EET-225 Homework #2
Sr. Professor Wheeler

Instructions: This homework must be turned in within a flat 3-tab paper folder (no three-ring binders will be accepted). Answers must be written very neatly or typed. Use complete sentences when answering all questions. Where a problem involves a circuit, you must redraw the circuit as part of the solution, showing all indicated voltages and currents on the circuit diagram. Box or underline all final answers and show all work (see syllabus for example of homework standards).

1. Explain the meaning of each of the following diode ratings:

   a) I_f is the maximum RMS or average forward current the diode can support
   b) PIV (or V_R) is the maximum (peak) reverse bias voltage the diode is designed to handle
   c) P_D is the maximum steady-state power dissipation the device can support. The power dissipation is calculated by multiplying the RMS forward diode voltage and current.

2. Look up the ratings of problem 1 for a 1N4001 rectifier diode. Use a manufacturer's web site to get the information. For example, Fairchild Semiconductor (`http://www.fairchildsemi.com`) is one of several manufacturers that make this device, and they keep data sheets online.

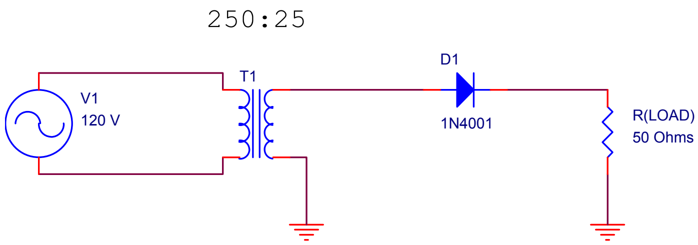
   For a 1N4001 rectifier, the ratings are as follows:

   I_f = 1 A   PIV = 50 V P_D = 2.5 W (Derated 20 mW/C above 25 C)

3. What diodes in the 1N400x family can withstand 100 PIV?

   The 1N4002, 1N4003, 1N4004, 1N4005, 1N4006, and 1N4007 devices can withstand 100 PIV.

4. Calculate the following for the half-wave unfiltered power supply circuit below. The input frequency is 60 Hz.



a) The RMS output voltage at the transformer secondary

$$V_s = V_p\left(\frac{Ns}{Np}\right) = 120V\left(\frac{25}{250}\right) = \underline{\underline{12V}}$$

b) The peak output voltage at the transformer secondary

$$Vpk = Vrms\sqrt{2} = 12V\sqrt{2} = \underline{\underline{16.97V}}$$

c) The average output voltage at the load

$$Vav = \frac{Vload(pk)}{\pi} = \frac{Vpk - Vdiode}{\pi} = \frac{16.97V - 0.7V}{\pi} = \underline{\underline{5.18V}}$$

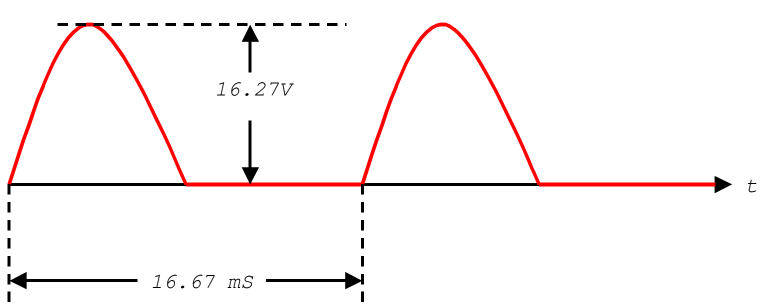
d) The PIV experienced by the rectifier diode

$$PIV = Vpk = \underline{\underline{16.97V}}$$

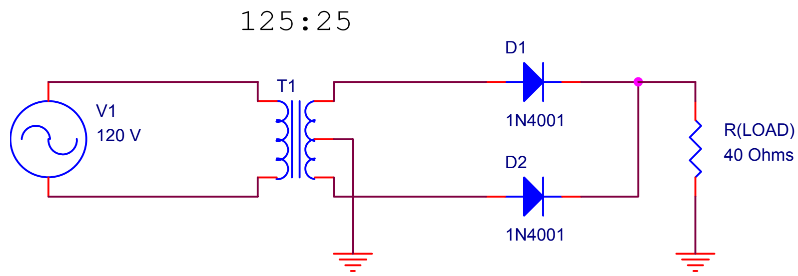
e) The average forward current I_f experienced by the diode

$$Iav \approx \frac{Vav}{RL} \approx \frac{5.18V}{50\Omega} \approx \underline{\underline{103.6mA}}$$

f) Sketch the waveform appearing at the load, accurately showing time and voltage



5. Calculate the following for the full-wave unfiltered power supply circuit below. The input frequency is 60 Hz.



a) The RMS output voltage at one half of the transformer secondary

$$V_s = V_p\left(\frac{Ns}{Np}\right) = 120V\left(\frac{25}{125}\right) = 24V$$

$$Vhalf = \frac{V_s}{2} = 24V/2 = \underline{\underline{12V}}$$

b) The peak output voltage at one half of the transformer secondary

$$Vpk = Vrms\sqrt{2} = 12V\sqrt{2} = \underline{\underline{16.97V}}$$

c) The average output voltage at the load

$$Vav = \frac{2\times Vload(pk)}{\pi} = \frac{2(Vpk - Vdiode)}{\pi} = \frac{2(16.97V - 0.7V)}{\pi} = \underline{\underline{10.36V}}$$

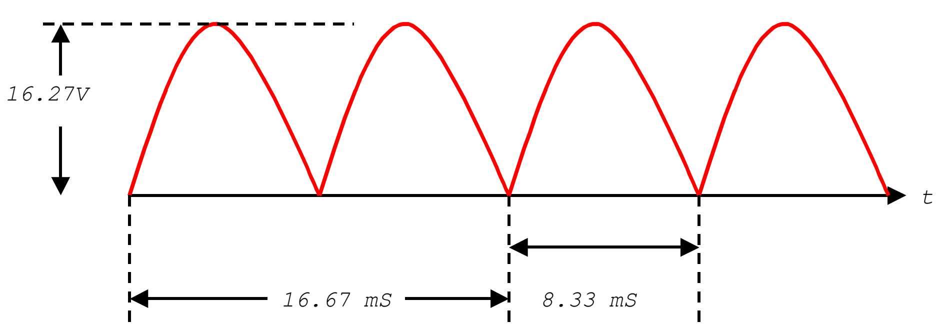
d) The PIV experienced by each rectifier diode

$$PIV = 2Vpk = \underline{\underline{33.94V}}$$

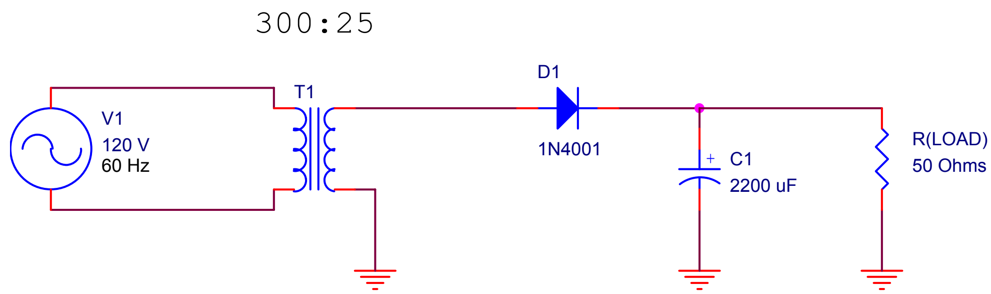
e) The average forward current I_f experienced by each rectifier diode

$$Iav \approx \left(\frac{1}{2}\right)\frac{Vav}{RL} \approx \frac{10.36V}{40\Omega} \approx \underline{\underline{130mA}}$$

f) Sketch the waveform appearing at the load, accurately showing time and voltage



6. For the half-wave capacitor input filtered power supply circuit below, calculate:



a) The ripple frequency

$f_{rip} = f_{in} = \underline{\underline{60Hz}}$ by inspection (half-wave configuration)

b) The approximate load voltage (assuming that the Vpp ripple voltage is much smaller than the DC load voltage)

$$VL \approx Vpk \approx (\sqrt{2})Vpri\left(\frac{Ns}{Np}\right) - Vdiode \approx \sqrt{2}(120V)\left(\frac{25}{300}\right) - 0.7V \approx \underline{\underline{13.4V}}$$

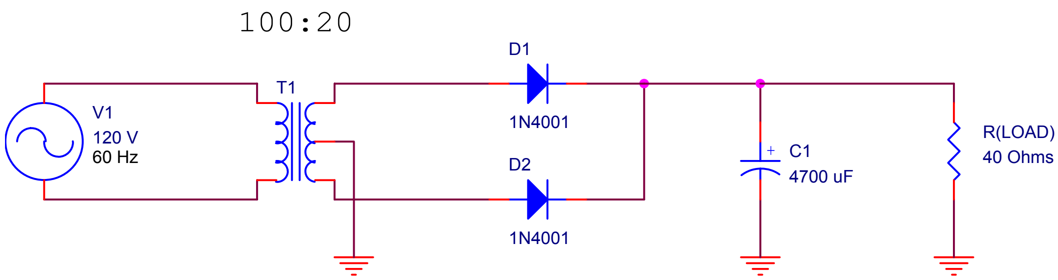
c) The load current

$$IL = \frac{VL}{RL} = \frac{13.4V}{50\Omega} = \underline{\underline{269mA}}$$

d) The Vpp (peak-to-peak) AC ripple voltage appearing across the load.

$$Vpp = \frac{I}{f_{rip}C} = \frac{269mA}{(60Hz)(2200\mu F)} = \underline{\underline{2.04Vpp}}$$

7. For the full-wave capacitor input filtered power supply circuit below, calculate:



a) The ripple frequency

$f_{rip} = 2f_{in} = \underline{\underline{120Hz}}$ by inspection (full-wave configuration doubles input frequency)

b) The approximate load voltage (assuming that the Vpp ripple voltage is much smaller than the DC load voltage).

$$VL \approx Vpk \approx \frac{\sqrt{2}}{2} Vpri\left(\frac{Ns}{Np}\right) - Vdiode \approx \frac{\sqrt{2}}{2}(120V)\left(\frac{20}{100}\right) - 0.7V \approx \underline{\underline{16.27V}}$$

c) The load current

$$IL = \frac{VL}{RL} = \frac{16.27V}{40\Omega} = \underline{\underline{407mA}}$$

d) The Vpp (peak-to-peak) AC ripple voltage appearing across the load.

$$Vpp = \frac{I}{f_{rip}C} = \frac{407mA}{(120Hz)(4700\mu F)} = \underline{\underline{0.72Vpp}}$$

8. Design a full-wave capacitor input power supply to meet the following specifications:
   * V(LOAD) to be in the range of 11V to 14V DC.;* I(LOAD) to be 500 mA typical;* Vpp (ripple) must be <= 1 Vpp @ I(LOAD) = 500 mA;* A center-tapped transformer secondary will be used (two diodes required);* Vin = 120 VAC @ 60 Hz;* Input must be properly fused

   Design method:

   a) Specify the power transformer needed:

   Choose V(LOAD) in center of range which is (11V+14V)/2 = 12.5 V

   This means that Vpk-Vdiode = 12.5 V so Vpk = 12.5V + 0.7 V = 13.2 Vpk

   Because this is a full-wave design with a center-tapped secondary, the total peak secondary voltage will be *twice* the Vpk value or 2(13.2Vpk) or 26.4 Vpk

   The RMS secondary voltage is therefore $26.4Vpk/\sqrt{2}$ or 18.66 V

   The transformer turns ratio (Np/Ns) = (120V/18.66V) = 6.428:1

   The transformer secondary must be rated at least IL/2, 250 mA, because this is the effective value of secondary current (each half of the secondary only passes load current during half the cycle).

   b) Specify the rectifier diodes:

   The rectifier diodes must have a PIV greater than or equal to 2 Vpk or 2(13.2Vpk), so the PIV of each diode must be >= 26.4 V. Each rectifier diode sees an average of 1/2 the load current IL (due to the full-wave design), so each diode must be able to handle at least 250 mA. A safety factor of at least two and preferably four should be employed when choosing the diode current. A pair of 1N4001 diodes meet the specifications (PIV = 50 V, I_f = 1 A)

   c) Calculate the filter capacitance needed:

   The filter capacitor value can be determined by manipulating the ripple equation:

$$Vpp = \frac{I}{f_{rip}C} \quad \dashrightarrow \quad C \geq \frac{I}{f_{rip}Vpp} \geq \frac{500mA}{(120Hz)(1Vpp)} \geq 4166\mu F$$

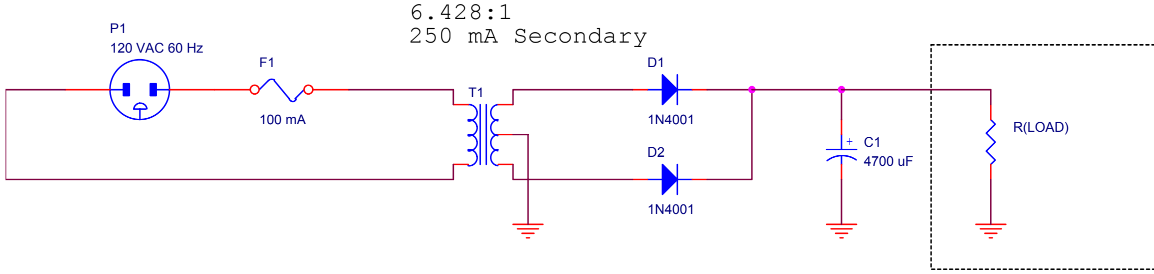
   Use a standard value of 4700 uF.

   d) Calculate the primary circuit fuse rating:

   Conventional fuses "blow" at 150 - 200% of the fuses nominal (nameplate) value.

   Estimate the primary current: $Ip = Is\left(\frac{Ns}{Np}\right) = 250mA\left(\frac{1}{6.428}\right) = 39mA$

   Double this value to allow for power-on charge surge and round up to the next available standard fuse value, which is 100 mA



9. Design a full-wave capacitor input power supply to meet the following specifications: * V(LOAD) to be in the range of 100V to 110V;* I(LOAD) to be 100 mA typical;* Vpp (ripple) must be <= 5 Vpp @ I(LOAD) = 100 mA;* A bridge rectifier will be used (the transformer secondary is not center-tapped);* Vin = 28 VAC @ 400 Hz;* Input must be properly fused

Design method:

a) Specify the power transformer needed:
Choose V(LOAD) in center of range which is (100V+110V)/2 = 105 V
This means that Vpk-2Vdiode = 105 V so Vpk = 105V + 2(0.7 V) = 106.4 Vpk
Because this is a full-wave design with a bridge, the total peak secondary voltage will be *the same* as the Vpk value or 106.4 Vpk
The RMS secondary voltage is therefore $106.4Vpk/\sqrt{2}$ or 75.24 V
The transformer turns ratio (Np/Ns) = (28V/75.24V) = 1:2.687 (a step-up)
The transformer secondary must be rated at least IL, 100 mA, because the entire secondary passes current for 100% of the cycle.

b) Specify the rectifier diodes:
The rectifier diodes must have a PIV greater than or equal to Vpk or 106.4Vpk, so the PIV of each diode must be >= 106.4 V. Each rectifier diode sees an average of 1/2 the load current IL (due to the full-wave design), so each diode must be able to handle at least 50 mA. A safety factor of at least two and preferably four should be employed when choosing the diode current. A bridge of (4) 1N4003 diodes meet the specifications (PIV = 200 V, I_f = 1 A)

c) Calculate the filter capacitance needed:
The filter capacitor value can be determined by manipulating the ripple equation:

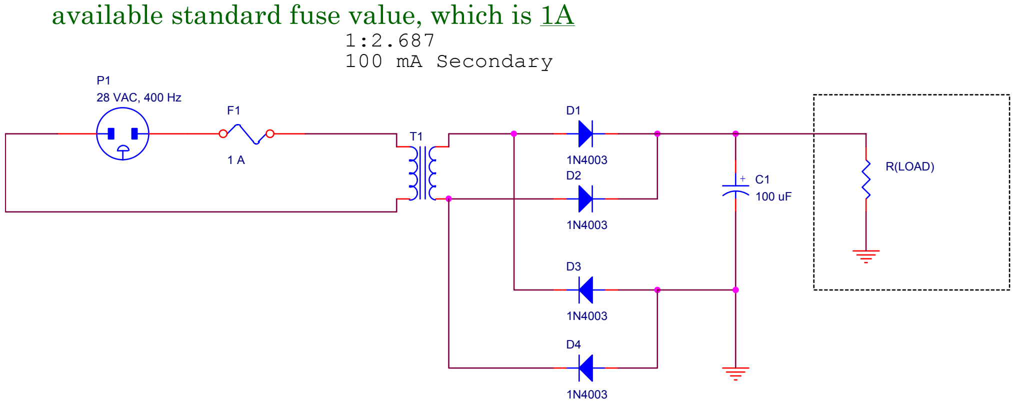
$$Vpp = \frac{I}{f_{rip}C} \quad \dashrightarrow \quad C \geq \frac{I}{f_{rip}Vpp} \geq \frac{100mA}{(2)(400Hz)(5Vpp)} \geq 100\mu F$$

Use a standard value of 100 uF.

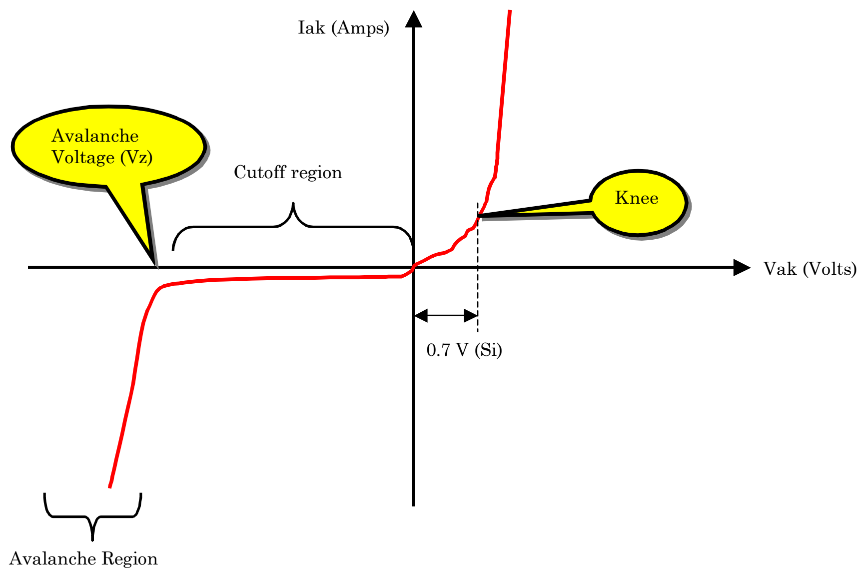
d) Calculate the primary circuit fuse rating:
Conventional fuses "blow" at 150 - 200% of the fuses nominal (nameplate) value.

Estimate the primary current: $Ip = Is\left(\frac{Ns}{Np}\right) = 100mA\left(\frac{2.687}{1}\right) = 268.7mA$

Double this value to allow for power-on charge surge and round up to the next available standard fuse value, which is 1A



10. Draw the V-I characteristic curve for a Zener diode, labeling the following parts of the graph: a) Knee ; b) Avalanche region ; c) Avalanche voltage. What type of bias is normally applied to a Zener diode?



A Zener diode is normally operated in reverse bias, specifically in the avalanche region.

11. Explain the meaning of the following Zener diode ratings:

a) Vz: The nominal avalanche (Zener) voltage under reverse bias
b) Izm: The maximum allowed Zener current
c) P_D: The maximum power dissipation for the diode; decreases as temperature increases

12. Look up the ratings for a 1N4735 Zener diode using a manufacturer's web site of your choice.

For a 1N4735A (Fairchild): Vz = 6.2 V, Izm = 146 mA, P_D = 1 W

13. Design a Zener voltage regulator to meet the following specifications:

* V(LOAD) = 9 V
* Izt = 4 mA
* I(LOAD)max = 30 mA
* Vin ranges from 12 V to 16 V (unregulated)

Calculate the power dissipation of the Zener diode and the series limiting resistor. Use only standard values in your design. Neatly draw the circuit showing all component values.

Design approach:

a) Vz = V(LOAD) = 9V

b) Calculate input current and series resistor using *minimum* value of Vin:

$$I_{IN} = I_{ZT} + I_{L(\max)} = 4mA + 30mA = 34mA$$

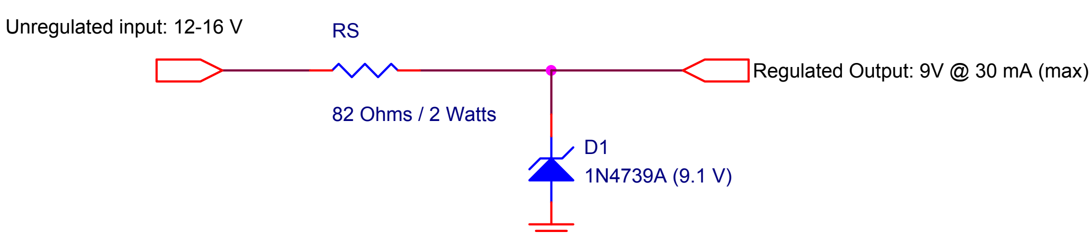
$$R_S = \frac{(Vin_{MIN} - V_Z)}{I_{IN}} = \frac{(12V - 9V)}{34mA} = 88.2\Omega$$ (Use 82 Ohms, std value -- round down)

c) Check Zener and series resistor power dissipation (worst at no load current, highest input voltage)

$$I_{IN(MAX)} = \frac{(Vin_{MAX} - V_Z)}{R_S} = \frac{(16V - 9V)}{82\Omega} = 85.3mA$$

$$P_{D(ZENER)} = I_Z V_Z = I_{IN(MAX)} V_Z = (85.3mA)(9V) = \underline{\underline{768mW}}$$

$$P_{RS} = I_R^2 R_S = I_{IN(MAX)}^2 R_S = \underline{\underline{598mW}}$$ (The resistor should be at least double this rating in power)



14. Design a Zener voltage regulator to meet the following specifications:

* V(LOAD) = 12 V
* Izt = 5 mA
* I(LOAD)max = 50 mA
* Vin ranges from 16V to 25V (unregulated)

Calculate the power dissipation of the Zener diode and the series limiting resistor. Use only standard values in your design. Neatly draw the circuit showing all component values.

Design approach:

a) Vz = V(LOAD) = 12V

b) Calculate input current and series resistor using *minimum* value of Vin:

$$I_{IN} = I_{ZT} + I_{L(\max)} = 5mA + 50mA = 55mA$$

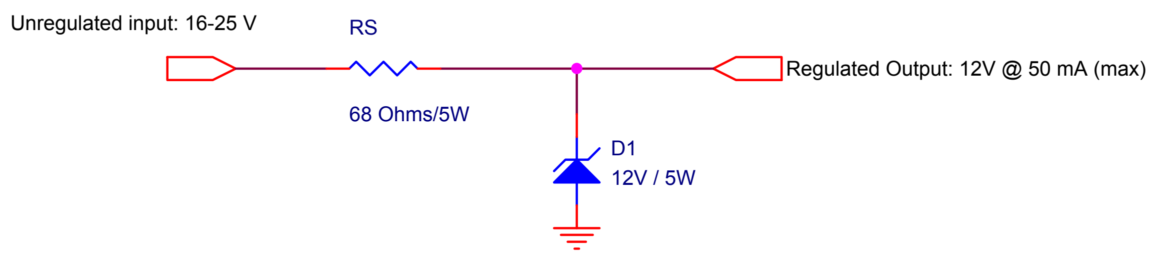
$$R_S = \frac{(Vin_{MIN} - V_Z)}{I_{IN}} = \frac{(16V - 12V)}{55mA} = 72.7\Omega$$ (Use 68 Ohms, std value -- round down)

c) Check Zener and series resistor power dissipation (worst at no load current, highest input voltage)

$$I_{IN(MAX)} = \frac{(Vin_{MAX} - V_Z)}{R_S} = \frac{(25V - 12V)}{68\Omega} = 191.2mA$$

$$P_{D(ZENER)} = I_Z V_Z = I_{IN(MAX)} V_Z = (191.2mA)(12V) = \underline{\underline{2.3W}}$$

$P_{RS} = I_R^2 R_S = I_{IN(MAX)}^2 R_S = \underline{\underline{2.5W}}$ (The resistor should be at least double this rating in power, so a 5W power resistor must be used)



15. In a practical Zener regulator, what component is placed in parallel with the Zener diode for reducing noise? Explain how the arrangment works.

At least one capacitor is usually placed in parallel with a Zener diode in order to reduce the avalanche noise inherent in all Zener diodes. Avalanche noise is an AC signal component that contains nearly all frequencies from just above DC through the RF (radio frequency) range. Capacitors tend to block DC voltages and pass AC signals. The parallel capacitor "bypasses" the AC noise signal to ground where it will be absorbed while allowing the DC to get through to the load. Thus, the capacitor is often referred to as a bypass capacitor.