ECE 320: Lecture 32

Notes

Comments from last lecture:

1. Exam #2 moved from next Wednesday to next week Friday

Power Converter Components:

1. Power Electronic Devices:

This is just a quick overview for background. The specifics of the devices won't be on the exar or homework.

* Power diodes and thyristors were discussed last time. Diodes and thyristors both require the external circuit to drive the current through the device to zero before they can turn off. For more detail on these devices, see Chapters 20 and 23 in Mohan, Undeland and Robbins.

* Devices that are able to interrupt current are better for most applications. These are sometimes referred to as self-commutating devices. The two most commonly used ones are:

1. Power MOSFETS (see Chapter 22 for more detail):

- Figure 22-1 shows the basic structure.
- When device turns-on, a voltage pulse is applied to the gate which allows current to cross P region between Source and Drain. Turn-on time approx 50-100 ns. See Figure 22-5
- When the pulse is remove, the device will slowly turn off. If the polarity of the gate voltage reversed, the device will turn-off rapidly (again in about 50-100 ns).
- Will have a resistive voltage drop when turned on (approx. 2 V).
- Limited to lower blocking voltages when turned off (400-500V common)
- Limited current conduction ability due to nature of conducting channel (limited to a few hundred Amps)

2. Insulated gate bipolar transistor (see Chapter 25)

- Hybrid device combining best aspects of a power BJT and a power MOSFET
- Power IGBT's require significant current pulses to turn them on or off and have fairly slow turn-off times but can operate at relatively high currents/voltages
- Power MOSFETs turn-on/turn-off with a voltage applied to the gate but are limited in voltage/current capabilities
- IGBT is the result. Can use same gate circuit as MOSFET
- Turn-off time slower than for a MOSFET, but much faster than BJT
- Up to 2-3 kV and 2-3kA.

Switch Characteristic:

- Instead of operating in linear region, devices are operated in saturation or Ohmic region.
- The device can have a significant voltage drop in the linear region. Energy dissipation in the device is a problem.
- Treat as a somewhat non-ideal switch. It will have a small voltage drop across it when on ar small leakage current when off.

2. Passive Elements

- Converter will have L and C components act as filters or energy storage (this also strengt voltage or current sources)
- Will also be RC networks across switches to help protect them

3. Gate Driver Circuitry

- Produces the gate pulses appropriate for the device.
- Produce sharp pulses to get desired turn-on or turn-off
- Essentially a small power converter

4. Control Circuit

- Often put in closed loop controls to regulate a specific quantity
- Compare measured quantity with a preset reference. For example, one might regulate outp current or voltage
- Controls could be implemented as an analog circuit or a digital circuit
- Can often describe in LaPlace domain.

DC-DC Converters (Chapter 7 in text book)

- Want to produce a regulated dc output voltage or current
- Options include:
  1. Voltage divider (poor efficiency)
  2. Using a dc generator (high cost and bulky)
  3. Linear regulator (again, poor efficiency since drop the difference between input and output voltage across a transistor)
  4. But we can take that linear regulator circuit and push in into non-linear region where device carries high current, but has a low voltage drop. Repeated turn device on and off to synthesize a waveform with desired average characteristics

- As we have discussed in the last lectures, the 4th option is the one we will discuss here.

Buck Converter:

- See section 7-3 in the text book.
- The basic topology is in Figure 7-4.
- Assume that Vd is a stiff voltage source.
- Inductor added to act as a filter and prevent connection of two voltage sources.
- Capacitor added to filter the output voltage
- Evaluate based on state of the switches.

  1. Switch closed:

$$Vo = Vd = Vin$$

$$Io = \frac{Vo}{R}$$

$$V_o = \frac{1}{T_s}\cdot\int_0^{T_s} v(t)_o\,dt = \frac{1}{T_s}\cdot\left(\int_0^{D T_s} V_d\,dt + \int_{D\cdot T_s}^{T_s} 0\,dt\right) = \frac{t_{on}}{T_s}\cdot V_d = D\cdot V_d$$

$$\boxed{V_o = D\cdot V_d}$$ Average value of v_o

- Where: $0 \le D \le 1$

- Now consider convservation of power:

$$Pd = Po$$

$$V_d\cdot I_d = V_o\cdot I_o$$

- Which can be rewritten as:

$$\boxed{\frac{I_o}{I_d} = \frac{V_d}{V_o} = \frac{1}{D}}$$ I_o is the average current

- Combining the voltage and current relations, we have what behaves like a variable ratio, DC transformer.
- The average current flows through the inductor.