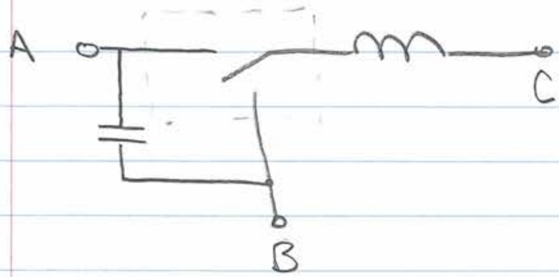
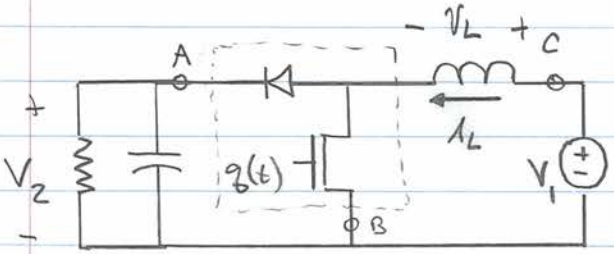
6.334 Lecture Notes — DC/DC Lecture #2

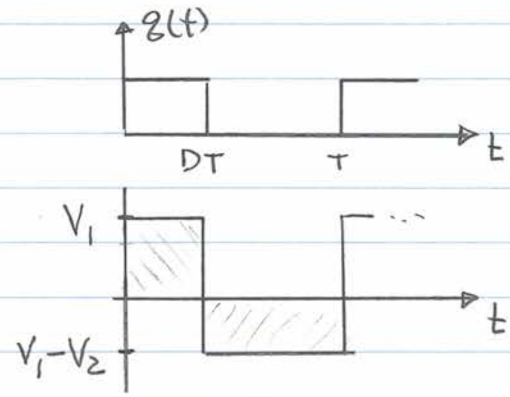
Last class we introduced the canonical switching cell:



we can construct various types of converters from this.

e.g. "Boost" converter



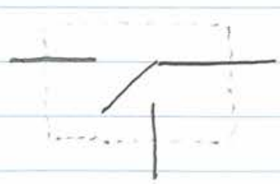


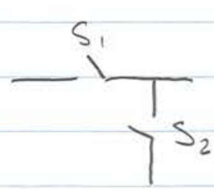
$$\langle v_L \rangle = DTV_1 + (1-D)T(V_1 - V_2) = 0 \quad \text{in P.S.S.}$$

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

by conservation of power $\quad \boxed{\dfrac{I_2}{I_1} = 1-D}$

The operational capabilities of a converter are heavily influenced by <u>switch implementation</u>





S_1, S_2 controlled so that inductor is never open-circuited with current through it.

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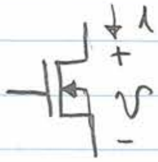
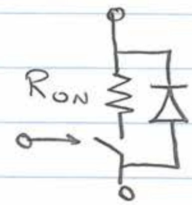
SWITCH IMPLEMENTATIONS:

POWER MOSFET

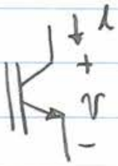


CAN:
Block + v
Carry + or − i

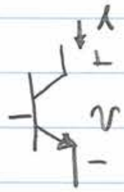
model as



IGBT



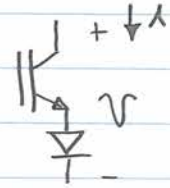
or BJT



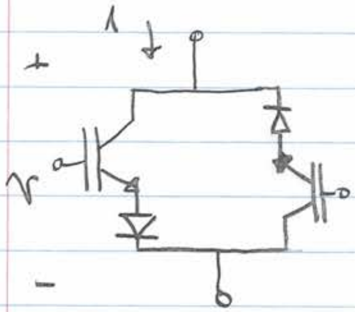
Similar, but cannot block reverse v or carry reverse i → most versions will Blow up!

So:

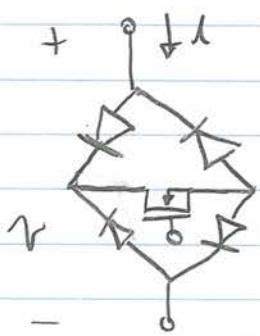
Block + v
CARRY +,− i



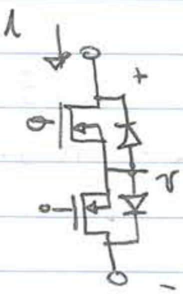
Block +,− v
Carry + i



OR

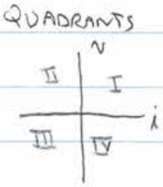


or



Block +,− v
Carry +,− i

QUADRANTS



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

1. Switch implementation
2. EXTERNAL NETWORKS
3. CONTROL

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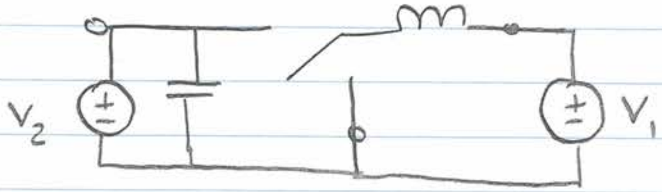
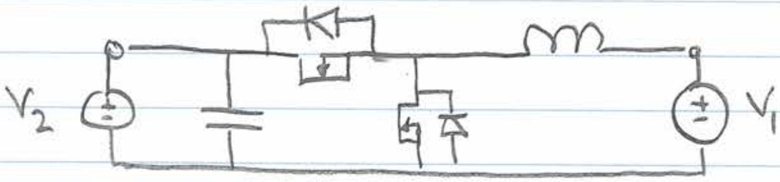
e.g.



CAN WE TELL POWER FLOW DIRECTION ?
⇒ NO

Adding switch implementation

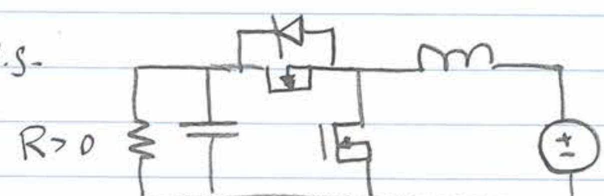


WE STILL CANNOT TELL
⇒ COULD DO "BUCK" L→R or "BOOST" R→L operation (DEPENDS ON CONTROL)
⇒ We DO know V_1, V_2 must be > 0
⇒ Also $V_2 \geq V_1$

NOTE: The Intronics/MIT converter is an example of a bidirectional unit of this type

EXTERNAL NETWORKS +/OR CONTROL MAY BE SUFFICIENT

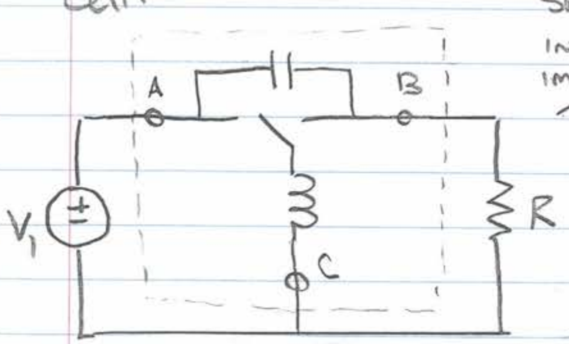
e.g.



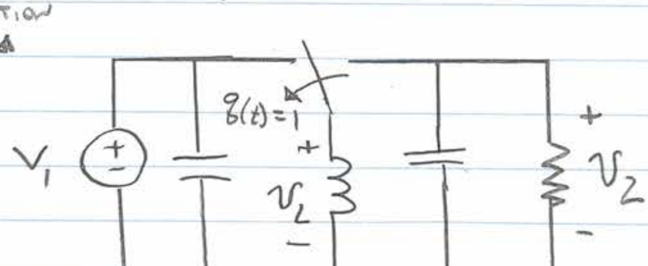
This must send power R→L in p.s.s. (but may transiently be bidirectional)

The buck, boost converters are Direct converters
⇒ energy transfer directly from one port to the other in one switch state.

Other types are possible. Consider rearranging the canonical cell:



Buck/Boost "indirect" converter



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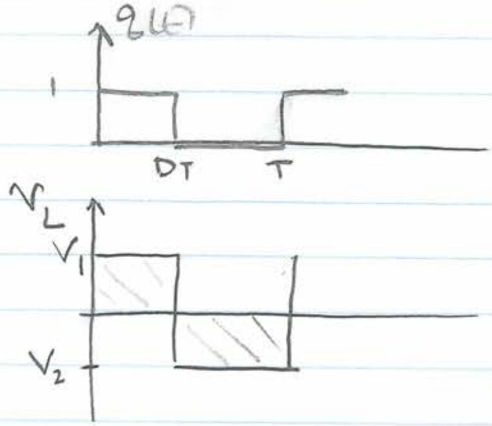


If L's, C's are big, (small ripple) in P.S.S.

$$\langle V_L \rangle = V_1 DT + V_2(1-D)T = 0$$

Assume $V_1 > 0$ in this case

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

$\therefore V_2 < 0$ so zero avg!

$\Rightarrow V_2$ has opposite sign to V_1

$\Rightarrow$ $0 < D < 0.5$ $\quad |V_2| < |V_1|$
$0.5 < D < 1$ $\quad |V_2| > |V_1|$

So as $0 < D < 1$, $-\infty < V_2 < 0$!

Explain: ① In 1st part of cycle, store incremental energy in L from V_1

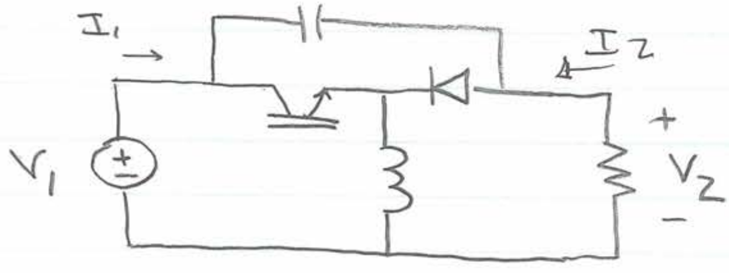
② 2nd part of cycle, transfer energy from L to V_2

INDIRECT $\Rightarrow$ All energy is transferred via the inductor!

$\Rightarrow$ must have voltage inversion to get $\langle V_L \rangle = 0$

SWITCH IMPLEMENTATION FOR $V_1 > 0$, $V_2 < 0$

"Buck/Boost" Converter



If $V_1 > 0$, $V_2 < 0$
$\therefore I_1 > 0$, $I_2 > 0$

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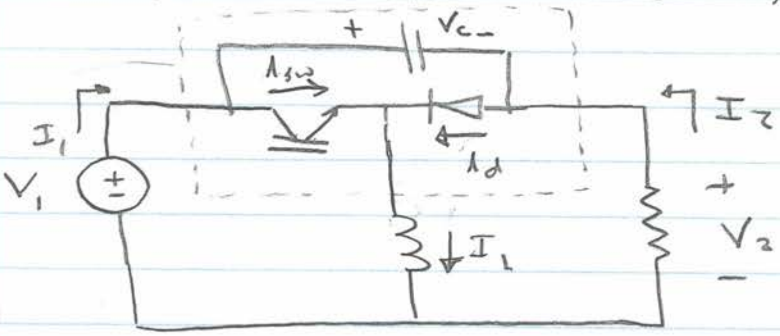
Look @ AVERAGE CKT VARIABLES IF L, C Very large (no ripple)



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":

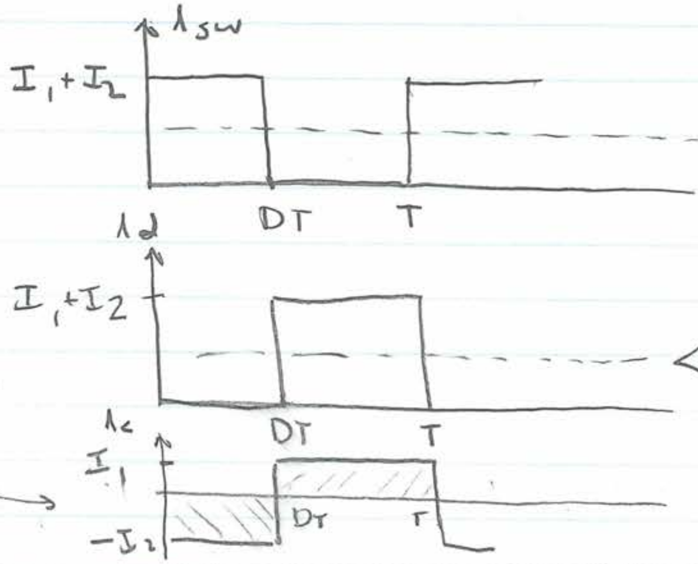
$$I_L = I_1 + I_2 \quad \text{OR} \quad |I_L| = |I_1| + |I_2|$$

Switch order of presentation

Average KVL around outer loop

$$V_C = V_1 - V_2 \quad \text{OR} \quad |V_C| = |V_1| + |V_2|$$

It may be counterintuitive why $I_L = I_1 + I_2$: look @ i_{sw}



$i_{sw,peak} = I_1 + I_2$
$\langle i_{sw} \rangle = D(I_1 + I_2) = I_1$
(since $\langle i_c \rangle = 0$)

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

Capacitor sees large ripple current

$D I_2 = (1-D) I_1$

In general, for an INDIRECT CONVERTER

$$I_L = i_{q,peak} = i_{d,peak} = |I_1| + |I_2|$$

$$V_C = v_{q,peak} = v_{d,peak} = |V_1| + |V_2|$$

SHOW SIMULATION OF BUCK/BOOST!