Switched Capacitor Converter (SCC) By: Nick Stephen

The two most common switched capacitor voltage converters are the voltage inverter and voltage doubler shown in figure 4.1. A Switched Capacitor Converter accomplishes energy transfer and voltage conversion using capacitors. In a voltage inverter, the charge pump capacitor, C1, is charged to the input voltage during the first half of the switching cycle. During the second half of the switching cycle, its voltage is inverted and applied to capacitor, C2 and the load. The output voltage is the negative of the input voltage, and the average input current is approximately equal to the output current. The switching frequencies allow the use of smaller capacitors Switched capacitor converters are low cost and compact and can achieve efficiencies greater than 90%.

The voltage doubler works similarly to the inverter, however the pump capacitor is placed in series with the input voltage during its discharge cycle, thereby accomplishing the voltage doubling function. In the voltage doubler, the average input current is approximately twice the average output current.

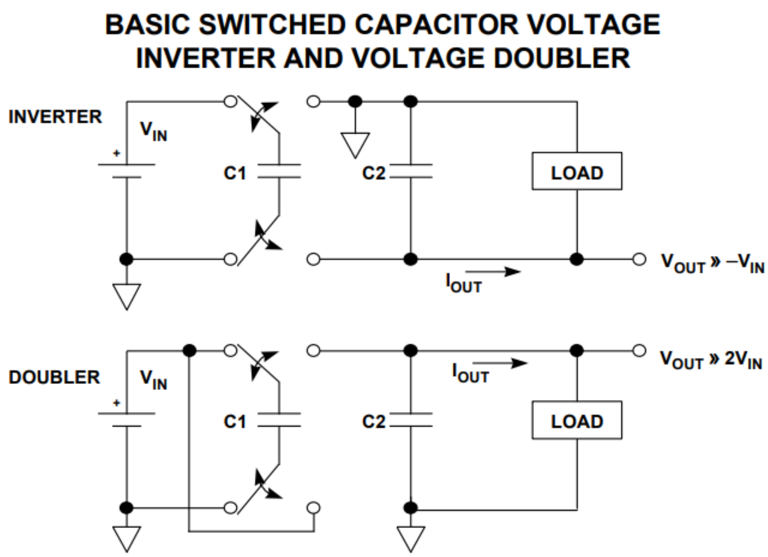

Figure 4.1

SCC Advantages

- No magnetic elements (Inductors)
- Minimal radiated EMI
- Simple implementation: only 2 external capacitors
- Efficiency > 90% achievable
- Optimized for doubling or inverting supply voltage- efficiency degrades for other output voltages
- Low cost, compact and low profile

SCC Disadvantages

- Inherent power losses
- Relatively large number of switches
- High inrush current at start-up

Application Information

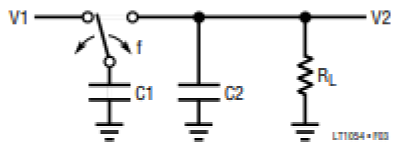

Figure 3. Switched-Capacitor Building Block

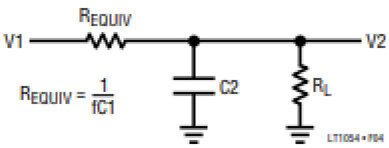

Figure 3. Switched-Capacitor Equivalent Circuit

In figure 3 when the switch is in the left position, capacitor C1 will charge to voltage V1. The total charge on C1 will be q1= C1V1. The switch then moves to the right, discharging C1 to voltage V2. After this discharge time the charge on C1 IS q2= C1V2. Note that charge has been transferred from the source V1 to the output V2. The amount of charge transferred is:

$$\Delta q = q1 - q2 = C1(V1 - V2)$$

If the switch is cycled f times per second, the charge transfer per unit time(Current) is:

$$I = (f)\,(\Delta q) = (f)\,[C1\,(V1 - V2)]$$

To obtain an equivalent resistance for the switched capacitor network we can rewrite this equation in terms of voltage and impedance equivalence:

$$I = \frac{V1 - V2}{\frac{1}{fC1}} = \frac{V1 - V2}{Requiv}$$

A new variable R_{EQUIV} is defined such that R_{EQUIV}= 1/fC1. Thus, the equivalent circuit for the switched-capacitor network is as shown in Figure 3.the

Capacitor selection

For unregulated circuits the nominal values of C_{in} and C_{out} should be equal. Good quality, low ESR capacitors such as solid tantalum is necessary to minimize voltage losses at high currents. For C_{in} the effect of ESR of the capacitor will be multiplied by 4 due to the fact that switch currents are approximately two times higher than output current and losses will occur on both the charge and discharge cycle. This means that using a capacitor with 1 ohm of ESR for C_{IN} will have the same effect as increasing the output impedance by 4Ω. This represents a significant increase in the voltage losses, for C_{Out} the affect of ESR is less dramatic. C_{out} is alternately charged and discharged at a current approximately equal to the output current and the ESR of the capacitor will cause a step function to occur in the output ripple at the switch transitions.

Realizing that large value tantalum capacitors can be expensive, a technique that can be used is to parallel a smaller tantalum capacitor with a large aluminum electrolytic capacitor to gain both low ESR and reasonable cost. Where physical size is a concern some of the newer chip type surface mount tantalum capacitors can be used. These capacitors are normally rated at working voltages in the 10V to 20V range and exhibit very low ESR

KEMETs U2J Dielectric capacitors are a good option. U2J is an extremely stable dielectric material for Class I multilayer ceramic capacitors (MLCCs). Ceramic capacitors using the U2J dielectric retain over 99% of nominal capacitance at full rated voltage. When referenced to ambient temperature, U2J ceramic capacitors provide a predictable and linear change in capacitance.

KC-LINK DC LINK Capacitors for Fast Switching Semiconductor Applications

KEMETs KC-LINK surface mount capacitors are designed to meet the growing demand for fast switching semiconductors that operate at higher voltages, temperatures, and frequencies. By utilizing KEMET's robust and proprietary C0G/NPO base metal electrode dielectric system, these capacitors are well suited for power converters, inverters, snubbers, and resonators where high efficiency is a primary concern. With extremely low equivalent series resistance (ESR) and very low thermal resistance, KC-LINK capacitors can operate at very high ripple currents with no change in capacitance versus DC voltage and negligible change in capacitance versus temperature. Operating temperatures of 150^{o} C enable these capacitors to be mounted close to fast switching semiconductors in high power density applications which require minimal cooling.

Texas instrument's LM2776 Switched Capacitor Inverter

TI's LM2776 inverts a positive voltage in the range of 2.7 to 5.5 v to the corresponding negative voltage, it uses 3 low cost capacitors to provide 200mA of output current without the cost, size, and Electromagnetic Interference related to inductor-based converters.