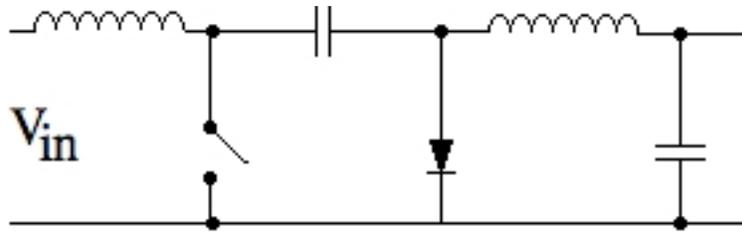


TLM simulation of the Cúk converter.

A Cúk converter is an extremely elegant circuit which is used for 'buck-boost' (up-down) DC-DC conversion.



There is no direct connection between the input and the output and hence the designation 'indirect converter'. The switch (power MOSFET with suitable protection) operates between 10^2 and 10^4 Hz and causes the entire topology of the circuit to change during each cycle. At one instant the capacitor is picking up charge from the left and at the next instant it is delivering it to the output on the right.

If the duty-cycle, D is defined in terms of the ratio of the time for which the switch is on during the whole switching period, then the output voltage is given by:

$$V_{out} = V_{in} \left[\frac{D}{1-D} \right]$$

This was given as part of the laboratory practical exercise in a course that I had to take (in the absence of the incumbent teacher) during the spring semester this year. Students were given sample TLM code for RC and LC circuits, where they were able to demonstrate that so long as the sampling time, Δt was such that its reciprocal was significantly less than the operational frequencies, then the replacement of the inductor by a short-circuit transmission line and the capacitor by an open-circuit transmission line gave excellent agreement with the conventional expressions for $V(t)$ and $I(t)$.

Armed with this they modelled half-wave and full-wave rectifier circuits and got values for the ripple voltages that agreed with theory both in frequency and amplitude.

They then went on to construct a model for the Cúk converter and the code that was developed by one student is attached. The amusing thing is that they had much greater difficulty when they came to build a real circuit as the back emf from the inductors (which they had observed in their models) destroyed unprotected transistors.

%Cuk Converter

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% February 27th 2006

L1 = 10e-3; %Inductor 1
C1 = 10e-3; % Capacitor 1
L2 = 199e-3; % Inductor 2
C2 = 417e-6; % Capacitor 2
RP = 20;
Vs = 5; % DC supply voltage
dt = 1e-5; % Temporal discretisation
kmax = 1000000; % Maximum number of iterations in simulation

% Variables to control switch
TON = 500; % Time to open switch for
TOFF = 500; % Time to close switch for
switchclosed = 0; % State of switch
count = 0; % Holds how long the switch has been open/closed for

% Calculation of impedances
ZC1 = dt / (2*C1); % Impedance due to C1
ZL1 = 2*L1 / dt; % Impedance due to L1
ZC2 = dt / (2*C2); % Impedance due to C2
ZL2 = 2*L2 / dt; % Impedance due to L2
ZT = RP*ZC2/(RP + ZC2); % Thevenin impedance of capacitor and resistor in parallel

% Initialisation of pulses
iVC1 = 0; iVC2 = 0;
iVL1 = 0; iVL2 = 0;
sVC1 = 0; sVC2 = 0;
sVL1 = 0; sVL2 = 0;
VT = 0;

% Allocation of memory to improve simulation speed
VOU1(kmax) = 0;
VOU2(kmax) = 0;
VOU3(kmax) = 0;
VOU4(kmax) = 0;
switchplot(kmax) = 0;

% Start of iterative process
for k=1:kmax

```
    % Switch operation
    if(switchclosed==1)
        if(count<TON)
            count=count + 1;
        else
            switchclosed = 0;
            count = 0;
        end;
    else
        if(count<TOFF)
            count=count + 1;
        else
```

```

        switchclosed = 1;
        count = 0;
    end;
end;

% TRANSISTOR ON
if(switchclosed==1)

    % Calculation of current around circuit
    I1 = (Vs - 2*iVL1) / (ZL1);
    I2 = (-2*iVC1 - 2*iVL2 - VT) / (ZL2 + ZC1 + ZT);

    % Left loop
    % Right loop

    % Calculation of terminal voltages at components
    VC1 = 2*iVC1 + I2*ZC1;
    VL1 = 2*iVL1 + I1*ZL1;
    VC2 = 2*iVC2 + I2*ZC2;
    VL2 = 2*iVL2 + I2*ZL2;

    % At capacitor 1
    % At inductor 1
    % At capacitor 2
    % At inductor 2

    % Calculation of scattered pulses in terms of component voltages and incident pulses
    sVC1 = VC1 - iVC1;
    sVL1 = VL1 - iVL1;
    sVC2 = VC2 - iVC2;
    sVL2 = VL2 - iVL2;

    % Scattered into the capacitor line
    % Scattered into the inductor line
    % Scattered into the capacitor line
    % Scattered into the inductor line

    % Calculation of pulses that will be incident at start of next time step
    iVC1 = sVC1;
    iVL1 = -sVL1;
    iVC2 = sVC2;
    iVL2 = -sVL2;

    % Scattered at open circuit
    % Scattered at short circuit
    % Scattered at open circuit
    % Scattered at short circuit

% TRANSISTOR OFF
elseif(switchclosed==0)

    % Calculation of currents around circuit
    I1 = (Vs - 2*iVC1 - 2*iVL1) / (ZC1 + ZL1);
    I2 = (-2*iVL2 - VT) / (ZL2 + ZT);

    % Left loop
    % Right loop

    % Calculation of terminal voltages at components
    VC1 = 2*iVC1 + I1*ZC1;
    VL1 = 2*iVL1 + I1*ZL1;
    VC2 = 2*iVC2 + I2*ZC2;
    VL2 = 2*iVL2 + I2*ZL2;

    % At capacitor 1
    % At inductor 1
    % At capacitor 2
    % At inductor 2

    % Calculation of scattered pulses in terms of component voltages and incident pulses
    sVC1 = VC1 - iVC1;
    sVL1 = VL1 - iVL1;
    sVC2 = VC2 - iVC2;
    sVL2 = VL2 - iVL2;

    % Scattered into the capacitor line
    % Scattered into the inductor line
    % Scattered into the capacitor line
    % Scattered into the inductor line

    % Calculation of pulses that will be incident at start of next time-step
    iVC1 = sVC1;
    iVL1 = -sVL1;
    iVC2 = sVC2;
    iVL2 = -sVL2;

    % Scattered at open circuit
    % Scattered at short circuit
    % Scattered at open circuit
    % Scattered at short circuit

end;

```

```
% Calculate VT and update capacitor 2 pulses
```

```
VT = 2*iVC2*RP/(RP + ZC2);
```

```
sVC2 = VT - iVC2;
```

```
iVC2 = sVC2;
```

```
% Add values to arrays
```

```
switchplot(k) = switchclosed;
```

```
VOU1(k) = VL1;
```

```
VOUC1(k) = VC1;
```

```
VOU2(k) = VL2;
```

```
VOUC2(k) = VC2;
```

```
end;
```

```
% Plot data
```

```
hold;
```

```
plot(switchplot, 'r');
```

```
plot(VOU1, 'y');
```

```
plot(VOUC1, 'g');
```

```
plot(VOU2, 'b');
```

```
plot(VOUC2, 'm');
```