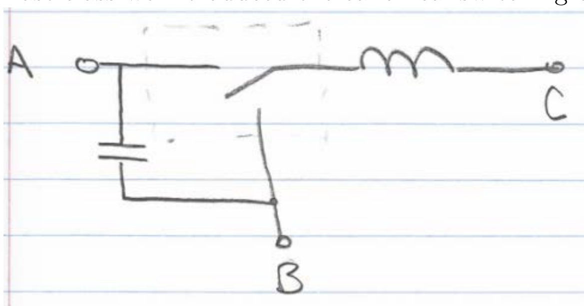
6.622 Power Electronics *Prof. David Perreault*

Lecture 6 — DC/DC Lecture 2

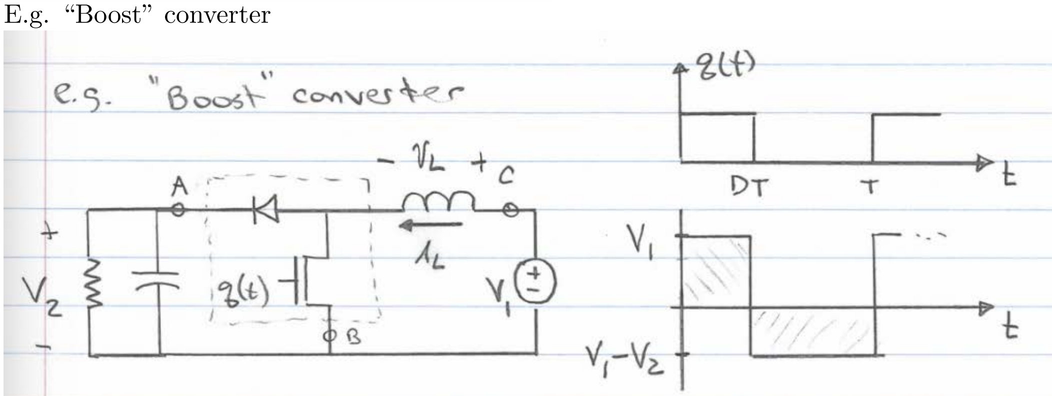
1 Switching

Last class we introduced the canonical switching cell:



We can construct the various types of converters from this.

E.g. "Boost" converter

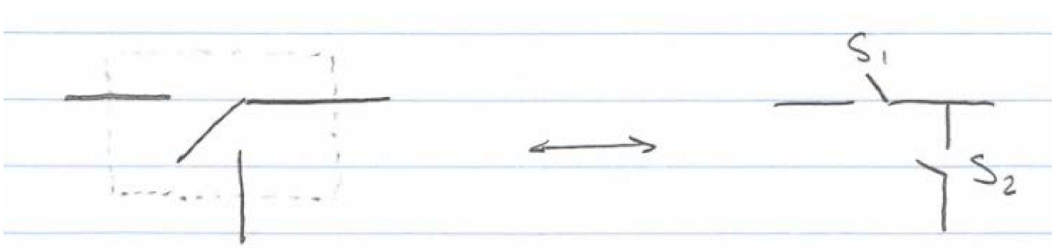


$$< V_L >= DTV_1 + (1-D)T(V_1 - V_2) = 0 \text{ in P.S.S.}$$

$$\therefore V_1 = (1-D)V_2 \rightarrow \boxed{\frac{V_2}{V_1} = \frac{1}{1-D}}$$

$$\text{by conservation of power } \boxed{\frac{I_2}{I_1} = 1-D}$$

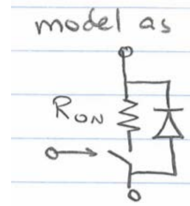
The operational capabilities of a converter are heavily influenced by switch implementation

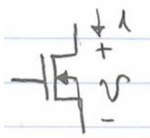


s_1, s_2 controlled so that inductor is never open-circuited with current through it.

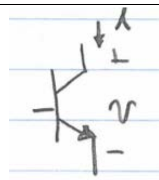
Switch implementations:

Model as:



Power mosket 

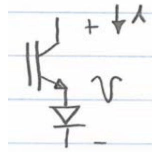
Can:
block +v
carry + or - i

IGBT  or BJT 

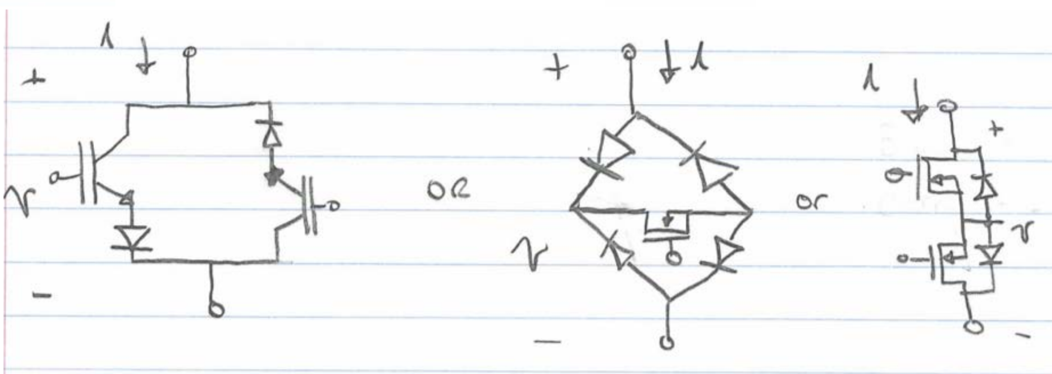
Similar, but cannot block reverse v or carry reverse i → Most versions will blow up!

So:

block +v
carry +, - i



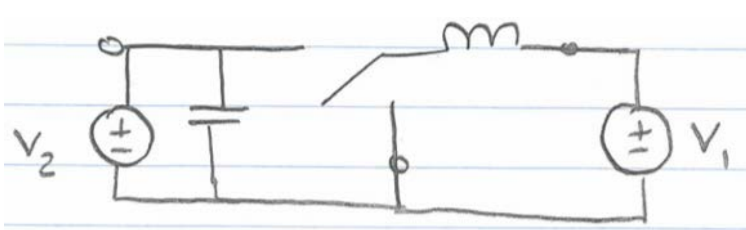
block +, = v
carry + i



Block +, - v
Carry +, - i

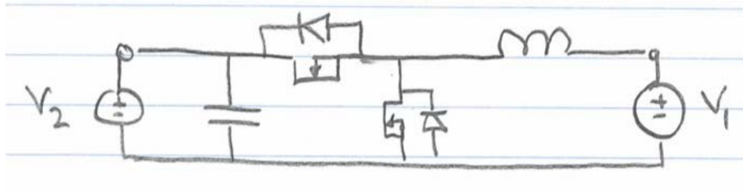
In analyxing a converter and identifying power flow direction we need to know many things:

1. Switch implementation
2. External networks
3. Control

E.g. 

Can we tell power flow direction?
→ No

Adding switch implementation



Note: the intronics/MIT converter is one example of a bidirectional unit of this type.

We <u>still</u> cannot tell

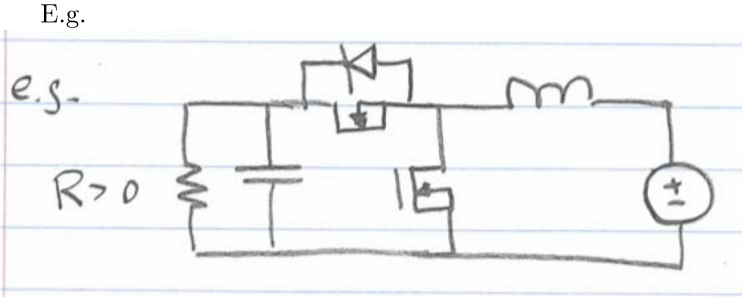
→ Could do "buck" L→R or "boost" R→L operation (depends on control)

→ We <u>do</u> know that v_1, v_2 must be > 0

→ Also $v_2 \geq v_1$

<u>External</u> networks +/ or control may be sufficient.

E.g.

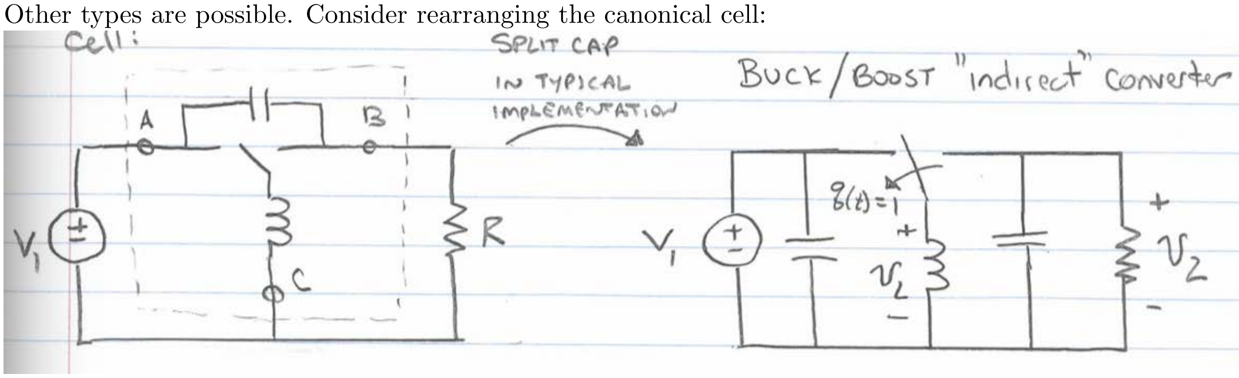


This must send power R→L in P.S.S. (but may transiently be bidirectional)

The buck, boost converters are <u>direct</u> converters

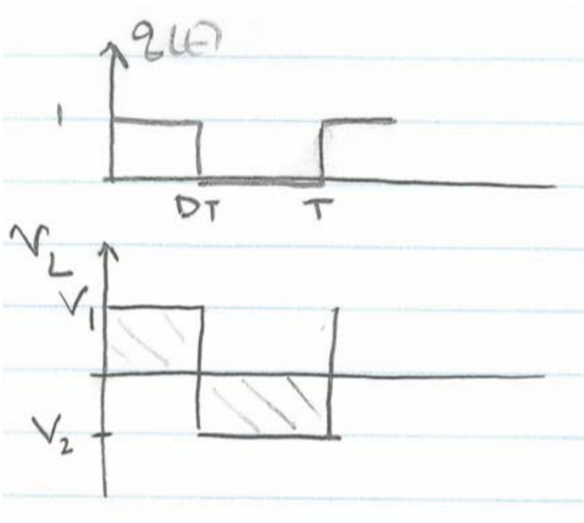
→ energy transfer directly from one part to the other in one switch state.

Other types are possible. Consider rearranging the canonical cell:



Arrow on top: split cap in typical implementation.

Right text: Buck/boost "indirect" converter.



If L's, C's are big, in P.S.S. (small ripple)

$$< v_L >= V_1DT + V_2(1-D)T = 0$$

$$\boxed{\therefore v_2 = \frac{-D}{1-D}v_1}$$

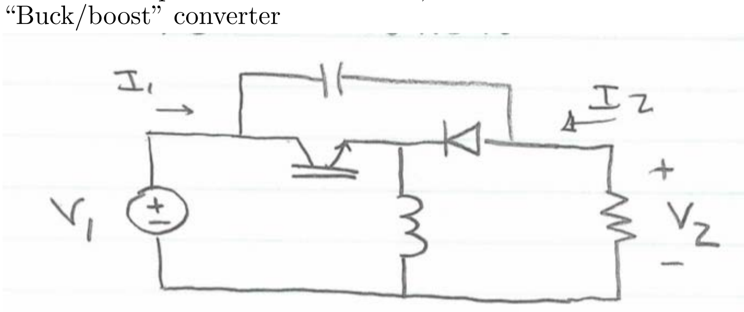
Assume $v_1 > 0$ in this case, $\therefore v_2 < 0$ so average 0!

$\rightarrow v_2$ has opposite sign to v_1
$\rightarrow 0 < D < 0.5$ $|v_2| < |v_1|$ $0.5 < D < 1$ $|v_2| > |v_1|$
So as $0 < D < 1$, $-\infty < v_2 < 0$!

Explain:

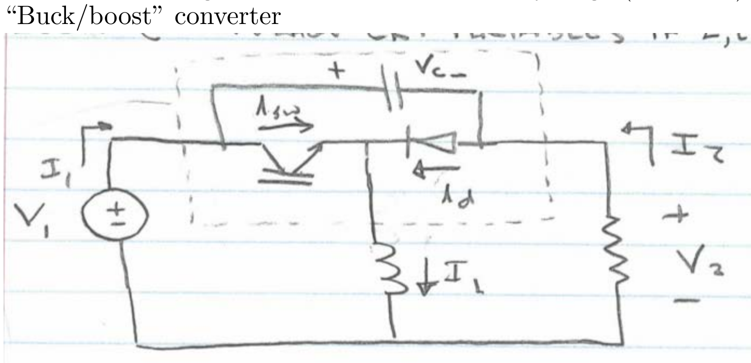
1. In 1st part of cycle, store incremental energy in L from v_1
2. 2nd part of cycle, transfer energy from L to v_2 $\rightarrow$ All energy is trasnfered via the inductor!
   $\rightarrow$ must have voltage inversion to get $< v_L >= 0$

Switch implementtion for $v_1 > 0$, $v_2 < 0$
"Buck/boost" converter



If $v_1 > 0, v_2 < 0$
$I_1 > 0, I_2 > 0$

Look @ average CKT variables if L, C very large (no ripple)
"Buck/boost" converter



If L's, C's large
$v_1(t) = V_1$
$v_2(t) \approx V_2$
$i_L(t) \approx I_L$

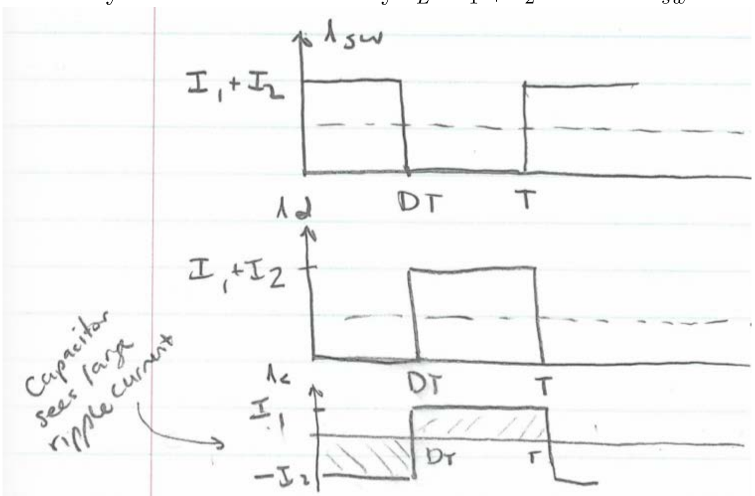
Average KCL into dotted box "supernode":

$$I_L = I_1 + I_2 \text{ or } |I_L| = |I_1| + |I_2|$$

Average KVL around outer loop

$$V_c = V_1 - V_2 \text{ or } |V_c| = |V_1| + |V_2|$$

It maybe counterintuitive why $I_L * I_1 + I_2$: Look @ i_{sw}



$$i_{sw,peak} = I_1 + I_2$$
$$< i_{sw} >= D(I_1 + I_2) = I_1$$
$$(\text{since} < i_c >= 0)$$

$$i_{d,peak} = I_1 + I_2$$
$$< i_d >= (1 - D)(I_1 + I_2) = I_2$$
$$(\text{since} < i_c >= 0)$$

$$DI_2 = (1 - D)I_2$$

In general, for an **indirect converter**:

$$I_L = i_{z,peak} = i_{d,peak} = |I_1| + |I_2|$$
$$V_c = v_{q,peak} = v_{d,peak} = |V_1| + |V_2|$$

Show simulation of a buck/boost!