Problem Statement Day #2

Circuit Designing
Analog
IEEE - Delhi Technological University

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Half-Bridge Rectifier

A *Rectifier* is an electrical device that converts alternating current, which periodically reverses direction, to direct current, which flows in only one direction. The process is known as rectification, since it "straightens" the direction of current. The output of a full bridge is shown in Fig. 1. Note that the "straightening" action is observed after this output is fed to a capacitor and other filtering components. This circuit averages this input waveform and gives DC output with

$$V_{DC} = V_{average} = \frac{2 \cdot V_{peak}}{\pi}$$

In many applications, we need to control the power fed to the load. We can do this by varying the V_{dc} output voltage. This process of converting alternating current (AC) to variable direct current (DC) is also called as controlled rectification.

Basic Principle
Controlled rectification is achieved by "chopping" the AC voltage waveform. Instead of a repeating sinusoidal AC signal from 0 to π we get after rectification (Fig. 1), we chop the signal such that the wave starts from a phase α (Fig. 2), and then this is supplied to the filtering circuit. The result is a DC voltage, which is the average of chopped AC voltage, given by:

$$V_{DC(Controlled)} = V_{average} = \frac{V_{peak}}{\pi} \cdot (1 + \cos\alpha) \tag{1}$$

The phase α is called firing angle.To know more about the derivation and detailed theory, see the attached PDF document.

For controlling the phase, instead of diodes, thyristors/SCRs are used. The thyristors can be made to conduct like normal diodes, by applying a gate pulse. This process of

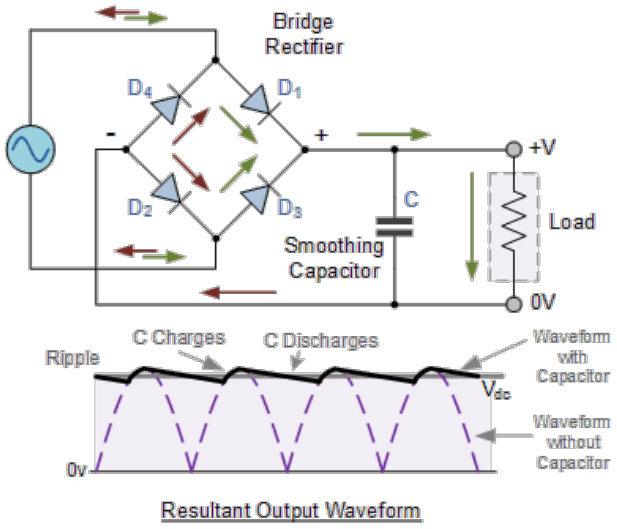

Figure 1: Bridge Rectifier output before and after filtering

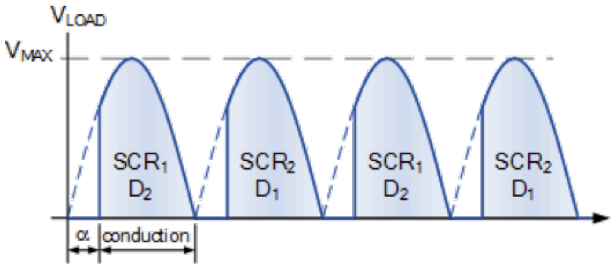

Figure 2: Full wave Half-Bridge Rectifier output

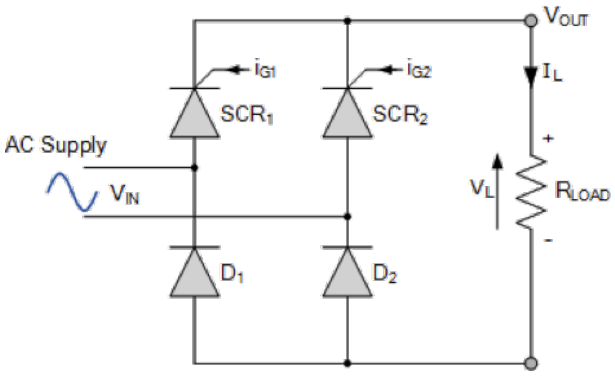

Figure 3: Half-Bridge Rectifier basic circuit

triggering thyristors is called thyristor firing. By applying a delayed gate pulse, we can control from which phase the thyristors starts to conduct, thus controlling firing angle α. (To know more about thyristors and firing circuits, go through the tutorial, link is available on the website.)

A circuit of half-bridge rectifier is given (Fig. 3). During the positive half cycle of the input waveform, current flows along the path of: SCR_1 and D_2, and back to the supply. During the negative half cycle of V_{IN}, conduction is through SCR_2 and D_1 and back to the supply. It is clear then that one thyristor from the top group (SCR_1 or SCR_2) and its corresponding diode from the bottom group (D_2 or D_1) must conduct together for any load current to flow. Thus the average output voltage, $V_{average}$ is dependent on the firing angle α for the two thyristors included in the half-controlled rectifier as the two diodes are uncontrolled and pass current whenever forward biased. So for any gate firing angle, α, the average output voltage is given by (1).

Problem Statement
A Half-Bridge Rectifier is used to control the speed of a DC motor, by controlling the DC voltage. Design a Half-Bridge Rectifier and it's firing circuit that can control the DC voltage output. Varying a resistor should vary DC voltage in your design. Highlight that resistor (use name `Rcontrol` for that resistor) for evaluation of circuit.

Additional Information

a) Voltage waveform of triggering pulse, Half-Bridge (Before filtering), and $V_{DC(Controlled)}$ (after filtering) will be used to evaluate points for output. Output will be checked for different value of `Rcontrol`.

b) Use a resistor `Rload` of 10k for Load.

c) Input AC voltage (V_{IN}) is 220V (V_{rms}). DO NOT use Pulse Voltage Source IF square wave is required, implement using discrete components only.

d) Keep checking the website for design tips.

Optional

Design a circuit that turns off the firing circuit, and hence the output voltage, when current through the load exceeds a set threshold value. It should also give a logic high output when this happens. A resistor should set this threshold value (use name `RiLimit''` for that resistor).