Diode Voltage Doubling Notes

The large difference between forward- and reverse-bias conduction of a semiconductor diode is the basis for the (simplified) voltage doubling circuit shown. A square-wave bipolar signal (amplitude ± V for simplicity) is applied as shown.

The circuit operates by enabling C2 to be continually charged through D2, but preventing it from being discharged. Assume for simplicity that idealized diodes are used. For convenient reference number the half-periods consecutively from 0, starting with a negative half-period. Consider the nth negative half-period (noting that n is zero or even); C1 charges rapidly through the low resistance path provided by D1 to V. Note that D2 isolates C2, so that the voltage across C2 does not change during the negative half-period from what it was during the preceding positive half-period, i.e., e2(n) = e2(n-1). The circuit during the nth positive half period is as shown below left. The net charge at nodes 2-3 is the sum of the charges on C1 and C2, i.e., C1*V + C2*e2(n). During the next, i.e., the (n+1'st) half period the circuit is as shown below, right. Charge on the capacitors redistributes itself in keeping with the capacitor terminal requirements. Because the total charge at nodes 2-3 can not change from the previous half cycle it is necessary that

$$C1*e1(n+1) + C2*e2(n+2) = C1*V + C2*e2(n)$$

Finally observe from Kirchoff's Voltage Law that

$$e1(n+1) + e2(n+1) = V$$

From these equations determine that for successive half-periods (positive or negative)

$$e2(n+1) = \frac{2C1 + C2*e2(n-1)}{C1 + C2}$$

The solution to this difference equation (verify by substitution) is

$$e2(n) = 2V + B \left\{ \frac{C2}{C1 + C2} \right\} \frac{n}{2}$$

where n is odd. The value of the constant B depends on the initial charge of the capacitors, but in any event since the second term is a fraction it rapidly becomes negligible.

Assume that both C1= 3µF and C2 = 1 µF are initially uncharged. Compute the charging transient for a 1 millisecond period, ± 10 volt square wave. Note the effect of the finite diode forward voltages.
* Doubler

VS  1  0  PULSE(-10, 10, 0, 1U, 1U, .5M, 1M)
C1  1  2  1U  IC=0
D1  0  2  D1N4004
D2  2  3  D1N4004
C2  3  0  3U  IC=0

.MODEL D1N4004 D(Is=14.11n  N=1.984 Rs=33.89m Ikf=94.81 Xti=3 + Eg=1.11 Cjo=25.89p M=.44 Vj=.3245  Fc=. Bv=600 Ibv=10u Tt=5.7u)
.LIB EVAL.LIB
.TRAN 10U 20M UIC
.PROBE
.END