Full bridge converter

Transformers and isolated converters

Most DC power supplies have the following requirements:

1. Regulated output voltage

   Solved by a large capacitor at the output, and feedback control.
2. High power factor

   PFC - discussed previously.
3. Isolation
4. Multiple outputs

Isolated topologies include transformers, which easily solve the two latter requirements, as we will see.

Transformers

A transformer consists of two or more coils that are magnetically coupled (a common magnetic flux flows through them). Usually, the coils are windings around a common magnetic core, as shown in Figure 1.

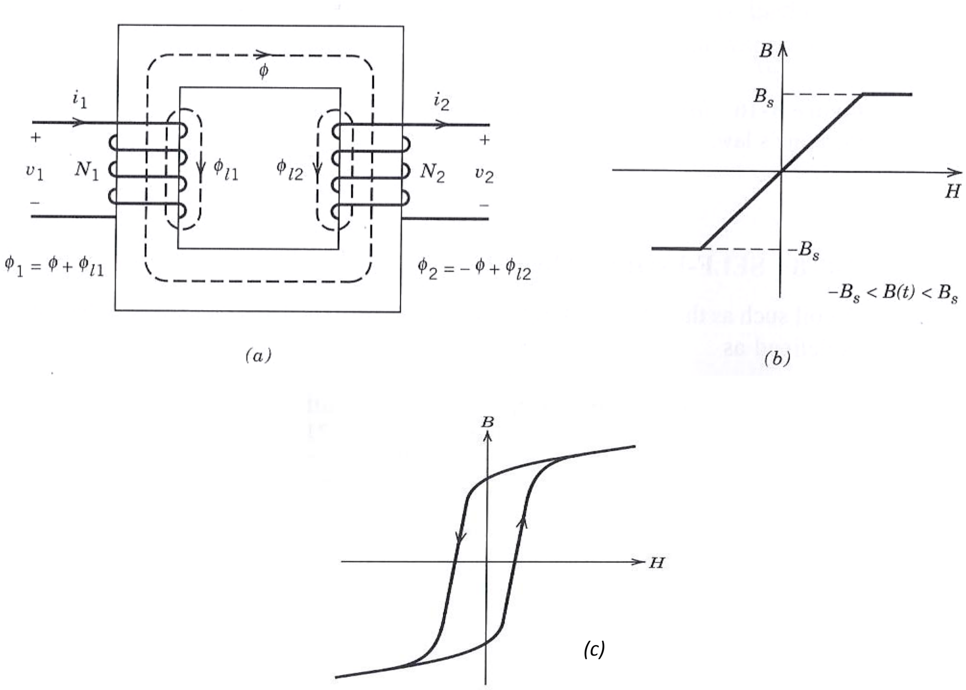

Fig. 1: (a) cross section of a transformer. (b) Ideal *B*-*H* characteristics of the core. (c) *B*-*H* characteristics of the core with hysteresis.

Figure 2 shows the equivalent circuit of a transformer. Ideal transformers (Figure 2(b)) have the following properties:

1. No conduction losses in the windings $(R_1 = R_2 = 0)$.
2. Infinite core permeability $(L_m = \infty)$.
3. No leakage fluxes $(L_{l1} = L_{l2} = 0)$.

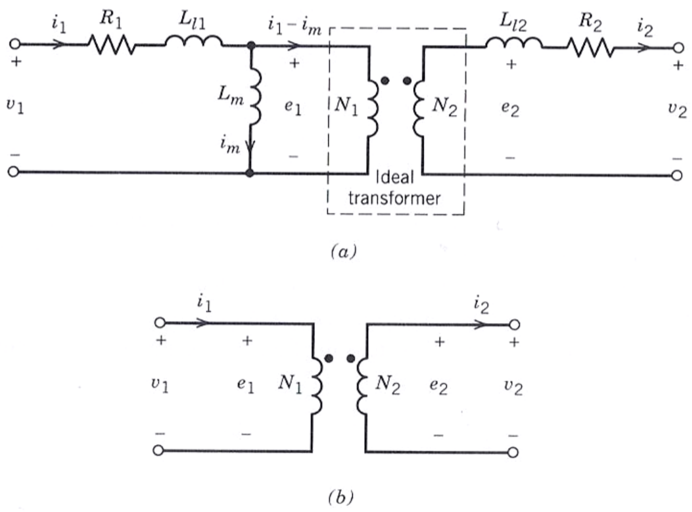

Fig. 2: (a) Equivalent circuit for a non-ideal transformer with a lossless core and no hysteresis. (b) Equivalent circuit for an ideal transformer.

In an ideal transformer, the current and voltage in both side are:

$$\frac{i_1}{i_2} = \frac{N_2}{N_1}, \qquad \frac{v_1}{v_2} = \frac{N_1}{N_2}.$$

- Since there is no electrical connection between the two sides of the transformer (only magnetic one), it is *isolated*.
- Multiple outputs can be created by having multiple windings (in addition to the secondary winding), as shown in Figure 3.

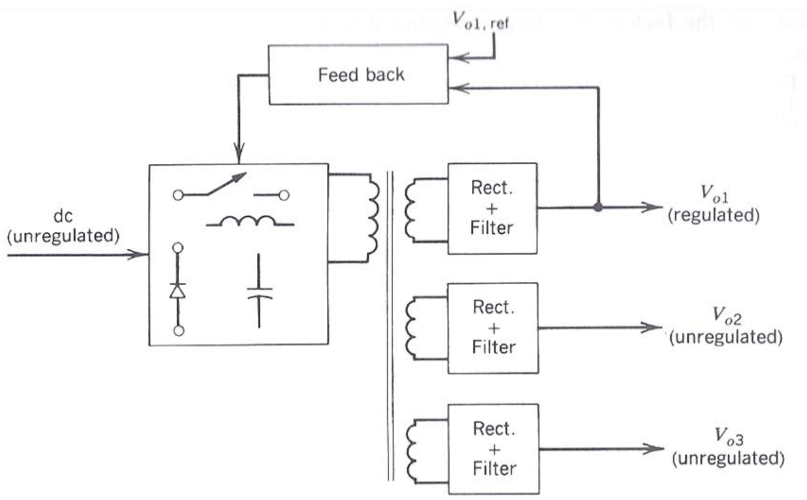

Fig. 3: Multiple outputs

There are two kinds of isolated converter topologies:

1. Unidirectional core excitation – only the positive part of the *B-H* curve is used. Include: Flyback converter (shown in the lecture by Prof. Weiss), forward converter.
2. Bidirectional core excitation – both positive and negative parts of the B-H curve are used. Include: push-pull, half-bridge, full-bridge (explained below).

An example - full-bridge converter

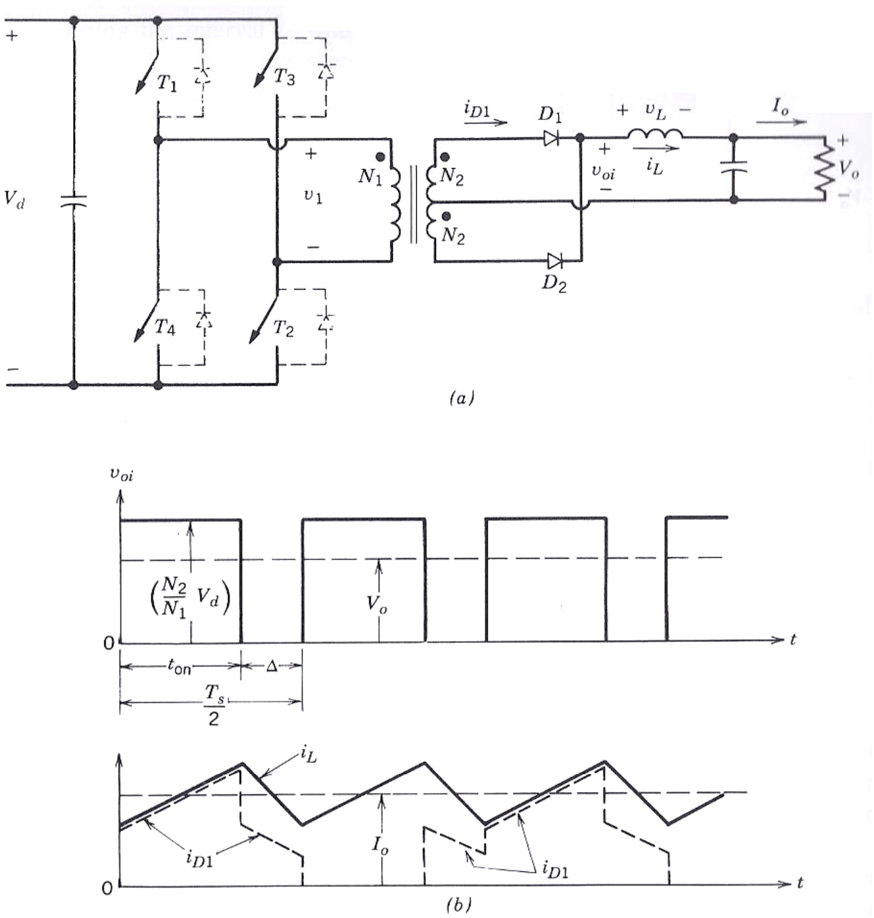

Fig. 4: (a) Full-bridge converter. (b) voltage and current waveforms: i_L the current of the inductor, v_{oi} is the voltage from the left side of the inductor to the middle tap of the secondary winding.

Figure 4 shows a full bridge converter where (T_1, T_2) and (T_3, T_4) are pairs of switches, switched together alternatively for a time t_{on} in a switching cycle T_s (what is the switching frequency?). After each pair is turned off, there is a time interval Δ when all switches are "off". When either pair is "on", $v_{oi} = (N_2/N_1)V_d$, and therefore

$$v_L = \frac{N_2}{N_1} V_d - V_o \,, \qquad\qquad 0 < t < t_{on} \,.$$

Similarly, when all switches are "off", $v_{oi} = 0$ (assuming ideal diodes), and therefore

$$v_L = -V_o, \qquad\qquad t_{on} < t < t_{on} + \Delta.$$

In steady state, no energy is accumulated in the inductor, hence the time integral of the inductor voltage over one switching cycle is zero. Since $t_{on} + \Delta = \frac{1}{2} T_s$, we obtain:

$$\frac{V_o}{V_d} = 2 \frac{N_2}{N_1} D \ ,$$

where $D = t_{on}/T_s$ is the duty cycle (in this case, $0 < D < 0.5$).

The figures are taken from: N. Mohan, T. M. Undeland and W. P. Robbins, Power electronics: converters, applications and design, 3rd ed., Hoboken, NY: John Wiley and Sons, Inc., 2003.