AC-power your circuit without a transformer

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**Editor's Note:** Here's another take on the transformerless AC line power supply, which finds use in some well-insulated, low-power devices. Our technical reviewer pointed out that $C_{ac}$ should be an X-rated safety type, and I think we'd both feel better if the ground symbol wasn't there!

SMPS circuits offer an efficient way to reduce AC from a mains source to any desired level for powering low-voltage circuits, though this comes at the cost of components such as control ICs, switching transistors, inductors, etc. Figure 1 shows a simple way you can use more common components to step-down and regulate the AC mains to the desired low DC voltage.

The reduction in AC voltage is obtained by dropping the unwanted extra voltage across a capacitor (impedance $Z=1/\omega C_{ac}$) of suitable value and voltage rating. The remaining AC is drawn as rectified output through a diode bridge. So even though DC flows through the output circuit of the bridge, the voltage dropping series capacitor $C_{ac}$ sees an AC flowing in its remaining part of the circuit.

The value of the capacitor determines the current output at reduced voltage. A larger capacitor is required for larger output currents. A bleeder resistor (1MO) is set in parallel with $C_{ac}$ to discharge it when the AC is disconnected. The DC after rectification and filtering is shunted by the Q1-based regulation circuit, which basically tries to maintain the output voltage within certain limits.

![Figure 1](image)

*Figure 1* This step-down converter drops AC mains voltage across $C_{ac}$ to produce a lower DC voltage. $V_{UZ}$ is optional and is related
to safety issues – choose higher wattage if necessary. $V_{U}$ is the unregulated output which can be further regulated using chips like 7805/12 etc or a simple zener-transistor regulator. Q1 should be chosen according to power requirement – essentially it should be able to drain the unused current when the load is absent. The values/type of fuse are indicative – choose it according to your design/need.

The circuit has two LEDs. The red LED indicates whether the power from AC is being used, or bledd as waste through Q1. The green LED indicates the power availability at the output where further regulating devices can be added.

R1, R2, and RB (R1,R2 » RB) form a voltage divider network which essentially monitors the residual rectified AC from the bridge. Their values are chosen such that when the current is flowing through the load (not shown), Q1 is switched off and hence little current flows through the second bleeder resistor RB, limited by the large values of R1 and R2. The voltage drop across RB is not sufficient to turn on the red LED. At this point, we say the current flowing through R1, R2, and RB is the housekeeping current which constantly flows apart from the maximum load current.

Q1 is biased by the voltage drop across R2, which should be at least 0.6V for Q1 to turn on. During normal operation (current flowing through the load), the values of R1, R2, and RB are chosen such that this voltage is less than 0.6V. However, if the load is disconnected (no output current is being drawn) then the voltage after the diode bridge will increase, which in turn will increase the voltage drop across R2 until the transistor turns on and draws current through RB. This stops the voltage from increasing further, simultaneously increasing the current through the red LED. A glowing red LED indicates power wastage. However, the green LED always glows when power is available at the output. RB should be chosen such that the rise in voltage at the bridge output during no load condition is within the upper limit of any final regulator connected to $+V_{U}$.

The required capacitor $C_{ac}$ is calculated as:

$$C_{ac} = \frac{I_{L} + \Delta I_{L}}{\omega(V_{rms} - V_{E})}$$

where $I_{L}$ is the maximum load current, $V_{rms}$ is the RMS AC voltage, $V_{E}$ (~$V_{U}$+1.2) is the residual expected voltage at the bridge input, which is taken to be the sum of $V_{U}$ and 1.2V across the bridge diodes. $\Delta I_{L}$ is the housekeeping current apart from the maximum load current. A rough estimate of $C_{ac}$ is $I_{L} / (?V_{rms})$ (where $? = 2pf_{AC}$) as can be seen from the formula by neglecting $\Delta I_{L}$ and $V_{E}$, which are small compared to $I_{L}$ and $V_{rms}$ respectively.

This circuit offers an alternative to a bulky, noisy, vibration/magnetic field/heat producing transformer. However, the advantage of the transformer is in the isolation it offers from live AC. The danger with the proposed circuit is when $C_{ac}$ shorts out. Precautions should be taken to see that the fuse blows out before the voltage across the output rises to a hazardous level. Under increased voltage conditions, extra current paths are offered by the zener $V_{UZ}$ and the filter capacitor $C_{F}$.

Additional cheap neon lamps can be added across the bridge input to salvage the output regulating circuit and the load.

In a test set up which was designed to obtain a zener-transistor regulated 4.8V supply at 5mA current: $C_{ac}=0.068\mu F$, $R1=10k\Omega$, $R2=4700$, $R_{B}=4700$, $C_{F}=470\mu F$, and Q1=BC549, with a 240V AC line. This power supply could power a 555 oscillator driving an LED. Another test used $C_{ac}=0.22\mu F$, $R1=10k\Omega$, $R2=4700$, $R_{B}=4700$, $C_{F}=470\mu F$, and Q1=BC549. This could be used to build a zener-transistor regulated power supply of 4.8V at 15mA current. It could easily power a 555 astable, a
flashing LED, and a CD4518 counter driving eight LEDs.

It should be noted that the reactance of $C_{ac}$ is normally much higher than that of the power recipient circuit, and as such, the power supply behaves as if it is a constant current source. This type of power supply seems to be useful to power circuits with low current requirements, on the order of about 1mA to 100mA.

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