2.3 Voltage-multiplier circuits

Voltage-multiplier circuits are employed to maintain a relatively low transformer peak voltage while stepping up the peak output voltage to two, three, four, or more times the peak rectified voltage.

2.3.1 Voltage Doubler

The network of Fig.(2-12) is a half-wave voltage doubler. Daring the positive voltage half-cycle across the transformer, secondary diode D_1 conducts (and diode D_2 is cut off), charging capacitor C_1 up to the peak rectified voltage (V_m). Diode D1 is ideally a short daring this half-cycle, and the input voltage charges capacitor C_1 to V_m with the polarity shown in Fig.(2-13a). During the negative half-cycle of the secondary voltage, diode D_1 is cut off and diode D_2 conducts charging capacitor C_2. Since diode D_2 acts as a short during the negative halt-cycle (and diode D_1 is open), we can sum the voltages around the outside loop (see Fig. 2-13b):

$$-V_m - V_{CI} + V_{C2} = 0$$

$$-V_m - V_m + V_{C2} = 0$$

from which we obtain

$$V_{C2} = 2V_m$$

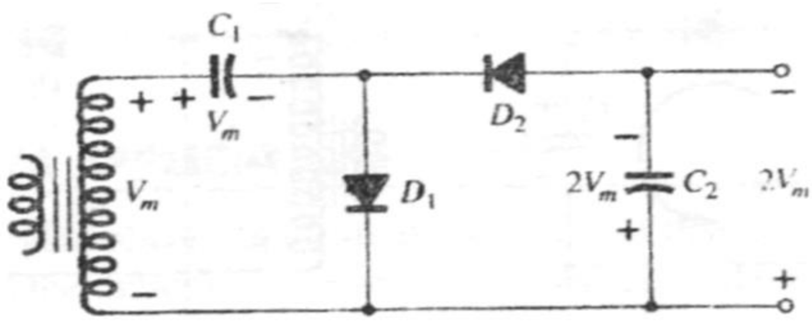
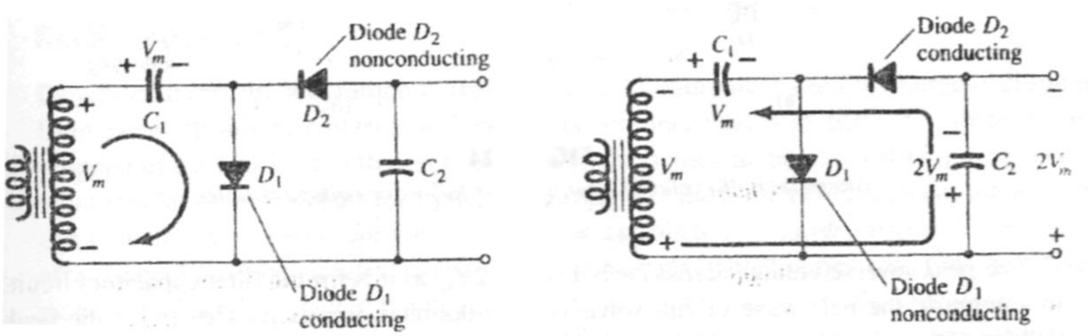


Fig. (2-12)

Half-wave voltage doubler



(a) (b)

Fig.(2-13) Double operation showing each half cycle of operation

(a) positive half-cycle (b) negative half-cycle

On the next positive half-cycle, diode D_2 is nonconducting and capacitor C_2 will discharge through the load. If no load is connected across capacitor C_2, both capacitors stay charged C_1 to V_m and C_2 to $2V_m$. If, as would be expected, there is a load connected to the output of the voltage doubler, the voltage across capacitor C_2 drops during the positive half-cycle (at the input) and the capacitor is recharged up to $2V_m$ during the negative half-cycle. The output waveform across capacitor C_2 is that of a half-wave signal filtered by a capacitor filter. The peak inverse voltage across each diode is $2V_m$.

Another doubler circuit is the full-wave doubler of Fig. (2-14). During the positive half-cycle of transformer secondary voltage (see Fig. 2-15a) diode D, conducts, charging capacitor C, to a peak voltage V_m. Diode D_2 is nonconducting at this time.

During the negative half-cycle (see Fig. 2-15b) diode D_2 conducts, charging capacitor C_2, while diode D_l is nonconducting. If no load current is drawn from the circuit, the voltage across capacitors C_1 and C_2 is $2V_m$. If load current is drawn from the circuit, the voltage across capacitors C_1 and C_2 is the same as that across a capacitor fed by a full-wave rectifier circuit. One difference is that the effective capacitance is that of C_1 and C_2 in series, which is less than the capacitance of either C_l or C_2 alone. The lower capacitor value will provide poorer filtering action than the single-capacitor filter circuit.

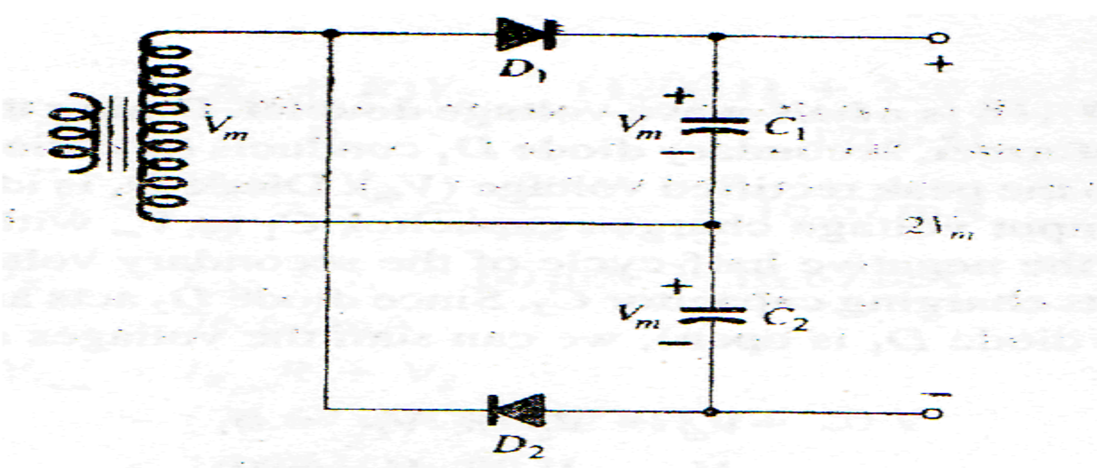


Fig.(2-14) Full-wave voltage doubler

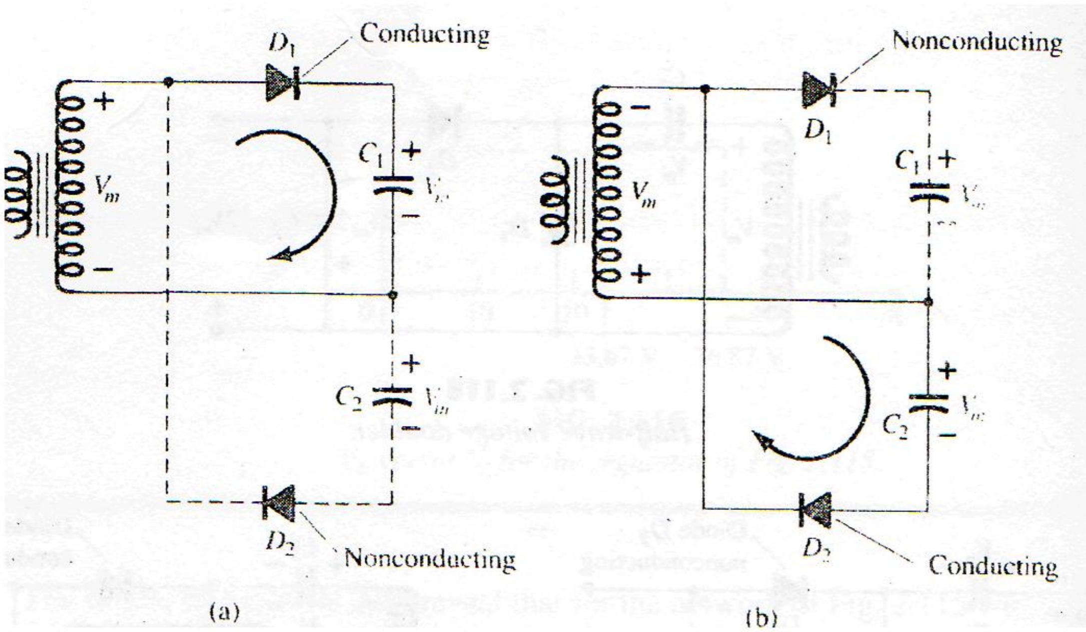


Fig.(2-15) Alternate half cycles of operation for full-wave voltage doubler

The peak inverse voltage across each diode is $2V_m$as it is for the filter capacitor circuit. In summary, the halt-wave or full-wave voltage-doubler circuits provide twice the peak voltage of the transformer secondary while requiring no center-tapped transformer and only $2V_m$ PIV rating for the diodes.

2.3.2 Voltage Tripler and Quadrupler

Figure 2.16 shows an extension of the half-wave voltage doubler, which develops three and four times the peak input voltage. It should he obvious from the pattern of the circuit connection how additional diodes and capacitors may be connected so that the output voltage may also be five, six, seven, and so on, times the basic peak voltage (V_m).

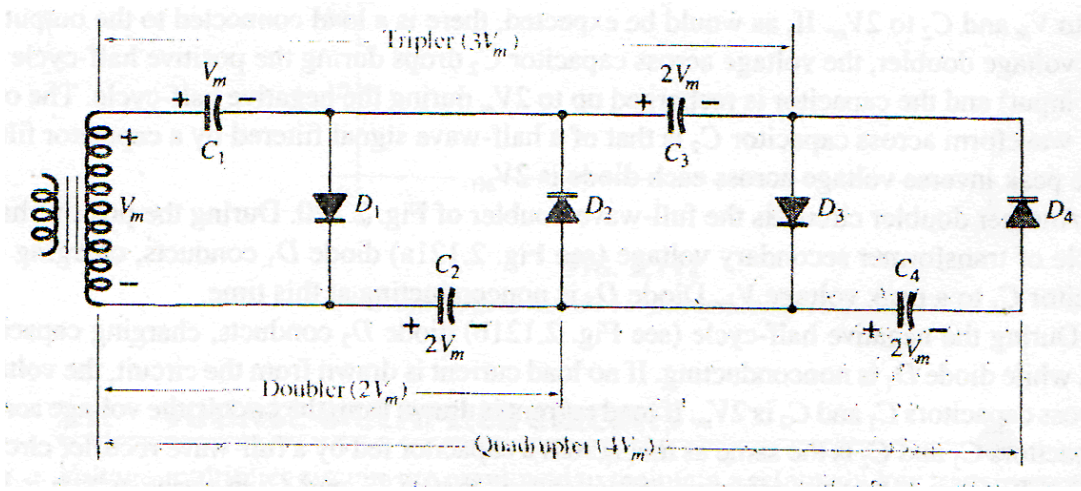


Fig.(2-16) Voltage Tripler and Quadrupler.

In operation, capacitor C_1 charges through diode D_1 to a peak voltage V_m during the positive half-cycle of the transformer secondary voltage. Capacitor C_2 charges to twice the peak voltage, $2V_m$,developed by the sum of the voltages across capacitor C_1 and the transformer during the negative half-cycle of the transformer secondary voltage.

During the positive half-cycle, diode D_3 conducts and the voltage across capacitor C_2 charges capacitor C_3 to the same $2V_m$ peak voltage. On the negative half-cycle, diodes D_2 and D_4 conduct .with capacitor C_3, charging C_4 to $2V_m$

The voltage across capacitor C_2 is $2V_m$ across C_1 and C_3 it is $3V_m$ and across C_2, and C_4 it is $4V_m$. If additional sections of diode and capacitor are used, each capacitor will be charged to $2V_m$. Measuring from the top of the transformer winding (Fig. 2-16) will provide odd multiples of V_m at the output, whereas measuring the output voltage from the bottom of the transformer will provide even multiples of the peak voltage V_m.

The transformer rating is only V_m maximum, and each diode in the circuit must be rated at $2V_m$ PIV. If the load is small and the capacitors have little leakage, extremely high dc voltages may be developed by this type of circuit, using many sections to step up the dc voltage.