Analog Electronics

DIPLOMA WALLAH

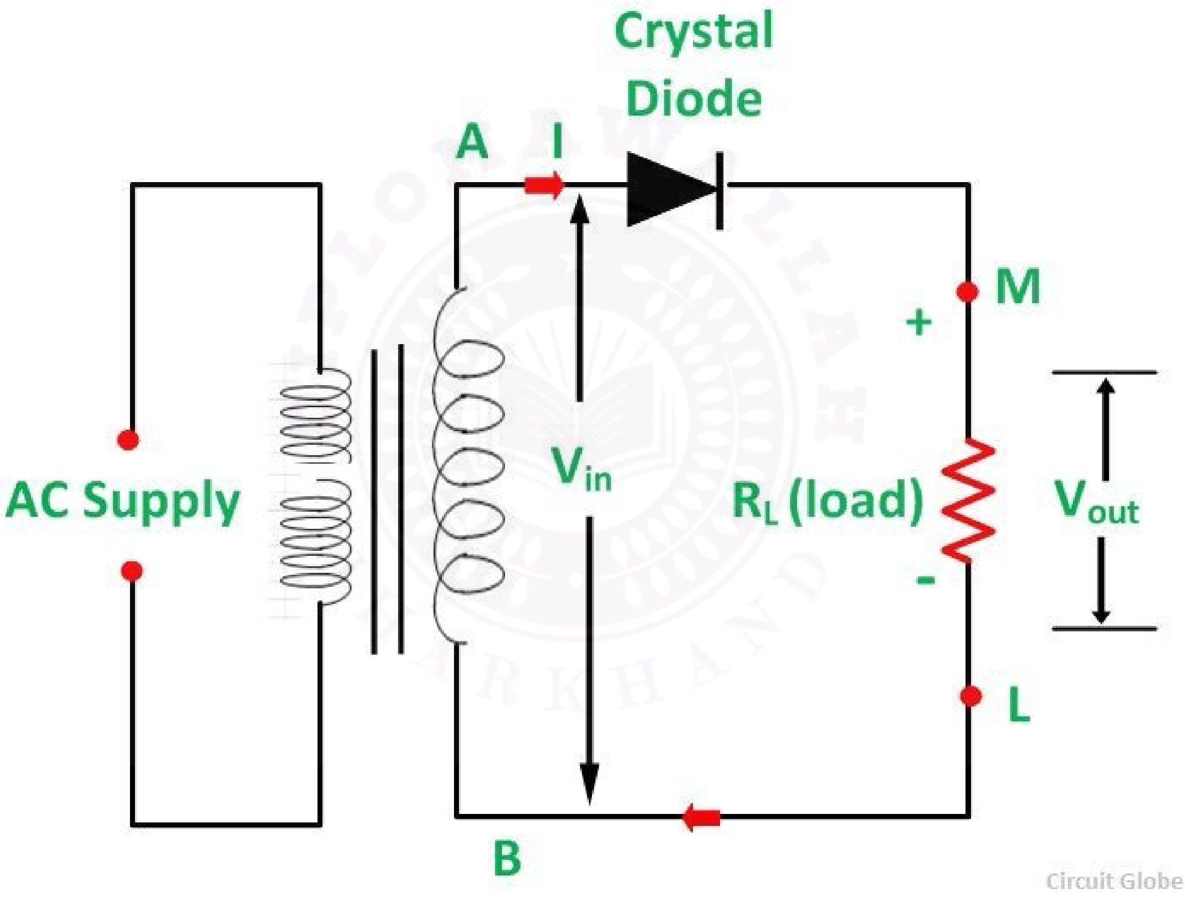
EE/EEE

Jharkhand University Of Technology (JUT)

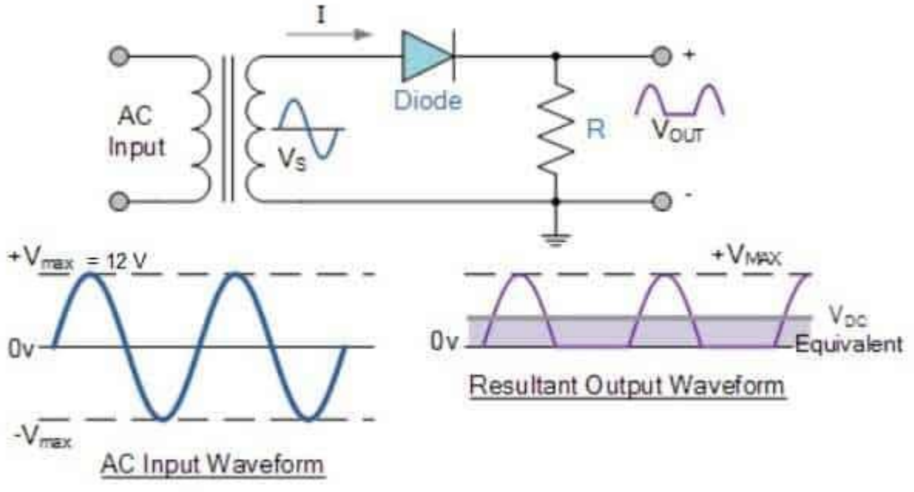
Unit 04

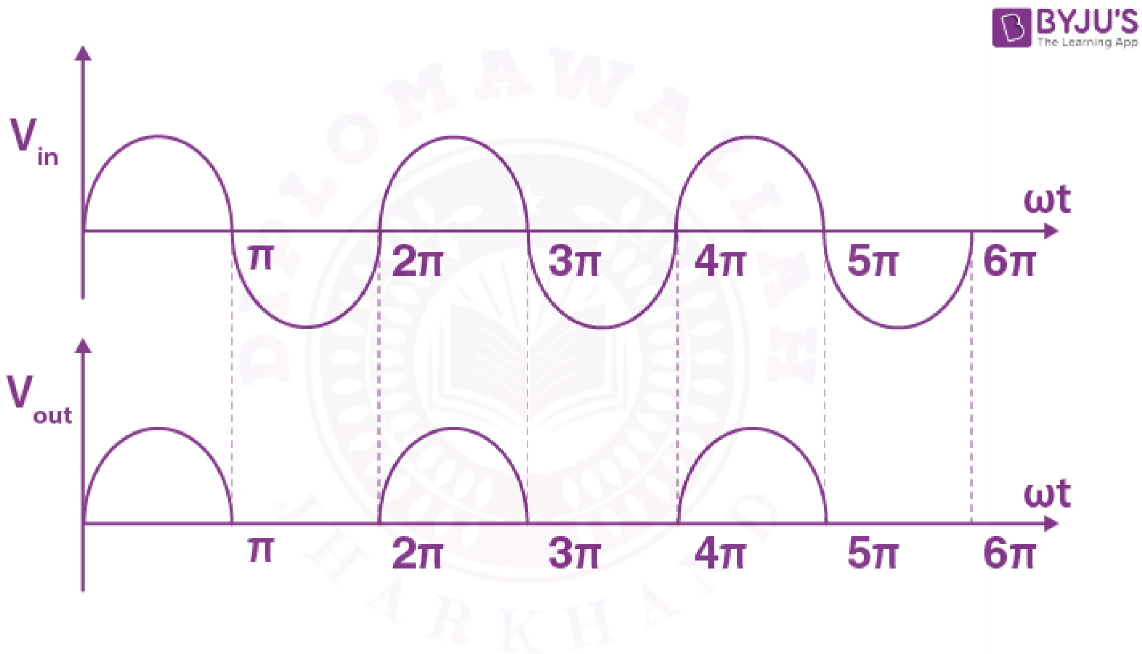
1. Rectifiers: Half-Wave & Centre-Tapped Full-Wave

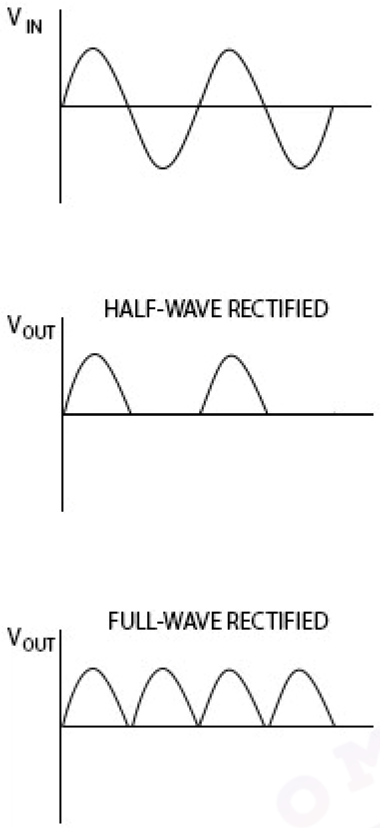
1.1 Half-Wave Rectifier



Half Wave Rectifier






V IN
HALF-WAVE RECTIFIED
VOUT
FULL-WAVE RECTIFIED
VOUT

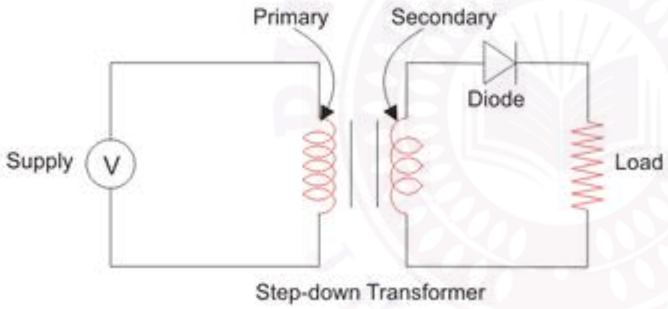
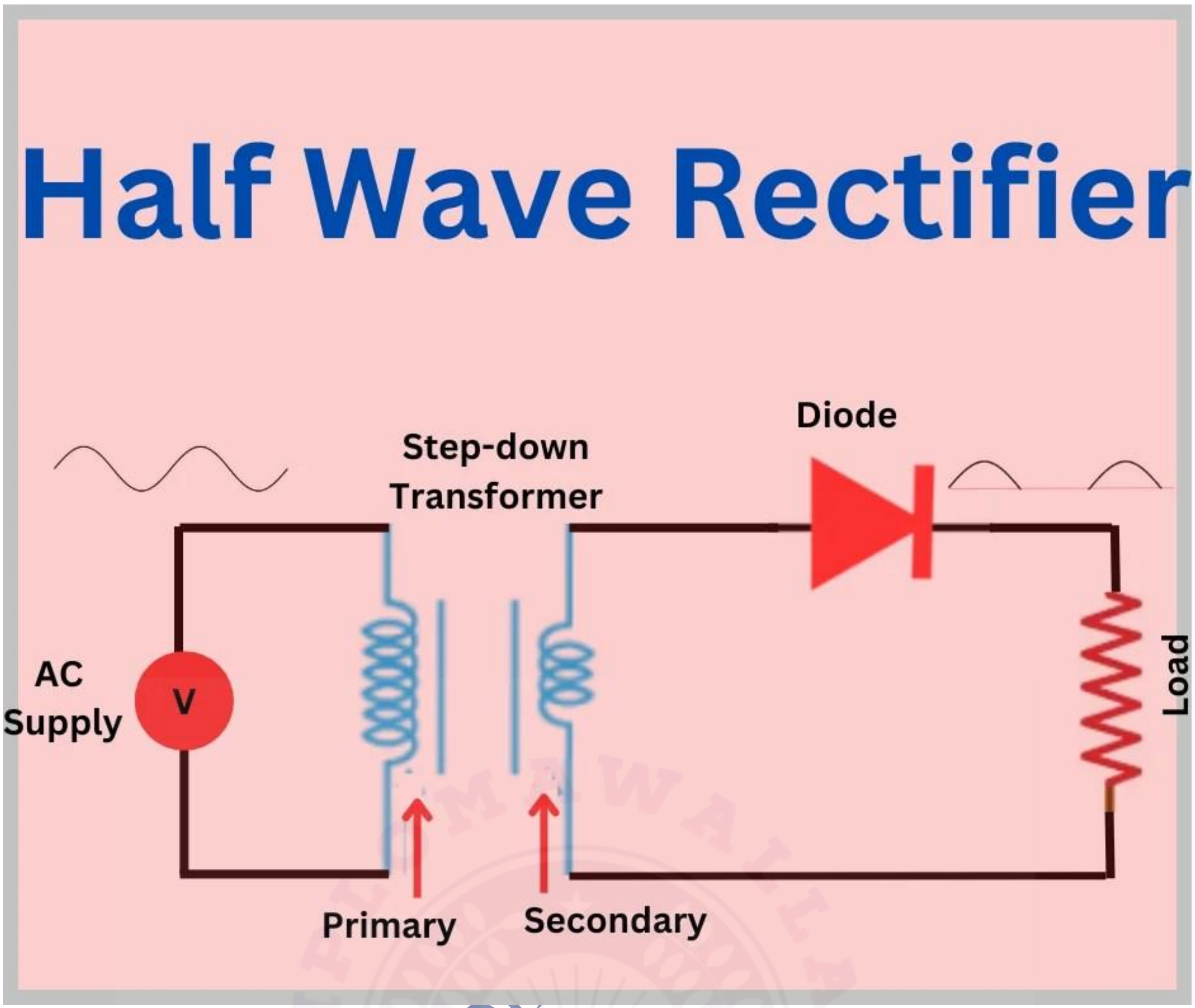

Primary
Secondary
Diode
Supply
V
Load
Step-down Transformer

Figure - 2



Circuit & Working

- In a half-wave rectifier one diode is connected in series with the load and AC source (often via a step-down transformer). (Electrical 4U)
- During the positive half-cycle of the AC input the diode is forward-biased and conducts; the load receives current. During the negative half-cycle the diode is reverse-biased and no current flows through the load. (Electrical 4U)
- The output across the load is thus a pulsating DC (only positive halves) — many "gaps" in between.

Key Performance Parameters

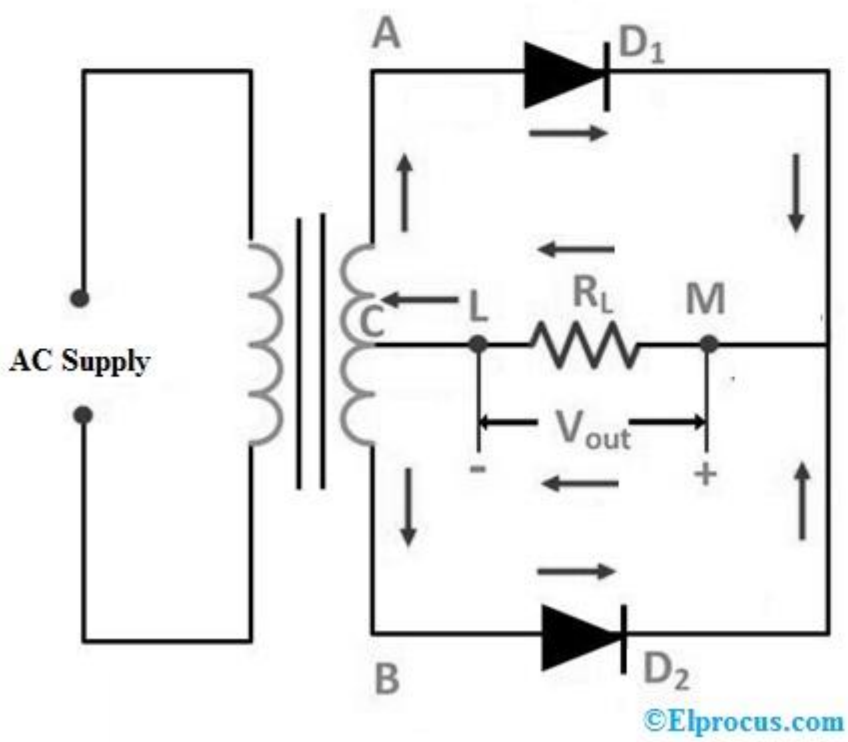
- **Average (DC) output voltage** (V_{\text{DC}}): For an ideal diode and ignoring losses, the average value is:. (Gyan Sanchay)

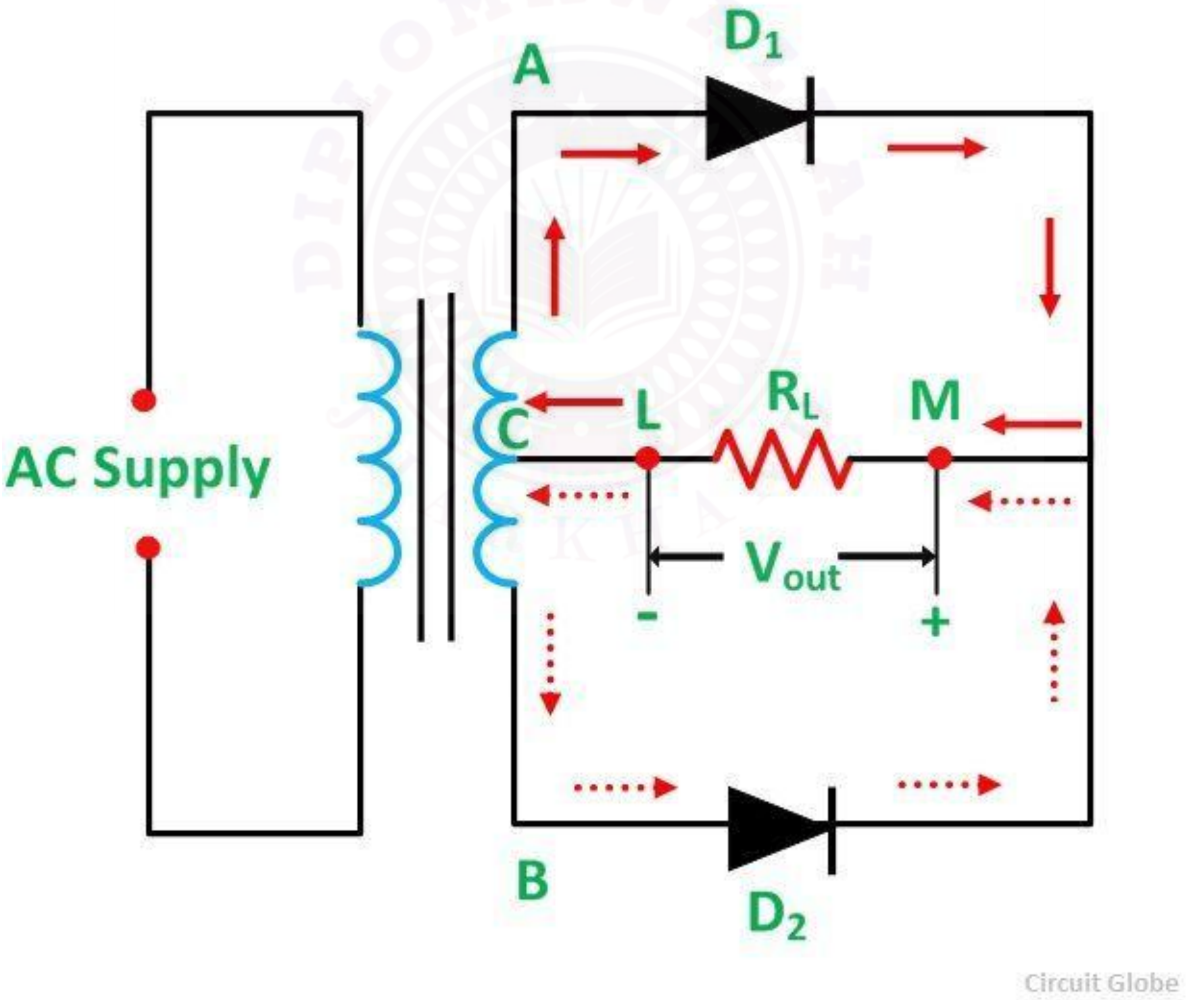
- **RMS value** of the load current / voltage can be derived similarly (for current (i(t)=I_m \sin\omega t) for (0\le t\le T/2)). (Gyan Sanchay)
- **Rectification Efficiency** (\eta): It is the ratio of DC power delivered to the load to the AC power drawn from the source. For the ideal half-wave:
  [
  \eta_{\max} = 40.6% \quad (\approx 0.406)
  ]
  (Electrical 4U)
- (BYJU'S)
- **Peak-Inverse-Voltage (PIV)**: This is the maximum reverse voltage that the diode must withstand during the non-conducting half-cycle. For the half-wave rectifier, the PIV ≈ the peak of the secondary voltage (assuming ideal diode) i.e.,
  [
  \text{PIV} \approx V_{m}
  ]
  (Electrical 4U)

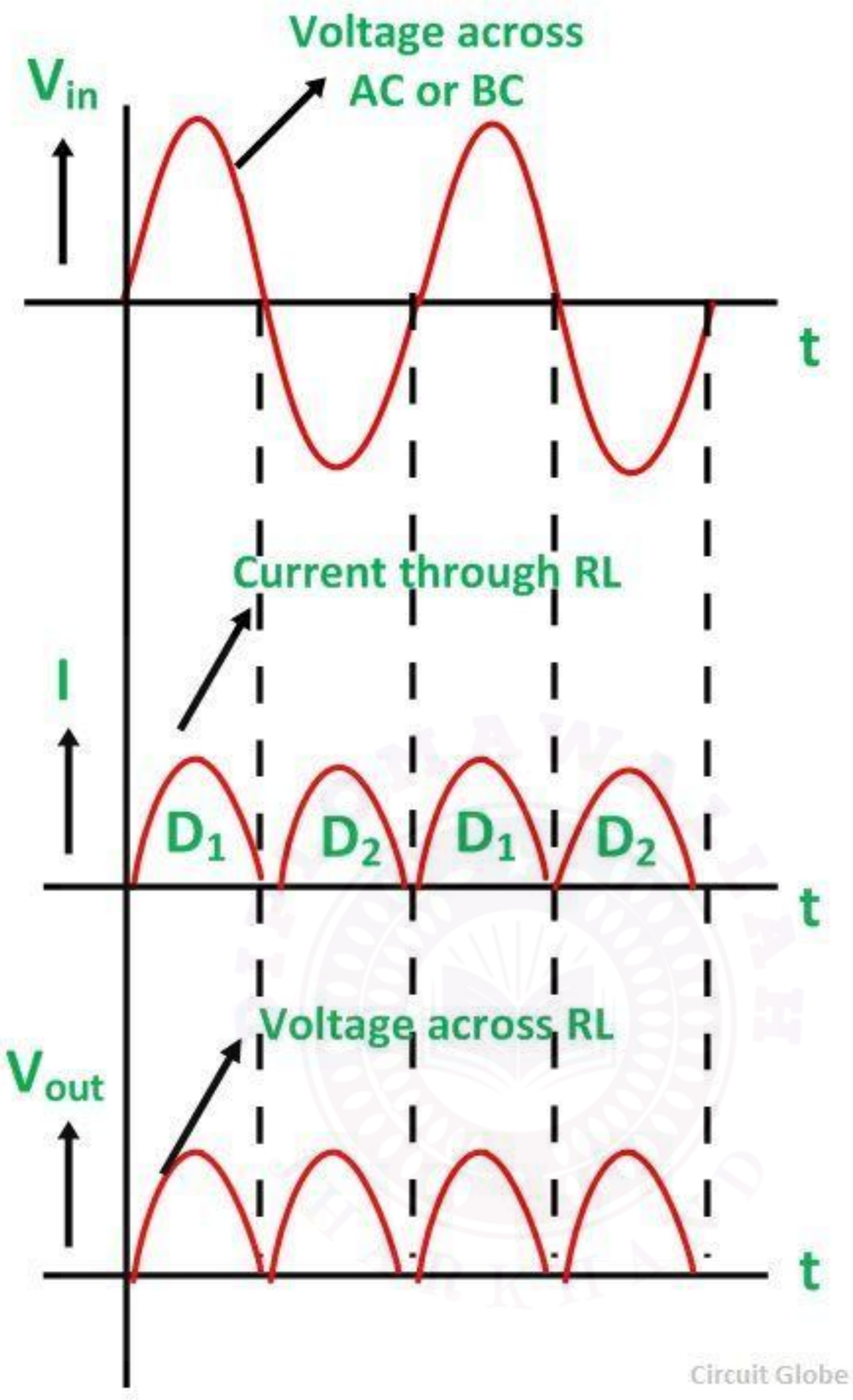
Advantages & Disadvantages

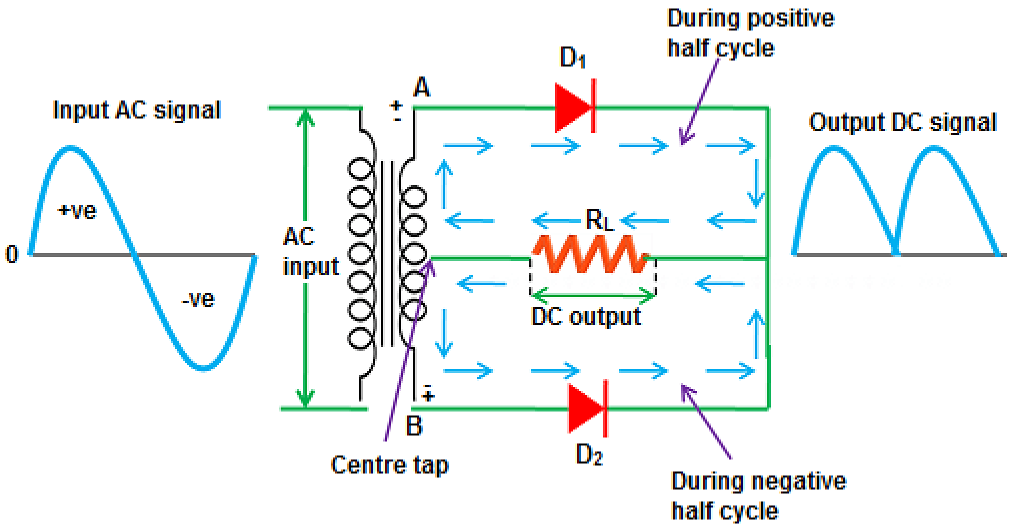
- *Advantages*: Simple circuit (single diode), low cost.
- *Disadvantages*: Low efficiency (≈ 40.6 %), high ripple (γ ≈ 1.21), output DC voltage is lower, utilization of transformer is poor, large filtering required for smooth DC.

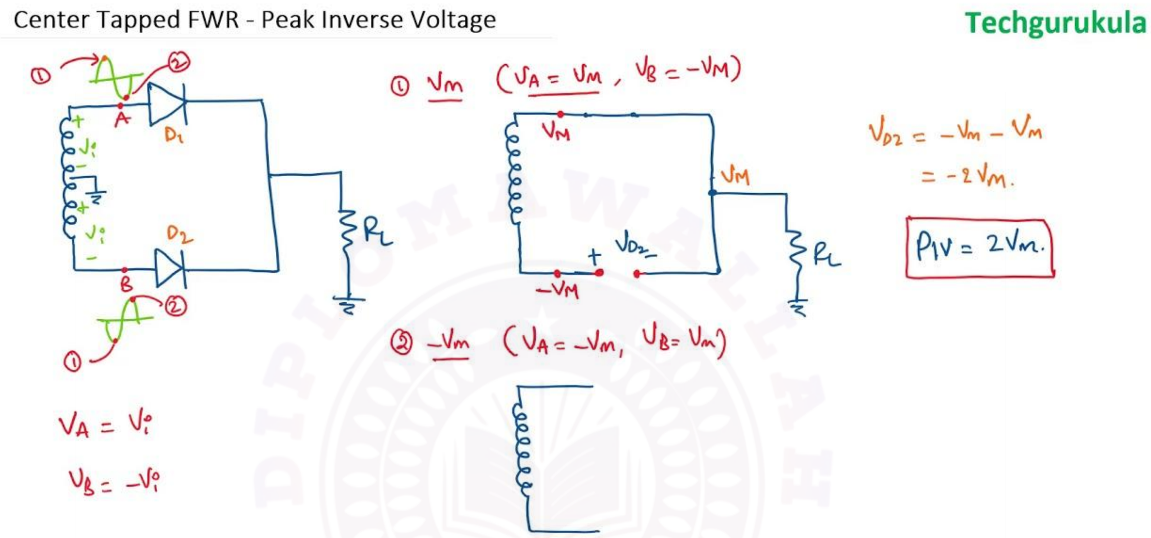
1.2 Centre-Tapped Full-Wave Rectifier (CT FWR)


A
D1
AC Supply
C
L
RL
M
Vout
-
+
B
D2
©Elprocus.com


D1
A
AC Supply
C
L
RL
M
Vout
-
+
B
D2
Circuit Globe


Vin
Voltage across
AC or BC
t
Current through RL
I
D1
D2
D1
D2
t
Voltage across RL
Vout
t
Circuit Globe





$$\text{PIV} = \left(\frac{V_{p(sec)}}{2} - 0.7\text{ V}\right) - \left(-\frac{V_{p(sec)}}{2}\right) = \frac{V_{p(sec)}}{2} + \frac{V_{p(sec)}}{2} - 0.7\text{ V}$$

$$= V_{p(sec)} - 0.7\text{ V}$$

Since $V_{p(out)} = V_{p(sec)}/2 - 0.7\text{ V},$

$$V_{p(sec)} = 2V_{p(out)} + 1.4\text{ V}$$

Circuit & Working

- In a centre-tapped full-wave rectifier, the secondary winding of a transformer is tapped at its centre. Two diodes are connected such that during the positive half-cycle one diode conducts via upper half of winding, and during negative half-cycle the other diode conducts via the lower half of winding. The load current flows in the same direction during both halves.

- Thus both halves of the input AC waveform are used (unlike in half-wave). (Basic Electronics Tutorials)

Key Performance Parameters

- **Average (DC) output voltage** (V_{\text{DC}}): For ideal case (ignoring losses) approximately:
  [
  V_{\text{DC}} = \frac{2V_{m}}{\pi}
  ]
  where (V_{m}) is the peak voltage of one half-winding.
  (GeeksforGeeks)
- **Efficiency (\eta)**: For ideal CT full-wave rectifier:
  [
  \eta_{\max} \approx 81.2% \quad (\approx 0.812)
  ]
  (BYJU'S)
- **Ripple factor (\gamma)**: For full-wave rectifier:
  [
  \gamma \approx 0.48
  ]
  (physics-and-radio-electronics.com)
- **Peak-Inverse-Voltage (PIV)**: For the centre-tapped version each diode sees twice the half-winding peak in the non-conducting half cycle. So PIV for each diode:
  (Because when one half conducts, the other end goes negative etc).

Advantages & Disadvantages

- *Advantages*: Higher efficiency (~81%), lower ripple (γ ~0.48) so simpler filtering needed, better utilization of input waveform.
- *Disadvantages*: Requires centre-tapped transformer (which is larger/expensive), each diode sees higher PIV (twice half winding) so diode rating must be higher, bigger transformer size for same output voltage.

1.3 Summary Comparison

Parameter	Half-Wave Rectifier	Centre-Tapped Full-Wave Rectifier
Uses available AC halves	1 half only	Both halves
Maximum Efficiency η	~ 40.6 %	~ 81.2 %
Ripple Factor γ	~ 1.21	~ 0.48
PIV for each diode	~ (V_{m})	~ (2V_{m,half})
Transformer Utilization	Poor	Better, but requires centre-tap winding

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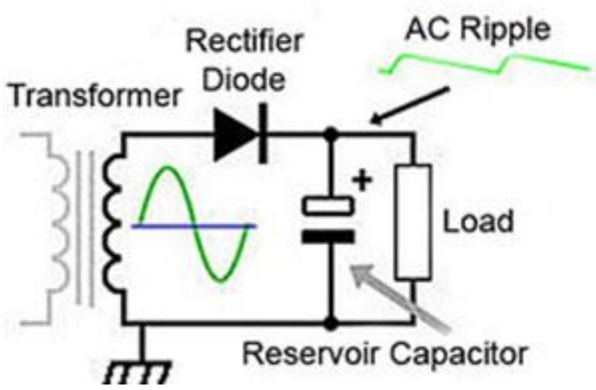
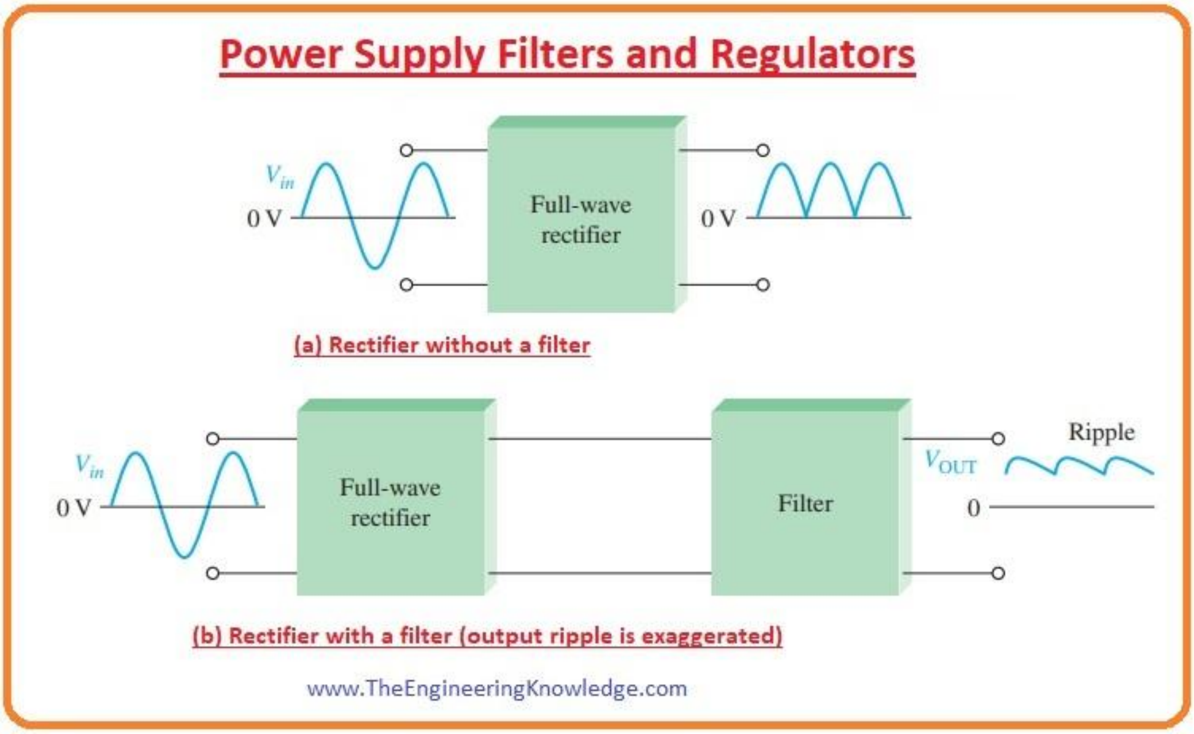
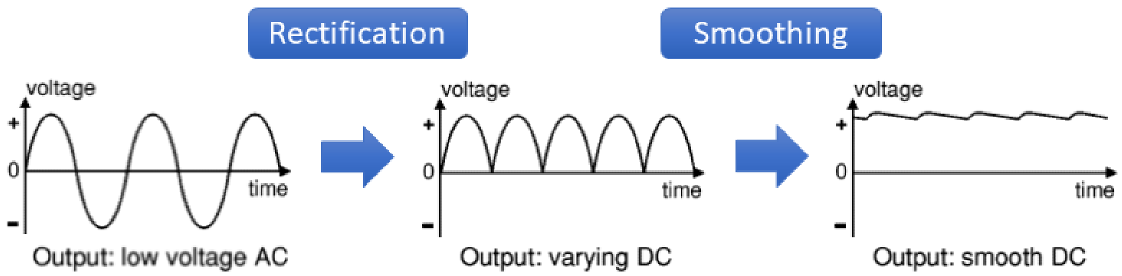
1.5 Exam-Style Notes

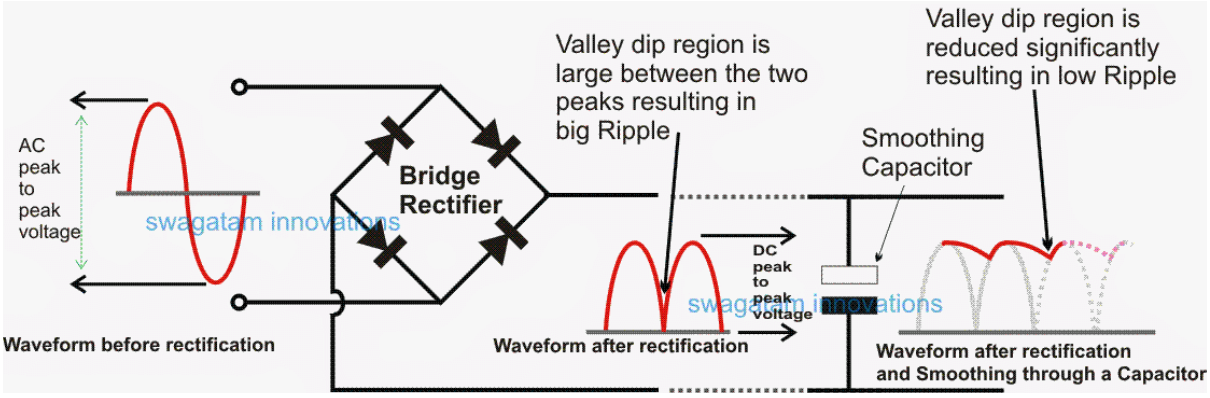
- A rectifier converts AC to pulsating DC by making current flow in one direction.
- In the half-wave rectifier only one half of the input waveform is used; so lots of wasted energy and large ripple.
- In the centre-tapped full-wave rectifier both halves are used; that improves DC output, reduces ripple, and makes filtering easier.
- Ripple factor is a measure of the "rippliness" of the DC output: lower is better.
- Efficiency tells how well input AC power is converted to DC usable output. Higher efficiency is better.
- PIV is the stress the diode sees in reverse bias; if diode rating is insufficient the device may fail. Always consider PIV when choosing diodes.
- In exam answers: define the circuit, show waveform, derive/quote key parameters (η, γ, PIV), list pros & cons.

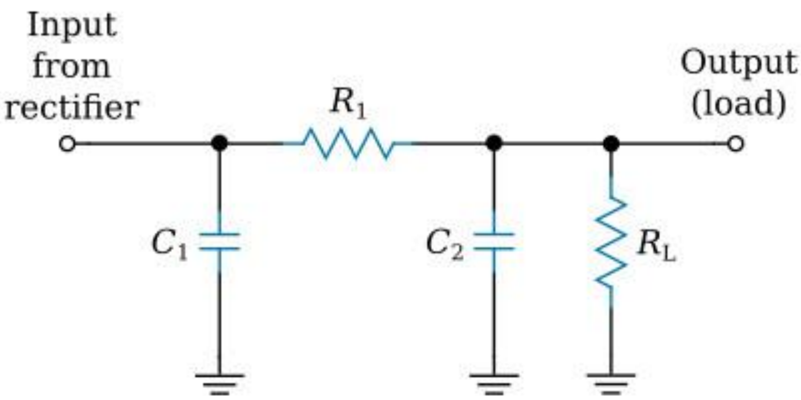
Filters – Definition & Necessity

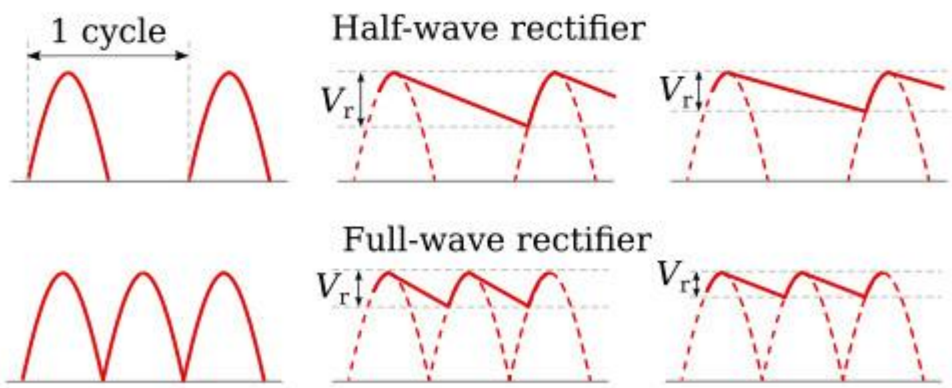

Rectifier
Diode
AC Ripple
Transformer
+
Load
Reservoir Capacitor


Power Supply Filters and Regulators
V in
0 V
Full-wave rectifier
0 V
(a) Rectifier without a filter
V in
0 V
Full-wave rectifier
Filter
V OUT
0
Ripple
(b) Rectifier with a filter (output ripple is exaggerated)
www.TheEngineeringKnowledge.com

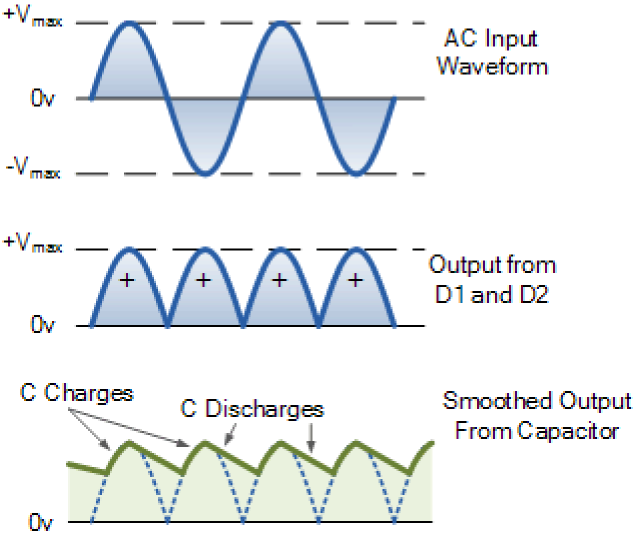

Rectification
Smoothing
voltage
+
0
-
time
Output: low voltage AC
voltage
+
0
-
time
Output: varying DC
voltage
+
0
-
time
Output: smooth DC







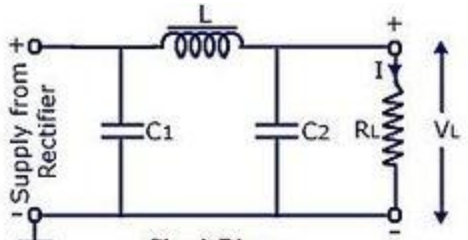
(A) Unfiltered output from rectifier (B) Voltage across capacitor C_1 (C) Voltage across capacitor C_2



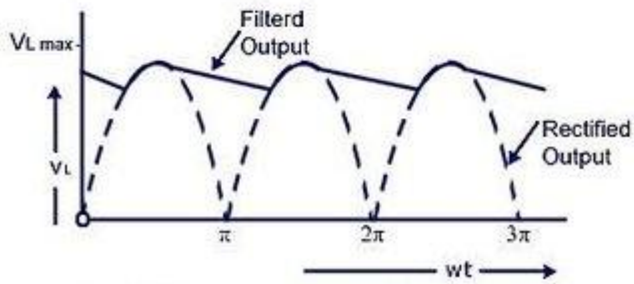
Definition: A filter in a power supply context is a circuit (usually comprising capacitors and/or inductors) that removes or significantly reduces the AC ripple component from the pulsating DC output of a rectifier, thereby supplying a smoother DC voltage to the load.
Necessity: After rectification, the output is *pulsating DC* (with peaks and valleys). Many electronic circuits require as steady-as-possible DC (for e.g., logic circuits, analog amplifiers). Without filtering:

- The ripple voltage may cause unstable operation or noise in circuits.
- The effective DC voltage is lower because of the dips.
  So we insert a filter stage after the rectifier (and before regulation, or sometimes in unregulated supplies) to smooth the output. (Wikipedia)

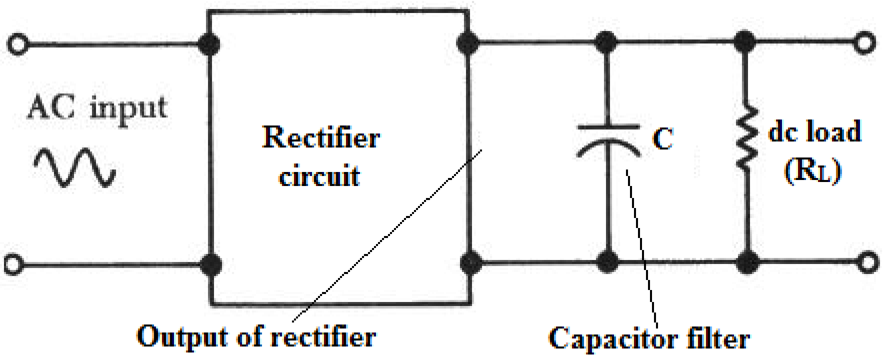
C-Filter (Capacitor-Input Filter)

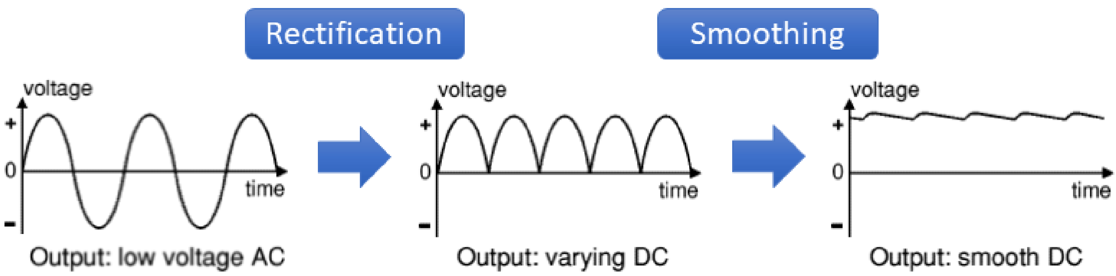


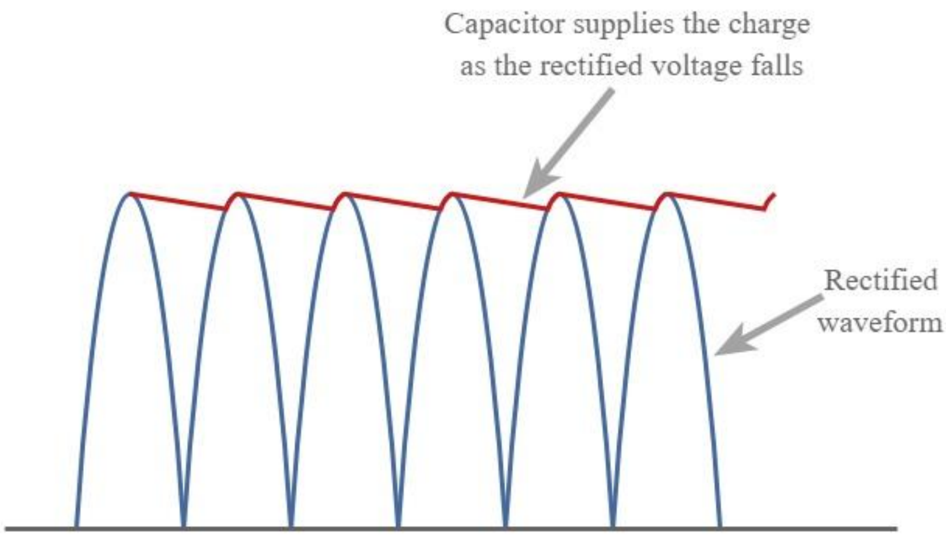
Circuit Diagram

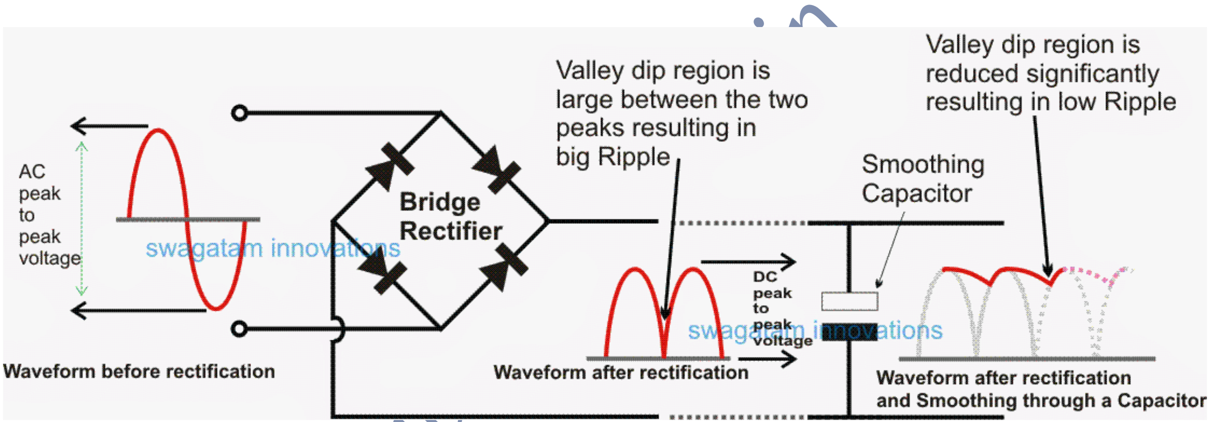


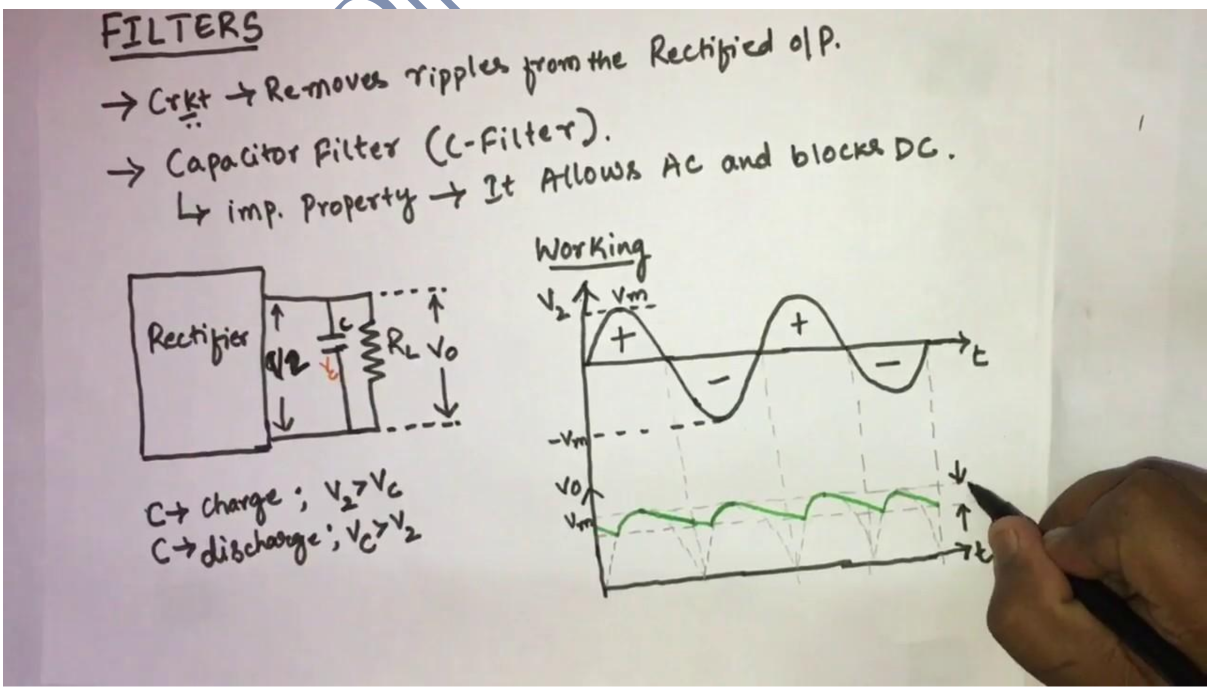
Rectified and Filtered Output Voltage Waveform
Full Wave Rectifier with Capacitor Input Filter






Capacitor supplies the charge
as the rectified voltage falls
Rectified
waveform

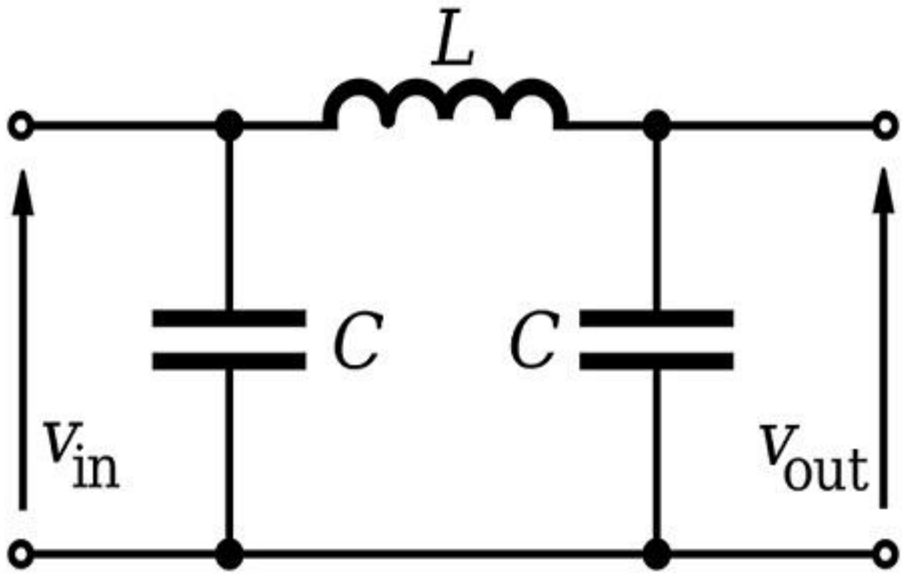

AC
peak
to
peak
voltage
Bridge
Rectifier
Valley dip region is
large between the two
peaks resulting in
big Ripple
Valley dip region is
reduced significantly
resulting in low Ripple
Smoothing
Capacitor
DC
peak
to
peak
voltage
swagatam innovations
Waveform before rectification
Waveform after rectification
Waveform after rectification
and Smoothing through a Capacitor

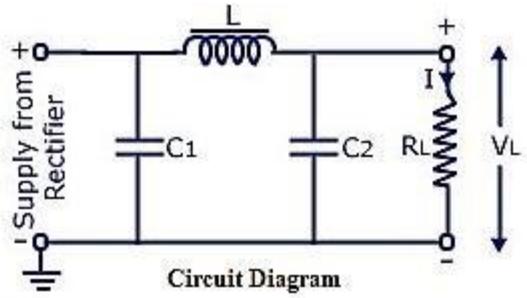

FILTERS
→ Ckt → Removes ripples from the Rectified o/P.
→ Capacitor Filter (C-Filter).
↳ imp. Property → It Allows AC and blocks DC.
Working
Rectifier
C
RL
Vo
C→ charge ; V2>Vc
C→ discharge ; Vc>V2

Structure: After the rectifier, a large capacitor is connected in *parallel* with the load (i.e., across the output).
Working:

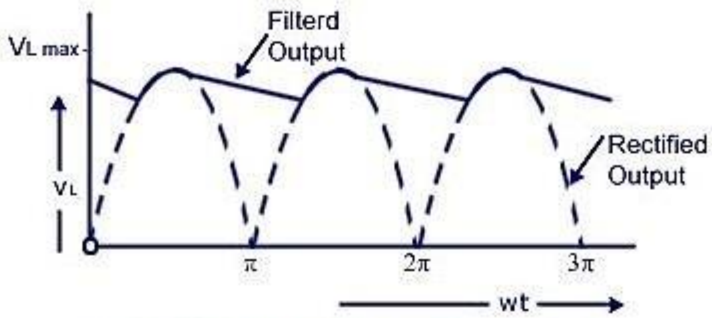
- During each conduction interval of the rectifier the capacitor charges up to near the peak of the rectified waveform.
- During the non-conduction interval, the capacitor discharges into the load, thus "filling in" the valleys and keeping the voltage from dropping significantly until the next charging interval.
- The result is a DC output with superimposed small ripple (ideally very small if capacitor is large and load current low). (Wikipedia)
  Key Points:
- Ripple voltage magnitude depends inversely on capacitance and directly on load current and time between re-charges.
- The "reservoir" capacitor must have sufficient voltage rating (peak + margin) and low ESR for good smoothing.
- The filter does *not* remove 100% ripple; heavy loads or insufficient capacitor lead to residual ripple.
- It is simple and inexpensive.
  Limitations:
- For high load current, large capacitor size and cost increase.
- With very large currents, other filter types or regulator stages may be needed.
- The capacitor must withstand the ripple and surge currents.

Π (Pi)-Filter

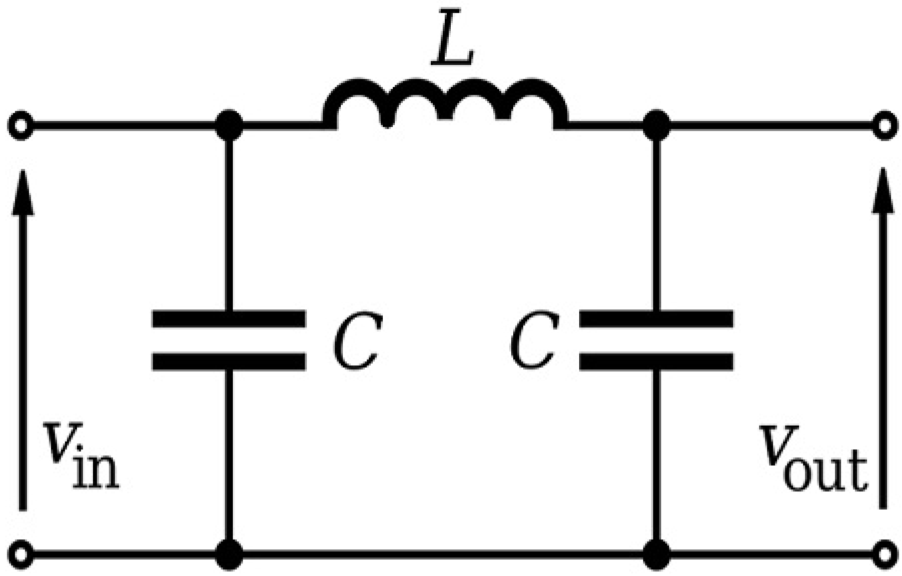




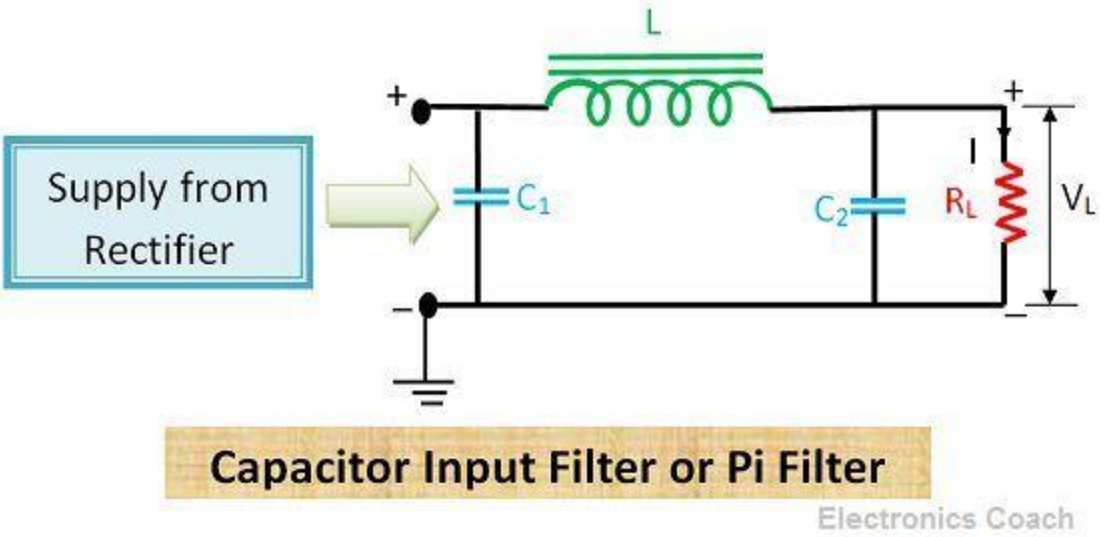
Circuit Diagram



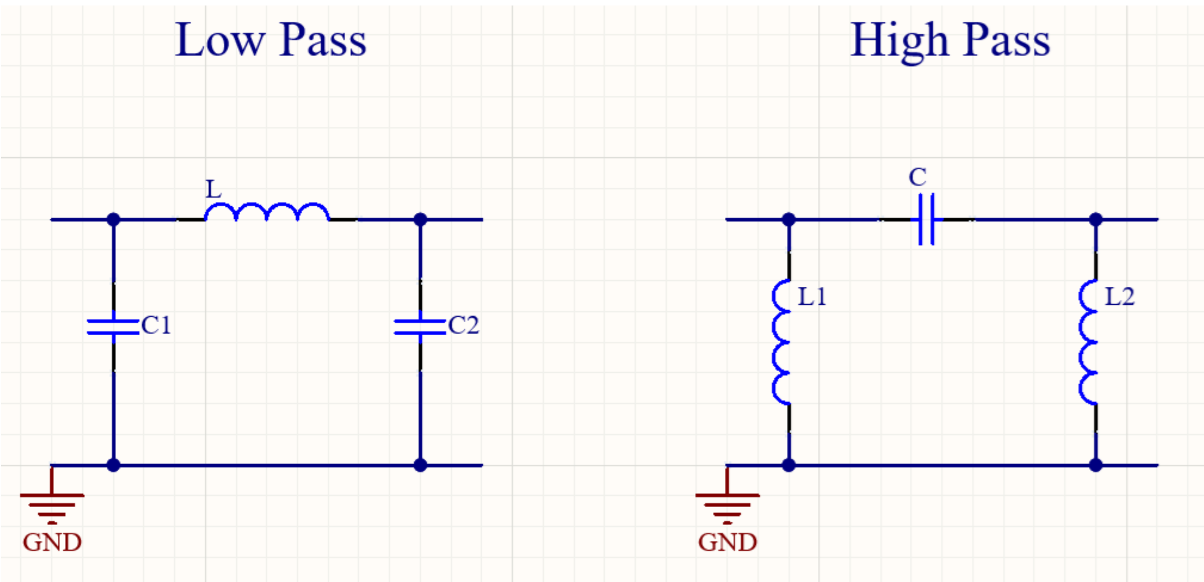
Rectified and Filtered Output Voltage Waveform
Full Wave Rectifier with Capacitor Input Filter



L
C
C
V_{in}
V_{out}



Supply from Rectifier
L
C1
C2
RL
I
VL
+
−
Capacitor Input Filter or Pi Filter
Electronics Coach



Low Pass
High Pass
L
C1
C2
GND
C
L1
L2
GND

Structure: The type called "Π-filter" is so named because its arrangement resembles the Greek letter "π":

- First a capacitor connected from the rectifier output to ground (shunt).
- Then a series inductor (or choke) feeding the load.
- Then another capacitor from load side to ground (shunt). (DIYguru)

Working:

- The first capacitor smooths the bulk of ripple output from rectifier.
- The inductor (choke) resists changes in current (thus opposing ripple current).
- The second capacitor further smooths any residual ripple that passes the inductor.
- Overall result: much better ripple rejection and smoother DC than simple C-filter. (Cadence PCB Resources)

Advantages:

- Lower ripple for given load and capacitance/inductance values.
- Better performance for heavier loads or where very smooth DC is required.

Considerations/Limitations:

- More components (inductor cost/size) compared to simple capacitor-input filter.
- Inductor adds impedance and can cause voltage drop if DC current is high; design must account for series resistance and saturation of choke.
- Space and cost may increase.

Design Basics (for power supply filters):

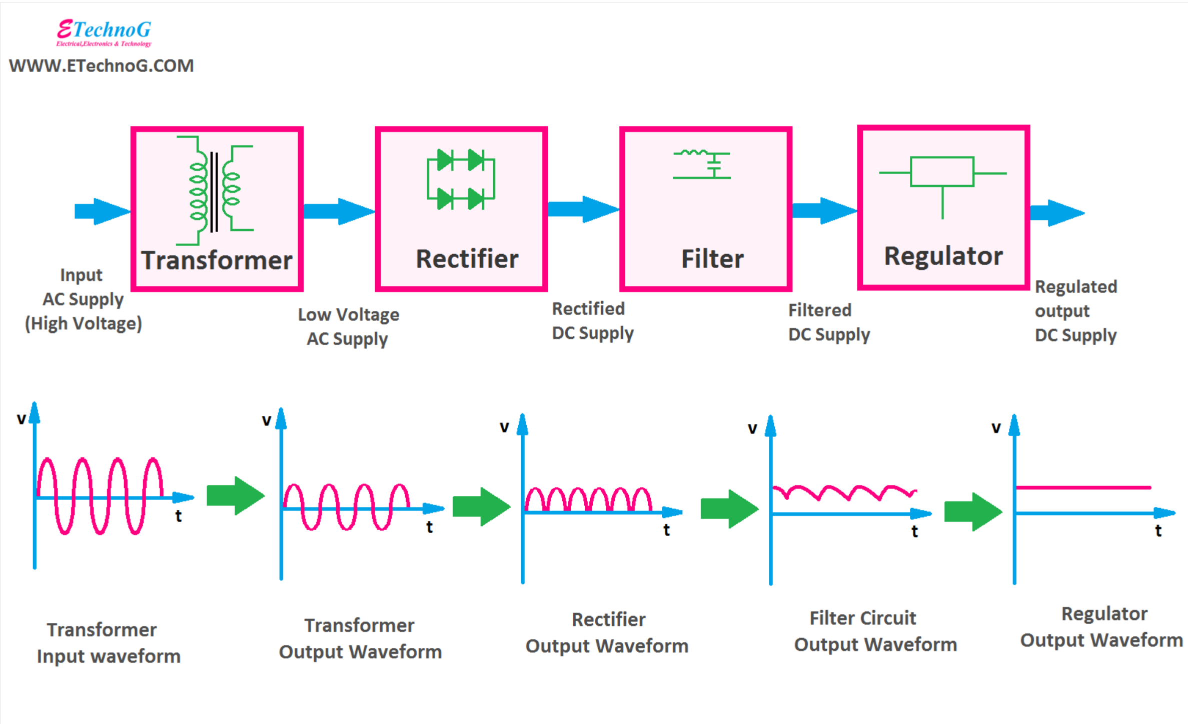
- Choose capacitor values so that ripple is within acceptable limits.
- Choose choke so that its DC resistance is low (to minimize voltage drop), but ripple current is opposed.

- Design second capacitor to absorb residual ripple. Formulas and selection guidelines are available. (Altium)

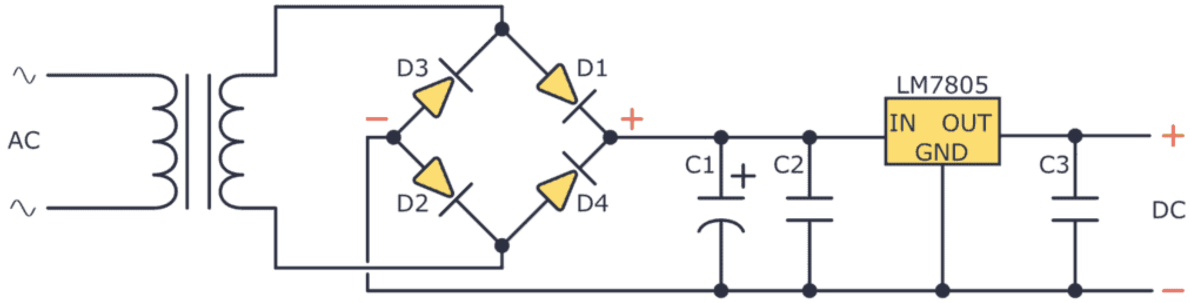
Summary – Comparison & When to Use What

- If load current is moderate and cost/size must be minimal → C-filter is often sufficient.
- If load current is larger, or ripple must be very small (for audio, precision circuits) → Π-filter is better.
- In both cases, after filtering often comes a regulator if even tighter voltage control is required.
- Choice depends on load current, acceptable ripple magnitude, cost, size, and whether subsequent regulation is present.

Regulated Power Supply



Regulated Power Supply Block Diagram



1. Block Diagram & Operation

1.1 Block Diagram

A typical regulated power supply consists of four major blocks:

1. **Step-down transformer**: Reduces the mains AC voltage to a lower AC voltage appropriate for the subsequent stages. (ElProCus)
2. **Rectifier**: Converts the reduced AC voltage into a pulsating DC voltage (either using half-wave, full-wave, bridge etc). (ques10.com)
3. **Filter**: Removes most of the AC ripple component from the pulsating DC to provide a smoother DC voltage. (Electrical 4U)
4. **Voltage regulator**: Maintains the DC output at a fixed, stable value despite variations in input voltage, load current, or temperature. (TutorialsPoint)

1.2 Working Principle

- The mains AC is first stepped down, then rectified → gives unregulated DC which still varies with mains and load.
- The filter smooths out the major ripple and provides a more stable DC.
- The regulator monitors the output and adjusts (via a pass-element, feedback loop or IC) to keep the output voltage constant. For example, if load increases and output tends to drop, the regulator increases conduction to maintain voltage; if input rises, it reduces conduction or adjusts accordingly. (Keysight Documentation)
- The result is a **constant DC voltage** which is independent (within limits) of input or load changes. (Electrical 4U)

1.3 Why we need it

- Many electronic devices (logic circuits, microcontrollers, analog amplifiers) require a stable DC voltage; variations cause malfunction or distortion.
- An unregulated supply would result in output changes when mains changes or load varies → unstable operation. (talkingelectronics.com)
- Hence, regulated supplies ensure reliable performance and protect circuits from supply fluctuations.

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2. Applications of Regulated Power Supplies

Regulated power supplies are used widely where stable voltage is required. Examples include:

- Bench power supplies and laboratory equipment where variable, stable DC is required. (Wikipedia)
- Audio amplifiers, oscillators, communication equipment – where ripple or voltage drift would degrade performance. (TutorialsPoint)
- Digital logic circuits and microcontroller systems where supply voltage variation may cause logic errors or resets.
- Instrumentation, measuring devices, automation systems – need accurate, stable DC.

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3. Regulators – Working of Specific ICs & Types

3.1 78xx / 79xx Series (Fixed Linear Regulators)

- **78xx** series: Positive fixed regulators (e.g., 7805 outputs +5 V, 7809 outputs +9 V, 7812 outputs +12 V).
- **79xx** series: Negative fixed regulators (e.g., 7905 outputs −5 V, 7912 outputs −12 V).
  These ICs provide a fixed regulated output when their input voltage is sufficiently higher than the required output and they are properly decoupled/filtered.

- For example: The IC 7805 provides +5 V output. Typical input might be ≥ ~7 V.
- Similarly: 7809 → +9 V, 7812 → +12 V, 7905 → −5 V, 7912 → −12 V.
  These are commonly used three-terminal regulators.

3.2 Working of 7805 (Example)

- It includes a reference voltage, internal error amplifier, pass transistor and protective features (thermal shutdown, current limit).
- It maintains the output at +5 V by sensing the output, comparing with the internal reference, and adjusting the pass transistor conduction accordingly.
- External capacitors on input and output are recommended for stability and transient response.

3.3 Op-amp/IC Regulators (e.g., LM723)

- The LM723 is an example of a more flexible regulator IC: it has an internal reference, error amplifier, and can be used for fixed or variable output, positive or negative supplies, and with external pass transistors for higher current.
- It offers more adjustability compared to the fixed 78xx series.

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4. Testing and Troubleshooting of Regulated Power Supply

When a regulated power supply is not performing correctly (voltage drifting, high ripple, unable to supply current, overheating), follow a systematic approach:

4.1 Visual & Initial Checks

- Verify all connections, component orientation (diodes, ICs).
- Check for visibly damaged components – bulged caps, burnt traces, overheated parts.
- Ensure heat-sink is properly mounted, regulator/txn is not overheated.

4.2 Check Stage by Stage

- **Transformer output**: Measure AC secondary voltage (no load). Should be as expected.
- **Rectifier + Filter**: Measure DC at filter output (before regulator). Check magnitude and ripple. If large ripple, filter capacitor might be weak or wrong value.
- **Regulator input vs output**: Measure regulator input voltage (should be above dropout threshold) and regulator output. If input is too low, output can't regulate.
- **Load test**: Apply expected load current and verify the output still stays within tolerance. If it sags or drops, regulator or pass transistor or thermal issue may be present.
- **Ripple/noise**: Use an oscilloscope to check ripple on output. Excessive ripple indicates filter or regulator problem.

4.3 Specific Fault Symptoms & Causes

- **Output voltage too low or sagging under load**: Insufficient input voltage, series resistance high, pass transistor under-rating, filter capacitor bad.
- **Output fluctuates with input mains**: Poor regulation, faulty regulator, incorrect feedback path, weak reference.
- **High ripple on output**: Filter stage failing, capacitor aging (electrolytic ESR increased), high load current, poor decoupling on regulator input.
- **Overheating regulator or transistor**: Excess power dissipation (large difference between input & output voltage × current), insufficient heat-sink, thermal protection kicking in.
- **No output**: Could be fuse blown, transformer secondary open, diodes open/shorted, regulator protection active, short at output.

4.4 Preventive Checks & Maintenance

- Replace aging electrolytic capacitors (they lose capacitance and increase ripple).
- Ensure correct heatsinking and ventilation for regulators.
- Confirm component ratings (diodes, caps, transformer) are as required for load.

- Periodically check output under load and monitor output drift with temperature or mains variation.

5. Summary

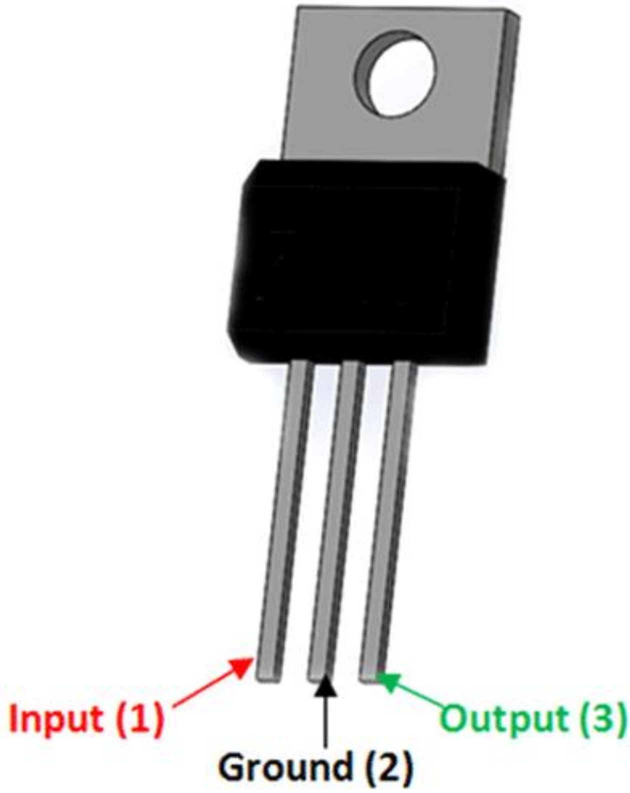
- A regulated power supply takes AC → steps down → rectifies → filters → regulates to produce a stable DC output.
- Regulation is essential for electronic circuits requiring stable voltage under varying input/load conditions.
- Fixed regulators (78xx/79xx), and more flexible ICs (LM723) are commonly used.
- Thorough testing/troubleshooting requires stage-by-stage checking of transformer, rectifier, filter, regulator, and verifying load/thermal behaviour.

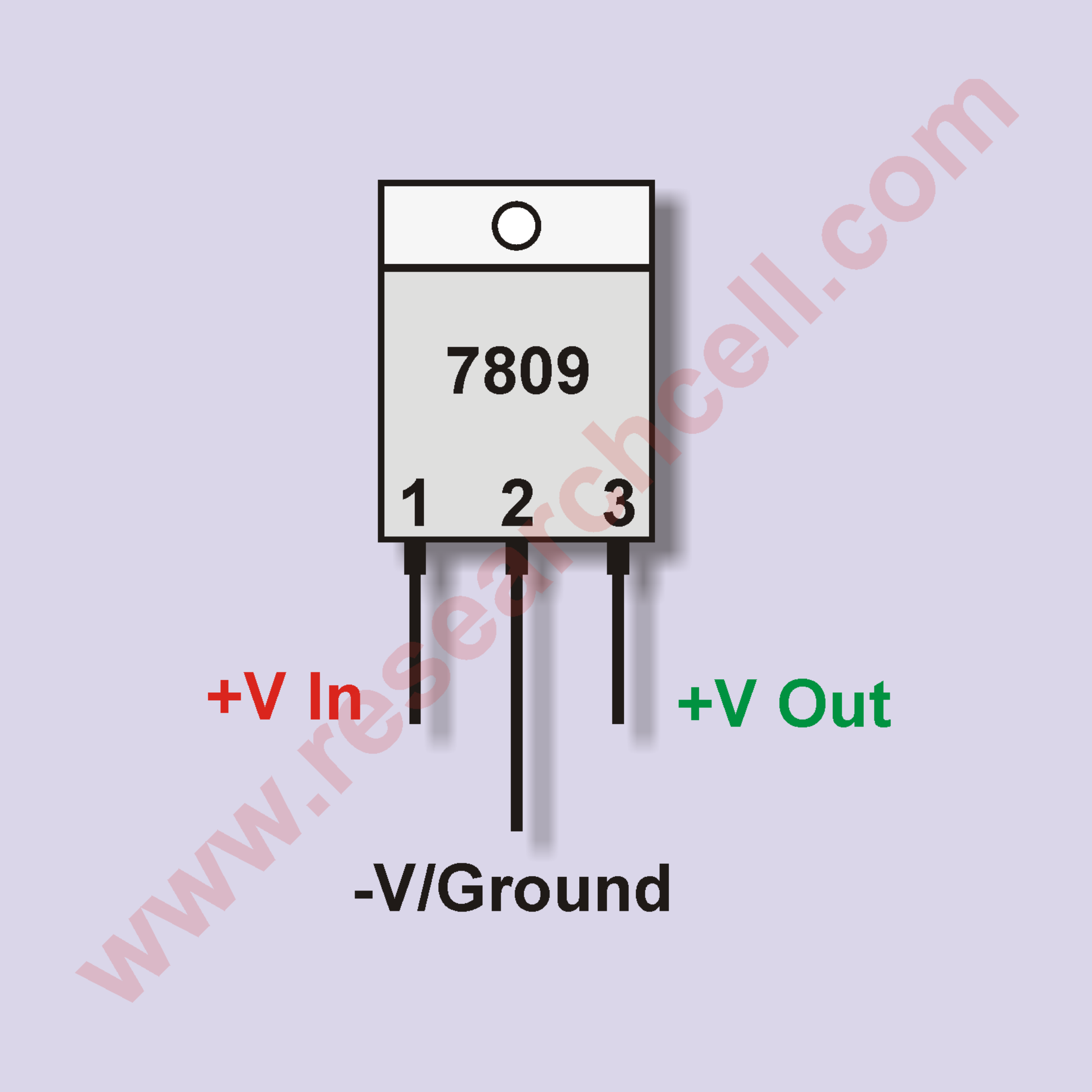
Fixed Linear Regulator ICs: 7809, 7812, 7905, 7912

What they are

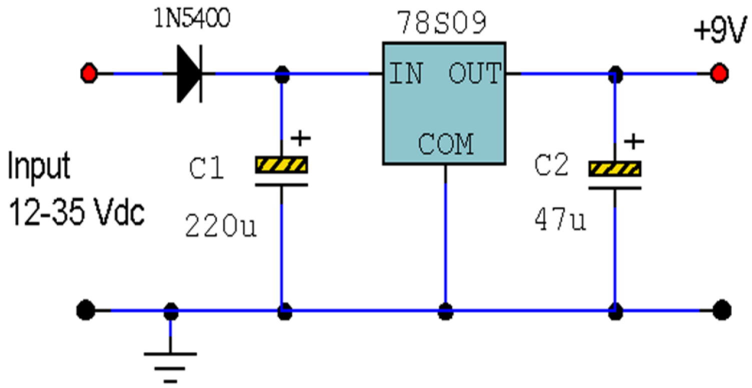
- The "78xx" series are **positive fixed-voltage** linear regulator ICs. For example, 7809 outputs +9 V, 7812 outputs +12 V. (STMicroelectronics)
- The "79xx" series are **negative fixed-voltage** linear regulator ICs. For example, 7905 outputs -5 V, 7912 outputs -12 V.
- They are three-terminal devices (Input, Ground/Common, Output) and provide a regulated voltage when the input is higher than the required output by a margin (drop-out voltage), and when heat sinking is adequate.

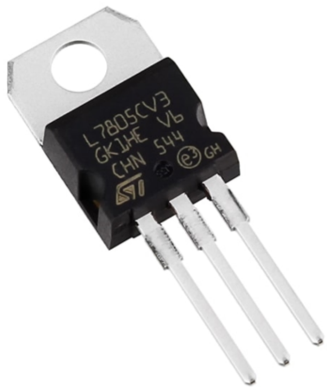
Example: 7809 (+9 V regulator)

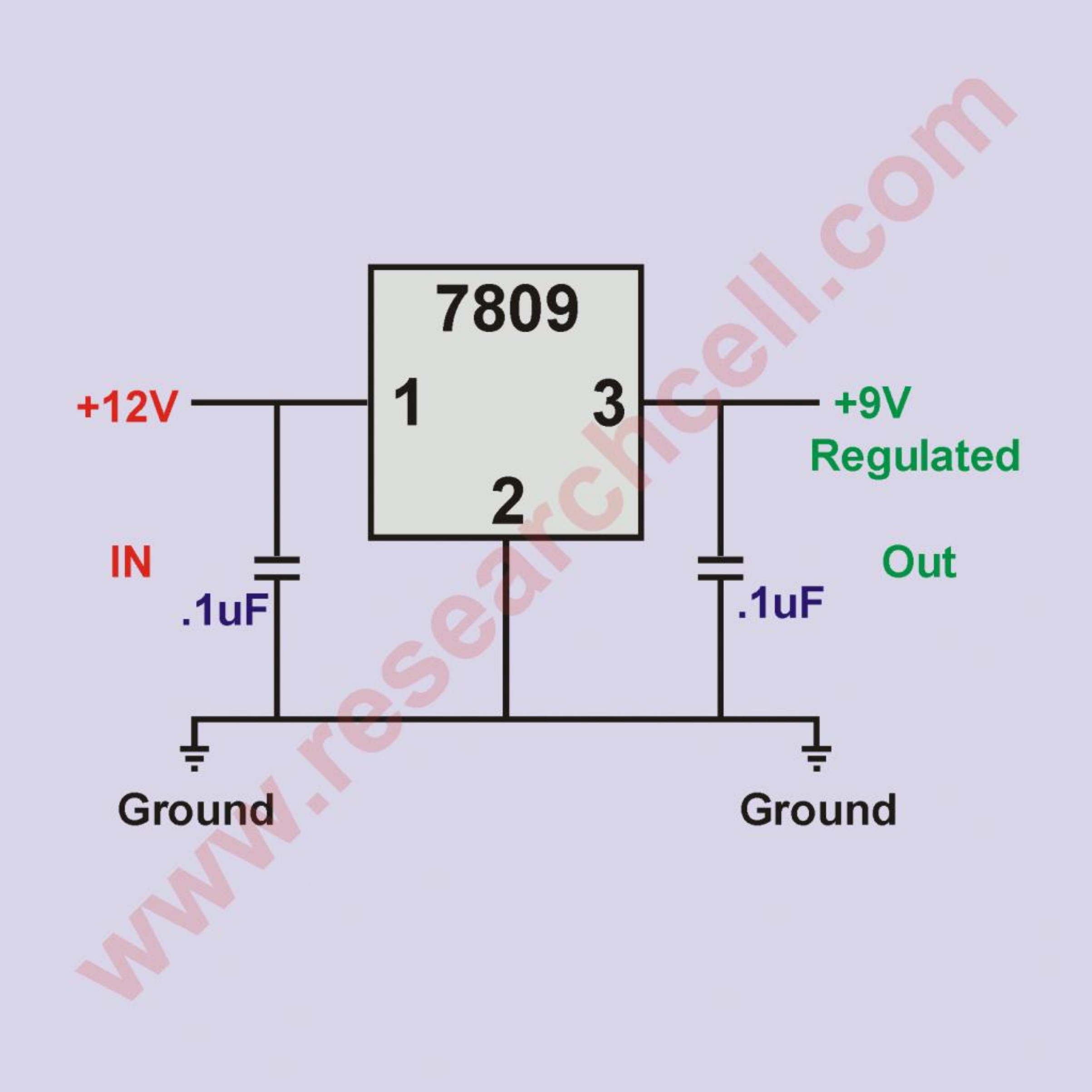

Input (1)
Ground (2)
Output (3)


7809
1
2
3
+V In
+V Out
-V/Ground
www.researchcell.com

9V 2A Power Supply






7809
+12V
1
3
+9V
Regulated
2
IN
.1uF
.1uF
Out
Ground
Ground
www.researchcell.com

7809

3-terminal 1 A positive voltage regulator

Features
- Output Current up to 1 A
- Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating Area Protection

1 Input 2 Common 3 Output
TO-220 Plastic Package

Absolute Maximum Ratings (T_a = 25 °C)

Parameter	Symbol	Value	Unit
Input Voltage	V_I	35	V
Thermal Resistance Junction-Cases	R_{thJC}	5	°C/W
Thermal Resistance Junction-Air	R_{thJA}	65	°C/W
Operating Temperature Range	T_{opr}	0 to + 125	°C
Storage Temperature Range	T_S	- 65 to + 150	°C

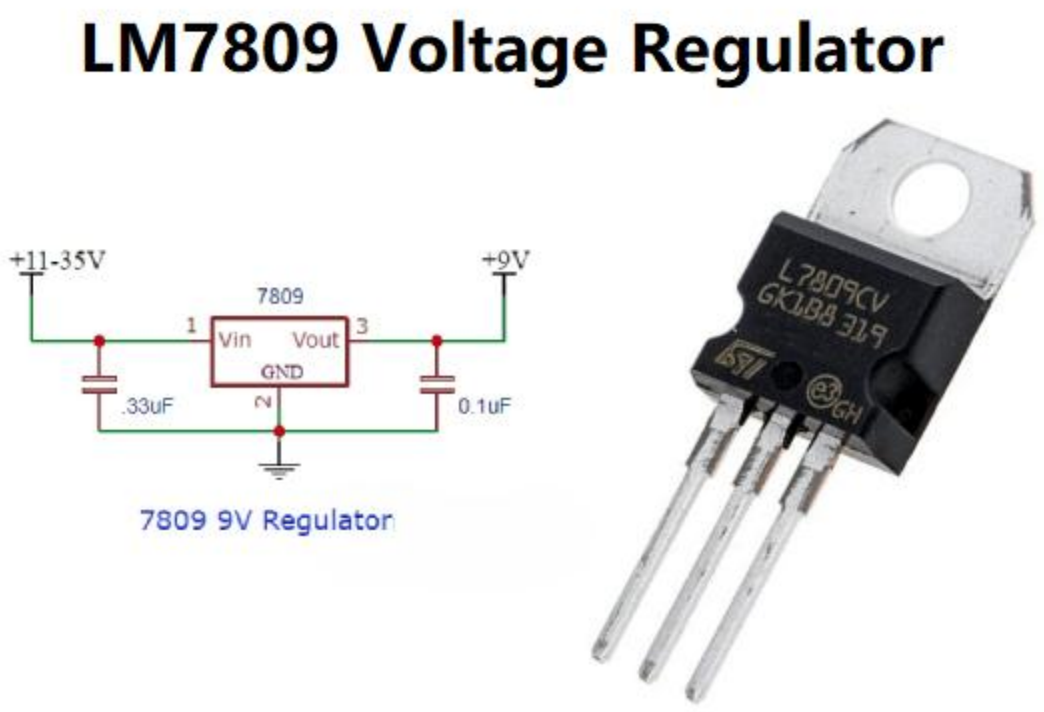
alldatasheet.com

[illegible] C_O = 0.1 μF, unless otherwise specified)

Parameter	Symbol	Test Conditions		Min.	Typ.	Max.	Unit
Output Voltage	V_O	[illegible]		8.65	9	9.35	V
		5 mA ≤ I_O ≤ [illegible], V_I = 11.5 V to 24 V		8.6	[illegible]	9.4	
Line Regulation *	Regline	T_J = 25 °C	V_I = 11.5 V to 25 V	[illegible]	[illegible]	[illegible]	mV
			V_I = 12 V to 17 V	-	-	[illegible]	
Load Regulation *	Regload	T_J = 25 °C	I_O = 5 mA to 1.5 A	-	-	180	mV
			I_O = 250 mA to 750 mA	-	-	90	
Quiescent Current	I_Q	T_J = 25 °C		-	-	8	mA
Quiescent Current Change	ΔI_Q	I_O = 5 mA to 1 A		-	-	0.5	mA
		V_I = 12 V to 26 V		-	-	1.3	
Output Voltage Drift	$\Delta V_O/\Delta T$	I_O = 5 mA		-	-1	-	mV/°C
Output Noise Voltage	V_N	f = 10 Hz to 100 KHz, T_A = 25 °C		-	58	-	μV
Ripple Rejection	RR	f = 120 Hz, V_I = 13 V to 23 V		56	-	-	dB
Dropout Voltage	V_{Drop}	I_O = 1 A, T_J = 25 °C		-	2	-	V
Output Resistance	R_O	f = 1 KHz		-	15	-	mΩ
Short Circuit Current	I_{SC}	V_I = 35 V, T_A = 25 °C		-	250	-	mA
Peak Current	I_{PK}	T_J = 25 °C		-	2.2	-	A

* Load and line regulation are specified at constant junction temperature. Changes in Vo due to heating effects must be taken into account separately. Pulse testing with low duty is used.

SEMTECH ELECTRONICS LTD.



Key specifications/features (for 7809) include:

- Output voltage: ~9 V. (Components101)
- Output current up to about 1 A (depending on model/heat-sink) in many cases. (ProtoSupplies)

- Input voltage must be higher than output + dropout margin (e.g., for 9 V output perhaps ~11 V minimum input) to maintain regulation. (Components101)
- Internal protections: thermal shutdown, current limiting (makes them robust). (alldatasheet.net)
- Pin-out (for TO-220 type): Pin 1 = Input, Pin 2 = Ground, Pin 3 = Output.

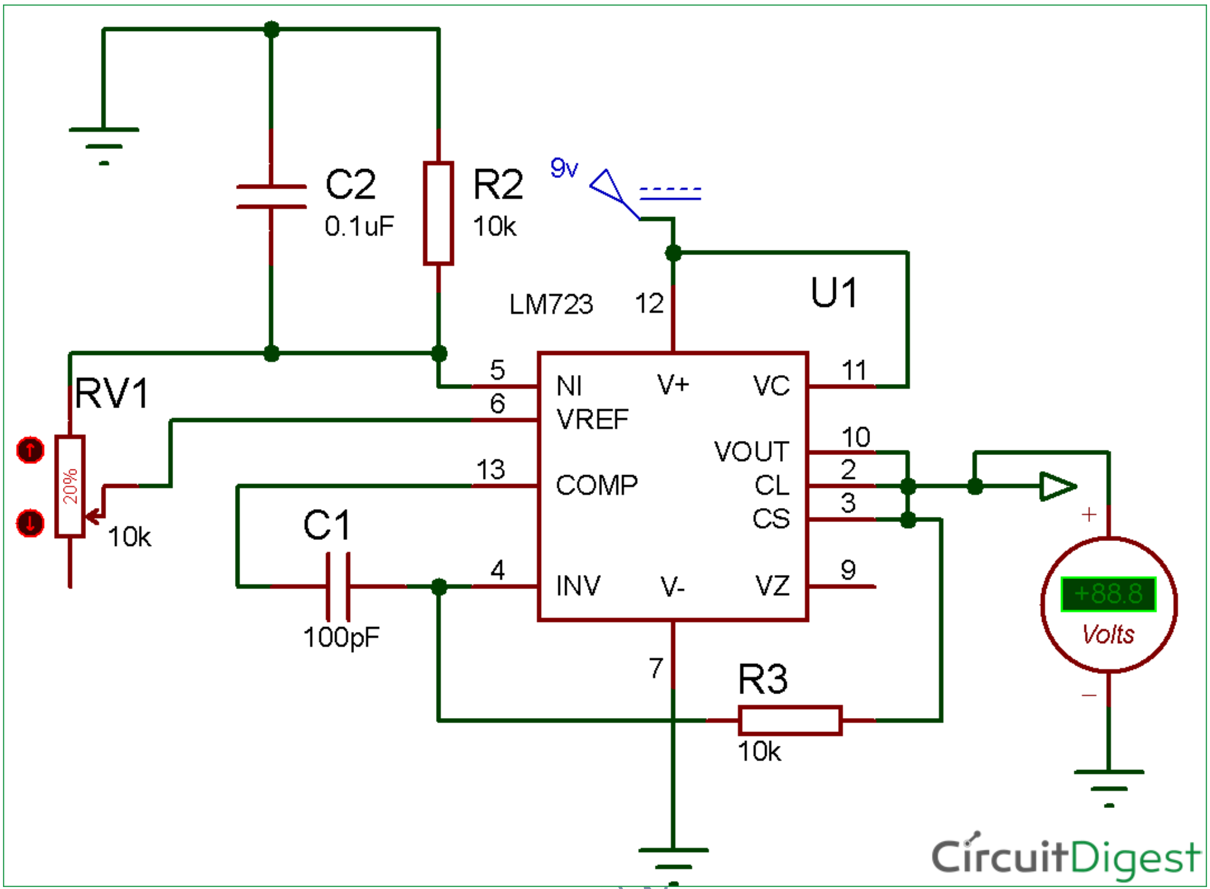
Other fixed regulators

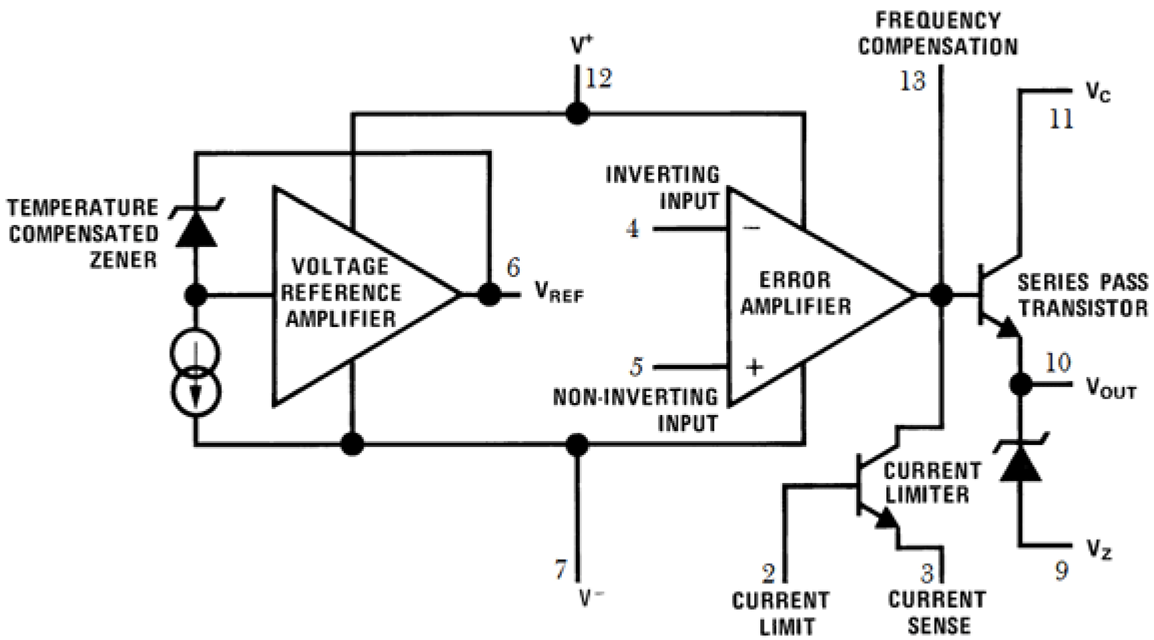
- 7812: +12 V output (positive)
- 7905: -5 V output (negative)
- 7912: -12 V output (negative)
  These cover common supply voltages in many analog/digital circuits (for example ±12 V rails).
  In the 78xx/79xx family, the first two digits "78" or "79" indicate positive/negative fixed regulator series, and the last two digits indicate the output voltage.

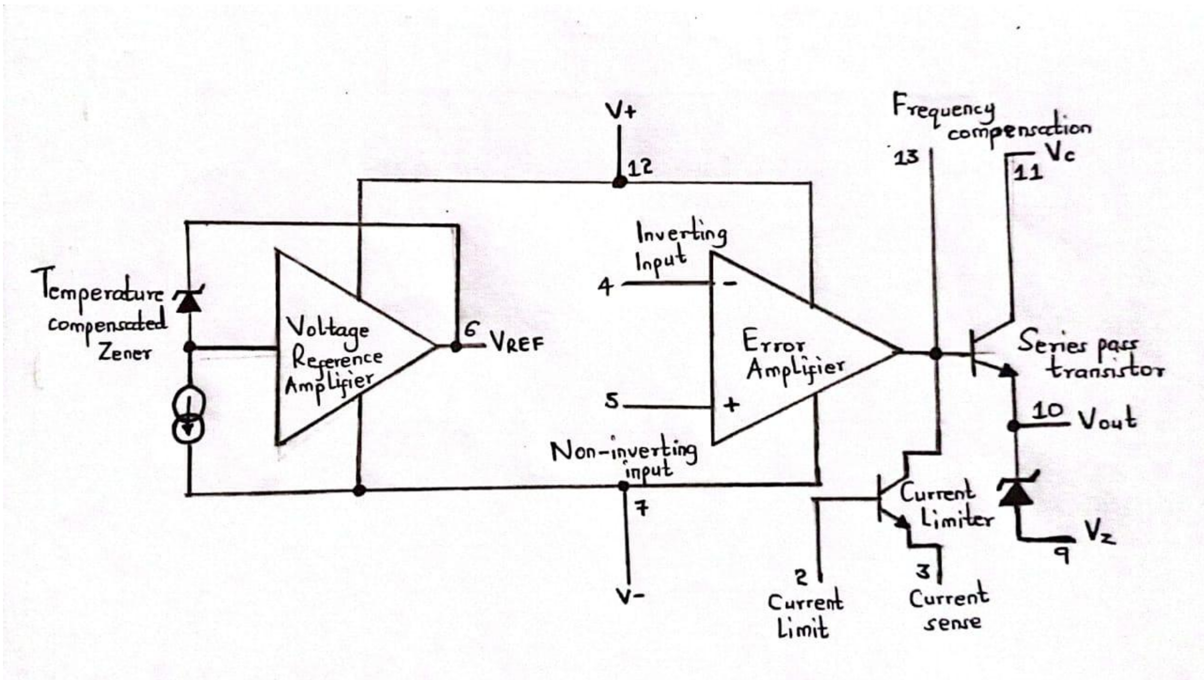
Usage tips / practical considerations

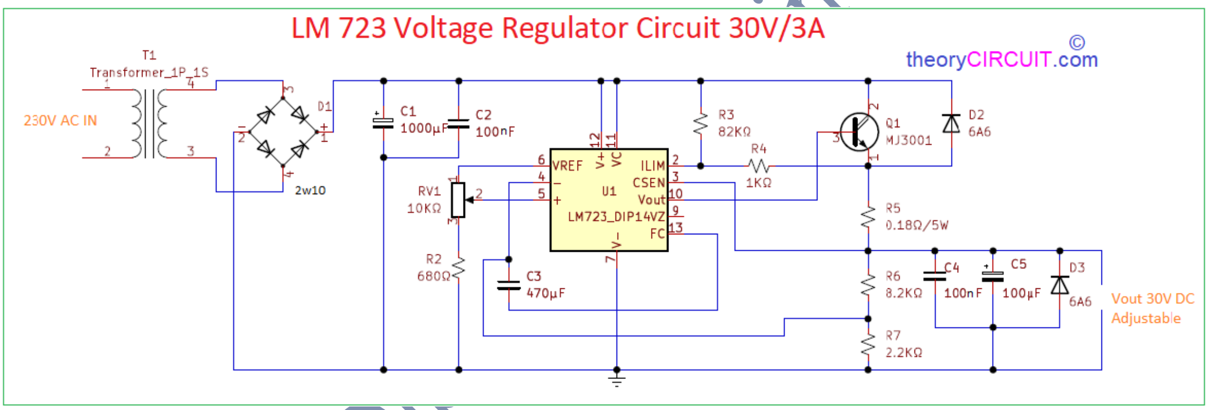
- Ensure **input-output difference** is adequate (drop-out voltage) so the regulator can maintain regulation.
- Use **input and output capacitors** (e.g., ~0.33 µF at input, ~0.1 µF at output) close to the IC to ensure stability and filter out transients.
- Heat-sinking: Because these are linear regulators, the power dissipated is ((V_{\text{in}} - V_{\text{out}}) × I_{\text{out}}). High difference or high current → high heat → risk of thermal shutdown or damage.
- Negative regulators (79xx) require correct polarity wiring (common/ground reference) and are used for negative rails.
- Regulation is good for many typical loads, but if load current is high (several amps) or input-output difference large, efficiency is poor (lots of heat). In those cases, other solutions (switching, pass transistor, etc) may be better.

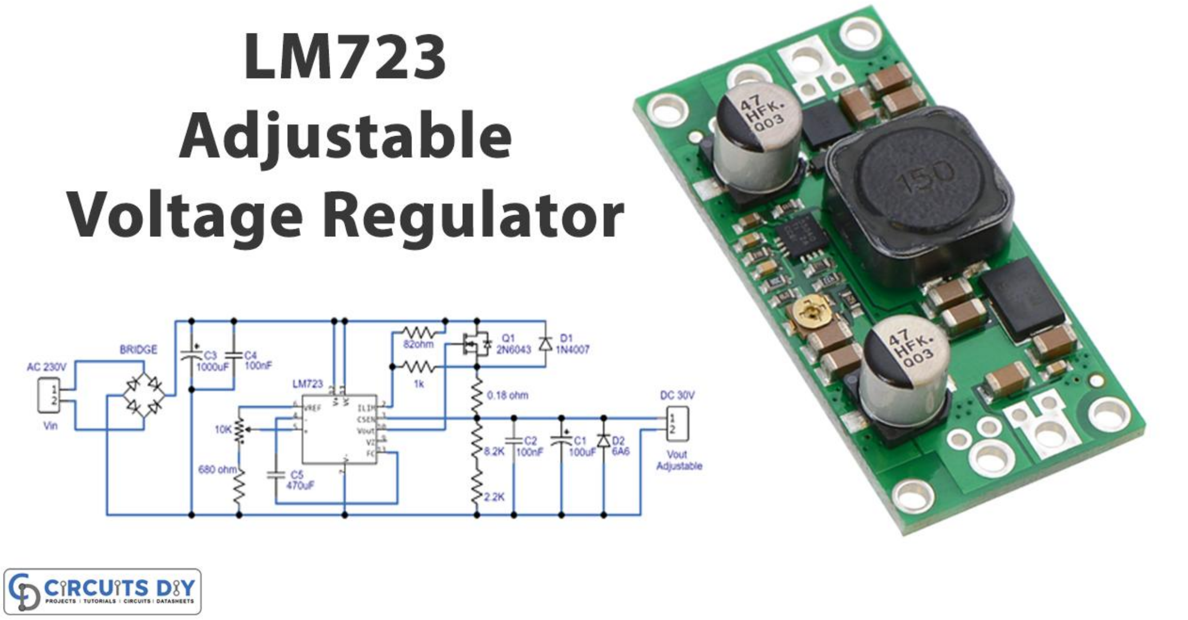
Op-Amp / Adjustable Regulator: LM723


C2
0.1uF
R2
10k
9v
LM723
12
U1
5
6
NI
VREF
V+
VC
11
RV1
20%
10k
13
COMP
VOUT
10
CL
2
CS
3
C1
100pF
4
INV
V-
VZ
9
7
R3
10k
+88.8
Volts
CircuitDigest


V+
12
FREQUENCY COMPENSATION
13
VC
11
TEMPERATURE COMPENSATED ZENER
VOLTAGE REFERENCE AMPLIFIER
6
VREF
INVERTING INPUT
4
ERROR AMPLIFIER
SERIES PASS TRANSISTOR
5
NON-INVERTING INPUT
10
VOUT
CURRENT LIMITER
7
V-
2
CURRENT LIMIT
3
CURRENT SENSE
VZ
9


V+
12
Frequency compensation
13
Vc
11
Inverting Input
4
Temperature compensated Zener
Voltage Reference Amplifier
6 VREF
Error Amplifier
Series pass transistor
5
10 Vout
Non-inverting input
7
Current Limiter
V-
2
Current Limit
3
Current sense
Vz
9


LM 723 Voltage Regulator Circuit 30V/3A
theoryCIRCUIT.com
T1
Transformer_1P_1S
230V AC IN
D1
2w10
C1 1000µF
C2 100nF
R3 82KΩ
R4 1KΩ
Q1 MJ3001
D2 6A6
RV1 10KΩ
VREF
U1
LM723_DIP14VZ
ILIM
CSEN
Vout
FC
R5 0.18Ω/5W
R2 680Ω
C3 470µF
R6 8.2KΩ
C4 100nF
C5 100µF
D3 6A6
Vout 30V DC Adjustable
R7 2.2KΩ


LM723
Adjustable
Voltage Regulator
AC 230V
Vin
BRIDGE
C3 1000uF
C4 100nF
LM723
82ohm
1k
Q1 2N6043
D1 1N4007
0.18 ohm
10K
680 ohm
C5 470uF
8.2K
2.2K
C2 100nF
C1 100uF
D2 6A6
DC 30V
Vout Adjustable
CIRCUITS DIY

What it is

- The LM723 is a general-purpose **programmable** voltage regulator IC. It includes an internal reference, error amplifier, current limit and can be used either by itself (for modest output current) or with external pass-transistors for higher currents. (mpja.com)
- It is often used when you need variable output voltage (e.g., 3 V to ~40 V), or positive/negative supply, or when more features (current limiting, fold-back, etc) are required. (Microcontrollers Lab)

Working/principle (simplified)

- The LM723 has an internal precision reference and error amplifier. The output (via series pass element) is compared (via feedback network) to the reference – the difference makes the transistor adjust the output to maintain regulation. (ElProCus)
- For higher current output, an external pass transistor (or several in parallel) is used; the LM723 controls the transistor's base/gate so that the output remains stable. (repeater-builder.com)
- Can be used for both positive and negative output depending on wiring.

Key specs / features

- Output voltage range: about 3 V up to ~37 V (depending on external components) with suitable input. (Circuit Digest)
- By itself, internal output can supply ~150 mA; with external transistor you can achieve much higher currents (e.g., several amps) depending on design. (Utmel)
- The device offers features like current limiting, over-voltage protection, good line/load regulation.
- Because it offers more flexibility, the LM723 is often used in bench power supplies, variable supplies, high-current regulated supplies, etc.

Usage / circuit considerations

- Design feedback resistor network carefully so that correct output voltage is maintained.

- Choose input (unregulated) voltage high enough above desired output (including margin) so regulator and pass transistor can operate in linear region.
- Power dissipation: The pass transistor/regulator will drop ($(V_{\text{in}} - V_{\text{out}}) \times I_{\text{out}}$) as heat – good heat-sink/thermal design needed.
- Stability: Add proper compensation capacitors; ensure layout minimises noise/oscillation.
- Filtering: Make sure input DC is sufficiently smooth (after rectifier & filter) before hitting regulator.
- For negative supplies, dual supply and correct polarity wiring is required.

Summary Table

Regulator	**Output Voltage**	**Polarity**	**Typical Max Current**	**Typical Drop-out/Input Margin**	**Notes**
7809	+9 V	Positive	~1 A (varies by package/heat sink)	Input ≥ ~11 V typical (for regulation)	Simple fixed regulator, low cost
7812	+12 V	Positive	~1 A typical	Similar margin requirement	Common for +12 V rails
7905	-5 V	Negative	~1 A typical	Input (negative side) must meet spec	Negative rail regulator
7912	-12 V	Negative	~1 A typical	As above	Negative rail for

					±12 V supplies
LM723	Variable (~3 – 37 V)	Positive/Negative (with configuration)	~150 mA internal, several A with external transistor	Depends on design & transistor	Flexible, used for adjustable/higher current supplies

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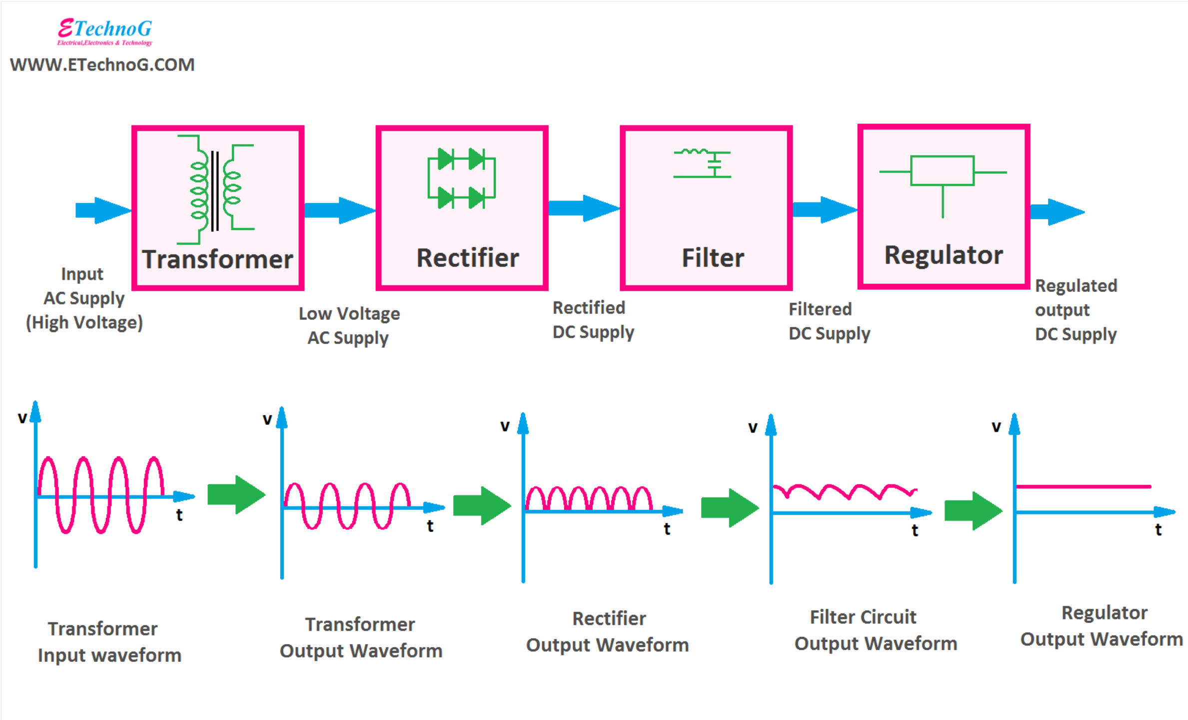
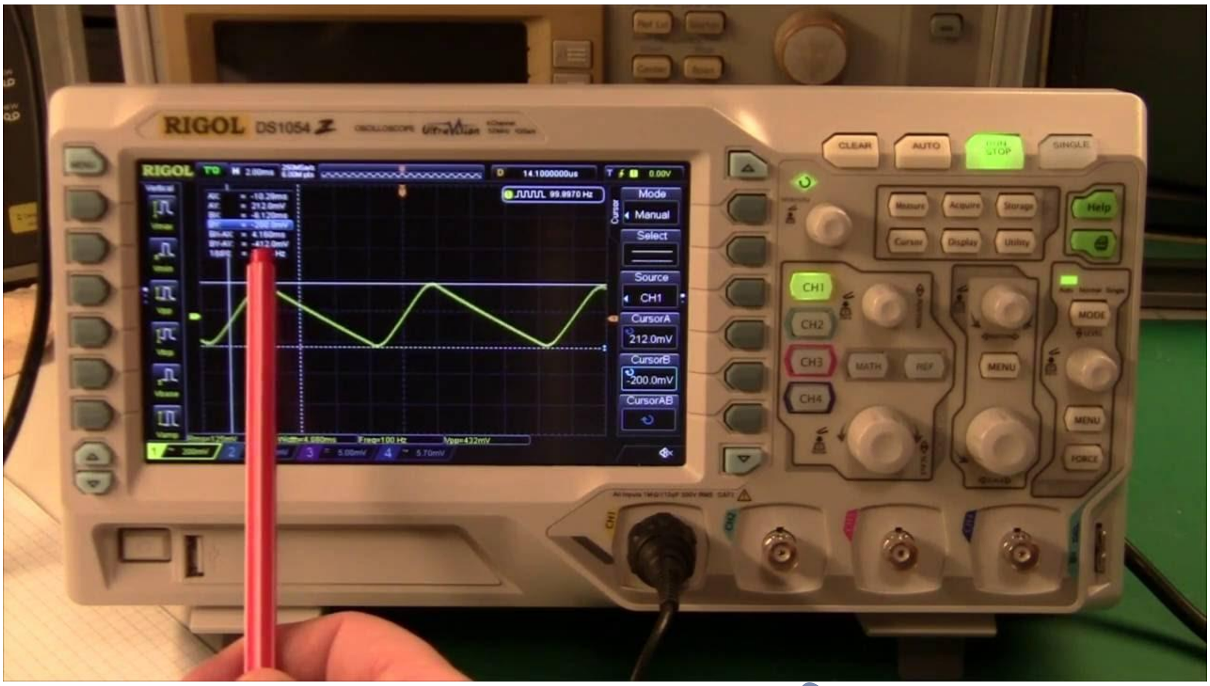
Testing & Troubleshooting a Regulated Power Supply



Regulated Power Supply Block Diagram



Here are **detailed, exam-friendly steps** for testing and troubleshooting a regulated power supply, broken into clear parts: **what to test**, **how to test**, **common fault symptoms & causes** and **best practices**. Use these to structure your answer in exams or practicals.

---

1. What to Test

When you have a regulated power-supply unit (linear type with transformer + rectifier + filter + regulator), these are the critical aspects to verify:

- Input side (transformer, AC mains, fuse)
- Rectifier output (DC before regulation)
- Filter stage (ripple, smoothing)
- Regulator stage (stabilised voltage, load/line regulation)
- Output under load: voltage accuracy, ripple/noise, regulation, thermal behaviour

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2. How to Test – Step-by-Step Procedure

Step 1: Visual & Safety Check

- Ensure the supply is disconnected power, then inspect for damaged components (burnt resistors, bulged capacitors, blown fuse).
- Check fuse continuity, wiring, transformer primary/secondary connections.
- Power up carefully. Use proper safety precautions when working with mains/transformer.

Step 2: Measure input & transformer output

- With input connected (mains), measure primary current/voltage to check transformer is receiving normal mains.
- Measure secondary AC voltage (unloaded) of the step-down transformer. Confirm it matches expected (e.g., 12 V, 15 V etc).
- If AC is missing or too low, fault may be transformer, primary fuse or mains supply.

Step 3: Rectifier + filter stage

- Measure DC voltage at the rectifier output (before regulator). It should be roughly the AC peak minus diode drops: ($V_{DC} \approx V_{m} - 2V_{d}$) (for full-wave).
- Observe ripple on this DC with an oscilloscope or use a meter if available for ripple. If ripple is excessive → filter capacitor or inductor choke may be faulty.
- Check diodes in the rectifier: open or short diodes change waveform (e.g., full-wave becomes half-wave, ripple doubles). (Scribd)

Step 4: Regulator input & output

- Measure input to the regulator: Ensure regulator input voltage is sufficiently higher than the nominal output (to allow regulation).
- Measure the output voltage with no load (or light load) and check if it is the correct nominal voltage (e.g., +12 V, +5 V).
- Apply a load (within rating) and measure output again. The voltage should remain nearly the same; drop should be within specified regulation limits. (MaxBotix)

Step 5: Ripple / Noise measurement

- On the regulated output, measure ripple and noise using an oscilloscope: set proper bandwidth (e.g., 20 MHz) and use good ground-probe techniques. (mornsun-power.com)
- Excess ripple or spikes indicate filtering/regulator not suppressing AC components properly or ground/decoupling issues.

Step 6: Load and line regulation tests

- **Line regulation**: Vary the input voltage (within specified range) and check output stays constant. (prodigit.com)
- **Load regulation**: Vary the load current from minimum to maximum, check voltage drop. Good regulator: small change.
- Many end-failures appear only under load or under input variation.

Step 7: Thermal / Power dissipation check

- Measure current drawn by load, calculate power dissipation in regulator or pass transistor: (P = (V_{in}-V_{out}) \times I).
- Check temperature of regulator/heat-sink under load; excessive heat may trigger thermal shutdown or drift.
- If regulator shuts down or output drifts on warm-up → thermal/heat-sink inadequate.

---

3. Common Faults: Symptoms & Possible Causes

Symptom	Possible Cause(s)
No output at all	Primary fuse blown, transformer open, rectifier open/short, regulator failure
Output voltage too low (even with no load)	Input to regulator too low, regulator damaged, load shorted
Output voltage sags under load	Load too heavy, regulator current limit engaged, heat-sink poor, supply droop
Excessive ripple or AC component on output	Filter cap failed/low value/high ESR, inductor/choke damaged, ground issues

Output fluctuates with input voltage	Poor line regulation, regulator defective, unstable feedback
Regulator overheats / shuts down	(V_in – V_out) large × high current → power dissipation too high, insufficient heat-sink, blocked ventilation

Example explanation: If the filter capacitor is open or has lost capacitance, the rectified output will have high ripple; the regulator then may not be able to fully regulate, causing voltage drop or ripple passing to output. (Scribd)

---

4. Practical Tips for Troubleshooting

- Always **start with measurements** of voltages at key points (transformer secondary, rectifier output, regulator input, output) — this narrows down which block is failing.
- Use **no-load and full-load** tests. Some faults only show under load.
- Check **heat-sink mounting**, ensure good contact and no thermal paste missing (for power regulators).
- Replace **electrolytic capacitors** if supply is old — capacitance drops and ESR rises, causing ripple/instability.
- Probe ripple with short ground lead on probe; avoid loop areas causing false noise readings.
- When in doubt, substitute suspect component (diode, capacitor, regulator) with known good one and see if fault clears — helps isolate.
- Document normal behaviour (voltages, ripple, temperature) so deviations can be quickly spotted.

---

5. Sample Trouble-Shooting Scenario (Exam Style)

Scenario: A 12 V regulated power supply gives ~11 V output unloaded and drops to ~9 V on load; ripple on output is visible.
Steps:

1. Measure transformer secondary AC – check if expected.

2. Measure rectifier output DC & ripple – if large ripple → filter capacitor weak.
3. Measure regulator input – if too low under load (droops to <--margin) → insufficient input.
4. Check output capacitor/regulator heat-sink.
   Likely cause: Filter capacitor loss → high ripple → regulator unable to maintain voltage under load → output sag, excessive ripple. Fix: replace filter cap, re-test.

---

6. Key Formulas

- Load regulation (%):
  [
  %;\text{Load Regulation} = \frac{V_{\text{NoLoad}} - V_{\text{FullLoad}}}{V_{\text{FullLoad}}} \times 100%
  ] (prodigit.com)
- Line regulation: change in output per change in input (often %).
- Ripple/Noise: measured as peak-to-peak AC on output (mV_pp) at specified bandwidth.

Summary

Testing and troubleshooting a regulated power supply is about **structured measurement** and **logical isolation** of faults across transformer, rectifier, filter and regulator. By systematically checking each block, measuring key voltages, ripple, load/line behaviour and thermal condition, you can identify and fix faults effectively.

Diploma Wallah

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