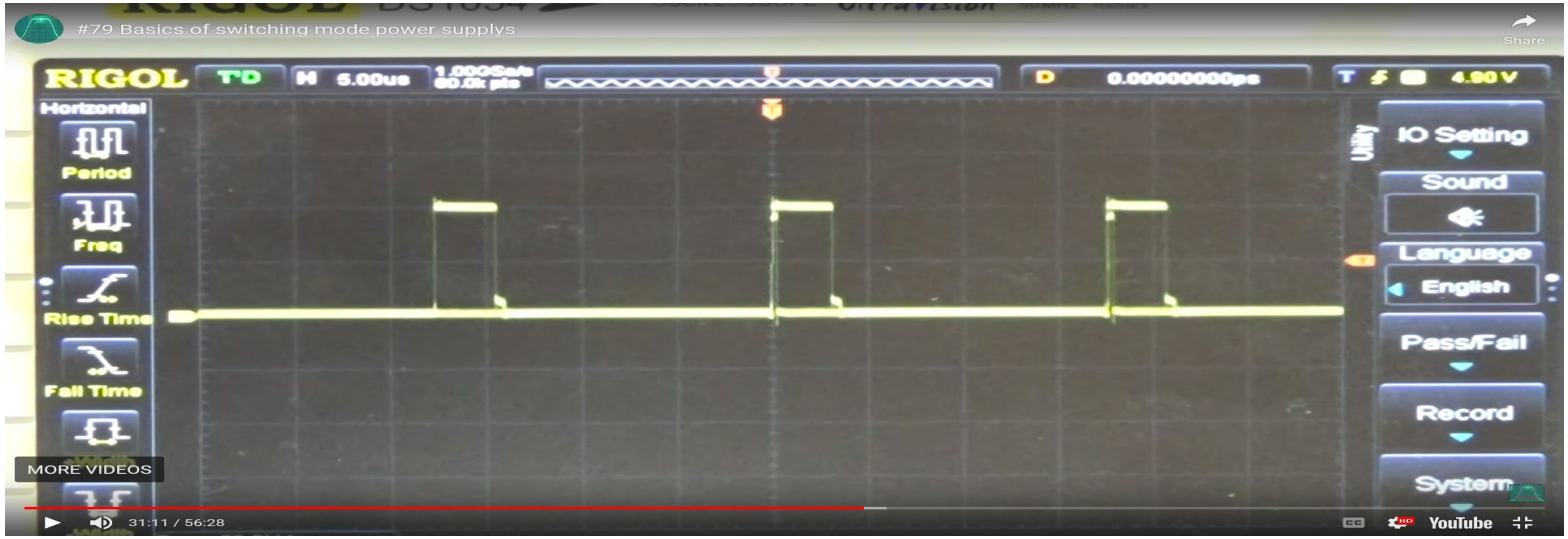


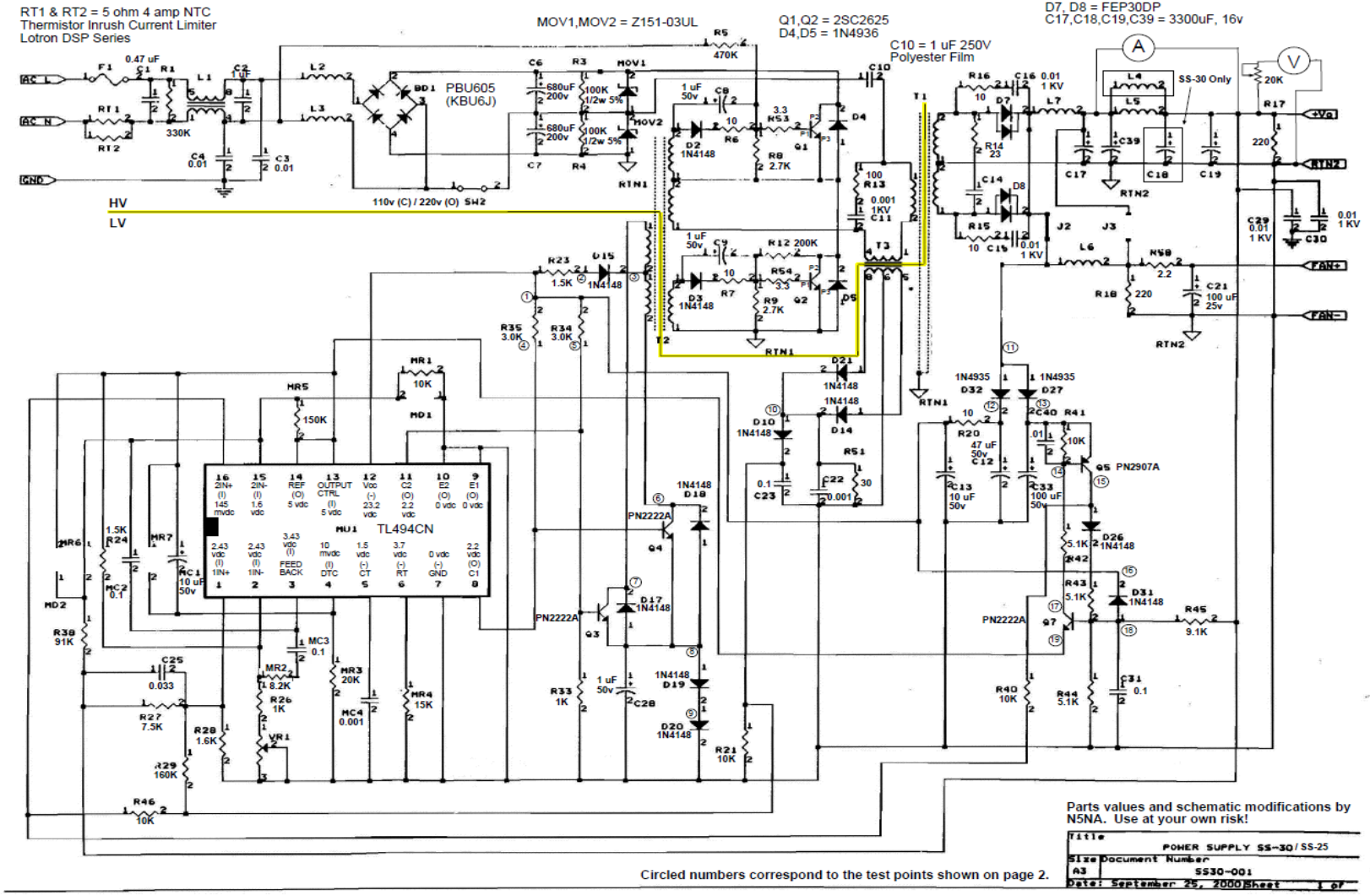
Power Supplies -- Linear and Switched Mode Power Supplies

Switched Mode Power Supply Pulses (Not Loaded & Loaded)



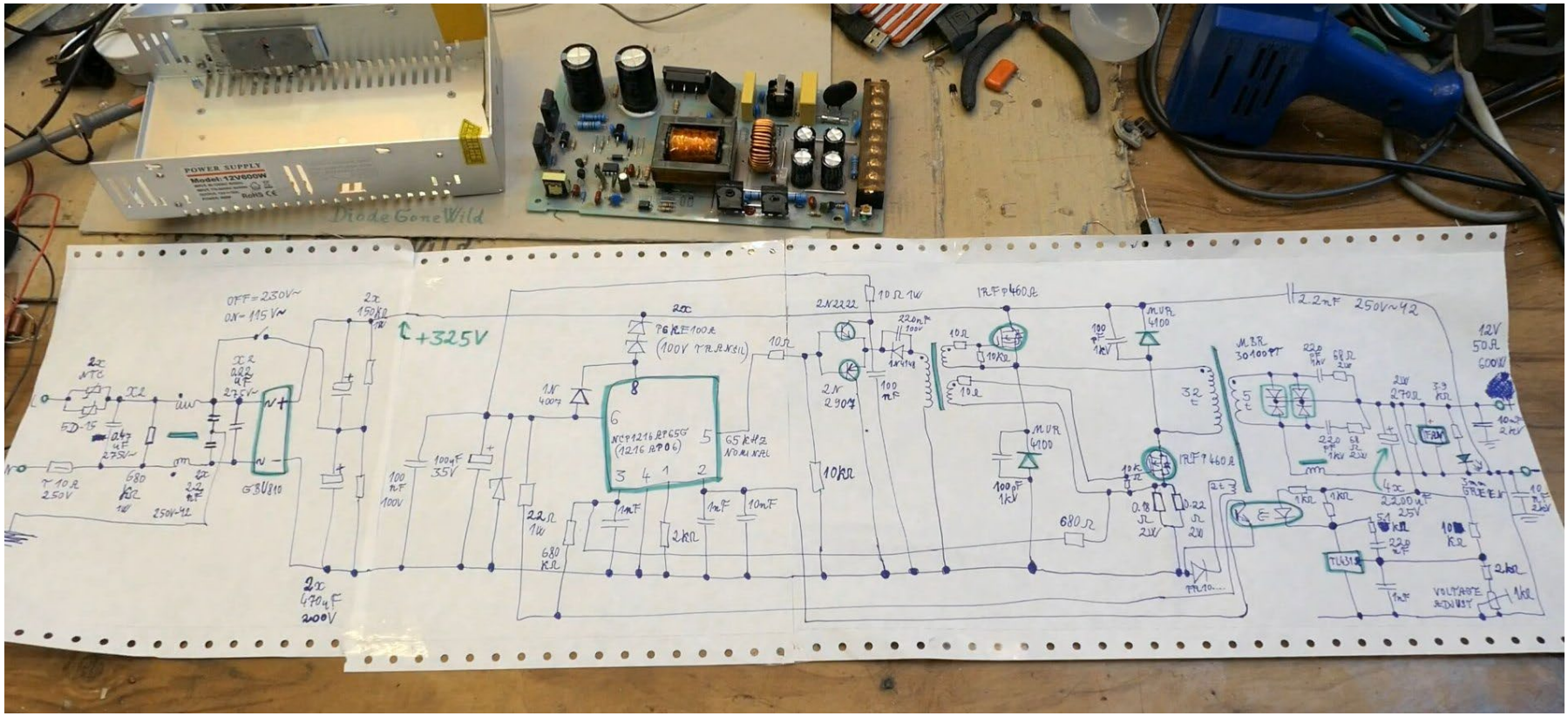
Typical Switched Mode Power Supply (Astron SS-25M)

Typical Switched Mode Power Supply (Astron SS-25M)

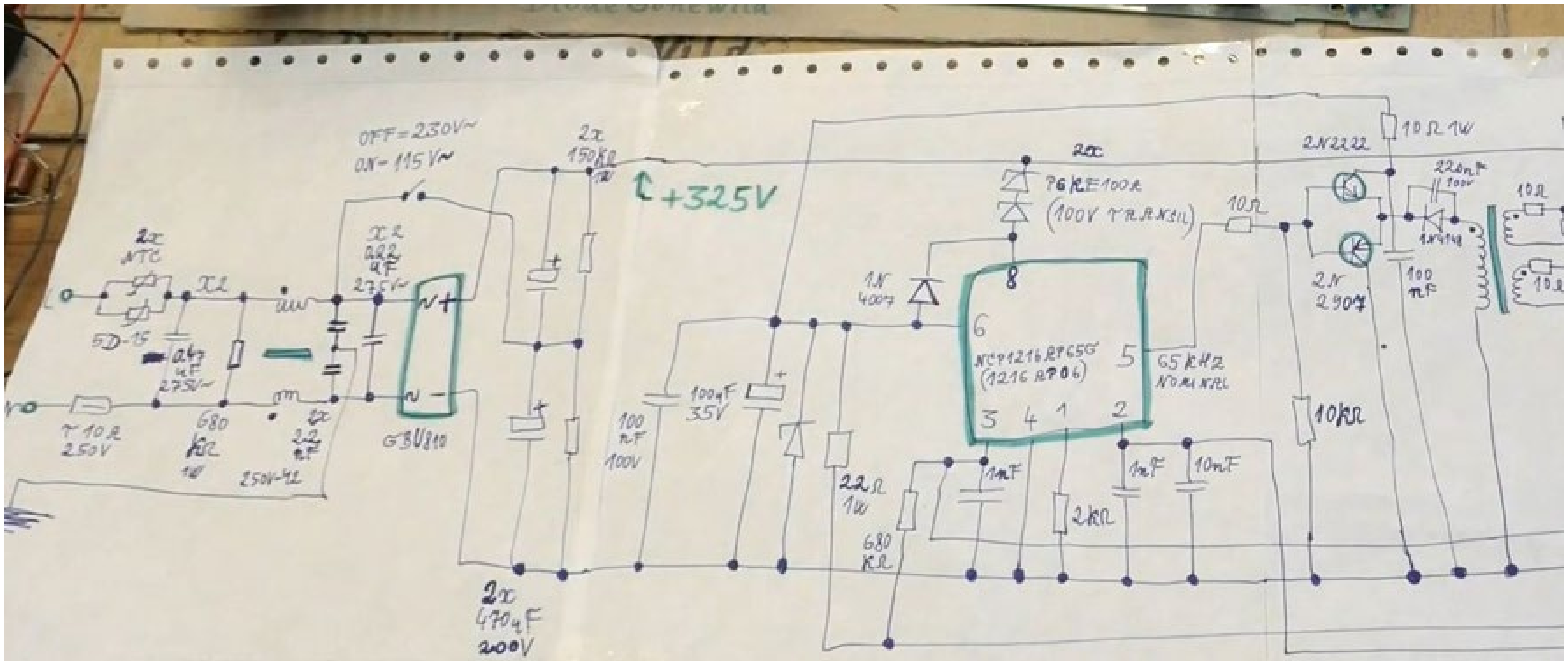


Cheap Chinese Switch Mode Power Supply (SMPS)

Schematic of a Cheap Chinese SMPS

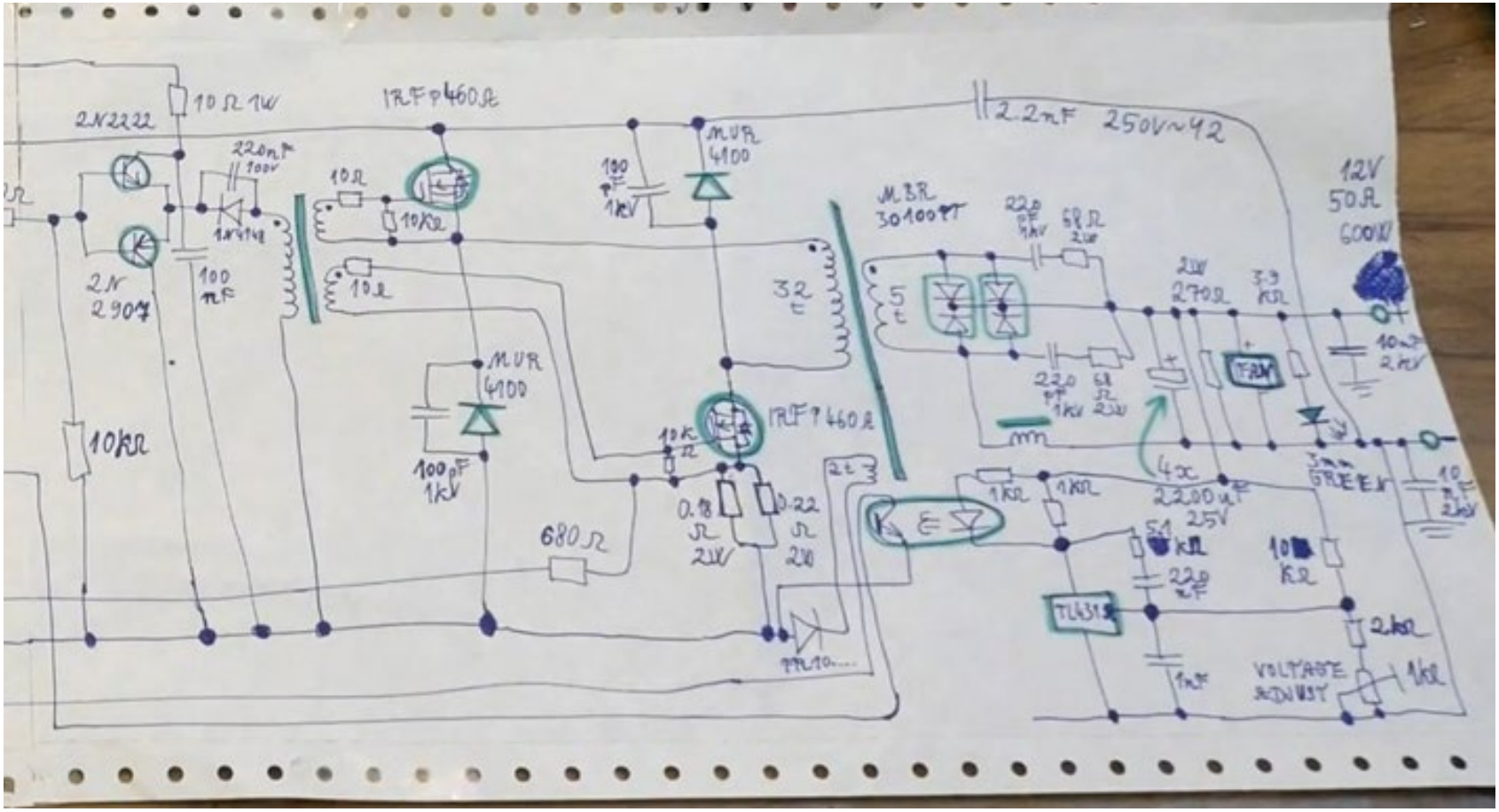


Left Side


OFF=230V~
ON-115V~
2x
150kΩ
+325V
2x NTC
5D-15
0.47 uF 275V~
680 kΩ 1W
GBU810
2x
470uF
200V
100 nF 100V
100uF 35V
22Ω 1W
680 kΩ
1N 4007
2x
P6KE100A
(100V TRANSIL)
NCP1216AP65G
(1216 AP06)
65kHz NOMINAL
1nF
2kΩ
10nF
10Ω
10kΩ
2N2222
2N 2907
10Ω 1W
220nF 100V
1N4148
100 nF

Power Supplies -- Linear and Switched Mode Power Supplies

Right Side



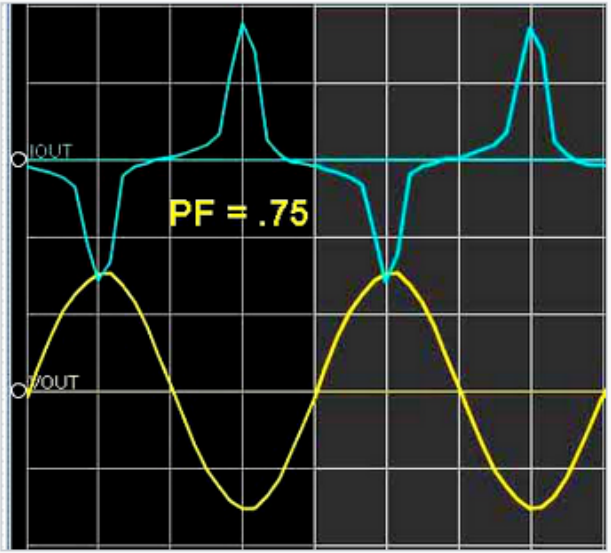
AC Input of Power Supply

Non-sinusoidal components [edit]

In linear circuits having only sinusoidal currents and voltages of one frequency, the power factor arises only from the difference in phase between the current and voltage. This is *displacement power factor*.[11]

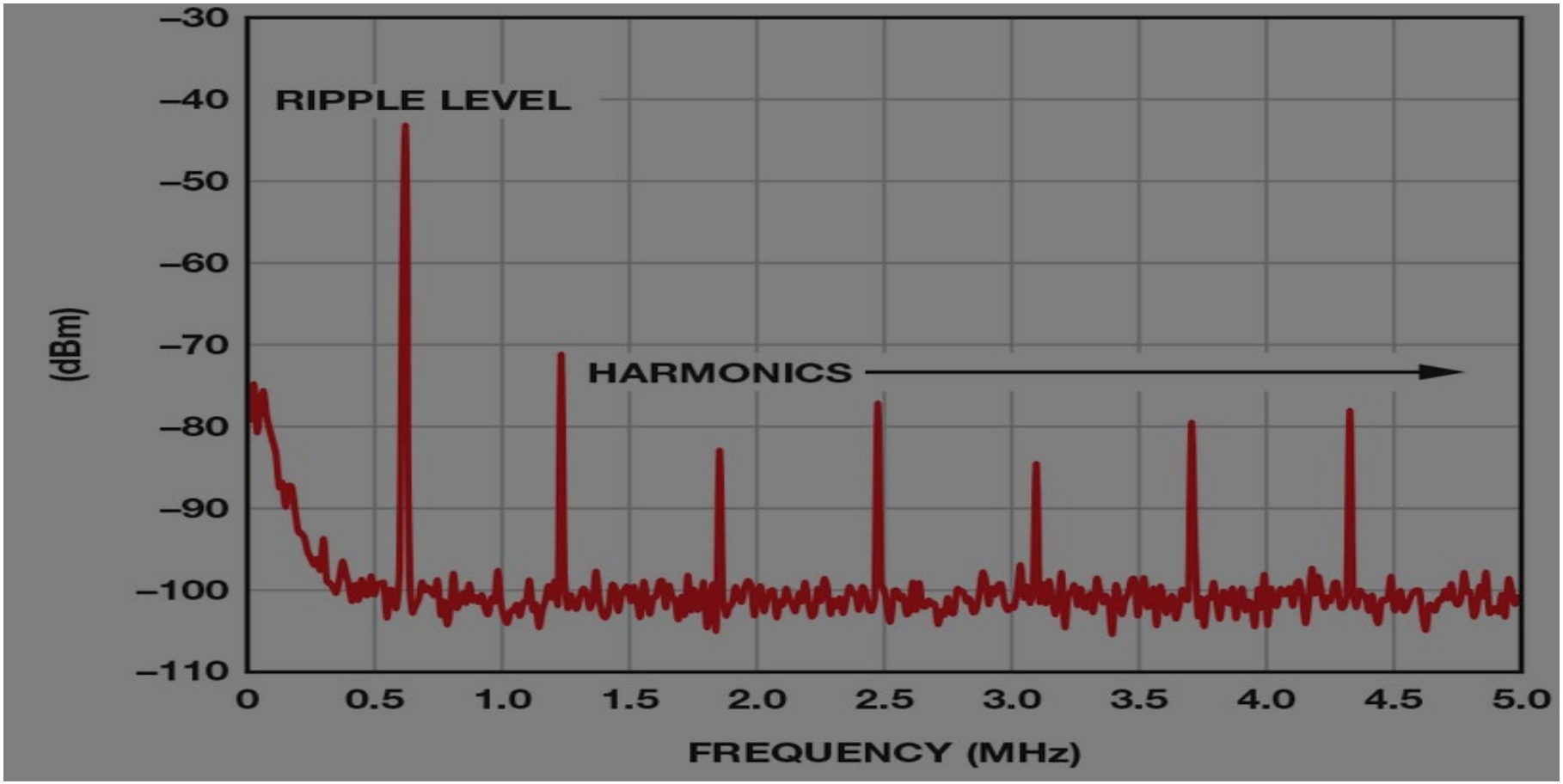
Non-linear loads change the shape of the current waveform from a sine wave to some other form. Non-linear loads create harmonic currents in addition to the original (fundamental frequency) AC current. This is of importance in practical power systems that contain non-linear loads such as rectifiers, some forms of electric lighting, electric arc furnaces, welding equipment, switched-mode power supplies, variable speed drives and other devices. Filters consisting of linear capacitors and inductors can prevent harmonic currents from entering the supplying system.

To measure the real power or reactive power, a wattmeter designed to work properly with non-sinusoidal currents must be used.



Sinusoidal voltage and non-sinusoidal current give a distortion power factor of 0.75 for this computer power supply load.

A poorly designed SMPS - Ripple and Noise



Power Supply Specifications:

Linear (Astron RS-70A)

- SOLID STATE ELECTRONICALLY REGULATED
- FOLD BACK CURRENT LIMITING Protects Power Supply from excessive current and continuous shorted output
- CROWBAR OVER VOLTAGE PROTECTION ON ALL MODELS
- MAINTAIN REGULATION AND LOW RIPPLE at low line input Voltage
- THREE CONDUCTOR POWER CORD
- HEAVY DUTY HEAT SINK
- INPUT VOLTAGE: **105-125VAC**
- OUTPUT VOLTAGE: **13.8VDC ±0.05 volts**
- INTERNALLY ADJUSTABLE VOLTAGE (11-15VDC)
- RIPPLE: LESS THAN 5MV PEAK TO PEAK (full load and low line)
- LOAD REGULATION: **0.08%** from 0 to Full Continuous Load
- EFFICIENCY: **77%**
- OPERATING TEMP: **-10 to 55°C**
- 220V MODELS AVAILABLE BY SPECIAL ORDER

Astron SS-50 (SMPS) Specifications

Specifications	
• **INPUT VOLTAGE:**	120 to 230 VAC, 50/60Hz (Nominal Automatic Wide-Range selected)
• **OUTPUT VOLTAGES:**	13.8 VDC (User manual adjustable ± 1 V) 2 USB ports: 5.2V, 1.5A per port
• **OUTPUT CURRENT**	50A peak current - ICS Intermittent Communication Service (*)
• **TEMPERATURE**	0 to +50ºC Operating, −20 to +85ºC Storage 120ºC max over-temperature setting
• **HUMIDITY**	5 to 90% RH Operating, 5 to 95% RH Storage (Non-condensing)

Model No.	Voltage Input	Voltage Output	Continuous Amps	ICS (*) Current
SS-50M	Nominal Auto Selected 120 to 230 VAC 50/60Hz	User Manual Adjust ±1V 12.4 to 14.4 VDC ± 2%	40 A max	50 A peak max

Case Size (H x W x D)	Weight (Approx)
$2\,^{5}/_{8}$ x 7 x $8\,^{1}/_{4}$ in 67.5 x 7 x 207.5 mm	5 lbs 2.3 kg

(*) Intermittent Communication Service. Peak current limited to 33% max Duty Cycle, 5 minutes max ON time.