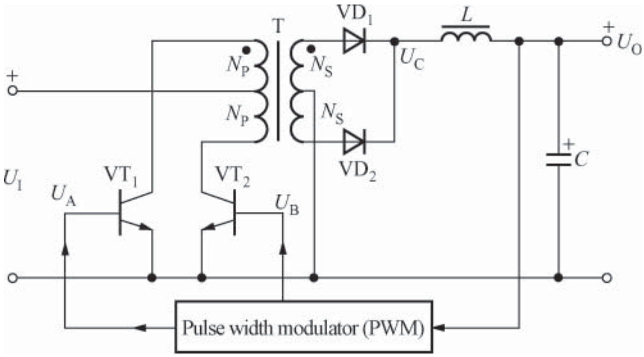

Figure 3.14 Basic principle of push-pull converter

3.9 Basic Principle of Push-Pull Converter

Push-pull converter uses two bipolar power switch tubes (or MOSFET) working alternately to complete the conversion. See Figure 3.14 for its basic principle. This circuit is a forward converter, and both the primary and secondary windings of the high-frequency transformer have a center tap. The two paths of control signal, U_A and U_B, are generated by PWM. When U_A and U_B are high and low level, respectively, MOSFET VT_1 is conducted, and the input voltage U_I passes through the upper half N_P of the primary winding with negative polarity, the voltage polarity being positive at the lower end and negative at the upper end, and at this point VT_2 is cut off. After passing through the high-frequency transformer, the voltage polarity of the lower half N_S of the secondary winding is positive at the lower end and negative at the upper, so that VD_2 is conducted and the current at the secondary side supplies power to the filter capacitor and the load through the output rectifier VD_2. At this point, VD_1 is cut off. Conversely, when U_B and U_A are high and low level, respectively, VD_1 is conducted, while VD_2 is cut off, and the secondary current supplies power to the output filter capacitor and the load through VD_1.

See Figure 3.15 for the timing waveform of push-pull converter, wherein U_A and U_B indicate the waveform of the two input pulses respectively, and U_C refers to the output pulse waveform. It needs to be noted that the pulse frequency of U_C is twice each driving frequency of PWM. For example, when the operating frequency of PWM is 50 kHz, the pulse frequency of U_C is 100 kHz. Push-pull converter is suitable for high-power converter with low-voltage input, such as +12 or +24 V battery-powered systems.

The expression of DC output voltage U_O is as follows:

$$U_O = U_{PK}(T_{ON}/T) \tag{3.7}$$

wherein U_{PK}, the peak voltage of the secondary output pulse, is determined by the following expression:

$$U_{PK} = (U_I - U_{SWITCH})\ N_S/N_P - U_F \tag{3.8}$$

wherein U_{SWITCH} is the saturation voltage of the transistor; N_S/N_P, the turns ratio between the secondary and primary windings; and U_F, the conduction voltage drop of output rectifier. If

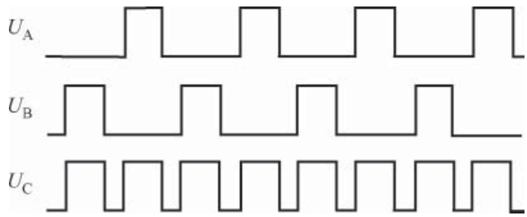

Figure 3.15 Timing waveform of push-pull converter

the bipolar power switch tube is replaced with MOSFET, conversion efficiency can be further improved.

The output voltage expression of push-pull converter is as follows:

$$U_O = 2 \times \frac{N_S}{N_P} \cdot \frac{t}{T} \cdot U_I = 2 \times \frac{N_S}{N_P} \cdot DU_I \tag{3.9}$$

When using push-pull converter, multiple output voltages (including negative voltage output) can be generated by designing more secondary winding, thus providing battery-powered systems with various necessary voltages.

The disadvantage of push-pull converter is that the conduction time of VT_1 and VT_2 must be strictly matched, or the magnetic core of high-frequency transformer will be saturated because of the inconsistent on-off time of them.

3.9.1 Two Types of Push-Pull Converter

Push-pull converter is divided into two topologies of current mode and voltage mode. Their main difference is that the input stage of current mode requires adding a large inductor *L*, but does not need an output filter inductor, while the input stage of voltage mode has no large inductor; however, the output stage must be connected to the filter inductor *L*.

See Figure 3.16(a) for the topology of voltage-mode push-pull converter. It is a forward converter. Two MOSFET power switch tubes V_1 and V_2 are respectively connected to both ends of the primary winding with a center tap and alternately conducted as per the phase difference of 180°.

When V_1 is conducted, positive voltage is applied to the rectifier diode VD_1 to make it conducted. At this point, V_2 is switched off and VD_2 is cut off, and the voltage applied to the drain of V_2 is $2U_I$. This requires MOSFET to withstand a high voltage of at least $2U_I$. For example, if the DC high voltage $U_I \approx +300\,V$ after a 220-V AC voltage is rectified and filtered, the voltage-withstanding value of MOSFET should be at least $2 \times 300\,V = 600\,V$. In view that there is surge voltage in the electric network, MOSFET withstanding a voltage of 1000 V shall be actually used to avoid tube damage. Furthermore, there shall be a dead time during the conversion of V_1 and V_2 to avoid that the two MOSFETs are conducted simultaneously due to the turn-off delay, which will cause short circuit of the high-frequency transformer and a sudden increase in the current (just with the leakage inductance limiting current in this case), thereby damaging the tube.

See Figure 3.16(b) for the topology of current-mode push-pull converter. A large inductor *L* is connected in series between the input voltage and the transformer. When MOSFET

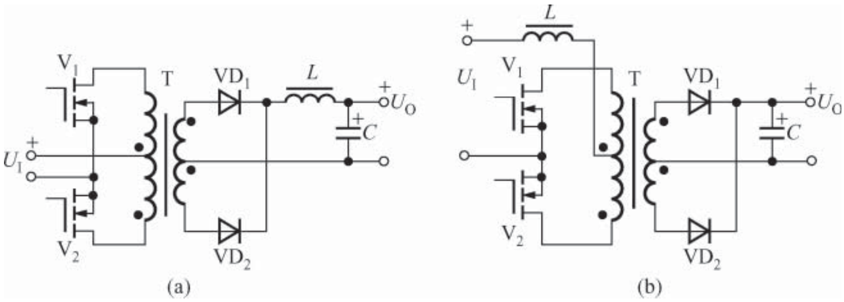

Figure 3.16 Topology of push-pull converter (a) Voltage mode converter and (b) Current mode converter

is conducted, L can be used to reduce the impact current generated during the conduction of MOSFET and rectifier. The disadvantage of the converter is that its output power will be reduced due to the connection of a large inductor.

3.10 Basic Principle of Half/Full Bridge Converter

3.10.1 Basic Principle of Half-Bridge Converter

Half-bridge converter is based on the push-pull converter. It uses two power switch tubes to constitute a half bridge, generally with AC input and applicable to isolated converters with an output power of 500–1500 W. See Figure 3.17 for the basic principle of half-bridge converter, to which a rectifier bridge and a filter capacitor are added at the input stage.

This circuit is basically the same as that in Figure 3.14. The main differences are as follows: (i) The drive circuit must be isolated from the power switch tube and coupled with high-frequency transformer. PWM in Figure 3.17 does provide drive pulses for the power switch tube through one coupling transformer. (ii) The primary winding of high-frequency transformer has no center tap. The timing waveform of half-bridge converter is the same as that of push-pull converter (Figure 3.15); however, its drive circuit is comparatively complicated.

The output voltage expression of half-bridge converter is as follows:

$$U_O = \frac{N_S}{N_P} \cdot \frac{t}{T} \cdot U_I = \frac{N_S}{N_P} \cdot DU_I \tag{3.10}$$

3.10.2 Basic Principle of Full-Bridge Converter

Full-bridge converter requires four power switch tubes to constitute a full bridge. See Figure 3.18 for its basic principle. Among various converters, full-bridge converter has the highest output power, which is suitable for constituting high-power isolated converter with an output power of 1–3 kW. The four power switch tubes are divided into two groups: one is VT_1 and VT_4, and the other is VT_2 and VT_3. When U_B is high level, VT_1 and VT_4 are conducted simultaneously, and when U_A is high level, VT_2 and VT_3 are conducted simultaneously.