Ch. 23: Permanent Magnet Brushed DC Motor Applications

23.1)
Why is it necessary to include a snubber circuit when switching inductive circuit elements (e.g., brushed DC motors)?

23.2)
Name at least two benefits of using higher PWM frequencies.

23.3)
For each of the snubbing methods described in this chapter:
a) Rank them in order of slowest current decay time to fastest.
b) Draw a schematic showing how each is connected, label the peak voltage drops across each of the components that comprise the snubber circuit, and write the expression for the peak voltage at the connection to the switching element.

23.7)
Design a circuit that performs bi-directional control of a DC motor that uses only the following components: a 2-position, ON-ON type, double-pole, double-through (DPDT) switch; a DC motor; and standard diode(s). Show a wiring diagram of your circuit and be sure to include kickback protection with the standard diodes.

23.9)
In a general and qualitative way, sketch the current response vs. time for a motor with L = 15 mH and R = 5 Ohms ($\tau = L/R = 3$ ms) under PWM control for the following scenarios. Include a sketch of the PWM drive signal on a separate axis for reference. Do not perform any calculations or analysis to answer these questions. Assume that the motor is stalled, and that a snubbing technique is used that results in a current fall time that is roughly equivalent to the rise time.
a) PWM frequency = 25 Hz, duty cycle = 90% (period = 40 ms, on time = 36 ms, off time = 4 ms).
b) PWM frequency = 500 Hz, duty cycle = 40% (period = 2 ms, on time = 0.8 ms, off time = 1.2 ms).
c) The motor is initially off. At time t0, a 20 kHz drive signal is enabled at 60% duty cycle (period = 50 μs, on time = 30 μs, off time = 20 μs). Illustrate the current transient response.
d) The motor is initially running at 100% duty cycle. At time t0, the PWM duty cycle is changed to 25% at 20 kHz (period = 50 μs, on time =12.5 μs, off time = 37.5 μs). Illustrate the current transient response.
e) The frequency of the PWM drive signal is increased steadily from 25 Hz to 1 kHz while the duty cycle is held constant at 20%. (The initial period = 40 ms, initial on time = 8 ms and initial off time = 32 ms. The final period = 1 ms, final on time = 0.2 ms and final off time = 0.8 ms).

23.10)

A motor with KT = 1.657 oz.in./A, KE = 1.230 V/krpm and terminal resistance R = 20.3 Ohms is driven at 14 V. How fast will the motor spin under a constant 0.15 oz.in. load if it is driven by PWM with a 25% duty cycle and a frequency well above the motor's electrical time constant? What is the speed if the duty cycle is increased to 85%?