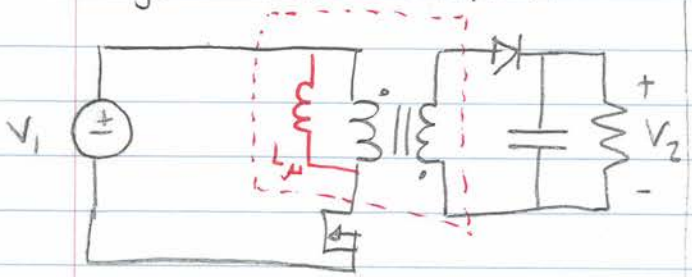
★ DEMO OF FLYBACK CONVERTER!

6.334 Lecture — Isolated dc/dc converters #2

Review: Isolated converters provide: (1) Galvanic Isolation
(2) Large conversion ratios
(3) Ease of multiple outputs

Examples:

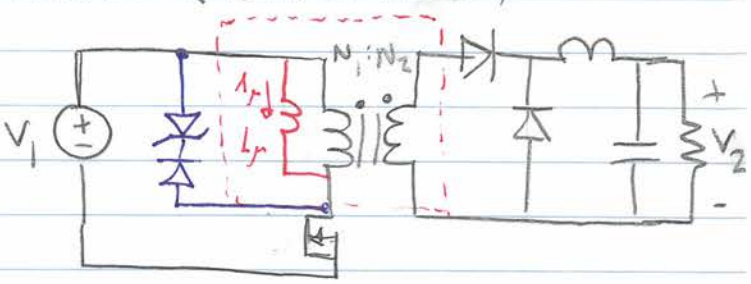
Flyback (isolated buck/boost)



$$\frac{V_2}{V_1} = \left(\frac{N_2}{N_1}\right)\frac{D}{1-D}$$

gapped flyback transformer serves as energy storage element (L_M acts as inductor)

Forward (isolated buck)



$$\frac{V_2}{V_1} = \left(\frac{N_2}{N_1}\right)D$$

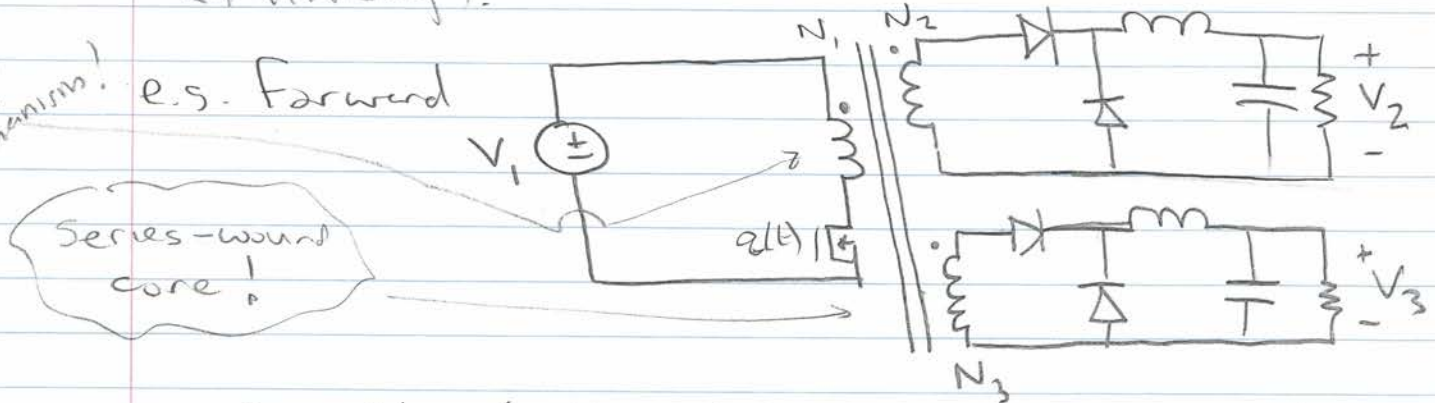
L_M is an undesired parasitic. We must add extra circuitry to reset the core! —

★ Multiple Outputs

To get additional outputs having a (rational) proportional voltage, we need only add extra transformer windings (+ filtering).

Need reset mechanism!

e.g. Forward



Ideally $\frac{V_2}{V_1} = \left(\frac{N_2}{N_1}\right)D$, $\frac{V_3}{V_1} = \left(\frac{N_3}{N_1}\right)D \Rightarrow V_3 = \frac{N_3}{N_2}V_2$

- This can give us (many) multiple outputs with only modest increases in complexity

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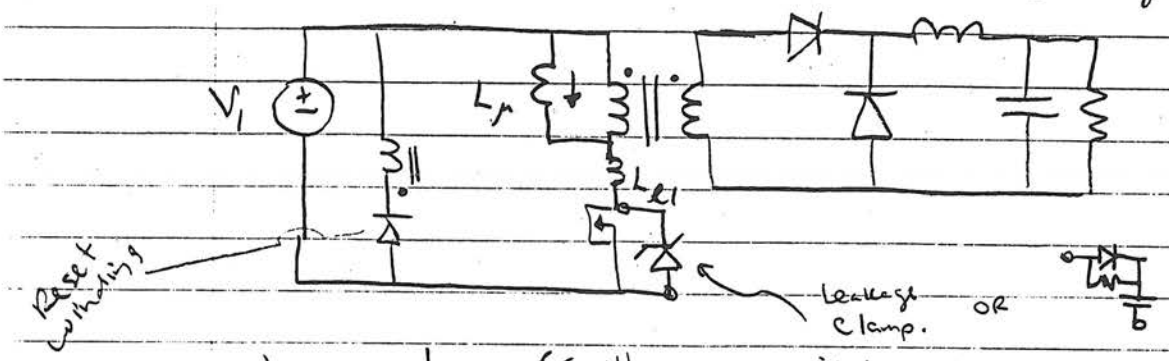
★ TRANSFORMER LEAKAGE INDUCTANCES

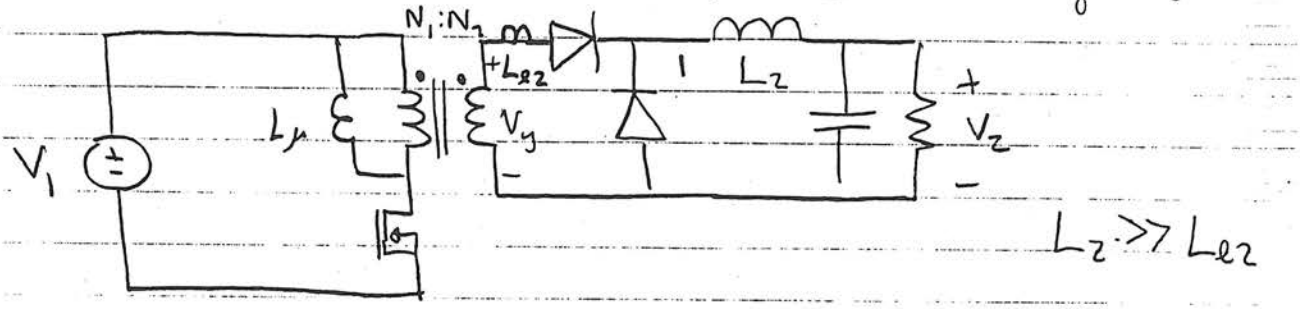
Leakage inductance parasitics also influence operation:

Consider a forward converter with primary leakage (only)

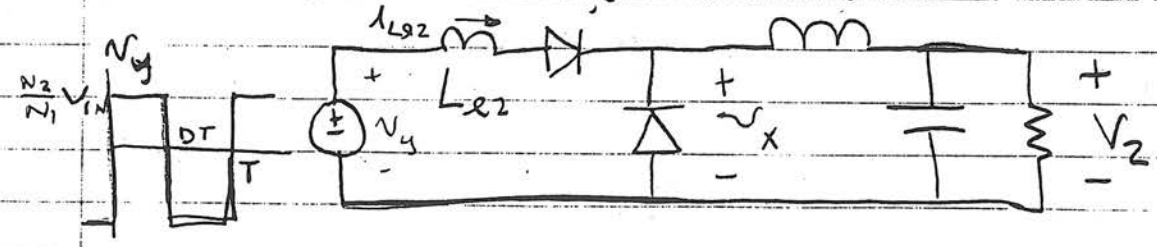


When we turn off the main switch, the reset winding can handle magnetizing current/energy, but not primary-side leakage inductance. We may need to add additional circuitry to absorb or recycle this energy! (e.g. Zener).

Consider a forward converter with secondary-side leakage only



We can model the secondary side as: $\rightarrow I_2$



From this, we can calculate the voltage conversion ratio

⇒ Load regulation effects due to secondary leakage result in a load current dependence of the conversion ratio!

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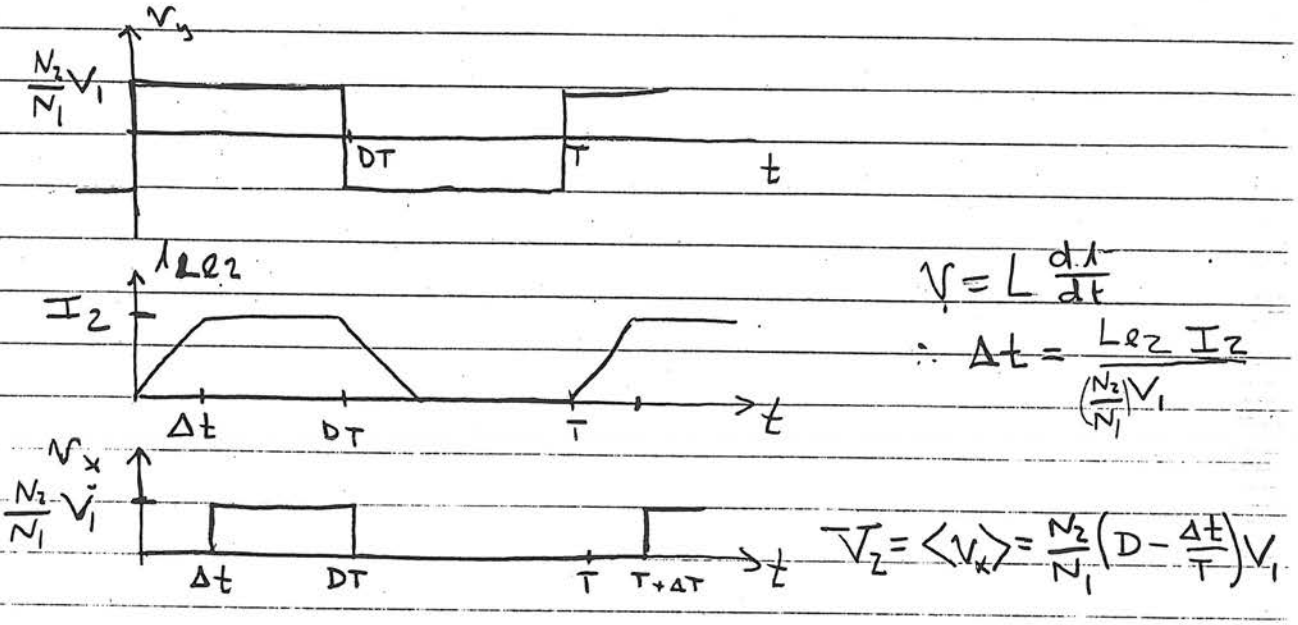


$$V = L\frac{d\lambda}{dt}$$

$$\therefore \Delta t = \frac{L_{g2} I_2}{\left(\frac{N_2}{N_1}\right)V_1}$$

$$\overline{V_2} = \langle v_x \rangle = \frac{N_2}{N_1}\left(D - \frac{\Delta t}{T}\right)V_1$$

So we may calculate the conversion ratio as:

$$\boxed{V_2 = \frac{N_2}{N_1} D V_1 - \frac{L_{g2}}{T} \cdot I_2}$$

SO THE CONVERSION RATIO NOW NOT ONLY DEPENDS ON DUTY RATIO, BUT LOAD CURRENT

- WE WILL HAVE TO INCREASE DUTY RATIO AS LOAD ↑
- THIS IS CALLED <u>LOAD REGULATION</u>! (as with rectifiers)
- maximum D increases, increasing device stress

This becomes <u>VERY IMPORTANT</u> with multiple outputs.

- we can only adjust D to regulate one output
- since conversion ratios now depends on load currents, the output voltages are not related by turns ratio (adjusting for load variations on one output can change the voltage at the other output!)

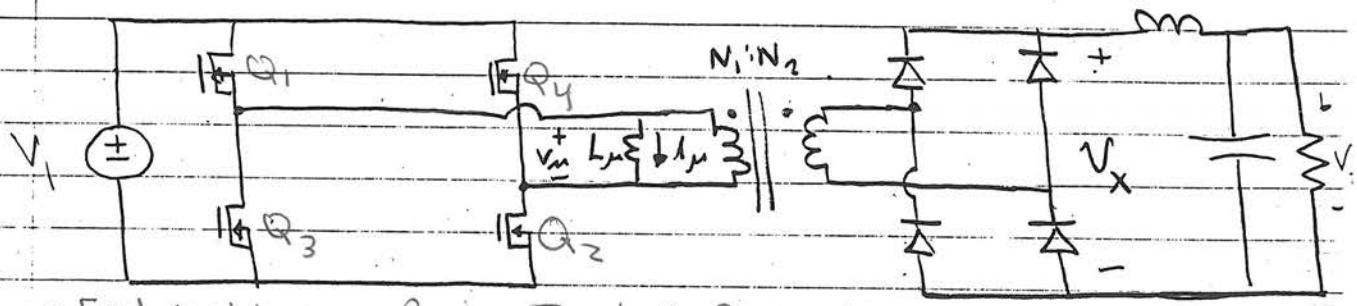
⟹ This is called "cross regulation" + is undesirable!

∴ The transformer parasitics are important for isolated converter operation

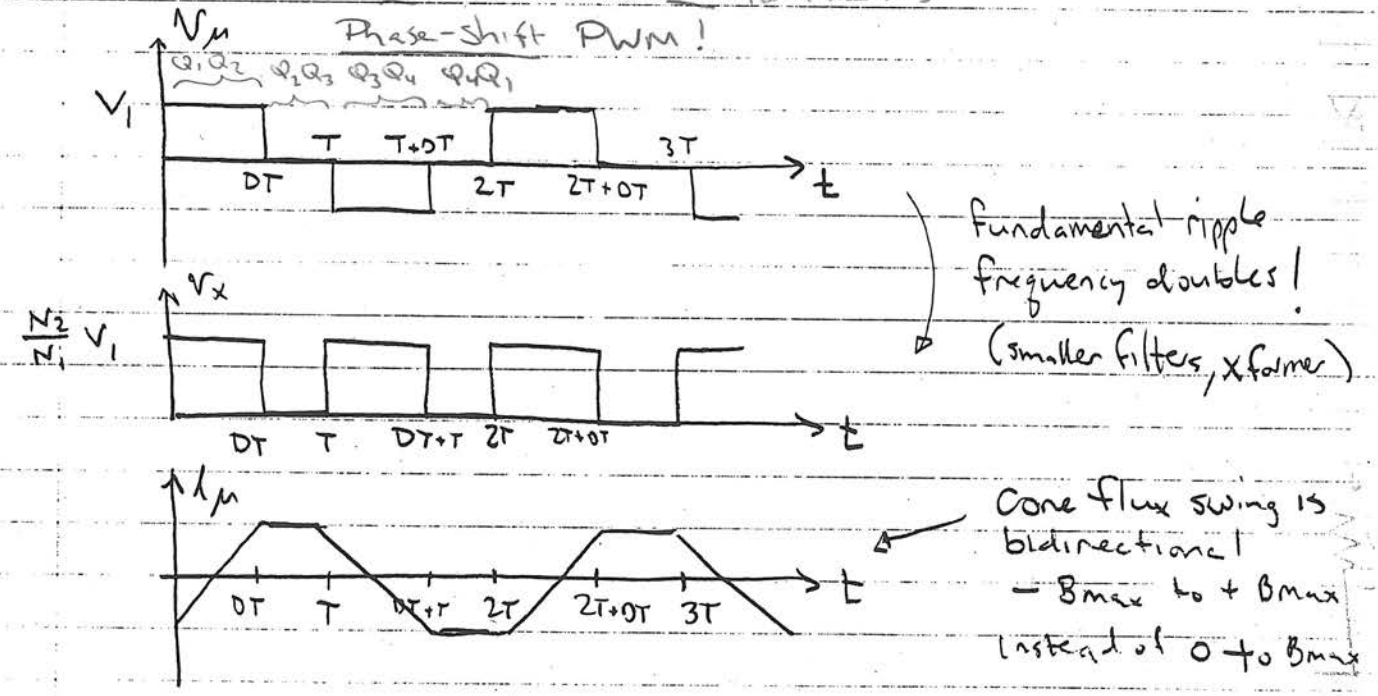
6.334 Lecture Notes — Isolated dc-dc #2

★ Double-Ended Converters:

So far we have considered converters that only use unidirectional primary-side xformer magnetizing current. We can better utilize the transformer with bidirectional current/flux.



- Each switch is on for time T and off for time T: →



- Bidirectional flux swing allows smaller xformer
- frequency doubling allows smaller filters

- However we must use control or a blocking capacitor to ensure that $\langle i_\mu \rangle \sim 0$, or we will saturate the transformer! (TRICKY)

★ If time, discuss current-fed designs, 3φ designs, flyforward, ...

Isolated dc-dc #2

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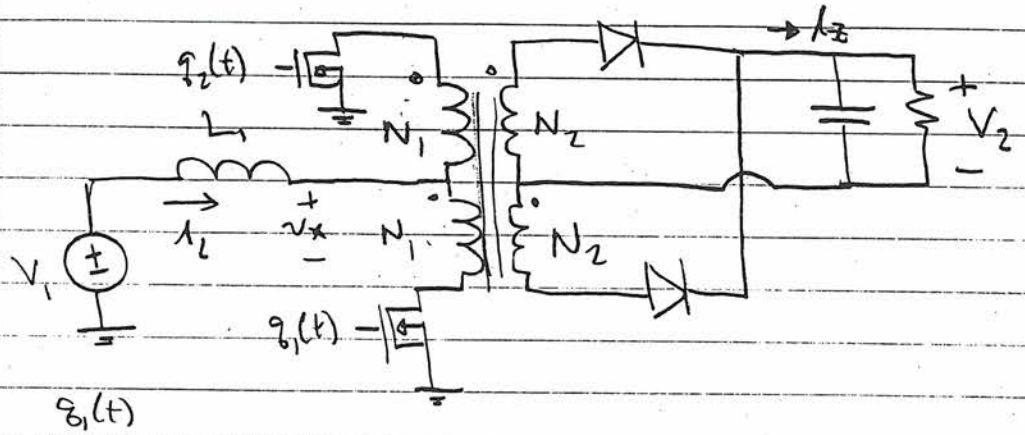
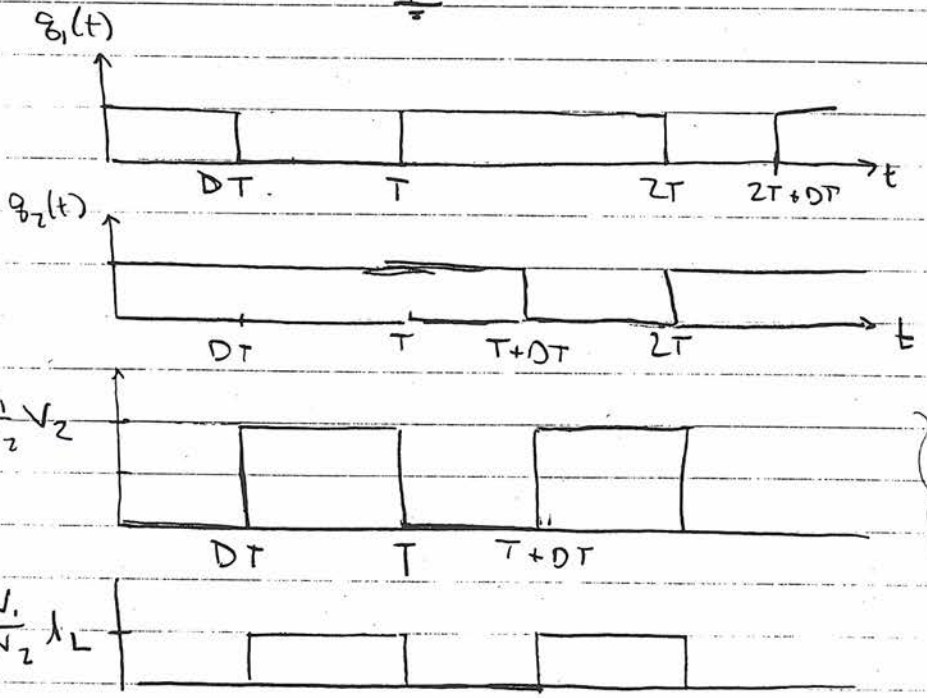
MANY OTHER KINDS OF ISOLATED CONVERTER VARIANTS EXIST !

e.g. current-fed push-pull (like isolated boost)





we can also create structures that don't exist in nonisolated, eg flyback and use different rectifiers (e.g. current doubler)

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