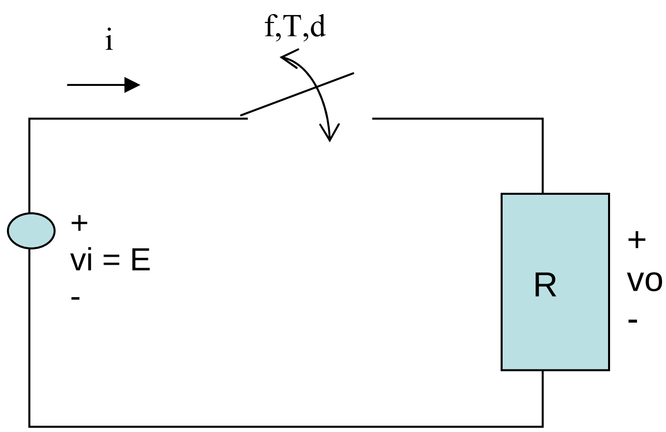
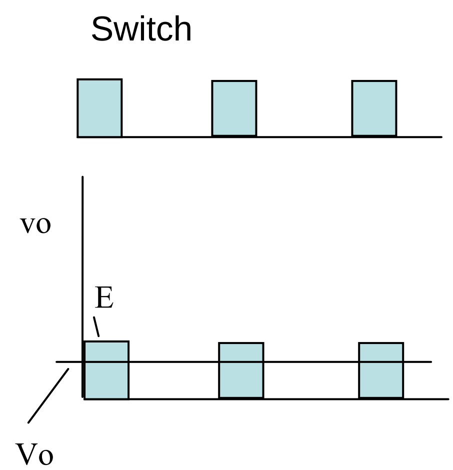
Part 1 A. Analysis and Simulation of Power Electronic Circuits (Continued)

Example 4 Choppers, Switchers and Pulse Width Modulated dc-dc conversion





The switch in the circuit above is turned on and off periodically at frequency f or period T=1/f. The switch is on for time T1≤T and of for time T-T1. T1 is the pulse width. We define

Duty ratio $d=T1/T$

The output voltage is a rectangular wave with a peak of E volts and duty ratio d

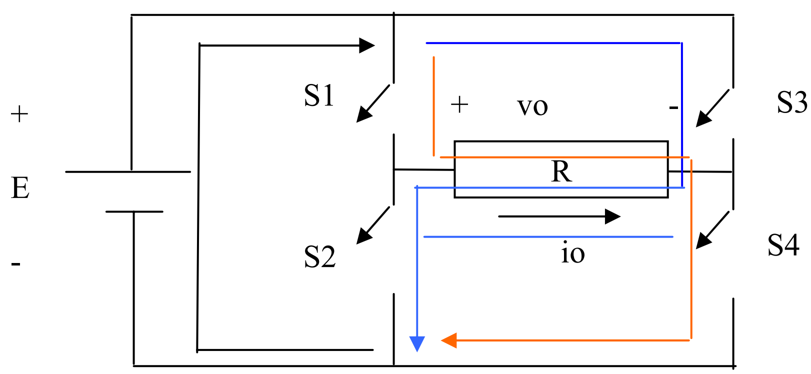
The dc component or average value Vo of output voltage vo(t) is

$Vo = T1\ E\ /T = d\ E$ volts

If we build a circuit that can provide a control signal for the switch with variable T1 or d we can control the average output voltage in direct proportion to the duty ratio d

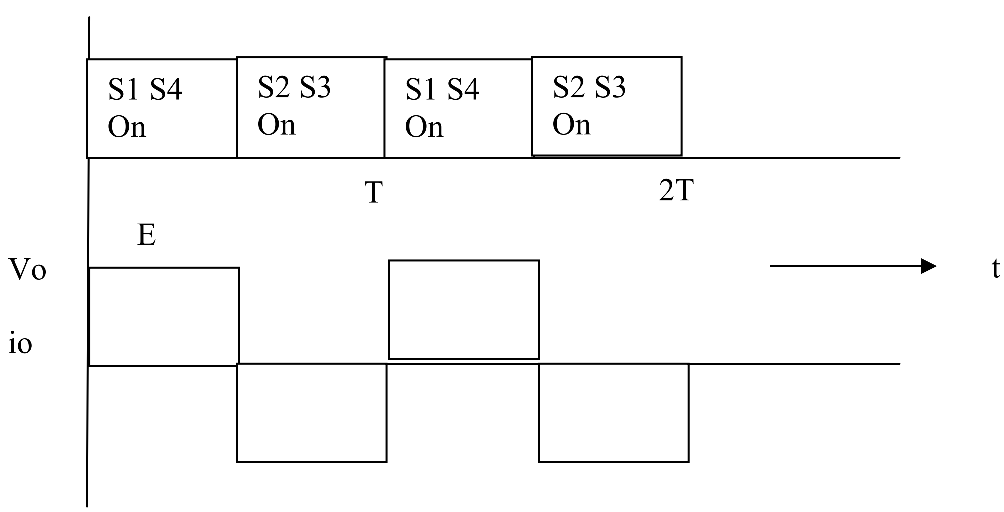
Such a control circuit is called a Pulse Width Modulator (PWM) or duty ratio controller.

Example 5 dc –ac conversion or Inverter

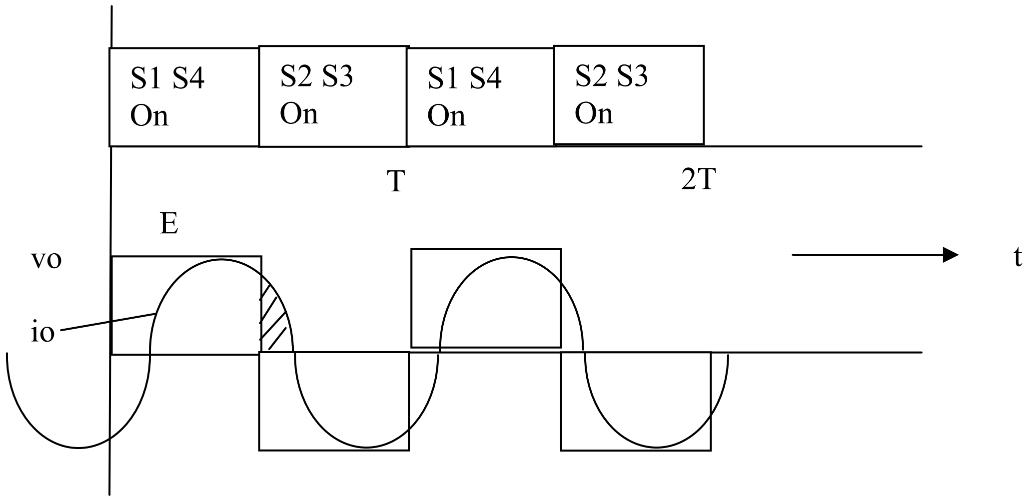


A basic dc-ac converter can be constructed using four switches in a bridge, or H, arrangement. The switches, SCR's or transistors, are usually unidirectional as indicated by the arrowhead on the switch pole.

As usual let T = 1/f denote the switching period. Only one switch pair (S1-S4 or S2-S3) is on at any given time. The switching pattern, and resulting output voltage vo are shown below for a resistive load. Output voltage vo and current io are in phase, and both are square waves. When S1 and S4 are on current from the source follows the red path through the load. With S2 and S3 on, the current reverses through the load along the blue path. The current from the dc source is unidirectional and constant.

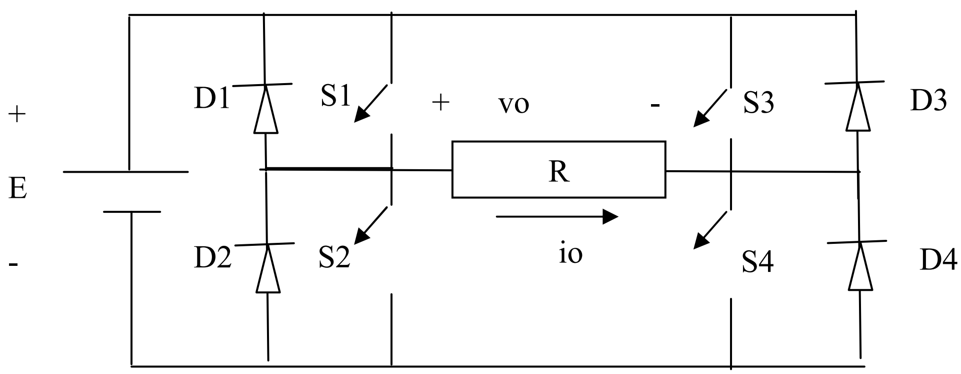


The situation is a little more complicated for inductive loads. In this case load inductance smoothes the current and this current lags the voltage as illustrated below.

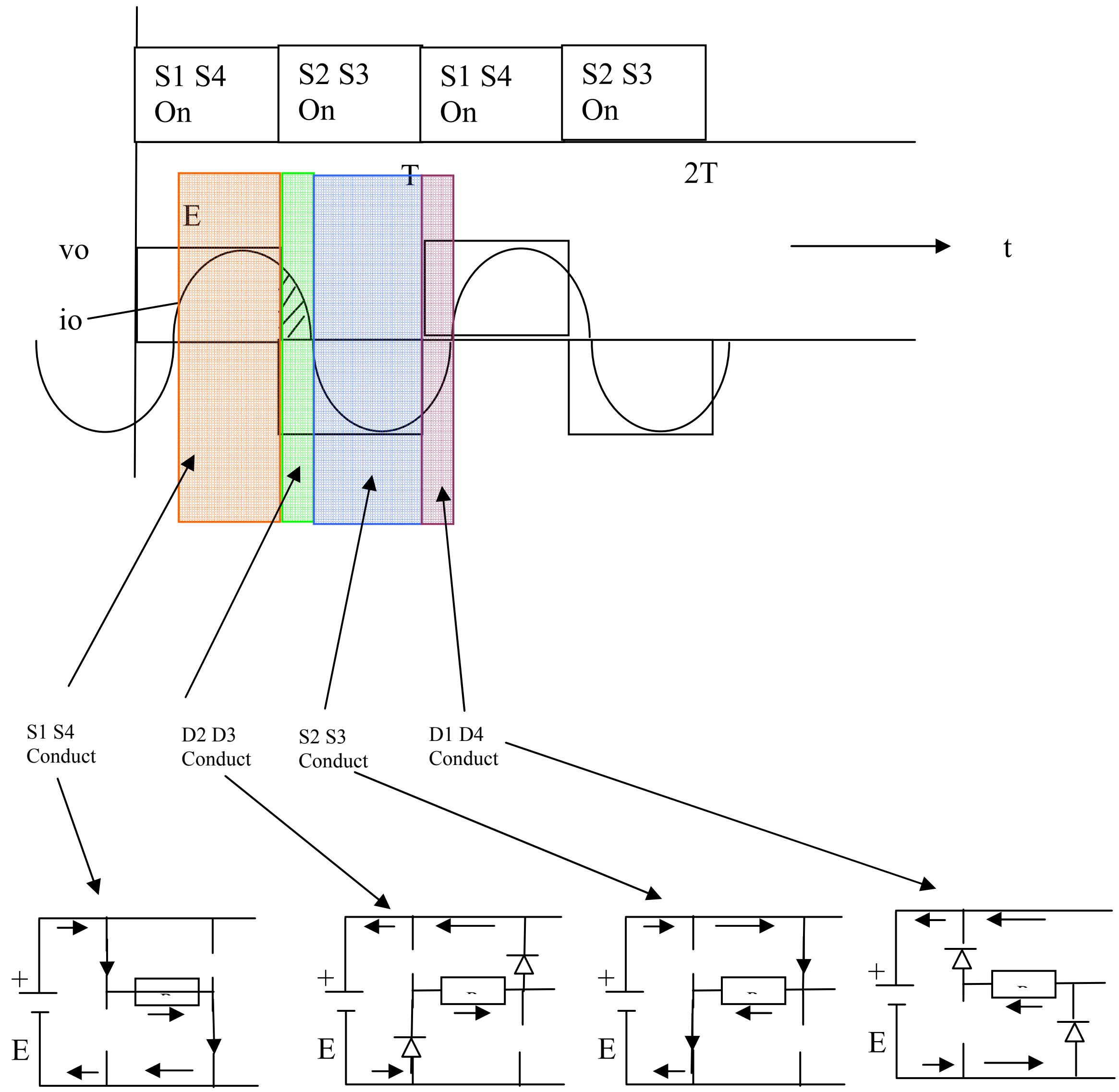


Consider the hatched region in the waveform above.. S2 and S3 have been turned on resulting in negative output voltage vo=-E. However, because of load inductance, the current io is still positive through the load. Since S2 and S3 conduct in the forward direction only (as indicated by the arrowhead on the switch pole) there is no path for positive current to flow!

The situation can be rectified by adding back-diodes as shown below.



With the same switching sequence for S1-S4 as before the resulting conduction pattern is shown below.



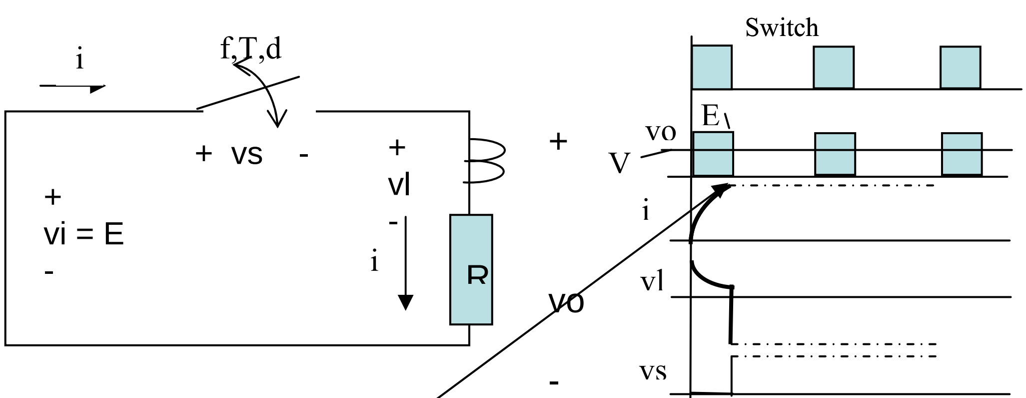
With an inductive load, a reactive power flow exists on the ac side; in other words, energy and power into the load oscillate. Look at the direction of current from the source. When the switches conduct, energy is supplied by the source. When the diodes conduct energy is returned to the source.

Example 6 Obtaining desired waveforms.

In examples 2-5 we were able to obtain desired functions, e.g., ac – controlled dc. However, most applications require more specific waveforms than we have shown how to provide[1]. For example, in a dc motor control application we would like the output to be a dc with as small a ripple as possible(economical). In a power supply we want a clean dc voltage. In the inverter we might want a clean sine wave in a utility application or a specific waveform in an audio amplifier.

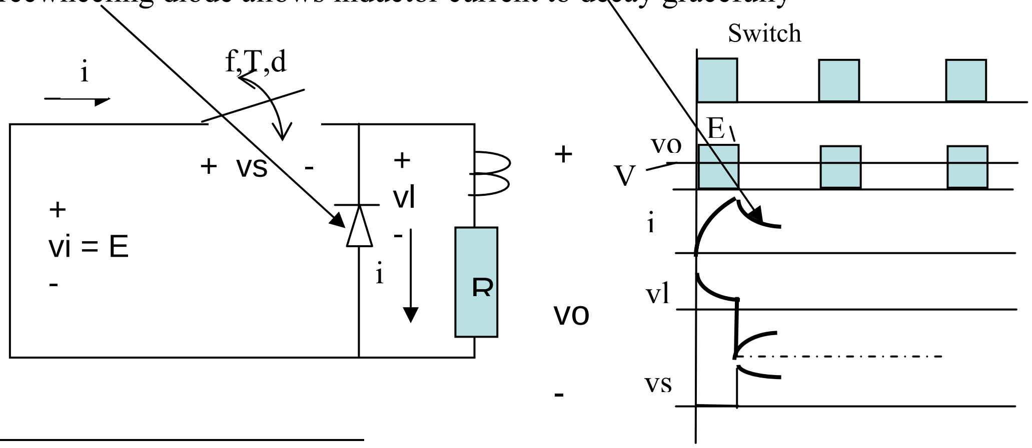
Waveform control is achieved both through the manner in which switching is organized as well as through passive and active filters. In this example we consider passive filters.

6a. In the chopper (Example 3) let us suppose we want a direct current. We can place an inductor in series with the resistive load. We immediately run into a problem when the switch turns off the current in the RL load is not zero and cannot change instantaneously; the circuit shown will result in a very large forward voltage across the switch as the inductor attempts to maintain current flow. This circuit will not work; we must provide an alternative path for the inductor current. The free-wheeling diode below provides such a path.



Current in in inductor cannot change instantaneously when switch is turned off

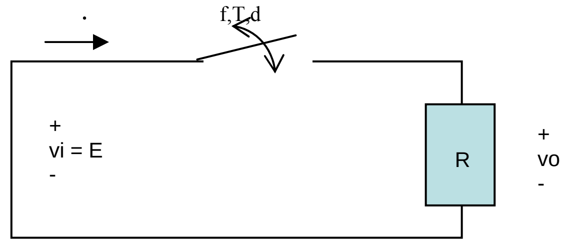
Freewheeling diode allows inductor current to decay gracefully

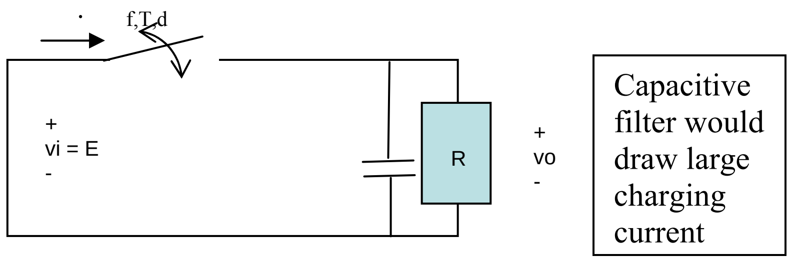


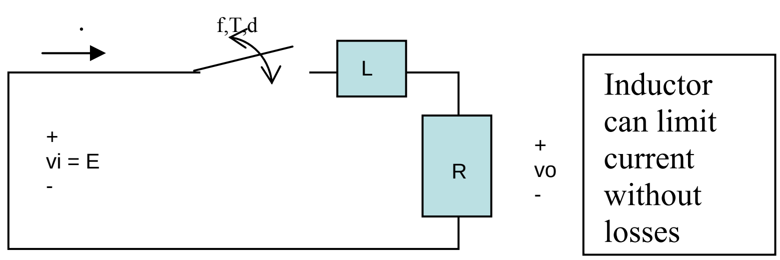
[1] An exception might be a heater element that does not much care about waveform but requires control.

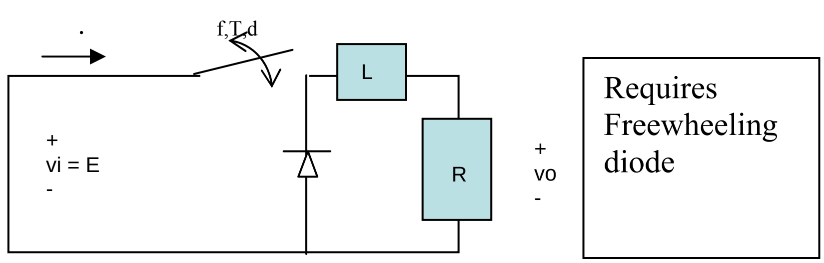
6b

In a power supply the dc voltage can be filtered using a capacitor as shown below. However, if the capacitor is discharged and the switch turns on, an infinite inrush current will flow. We would not want to limit this current with a resistor, but an inductor will work. But then we need a freewheeling diode.









This final circuit is the “Buck Converter” – a converter that changes dc voltage to a controlled dc voltage with a small amount of ripple. It is a fundamental unit in dc-dc power supplies.