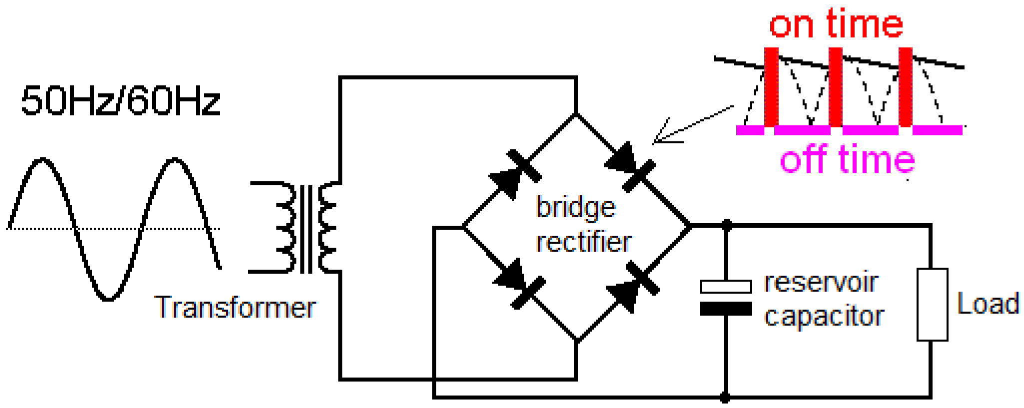
# To snubber or not to snubber … and how..

Sometimes in power supply circuits there are (small value) capacitors mounted in **parallel** to the rectifier **diodes** accompanied with many claims of improved sound quality. Not many people know what they are for but still many people just solder them in parallel when they aren't installed. Sometimes these capacitors are used to 'short' high frequency signals or are used to lower RFI emissions generated by diodes or the circuits behind it.
Below an explanation as to why and when and how **snubber circuits** are used.

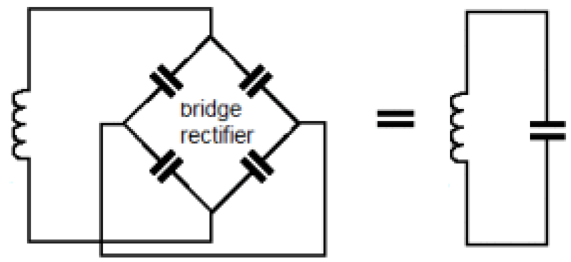
A **snubber circuit** may be needed if the circuit is connected to mains and the whole circuit is not allowed to induce **RF (Radio Frequencies)** back **into** the **mains**, for instance when lacking a proper **mains filter**. The reason a rectifier can do this (generate RF signals) is explained below.

The schematic of a **standard bridge rectifier**. As explained above a rectifier is only working a short period of time. Namely only when the AC voltage on the input of the rectifier is about 0.6V higher than that on the reservoir capacitor behind the rectifier. This is shown in the picture below where in red the diode is 'conducting' and thus 'on' and during the pink time period the diode is 'off' because the voltage of the reservoir capacitor is higher than that on the input of the rectifier.



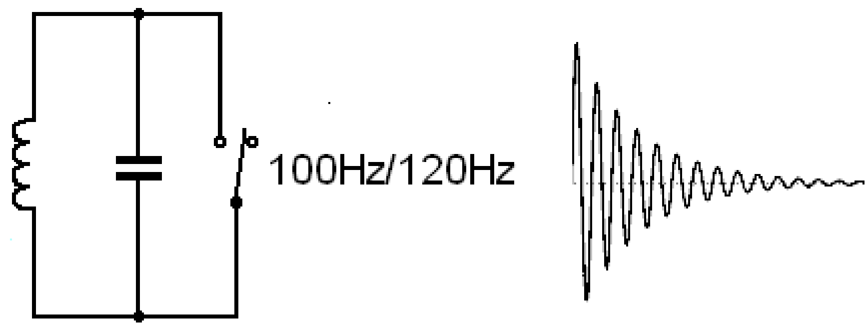

When the diode is **not conducting** it actually becomes a (somewhat voltage dependent) **capacitor** with a very small value. For the well known **1N4007** this capacitance lies in the order of **10pF**. For **Schottky diodes** this usually is much smaller and can be **below 1pF.** This means that during a small period the diode in the rectifier is a diode (a switch that conducts ONLY when the input voltage is higher than the output voltage) and the entire period it doesn't conduct it becomes a capacitor. Below you see the substitute diagram for this.
What may be obvious here is that the reservoir capacitor and load has been **replaced** by a wire (short) which at first appearance seems strange but the reason for this is that a reservoir capacitor is very low impedance for higher frequencies (certainly when decoupled with a smaller ceramic capacitor) and is thus **irrelevant** for the explanation/occurring phenomenon. As can be seen there are 4 diodes of which 2 pairs of parallel capacitors that are effective in series. They thus form a single capacitor of the same value of a single diode. The secondary winding of the transformer is an **inductance**. In practice the **transformer** also has some **capacitance** and the **wiring** between the transformer and rectifier also form a **capacitance**. This means the capacitances are in parallel (and thus can be added) to the inductor = **Cdiode**

**+ Ctrafo + Cwiring**. This creates a **resonance circuit,** but as the frequency present on the mains is just 50 or 60 Hz nothing really will resonate as the resonance frequency of that circuit is in the + 1MHz range… so no problem it seems.

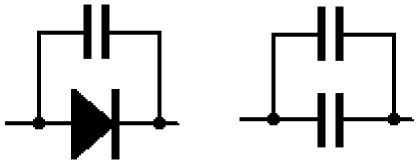



**But** at the top of the voltage of that 50/60Hz frequency the capacitor is replaced by a 'switch' and shortly after it became a switch it **goes off again** and becomes a capacitor. At this switching point high currents/voltage and speeds are present and thus energy is involved.

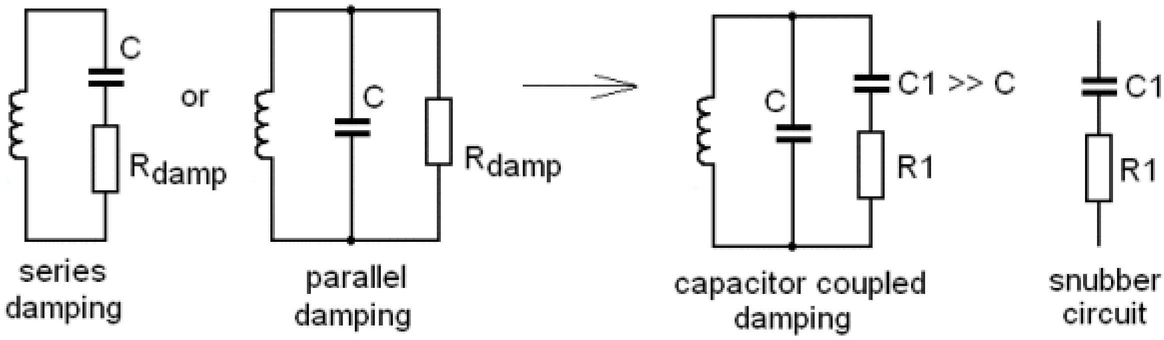
Most people have pulled a mains plug with a device that was active quite a few times in their lives and sometimes, when the mains was at its peak, you can see a massive '**flash**'. Also visible in light switches e.t.c. The same can happen with a mains switch. The voltage peaks that are generated at that point can be very high and the energy as well, creating a **spark** as the circuit basically doesn't like to be interrupted.
So when a circuit is **switched off** on a high peak voltage on the **inductor-side** is the result. In the case of a bridge rectifier **this happens 100x (or 120 times) per second**. Because the inductor has capacitor(s) in parallel that peak becomes a resonance (slowly dying sinewave).




As the diodes are in reverse mode (so not conducting) they do NOT form a load and the resonance circuit will 'swing' out as shown above. The **frequency** of this resonance is thus determined by the **inductor (trafo)** and all the capacitances in parallel to it (**Cdiode + Ctrafo + Cwiring**) and lies in the **MHz range.** When the capacitance of the wiring is very low (short wires wide apart) and the trafo has little capacitance the influence of the diodes is bigger. The higher powered the diode the bigger it is and the larger the capacitance. When using Schottky diodes this means the resonance frequency will be higher than when 'normal' diodes are used. Higher frequencies usually means more potential trouble and higher 'emission' by the way. For this reason you sometimes see **capacitors in parallel to diodes** which effectively **enlarges the capacitance** and thus **moves** the resonance to l**ower frequencies**… BUT **they still are there**. below a picture of a diode with a capacitor in parallel. On the right you see what it essentially becomes in reverse voltage. The capacitors used in parallel should be around 1nF in practice. The diode capacitance of 1pF or 10pF then has no influence any more. So when using a Schottky diode instead of a ‘normal’ (bipolar) diode they are equally ‘fast’ and have the same ‘capacitance’. The only difference being the voltage across the ‘switch’ which is between 0.5V and 1V for bipolar ones and between 0.2V and 0.8V for Schottky diodes. Using Schottky diodes thus only creates higher RF (when no counter measures are taken) and ensure a slightly (0.4 to 0.8V higher DC voltage on the reservoir capacitor.



As stated the resonance still exists at the **inductor side** (NOT at the DC side, the reservoir capacitor) and isn’t damped as there is no ‘load’ to damp it. With added caps that frequency is lower and thus less harmful in most cases. What is needed is a load on the input side of the rectifier. A load that can **dissipate** the energy of that peak/resonance and turn it into **heat**.

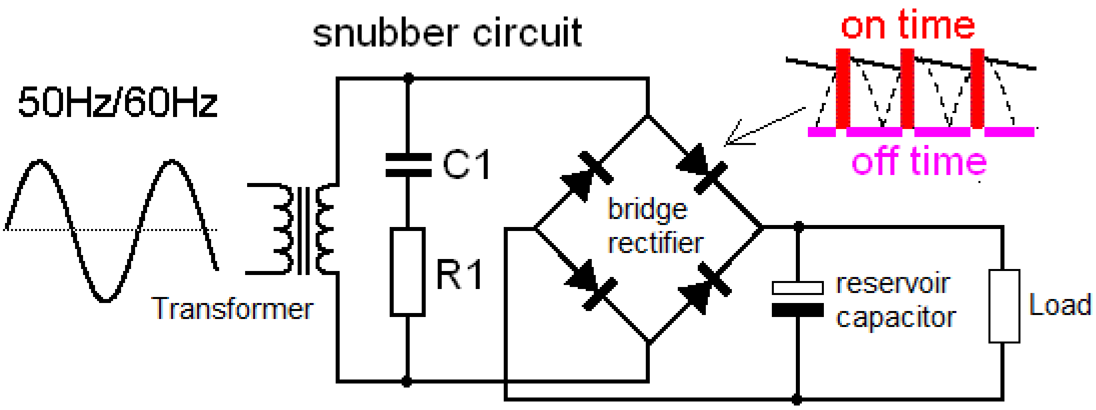



For this we need a **damping resistor** that is either in **series** (above on the left) or in **parallel** (2nd from the left). A resistor in **series** is **NOT possible** as the resistor would be in series with the diodes severely limiting the current and thus power. We will need a resistor in parallel to transformer coil. To dissipate energy it would have to be a low value (between 10Ω and 100Ω). Needless to say that when using a 15V trafo and 10Ω resistor in parallel this resistor would dissipate 22 Watt and become **steaming hot**. Not very practical….
Fortunately the resonance **frequency** is **very high**. This means that when the **damping resistor** has a **capacitor in series** that is much **higher** in **value** than that of the total capacitance of the circuit that capacitor in series with the damping resistor will act as a ‘**short**‘ (impedance will be close to 0 Ohm) for those frequencies. For 50/60Hz the **impedance** of that series capacitor should be **high** so at 50/60Hz there will be practically no AC current flowing. For this the **capacitance** needs to be **small**. In essence the **snubber circuit** on the right needs to have a capacitor (C1) with a value much **higher than** that of the **present capacitance** and **small enough** to limit the **current** for **50/60Hz** AC currents. R1 needs to **dissipate** the **power** of the **resonance** + the power from the **50/60Hz** AC. When **R1 = 0Ω** there will be **no damping** only the resonance frequency will be lowered. When this resistance value is too high there will also be **no damping** as there is **no load**.

**Practical values of C1** will be between **47nF** and **1µF** and practical values of **R1** will be between **4.7Ω** and **47Ω** depending on the situation.
In general it is better to use a 220nF and 10Ω resistor than not use anything at all. If you do

not care about a little bit of RF common mode energy fed back into the mains you can leave the snubber circuit out.

This results in the circuit below and shows the proper way to prevent RF emissions back onto the mains via the transformer (common mode currents)




In short, capacitors in parallel to the diodes only shifts the problems in frequency (which makes it less problematic) but mounting a snubber circuit in parallel to the transformer/rectifier input ensures the resonating energy is removed quickly and eliminates the possible RF garbage source.